FreeBSD®6 Unleashed

By Brian Tiemann

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Publisher: **Sams**
Pub Date: **June 15, 2006**
Print ISBN-10: **0-672-32875-5**
Print ISBN-13: **978-0-672-32875-6**
Pages: **912**

Overview

FreeBSD is extremely robust and powers some of the largest internet sites in world including Yahoo!. *FreeBSD 6 Unleashed* provides complete coverage of everything you need to know to use FreeBSD to its full potential, including coverage of FreeBSD 6.0. This edition includes updated coverage of Apache, MySQL and Sendmail, as well as added coverage of PowerPC support for Macintosh G3 and G4 platforms. This is the most up to date, comprehensive reference on the market covering FreeBSD 6.0.

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Library of Congress Catalog Card Number: 2005935242

Printed in the United States of America

First Printing: May 2006

09 08 07 06 4 3 2 1

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Dedication

To my parents, Keith and Ann, my brother, Mike, and his wife, Julie.

Brian Tiemann

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About the Author

Brian Tiemann is a freelance technology columnist whose writing credits include books on Mac OS X, iTunes, the iPod, and iLife, as well as three editions of *FreeBSD Unleashed*. He has been a constant user of FreeBSD since his student days at Caltech, where he used it to build a movie fan website that continues to grow and sustain an ever-increasing load. A native Californian, Brian lives in San Jose and works in the field of network optimization appliances, when he isn't busy looking after two hairy dogs.

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Acknowledgments

Over its three editions, *FreeBSD Unleashed* has changed significantly right along with the cutting-edge software it covers; but some things haven't changed at all, namely the outstanding efforts by the editorial staff at Sams Publishing. These include Kate Givens for keeping all the usage looking proper and reading right, Josh More for making sure the technical instructions all work, George Nedeff for managing the author-review and editorial process, and Scott Meyers and Jenny Watson for ably bringing the whole project together. I must also thank Kathryn Purdum for giving me the opportunity to work on this book in the first place, years ago when such a chance seemed beyond possibility.

A thick slice of credit should also go to my co-author from previous editions, Michael Urban, whose work on the chapters he originated still forms the basis for the coverage in the current book. His experience with FreeBSD always served as a perfect complement to my own, and his expertise was always available where mine was lacking.

As complex and ramifying as a project like a book covering FreeBSD might be, it's still nothing compared to the complexity of FreeBSD itself, and the efforts of those writing a book like this pale next to those of the FreeBSD developers who put in endless hours making FreeBSD shine, and the tireless community of users who share their documented experiences with one another on the Internet. Without these all-volunteer community efforts, no documentation project of this magnitude would be possible by any one person.

On a personal note, I would like to thank Paul Summers for his untiring efforts doing all the hard and expensive site-admin work while I philosophize and hack and rant from afar; Lance, Kris, Chris, Brian D., David, Drew, Zjonni, Gerrit, Marcus, Matt, Trent, and the rest of my friends who have helped me solidify my opinions and passions about operating systems and software; James, Steven, Mike, Mike, and everyone else who has seen fit to read my daily online writing, supply encouragement, and keep me honest; and [adult swim] for much-needed late-night distraction. Finally, I thank all the members of the TLK-L and Lionking.org for supporting me so steadfastly all these years and making me feel as if I know what I'm talking about. Maybe a copy of this book will find its way into the γδβ library, as would be appropriate.

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Introduction

If you're reading this book, chances are good that you're a technical professional who makes a living from the Internet and its related industries. You've probably heard of the open-source software movementthe phenomenon of software developed by volunteers and distributed for free along with its source code so users can examine every feature's basic engineering and even modify or add to it. You're probably interested in making open-source software work for you.

The chances are not so good, however, that you've heard of FreeBSD. The brightest star of the open-source software world today is the free Linux operating system, which has achieved the financial backing of software giants such as IBM and consistently steals headlines across the technology industry; but Linux is not the only open-source, freely available UNIX-style operating system available. Gaining few headlines, yet continuing to boast technical and philosophical advantages that elude its flashier cousin, FreeBSD is an older and yet more robust operating system whose roots extend back to the very beginnings of UNIX.

The merits of FreeBSD include an implementation of the TCP/IP networking stack that is widely regarded as the best in the industry and the reference implementation to which other software developers look for guidance. It also boasts a rock-solid microkernel architecture that can be tuned for performance that often exceeds that of Linux in the same rigorous test and production environments. FreeBSD's packaging system for third-party application software is a model of efficiency and simplicity; and because all of FreeBSD is developed by the same core of dedicated developers, from the kernel to the smallest supporting programs, the same level of attention is paid to the entire system in a way that is seldom seen in the Linux world. Differences such as these between FreeBSD and Linux abound wherever you look, no matter how similar the two systems might appear on the surface. Where, however, do these differences originate?

A frequently overlooked fact is that Linux is not UNIX. It's more properly called "UNIXlike," in that it performs the same functions that most commercially sold UNIX variants do. However, it was developed entirely by its user community from original code, hence the recursive prefix of GNU ("GNU's Not UNIX"). The guiding principles of the project are embodied in the *GPL* (*GNU General Public License*), which states, in part, that any code developed under it must be made freely available to the public. This extends to commercial software development entities, which must rerelease any software that they develop from GPL-licensed materials as freely available source code.

If there is any single strong point of contention between the supporters of open-source and those of commercial software, it is this seemingly innocent license. The problem is that many companies are unwilling to abide by its terms because, to them, giving away the source code that they develop is tantamount to publishing trade secrets. GPL-based software embodies an ideal: the notion of software written by the people, for the people, owned by nobody, and leveraged by everybody. It is the antithesis of commercial, closed-source softwaresold in compiled, executable form from only one supplier. Linux adheres to that ideal in a number of important ways, but the unattractiveness of the spirit of the GPL to business has caused many companies to decide against basing software on it. It is here, where the open-source ideal meets the market forces that drive the technology industry, that FreeBSD's advantages become clear.

FreeBSD and the Commercial Software Tradition

FreeBSD comes from a different open-source tradition than Linux does. It is not based on software developed under the GPL, but instead favors the BSD (Berkeley Software Design) open-source license that allows code originally developed at the University of California at Berkeley (and later commercially) to be reused in software development, whether or not the source is published. This is part of the reason why Steve Jobs' company, NeXT, chose the BSD operating system to form the core of the NeXTSTEP platform that later evolved into Mac OS X. Similarly, when Microsoft made overtures to the academic community in 2002 by releasing a programming environment for its C# language, it made it available on two operating systems: Windows and FreeBSD. The BSD license, lacking the requirement for developers to publish the "keys to the kingdom," is friendlier to commercial software companies than the GPL. It strikes a balance that encourages grass-roots contributions from users, but does not place undue restrictions on companies. This makes the companies more likely to use their resources to develop BSD-licensed software into truly great products.

Linux's runaway popularity has meant that FreeBSD has had to fight for its share of the spotlight; and whereas it used to be mentioned nearly as often as Linux in the tech press, today most of that glory has gone in Linux's direction. This does not, however, mean that FreeBSD is any less attractive a platform, especially from a purely technical standpoint. FreeBSD is still the reference platform for new code and features that are eventually folded into commercial products like Mac OS X. The advantages of FreeBSD's whole-system modelwith only one "distribution" and an ever-more-streamlined installation and software packaging processremain as valid today as ever. FreeBSD's software releases continue on schedule, keeping pace with the proliferation of emerging technologies (Wi-Fi, FireWire, and multicore symmetric multiprocessing, among others) so that a FreeBSD user can wring out every bit as much power as a Linux user can (more, in some cases), and can accomplish tasks still all but impossible in Windows.

What this means is that FreeBSD is for you if you are any of the following:

- An academic with a need for a stable testing platform in a laboratory
- An adventurous enthusiast who wants to explore the open-source desktop world
- An engineer running a high-performance networking test topology
- A website operator with a need for stability and a well-organized operating system layout
- A software developer looking for the opportunity to contribute to commercial efforts like Mac OS X
- Just someone who wants to be free from the trammels of closed-source software

The Benefits of FreeBSD

I had my first exposure to FreeBSD in 1997, with release version 2.2.2. What attracted me was that even at this early point in its development, Yahoo! had given it the nod as the platform of choice rather than Linux, and Hotmail (before it was taken over by Microsoft) used it side-by-side with Solaris to handle its extraordinary load of web-based email users. I considered these to be strong testimonials, and the convenient floppy-disk-based "net install" feature sealed the deal.

Since that time, FreeBSD has undergone significant evolution. The layout of the system has become increasingly organized; the security model has been iteratively tightened and enhanced; and the revolutionary "ports collection" mechanism for installing third-party software has been so successful that it has been ported to NetBSD, OpenBSD, and Mac OS X. It has also become easier and easier to migrate to FreeBSD from other platforms than it was when I first encountered it. The many commercial and open-source UNIX variants each have their own filesystem hierarchies and configuration methods, and learning each one can be like learning another foreign language; but FreeBSD's model, incorporating centralized configuration files and a tightly controlled filesystem structure, lends to more predictability and easier administration than elsewhere in the UNIX world. This makes it especially easy to learn for veterans of other UNIX platforms. Lastly, a Linux binary compatibility kernel module allows software that is commercially developed for Linux, such as RealPlayer and Oracle, to run on FreeBSD. Although FreeBSD doesn't enjoy the notoriety of Linux (or suffer from the backlash against that notoriety), it does provide nearly all the meaningful benefits one can have by running Linux, and many that are uniquely its own.

When it comes to open-source operating systems, Linux has the spotlightand probably will continue to have it for the foreseeable future. However, FreeBSD continues to hold its stake in the market, simply by being there as an alternative for companies wanting out of the Microsoft hegemony, but concerned by the politics inherent in backing Linux, or the uncertainty of choosing an appropriate distribution. Other BSD-licensed operating systems keep a firm grasp on their respective corners of the market: OpenBSD is focused on being the most secure operating system available, and NetBSD has bragging rights for being able to run on a vast number of different hardware platforms, from Intel's x86 architecture to the Motorola PowerPC to the Sega Dreamcast. FreeBSD's appeal is more general; it excels in the role of a full-featured Internet server or workstation on modern, top-grade hardware. It does so without excessive specialization and without being so politically charged as to alienate all-important corporate finance managers. It holds to a course that runs squarely between the extremes, and in the coming years it's likely to remain a well-respected player and the choice of the most demanding computing professionals in the world.

Twenty, or ten, or even five years ago, the state of the computer industry could not have been accurately predicted. We can't hope to imagine what the next decade or two will bring, but if FreeBSD's successful history is any indication, it will be with us as long as the open-source movement is relevant. Someday, the compromise between open-source flexibility and commercial assurance that FreeBSD represents may be the only type of platform that anyone can imagine.

How This Book Is Organized

FreeBSD Unleashed is written with the computer-savvy, technologically-curious reader in mind. My goal is to provide a thorough education in how to leverage whatever level of computer knowledge you might already have (whether in Windows or in UNIX) to get the most possible benefit out of a move to FreeBSD. Whether your goal is to migrate a high-profile corporate server to a fast, stable FreeBSD installation, to deploy a demanding test environment, or to set up a hobbyist machine for casual tinkering, this book gives you the know-how you need.

If you read this book from cover to cover, you will get a tour of FreeBSD, from initial installation procedures to high-level administration details and techniques. Depending on your experience with computers or FreeBSD, you might want to start at a chapter in the middle of the book that's pertinent to your needs. However, to get the fullest understanding of what makes FreeBSD a unique operating system and of the ideas behind its design, I encourage you to start at the beginning and with a fresh, guided installation of FreeBSD.

Whether you're reading *FreeBSD Unleashed* sequentially or searching for information on a specific task or topic, you'll appreciate the logical organization of this book's information:

- Part I, "Introduction to FreeBSD," deals with installing FreeBSD for the first time. If this is your first FreeBSD installation, or if you need a refresher on how it's done, you should begin with this section.

- Part II, "FreeBSD on the Desktop," provides an overview of the graphical user environments available on FreeBSD, with a focus on the well-developed KDE desktop system. This will be of use to you if you're unfamiliar with using the command-line interface of the shell, or if you're a more advanced user wanting to put FreeBSD to work as a desktop operating system. You can skip this part if you're an experienced shell user and are interested in FreeBSD more for its server capabilities than as a Windows replacement on your desk.

- Part III, "FreeBSD on the Command Line," introduces you to the shell environment: the command-line interface central to FreeBSD and all UNIX-style operating systems. These chapters familiarize you with customizing the shell to fit your work style, automating your work with shell scripts, and the basics of programming in Perl.

- Part IV, "System Administration," delves deeper into the details of customizing FreeBSD for your specific purposes. You learn how FreeBSD's filesystem is laid out, how users and permissions work, and how to configure and monitor the system's operation. This part of the book teaches you how to install and upgrade third-party software as well as FreeBSD itself, how to configure printing, and how to add more hard disk space configured exactly as you need it. Finally, you'll get a "FreeBSD Survival Guide"a quick reference chapter that gives you some of the most important tips and tricks necessary for successfully administering a FreeBSD system, including tips on how to tune your FreeBSD machine for maximum performance. Many of the tricks you learn here have taken UNIX gurus years of painful first-hand experience to learn.

- Part V, "FreeBSD Networking," prepares you for the daunting task of turning your FreeBSD machine into a world-class Internet server platform. The tour begins with background information on TCP/IP networking and how to set it up in FreeBSD. Then it proceeds step-by-step through setting up email, web, database, FTP, and routing services, as well as DNS, Windows file sharing, and NFS. Network security is an extremely critical topic for anyone interested in running a network server, and one you should not miss.

- Part VI, "Appendices," contains collections of information that are useful for reference regardless of your level of expertise. You'll find UNIX command definitions, listings of compatible hardware, troubleshooting guides, and a set of further sources for information that pick up where this book's usefulness leaves offat which point you'll presumably be an expert.

FreeBSD Unleashed, Third Edition covers FreeBSD 6.1, the most recent release as of mid-2006. The development of FreeBSD in prior years has proceeded deliberately, such that if you are working with a system running FreeBSD 5.x, most of what this book covers applies to you too. Significant differences between FreeBSD 6.x and the last few releases in the 5.x series will be discussed, though the primary focus will be on the usage and conventions of the 6.x series.

Conventions Used in This Book

Features in this book include the following:

Note

Notes give you comments and asides about the topic at hand, as well as full explanations of certain topics.

Tip

Tips provide great shortcuts and hints on how to work more effectively with FreeBSD.

Caution

Cautions warn you against making your life miserable by pointing out common pitfalls that snare the unwary.

In addition, you'll find the following typographic conventions throughout this book:

- Commands, variables, directories, and files appear in a `monospaced font`.
- Commands and text strings that you type appear in **`bold monospaced`** type.
- Placeholders in syntax descriptions appear in *`italic monospaced`* type. This indicates that you should replace the italicized text with the actual filename, parameter, or other element that it represents.

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Part I: Introduction to FreeBSD

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Chapter 1. What Is FreeBSD?

IN THIS CHAPTER

FreeBSD is, simply put, UNIX. It's a full-featured operating system based on the original, highly robust UNIX software developed at the University of California at Berkeley. It is designed to run on the widely available Intel x86 PC architecture, as well as on several other hardware platforms such as AMD's 64-bit Opteron, Intel's Athlon 64 and Alpha, and Sun's UltraSPARC. You can install FreeBSD for free on any garden-variety PC you might have lying around. Volunteers from all over the world develop FreeBSD, and the source code for the system is available free of charge to anyone who wants it.

This chapter introduces some of FreeBSD's most important features and some of the benefits of using the FreeBSD system. From this chapter, you gain a basic understanding of what FreeBSD is, and what you can do with it. You also learn a bit of the history of FreeBSD and how it got to be where it is today. Finally, the chapter looks at some other operating systems and how they compare with FreeBSD.

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Why Use FreeBSD?

There are probably as many reasons to use FreeBSD as there are people who use it. Perhaps the most obvious reason is that FreeBSD is free, in the truest sense of the word: not only does it cost nothing to download and install it, there are also no expensive licensing fees. You can install a single copy of FreeBSD on as many computers as you want without paying a dime. Unlike some commercial network operating systems, there are also no "per-connection" or "per-user" fees for using FreeBSD on a server.

Just because FreeBSD is free doesn't mean it's lacking the quality found in commercial operating systems. Here are some other very convincing reasons to consider using FreeBSD:

- *It is extremely stable.* FreeBSD servers have been known to run for more than three years without being rebooted.
- *It's trusted by some of the largest companies and busiest sites in the world.* Some of the companies and sites running FreeBSD have included Sony, Yahoo!, and The Apache Project.
- *It's open source.* The entire source tree for the operating system is available to you, the user. You can change it, perform security audits on it, develop new features, and contribute them back into the operating system.
- *Thousands of free software packages are available.* FreeBSD users can take advantage of the thousands of free programs available for UNIX for everything from playing chess to simulating the division of cells and bacteria growth, word processing, image editing, and serving up web pages.

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What Can You Do with FreeBSD?

Because FreeBSD comes with compilers for multiple programming languages, what you can do with FreeBSD is limited only by your imagination and the technical capabilities of your hardware. Various organizations are using FreeBSD for everything from low-end file sharing on old 486-class machines to creating high-end special effects and computergenerated animation rendering.

Note

The special effects for the Warner Brothers motion picture *The Matrix* were rendered on a powerful cluster of multiprocessor FreeBSD systems.

The following list provides some of the more common uses for FreeBSD that don't require any programming skill or custom software:

- *File and print sharing* The freely available Samba software (covered in Chapter 34, "File and Print Sharing with Microsoft Windows") allows file and print sharing with Windows-based computers. Using Samba, FreeBSD can even serve as a primary domain controller (PDC) for a Windows network.
- *Web serving* As mentioned previously, FreeBSD powers some of the busiest websites in the world. Even if you aren't setting up a website for the Internet, FreeBSD can make a great intranet server for your business. The wildly popular Apache server software, which is developed for compatibility with almost every platform in the world, is primarily written with FreeBSD as its reference platform.
- *Email services* You can set up an email server for your company with everything from encrypted IMAP access to sophisticated spam control, or even a web-based mail access system with calendaring.
- *Routing, DNS services, and Internet sharing* You can turn even a low-end Pentium into a very serviceable router, DNS server, or a gateway for sharing a single Internet connection with multiple computers.
- *Database solutions* Using FreeBSD and one of the several freely available SQL databases for it, you can create a database solution whose commercial equivalent could easily cost tens of thousands of dollars to implement. If the freely available databases don't have enough horsepower for your needs, you can run the Linux version of Oracle (or its free version, Oracle Express) on FreeBSD because FreeBSD can run most Linux applications as well as (and sometimes even better than) Linux itself. Adding a relational database back-end (as described in Chapter 29, "Configuring a Database Server") to your Apache server gives you a web hosting capacity to rival the best dedicated solutions from other vendors.
- *Custom solutions* FreeBSD has a very liberal license agreement that allows you to use its code in other applications free of royalties. This makes it a perfect solution if you are an embedded systems designer or a developer for one of the many projects that use code from the FreeBSD project, such as Apple's Mac OS X.

Any one of these individual tasks might seem like a small reason to consider FreeBSD, and in fact might seem better suited to a different operating system more dedicated to that particular task. However, the real strength in FreeBSD, bolstered by its open-source nature, is that it can do *all these things at once*. Need a machine to be a Windows domain controller, and also to act as an AppleShare file server and an NFS repository, all while serving a CGI-based website interface with an SQL database back-end? You could buy a Windows server, a Mac OS X server, and a Linux server to handle all these tasks, and spend months linking them all seamlessly together...or you could just use a single FreeBSD machine and do it all in one package.

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FreeBSD: It's Not Just for Servers Anymore

"Well, that's all well and good," you might be saying. "But I don't need any of that stuff. I'm not setting up a server or anything."

Well, don't put this book back on the shelf quite yet. There are plenty of workstation uses for FreeBSD that you might also be interested in:

- *Developing and testing websites* The days of web pages that display static HTML content are history. These days, websites that are competitive in the marketplace use server-side technologies such as CGI, embedded scripting, and database back-ends to display content that is dynamic and interactive. This means that locally testing your website by loading the pages into your browser from your hard drive are also long gone. To design a website of any complexity these days, you need to have a web server available for development and testing. Even if you will not be running a web server for public use, you can still use Apache, PHP, and one of the free SQL databases (MySQL or PostgreSQL) on a FreeBSD workstation to do website development and testing offline, without uploading any pages to your hosting service until they're ready. This can save you a lot of time and money in this world of zero tolerable downtime.

- *Developing and testing databases offline* Another benefit of local web development is local database construction. Use your local FreeBSD machine to build and test your database under MySQL or PostgreSQL and populate it with data. When you finish, export the content as an SQL script, upload the database to your hosting service, and import it into whatever SQL-compatible database the server supports, instantly bringing the live data store up to date.

- *Learning software development or programming* If you ever wanted to learn a programming language, you might be glad to know that using FreeBSD doesn't require you to spend hundreds of dollars on compilers and debuggers. Everything you need to learn programming and write powerful applications is available, waiting for you to dive in whenever you're ready.

- *Learning OS design or UNIX* If you are a computer science student and need to learn the ins and outs of operating system design, having access to all the source code for a real UNIX operating system can be a great help. Suppose that you need to learn UNIX for your job or for a course you are taking in college. Though you might be able to use the UNIX cluster on campus for programming and research, having FreeBSD on your own machine means you can experiment freely with administrator-level access without damaging critical data.

- *Using free software to run an inexpensive workstation* With so much free software available, and graphical user environments such as KDE or GNOME, FreeBSD can make a very powerful and inexpensive desktop workstation for just about anything you might want to do. Some of the free applications available for FreeBSD include email programs, web browsers, word processors, spreadsheets, databases, CAD programs, and image editors. There is even a Winamp clone for FreeBSD to support your MP3 collection!

You've probably already found one or two things in the preceding lists that have interested you in the potential usefulness of FreeBSD. Before you commit yourself to installing it, however, you'll probably want to know a little more about where FreeBSD comes from, how long it has been around, and whether it will still be there for you 5 or 10 years from now. This next section gives an overview of the history of UNIX and how FreeBSD fits into it, as well as describing the design philosophy that underlies the UNIX tradition, setting it apart from what you may be used to in Windows.

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A Brief History of FreeBSD and UNIX

The original UNIX operating system was developed at AT&T Bell Laboratories. Two AT&T engineersKen Thompson and Dennis Ritchiewere the main driving forces behind the UNIX project.

The origins of UNIX can probably be traced to the spring of 1969. It was an offshoot of a largely unsuccessful effort by a conglomeration of companies to develop a "time-sharing" operating system, one in which a mainframe system's limited computing resources could be shared among many different users logged in simultaneously from remote terminals. The operating system that this consortium developed was called MULTICS; although it introduced many innovative features and created the template for what we think of today as a multiuser operating system, it never achieved any commercial success to speak of, and AT&T's Bell Labs pulled out of the project.

Ken Thompson, one of the members of the AT&T team working on MULTICS, continued in the same spirit by writing (with the help of Ritchie and others) a new operating system, similar to MULTICS but smaller and simpler, for the DEC PDP-7 minicomputer instead of expensive mainframes as before. Its name, UNIX, evoked the new system's simplicity in comparison to the sprawling MULTICS. To support and underpin the new system, Thompson and Ritchie developed a new programming language called C, which made development far faster than prior efforts (which had relied on the DEC assembly language specific to the PDP-7). The C programming language and UNIX (also, interchangeably, Unix) are two of the most important developments in the history of the computer, not least because C was the first "portable" programming languageit allowed applications (written in C) to be ported to other types of computer platforms relatively easily. Because UNIX was written in C, it was itself also portable and could be made to run on other types of computer platforms with comparatively little effort. This breakthrough, seemingly unremarkable from a modern perspective, was what led to the meteoric rise in popularity of UNIX and the software development tradition we take for granted today.

Note

If it weren't for a game called "Space Travel" that he was writing in his spare time for the GE-645 mainframe computer (the platform for MULTICS), Ken Thompson might never have been inspired to write UNIX in the first place.

BSD Is Born

Because AT&T Bell Laboratories was not really in the business of selling computer operating systems, it licensed the UNIX operating system and its source code to various academic institutions relatively cheaply. One of the institutions that did a lot of early work on UNIX was the Computer Systems Research Group (CSRG) at the University of California at Berkeley. The CSRG made some very important contributions to UNIX, including the development of the UNIX File System (UFS) and the addition of the TCP/IP networking stack. Eventually, the CSRG made so many changes to UNIX that it released its own version, known as the Berkeley Software Distribution.

Note

Contrary to popular belief, CSRG did not do the first port of UNIX to the DEC VAX. The first VAX port was done at AT&T Bell Labs, but this port did not support the VAX's virtual memory system. CSRG thus undertook the task of porting BSD UNIX to the VAX, in the process adding support for the platform's virtual memory architecture.

CSRG made much of the BSD source code available to the public for free, and a CSRG engineer by the name of Bill Jolitz ported BSD to the Intel x86 platform in 1991. The port was called 386BSD. In addition, Jolitz and some of his colleagues from CSRG formed a commercial spin-off company named Berkeley Software Distribution, Incorporated (BSDi), and sold a commercial version of BSD that included source code.

FreeBSD Is Born

In 1993, two groups of developers became dissatisfied with the direction in which Bill and Lynne Jolitz were taking 386BSD, and they took the freely available, stagnant source code andas would become a tradition in the open-source community for many years to comestarted doing their own work on it. The first of these groups was FreeBSD, which focused on making the system as easy as possible to use for nontechnical users and directed its efforts primarily upon Intel x86 hardware. A second group, NetBSD, started work slightly later; it sought to bring BSD to every possible hardware platform. If it even slightly resembles a computer, chances are that you'll be able to run NetBSD on it. OpenBSD, a third group that dedicated itself to being the most secure operating system available, split off from the NetBSD group somewhat later. Today, FreeBSD is the most popular of the BSD-based, UNIX-like operating systems, largely because of its generalist approach and wide applicability to everyday tasks.

The modern FreeBSD is a full-fledged operating system that's suitable for everything from the most security-sensitive, performance-demanding server applications to the most userfocused, graphics-intensive productivity applications on the desktop. Since the release of FreeBSD 5.4 in 2005, the FreeBSD project has split once again and spawned PC-BSD, a flavor of FreeBSD specifically dedicated to desktop applications.

Tip

If you're interested in FreeBSD as a desktop operating system, look into PC-BSD; information is available at http://www.pcbsd.org. PC-BSD is in an early stage of development at the time of this writing.

The history of FreeBSD and UNIX is one of the most challenging, yet fascinating, studies in the computing industry, and it's far more complex than has been described here. Numerous lawsuits, changes of philosophical direction, cross-pollination of code, splits, merges, new projects, and abandoned efforts litter any exhaustive account of this ongoing tale. The following links are invaluable sources of information on the subject:

- http://www.bell-labs.com/history/unix/ Contains a detailed history of the development of UNIX at Bell Labs, including some rare photographs.
- http://daemonz.org/bugs/history.html A reminiscence of the early days of UNIX through the eyes of Marshall Kirk McKusick, a key figure in BSD and FreeBSD history since the days of CSRG.
- http://www.freebsd.org/handbook/history.html Jordan Hubbard's modern history of the FreeBSD project since 1993.
- http://www.levenez.com/unix/ An amazing printable, graphical timeline of all flavors of UNIX since its inception in 1969, compiled and kept up-to-date by BSD/NeXT fan Éric Lévénez.

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The Design Philosophy of UNIX

Several things have kept UNIX going strong even after 30 years. One of these is its portability, as mentioned earlier. One widely held opinion among its adherents, however, is that the most important thing that has kept UNIX on the cutting edge, when most other software that old is considered obsolete, is its design philosophy dictating how an operating system should work. Many people tend to think of UNIX as an extremely complicated, austere, and confusing operating system. But to seasoned users, UNIX is the ultimate example of the KISS (Keep It Simple, Stupid) credo of software engineering. This enables savvy users to perform very complex tasks with rudimentary tools, as long as they tie together the right way.

The UNIX design philosophy is that every task should have its own small software program that performs that one task and does it well. But the designers of UNIX had a brilliant ideathat these programs should be able to be combined together by the user to do things that a single program could not do by itself.

Note

This combination concept is known as *piping*. Doug McIlroy of Bell Labs is credited with coming up with the idea. Ken Thompson implemented it in UNIX. (We cover pipes in detail as part of Chapter 8, "Working with the Shell.")

Here is an example of the way these "pipes" of data processing programs work. Suppose that you have a plain-text file that serves as a simple address book. It uses one line per person and contains names, addresses, phone numbers, email addresses, and so on. Fields in this file are separated by a tilde (`~`), a character unlikely to be used in any of the data fields. A few sample lines from the file might look like these:

```
Doe, John~505 Some Street~Anytown~NY~55555~505-555-1212~jdoe@email.com

Doe, Jane~121 Any Street~Sometown~NY~12121~121-555-1212~jadoe@isp.com

Bar, Foo~501 Some Street~Anytown~NY 55555~505-123-4567~foobar@email.com
```

This file could contain 50 names or 500 namesit really doesn't matter. You want to be able to mine and rearrange the data in the file to generate several different results: to get a list of all the people that live in Anytown; to get just their names and phone numbers; to sort the list alphabetically; and to print out a hard copy of the list. There is no single command that will do everything you want, but you can combine several commands together in a pipe to do what you want. Here is one of several ways that this task could be accomplished:

```
# awk 'BEGIN {FS="~"} $3 == "Anytown" {print "%s\t%s\n",$1,$6}'\
address.txt |sort |lp
```

Don't worry if you don't understand exactly what this code does; it's explained in Chapter 10, "Shell Programming." In simple terms, the code sets the field separator to the tilde, selects lines where the third field (the field that contains the city name) is equal to `Anytown`, and then prints the first and sixth fields (the name and phone number) of these lines, separated by tabs (`\t`), with a newline at the end of each line (`\n`). The file it gets the information from is `address.txt`. The output is then piped to the `sort` command, which sorts it in alphabetical order. It is then piped to the `lp` command, which will print the output on the default printer. Here is what the output looks like using our simple three-record data file:

```
Bar, Foo        505-123-4567
Doe, John       505-555-1212
```

Although this command string may seem somewhat arcane to a novice, a UNIX user with only a little bit of experience can decode it easily and tell what it's meant to do. The single line of code shown here creates a simple database that, with a few judicious modifications, can be made to search by any field and present output in any form you want.

Just so you can see how powerful this single line of code can be, here is a second example that modifies the previous example slightly to print a simple mailing list:

```
# awk "BEGIN {FS="~"} $3 == "Anytown"\
{printf "%s\n%s\n$s, $s $s\n\n",$1,$2,$3,$4,$5}" address.txt |lp
```

The output of the preceding code is as follows:

```
Doe, John
505 Some Street
Anytown, NY 55555

Bar, Foo
501 Some Street
Anytown, NY 55555
```

Being able to reduce complex functions like these to a single command line is critical to writing shell programs, as you'll see in Chapter 10; with just a few lines made up of these rudimentary UNIX commands, you can create deceptively simple scripts that perform very useful tasks, and which you can modify to suit any need. For those who are willing to learn, UNIX is about as close to an infinitely customizable and flexible operating system as you can get. Immense power is locked up inside UNIX (and therefore FreeBSD) that can be unleashed and used to do things for free that you might expect to require expensive, dedicated software.

It is the flexibility of this timeless design philosophy, retaining its usefulness no matter how fast computer hardware becomes or how complex desktop GUIs get, that has kept UNIX relevant, unlike so many other software efforts over the years.

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How FreeBSD Compares to Other Operating Systems

When determining how FreeBSD compares to other operating systems, it's important to consider the mainstream desktop operating systems such as Windows XP and Mac OS X, as well as FreeBSD's chief open-source rival, Linux. This section explores these comparisons as well as those of other BSD-based operating systems.

Windows XP

Microsoft has done a good job of listening to what its customers want in an operating system. Windows XP doesn't allow you to "get under the hood" much. It is designed to work reasonably well for a wide variety of tasks without the user having to learn about the internals of the system. It does this, however, at the expense of some raw performance, efficiency, and especially flexibility. Windows XP has relatively steep hardware requirements, but many users are willing to accept this in exchange for ease of use, especially with the ever-plummeting costs of new computer hardware. In addition, because of the graphical design of Windows, "power users" can easily hit limits. There is only so much that can be done from a graphical user interfacethe user is limited to what buttons and controls are available in the software. The following list outlines some of the important differences between FreeBSD and Windows:

- *The Windows kernel cannot be customized.* The kernel is the core of the operating system; it controls virtually every other aspect of how the system works. FreeBSD allows you to build a new kernel for the operating system that is customized for your specific system, enabling only the features and device drivers that you need, or adding driver support for newly developed devices. This can increase performance and reduce memory usage, as well as keep you from being at the mercy of official driver makers. Windows XP does not allow you to rebuild or customize the kernel. This is one of the areas where Windows XP sacrifices some efficiency and performance for ease of use.

- *Windows XP uses a GUI (graphical user interface) for almost all tasks, whereas FreeBSD relies much more on the command line.* The GUI in Windows XP is laid out so that things are easy to find and common tasks are easy to perform. For example, setting up a network in Windows XP is done from a network control panel, and there are "wizards" that walk you through the process. FreeBSD, on the other hand, uses textbased configuration files for network configuration. Setting up the network involves editing one or more configuration files by hand. FreeBSD's philosophy means you're much more free to mess things up than in the regimented Windows interface, but it also means there is no Registry to corrupt, and configuration changes can be backed out using simple version control systems such as CVS (or merely with a text editor).

- *The Windows XP GUI is always running; the GUI in FreeBSD is optional.* Although a GUI can make a workstation easier to use, it is wasteful on a backroom server because no one ever sees its screen anyway (and it can lead to security vulnerabilities as well). FreeBSD gives you the option of turning off the GUI or not using it at all. If you do choose to use a GUI, a wide variety of desktop environmentsGNOME, KDE, and many othersgive you great flexibility in tuning your GUI to your needs.

- *Windows requires special software for remote administration.* Because everything in FreeBSD can be done from the command line, it is very easy to administer remotelyyou can connect to the command line shell using SSH and exchange simple text commands to control the computer. In FreeBSD, all system-administration tasks can be done from the command line. This makes remote administration easy. It can be done from any terminaleven a terminal that cannot display graphics. It can also be done from any type of system that is capable of running a terminal emulator. FreeBSD can be administered from another UNIX-like system, Windows system, Macintosh, and so on. Windows XP, on the other hand, requires the use of the GUI, and accessing a Windows system remotely requires that you install special remote client software and perform graphics-intensive operations that involve moving windows and mouse pointers on the remote system. Most remoteadministration tasks for Windows can be done only from a Windows machine or Macintosh with the Remote Desktop client installed, or from Linux or FreeBSD using the `rdesktop` package.

- *By nature, any GUI (including that of Windows XP) has limits that are not present in a command-line interface.* A GUI is a user interface layer that exists at a high level, far separated from the kernel, and constrained by what features are designed into it. Only so many features can be crammed into a GUI. Sooner or later, a "power user" will want to do something that the operating system designers didn't consider. For example, the simple address book database demonstrated in the previous section could not be done with the software that is included with Windows. A similar system would require third-party software in Windows. The mailing list example could not be done with the software included with Windows, either. Using the textual command-line interface (CLI) in FreeBSD, where your commands are executed much closer to the kernel level, your flexibility and power is much greater than in a GUI-based system.

Mac OS X

Apple's graphical operating system, Mac OS X, serves much the same purpose as Windows XPit occupies the same niche in the computing world, with prescribed workflows designed into the graphical layout in a way that most agree is more intuitive and userfriendly than in Windows (it is, after all, Apple's claim to fame). It thus involves all the same advantages and sacrifices that Windows does, including the non-customizable kernel and the omnipresent, heavy GUI. It's also encumbered by requiring proprietary hardware on which to run, something that's anathema to FreeBSD.

However, Mac OS X can also be thought of as a hybrid operating system, falling somewhere between Windows and FreeBSD. Mac OS X is based on a true UNIX architecture, with a remotely accessible command-line interface that can be driven as usefully from a remote Windows or UNIX machine as the command-line shell of FreeBSD. Mac OS X is in fact based on NeXTSTEP, the operating system of Steve Jobs' company NeXT, which he based on 4.4BSDthe same code base that contributed much of its architecture to FreeBSD itself. If you're familiar with the plumbing underneath the pretty GUI of a Mac, you're already largely familiar with FreeBSD. Similarly, after you finish reading this book, you'll know a whole lot more about Mac OS X than you ever did before.

Linux

Unless you've been living in a cave for the last few years, you have at least heard of Linux, even if you don't know what it is. Linux is a work-alike clone of UNIX that has become extraordinarily popular in recent years. Like FreeBSD, it is open-source and developed by volunteers. Unlike FreeBSD, there is no single controlling authority for Linux, and there are well over 60 different distributions of it. More similarities than differences exist between FreeBSD and Linux. Both are excellent, multipurpose operating systems, and both can serve the needs of most users quite well. Although more software is available for Linux than for FreeBSD, FreeBSD can run almost all Linux software that is available, so compatibility is not really an issue. When running Linux software under FreeBSD, performance rarely suffersin fact, FreeBSD actually runs some Linux software faster than Linux itself does.

Here are some of the most important differences between FreeBSD and Linux:

- *FreeBSD has only one distribution, whereas Linux has more than 60 distributions.* FreeBSD will work the same way on all systems in which it is installed. This is not true with Linux. Each Linux distribution has a slightly different way of doing things. For example, Slackware Linux uses BSD-type run control scripts, which control how various services are launched at startup. Debian Linux uses Sys V run control scripts in a different architecture than the BSD-style scripts; Red Hat Linux uses Sys V run control scripts but stores them in a different location than standard Sys V UNIX does. This can be confusing for users who move from one distribution of Linux to another because things may not work the same way from one distribution to the next. (The same argument can be made with FreeBSD versus NetBSD and OpenBSD, but the differences between these "flavors" of BSD UNIX are arguably more fundamental and significant than between the various distributions of Linux.)

- *FreeBSD is a complete operating system maintained by a core team; Linux is a kernel maintained by Linus Torvalds.* Linux is not a complete operating system. It is a *kernel*. As mentioned in the section on Windows, the kernel is the core of the operating system. It controls the flow of data through the system, managing device drivers and networking, and keeping the system running while you run your applications in the foreground. The various companies that sell Linux distributions take the Linux kernel and package it with a bunch of other programs designed to work with Linux. Because each company has its own idea about what should be included in a distribution, you may find that a program you had available on one Linux system does not exist on another Linux system (although you could download and install it). This fact can also cause dependency problems when upgrading Linux. For example, you may upgrade your Linux kernel, only to find out that you need to upgrade several other packages as well, and in the meantime your system might not even boot. Because FreeBSD is a complete operating system, upgrades are generally easier to do because any dependencies are upgraded at the same time.

- *Development of Linux by its distribution organizations leads to many parallel code bases; contributions to FreeBSD are part of a single development effort.* Although anyone can contribute to the FreeBSD project, such contributions can take place anywhere in the operating system. In Linux, kernel code changes must be approved by Linus Torvalds, but contributions elsewhere in the system become part of one distribution or another. Contributions to the FreeBSD source code need to be approved by the core team of *committers* (programmers who are part of the central FreeBSD development effort) before they will be merged into FreeBSD. This is good for most users because you can be sure that the code has been checked for problems by people who know what they are doing. It also helps to ensure that the code will not cause problems with other code that already exists. This is a common problem with Linux, which is why many Linux distributions seem to come with at least some part "broken" out of the box. Because there is only one base of FreeBSD code (commonly known as a *source tree*), this is far less of a problem with FreeBSD.

These are some of the most important differences between Linux and FreeBSD. Because FreeBSD has a single source tree that is controlled by a core team, it tends to be more stable than Linuxand therefore is often more suitable for a production environment. (Different distributions of Linux are focused on different applications, some for the flexibility of hobbyist machines, some for top-end enterprise and server installations.) The main drawback to this approach is that new features are not always implemented as quickly in FreeBSD as in Linux. There is a tradeoff here. Do you want stability for a production environment? Or do you want the latest gizmos and gadgets to play with at the expense of performance and stability?

NetBSD

NetBSD's claim to fame is the sheer number of platforms that it runs on. NetBSD has been ported to everything from PDAs to gaming consoles such as the Sony PS2. It also, of course, runs on the standard x86 hardware found in most PCs. The main drawbacks of NetBSD are that it is not as user-friendly as FreeBSD or as aggressively developed, and it doesn't have the number of applications ported to it that FreeBSD does. Because of this, new users who have x86 hardware are probably better off with FreeBSD.

OpenBSD

OpenBSD's main selling point is its security. Although much of this security comes from the default configuration, which can be mimicked in FreeBSD, some of it comes from unique OpenBSD features, such as the ability to encrypt the swap file (the region of the disk used for virtual memory). However, like NetBSD, OpenBSD is not nearly as userfriendly as FreeBSD, and it also doesn't have nearly the number of ported applications that FreeBSD has. Again, this is a result of the security-conscious focus of OpenBSD, which actively avoids incorporating superfluous features for fear of exposing security weaknesses. So once again, new users with x86 hardware who want the widest choice of applications and features are probably better off with FreeBSD.

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"Beastie," the FreeBSD Mascot

Linux has "Tux" the penguin; it seems only fair that FreeBSD should have its own mascot as well. So why is it a devil?

Figure 1.1. The popular BSD "Beastie" mascot artwork, © Kirk McKusick. In what should amuse animation fans, Pixar's John Lasseter drew this and several other renditions of Beastie.

The short answer is that it's not a devilit's a *daemon*. Daemons are the background processes that handle all automated tasks the system needs done. Daemons are actually wonderfully helpful things. If you've ever sent an email or visited a web page, you have used the services of a daemon without even knowing it. Windows XP also has daemons; they just aren't called that. Microsoft calls them "services" instead.

Note

Many observers of the BSD Daemon mascot carry the metaphor further and insist that the character's trident, or fork, is intended as a reference to the ability of the operating system to *fork* new processes, which means to create carbon copies of running processes so as to handle new requests, such as a new Apache process to serve a web surfer's demand for a web page, while still leaving Apache running and able to handle incoming requests from other visitors at the same time.

A controversial effort is underway to abolish the BSD mascot in deference to those users who consider it to be a religious affront. Naturally, there is an equally energetic defense of the character entrenched in the message boards of the BSD advocacy community, and we can surely expect the battle to rage on in the future. Now's your chance to develop your first emotional investment in FreeBSD: Will you be a defender of Beastie? Or will you call for his execution? This is the open-source community; your voice has as much chance to be heard and heeded as that of the most central FreeBSD committer!

Chapter 2. Installing FreeBSD

IN THIS CHAPTER

Before you can use FreeBSD, you need to install it on your system's hard disk, just as you would install Windows or any other operating system. FreeBSD's installation procedure is a bit more complex and requires a bit more attention to detail than the average Windows installation, but following the procedure outlined in this chapter should get you through it without any mishaps. Depending on how fast your system and your optical drive run, the installation process will take anywhere from about 20 minutes to an hour or moreor, if you're installing over the network, several hours. Most of this time is spent copying files, so you will not always need to be sitting in front of your computer.

I strongly suggest that you read this entire chapter before beginning the installation to familiarize yourself with the procedure ahead of you and plan for possible pitfalls. There are considerably more things that can go wrong in a FreeBSD installation than you might be used to in installing Windows, and it pays to know in advance what kind of information to give the installer and what the computer will be used for in its work environment. Refer also to Chapter 3, "Advanced Installation Tasks," for an overview of some procedures that may be necessary, including backing up your existing files and repartitioning your disk without losing data.

Caution

Make sure to pick a time to perform the installation when you will not be distracted. You will be performing actions during the installation that are potentially hazardous to existing data on your system if you make mistakes.

Tip

Now is a good time to look over the hardware compatibility list in Appendix B, "Hardware Compatibility Lists," to make sure your hardware is supported. You won't want to continue the install if you find out a key piece of hardware in your system is not supported by FreeBSD.

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Checking Your Hardware

Before you begin the installation, you should have available some information about your hardware in case the system can't automatically detect it or configure it without your help. Here is a list of the hardware information you may need during the FreeBSD installation:

- The type of video card and the amount of video RAM installed.
- The manual for your monitor. You need to know the horizontal and vertical refresh rates for setting up X, the graphical windowing system for FreeBSD.
- If you have a modem, the COM port (for example, COM1 or COM2) and IRQ (interrupt request number) it is using.
- The type of mouse you have (serial, PS/2, bus, or USB) and what port it uses.
- The memory address and IRQ of your Ethernet card, particularly if it's an old ISA card. The model and manufacturer of the card is also very important. (Most modern Ethernet cards are automatically detected and don't require you to know this information; they're also so inexpensive that it's often best to just get a new one if yours is even slightly outdated.)
- If you are connected to a network, you will also need to gather certain network information, such as your hostname, IP address, subnet mask, DNS servers, and gateway router. If you are unsure of these numbers, ask your network administrator or Internet Service Provider for this information. (If you are on a network that uses DHCP to assign network addresses automatically, you won't need this information.)
- The capacity of your hard drive. A FreeBSD installation with the X Window System (X11) and the ports collection will consume about 1.2 gigabytes of space.

If you don't have this information available and you currently have Microsoft Windows installed on your system, you can often get the numbers you need from the Device Manager in the Windows Control Panel. See your Microsoft Windows documentation or Windows Help for information on how to do this.

Caution

Users moving from FreeBSD 4.x to FreeBSD 5 or FreeBSD 6 should be aware that the "Binary Upgrade" option in Sysinstall is broken when trying to make a major version jump like this. If you want to upgrade from FreeBSD 4 to FreeBSD 6, you should consider backing up your data and performing a fresh installation from scratch; if this is not feasible, try performing a source upgrade instead. This is relatively easy to do. Chapter 19, "Keeping Up to Date with FreeBSD," discusses upgrading from source in detail.

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Creating Installation Floppies

The FreeBSD installation DVD included with this book is bootable. If you plan to install on a system that supports booting from the CD/DVD drive, you can probably skip this section. If your optical drive does not support booting or if you plan to install from some method other than from the DVD (such as installing over a network), read on.

If you're installing over a network or if your system doesn't support booting from a DVD, you need to create three boot floppy disks so that you can boot the system with a bare kernel and minimal skeleton operating system, which then downloads the entire operating system from the FreeBSD FTP server and installs it onto your hard disk. The boot disks are created by copying disk image files, downloaded from the FTP server, onto standard floppy disks.

Caution

A floppy installation involves downloading several hundred megabytes from the FreeBSD FTP server. Be sure you have an adequate Internet link for doing this, or at least a lot of spare time if your link is slow!

You can download the boot disk images from the FreeBSD FTP server; use your favorite FTP client to connect to `ftp.freebsd.org`. The images are located in `/pub/FreeBSD/releases/i386/6.1-RELEASE/floppies`assuming that 6.1 is the most recently released version of FreeBSD. If it isn't, replace `6.1` with whatever the current `RELEASE` version is. The three files you need to download are `boot.flp`, `kern1.flp`, and `kern2.flp`. If you create the floppies on a DOS or Windows system, you also need the `fdimage.exe` program located in the `/pub/FreeBSD/tools` directory on the FTP server.

Tip

For better response time and also to cut down on the traffic load on the main FTP server, you might want to try downloading the boot floppies from one of the mirror sites, whose hostnames are generally `ftp` followed by a number (for example, `ftp1.freebsd.org` or `ftp2.freebsd.org`). Using a less-trafficked mirror can speed up the transfer.

The boot floppy files cannot simply be copied onto a floppy disk. The disks must be "cloned" from the disk images using one of the procedures described in the following subsections. These procedures show you how to create the boot floppies in various environments, such as on a Windows machine or another UNIX or Linux computer. To begin any of the methods described next, you need three blank 1.44MB 3.5-inch floppies.

Tip

Use brand-new floppies to create the boot disks. The boot disks write raw data to the floppies with no regard for the format of the disks or their condition; there is no error checking, and a disk with bad sectors can cause a stalled or corrupted installation. Save yourself the headache and just use brand-new floppies.

Creating the Boot Floppies from a DOS or Windows System

Open a window containing the DOS prompt (on modern versions of Windows, go to Start, Run and enter the command **`command`**). You are placed into your user account's home folder.

Change to whatever directory you used when saving `fdimage.exe`, `boot.flp`, `kern1.flp`, and `kern2.flp`. For example, if you saved them to your Desktop, type the following commands at the DOS prompt:

```
C:\Documents and Settings\Administrator> cd Desktop

C:\Documents and Settings\Administrator\Desktop> fdimage boot.flp a:
```

When the program finishes running, remove the first floppy from the drive and insert the second one. Then type the following at the DOS prompt:

```
C:\Documents and Settings\Administrator\Desktop> fdimage kern1.flp a:
```

Repeat the process to create the third disk from `kern2.flp`. Finally, label the disks! (You'll be glad you did.)

Creating the Boot Floppies from Another FreeBSD or UNIX System

If you are creating the floppies on another FreeBSD or UNIX system, you do not need the `fdimage.exe` program. (You still need the `boot.flp`, `kern1.flp`, and `kern2.flp` disk image files, though.)

Use the UNIX `dd` utility to write the disk images bit-by-bit to the floppies. On a FreeBSD system, it looks like this:

```
# dd if=boot.flp of=/dev/fd0c
```

When the copy finishes, remove the first floppy from the drive and insert the second one. Once again, use `dd` to create the second floppy. On a FreeBSD system, it would look something like this:

```
# dd if=kern1.flp of=/dev/fd0c
```

Repeat the process once more to create the `kern2.flp` disk.

Note that for the preceding commands to work, you must have write access to the floppy device, whose name under FreeBSD is `/dev/fd0c`. Other operating systems might use a different name for the floppy device, or require that you use a "raw" device name; Red Hat Linux, for example, might use `/dev/fd0 or /dev/floppy`. See the documentation for your operating system to find out the name of the appropriate device name for writing data to the floppy drive with `dd`.

Now that you have created the installation disks, you are ready to begin the installation.

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Booting into the Install Program

Caution

If you are installing on a system that already has Windows or some other operating system on it and you don't want to lose that operating system and all its data, stop here and read "Potential Problems with and Limitations of Dual-Boot Systems" in Chapter 3. *It is very important that you read this first.* Failure to follow the instructions in that section could result in the loss of all data on your hard disk!

The next few sections assume that you either plan to wipe out everything currently on your hard disk to install FreeBSD, that you are installing on a new disk, or that you have already followed the instructions in Chapter 3 to create space for FreeBSD on a system that already has another operating system installed on it. These sections also assume that you are installing from the FreeBSD DVD included with this book. If this is not the case, stop here and read the relevant sections in Chapter 3 on NFS or FTP installation. After you do that, come back and continue with the instructions given here.

When you are ready to begin the installation, insert the included DVD into your optical drive. (If you chose to install from floppy disks, insert the floppy disk on which you installed `boot.flp` into your A: drive instead.) Reboot your system. If necessary, enter your BIOS setup program and enable booting from the optical drive or floppy drive, as necessary.

Note

Some BIOSes also have a security feature that prevents booting from the floppy drive. If you have to boot from the floppy drive, you might need to check for this option and set it to allow booting from the A: drive. See your system documentation for the way to configure the BIOS settings to control boot devices.

As the system boots, you should see some FreeBSD status messages on your screen. You should also see a "twirling baton," an animated cursor that indicates an in-progress task. As long as the baton keeps twirling, the system is doing something. If the baton stops twirling for a long period of time, it probably means your system is hanging. If that happens, refer to Appendix C, "Troubleshooting Installation and Boot Problems."

Note

In versions of FreeBSD earlier than 6.0, you'll see a message like the following instead of the full-screen boot menu:

```
FreeBSD/i386 bootstrap loader, Revision 1.1
(root@x64.samsco.home, Thu Nov  3 07:33:10 UTC 2005)
|
Hit [Enter] to boot immediately, or any other key for command prompt.
Booting [kernel] in 9 seconds... _
```

If you see this message, go ahead and press Enter to continue.

At some point during this process, if you're installing from floppies, you will be asked to "`Insert disk labeled "Kernel floppy 1" and press any key`"; that's the `kern1.flp` disk. After it's loaded, you will be prompted to replace it with the `kern2.flp` floppy. Finally you're asked to reinsert the boot floppy, `boot.flp`, once more.

When the kernel is loaded, a textual boot menu appears, giving you several options for how to launch FreeBSD. Depending on your console's capabilities, this screen might show the "daemon" mascot in color or black-and-white, or a FreeBSD logo in ASCII text, to the right of the list of options. For now, press Enter to accept the default option, Boot FreeBSD. This option leads you into the Sysinstall program.

Note

A flurry of messages will go past your screen as the kernel detects and initializes the hardware in your system. If your system hangs at any point during this period, see Appendix C for help on troubleshooting installation problems.

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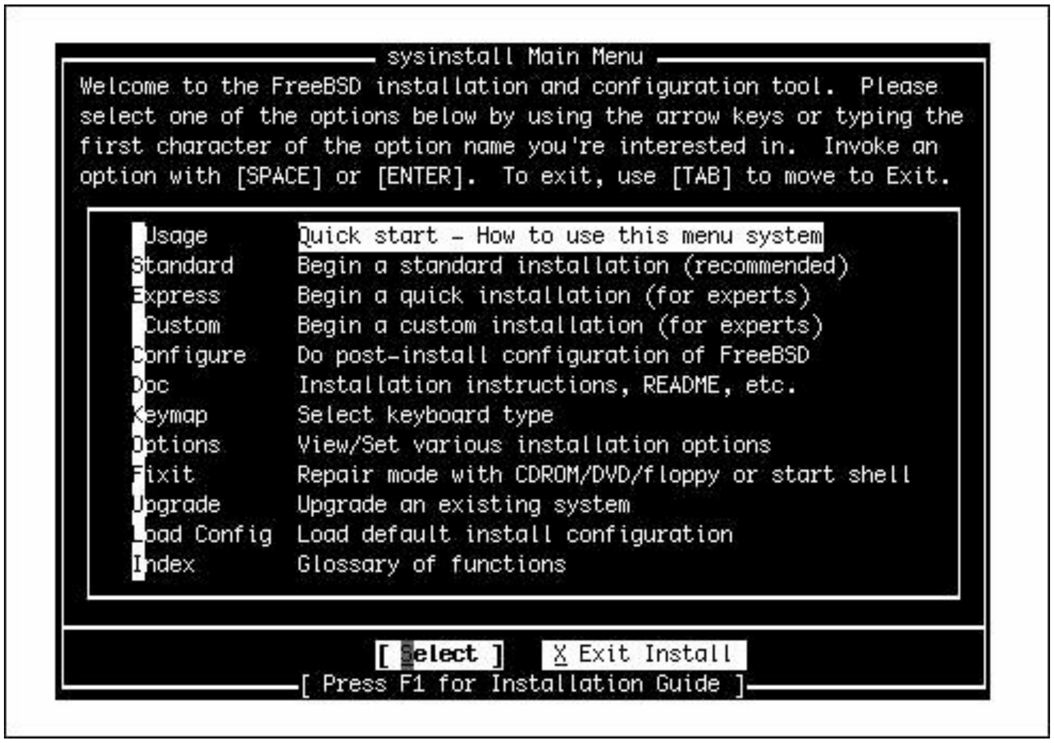
Navigating the Sysinstall Program

After the kernel has finished booting (and assuming you didn't run into any problems), you will be placed into the FreeBSD Sysinstall program. The first screen you see looks like Figure 2.1.

Figure 2.1. The main Sysinstall menu.



```
sysinstall Main Menu
Welcome to the FreeBSD installation and configuration tool.  Please
select one of the options below by using the arrow keys or typing the
first character of the option name you're interested in.  Invoke an
option with [SPACE] or [ENTER].  To exit, use [TAB] to move to Exit.

   Usage        Quick start - How to use this menu system
   Standard     Begin a standard installation (recommended)
   Express      Begin a quick installation (for experts)
   Custom       Begin a custom installation (for experts)
   Configure    Do post-install configuration of FreeBSD
   Doc          Installation instructions, README, etc.
   Keymap       Select keyboard type
   Options      View/Set various installation options
   Fixit        Repair mode with CDROM/DVD/floppy or start shell
   Upgrade      Upgrade an existing system
   Load Config  Load default install configuration
   Index        Glossary of functions

             [ Select ]  X Exit Install
           [ Press F1 for Installation Guide ]
```

You can't use the mouse in Sysinstall, but the program is easy to navigate. Table 2.1 lists the navigation keys you can use in Sysinstall.

Table 2.1. Navigation Keys

Navigation Key	Command
Up arrow	Moves up to the previous option in the menu.
Down arrow	Moves down to the next option in the menu.
Left/right arrow	Toggles between the choices at the bottom of the menu. For example, on the main menu the left and right arrow keys toggle between Select and Exit Install.
Spacebar	In menus where multiple options can be selected, the spacebar toggles the current highlighted option on and off.

Tab key	Has the same effect as the left and right arrows in menus. You can tab between fields in screens in which you need to fill in blanks.

In addition, you can also select most options by typing their highlighted letterusually the first letter in the option name.

If you want to read more about using Sysinstall, you can press Enter on the highlighted option Usage, but because it will all be explained here, I suggest you press the down arrow to move to the second option and then select it to begin a standard install.

After you select the Standard option, a message will inform you that you need to set up a DOS-style (`fdisk`) partitioning scheme for your hard disk. After you read this message, simply press Enter to continue.

PREV NEXT

Creating Partitions and Assigning Mount Points

After you press Enter on the informational message telling you about creating a DOS-style (`fdisk`) partitioning scheme, one of two things will happen:

- If you have only one hard disk in your system, you will be placed directly into the FreeBSD Partition Editor. In this case, you can skip the next section, "Selecting Hard Disks," and continue with "Partitioning the Disk(s)."
- If you have more than one hard disk in your system, you will be given a menu to select on which hard disk or disks you want to install FreeBSD. If this is the case, read the next section, "Selecting Hard Disks."

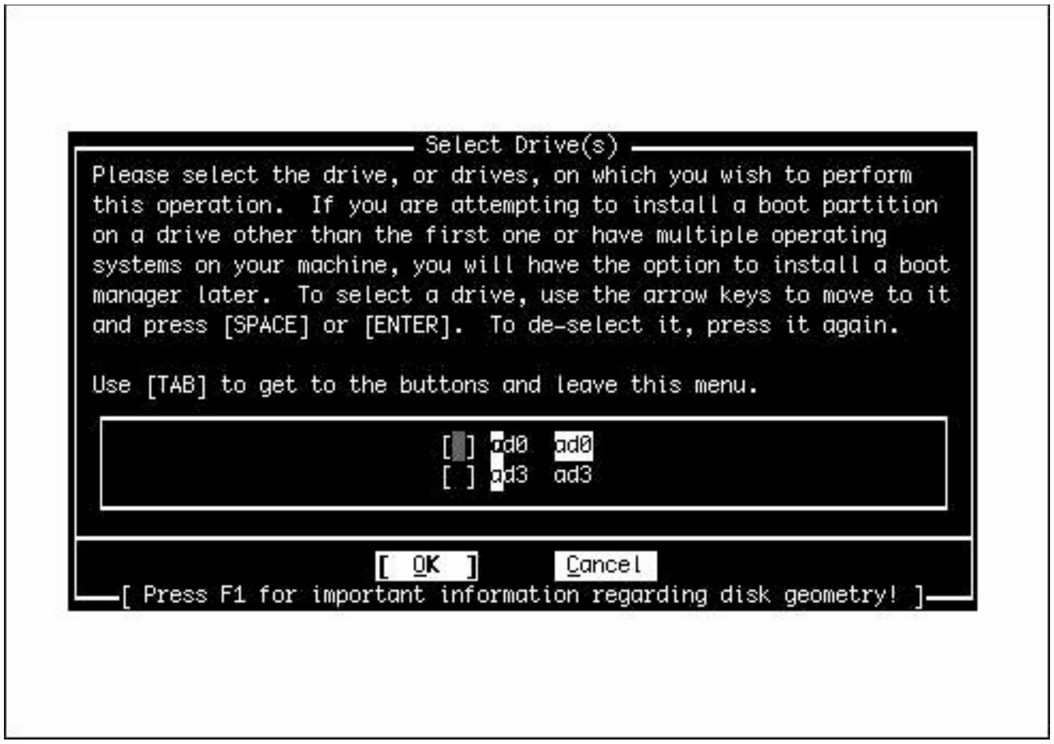
Caution

Creating partitions and assigning mount points are areas in which a mistake can cause the loss of all data on your hard disk. If your hard disk contains anything you want to keep, make sure you back it up first. Also, read Chapter 3 if you will be installing FreeBSD on a drive that already has another operating system on it.

Selecting Hard Disks

If you have multiple hard disks on your system, you will see a menu that looks similar to Figure 2.2.

Figure 2.2. Selecting the hard disks on which to install FreeBSD.



```
                         Select Drive(s)
Please select the drive, or drives, on which you wish to perform
this operation.  If you are attempting to install a boot partition
on a drive other than the first one or have multiple operating
systems on your machine, you will have the option to install a boot
manager later.  To select a drive, use the arrow keys to move to it
and press [SPACE] or [ENTER].  To de-select it, press it again.

Use [TAB] to get to the buttons and leave this menu.

                         [ ] ad0  ad0
                         [ ] ad3  ad3

                     [  OK  ]      Cancel
   [ Press F1 for important information regarding disk geometry! ]
```

Your menu might not look exactly like the one shown in the figure. Table 2.2 lists some of the values you might see in the menu and what they mean.

Table 2.2. Menu Values

Value	Meaning
`ad0`	The first physical hard disk on the system (the name stands for *ATA Disk*). This is the master drive on the primary IDE controller. If you have DOS or Windows installed on your system, it will be located on this drive.
`da0`	Similar to `ad0`, except that it indicates an SCSI disk ("Direct Access") instead of an ATA disk. Once again, this would be the first SCSI disk on your system. If you have only SCSI drives on your system and you have DOS or Windows installed, it will be located on this drive.
`ad1`	The second ATA disk on the system. Depending on how your system is set up, this can be either a slave disk on the primary controller or a primary disk on the secondary controller.
`da1`	The second SCSI disk on the system.

You might also have `ad2` and `ad3` in your listor `da2`, `da3`, and so on. Just remember that the number represents the number of the drive in your system and that FreeBSD starts numbering the drives at zero instead of one.

Use the spacebar to select which disk or disks you want to use for FreeBSD. You can select more than one disk for the FreeBSD installation. This is fairly common, and the end result is transparent for everyday operation. In other words, even if FreeBSD is installed across multiple disks, it appears to the end user that everything is on a single disk. You will see in the next section, "Partitioning the Disk(s)," why it might be advantageous to install on multiple disks.

When you select a disk from this menu, you are placed in the FreeBSD Partition Editor, where you can edit the partition table for that disk. After you finish editing the partition table and leave the Partition Editor, you are placed back at this menu. You can then select another disk to edit or press Enter to leave the menu and continue with the installation. After you finish editing disks, you are placed into the FreeBSD Disk Label Editor (more on that after the next section, which explains the Partition Editor).

Caution

If you're going to install FreeBSD on a second hard disk, you have another operating system on the first hard disk, and you don't plan to make any changes to the first hard disk, you need to install a boot manager so that you can choose which operating system you want to boot at system startup. FreeBSD will give you the option of installing the boot manager later in the process. However, the boot manager *must* be installed on the first disk in your system. In order for this to happen, you *must* select the first drive in this menu. If you do not want to make any changes to the first disk, simply select it in the menu and then exit the Partition Editor without making any changes to the disk. You can then select a different disk in the menu and partition it for use with FreeBSD. This allows FreeBSD to install the boot manager on the first disk. If you do not do this, the boot manager will not be installed on the first disk, and you will not be able to boot FreeBSD after the installation is finished.

Partitioning the Disk(s)

Here is what the Partition Editor looks like:

```
Disk name:      ad0                                     FDISK Partition Editor
DISK Geometry:  29795 cyls/16 heads/63 sectors = 234436482 blocks (113664MB)

Offset       Size(ST)        End      Name  PType       Desc  Subtype    Flags

         0          63          62         -     12     unused        0
        63    30033297    30033359    ad0s1       8    freebsd      165




The following commands are supported (in upper or lower case):

A = Use Entire Disk    G = set Drive Geometry   C = Create Slice   F = 'DD' mode
D = Delete Slice       Z = Toggle Size Units    S = Set Bootable   | = Wizard m.
T = Change Type        U = Undo All Changes     W = Write Changes


Use F1 or ? to get more help, arrow keys to select.
```

In this case, the first line tells you that you are working on the disk `ad0`, which, as mentioned previously, is the first ATA disk in the system. The second line gives you information about the geometry of this disk. (See Chapter 20, "Adding Hard Disk Storage," if you need help with this. It's not important that you understand the geometry of your disk unless FreeBSD is having trouble detecting it.) The next several lines give you information about each currently defined partition on the system. If this is a new disk, or if you deleted all the partitions on it before installing FreeBSD, there will be only one partition with the description "unused" that takes up the entire disk. Table 2.3 explains what each column of information means.

Table 2.3. Partition Table Information

Column	Information
`Offset`	The starting sector of the partition.
`Size (ST)`	The size of the partition in sectors.
`End`	The last sector in the partition.
`Name`	The FreeBSD-assigned device name of this partition (if known).
`PType`	A number representing the partition type.
`Desc`	The type of partition.
`Subtype`	More information about the partition type.
`Flags`	The following symbols can appear in this column:
	`=` The slice is properly aligned.
	`>` The slice extends past the 1,024th cylinder on the hard disk. This becomes an issue later on when you create the disk labels because boot partitions that extend past the 1,024th cylinder can cause problems on some systems (this is a BIOS limitation, not a limitation of FreeBSD).
	`R` The slice contains the root filesystem, which is the top-level filesystem on the FreeBSD system.
	`B` The slice uses BAD144 bad-spot handling.
	`C` The slice is a FreeBSD partition.
	`A` The slice is the active partition (that is, the slice is the bootable slice).

Note

If you are unfamiliar with the terms used in the next section (such as *sectors*), see Chapter 20, which provides an introduction to hard disks and the terminology related to them.

Tip

Press Z to toggle the display units between sectors, kilobytes, megabytes, and gigabytes.

To assign all available space on this hard disk to FreeBSD, simply select A for Use Entire Disk. After this, you should see a line that shows a single partition of subtype `165` with the description `freebsd`. You will also see a line with the description `unused`. Don't worry about thisit's normal, even when you're selecting the entire disk for use. Press Q to exit the Partition Editor. Do not press W (Write Changes) first because that option is intended only for making changes to existing filesystems, not for initial installs.

Caution

Selecting the entire disk for use deletes everything currently on the disk. Make sure you have backed up any information you want to keep from the disk. If you don't want to delete everything on this disk, see Chapter 3 before you proceed with the install.

Note

Unlike with Linux, you do not create multiple partitions on a single disk for FreeBSD, even if you will probably be creating more than one partition on the disk to hold your FreeBSD filesystems. You use the Disk Label Editor to create the separate areas for your different filesystems. The difference between BSD-style "partitions" (slices) and DOS/Linux-style partitions is explained in Chapter 20.

FreeBSD will then ask whether you want to install the FreeBSD boot manager. If you are installing FreeBSD on a drive other than the first one, select the BootMgr option. You also select this option if you are installing more than one operating system on this drive. If FreeBSD is the only operating system to be installed and it will be installed on the primary drive, you can select the Standard option.

If you have only a single hard disk on your system, you will receive a message that tells you to create BSD partitions inside the `fdisk` partition(s) just created. Go ahead and press Enter to go to the Disk Label Editor. If you have multiple disks, go back to the disk selection menu.

Note

If you want to spread your FreeBSD installation out across more than one disk (either because you don't have enough space on one disk for a complete install or for performance reasons), select any other disks you want to use for FreeBSD, repeating the previous steps outlined in this section. When you have partitioned all the disks you want to use for FreeBSD, make sure OK is highlighted and then press the Enter key.

The Disk Label Editor

The Disk Label Editor is where you will actually create the filesystems that will hold the FreeBSD installation. In this system, you subdivide the storage space in the partitions (*slices*) you created in the Partition Editor into subpartitions (*BSD partitions*) that are attached to specific locations in the system. When you first enter the editor, it will look like this:

```
                        FreeBSD Disklabel Editor

Disk: ad0       Partition name: ad0s1   Free: 234436482 blocks (113664MB)

Part      Mount          Size Newfs   Part      Mount          Size Newfs
----      -----          ---- -----   ----      -----          ---- -----


The following commands are valid here (upper or lower case):
C = Create        D = Delete   M = Mount pt.            W = Write
N = Newfs Opts    Q = Finish   S = Toggle SoftUpdates   Z = Custom Newfs
T = Toggle Newfs  U = Undo     A = Auto Defaults        R = Delete+Merge
```

```
Use F1 or ? to get more help, arrow keys to select.
```

Your system may have one or more disks listed here. It depends on how many disks you selected to use with FreeBSD.

Beginning with FreeBSD 5.0, the Auto Defaults option provides reasonable defaults that will work for most purposes. If you aren't sure about partitioning (explained in the next section), you should probably choose the Auto Defaults option (press A) and then press Q to quit the editor and move on to "Selecting a Canned Distribution Set," later in this chapter. If you use more than one disk, you need to manually set up the partitions. If you need to manually create your partitions or if you aren't sure whether you need to create custom partitions, read on.

Manual Partitioning

At a bare minimum, you need to create two partitions: a root filesystem and a swap partition. The minimum is not the best way to do things, however. You might be tempted to do this because it ensures you won't end up in a situation in which you run out of space on a partition where you need it and have 150 zillion gigabytes of free space on a different partition that you can't use for what you need. In fact, there is at least one well-known Linux distribution that encourages putting everything in the root filesystem. This is a dangerous way to live for two reasons.

First of all, FreeBSD and all other versions of UNIX are powerful multitasking operating systems. They are almost always doing somethingespecially on a busy server. These systems usually have several files open at the same time, and they often write to the disk. If the system crashes, a power failure occurs, or the janitor runs the vacuum cleaner over the server's power cord while a write is in progress, the filesystem can be damaged. Depending on what was being written when the crash occurred, the damage can be severe enough to destroy the filesystem. Filesystem damage is far less likely to occur if the filesystem is not being written to when the crash or power failure occurs.

This is why it is a good idea to use multiple filesystems. It not only helps to restrict damage to one areainstead of the entire systemit also helps protect the all-important root filesystem. In a properly laid-out filesystem, the root partition is almost never written to.

The second reason why having everything in one partition is dangerous is that it opens a server to various forms of malicious Denial of Service (DoS). Whether these situations are intentional or not, they can occur, and all too frequently they do. For example, on a system in which user disk quotas are not enforced, a user could either intentionally or accidentally (through the misuse of the command that copies files) create a file that fills up the entire partition where the home directory is located. If all the filesystems are located on that same partition, this would do far more than prevent users from saving files in the home directory. Other fallout from this event could include denial of mail service because there is no room in the mail spool directory, and denial of print service because there is no room to queue print jobs. Also, the web server could stop serving because it can't write its log file. `syslogd` (the program that logs system messages) will be unable to record important messages, which could allow crackers to enter your system undetected. Any programs that need to write temporary files will fail because no room is left in the `tmp` filesystem.

Predicting when you'll run out of space on all filesystems is difficult. However, having more partitions than you need is generally better than having too few; accordingly, I recommend a minimum of five partitions: One for the root filesystem (`/`), one for the swap space, one for the user filesystem (`/usr`), one for the var (`/var`) filesystem, and a final one for temporary files that's writable by all users (`/tmp`). Some people recommend placing the `/var` filesystem in the same partition as `/usr` because it is difficult to judge how much space to give `/var`. I don't recommend doing this, however, because it subjects your system to various possible Denial of Service attacksespecially if users' home directories are also located in the same partition as the `/usr` filesystem.

Note

FreeBSD has the capability to use more memory than is actually installed in the system, through the use of what's known as *virtual memory*. To use virtual memory, FreeBSD moves to the disk any memory pages that are not currently in use. That frees up room in memory for data that's currently needed. When a memory page that was moved out to disk is needed again, FreeBSD moves it back into memory and, if necessary, moves something else in memory out to the disk to make room. These operations are known as *swapping*, and the area of the disk that the swapped-out memory pages are stored in is called the *swap partition*.

To help you better decide what filesystems you want to put on each partition, Table 2.4 describes some of the directories in FreeBSD and what they are used for. Note that this is not a complete list; it has only the directories for which you might want to have separate partitions. For a complete list of all directories and their purposes, see Chapter 12, "The FreeBSD Filesystem."

Table 2.4. FreeBSD Directories and Their Purposes

Directory	Purpose
`/`	This is the root filesystem. It is the directory under which all other filesystems will appear (even if they are located on different partitions, different disks, or even different computers on different continents). The root filesystem needs to have a partition, and FreeeBSD's philosophy is that the smaller this partition is, the better. 256MB should be enough for this partition. If you are really tight on space, you could probably get away with as little as 100, but don't go any lower than that. Note that FreeBSD will give you a warning if you set the root partition to less than 118MB.
`/boot`	The kernel, its modules, and other files required to start the operating system are located in the `boot` directory. You can have a root partition that extends past the 1,024th cylinder by putting `/boot` on its own partition. (Note that `/boot` has to be contained completely in the first 1,024 cylinders.)
`/usr`	The `/usr` filesystem contains most of the utilities and programs that will be accessed by normal users. `/usr` should definitely have its own partition. Traditionally, `/usr` consumes all the space on the disk that is not allocated to the other partitions with their specialized recommended sizes.
`/usr/local`	This is where third-party software that is not part of the operating system is installed (such as web servers and database programs). Some people like to put `/usr/local` on its own partition, separate from the `/usr` partition. Personally, I don't recommend this for normal operations. The only time I would recommend this is if you have multiple disks and need to split `/usr` for space reasons.
`/var`	This is where the system stores "variable" files, or files that are written by programs as part of their operation (such as runtime data files, database content, and logs). I like to put `/var` on its own partition. Some of the things stored in `/var` include incoming mail, system logs, web server logs, and jobs queued for the printer. The size you need to make `/var` depends on whether you will be running a print server, mail server, or web server. Note that on a busy web server, log files can easily grow to more than 100MB in only a couple of days. If you are going to be running a high-profile web server, either give `/var` a lot of space (1GB or more) or make sure you rotate your logs often. If you expect to receive a lot of mail, you will also want to make `/var` quite large, with several gigabytes of space to store all your users' mail spool files (which can become very large, especially if unmaintained).
`/tmp`	This is where programs and users can write temporary files. This directory is usually cleaned out automatically at each reboot. Properly behaved programs that need to write very large temp files should not use this directory; they should use `/usr/tmp` or `/var/tmp` instead, to avoid overfilling the small root partition. You can either give `/tmp` its own partition (as is the default behavior in Sysinstall) or link it to a place in `/usr`. Also, note that if a particular operation requires more temp space than is available, you can temporarily

	change the location where temp files are written for that one operation.
`/home`	This is where users' home directories are located. It is often placed under the `/usr` partition. If you are going to have a lot of users and you expect them to have a lot of files, you might want to put `/home` in its own partition or even give `/home` an entire disk.

Tip

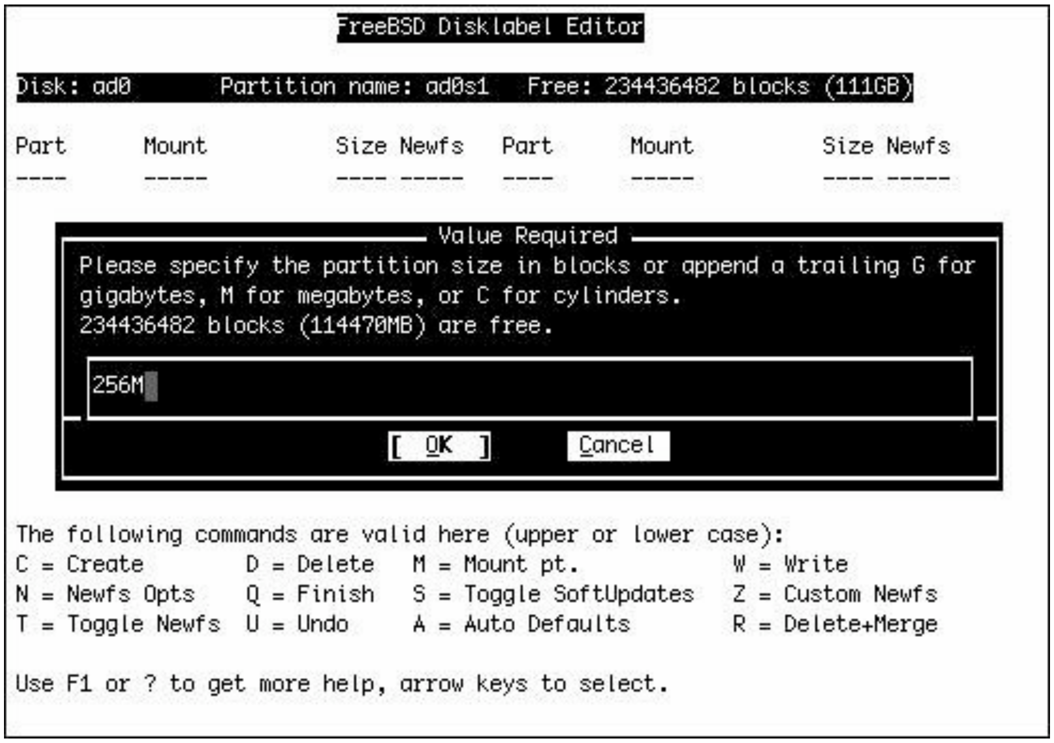
If you have more than one hard disk on your system, you can optimize your system's performance by carefully dividing up disk-intensive tasks between multiple hard disks. For example, if you run a Usenet news server (which is rather disk-intensive) and a web server (also quite disk-intensive), you should put the news directory and the directory where the web server keeps its pages on separate disks. Similarly, keeping your database content on a separate disk from your static web content can speed up a web server by a huge amount.

The Root Partition

If you aren't using a dedicated `/boot` partition, the first partition on your drive should be the root partition (`/`). To create the root partition, use the up or down arrow key to highlight the disk slice (labeled with Disk and Partition name fields, as well as a readout of how much unallocated space is available on it) at the top of the Disk Label Editor that you want to put the root partition on. Then press C for Create Partition.

You then see a dialog box that asks you for the size of the partition (see Figure 2.3).

Figure 2.3. Setting the size of the partition.



```
                          FreeBSD Disklabel Editor

Disk: ad0       Partition name: ad0s1   Free: 234436482 blocks (111GB)

Part      Mount          Size Newfs   Part      Mount          Size Newfs
----      -----          ---- -----   ----      -----          ---- -----

                          Value Required
    Please specify the partition size in blocks or append a trailing G for
    gigabytes, M for megabytes, or C for cylinders.
    234436482 blocks (114470MB) are free.

     256M

                       [  OK  ]        Cancel

The following commands are valid here (upper or lower case):
C = Create        D = Delete   M = Mount pt.            W = Write
N = Newfs Opts    Q = Finish   S = Toggle SoftUpdates   Z = Custom Newfs
T = Toggle Newfs  U = Undo     A = Auto Defaults        R = Delete+Merge

Use F1 or ? to get more help, arrow keys to select.
```

As mentioned previously, 256MB should be sufficient for the root partition. As the dialog box says, you can specify a size in megabytes by adding an M to the end of the number. So, assuming you want to make your root partition 256MB in size, enter **`256M`** at the prompt and then press Enter. You are then asked to choose a partition type for this partition. Because this will hold the root filesystem, select the FSA File System option and press Enter. You are then asked to specify a mount point for this partition. The *mount point* is the directory under which the filesystem will be available. Because this is the root filesystem, enter **`/`** in this box and press Enter.

Your screen should now look similar to this:

```
                         FreeBSD Disklabel Editor

Disk: ad0       Partition name: ad0s1   Free: 29761379 blocks (113408MB)

Part      Mount          Size Newfs   Part      Mount          Size Newfs
----      -----          ---- -----   ----      -----          ---- -----
ad0s1a    /             256MB UFS1   Y





The following commands are valid here (upper or lower case):
C = Create        D = Delete   M = Mount pt.            W = Write
N = Newfs Opts    Q = Finish   S = Toggle SoftUpdates   Z = Custom Newfs
T = Toggle Newfs  U = Undo     A = Auto Defaults        R = Delete+Merge

Use F1 or ? to get more help, arrow keys to select.
```

This code shows that you now have a filesystem at `ad0s1a` (the device name and slice entry that FreeBSD uses to refer to this filesystem), it is mounted on `/`, the size is 256MB, and it is of type `UFS1` (the standard filesystem type for FreeBSD). Next, you deal with the swap partition.

The Swap Partition

FreeBSD is a virtual memory operating system; it can use more memory than it has available in physical RAM. It does this by swapping memory pages of programs that are not currently being used out to the hard disk. When those pages are needed again, FreeBSD swaps them back into memory from the hard disk and, if necessary, swaps something else out to the hard disk to make room for the pages it is bringing in. Of course, accessing something from the hard disk is many times slower than accessing something from RAM, so swap space is no alternative for having enough RAM in a system. But still, swap space is a crucial part of how UNIX and all modern operating systems operate, and a key reason why you seldom have to worry about "Out of Memory" errors these days.

The proper (or improper) configuration of your swap partition can have a significant impact on the performance of your system. Here are some guidelines for choosing where to put your swap partition:

- Put the swap partition as close to the beginning of the disk as possible. Lower-numbered cylinders on the disk, which are closer to the edge, can be accessed and read faster than higher-numbered cylinders (they're moving faster than the ones in the middle).
- If you have multiple drives in your system, as a general rule, you should put the swap partition on the fastest drive in your system.
- If the fastest drive on your system is also the most heavily accessed by users, web servers, mail transfer agents, and so on, you will probably want to ignore the previous point and put the swap partition on the least-accessed drive in your system. Not only does this allow more time for the drive to access the swap space instead of accessing other things, but it also increases the chances that the hard disk heads will already be positioned within the swap partition when swapping is needed. Little things like the time it takes the hard disk heads to cross the disk to where the swap partition is located really make a difference during high loads and heavy swapping.

So, how much space should you allocate for your swap partition? Long ago, when RAM was an expensive commodity and most users made do with 4MB to 16MB of RAM, the rule of thumb was to have 2.5 times as much swap space as you had RAM. But today, RAM is cheap and affordable. A high-end workstation with 1GB of RAM and servers with 4GB or more of RAM are not uncommon these days. The average user can afford to have more RAM than he actually needs. At the same time, though, hard disk space is cheap too, and it's easy to outfit a new system with a disk that's far larger than you need. Because it's much easier to boost the RAM in your system (simply by plugging in new memory modules) than upgrade your primary installation to a bigger disk, you might still want to make sure to start out your FreeBSD career with a swap partition that's at least twice the size of your available RAM. That way, when you double your system's RAM, you won't have to worry about resizing your swap partition because it will still be at least the size of the physical RAM, and thus still useful.

512MB of swap space is a nice number to use if you have 512MB of RAM or less and you aren't really pressed for disk space. If at all possible, you should try to have at least as much swap space as you have RAM. If you plan to do development or track the FreeBSD `CURRENT` branch, this is practically a necessity. Here is why.

Occasionally, something happens that the operating system's kernel doesn't know how to handle. When such an event occurs, the kernel gives up, panics (you get a message that reads "Kernel panic"), and then reboots the system. If configured to do so, however, the panicked kernel attempts to dump the contents of RAM into the swap partition before it reboots. The contents of RAM when the panic occurred are essential to programmers for debugging what is causing the panics. One of two things happens if there is more information in RAM than can fit in the swap space:

- The kernel will refuse to dump the RAM contents. This is the most likely scenario. In this case, no debugging information will be available for diagnosing the cause of the panic.

- If the panic was caused by some state of confusion in the kernel over something regarding the filesystems, it's conceivable that the kernel could dump the RAM contents to the swap partition and keep right on going when it hits the end boundary of the swap partition. The result would likely be irreparable damage to whatever filesystem came after the swap partition on the disk.

Kernel panics don't happen often in FreeBSD. When they do happen, it's nice to be able to use the RAM dump feature so that you or someone else can examine the contents of RAM when the panic occurred and attempt to figure out what is causing the panic. Therefore, try to make your swap partition at least as big as the amount of RAM you have in your system, and bigger if you can spare the disk space.

Note

UNIX kernel panics are similar to the infamous BSOD (Blue Screen of Death) errors in Windows NT/2000/XP. If you are used to working with Windows, you can breathe a sigh of reliefyou won't be seeing nearly as many kernel panics with FreeBSD as you see blue screens in Windows, especially if you don't use any experimental kernel patches or untested features. I've personally only had one kernel panic on my FreeBSD workstation in nearly 12 years of working with FreeBSD.

After you decide on a size for your swap partition, create it just like you created the root partition, except this time select SwapA Swap Partitionwhen prompted for the filesystem type. The swap partition does not get a directory mount point, so you will not be asked the question about where you want to mount the partition when you are creating a swap partition.

Creating the Rest of the Partitions

After you create the root (and possibly boot) partition and the swap partition, create the rest of the partitions as filesystems, give them the sizes you decided on earlier, and set the mount points to the proper directories when asked (for example, `/usr` or `/var`). Don't forget to include the leading slash.

Tip

If you prefer to let Sysinstall figure out how to allocate disk space to your partitions, simply delete any partitions you've created already and press A for Auto Defaults. The mount points and partition sizes created by this option are usually appropriate for all but the most specialized configurations.

You can correct any mistakes and re-create your partitions at any time during this session; no changes are made to your disk until the very end of the process. Simply highlight a partition and press D to delete it, and then move up to the slice at the top of the screen and press C to create a new partition.

If you have more than one hard disk on your system and you need to switch between them, use the up and down arrow keys to move the highlighted line over the disk at the top of the screen on which you want to create the partition.

Here is an example of what a final result might look like:

```
                       FreeBSD Disklabel Editor

Disk: ad0       Partition name: ad0s1   Free: 0 blocks (0MB)
Disk: ad1       Partition name: ad1s1   Free: 0 blocks (0MB)

Part      Mount            Size Newfs   Part      Mount            Size Newfs
```

```
----       -----           ---- -----   ----      -----           ---- -----
ad0s1a     /              256MB UFS1    Y
ad0s1b     swap           756MB SWAP
ad0s1e     /var           256MB UFS1+S Y
ad0s1f     /tmp           256MB UFS1+S Y
ad0s1g     /usr         48817MB UFS1+S Y
ad1s1e     /home       124664MB UFS1+S Y


The following commands are valid here (upper or lower case):
C = Create         D = Delete    M = Mount pt.            W = Write
N = Newfs Opts     Q = Finish    S = Toggle SoftUpdates   Z = Custom Newfs
T = Toggle Newfs   U = Undo      A = Auto Defaults        R = Delete+Merge

Use F1 or ? to get more help, arrow keys to select.
```

This example has two hard disks in the system, and the `/home` directory is on a partition in the second hard disk that takes up the entire disk.

Note

When creating a partition, if you get an error message at the bottom of your screen that reads "You can only do this in a master partition (see top of screen)," it means that you have to highlight one of the filesystem partitions (slices) at the top of the screen. Use the up arrow until the highlight is on the disk slice on which you want to create the partition and then try again to create the partition.

Notes on Soft Updates

Starting with FreeBSD 5.0, Soft Updates are enabled by default on most filesystems (except for `/`). You learn more about Soft Updates in Chapter 12, but for now simply know that they can greatly increase the performance and reliability of most filesystems, so you probably want to leave them enabled. To enable Soft Updates on a filesystem, move the highlight over the filesystem you want and press S to toggle Soft Updates on or off. A filesystem that has Soft Updates enabled will have `+S` following the filesystem type (for example, `UFS1+S`).

After you finish creating partitions, press Q to leave the Partition Editor. Once again, do not use the W option because this is intended for making changes to existing filesystems, not for installing new ones. As long as you're still in the same Sysinstall session, all the changes you've made so far are stored in memory and pending the final commitment after you choose the type of software installation you want. The next screen will ask you what parts of FreeBSD you want to install.

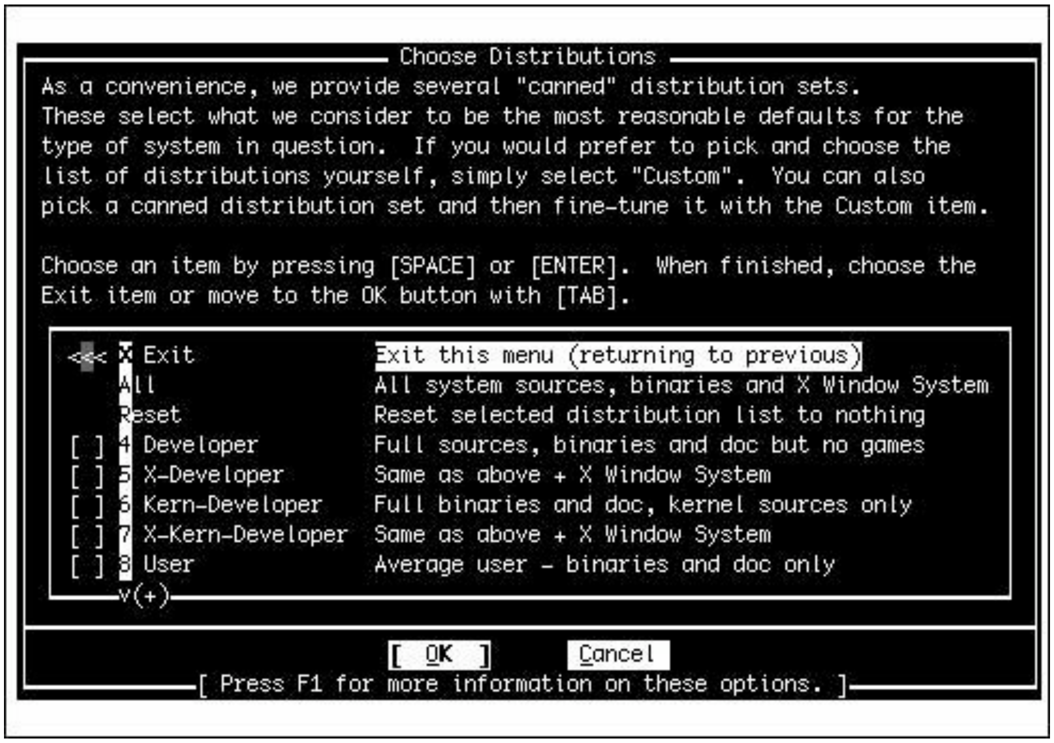
PREV

NEXT

Selecting a Canned Distribution Set

Figure 2.4 shows the Choose Distributions menu.

Figure 2.4. Selecting the distribution.



```
Choose Distributions
As a convenience, we provide several "canned" distribution sets.
These select what we consider to be the most reasonable defaults for the
type of system in question.  If you would prefer to pick and choose the
list of distributions yourself, simply select "Custom".  You can also
pick a canned distribution set and then fine-tune it with the Custom item.

Choose an item by pressing [SPACE] or [ENTER].  When finished, choose the
Exit item or move to the OK button with [TAB].

<<< X Exit              Exit this menu (returning to previous)
    All                 All system sources, binaries and X Window System
    Reset               Reset selected distribution list to nothing
[ ] 4 Developer         Full sources, binaries and doc but no games
[ ] 5 X-Developer       Same as above + X Window System
[ ] 6 Kern-Developer    Full binaries and doc, kernel sources only
[ ] 7 X-Kern-Developer  Same as above + X Window System
[ ] 8 User              Average user - binaries and doc only
    v(+)

            [  OK  ]        Cancel
[ Press F1 for more information on these options. ]
```

A "distribution" of FreeBSD refers to the subset of available software you can choose to install. Not all software is appropriate for all usersif you're not interested in working with the source code, for instance, you don't have to install it. If you have the space, though, I suggest that you select the All option. If you are running a server and you are sure you will not need the X Window System, you can select the Developer option instead. If you select an option that doesn't include the source code, you cannot build a new kernel or upgrade the system through CVSup (unless you download all the sources while running CVSup, which negates the space-savings of not installing the sources here). If you select an option that only installs the kernel sources but not the rest of the sources, you will be able to build a new kernel, but you still can't upgrade the system with CVSup. If you are a new user, you probably won't know what most of these packages are for. Therefore, I suggest you stick to one of the canned distributionspreferably, the All distribution.

Note

CVSup is a file synchronization system that automatically updates the FreeBSD operating system by connecting to servers and determining what has changed since the last time you ran CVSup.

Any changes are automatically downloaded from the server and applied to the FreeBSD source code. This is much faster than downloading the entire source tree. With CVSup, only the things that have changed need to be downloaded. CVSup is covered in detail in Chapter 19.

To select a distribution, highlight the one you want and press the spacebar. You will then be asked whether you want to install the FreeBSD ports collection in addition to the distribution you selected. You really should install the ports collection (covered in detail in Chapter 16, "Installing Additional Software") unless you can't afford the 300MB of disk space it consumes; it provides an easy, lightweight mechanism for downloading, installing, and tuning thousands of additional programs compiled specifically for your FreeBSD system. Installing additional software is a breeze if you have the ports collection installed. Use the Tab key to select the option you want and then press Enter.

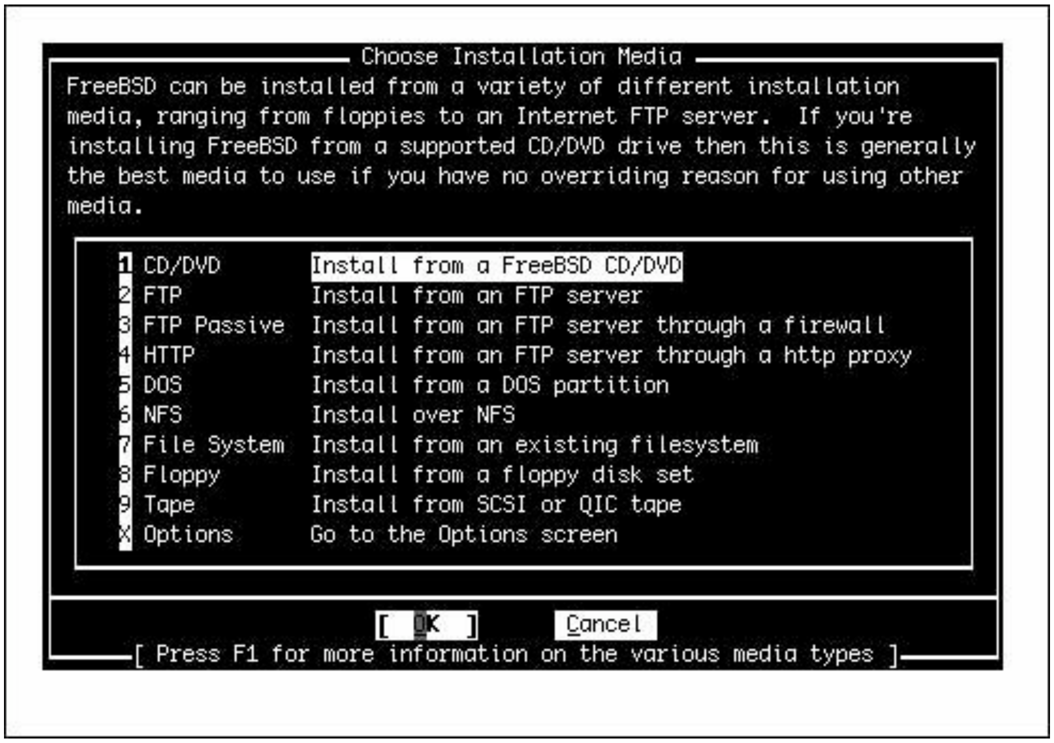
Next, you return to the Choose Distributions menu. The distributions you selected should be indicated with `X` marks; if you selected the All option, each of the distributions is selected. Use the up arrow to go to the Exit option and then press Enter.

PREV NEXT

Choosing the Installation Media

The next screen asks you to choose the installation media (see Figure 2.5).

Figure 2.5. Choosing the installation media.



```
Choose Installation Media
FreeBSD can be installed from a variety of different installation
media, ranging from floppies to an Internet FTP server.  If you're
installing FreeBSD from a supported CD/DVD drive then this is generally
the best media to use if you have no overriding reason for using other
media.

  1 CD/DVD         Install from a FreeBSD CD/DVD
  2 FTP            Install from an FTP server
  3 FTP Passive    Install from an FTP server through a firewall
  4 HTTP           Install from an FTP server through a http proxy
  5 DOS            Install from a DOS partition
  6 NFS            Install over NFS
  7 File System    Install from an existing filesystem
  8 Floppy         Install from a floppy disk set
  9 Tape           Install from SCSI or QIC tape
  X Options        Go to the Options screen

              [  OK  ]        Cancel
[ Press F1 for more information on the various media types ]
```

This chapter assumes that you are installing from the DVD included with this book (or from an official CD-ROM set). If this is not the case and you need to perform an installation from a network disk, tape drive, or FTP server, or if you are installing from an existing filesystem, see the relevant sections of Chapter 3 before continuing.

Note

If you're installing from floppies, select FTP and press Enter. At this point you are required to set up your network card so that Sysinstall can access the FTP server and download the operating system installation files. You're presented with a list of network devices (Ethernet cards), each with a label that should convey which one is the appropriate one hooked up to your network; generally speaking, the first option in the list, often with a device name such as `fxp0`, is correct. To set up the networking options for the selected Ethernet card, skip ahead to "Configuring the Network" later in this chapter; return here when you're done entering your TCP/IP information.

Assuming that you are installing from a CD or DVD, make sure the CD/DVD option is highlighted and press Enter.

The system will then print the following warning message:

```
                        User Confirmation Requested

   Last Chance! Are you SURE you want to continue the installation?

   If you're running this on a disk with data you wish to save then WE
   STRONGLY ENCOURAGE YOU TO MAKE PROPER BACKUPS before proceeding!

We can take no responsibility for lost disk contents!
```

Caution

Up to this point, no changes have actually been made to your hard disk. This is your last chance to back out of the installation. After you select Yes, the partitions you created will be formatted, and the installation will begin. Any existing data on the partitions you selected to use will be lost!

Assuming you are happy with the installation choices you made, select Yes. The system then prints a message telling you it is starting an emergency holographic shell on `vty4`, meaning that you can press Alt+F4 to switch to a command prompt to correct errors that might crop up. (Alt+F2 lets you watch the files being listed as they're installed. Press Alt+F1 to return to the Sysinstall screen.) It then proceeds to format the partitions. After partition formatting is done, Sysinstall will begin copying files to your hard disk(s).

The installation process can take as little as fifteen minutes or as much as several hours, depending on your installation medium. A fast optical drive will make short work of the installation, whereas if you're installing from floppies, your computer must download the entire operating system from the FreeBSD FTP serverseveral hundred megabytes. A floppy/network installation's length depends heavily on the speed of your Internet connection, and the slower your link, the longer it will take. If you need to leave the installation process going overnight, go aheadnothing requiring your immediate attention occurs after the installation is over.

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PREV NEXT

Post-installation Configuration and Customization

When the file-copying process is complete, you will see a screen that congratulates you for making it to this point. The screen also informs you that Sysinstall will now move on to the final configuration questions. From the initial step of configuring the network in this post-installation phase, you will proceed to set the time; configure the mouse; choose the desktop, software packages, and users you want to assign to your system; and set the root password. Select OK to continue.

Configuring the Network

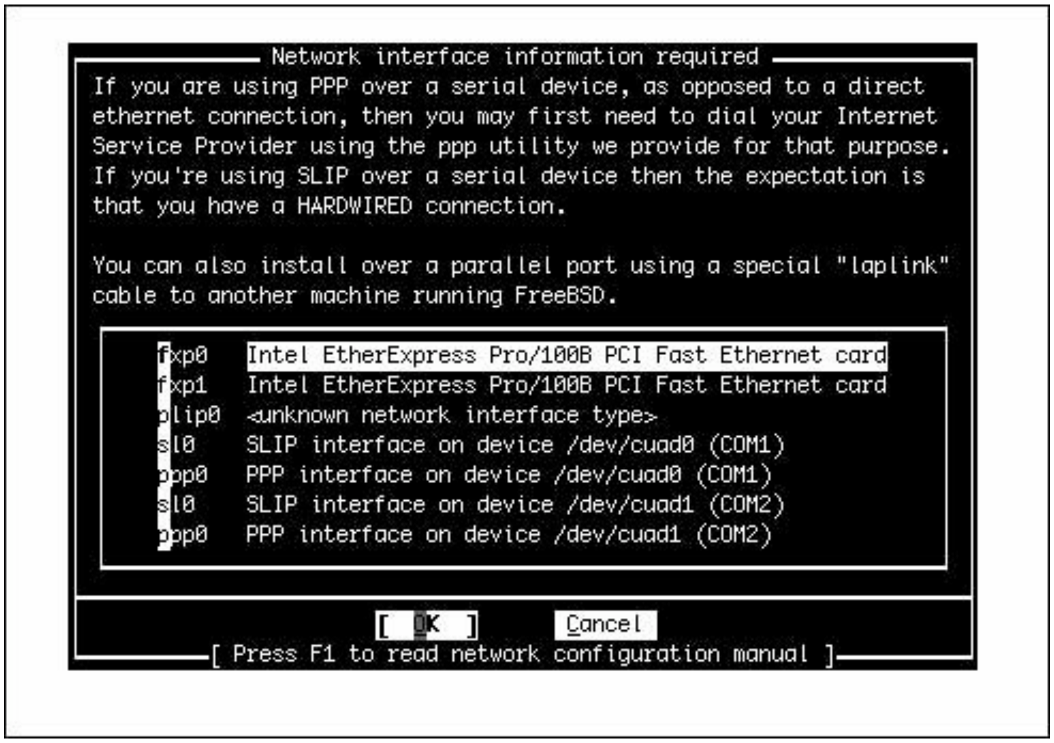
Next, you are asked if you want to configure any Ethernet or SLIP/PPP network devices. (This step will not be necessary if you are installing from floppies; you already had to configure your network earlier in the process.) If you have the necessary network configuration information from your system administrator, you can go ahead and set these up now. If you don't have this information available or if you are setting up a new network and are unfamiliar with networking, you can always re-enter this utility later after you have read the chapters on networking.

Caution

If you are on a network and you do not configure the network device(s) now, be aware that when the system reboots, you cannot access the network until you configure the network devices to work with it. With that said, if you don't have a network or you don't know what values should go in the fields for the network configuration, go ahead and skip this section and come back to it later after you have read the networking chapters in Part IV, "System Administration."

If you don't want to configure any network devices now, simply select No and move on to the next section of this chapter. If you do want to configure network devices at this time, select Yes. You should now see a screen like the one shown in Figure 2.6.

Figure 2.6. Selecting the network interface to configure.



```
Network interface information required
If you are using PPP over a serial device, as opposed to a direct
ethernet connection, then you may first need to dial your Internet
Service Provider using the ppp utility we provide for that purpose.
If you're using SLIP over a serial device then the expectation is
that you have a HARDWIRED connection.

You can also install over a parallel port using a special "laplink"
cable to another machine running FreeBSD.

    fxp0   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    fxp1   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    plip0  <unknown network interface type>
    sl0    SLIP interface on device /dev/cuad0 (COM1)
    ppp0   PPP interface on device /dev/cuad0 (COM1)
    sl0    SLIP interface on device /dev/cuad1 (COM2)
    ppp0   PPP interface on device /dev/cuad1 (COM2)

                 [ OK ]         Cancel
       [ Press F1 to read network configuration manual ]
```

Select the network device you want to configure from the list and then press Enter. Note that depending on the make and model of your Ethernet adapter, it may have various names. It will usually have the number zero, though (for example, `fxp0`), if it is the first or only Ethernet adapter in the system.

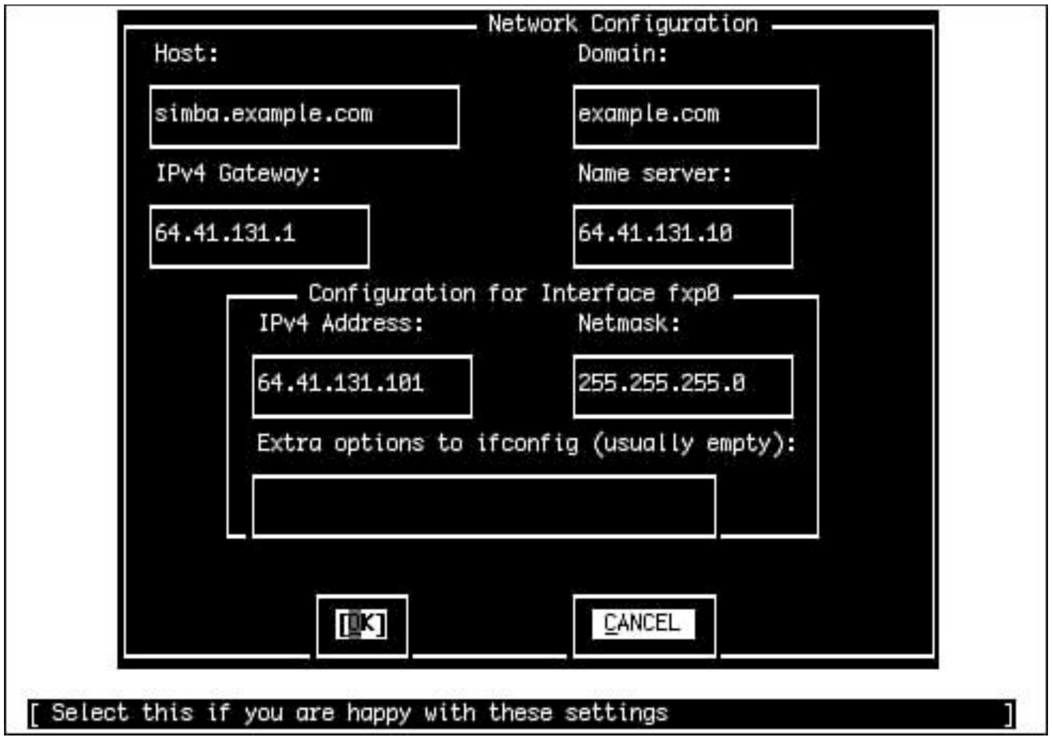
After you select the network device you want to configure, you are asked if you want to try the IPv6 configuration of the interface. Unless you are sure your network has an IPv6 server on it that is set up to send you configuration information, you should select No.

The next question asks you the same thing about the DHCP configuration of the interface. If your network has a DHCP server on it, FreeBSD will attempt to contact that server and obtain its network information. If your network does not have a DHCP server, you should select No. If you're on a corporate or routed home network and you're not sure whether DHCP is available, select Yesmost routed networks have DHCP servers. If DHCP responds by filling in your network information, you can skip the next few steps.

The next screen allows you to enter the information about your network. This will be covered in much more detail in Chapters 22, "Principles of TCP/IP Networking," and 23, "Configuring Basic Networking Services," but here are a few guidelines to get you started.

Figure 2.7 shows the Network Configuration screen; Table 2.5 lists what the fields in this screen are for.

Figure 2.7. Configuring the network interface.


```
Network Configuration
Host:                          Domain:
simba.example.com              example.com
IPv4 Gateway:                  Name server:
64.41.131.1                    64.41.131.10
      Configuration for Interface fxp0
      IPv4 Address:            Netmask:
      64.41.131.101            255.255.255.0
      Extra options to ifconfig (usually empty):

              [OK]             CANCEL
[ Select this if you are happy with these settings ]
```

Table 2.5. Network Configuration Fields

Field	Description
General Network Options for This System	
Host	The hostname and domain name of your system go here (in this example, simba.example.com).
Domain	The name of the domain name where your system is located (in this example, example.com).
IPv4 Gateway	If your system will use a router to access nonlocal network resources (the Internet), put the address of that router here.
Name server	The IP address of your DNS server, which is the server that resolves network names into IP addresses.
Network Options Specific to This Network Interface	
IPv4 Address	The IP address of this system.
Netmask	The netmask value for the network that this interface accesses.
Extra Options to ifconfig	Any extra options you need to pass to the network configuration should go here.

If you are unclear about any of these concepts, you should read Chapters 22 and 23 before configuring the network.

Caution

If you aren't sure what numbers or names should go in the Network Configuration screen, ask someone who will know. Never simply fill in random numbers or names if your system is on a network. If your system is connected to a network, simply inserting random numbers in the IPv4 Address field or a random hostname in the Host field is a sure way to get on the bad side of the network administrators as well as other network users. If you select an IP address that conflicts with an existing system on the network, bad things will happen, including possible denial of service to an important network resource if your IP address conflicts with that of a major server.

Use the Tab or Enter key to move between fields. When you are done, select OK to leave the configuration screen.

Depending on the type of network interface you set up, you may now be asked if you want to bring the interface up right now. Select No because you are almost done with the install and will be rebooting the system soon anyway.

Sysinstall will then ask you a series of questions about the network:

- Do you want this machine to function as a network gateway?

  Unless this machine will be a gateway that other systems on the network will use to get to the Internet, or a router that will handle network traffic intended for other systems, you should select No. Otherwise, select Yes and be sure to read Chapter 28, "Configuring an Internet Gateway."

- Do you want to configure `inetd` and the network services it provides?

  The `inetd` "super-server" is a process that handles incoming requests for certain types of services, such as Telnet, FTP, POP and IMAP mail services, and others. In the modern age, services that are launched from `inetd` are becoming rarer, and `inetd` itself is thought of as a security breach waiting to happen. If you don't have a need for the services provided by `inetd`, or if you're not sure, select `No`you can always enable it later if you have to.

- Would you like to enable SSH login?

  Select Yes here. SSH allows remote users to connect to a shell prompt (the UNIX command line) on your FreeBSD machine over a secure, encrypted channel. It's vastly preferable to use SSH than the unencrypted alternative, Telnet; it's good policy to require that all your users use SSH instead of Telnet for their remote access. However, if you don't want any remote access to your machine to be possible at all, choose No.

  ### Caution

  Enabling SSH means opening up your system for remote users to access its command-line interface after sending their usernames and passwords over the network. Although SSH is a secure transmission protocol, its security won't help you if your password is easily guessed or found through a brute-force attack. You should therefore never consider SSH alone to be a sufficient protection against unauthorized access, and it's imperative that you choose sufficiently strong or hard-to-guess passwords. See Chapter 30, "Network Security," for more information about strong passwords.

- Do you want to have anonymous FTP access to this machine?

I suggest you select No unless you have already read the chapters on networking, particularly Chapter 27, "Configuring an FTP Server." You can always configure anonymous FTP access later on if you need it.

- Do you want to configure this machine as an NFS server?

  The NFS server allows you to share directories on your hard disk so that users on other systems can mount them and read or write files to them. Once again, unless you have read Chapter 33, "The Network Filesystem (NFS)," I suggest you select No for now, even if you know that you will need this service. NFS can be a security problem if it's not set up properly. After you read Chapter 33, you can come back and set this up.

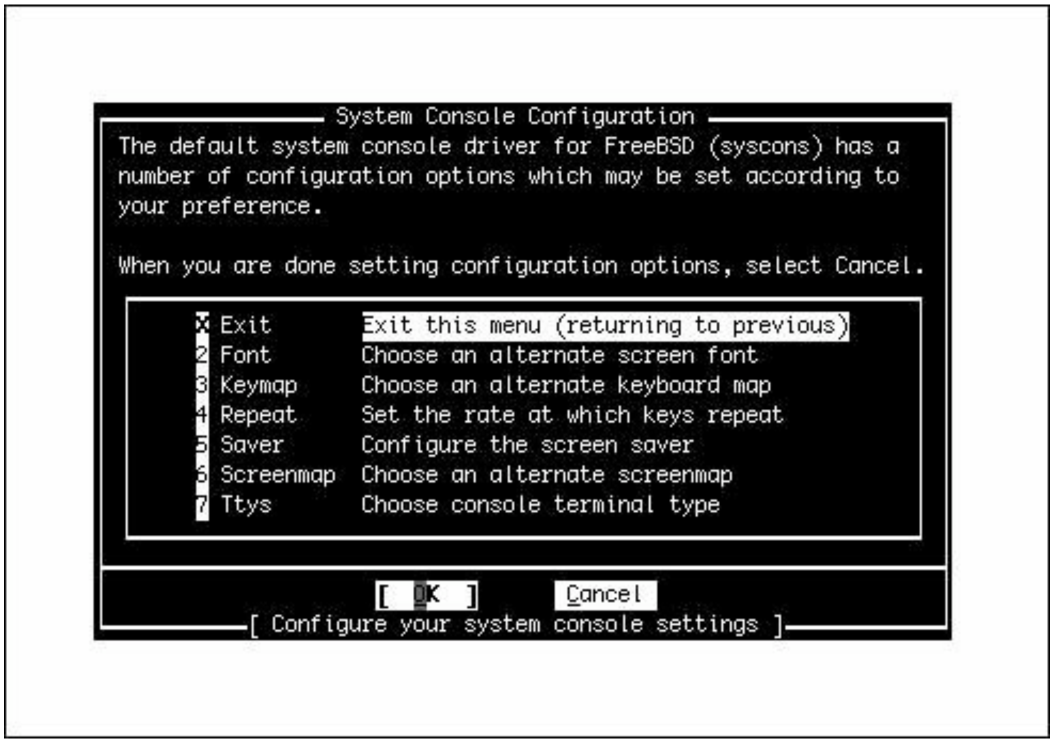
- Do you want to configure this machine as an NFS client?

  If you need to mount filesystems on your drive that are located on other computers, you need to set up the NFS client. Once again, see Chapter 33 for more information on configuring NFS.

Customizing the Console

Next, you have the opportunity to customize the FreeBSD console settings. You can use these settings to customize the behavior of your keyboard, to choose which font will be used on the screen display, and to select which screensaver to use. If you select Yes to the question asking you whether you want to customize your console settings, you see a menu like the one shown in Figure 2.8.

Figure 2.8. Customizing the console settings.



```
System Console Configuration
The default system console driver for FreeBSD (syscons) has a
number of configuration options which may be set according to
your preference.

When you are done setting configuration options, select Cancel.

X Exit        Exit this menu (returning to previous)
2 Font        Choose an alternate screen font
3 Keymap      Choose an alternate keyboard map
4 Repeat      Set the rate at which keys repeat
5 Saver       Configure the screen saver
6 Screenmap   Choose an alternate screenmap
7 Ttys        Choose console terminal type

[ OK ]        Cancel
[ Configure your system console settings ]
```

Most of these options don't need any explicit configuration; they're set by default to settings that will work as expected with most modern hardware. However, you can experiment with settings such as Font and Saver to alter how your console appears and blanks its screen, or Repeat to adjust the keyboard repeat rate.

Other options, such as Keymap and Screenmap, are less self-explanatory. Keymap allows you to choose a different keyboard layout from the default U.S. English layout, which you'll need to do if you're using a keyboard with a different set of keys. Similarly, the Screenmap option lets you choose a character set mapping that is appropriate for your country if the default one doesn't work for you; if you have older hardware where the built-in font can't be changed, it allows you to select how the text you encounter should be translated into text the hardware can display. Finally, the Ttys option (Terminal TYpes) allows you to change the default console terminal emulation mode from the default VGA terminal (cons25) to another whose behavior matches the screen mapping you choose in the Screenmap section.

For any of the console configuration options, choose the option you need to configure and then follow the onscreen instructions.

Setting the Time Zone

Next, Sysinstall asks whether you want to set the system's time zone. Select Yes. The next screen will ask whether your system's clock is set to UTC (known also as Coordinated Universal Time, Greenwich Mean Time, and Zulu Time). It probably isn't, so unless you are sure your clock is set to UTC, select No. The next menu asks you to select your region, your country, and other information about where you are located. After you provide Sysinstall with all this information, it shows you a three-letter abbreviation for your time zone and asks whether this abbreviation looks reasonable. If it looks correct, select Yes. If it doesn't, select No. You can always come back and do it again.

Linux Compatibility

The next question asks whether you would like to enable Linux binary compatibility. If you select Yes, Sysinstall will install a mini-Linux filesystem in your `/usr` partition that includes the Linux share libraries and other necessary programs for Linux to run on FreeBSD. Unless you are sure you will not be running any Linux programs, I suggest you select Yes. This can be a very useful option. (In fact, much of the manuscript for this book was originally written using StarOffice for Linux, running under FreeBSD's Linux emulation.)

Note

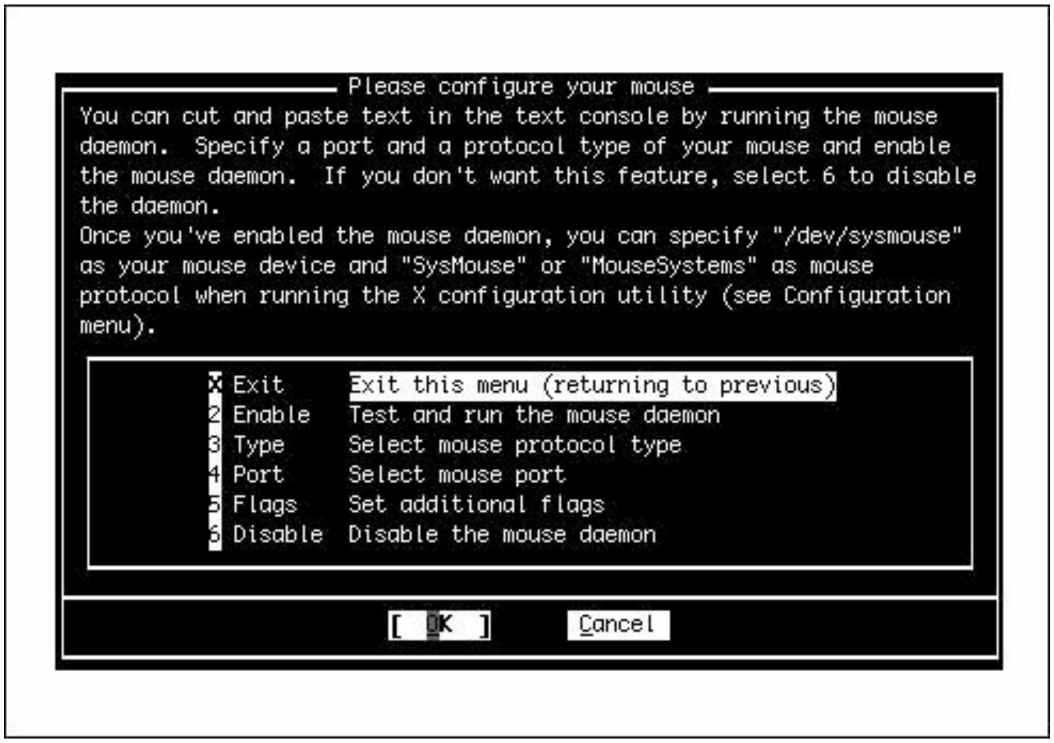
Your first thought might be that you don't want to install the Linux binary compatibility module. If you've worked with emulators under other operating systems, you know how slow they can be. With FreeBSD, however, this is not the case. Linux support in FreeBSD is not done through an emulator but rather is implemented at the kernel level. FreeBSD's Linux support is so good that it runs most Linux applications as fast as native Linux. In fact, FreeBSD will even run some Linux applications faster than Linux itself runs them!

Configuring the Mouse

In FreeBSD, you can use your computer's mouse whether you're in the text-mode console or in the graphical X Window System. The text-mode (console) mouse driver gives you the ability to copy and paste text at the command line or in console programs, making use of all three buttons on your mouse, if available. If the system will be a purely "headless" server, with no windowing system and no need for a console mouse pointer, you can elect not to enable the mouse driver. However, if you're going to be using FreeBSD as a desktop operating system, you'll want your mouse to work, and you need to configure and enable the mouse driver.

First, FreeBSD asks you whether you have a non-USB mouse attached to your system. Non-USB mice include PS/2 mice (as is standard on most PCsthe mouse plugs in right next to the keyboard, with a round plug) or serial mice that connect to the COM1 or COM2 port. Select Yes if you have a PS/2 or serial mouse, or No if your mouse connects through USB (see Figure 2.9).

Figure 2.9. Configuring the mouse.



```
Please configure your mouse
You can cut and paste text in the text console by running the mouse
daemon.  Specify a port and a protocol type of your mouse and enable
the mouse daemon.  If you don't want this feature, select 6 to disable
the daemon.
Once you've enabled the mouse daemon, you can specify "/dev/sysmouse"
as your mouse device and "SysMouse" or "MouseSystems" as mouse
protocol when running the X configuration utility (see Configuration
menu).

X Exit     Exit this menu (returning to previous)
2 Enable   Test and run the mouse daemon
3 Type     Select mouse protocol type
4 Port     Select mouse port
5 Flags    Set additional flags
6 Disable  Disable the mouse daemon

[ OK ]        Cancel
```

The next screen contains several steps for configuring your mouse. If you don't plan to use the mouse, in X or in the text console, select Disable here and skip the rest of this section. Otherwise, select Type to specify the type of mouse. The following screen contains several options for specialized or old-style mice, but the defaultAutois correct for just about any PS/2-style mouse available today. It's also the appropriate option if you have a USB mouse.

Next, select Port. If you have a PS/2 mouse, select Auto (the default). Otherwise, choose the appropriate serial port where your mouse is connected.

The X Window System makes use of all three buttons on a standard mouse. If you have a mouse with only two buttons on it, you need to emulate a three-button mouse by telling the mouse driver to interpret the clicking of both buttons at the same time (what's known as a *chord*) as a click of the virtual third button. You can do this by selecting the Flags option on the menu and typing `3` in the dialog that pops up. Another useful option you might want to put in here is `-r high` to make the pointer move faster or `-r low` if the pointer moves too fast and you want to slow it down. If you need both options, you can use `3 r high`, for example.

After you finish configuring the mouse settings, select the Enable option to test and run the mouse daemon. If the mouse is set up correctly, you should now be able to move the mouse pointer around on the screen. When you are done testing the mouse, select Yes if the mouse worked (note that the mouse still doesn't work in the menu; you still need to use the arrows and the Tab key) or choose No if it didn't.

You are then returned to the mouse configuration menu. Assuming that the mouse worked, select the Exit option.

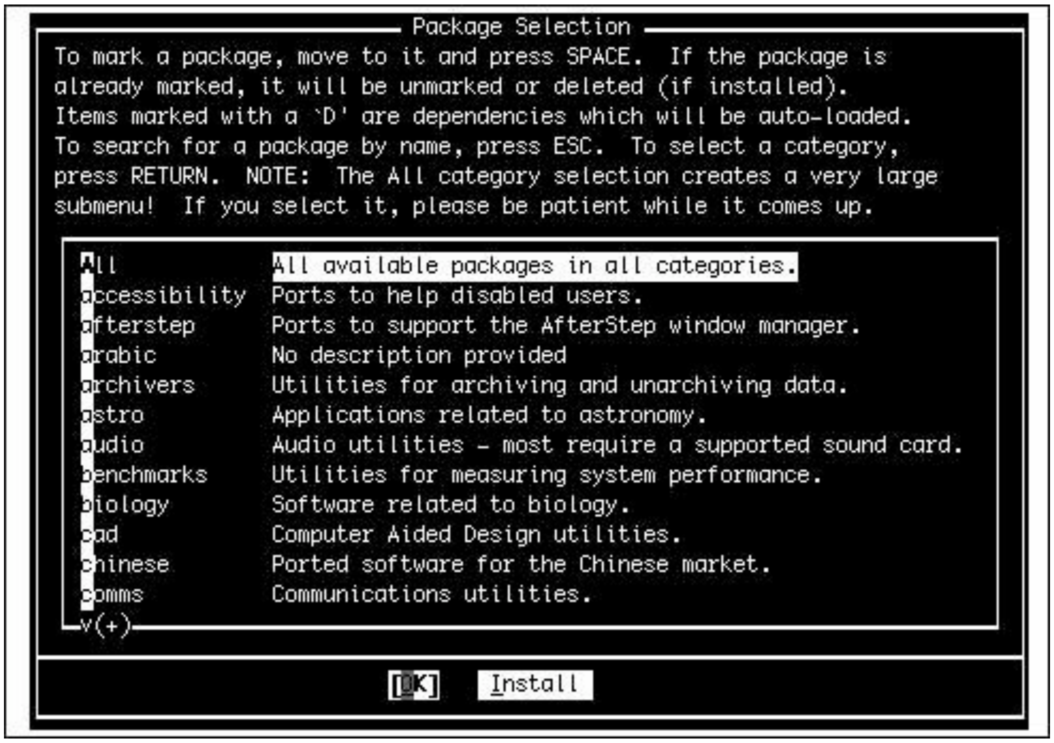
Installing Additional Software Packages

Select Yes when asked whether you want to browse the FreeBSD package collection. From the menu that follows, you can install some additional software that will be useful in the next couple of chapters. Feel free to browse through the collection as long as you want to see what is available. For now, I don't recommend that you install a ton of software at this pointthe first priority is getting your system booted, and it's very easy to add software later, once you're up and running. There are a few packages that I recommend you install for use in the next few chapters, however.

When you're asked where you want to install the packages from in the Choosing Installation Media menu, select CD/DVD if you are installing FreeBSD from the included CD-ROM. Otherwise, select FTP to get the packages from the distribution server.

Figure 2.10 shows the main menu for the package installation system.

Figure 2.10. Installing additional packages.



```
                         Package Selection
To mark a package, move to it and press SPACE.  If the package is
already marked, it will be unmarked or deleted (if installed).
Items marked with a `D' are dependencies which will be auto-loaded.
To search for a package by name, press ESC.  To select a category,
press RETURN.  NOTE:  The All category selection creates a very large
submenu!  If you select it, please be patient while it comes up.

  All            All available packages in all categories.
  accessibility  Ports to help disabled users.
  afterstep      Ports to support the AfterStep window manager.
  arabic         No description provided
  archivers      Utilities for archiving and unarchiving data.
  astro          Applications related to astronomy.
  audio          Audio utilities - most require a supported sound card.
  benchmarks     Utilities for measuring system performance.
  biology        Software related to biology.
  cad            Computer Aided Design utilities.
  chinese        Ported software for the Chinese market.
  comms          Communications utilities.
  v(+)

                        [OK]  Install
```

To navigate through the package installation system, use the arrow keys to move between packages and categories. Use the spacebar or Enter key to select or unselect a package. When you have finished selecting packages in a category, use the Tab key to highlight the OK option and press Enter to get back to the main selection menu (where you can select the category you want to browse).

Packages that are already installed will have an X next to them; unselecting these packages causes them to be uninstalled. Packages that have a D by them are *dependencies*, meaning that they are required by some other package currently installed. At the bottom of the screen is a short description of the currently highlighted package.

Note

By the time this book goes to press, some of the version numbers on the software listed may have changed. In this case, select the option that appears closest to what I list here. For example, I list `bash-3.0.16_1`. If your menu has `bash-3.0.17` instead, select it.

I suggest that you choose the `bash-3.0.16_1` package in the shells category. This is a very powerful and easy-to-use shell for the FreeBSD command-line interface. Linux users will be familiar with this shell because it is the default shell on almost all Linux distributions. UNIX gurus can also install any other shell in this list that they want to have available.

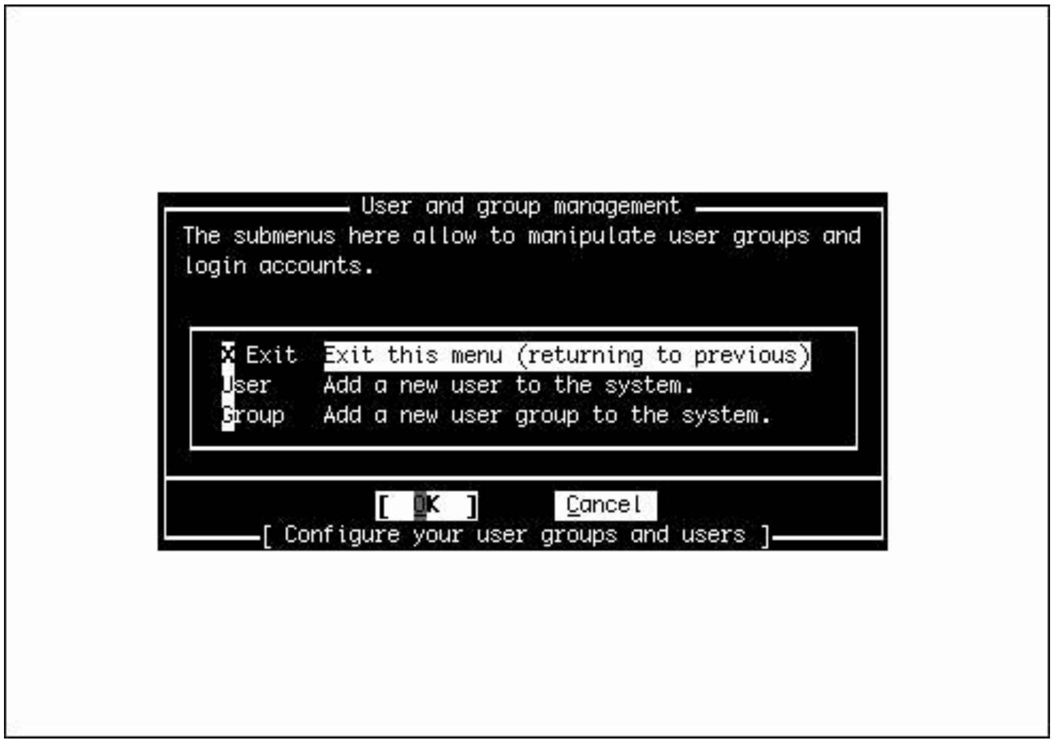
Browse as many categories as you like, selecting any packages you'd like to install. When you're done selecting packages, return to the main selection menu and press Tab until Install is highlighted; press Enter to proceed with the batch installation from the selected media.

Adding a User

When the package installation is complete, you are asked whether you want to add any user accounts to the system. Select Yes to create a normal user account for yourself. It is dangerous to use the root account for normal operations because root has no restrictions and can damage or destroy important system files if you make a mistake. Using your normal user account for most operations prevents this.

On the Help screen, shown in Figure 2.11, select User to add a new user to the system.

Figure 2.11. Adding users and groups to the system.



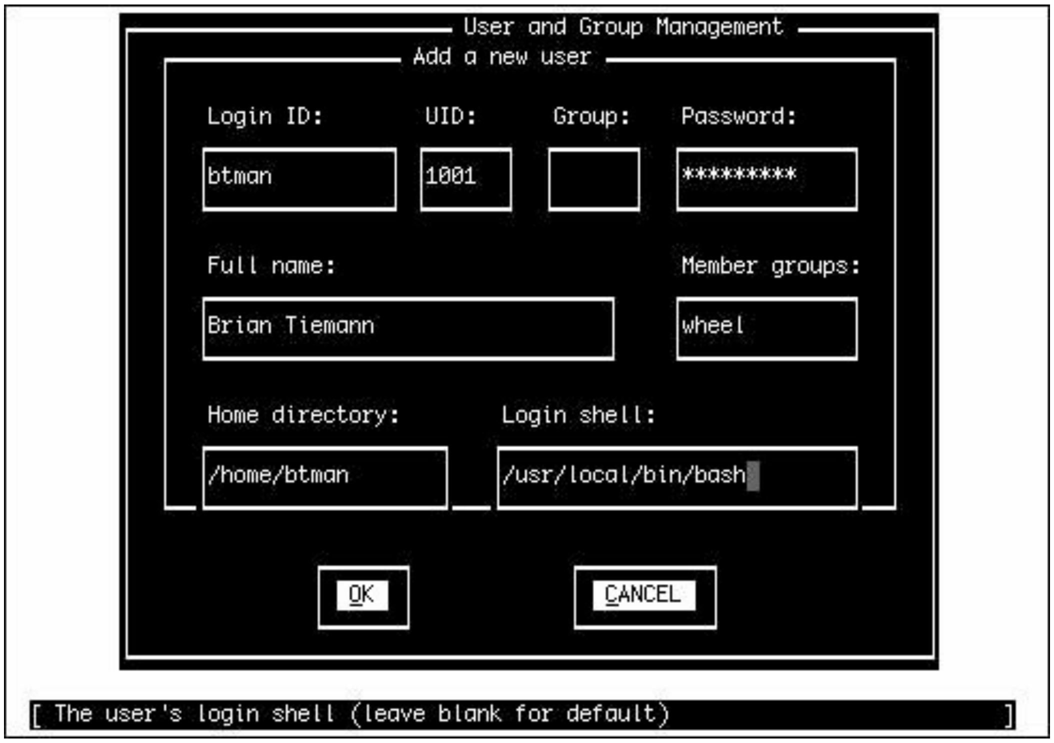
```
User and group management
The submenus here allow to manipulate user groups and
login accounts.

  X Exit   Exit this menu (returning to previous)
  User     Add a new user to the system.
  Group    Add a new user group to the system.

              [  OK  ]      Cancel
        [ Configure your user groups and users ]
```

You are then taken to a form you need to fill out to add the new user (see Figure 2.12).

Figure 2.12. The Add a New User form.



```
User and Group Management
Add a new user

Login ID:     UID:     Group:     Password:
btman         1001                *********

Full name:                        Member groups:
Brian Tiemann                     wheel

Home directory:      Login shell:
/home/btman          /usr/local/bin/bash

[ The user's login shell (leave blank for default) ]
```

Not all the fields on this form have to be filled in. Actually, you should leave some of them blank so the system can make a default choice for you. Use the Tab key to move between the various fields. The following sections describe each of these fields and make recommendations for adding values to them.

Login ID

Login ID is the name you use to identify yourself to the system when you sign in. The ID you type in this field should not be more than eight characters long, for compatibility reasons, though FreeBSD supports usernames up to 16 characters long. Common conventions are to use initials, nicknames, or combinations of initials and first or last name. For example, I might use `brian`, `briant`, or `btiemann` as my login name. Each user on the system must have a unique login name. Names are case-sensitive and, by convention, use all lowercase letters. Spaces and special characters are not allowed, aside from the hyphen (-) and underscore (_).

UID

UID is a numeric ID that the system uses to keep track of users. You should leave this field alone and let the system pick the number for you.

Group

This field refers to the primary group you will be a member of. Once again, leave this field alone and let the system pick for you.

Password

In this field, you type the password you will use to log in. Passwords are case-sensitive. Here are some guidelines for choosing good passwords that crackers (commonly known as *hackers*, although this is not the correct term for people who illegally break into computer systems) can't figure out:

- Use at least eight characters. Short passwords are easier for programs designed to try random combinations of letters and numbers to crack.
- Use a combination of uppercase and lowercase letters, numbers, and at least one special character, such as `$` or `!`.
- Don't use words found in a dictionary. Password-cracking programs exist that go through the dictionary trying various words until they hit one that works.
- Don't use things that other people know about you or can easily find out about you. In other words, the name of your child, your cat, or the city you were born in does not make a good password.

At the same time, it's good to pick something you can remember easily. Some techniques for doing this include combining parts of various words together (remembering, of course, to include both uppercase and lowercase letters and to stick a few numbers and at least one special character in somewhere). You can also use what I call *keyboard substitution*a technique where you pick a word that means something to you (but that others will not know) and then substitute the character to the upper-left, upper-right, lower-left, or lower-right as the actual character in the password. For example, Alice becomes Qoid3.

After you decide on a password, enter it carefullyyou will not be asked to verify it. The password will show up on the screen as asterisks (`*`). If you mistype it, you will not be able to log in (if you accidentally do mistype the password, you can read how to fix it in Appendix C).

After you decide on your password, do not write it down anywhere. Do not write it on the bottom of your desk. Do not write it down in your appointment book. Do not have it tattooed on your arm. And whatever you do, do not write it on a Post-It note and stick it on your monitor. (I know that seems like stating the obvious, but you would be surprised how many users do just that.) Also, do not tell your password to anybody, including your coworkers, your spouse, or your children.

Full Name

You can either type your name in this field or leave it blank (remove User & if you intend to leave it blank). Note that some programs, such as the UNIX mail program, will use this field to determine what to put in the From field of the email you send. Therefore, it is probably a good idea to enter your name here.

Member groups

I suggest you type **`wheel`** in this field. This will make you a member of the group "wheel," which will allow you to assume the identity of the root user (super-user or system administrator) without having to log out and log back in as a different user (although you still need to supply the root password to do this).

Caution

It's very important to set up at least one wheel user right awaythis ensures that you'll be able to connect to the computer remotely, using that user account, and become root (using the `su` command) to perform system administration tasks. You can't SSH directly to the machine as root (without performing some extra tricksssee Chapter 13, "Users, Groups, and Permissions"); unless you have a non-root user who can log in remotely and assume root privileges, you'll be dead in the water once you leave the facility where the machine has been installed.

Home Directory

This field lists the place where your home directory will be located on the hard disk. You should leave this field alone and let the system choose for you.

Login Shell

The login shell is the default command-line shell you will be placed in after you log in. Assuming you installed the `bash` shell, as suggested earlier, I suggest you type **`/usr/local/bin/bash`** in this field (including the slashes). If you later decide you do not like the `bash` shell, it is easy to change your default shell to a different one (see Chapter 8, "Working with the Shell" for more details).

Note

Be aware that `/bin/csh`, the default built-in shell included in FreeBSD, is the same thing as `tcsh` (also available by default at `/bin/tcsh`).

After you finish entering the information, tab over to the OK button and press Enter. The user account will be created for you, and you will be returned to the menu shown earlier in Figure 2.12. Select the Exit option.

Setting the Root Password

Press Enter when you see the message about setting the system manager's password. You are then given a prompt at the bottom of the screen that asks you to enter a root password. It looks like this:

```
Changing local password for root.
New password :
```

All the guidelines you read earlier for choosing and protecting your normal user password are doubly important here. Anyone who knows your root password (or can find it out) can access anything on your entire system and can do anything to your entire system as well. He will have access to read confidential information, email it to other places, change or destroy data on your system, and do whatever other evil things he pleases.

After you decide on a root password, enter it at the prompt. Notice that it will not show up onscreen as you type it. This prevents someone from looking over your shoulder as you type and reading your password or even seeing how long it is (a valuable piece of information in itself, to a password-cracker).

After you enter the password, press Enter. You will be asked to verify the password. Type it again and press

Enter. Assuming that you typed it the same way both times, the installation will ask whether you want to visit the general configuration menu for a chance to set any last options. Select No. You are then returned to the main menu.

PREV NEXT

Exiting the Sysinstall Program and Rebooting the System

At the main menu, tab over to Exit Install and press Enter. The system asks you to confirm that you want to exit. It then asks you to remove any CD-ROMs or floppies from the drives on your system. After you remove them, select Yes. The system will then reboot.

Note

You may find that you've pressed the Eject button on your optical drive but nothing happened. Don't worry. FreeBSD didn't break your drive; it just locked it to ensure you couldn't accidentally eject the DVD or CD in the middle of the install. If you can't open your optical drive, select Yes anyway and wait until just after your system has started to reboot (when it is counting the memory and such). Then, press the Eject button on your optical drive. It should now open and you can remove the FreeBSD DVD.

Tip

When the system reboots, you might want to go into your BIOS setup utility right away and configure the system so that it will not try to boot from the optical drive anymore. Some systems can hang for a long time while trying to boot from CD or DVD if there is no bootable disc in the drive (or no disc at all). Although most systems will eventually give up and boot from the hard disk, it can sometimes take as long as a minute or more before the system decides it can't boot from the optical disk and goes to the hard disk instead. Disable CD/DVD booting in the BIOS to avoid this problem. (See your hardware documentation for information on how to configure your system BIOS settings.)

PREV NEXT

Booting FreeBSD for the First Time

When your system restarts, one of two things should happen: Either you get a boot menu asking you which operating system you want to boot, or, if FreeBSD is the only operating system on the drive, the system begins to boot straight into FreeBSD. If this is not the case, and your system either hangs or boots right into some other operating system without giving you the option of starting FreeBSD, see Appendix C.

A full-screen textual FreeBSD boot menu, providing several options for booting FreeBSD in various modes and sporting the "daemon" mascot or a FreeBSD logo, is the first interactive part of the boot process. You saw this menu during installation; as you did before, press Enter to accept the default option, Boot FreeBSD.

You should subsequently get a long series of cryptic messages going past your screen as the kernel finds and initializes your system hardware. Kernel messages are in a bright white color. After the kernel is finished loading, it will pass control to a program called `init`, which starts up various other processes and programs in the system. These messages have a light gray color.

The boot process pauses, this first time, to request you to supply some random keyboard information. This rather strange request is necessary for the proper operation of the system's "entropy" generator, which is of interest primarily to those users for whom data security is paramount. Feeding random data to the entropy subsystem means that the random number generator that's part of FreeBSD can emit truly random numbers that can't be cracked or predicted. This random number generator lies at the heart of many secure systems in FreeBSD, such as the data path of the startup process itself. While the system is paused and waiting, you have the choice to either hammer on the keyboard randomly to input a pageful of garbage text (and then press Enter) for a system with good entropy and high security, or to simply press Enter to accept less rigorous entropy. (A third option is to simply wait 300 seconds, or five minutes; this is tantamount to choosing the second option.) If you are impatient, or data security doesn't thrill you, just hit Enter to continue.

FreeBSD then generates RSA and DSA encryption keys for your system (which are used for secure communication across networks or the Internet); this process takes several seconds more, but it too is only a one-time event. Eventually, after `init` is finished, you should be left with the following:

```
FreeBSD/i386 (simba.example.com) (ttyv0)
login:
```

Your display, of course, will have the name of your host and network instead of (simba.example.com). If you didn't set up the network, it will have the system default hostname, which will probably be `amnesiac`.

Log in using the name `root`. After pressing Enter, type in the password you gave to root (once again, the password will not display on the screen).

Assuming you type the username and password correctly, you will see a welcome message that tells you a little bit about FreeBSD and where you can get help (as well as how you can change this message or get rid of it), and then you are left with a shell prompt, which will look something like this:

```
Copyright (c) 1980, 1983, 1986, 1988, 1990, 1991, 1993, 1994
        The Regents of the University of California.  All rights reserved.
FreeBSD 6.0-RELEASE #0: Thu Nov  3 09:36:13 UTC 2005

#
```

Here, `#` is the command prompt, and it means the shell is waiting for you to give it something to do. Fortunately for the shell, there's one more configuration task that must be done: setting up the X Window System.

PREV NEXT

Setting Up the X Window System (X11)

The X Window System, also known as X11 (or simply X), is the ubiquitous windowing system for UNIX and Linux. Originally developed at MIT in the early 1980s, X reached its eleventh major revision in 1987, and was subsequently released to the public as an open-source project, and was developed through several more releases by the X Consortium. Development stalled for several years during the 1990s, at which time X11's rather arcane client-server architecture and lack of modern features did not daunt the geeks experimenting with FreeBSD and Linuxthey, after all, loved a challenge. However, since 2004, a new organization called the X.org Foundation (founded by the X Consortium and sponsored by a number of deep-pocketed corporations such as IBM, Sun, and Hewlett-Packard) has been pursuing a modernization of X11 with renewed vigor.

You will learn more about the day-to-day operation of X11 in Chapter 5, "Working with the X Window System." For now, the goal is to get X11 installed on your computer so that you can run graphical applications. This is not by any means an easy task. Rest assured, though, that it used to be a whole lot worse.

If you did not install the X Window System during the procedure described in this chapter, or if you don't want to use X11 at all, you can skip this section. If you change your mind, you can always install X11 laterinstall the `xorg` package, or build the port `/usr/ports/x11/xorg` in the ports collection. See Chapter 16 for more information on using the packages and ports.

Auto-Detecting Your Video Hardware

The core of X11 is what's called the *X Server*, a daemon that "serves" windows to a client program that draws the windows on the screen. This arrangement may seem confusing if you're coming from the Windows world. Just remember that X11 was originally developed for cluster-based computing, where many relatively low-powered computers in a lab or in dorm rooms around a campus would run lightweight window manager programs to request application windows from a central mainframe server. All the computing power, and all the applications, were centrally stored; in this context, it makes sense for the windowing system's heavy lifting to be done where all the power is, letting the client computers remain low-powered and inexpensive. Today, powerful desktop computers are cheap and plentiful, and cluster computing is all but obsolete; in this environment, the X Server and the windowing client (known as a "desktop" or "window manager") both run on the same computer. This greatly simplifies many aspects of installing and managing a graphical user environment on a UNIX system like FreeBSD. However, it doesn't change the fact that you have to set up the X Server first and independently before you can configure the client end of the equation, the desktop.

Note

Double-check to make sure you know the specifications of your monitor (vertical and horizontal sync rates) and the make and model of your video card, including how much video RAM is installed. X11 does its best to auto-detect this information, but chances are that you'll have to supply it yourself at some point during this procedure, even if it's auto-detected at first.

The first step is to run a utility that auto-detects your video hardware. Make sure you're logged in as root (if not, type **`logout`** and log back in as the root user); then type:

```
# Xorg -configure
```

This program probes your video card to detect its chipset and capabilities, and writes out a skeleton configuration file for the X Server. This file, saved into the `/root` directory, is named `xorg.conf.new`. Examine this file to see what it found out. Use the following command to page through the file:

```
# less xorg.conf.new
```

Use the up and down arrows to move up and down line by line, or the spacebar and W key to page up and down. Skip through until you find the section labeled Section "Device". In the lines in this section, you should see information describing your video card:

```
Section "Device"
        ### Available Driver options are:-
        ### Values: <i>: integer, <f>: float, <bool>: "True"/"False",
        ### <string>: "String", <freq>: "<f> Hz/kHz/MHz"
        ### [arg]: arg optional
        #Option     "SWcursor"                  # [<bool>]
        #Option     "HWcursor"                  # [<bool>]
        #Option     "NoAccel"                   # [<bool>]
        #Option     "ShowCache"                 # [<bool>]
        #Option     "ShadowFB"                  # [<bool>]
        #Option     "UseFBDev"                  # [<bool>]
        #Option     "Rotate"                    # [<str>]
        Identifier  "Card0"
        Driver      "nv"
        VendorName  "NVidia / SGS Thomson (Joint Venture)"
        BoardName   "Riva128"
        BusID       "PCI:1:0:0"
EndSection
```

Make sure this information agrees with what you know about your video card, and note the values for the `Driver`, `VendorName`, and `BoardName` fields. They'll be important as you further configure the X Server.

Note

If you're working with an already-installed version of FreeBSD 5.2.1 or earlier, the X11 implementation included with FreeBSD is XFree86, the older and more stagnant version, not Xorg. Configuring XFree86 is much the same as configuring Xorg; only a few commands are different. To run the hardware auto-detection script, type the following:

```
# XFree86 -configure
```

The file written by this program is `XF86Config.new`, rather than `xorg.conf.new`.

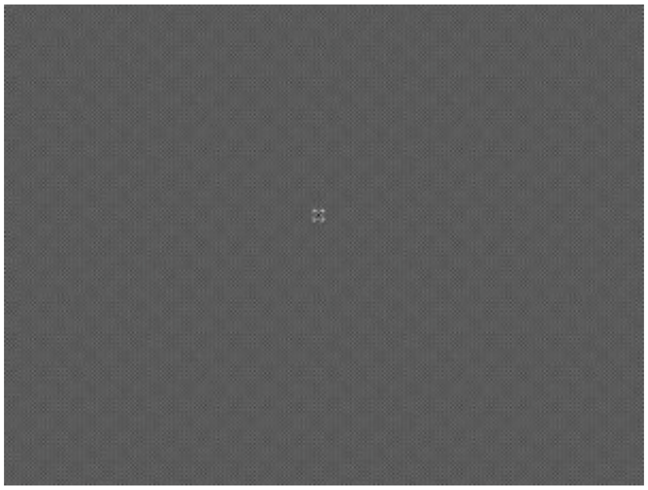
Testing the X Server

Next, you need to test the operation of this auto-detected configuration. Type the following command:

```
# Xorg -config xorg.conf.new
```

The X Server launches using your newly created, bare-bones configuration file. Because the file contains no high-resolution screen modes or information about your monitor's capabilities, the best you can hope to see is a black-and-gray grid pattern that looks like diagonal burlap, and an X-shaped cursor in the middle of the screen, as shown in Figure 2.13. If you see this, you're in luckX11 will work with your video card in at least its simplest display mode.

Figure 2.13. The test screen indicating that your Xorg configuration is working.



Try moving the mouse. If the cursor moves, count yourself doubly luckyyou've got a working mouse driver. If not, make sure you enabled the mouse driver during the initial installation procedure; if you didn't, you'll need to enable it now. Type `sysinstall` to reenter the Sysinstall program, and then navigate to Configure and then Mouse. Follow the instructions in the "Configuring the Mouse" section earlier in this chapter.

There are no controls in this test mode of X11; to end the test, press Ctrl+Alt+Backspace. This will return you to the command prompt.

Caution

Always remember the Ctrl+Alt+Backspace keystrokethis is your way out of X11 if something goes haywire. If the display doesn't appear correctly (for example, if you see a lot of wavy lines instead of a stable grid and cursor), press Ctrl+Alt+Backspace *immediately* to kill X11. If you let X11 run for too long in a video mode that your CRT doesn't support, you could permanently damage the monitor.

Configuring Xorg with `xorgcfg`

The next step is to tell X11 how it should treat your display. You're about to embark on a research project; whereas a lot of the configuration of X11 has come a long way in recent years, the process of determining a monitor's capabilities is still a matter of trial and error.

Your monitor is capable of several resolutions (pixel counts); this is determined by the vertical and horizontal sync rates that it can support. Your monitor's manual should tell you the appropriate sync ranges. If not, you should be able to look it up online by simply doing a Google search on your monitor's make and model, adding the keywords refresh rate or vertical sync if necessary. A monitor with a given vertical and horizontal sync range can only support certain resolutions; if the sync rate is too low for a chosen resolution, the display might be too flickery to use, or the monitor might not be able to use that resolution at all.

Now that you know the driver name to supply for your video card, you need to use it as the basis for a more full-fledged X11 configuration file than the one you created earlier. There is a graphical or text-mode configuration tool called `xorgcfg` that you can use for this purpose. Running this program in graphical mode under X11 might be tempting, but it's better to use it in text mode for now, just to be safethe text-mode version works a lot better. Type the following command:

```
# xorgcfg -textmode
```

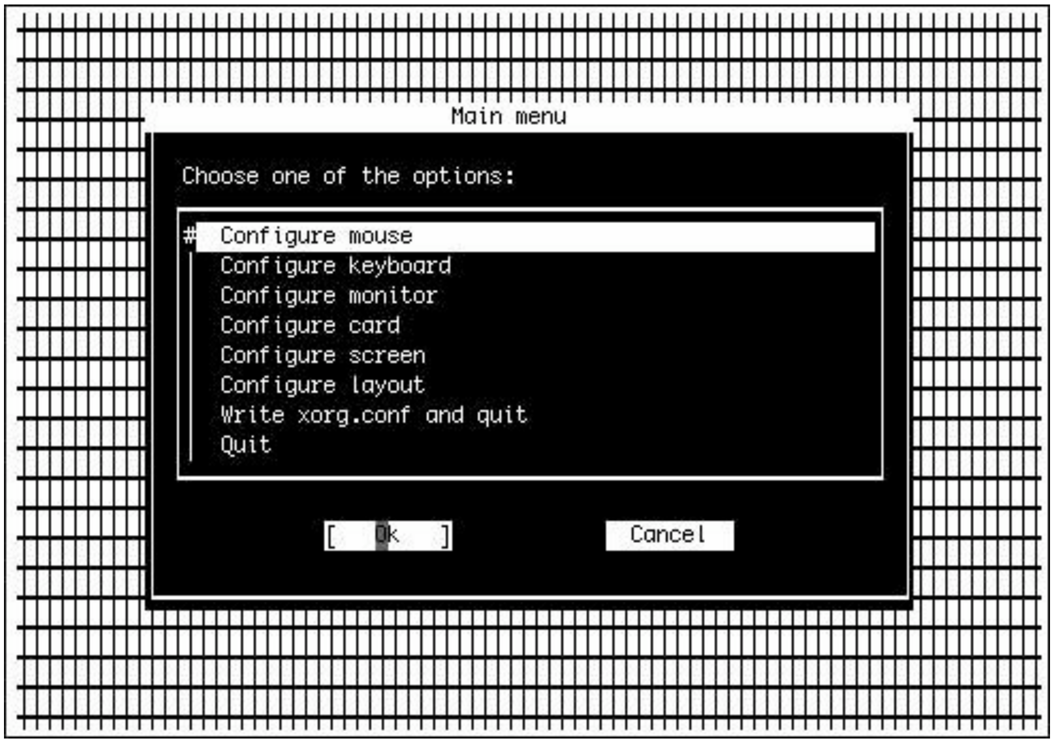
Note

If you're using an older FreeBSD installation with XFree86, use the command:

```
# xf86cfg -textmode
```

After all the driver modules are loaded, you enter a full-screen textual utility similar to Sysinstall. Read the introduction screen and select OK. You enter a Main Menu screen with several options, as shown in Figure 2.14.

Figure 2.14. The `xorgcfg` Main Menu.



```
Main menu

Choose one of the options:

# Configure mouse
  Configure keyboard
  Configure monitor
  Configure card
  Configure screen
  Configure layout
  Write xorg.conf and quit
  Quit

[  Ok  ]        Cancel
```

Go through each of the menu options in order. In each area, you set up a profile for your mouse, keyboard, display, and so on, giving each a name (such as `Mouse0`, `Keyboard0`, and so on).

First select Configure Mouse and specify an identifier such as the given Mouse0. The default port setting, Auto, should be appropriate for a standard PS/2 mouse. Otherwise, select the appropriate port. Enable three-button emulation if desired, and then specify the mouse driver (`/dev/sysmouse` is generally appropriate).

Next, select Configure Keyboard to set up your keyboard in the same manner. Select the appropriate keyboard layout for your region, for example U.S. English.

Next you need to configure your monitor (select Configure Monitor). From the list of horizontal sync rates presented, scroll until you find one that matches your monitor's capabilities as listed in its manual or online specs. If you've used this monitor in Windows, you can use that to help you determine the monitor's capabilitiesif you know you've been able to run in 1280x1024 mode, for example, you can choose an option such as 31.5 79.0; Monitor That Can Do 1280x1024 @ 74 Hz. Just make sure you don't choose too high a frequencyif X11 tries to put the monitor into a mode with a sync rate higher than it can support, you could end up blowing out your monitor. Try selecting the lowest sync rate for the resolution you know the monitor can handle, and then you can work up from there later. Better safe than sorry!

Similarly, choose a vertical sync rate corresponding to your monitor's specs. Choose a range narrower than what your monitor can support, if possible; if your monitor is listed as being capable of 45120 Hz, choose 50100, or enter the sync rate manually to match the monitor's specs exactly.

Next you need to select Configure Card to specify your video card's driver. This is where it's important to know what the auto-detection script thought your card is; because `xorgcfg` doesn't read in that file's contents automatically, you have to specify the card settings again manually. View the card database when it's offered, and scroll through the list until you find an entry matching your card's make and model.

Note

FreeBSD's support for modern video cards is difficult to pin down. There is support for almost all recent NVidia cards explicitly available in the driver database, but ATi cards are woefully unrepresented. If you can't find your card in the list, choose Unlisted Card and proceed to the next screen where you can pick the driver manually.

If you have an ATI Radeon card or any of several other modern 3D-accelerated cards, you might need to add support for them in the kernel before X11 will recognize them. (See Chapter 18, "Kernel Configuration," for more on recompiling your kernel.) A final fallback option is to choose the vesa driver and choose a resolution of 800x600; this setting will support almost any video card made in the last few years, though it won't have any 3D acceleration.

Choose a driver appropriate to your card. This can be tricky, as the drivers are cryptically named. Remember that `nv` is the NVidia driver, `ati` drives ATi cards, and `mga` is the Matrox driver. You should be able to select the same driver name that was originally configured in the auto-detection phase, earlier; it's what was listed in the `Driver` field in `xorg.conf.new`.

Next, choose Configure Screen. This is where you define the color depth of your display modes. This bit depth is limited by the amount of video RAM on your card. Most video cards produced in the last few years have plenty of video RAM, and displaying 24-bit color even at the highest resolutions is no problem; but if you have an older video card, this can be an important consideration. Again, if you used this computer for Windows previously, you should know what bit depths and at what resolutions you were able to run the video card; if not, choose a modest bit depth, for example 8 Bit, 256 Colors. (You can fine-tune this setting later, either by rerunning this configuration program, or by editing the config file manually, if you want to get 16-bit or 24-bit color.) In the next screen, use the arrow keys and the spacebar to place an X next to each of the resolutions you want to be able to use. X11 tries the highest resolution first, and then goes down the list to lower and lower resolutions if it can't put the display into that mode. Try selecting 1152x864, 1024x768, 800x600, and 640x480tried-and-true resolutions that any monitor should be able to handle.

Select Configure Layout to define a layout. This isn't really important if you only have one combination of monitor, keyboard, mouse, and video card, but it doesn't hurt.

Finally, select Write xorg.conf and Quit. This lets you choose to install the new global config file into `/etc/X11/xorg.conf` so that it applies to all users who start X11 from the local console.

Fine-Tuning the `xorg.conf` File

After you're done with `xorgcfg`, you'll want to edit the file it created manually in a text editor to make sure the entries are sensible. Use an editor such as the built-in `ee`, as follows:

```
# ee /etc/X11/xorg.conf
```

Use the arrow keys to browse through the file. Make sure the `Device` block shows information accurately identifying your card. Similarly, make sure the display modes shown in the `Screen` section correspond to valid modes that you know your monitor and card can handle. If you need to make any changes, save the file by pressing Esc and then Enter, then choosing Save Changes when you exit.

Note

X11 configuration is covered in much more detail in Chapter 7, "Advanced X11 Configuration." If you have any difficulties getting X11 to work properly with your video and display hardware, refer to that chapter for additional techniques for determining their appropriate settings.

When the file is configured to your satisfaction, start X11 with the following command:

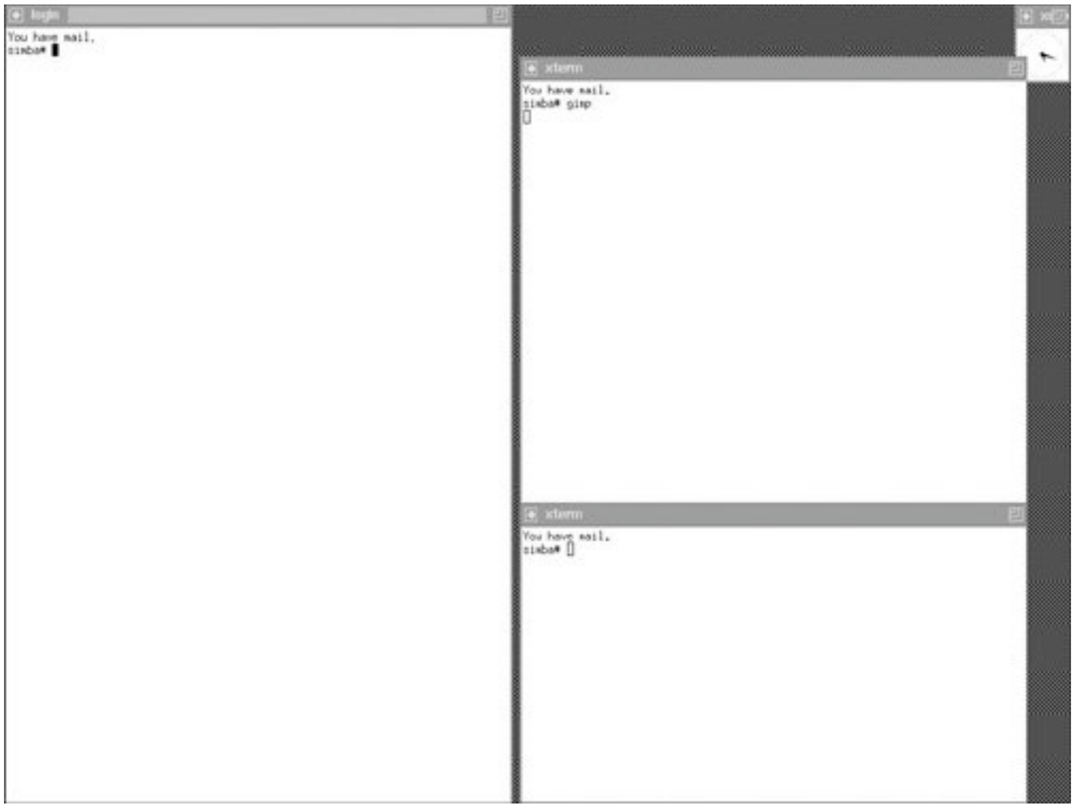
```
# startx
```

Remember to press Ctrl+Alt+Backspace to kill X11 if you get put into a display mode that's unusable or that fails to achieve video syncdon't risk damage to your monitor!

If X11 starts up properly, it does so using a very basic desktop: the TWM window manager (shown in Figure 2.15). This is a venerable but very lightweight desktop environment, providing the very basics in mouse-based control of window shapes and desktop utilities. In the default configuration, you get a command-line `xterm` window labeled login (which is tied to your X11 sessionexit this window and you'll drop to the command line), two more unlabeled `xterm` windows, and a clock. You can work in any of the terminal windows just as you would at the command line. TWM has "sloppy focus," meaning that the active windowthe one where your keyboard input goesis the one where your mouse pointer is; so if your typing doesn't go into the window where you expect to see it, move the mouse to point to that window and leave it there. Also note that each new program you launch, or each new window spawned by a running program, requires you to click the mouse to place its new window in a location of your choice on the screen.

Figure 2.15. The initial X11 desktop layout, running under the bare-bones TWM window manager.

[View full size image]



```
You have mail.
simba# 
```

```
You have mail.
simba# gimp
```

```
You have mail.
simba# 
```

TWM is good for experts and ascetics, but it's a pretty miserable experience trying to make it behave like a modern desktop GUI. For that, we have a variety of excellent desktop environments to choose from: GNOME, KDE, XFce, Window Maker, and many others. To see how to switch from TWM to one of those desktop environments, proceed to Chapter 5.

If you left-click on the desktop area in TWM, a menu appears with several window-management options; two of these, at the bottom, are Restart and Exit. Note that these do not mean "restart the computer" and "exit X11"; instead, they refer specifically to TWM, and will only restart or kill the TWM process, respectively, leaving you in a bare X11 session with no window manager. Shut down X11 for now by typing `exit` in the login window, or by using the Ctrl+Alt+Backspace keystroke.

PREV NEXT

Shutting Down FreeBSD

FreeBSD (like other versions of UNIX) is a multitasking, multiuser operating system. It is constantly doing something and usually has many files open at the same time. Because of this, you cannot simply turn off the power when you want to shut down a FreeBSD system. First, you have to tell FreeBSD to shut itself down so that it can terminate any programs it is running and save any files it has open in an orderly fashion. The proper way to do this right now is with the following command:

```
shutdown -h now
```

This tells FreeBSD to perform a system shutdown, to halt after the shutdown is complete (as opposed to rebooting or going into single-user mode), and that you want the shutdown to happen now instead of five minutes from now, for example. (Usually you put a delay here so that other users will get a warning of the upcoming shutdown and have time to save whatever files they are working on.)

Type **`shutdown -h now`** at the prompt and press Enter.

You'll see a few messages on your screen, including `Broadcast message from root` and various status messages from some processes as they shut down.

Look for the following message:

```
System halted
Please press any key to reboot
```

Then, and only then, is it safe to turn off your computer.

Caution

Never shut down a FreeBSD system or any other UNIX system by simply turning off the power. Doing so can cause serious damage to the filesystems. You should always issue a proper shutdown first. See Chapter 4, "Booting and Shutting Down FreeBSD," for more information on proper shutdown and reboot techniques.

Chapter 3. Advanced Installation Tasks

IN THIS CHAPTER

Chapter 2, "Installing FreeBSD," discussed a standard installation without complicating factors such as dual-boot disk configurations and coexistence with other operating systems. It also assumed that you were installing FreeBSD from a CD-ROM rather than via one of the many alternative installation media available.

This chapter serves mostly as a supplement to Chapter 2, by explaining a number of essential preinstallation tasks for those whose systems don't fit the previously mentioned assumptions. If you are installing FreeBSD on a system with another operating system previously installed, or if you aren't using a CD or DVD to install FreeBSD, you'll want to read this chapter before performing the installation. After you have completed the necessary preinstallation tasks you learn here, you should return to Chapter 2 and proceed with the normal installation.

Many new users who are curious about FreeBSD install it on a workstation that is already running Windows. This chapter shows how to prepare for a FreeBSD installation that will enable the two systems to operate side by side. We'll also look briefly at installing FreeBSD on a system that is running Linux. After reading this chapter, you will know how to install FreeBSD in such a way that you can choose at startup time whether to boot your computer into FreeBSD or into Windows or Linux.

In addition, we'll briefly cover NFS and FTP network installs for situations where an installation CD or DVD is not available.

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Backing Up an Existing Windows or Linux Filesystem

Before you go any further, back up any existing Windows or Linux filesystem you want to maintain. Although the next section shows you how to nondestructively create space for FreeBSD, mistakes can still happen, and programs can cause errors. It is best to have a backup of anything you want to keepit's small comfort, after losing your precious data, to reflect that at least you saved yourself the time and cost of a backup solution.

Media that can be used for backup purposes include recordable CDs or DVDs, Zip or Jaz disks, tape drives, externally mounted USB or FireWire hard drives, or even floppy disks, if the amount of data you need to save is small. Keep in mind that backing up the operating system and installed applications is not necessary because they can be easily reinstalled as long as you still have the installation discs. The primary things to worry about are your files containing data that cannot easily be replaced. (These days, of course, a large MP3 collection or a photo library can easily necessitate that you buy a cheap external hard drive and copy them onto it for safekeeping.)

If you do not have an actual backup program, you can use an archiving program such as WinZip to help you compress data for backup and also to place that data onto disks. You also might find a program called Partimage, available at http://www.partimage.org, to be helpful in this capacity.

Note

The exact procedures for doing a system backup are beyond the scope of this book. See the documentation for the backup program you plan to use for information on how to complete the backup.

After you have backed up any existing files that you want to keep, you will need to free up some space on your hard disk for installing FreeBSD. There are a few ways that this can be done:

- *Simply delete the partitions and start over.* This causes you to lose all the existing data on your system and you will have to reinstall everything that is currently on your system once you have re-created the partitions. This is a desirable option when you don't really care what's on the disk, or if you don't have a nondestructive partitioning program such as Partition Magic*and* if you aren't daunted by the idea of reinstalling Windows or Linux after you have made space for FreeBSD and installed it.
- *Use a commercial nondestructive partitioning program such as Partition Magic.* If you have Symantec's Norton Partition Magic, by all means use it. This $69 solution is the "best of both worlds," allowing you to reallocate the space on your hard disk for a FreeBSD installation without losing any of your data or configurations. A discussion of how to use this commercial program is beyond the scope of this book. See the Partition Magic documentation for instructions. Partition Magic's website is http://www.symantec.com/home_homeoffice/products/system_performance/pm80/. There's also a non-commercial, open-source clone of Partition Magic called QtParted, available at http://qtparted.sourceforge.net/.
- *Use the FIPS utility.* This freely available program, written by Arno Schäfer, allows you to split an existing partition to create free space. FIPS is included on the DVD with this book, and it is the method we'll discuss in this chapter. It's not as polished a solution as Partition Magic, but it's free and can give you similar results.

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Nondestructive Hard Disk Partitioning with FIPS

FIPS, which stands for *First (nondestructive) Interactive Partition Splitting*, is a partitioning program designed to run under DOS or Windows in DOS mode. It splits an existing DOS partition into two at the point you specify. You can then use the new partition it creates as the space for FreeBSD. Note that FIPS works only with DOS-style partitions (FAT16 or FAT32). FIPS does not work with Windows NT/2000/XP NTFS partitions, nor does it work with Linux Ext2FS/Ex+3FS partitions. Finally, those running OS/2 need to be aware that FIPS does not work with HPFS partitions, either.

FIPS has a couple of limitations:

- *It cannot split an extended DOS partition, only a primary one.* Extended DOS partitions are forms of second-level partitioning in common use in the DOS/Windows and Linux worlds; they allow a disk to contain more than the BIOS-supported four partitions by subdividing them and then providing access to them as though they were regular partitions. (FreeBSD doesn't use extended partitions; instead, it has the concept of *slices* and *BSD partitions*, which we will cover in Chapter 20, "Adding Hard Disk Storage.") If you are like most people running Windows, this will not be a problemyou likely have one primary partition that takes up the entire disk.

- *You cannot currently have more than three partitions on your disk.* FIPS creates a new primary partition with the free space it is assigned. Because you can only have four DOS-style partition entries on a disk, you can have no more than three existing partitions when you run FIPS. Note that this limitation only applies to IDE/ATA drives; owners of SCSI drives won't have this limitation.

If neither of these issues applies to you, and assuming you have made a backup, you are ready to begin the partitioning process.

Caution

Windows XP partitions are often formatted as NTFS. Because of this, FIPS may not work with Windows XP at all, even for Windows XP Home Edition. If you're using Windows XP or NT/2000 with an NTFS filesystem, you will need to look into the commercial Partition Magic for nondestructive disk partitioning.

Running ScanDisk and the Defragmenter

Before you use FIPS, you should first turn off your screensaver and any scheduled tasks that might be configured, and then run DOS or Windows ScanDisk to fix any problems on the disk. After ScanDisk has finished running, you need to run the disk defragmenter.

FIPS needs contiguous free space at the end of the drive in order to split the partition. It cannot split before the last sector on the disk containing data. Running the disk defragmenter moves all the data to the beginning of the disk without leaving holes in the middle.

Caution

Be aware that the defragmenter in Windows 2000 and XP often fails to move all files into a contiguous chunk; the NTFS filesystem tends to prevent this from working correctly, and defragmenting tools often leave large holes in the midst of the used disk space. Again, Partition Magic may be the best solution for these platforms if FIPS fails to find enough contiguous free space.

Depending on the speed of your computer, the size of your hard disk, how fast the disk is, and how badly fragmented it is, the defragmentation process could take anywhere from a few minutes to several hours.

Obtaining FIPS and Creating a Boot Disk

When the defragmentation process is finished, you are ready to start FIPS. You can download FIPS from the FreeBSD FTP server at ftp.freebsd.org or one of its mirror sites in the directory `/pub/FreeBSD/tools/fips.exe`. You can download `restorrb.exe` from the same directory. If none of these locations are available, the official FIPS website is http://www.igd.fhg.de/~aschaefe/fips/.

You should create a bootable floppy disk and copy the three files mentioned previously to it. This floppy disk will allow you to boot into MS-DOS (or FreeDOSsee http://freedos.org/ for more information) and run FIPS, but nothing else. In DOS or Windows 98/Me, you can create a bootable floppy from a DOS prompt with the command **`format a: /s`**, assuming that you have a blank floppy in drive A. The following is a sample procedure for creating the boot disk:

```
C:\> format a: /s
Insert new diskette in drive A:
and press ENTER when ready...

Checking existing disk format.
Verifying 1.44M
Format complete.
System transferred

Volume label (11 characters, ENTER for none)?

    1,457,664 bytes total disk space
      388,608 bytes used by system
    1,069,056 bytes available on disk

        512 bytes in each allocation unit.
        2,088 allocation units available on disk.

Volume Serial Number is 031B-0831

Format another (Y/N)? n

C:\> d:
D:\> cd tools
D:\TOOLS> copy fips.exe a:\
    1 file(s) copied
d:\TOOLS> copy restorerb.exe a:\
    1 file(s) copied
D:\TOOLS> copy errors.txt a:\
    1 file(S) copied
D:\TOOLS>
```

Note

You cannot use `format a: /s` to create a bootable floppy under Windows 2000 or XP. These newer operating systems require you to use the Windows interface to create boot floppies. In Windows XP, insert the disk, and then browse to it under My Computer; right-click the disk and choose Format. Enable the Create an MS-DOS Startup Disk check box, and then click Start.

When you've created the bootable floppy, use it to reboot your system (you may need to make sure your BIOS is configured to boot from the floppy drive if a disk is present). After the system has finished booting, type `fips` at the DOS prompt to start the FIPS program.

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Working with FIPS

When FIPS first launches, it gives you a warning not to use it in a multitasking environment, among other common-sense caveats. After you have read all the information, press any key to continue. If you have more than one hard disk in your system, FIPS will ask you which one you want to work on. Select the disk you want. FIPS will then show you the partition table of your disk. It will look something like the following:

```
     |        |     Start      |      |      End       | Start  |Number of|
Part.|bootable|Head Cyl. Sector|System|Head Cyl. Sector| Sector |Sectors  |   MB
-----+--------+----------------+------+----------------+--------+---------+-----
1    |    yes |   1    0      1|   06h|  12   983    32|      32|   409312| 4149
2    |     no |   0    0      0|   00h|   0     0     0|       0|        0|    0
3    |     no |   0    0      0|   00h|   0     0     0|       0|        0|    0
4    |     no |   0    0      0|   00h|   0     0     0|       0|        0|    0

Checking root sector ... OK

Press any Key
```

If you have more than one partition on your disk, FIPS asks you to select which one you want to split. If you only have one partition on your disk, you are asked to press any key, as in the preceding example. After you have selected a partition or pressed a key to continue, FIPS reads the boot sector and presents some more information on the disk:

```
Bytes per sector: 512
Sectors per cluster: 8
Reserved sectors: 1
Number of FATs: 2
Number of rootdirectory entries: 512
Number of sectors (short): 0
Media descriptor byte: f8h
Sectors per FAT: 200
Sectors per track: 32
Drive heads: 13
Hidden sectors: 32
Number of sectors (long): 409312
Physical drive number: 80h
Signature: 29h
```

When FIPS has finished presenting information, it shows you the size of the new partition and the size of the old partition, and asks you to choose the starting cylinder that divides them. Use the left- or right-arrow key to decrease or increase the number the new partition will start on. In addition, you can use the up- or down-arrow key to increase or decrease the size of the new partition in increments of 10 cylinders. You can use the "Start" and "End" numbers of heads, cylinders, and sectors to gauge how you want to divide up your disk; you can decrease the size of the existing partition(s) until the remaining space is big enough for your FreeBSD installation (use the Size column to determine how big it is). Note that, as we'll discuss shortly, a FreeBSD boot partition must exist entirely within the first 1,024 cylinders of the disk. When you have finished, press Enter to continue.

Tip

Write down the starting cylinder information for the new partition you create. This will help you verify later on during the FreeBSD installation that you have selected the correct partition on which to install FreeBSD.

After you have pressed Enter, FIPS shows you what the new partition table will look like. It then gives you the option to re-edit the partition table or continue. If you select Continue, FIPS asks you one last time if you are sure you want to write the changes to the partition table. Be careful at this point! Selecting Y will cause FIPS to write the changes and then exit. This is an irrevocable change; if you write the changes, you won't be able to revert back to the old configuration. After you commit the changes and exit FIPS, you need to reboot your system immediately.

If FIPS exits with any errors, see the README file included with FIPS for more information.

Caution

It is very important that after you exit FIPS, you do *not* create any new data on the hard disk until after you have rebooted. Doing so could corrupt the disk because DOS will not be aware that the partition table has changed until the system has been rebooted.

After you have rebooted, you should run FIPS again with the `-t` option. This will check to make sure the partition was split correctly. If errors are reported, restore the previous partition table by running `RESTORRB.EXE` and then reboot again.

Caution

After you have made *any* changes to the filesystems on the disk, you can no longer use `RESTORRB.EXE` to restore the old partition table. Therefore, it is very important that you run `fips` with the `-t` option after you reboot before you do anything else.

If `fips -t` doesn't report any errors, remove the floppy from the drive and then reboot again. When Windows or DOS has finished restarting, you should run ScanDisk on the partition you split to check for any errors.

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Potential Problems with and Limitations of Dual-Boot Systems

It is possible to have a dual-boot system in which you have two (or even more) operating systems on the hard disk, and you can select which one you want at each system boot. This is a very useful configuration in many circumstances; if you only have one computer, and you want to use FreeBSD for programming and Windows for gaming, dual-booting is an ideal solution. Working with dual-boot systems can present some problems, however, if you don't take steps to avoid and/or deal with them.

First, be aware that all the information necessary to boot FreeBSD must be located within the first 1,024 cylinders of the hard disk. This is necessary for the FreeBSD boot manager to work; it means that when you partition the disk for FreeBSD using FIPS, either the root partition must be completely located within the first 1,024 cylinders, or you can use a separate boot partition that is completely located in the first 1,024 cylinders. (The crux of the matter is that the BIOS is only equipped to look for a bootable partitionone that contains `/boot`in that first segment of the disk.) Use the "Start" and "End" cylinder readouts in FIPS to determine where your partitions start and end. If you choose the latter option (a bootable partition other than the root partition), the root partition does not have to be completely located in the first 1,024 cylinders. Note that "completely located" means that the partition has to both start and end below the 1,024th cylinder. Simply starting below the 1,024th cylinder is not good enough.

If you need more space for Windows or DOS than is available below 1,024 cylinders, you can use FIPS again to split the Windows or DOS partition into two partitions, giving you a `C:` drive and a `D:` drive in Windows or DOS. In between these `C:` and `D:` drives, you need to install a small partition for FreeBSD to boot from. This partition will be used as `/boot` later on during the install (30MB should be more than enough for this partition).

Second, when you reinstall programs after partitioning, be certain to install DOS or Windows before you install FreeBSD. DOS and Windows assume that they are the only operating system on the hard drive and will overwrite the master boot record without asking. If you install FreeBSD first, installing DOS or Windows later will "clobber" FreeBSD's boot manager, and you will no longer be able to boot into FreeBSD. This problem is easily fixed, but save yourself the headaches and just install DOS or Windows first.

Dual-Booting with DOS, Windows 95, Windows 98, Windows Me, or Windows XP

FreeBSD comes with a boot manager that allows you to dual-boot with various operating systems. Simply select the "Install the FreeBSD Boot Manager" option during installation. Subsequently, each time you boot your system, you'll be given a menu allowing you to choose between FreeBSD and your previously installed version of MS-DOS or Windows, by pressing the appropriate F-key.

Tip

GAG is an alternative, third-party boot manager that's graphical and even more flexible than FreeBSD's. Visit its website at http://gag.sourceforge.net/.

Dual-Booting with Linux

If you want to dual-boot with Linux and load Linux from the FreeBSD boot manager, install LILO or GRUB (Linux boot managers) at the beginning of your Linux boot partition rather than in the master boot record (MBR). See the LILO or GRUB documentation for instructions on how to do this. After you have installed the Linux boot manager, you can boot Linux from the FreeBSD boot manager.

If you want to boot FreeBSD from LILO or GRUB, the following subsections explain how.

Booting FreeBSD from LILO

If you're running Linux and want to boot FreeBSD from Linux's LILO loader, it is fairly easy to do so. In Linux, edit the file `/etc/lilo.conf` and add the following lines:

```
other=/dev/hda2
    table=/dev/hda
    label=FreeBSD
```

Change the line beginning with `other=` to reflect whatever device name Linux uses to identify your FreeBSD drive. (Remember, Linux's device names, including hard drive names, are significantly different from FreeBSD's naming convention.)

After you have changed the configuration file, reinstall LILO by typing **`lilo`** as the root user.

Booting FreeBSD from GRUB

To dual-boot Linux and FreeBSD using the GRUB boot manager, edit `/boot/grub/grub.conf` and add the following lines:

```
title FreeBSD 6.1 #1
        root (hd0,0,a)
        kernel /boot/loader
```

The arguments in front of the root statement indicate where FreeBSD's root partition is located; in the examples shown previously, that has been in BSD partition a of slice 0 on the primary hard disk, thus `(hd0, 0, a)`. If your FreeBSD installation uses different disks and slices, adjust these numbers accordingly.

Refer to http://geodsoft.com/howto/dualboot/grub.htm#freebsd for more information on using GRUB along with Linux and FreeBSD.

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The FreeBSD Boot Manager

You can install the FreeBSD boot manager during the FreeBSD installation to enable booting of multiple operating systems. After the install, you can configure the boot manager with the `boot0cfg` program.

`boot0cfg -B` will install the boot manager onto the hard disk's MBR. This is one way to restore the boot manager if Windows should wipe it out (if, for example, you install Windows after you install FreeBSD). Of course, you would have to boot from a FreeBSD boot disk to use `boot0cfg -B` if the boot manager has been wiped out. In addition, if you want to make changes to the boot manager configuration, you will need to reinstall it using this command, followed by the changes you want to make.

`boot0cfg` is command-line based. Fortunately, you probably do not need to be concerned with most of the options, although you might find them interesting in an academic sense, if nothing else. The options shown in Table 3.1 are the most important ones for making changes to the boot manager configuration.

Table 3.1. Boot Manager Configuration Options

Option	Description
`-v`	`boot0cfg` will be more verbose about what it is doing.
`-b` *`image`*	Here, *`image`* is the name of the boot image to use. The default is `/boot/boot0`.
`-d` *`drive`*	Here, *`drive`* is the drive number used by the PC's BIOS for referencing the disk. Usually this is `0x80` for the first drive, `0x81` for the second, and so on.
`-f` *`file`*	Here, *`file`* is the name of a file to which the original MBR should be backed up in case there are problems. If the file already exists, it will be replaced with the new version.

The `-o` option is also supported, and it allows a comma-separated list of arguments, whose meanings are listed in Table 3.2.

Table 3.2. Arguments for `boot0cfg -o`

Argument	Description
`packet`	If the PC's BIOS supports it, this will tell `boot0cfg` to use `int 0x13` extensions instead of the old-style CHS (Cylinder-Head-Sector) for disk I/O. This will get around the 1,024 cylinder boot limit described previously. However, if the PC's BIOS does not support this option, it may cause the system to hang on the next reboot.
`setdrv`	Forces boot0cfg to use the drive number specified in the `d` option to reference the drive you're working with.
`noupdate`	By default, the boot manager can write to the MBR and update it (to set the active flag, primarily). This can cause problems if you have hardware antivirus support enabled that prevents writing to the MBR. The `noupdate` option will prevent the boot manager from attempting to write to the MBR.

`boot0cfg` also supports the `-s` *`n`* option, where *`n`* is a number from `1` to `5` that specifies the default slice (commonly referred to as a *partition* in MS-DOS/Windows) to boot if no selection is made. The `-t` *`n`* option is also supported, where *`n`* is a number representing the number of "ticks" to wait before booting the default operating system. There are approximately 18.2 ticks in a second.

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Alternative Installation Methods

If you can't or (for whatever reason) don't want to install FreeBSD from the DVD included with this book, you have several other options available. These include network installs with FTP or NFS. Installation over the network is especially convenient when you are in a location with a lot of bandwidth and don't have the DVD handy, or if the machine doesn't have a working DVD drive or a BIOS that can boot from it. For many servers or workstations in enterprise environments, installing from a network source is the quickest and most efficient way to get FreeBSD installed.

Installing FreeBSD over the network requires that you first boot a minimal version of FreeBSD that contains the kernel, the Sysinstall program, and almost nothing else. If you can't boot into Sysinstall from the installation DVD, you have to use boot floppy disks. Create these three disks as described in the "Creating Installation Floppies" section of Chapter 2. Then put the first disk (`boot.flp`) into the floppy drive and boot the computer, inserting the other two disks when requested.

Installing FreeBSD over FTP

FTP stands for *File Transfer Protocol*. It is one of the oldest methods of transferring files over the Internet, from one system to another. Despite being unencrypted and insecure, FTP is still widely used; it's the backbone of file transfers on the Internet, as we will discuss in Chapter 27, "Configuring an FTP Server."

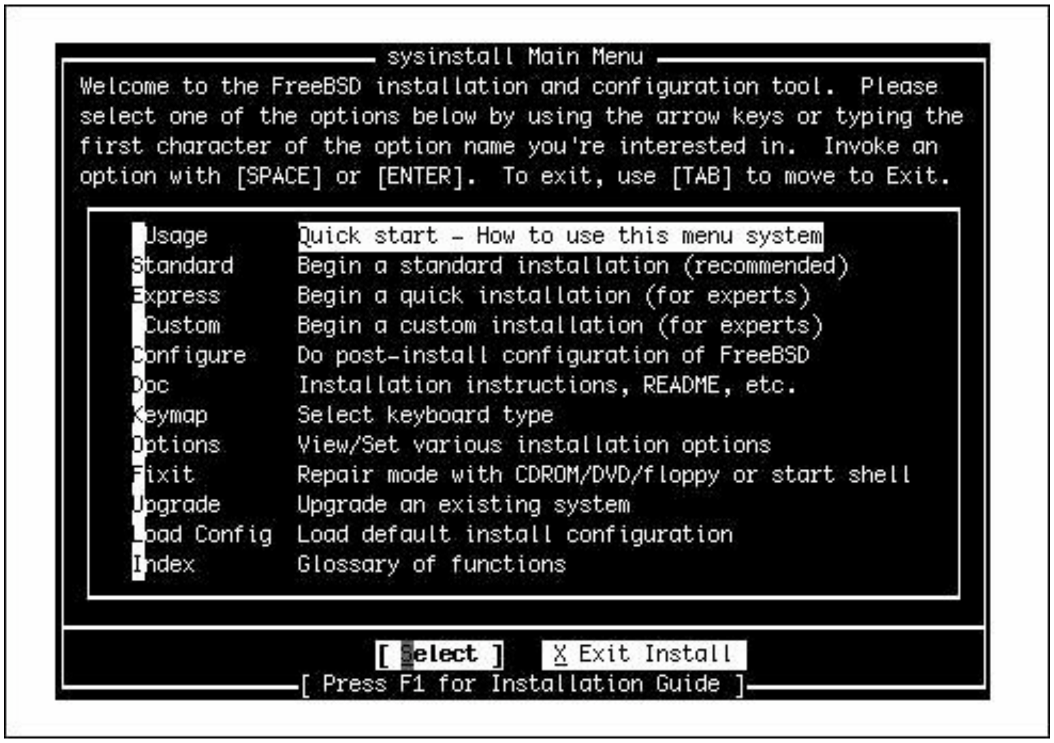
You can install FreeBSD directly from an FTP server, but you should have an always-on, fast Internet connection available in order to do so. Performing an FTP install over a modem will take a *very* long time.

If you are installing FreeBSD from the FreeBSD sites or one of the official mirrors, you can log in as anonymous. In this case, you can skip the next section. If, however, you are installing from an FTP server that does not allow anonymous logins (such as an internal FTP server on a LAN), you will need to follow the procedures in the next section to configure the username first.

Configuring the Username

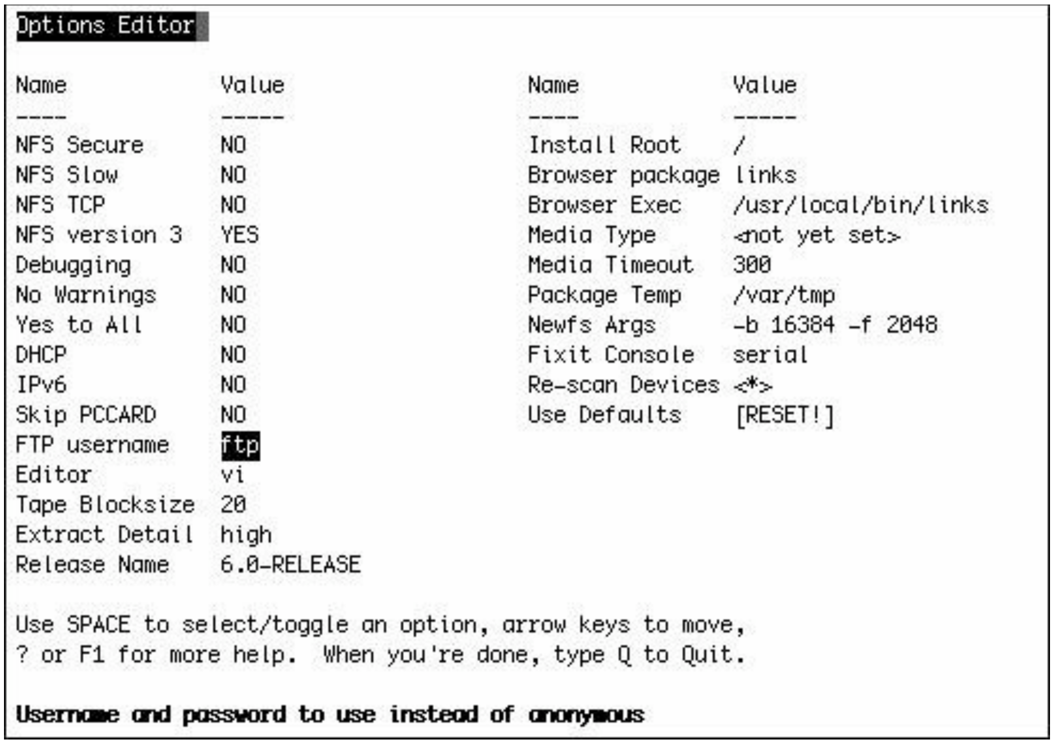
Sysinstall uses a preconfigured username and password for making FTP connections. From the Sysinstall main menu, shown in Figure 3.1, arrow down to Options and press Enter. In the Options menu, shown in Figure 3.2, you can set the FTP login name.

Figure 3.1. The FreeBSD Sysinstall main menu. From here, select the Options menu item.



```
sysinstall Main Menu
Welcome to the FreeBSD installation and configuration tool.  Please
select one of the options below by using the arrow keys or typing the
first character of the option name you're interested in.  Invoke an
option with [SPACE] or [ENTER].  To exit, use [TAB] to move to Exit.

   Usage         Quick start - How to use this menu system
   Standard      Begin a standard installation (recommended)
   Express       Begin a quick installation (for experts)
    Custom       Begin a custom installation (for experts)
   Configure     Do post-install configuration of FreeBSD
   Doc           Installation instructions, README, etc.
   Keymap        Select keyboard type
   Options       View/Set various installation options
   Fixit         Repair mode with CDROM/DVD/floppy or start shell
   Upgrade       Upgrade an existing system
   Load Config   Load default install configuration
   Index         Glossary of functions

              [ Select ]   X Exit Install
           [ Press F1 for Installation Guide ]
```

Figure 3.2. The Options menu, in which you can set the FTP login name (among other installation preferences).



```
Options Editor

Name             Value                   Name            Value
----             -----                   ----            -----
NFS Secure       NO                      Install Root    /
NFS Slow         NO                      Browser package links
NFS TCP          NO                      Browser Exec    /usr/local/bin/links
NFS version 3    YES                     Media Type      <not yet set>
Debugging        NO                      Media Timeout   300
No Warnings      NO                      Package Temp    /var/tmp
Yes to All       NO                      Newfs Args      -b 16384 -f 2048
DHCP             NO                      Fixit Console   serial
IPv6             NO                      Re-scan Devices <*>
Skip PCCARD      NO                      Use Defaults    [RESET!]
FTP username     ftp
Editor           vi
Tape Blocksize   20
Extract Detail   high
Release Name     6.0-RELEASE

Use SPACE to select/toggle an option, arrow keys to move,
? or F1 for more help.  When you're done, type Q to Quit.

Username and password to use instead of anonymous
```

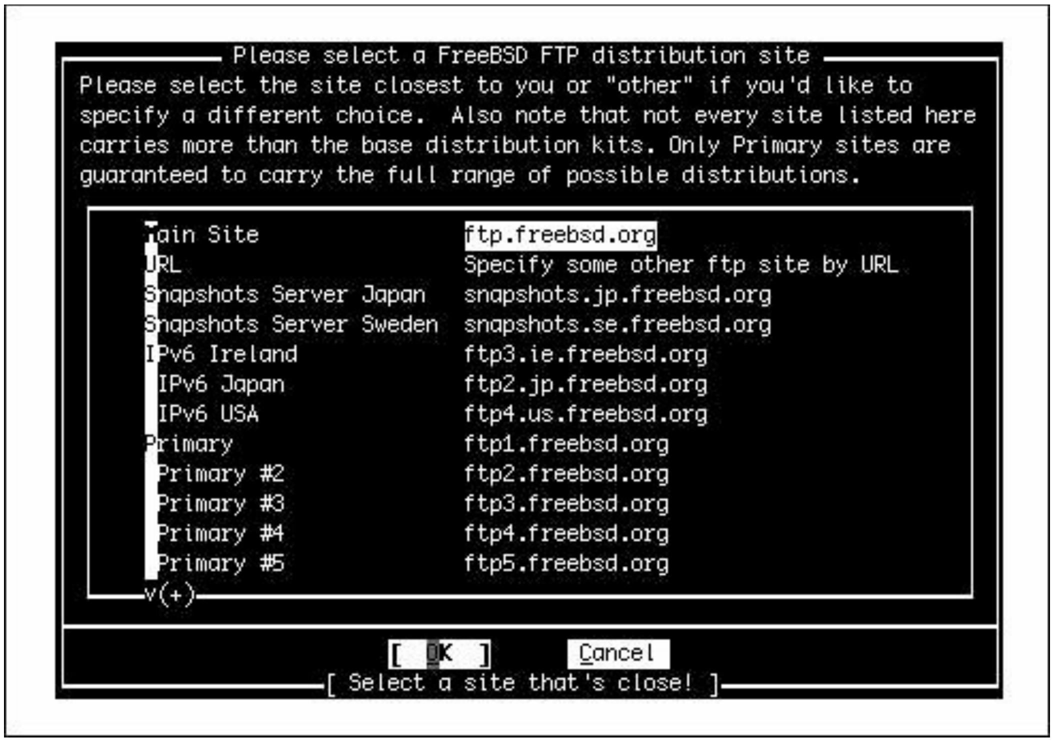
Arrow down to the option that reads FTP Username and press the spacebar. A dialog asks you to enter the username for FTP access; the administrator of the FTP server you will be using should furnish you with a username and password that will let you into the server. Enter the username and press Enter. You are asked to supply a password. Enter the password you need to use and press Enter again.

After you have finished, press Q to quit, and you will be returned to the Main Sysinstall menu.

Selecting an FTP Install

After you have set the FTP username and password (if necessary), follow the instructions in Chapter 2, found in the "Creating Partitions and Assigning Mount Points" and "Selecting a Canned Distribution Set" sections, until you get to the screen where you are asked to choose the installation media. From this screen, select FTP or FTP Passive if the server you intend to install from is behind a firewall (ask your system administrator if you are not sure). You will then be asked to select a distribution site (see Figure 3.3).

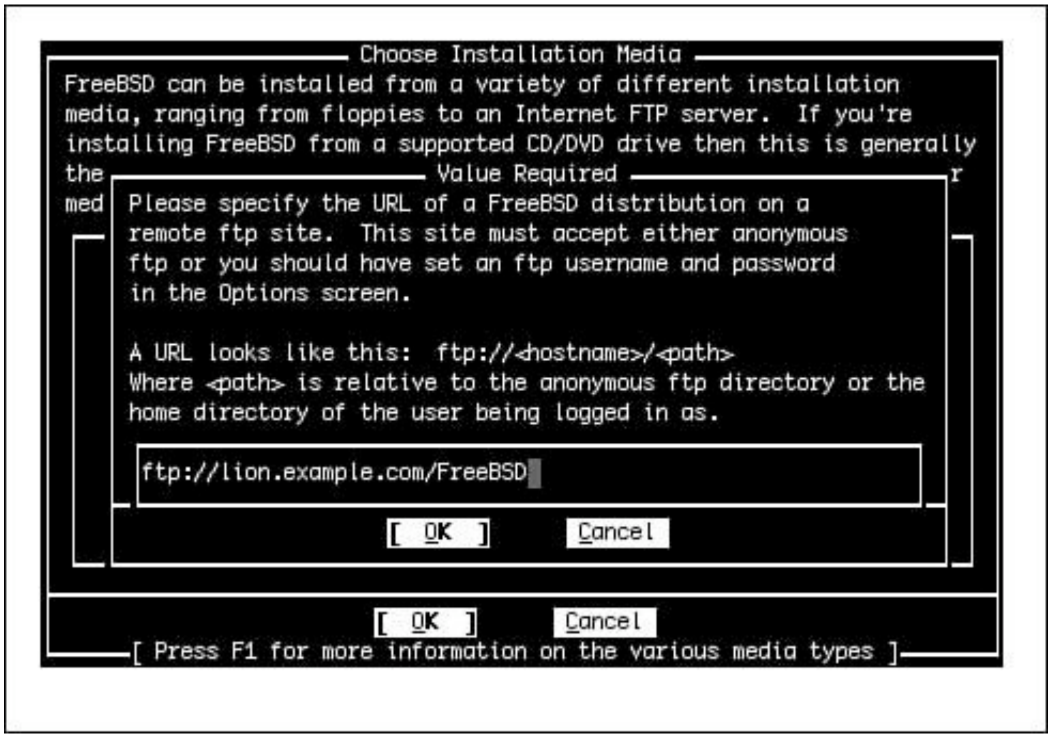
Figure 3.3. The list of available FTP servers from which you can install FreeBSD. Choose the public server closest to you or choose a custom URL.



```
Please select a FreeBSD FTP distribution site
Please select the site closest to you or "other" if you'd like to
specify a different choice.  Also note that not every site listed here
carries more than the base distribution kits. Only Primary sites are
guaranteed to carry the full range of possible distributions.

Main Site                  ftp.freebsd.org
URL                        Specify some other ftp site by URL
Snapshots Server Japan     snapshots.jp.freebsd.org
Snapshots Server Sweden    snapshots.se.freebsd.org
IPv6 Ireland               ftp3.ie.freebsd.org
 IPv6 Japan                ftp2.jp.freebsd.org
 IPv6 USA                  ftp4.us.freebsd.org
Primary                    ftp1.freebsd.org
 Primary #2                ftp2.freebsd.org
 Primary #3                ftp3.freebsd.org
 Primary #4                ftp4.freebsd.org
 Primary #5                ftp5.freebsd.org
v(+)

              [  OK  ]        Cancel
         [ Select a site that's close! ]
```

If you are installing from one of the FreeBSD mirror sites, you can select the site from the list, using whichever server is listed as being geographically closest to you (to maximize download speed). Otherwise, select URL to specify an FTP server manually. In the dialog that opens (see Figure 3.4), you will be asked to specify the name of the FTP server as well as the path to where the FreeBSD installation files are located. Figure 3.4 shows an example for an FTP site with the hostname `lion` located on the network example.com, with the FreeBSD files located in the `/FreeBSD` directory.

Figure 3.4. Specifying a custom FTP server location by URL.

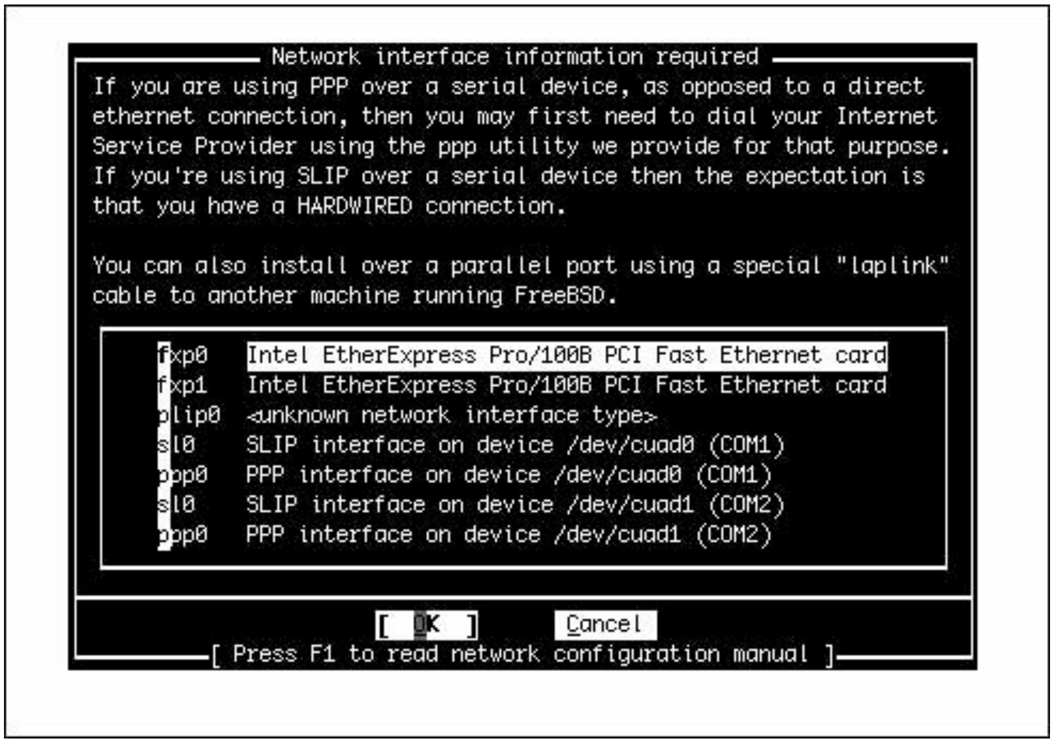


```
Choose Installation Media
FreeBSD can be installed from a variety of different installation
media, ranging from floppies to an Internet FTP server.  If you're
installing FreeBSD from a supported CD/DVD drive then this is generally
the                       Value Required                              r
med

Please specify the URL of a FreeBSD distribution on a
remote ftp site.  This site must accept either anonymous
ftp or you should have set an ftp username and password
in the Options screen.

A URL looks like this:  ftp://<hostname>/<path>
Where <path> is relative to the anonymous ftp directory or the
home directory of the user being logged in as.

ftp://lion.example.com/FreeBSD
```

[OK]
Cancel
[OK]
Cancel
[Press F1 for more information on the various media types]

After you have configured the FTP server you want to install from, you will need to configure the network (see Figure 3.5). Follow the procedure in the "Configuring the Network" section of Chapter 2 to complete this configuration. This step only needs to be completed once; after your network has been configured, you can return to Sysinstall and perform other post-installation tasks without having to configure the network again. The Sysinstall program gives you the option to skip that step or re-enter other network data.

Figure 3.5. Configuring the TCP/IP networking parameters. This information is stored as the system's TCP/IP configuration.


```
Network interface information required
If you are using PPP over a serial device, as opposed to a direct
ethernet connection, then you may first need to dial your Internet
Service Provider using the ppp utility we provide for that purpose.
If you're using SLIP over a serial device then the expectation is
that you have a HARDWIRED connection.

You can also install over a parallel port using a special "laplink"
cable to another machine running FreeBSD.

    fxp0   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    fxp1   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    plip0  <unknown network interface type>
    sl0    SLIP interface on device /dev/cuad0 (COM1)
    ppp0   PPP interface on device /dev/cuad0 (COM1)
    sl0    SLIP interface on device /dev/cuad1 (COM2)
    ppp0   PPP interface on device /dev/cuad1 (COM2)

                 [  OK  ]        Cancel
[ Press F1 to read network configuration manual ]
```

After you have finished configuring the network, the various distribution sets will be downloaded to your computer and automatically installed. This process will probably take a long time; you may want to turn your attention to something else for the next few hours. When files have finished copying, you can go ahead with the instructions offered in the "Post-Installation Configuration and Customization" section of Chapter 2. Because you have already configured the network to do the installation, you can skip the network-configuration portion of those instructions.

Note that this chapter has covered only how to install FreeBSD from an FTP server. If you want to set up an "installation server" that can be used by clients on your local network to install FreeBSD, see Chapter 27. After you have an FTP server set up and the FreeBSD installation files available on it, you can have other systems install from it using the procedures in this chapter.

Performing an NFS Install

NFS stands for *Network File System*. It provides a way for filesystems located on a server elsewhere on the network to be mounted into your own computer's directory structure, and the files in it to be made accessible as though they were on your own hard disk. File sharing with NFS is fully covered in Chapter 33, "The Network File System (NFS)." FreeBSD can be installed over NFS, assuming that there is an NFS server on your network that has the installation files available.

If your NFS server will work only on a secure port (or if you have an old computer with slow network hardware), follow the procedure in the following section. Otherwise, you can skip immediately ahead to "Selecting an NFS Install."

Configuring Sysinstall for a Secure Port or Slow Connection

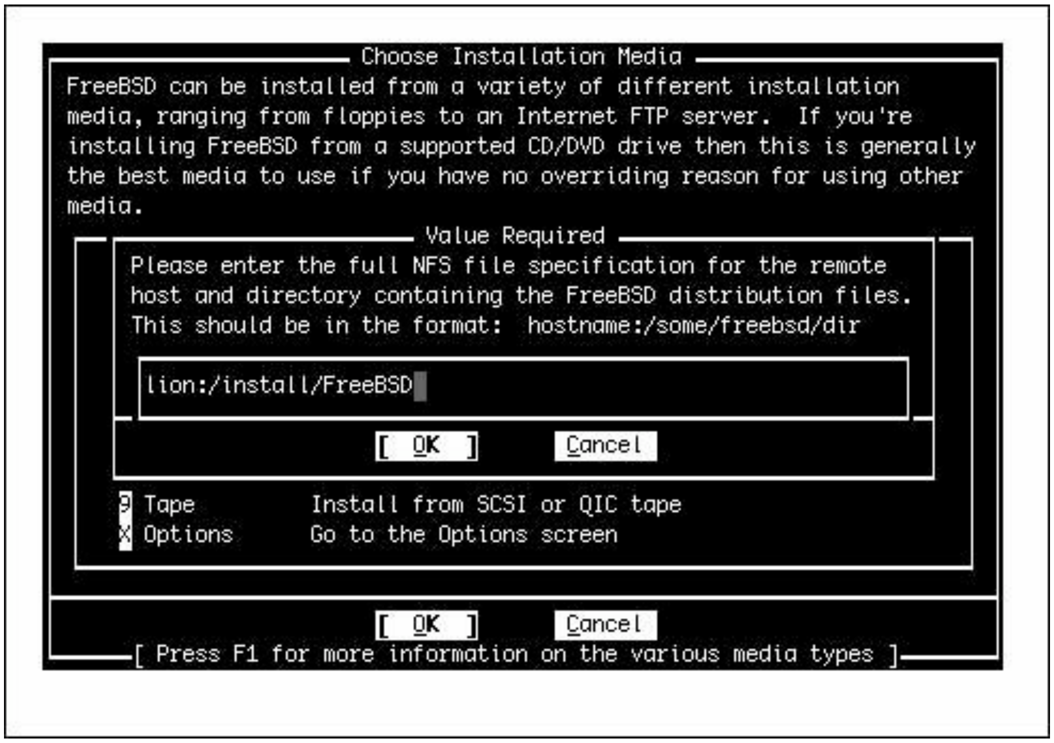
At the Sysinstall main menu (shown previously in Figure 3.1), select Options and press Enter. The first listing in the Options menu is NFS Secure. If your NFS server only works on a secure port (ask your system administrator if you're not sure), press the spacebar to toggle this to Yes. The second option (NFS Slow) should be toggled to Yes if you have a slow PC (something from the 386 era) or an Ethernet card with very poor performance. This is almost always unnecessary; the only cases where an Ethernet card would be slow enough to necessitate this option is if your own computer's filesystem is being remotely accessed, as from yet another NFS server, instead of being locally mounted. After you have made these changes, press Q to return to the Sysinstall main menu.

Installation then continues, as discussed in Chapter 2, up to the point where you are asked to choose the installation media.

Selecting an NFS Install

At the Choose Installation Media screen, select NFS. You will then be asked to enter the name of the NFS server followed by the path where the FreeBSD installation files are located. In the example in Figure 3.6, the server is `lion` and the installation directory is `install/FreeBSD`.

Figure 3.6. Specifying the NFS location of the remote FreeBSD installation files.



```
Choose Installation Media
FreeBSD can be installed from a variety of different installation
media, ranging from floppies to an Internet FTP server.  If you're
installing FreeBSD from a supported CD/DVD drive then this is generally
the best media to use if you have no overriding reason for using other
media.
                     Value Required
  Please enter the full NFS file specification for the remote
  host and directory containing the FreeBSD distribution files.
  This should be in the format:  hostname:/some/freebsd/dir

   lion:/install/FreeBSD

                [  OK  ]      Cancel

  9 Tape          Install from SCSI or QIC tape
  X Options       Go to the Options screen

                [  OK  ]      Cancel
   [ Press F1 for more information on the various media types ]
```

After you have entered this information, you will need to configure the network (shown previously in Figure 3.5). Follow the procedure shown in Chapter 2 under the "Configuring the Network" heading for instructions on how to do this.

After you have finished configuring the network, the various distribution sets will be downloaded from the remote server and installed. This will naturally take longer than installing from a CD-ROM, but it will likely be faster than an FTP installation. When the files have finished copying, you can go ahead with the "Post-

Installation Configuration and Customization" section of Chapter 2. Because you have already configured the network to do the installation, you can skip the network-configuration portion.

Note that this chapter has covered only how to install FreeBSD from an NFS server. If you want to set up an installation server that can be used by clients to install FreeBSD over NFS, see Chapter 33. After you have an NFS server set up and the FreeBSD installation files available on it, you can have other systems install from it using the procedures discussed in this chapter.

PREV NEXT

Part II: FreeBSD on the Desktop

In This Part

PREV NEXT

Chapter 4. Booting and Shutting Down FreeBSD

IN THIS CHAPTER

If you're a Windows or Mac user, you'll immediately discover some of the basic differences between your accustomed operating system and FreeBSD during your first session. When you first start up FreeBSD, your first view of the systemrather than an elegant or flashy graphical login screen or desktop layoutis a stark-looking command prompt in text mode, where you must log in with your username and password before you can do anything with the system.

This chapter provides a basic overview of the procedures for starting up, logging in to, logging out of, and shutting down your FreeBSD machine. Whether you're a beginner or a veteran, these procedures will be a part of your life every time you use FreeBSD, so it's important to know exactly what's going on under the hood.

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The FreeBSD Startup Process

When you first start FreeBSD, it prints a flurry of messages on your screen from the kernel and also from the various processes starting up. We won't go into detail about what all these messages mean right now (a complete discussion of the FreeBSD startup procedure and how to control it can be found in Chapter 14, "System Configuration and Startup Scripts"), but the following sections give a quick rundown of what you will be seeing while you wait for the command prompt.

Note

The following sections apply only to FreeBSD running on *x*86 (Intel) hardware. Although the startup process on Alpha, SPARC, or other platforms is similar, some of the details are slightly different.

The Power-On Self Test (POST) and BIOS

The first thing your computer does when you turn it on is run the POST, which stands for *Power-On Self Test*. During this phase, your computer's BIOS, which stands for *Basic Input/Output System*, checks out all its hardware and makes sure everything is working.

The BIOS is a small piece of software on a ROM or EPROM chip on your computer's system board. Among other things, the BIOS is responsible for testing hardware when the computer is first turned on. The BIOS also finds and tests the first part of the operating system off the hard drive. Then, it counts RAM and probes PnP (Plug and Play) devices to see what resources they can use. At that point, the POST is completed.

The Bootstrap

After the POST is complete, the BIOS searches for a device on your system that it can boot from. The system normally boots from the first bootable device it finds. The specific devices the BIOS searches for and the order in which it searches for them are both determined by the configuration you have specified in your BIOS setup program, as will be discussed more fully in Chapter 14.

Typically, the BIOS boots from the first hard disk in the system, but other possible devices include the floppy drive, attached USB or FireWire drives, and the CD/DVD drive. The BIOS can even boot from the network card on systems that have no hard disk and support loading the operating system over the network from a server. After a bootable device is found (in this case, we'll assume it is the hard disk), the BIOS begins the *bootstrap* procedurea multistage process, comprising several "boot blocks" (small programs that pull successively larger and larger pieces of the operating system into memory), as will be discussed in more detail in Chapter 14.

Selecting the Bootable Slice (`boot0`)

After the BIOS finds a bootable hard disk, it reads whatever is in sector 0 of the hard disk. Sector 0 is also known as the *master boot record* (MBR). Because of legacy PC BIOS limitations, the program located in the MBR can be only 512 bytes long. Therefore, it is a very simple program that knows just enough about the disk to be able to present a small but full-screen menu of the "slices" (partitions) that can be booted from. Here is an example of a menu that might be produced by `boot0`:

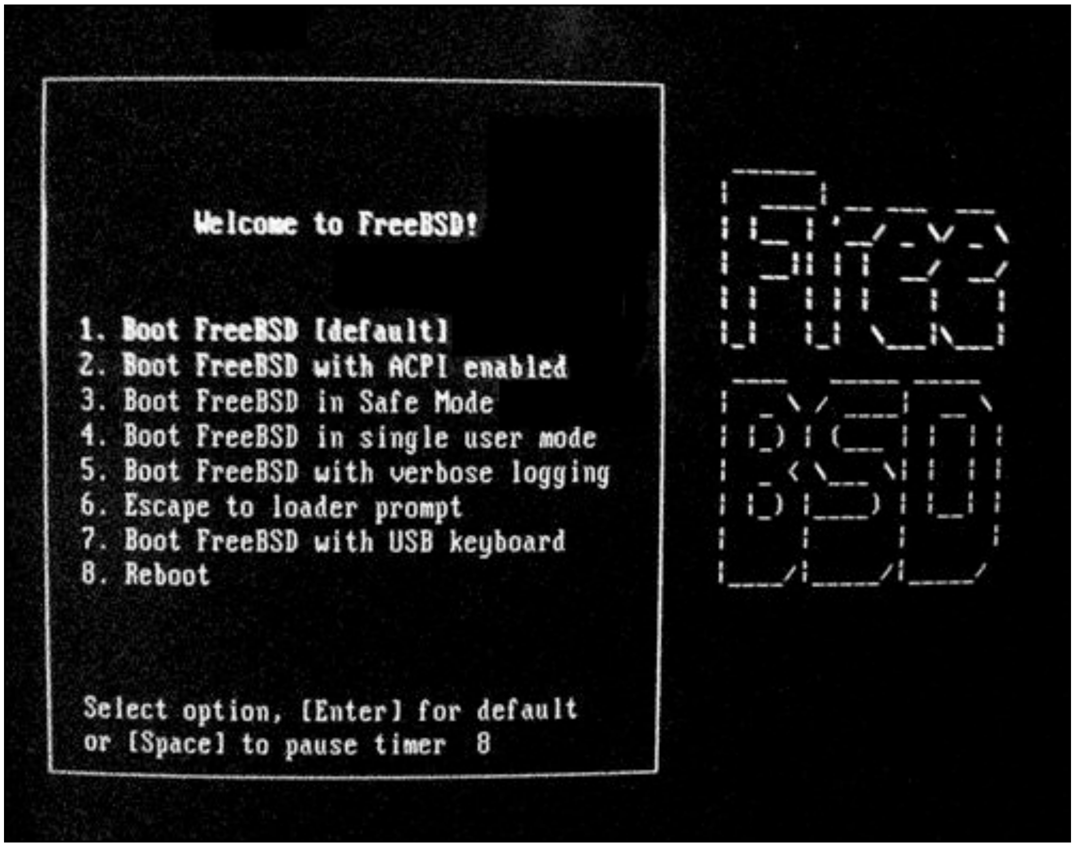
```
F1 DOS
F2 FreeBSD
F3 Drive 1

Default: F2
```

Here, you can use the function keys to select which slice you want to boot fromand thus which operating system you want to start. (A *slice* is what other operating systems refer to as a *partition* or a *BIOS partition*, as we will discuss in Chapter 14.) After you make a selection, `boot0` finds and loads whatever is in the boot sector of the slice you selected. If FreeBSD is the only operating system on your hard disk, you will not see this menu, and the FreeBSD boot sector will be loaded immediately.

The Loader Menu and the Kernel

The `boot1` and `boot2` boot blocks lead to the loader program, whose job is to give you an interface with which to control the *kernel*. As you will see, the kernel is literally the heart of the operating system, and it is loaded only after all the infrastructure of a bootable disk partition has been loaded into memory. The loader menu, which is covered in more detail in Chapter 14 along with fuller details on the disk partitioning structure that underlies the startup process, is a text menu with a "daemon" mascot rendered in ASCII art (or a FreeBSD logo) and a set of options for booting FreeBSD into various modes, analogous to the "Safe Mode" and "MS-DOS Mode" of Windows. One possible appearance of this menu screen is shown in Figure 4.1.

Figure 4.1. The FreeBSD loader menu, presenting a list of boot modes to choose from.



```
Welcome to FreeBSD!

1. Boot FreeBSD [default]
2. Boot FreeBSD with ACPI enabled
3. Boot FreeBSD in Safe Mode
4. Boot FreeBSD in single user mode
5. Boot FreeBSD with verbose logging
6. Escape to loader prompt
7. Boot FreeBSD with USB keyboard
8. Reboot

Select option, [Enter] for default
or [Space] to pause timer  8
```

In FreeBSD, you can boot the system into a single-user mode for performing intrusive administrative duties, or you can manually load kernel modules (such as the IPFW firewall, the Linux compatibility module, or various external filesystem types) to enhance its capabilities.

In the simplest and most common case, you will simply press Enter during the 10-second countdown that the loader gives you, or you can wait until it expires. The kernel will then load, completing the bootstrap process.

The Kernel

The standard kernel is normally located at `/boot/kernel` and is started by the `loader`. As mentioned before, the kernel is the core of the operating system. It controls all access to hardware resources from both programs and users.

Most of the lines that you see on the screen at this point are shown in bold white text, instead of the dimmer light-gray style of the normal screen text. These are status messages that the kernel emits for your information as it finds and initializes your hardware. Most of these messages will go by too fast for you to read, but after you log in to the system, you can use the command **`dmesg | more`** to view them one screen at a time, using the spacebar to advance to the next screen.

You may be interested in the kernel startup messages for a variety of reasons (for instance, to troubleshoot misbehaving hardware or to determine what device name FreeBSD has assigned to a particular component). Let's look at some sample messages from the kernel. This first example gives you an idea of the kind of messages you will see and what they mean (note that your messages might be different, depending on the type of hardware in your system):

```
Copyright (c) 1992-2005 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 1989, 1991, 1992, 1993, 1994
        The Regents of the University of California. All rights reserved.
FreeBSD 6.1-RELEASE #0: Thu Nov 3 09:36:13 UTC 2005
    root@x64.samsco.home:/usr/obj/usr/src/sys/GENERIC
```

The first three lines are simply copyright information. Line 4 gives the operating system version and the version of the kernel (the kernel version number will increase by one each time you rebuild the kernel). It also tells the date and time the kernel was built.

The first part of line 5 gives the username and local email address of the person who built the kernel. In this case, the `GENERIC` kernel was built by `root@x64.samsco.home` (an internal FreeBSD development address), and that kernel was then copied to the system during installation. If you compile your own kernel, which you will learn how to do in Chapter 18, "Kernel Configuration," the line shown here will reflect your own email address and your machine's hostname. The second part of line 5 tells where the directory is that this kernel was built in. (For you C-programming gurus, this is where you will find some of the C source files, the header files, and the object files that this kernel was built fromas well as the makefile for the kernel.)

In the next message, the kernel has detected the CPU type and identified its on-board features; it reports them along with the amount of memory in the system:

[View full width]
```
Timecounter "i8254" frequency 1193182 Hz quality 0
CPU: Pentium II/Pentium II Xeon/Celeron (400.91-MHz 686-class CPU)
  Origin = "GenuineIntel" Id = 0x653 Stepping = 3
  Features=0x183f9ff<FPU,VME,DE,PSE,TSC,MSR,PAE,MCE,CX8,SEP,MTRR,PGE,MCA,CMOV,PAT,PSE36
   ,MMX,FXSR>
real memory  = 402653184 (384 MB)
avail memory = 384602112 (366 MB)
```

Tip

The kernel information echoed to the screen during bootup, beginning with the FreeBSD copyright messages and the kernel's compilation environment, is available at any time by typing **`cat/var/run/dmesg.boot`**. This is very convenient if you have to diagnose hardware problems or determine the device names assigned to hardware FreeBSD has detected. The `dmesg` command, mentioned earlier, shows the current contents of the kernel message buffer, which can get overwritten by more recent messages if the system has been running for a long time.

Following this output is a long series of devices that FreeBSD has identified. These will vary according to the hardware in your system. One typical system begins its device configuration by listing the motherboard, PCI and AGP bus controllers, ATA controllers, USB hubs, and Ethernet cards (pay attention to the driver name FreeBSD assigns to the Ethernet card, `fxp0`it's particularly important):

[View full width]
```
npx0: [FAST]
npx0: <math processor> on motherboard
npx0: INT 16 interface
cpu0 on motherboard
pcib0: <Intel 82443BX (440 BX) host to PCI bridge> pcibus 0 on motherboard
pir0: <PCI Interrupt Routing Table: 7 Entries> on motherboard
pci0: <PCI bus> on pcib0
agp0: <Intel 82443BX (440 BX) host to PCI bridge> mem 0xe0000000-0xe3ffffff at device 0.0
   on pci0
pcib1: <PCI-PCI bridge> at device 1.0 on pci0
pci1: <PCI bus> on pcib1
$PIR: ROUTE_INTERRUPT failed.
```

```
pci1: <display, VGA> at device 0.0 (no driver attached)
isab0: <PCI-ISA bridge> at device 7.0 on pci0
isa0: <ISA bus> on isab0
atapci0: <Intel PIIX4 UDMA33 controller> port 0x1f0-0x1f7,0x3f6,0x170-0x177,0x376
   ,0xf000-0xf00f at device 7.1 on pci0
ata0: <ATA channel 0> on atapci0
ata1: <ATA channel 1> on atapci0
uhci0: <Intel 82371AB/EB (PIIX4) USB controller> port 0xe000-0xe01f irq 10 at device 7.2
   on pci0
uhci0: [GIANT-LOCKED]
usb0: <Intel 82371AB/EB (PIIX4) USB controller> on uhci0
usb0: USB revision 1.0
uhub0: Intel UHCI root hub, class 9/0, rev 1.00/1.00, addr 1
uhub0: 2 ports with 2 removable, self powered
pci0: <bridge> at device 7.3 (no driver attached)
fxp0: <Intel 82557 Pro/100 Ethernet> port 0xe400-0xe41f mem 0xe9200000-0xe9200fff,
    0xe9100000-0xe91fffff irq 9 at device 11.0 on pci0
miibus0: <MII bus> on fxp0
inphy0: <i82555 10/100 media interface> on miibus0
inphy0:  10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
fxp0: Ethernet address: 00:a0:c9:66:7b:32
```

Here, the kernel has found the mouse and has detected that it is a PS/2-type mouse. It has assigned the device `psm0` to refer to this mouse for future reference:

```
psm0: <PS/2 Mouse> irq 12 on atkbdc0
psm0: [GIANT-LOCKED]
psm0: model Generic PS/2 mouse, device ID 0
fdc0: <Enhanced floppy controller> at port 0x3f0-0x3f5,0x3f7 irq 6 drq 2 on isa0
fdc0: [FAST]
fd0: <1440-KB 3.5" drive> on fdc0 drive 0
```

The kernel has also found the floppy controller and the floppy drive. `fdc0` is the device name of the floppy controller, and `fd0` is the device name of the floppy drive itself. (`fd0` is analogous to A: in Windows/DOS. It is the device name you use when you want to access this device.)

The next message shows that the kernel has found the SoundBlaster AWE 64 sound card, and it gives information about the resources the card is using:

```
sbc0: <Creative SB AWE64> at port 0x220-0x22f,0x330-0x331,0x388-0x38b irq 5 drq 1,5 on isa0
pcm1: <SB16 DSP 4.16> on sbc0
```

Note that in this case, `sbc0` is actually the name for a group of devices related to the sound card. The sound card uses several devices, depending on what features you want to access, including `dsp`, which is where output such as WAV and MP3 files go, and `mixer`, which controls the levels of various audio devices.

You may also see some of the following lines on your startup message:

```
unknown: <PNP0303> can't assign resources (port)
unknown: <PNP0c01> can't assign resources (memory)
unknown: <PNP0a03> can't assign resources (port)
unknown: <PNP0f13> can't assign resources (irq)
unknown: <PNP0501> can't assign resources (port)
unknown: <PNP0700> can't assign resources (port)
```

These lines indicate that the kernel has found some "Plug and Play" (often abbreviated to PnP) devices in the system, but it doesn't know anything about them, and it can't assign resources for them. These messages are harmless. If you don't like seeing them, then note that, as the FreeBSD FAQ says, "the FreeBSD project will happily accept driver contributions via `send-pr`." (This is a not-so-subtle exhortation for you C gurus who are good at writing device drivers to contribute to the FreeBSD project in the spirit of the Open Source movement.)

The next message shows that the kernel has found the hard drives and CD-ROM drive; it provides various information about each drive, including the device name, size, manufacturer and model, geometry, and what controller the drive is located on:

```
ad0: 19473MB <Maxtor 92049U6> [39566/16/63] at ata0-master UDMA33
ad1: 14664MB <IBM-DJNA-351520> [29795/16/63] at ata1-master UDMA33
acd0: CDROM <ATAPI 44X CDROM/VER-3.40> at ata1-slave UDMA33
```

It also tells what access mode the drive is using. In this case, both of the hard drives and the CD-ROM are using Ultra DMA 33. (This will be covered in more detail in Chapter 20, "Adding Hard Disk Storage.")

The final message shows that the kernel has mounted the root filesystem:

```
Trying to mount root from ufs:/dev/ad0s1a
```

The fact that the system is running indicates that it was successful. After the root filesystem is mounted, the kernel passes control to a process called `init`. The messages in light gray are triggered by events that occur during the `init` stage. You can differentiate kernel messages from non-kernel messages by color. Kernel messages appear in white; non-kernel messages appear in light gray.

`init`

The `init` program is the first actual process that runs under the operating system, and as such its process ID is 1. `init` is responsible for starting up all the rest of the processes that constitute a completely functional operating system; to do that, though, it must first determine whether the disks are in suitable shape.

When a FreeBSD system is properly shut down, it runs a program called `sync` on each disk to ensure that all data is written out, dismounts the filesystems, and then sets the "clean" flag on the filesystems. This is similar to the process that Windows goes through when it shuts down. If a FreeBSD system is not properly shut down, the clean flag will not be set.

Filesystem Consistency Check

One of the first things that `init` does is to check whether the clean flag is set. If it is, `init` mounts the filesystem for use. If it isn't, `init` first runs the `fsck` program on the filesystem to make sure it isn't damaged. This program repairs any damage it finds that it knows how to repair. `fsck` is similar to the Scandisk program in Windows, and this process is similar to the "Your system was not properly shut down" procedure you see on a Windows reboot following an improper shutdown. If `fsck` encounters an error it cannot fix at this point, it drops the system into single-user mode so the system administrator (which is probably you, if you are reading this book) can make the necessary repairs manually.

Assuming that the clean flag was set, or that `fsck` was able to repair the damage if the flag was not set, `init` then proceeds to mount each filesystem listed in the `/etc/fstab` file that has the `mount at boot` flag set (see "Understanding the `/etc/fstab` File" in Chapter 12, "The FreeBSD Filesystem").

Tip

If you need to, you can also run `fsck` manually. More information on `fsck` and its various options can be found in Chapter 12.

System Configuration Scripts

After the filesystems are mounted, `init` reads the system-configuration scripts (known alternately as *Run Control* or *Resource Configuration* scripts, abbreviated to *rc* scripts) located in `/etc` and `/etc/defaults`. In addition, `init` checks the `/usr/local/etc/rc.d` directory for any additional scripts it should run at boot (these might be scripts to start web servers, database servers, or any other program you want to run automatically at startup). If you are familiar with Windows or DOS, this part of the boot process is similar to `config.sys`, `autoexec.bat`, `system.ini`, and the parts of the Windows Registry that control Windows startup options.

Note

The term *rc scripts* actually originates from RunCom, or "run commands," a facility from the CTSS system at MIT, circa 1965. While the acronym *rc* has been reassigned to numerous different meanings since then, its general application remains the same: a set of commands stored in a file and run in a batch. In typical UNIX parlance, the meaning of *rc* by itself is clear enough that it is unnecessary to know what it stands for, and most people don't. It simply means "a script associated with a certain daemon or subsystem, which executes when the daemon or subsystem is launched and sets up its runtime configuration."

This book will refer to *Run Control* for Sun-style run levels and *Resource Configuration* when it comes to FreeBSD's own startup scripts.

Note

For the sake of completeness, it should be mentioned that `init` also checks for and reads a file called `/etc/rc.local`, which can be used to start programs such as web servers. However, this file is deprecated and may not be supported in future versions of FreeBSD. Therefore, it is recommended that you put your startup scripts in the `/usr/local/etc/rc.d` directory, according to the best practices encouraged by FreeBSD's package management system, instead of in the `/etc/rc.local` file.

BSD versus Sys V Run Control

If you come from a Sys V UNIX background, you may be a little bit confused after that last section. Here is a clarification: In BSD `init`, the concept of "run levels" doesn't really exist. You pretty much have single-user mode and a multiuser mode with network support. There is no multiuser mode without network support as there is in Sys V run levels. Also, there is no `inittab` file in BSD as there is in Sys V. In addition, startup options are mostly controlled by a single file called `rc.conf`. There aren't separate files to start most services with links in different run-level directories, as there are in Sys V. (You'll learn much more about `init` in Chapter 14.)

`getty` and `login`

After reading the resource configuration scripts, `init` starts a program on the console (and several virtual terminals). This program is normally the `getty` program, but it doesn't have to be. Another common program used in place of `getty` is `xdm`, which starts a graphical login session for the X Window system immediately after system boot (similar to an NT login session). The program that is started is defined in the file `/etc/ttys`. For the purposes of this discussion, we'll assume it's `getty`.

The `getty` program initializes the terminal (or console), and it controls various security options and terminal-type options. Once again, these options and their values are defined in `/etc/ttys`. When you have entered your login name and password, the `getty` program starts the `login` program to validate them.

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Logging In to FreeBSD

After all the startup processes are complete, you see a couple of lines that look something like this:

```
FreeBSD/i386 (amnesiac) (ttyp0)

login:
```

The hostname you configured during installation appears in the first line, along with a readout that tells you what console device you're using to access the system (this varies depending on whether you're accessing it remotely or locally, and on how many other users are already logged in; in this case, `ttyp0` is the first "pseudo tty," or remote terminal). Enter the login name of the normal user (not the root user) that you created for yourself during the installation. Press Enter and then, when prompted, enter the password you gave yourself. Note that the password will not be displayed onscreen. Actually, nothing will be displayed onscreen. Don't worry, though. Your password is being read.

After you enter the password, the login program checks the password database for a match. If it finds one, you get a screen that looks something like this:

```
Last login: Tue Apr 10 15:19:17 on ttyp0
Copyright (c) 1980, 1983, 1986, 1988, 1990, 1991, 1993, 1994
        The Regents of the University of California. All rights reserved.

FreeBSD 6.1-RELEASE #0: Thu Nov 3 09:36:13 UTC 2005

>
```

If this is the first time you log in with your normal user account, you probably won't see the first line, `Last login`. In the future when you log in, however, this line will be present.

Caution

It's a good idea to pay attention to the "last login" information. If, for example, FreeBSD says your last login was

```
Sat Sept 15 14:05:29
```

and you know you haven't used the system since September 8, someone else has logged in to your account in the interim. If something like this ever happens, you need to change your password *immediately* (use the `passwd` command and follow the instructions it gives). Also, be sure to notify your system administrator of the security breach (assuming you are not the system administrator). If you are the system administrator, see Chapter 30, "Network Security," for further information on what to do if you think your system has been compromised.

The rest of the screen shows copyright information as well as data about the kernel and when it was built. The final line is the shell prompt. When you see the shell prompt, FreeBSD is waiting for you to give it something to do.

Caution

Notice the difference between the command prompt you get this time and the command prompt you got last time (when you logged in as the root user). The root user's login prompt is the pound sign (`#`). A normal user's login prompt will usually be either `$` for Bourne-style shells or `%` or `>` for C-style shells. The default shell in FreeBSD is `tcsh`, which is a C-style shell. Either way, the type of prompt you have serves as a constant reminder of whether you are logged in as root. If you are, be extra careful when issuing potentially dangerous commands.

If you mistype either the login name or the password, FreeBSD will respond with the following message:

```
Login incorrect
login:
```

If this happens, simply try again, starting with your login name.

Tip

If you mistype your login name or password three times in a row, it may appear that the system has hung because it looks as if nothing is happening. Don't worrythe system isn't frozen. This delay is a security feature built into the kernel that helps reduce the effectiveness of passwordcracking programs that simply try random words as passwords to break into an account. The delay may get progressively longer on each mistype after three. Wait several seconds, though, and the login prompt will reappear.

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Logging Out of FreeBSD

When you are finished using FreeBSD (or you need to leave your computer for a while), you should log out of the system. That prevents anyone from using your computer or terminal to access your account during your absence. To log out of FreeBSD, simply type `logout` or `exit` at the command prompt. This should return you to the login prompt, as you saw when FreeBSD first finished booting.

Tip

If you've been working on something that you don't want others to see when they walk past your screen, you can clear the screen before logging out by typing `clear` at a command prompt. After that, you can log out of the system as described earlier.

Shutting Down the FreeBSD System

As mentioned in Chapter 2, "Installing FreeBSD," it is very important that you always shut down a FreeBSD system (or any other UNIX system) properly before turning off the power. Failure to do so can result in serious damage to the filesystem. Disks in UNIX are treated as though they contain filesystems that are maintained in a very orderly fashion; if you shut down Windows abruptly by pulling the power cord, the disks will have some fragmented files lying around after it reboots, but the system can cope with them. However, FreeBSDlike most UNIX systemswrites data to the disk in such a way that fragmentation is kept to an almost insignificant level, but an abrupt loss of power can cause the system to actually lose data that was active at the time. FreeBSD has a mechanism called Soft Updates to help combat this problem; see Chapter 12 for more details on using Soft Updates.

Using the `shutdown` Command

The normal way to shut down the system is with the `shutdown` command, which you first read about in Chapter 2 in the section titled "Shutting Down FreeBSD." Before you actually shut down the system, however, take a moment to learn about several other options for using this command.

The basic syntax of the `shutdown` command is as follows:

```
shutdown option when broadcast message
```

The first argument tells `shutdown` what to do, the second argument tells `shutdown` when to do it, and the third argument tells `shutdown` the message it should send to all logged-in users. Table 4.1 lists the options that can be used for *`option`* in `shutdown` and what they do.

Table 4.1. The Options for `shutdown`

Option	Result
Nothing	Kicks everybody off the system and brings the system down to single-user mode with no network support. This is rude to the users, but quick and efficient.
`-h`	Halts the system.
`-p`	Halts the system and turns off the power (if the system supports automatic power-off and the kernel is configured to support power management).
`-r`	Reboots the system.
`-k`	Kicks everybody off the system and disables any further logins (except from the root user). This option leaves the system in multiuser mode and connected to the network, though. This is useful for occasions when you need to do emergency maintenance but require network access while you do it.
`-o`	Shuts down without sending a signal to `init`. This is not usually a good idea because it prevents program-specific shutdown scripts from running.
`-n`	If the `-o` option has also been specified, this option prevents the filesystem cache from being flushed before the shutdown. This is probably never a good idea because it can cause data loss.

The "when" part of shutdown can be specified in several ways. As you learned in Chapter 2, the keyword `now` tells `shutdown` to perform the action immediately. `shutdown` also recognizes the format *+n*, where *n* is the number of minutes `shutdown` should wait before performing the action (this gives users time to save their files and close their programs). You can use the format *yymmhhmm* to specify an exact time when the action should be performed. In this case, *yy* is the year, *mm* is the month, *hh* is the hour (in a 24-hour format), and *mm* is the minute. If the year and month parts are eliminated, `shutdown` assumes that the shutdown should happen today. If you specify a time that has already past, `shutdown` will complain.

The "broadcast message" option enables you to enter a shutdown-notification message that will be broadcast at regular intervals to all logged-in users. This message starts to appear 10 minutes before the impending shutdown and is broadcast more frequently as the shutdown time gets closer.

The following is a step-by-step walkthrough of a typical shutdown process that, in this case, uses a 10-minute delay (don't enter this command now if you don't actually want the system to shut down in ten minutes):

```
# shutdown -h +10 Hard disk needs to be replaced
```

This starts the `shutdown` command and runs it in the background. The system will halt in 10 minutes. In addition, the following broadcast message is displayed on all users' terminals:

```
*** System shutdown message from root@simba.somewhere.com ***
System going down in 10 minutes

Hard disk needs to be replaced
```

Five minutes before the impending shutdown (or immediately, if you specified a delay of less than five minutes), a file called `/var/run/nologin` will be created automatically by the `shutdown` program. This file disables any further logins and displays the shutdown message contents when someone attempts to log in. The `shutdown` command places the time of the shutdown and the broadcast message in this file. For example, in this case, anyone who attempts to log in will see the following:

```
NO LOGINS: System going down at 17:57

Hard disk needs to be replaced
```

When the countdown clock runs out, the following actions are performed:

- A `TERM` signal is sent to `init`, which ceases creating any new processes.
- `init` reads the file `/etc/rc.shutdown` and runs any program-specific shutdown scripts it contains.
- All processes are sent a `TERM` signal and given time to terminate themselves gracefully.
- Any processes that did not respond to the `TERM` signal in a reasonable amount of time are sent a `KILL` signal, which cannot be ignored. This will force the processes to terminate ungracefully.
- Cache data is written out to the filesystems with the `sync` command, the filesystems are dismounted, and the clean flag is set.
- The kernel is halted.

In addition, `shutdown` writes an entry in the system log noting the time of the shutdown and who performed the shutdown.

Note

You need to be the root user to shut down the systemeither by logging in directly as root or by using the su command to become root. Another method is the sudo command, which allows certain users to perform one-time administrative tasks.

To shut down your system now, you need to be root, so type **su** (for "super-user") and press Enter. This command gives you temporary root privileges. Enter the root password when prompted. If you receive a message complaining that you are not in the proper group to use su, log out and then log back in directly as root. Then, assuming there are no other users logged in to the system, issue the following command:

```
# shutdown -h now
```

As mentioned in Chapter 2, on a multiuser system, you would not normally shut down the system like this. Instead, you would give users some warning about the impending shutdown.

After the shutdown has completed, you will see the following message:

```
System halted
Please press any key to reboot
```

Then, and only then, is it safe to turn off your system.

Notes on halt and reboot

Two other commands can be used to halt and reboot the system: halt and reboot, respectively. However, I do not recommend that you get in the habit of using them. Neither of these commands runs the rc.shutdown script, which can cause some programs to terminate improperly. Also, neither of these programs allows you to specify a delay, and neither gives users any warning about the impending shutdown. Therefore, you should always use the shutdown command to halt the system.

However, these two programs do have their uses. You can use halt to make the system 100-percent safe to power down after you have shut down all multiuser processes through the shutdown command. The reboot command is also handy if you're working in singleuser mode; it simply kills all running processes with a SIGKILL (a nonignorable signal) and reboots immediately. These commands are helpful for saving time when it's safe to use them, but those occasions are rare.

Note

If you've used DOS or Windows in the past, you might be in the habit of using the Ctrl+Alt+Delete key combination to reboot a system. By default, FreeBSD will trap the signal sent by this keystroke and perform the equivalent of running the reboot command. This can be a problem when normal users have access to the server's keyboard because it allows them to reboot the system without being root.

Chapter 5. Working with the X Window System

IN THIS CHAPTER

In this chapter, you will look at the X Window System, also known as X11 or Xthe UNIX world's equivalent of the Windows operating environment. UNIX systems have traditionally been reluctant to adopt graphical user interfaces like the one in Windows or Mac OS X, owing to the usual niche of UNIX systems in server roles where a user-friendly application environment is seldom of any use. However, in recent years many people have sought to replace their Windows desktop systems with Linux or FreeBSD machines, and with that trend has come a plethora of software intended to make the venerable and downright arcane X11 windowing system more the seamless user experience that Windows offers.

The X Window System comprises two partsthe X Server and the window manager. The X Server runs as a daemon on your system and provides a graphical framework for applications to use. The window manager determines how the X11 environment looks and feels. In this chapter, you learn about these parts of the system in more detail and how to work with and customize the KDE user environment, as well as to switch from one window manager to another if you don't like the one you've got.

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Introduction to X11

The X11 system is a suite of programs developed at MIT and in the open-source community over the past two decades. Its current implementation, developed and endorsed by the X.org Foundation, is known as Xorg. As discussed during the coverage of its installation in Chapter 2, "Installing FreeBSD," X11 has a client/server architectural model that lends itself well to clustered workstation configurations, but it can also work well on a single-user desktop computer as long as you understand the reasoning behind its seemingly curious designnamely, why the separation between the X Server (the windowing system's heavy-lifting core) and the window manager exists.

Like early versions of Microsoft Windows, X11 is a graphical "shell" that runs on top of the command-line operating system core; you first log in to the command-line environment and then you start up to go into the mouse-driven graphical mode where you can run applications such as web browsers and word processors. When you quit X11, you are returned to the command-line shell prompt.

X11 itself is a very rudimentary structure. All X11 does is put the computer's interface in "graphics mode" (rather than the textual interface of the usual console screen), running programs in separate windows that can be painted at different positions on the screen. However, X11 running without a window manager shows only bare, unadorned, unlabeled, immovable, non-resizable program windows. X11 itself provides no menus, no utilities, and not even a mechanism for moving windows around. For that, you need a *window manager* and other extra tools, all of which run within X11 and handle the tasks you normally think of as being intrinsic to a windowing desktop environment.

Some popular window managers include FVWM, Window Maker, AfterStep, and XFce; these window managers each have their own look and feel, and some are very carefully designed to mimic the appearance and behavior of Microsoft Windows, Sun's CDE, NeXTSTEP, or other popular user environments that have driven various operating systems over the years. More complex and polished user environments, better suited to heavy desktop use than plain window managers, include KDE and GNOME. You can install different window managers from the packages or ports, in `/usr/ports/x11-wm` (see Chapter 16, "Installing Additional Software," for more information on using the ports).

Assuming that you configured X11 during the installation (which was covered in the "Setting Up the X Window System (X11)" section of Chapter 2) or afterward, you should now be able to type **`startx`** at the command line to launch the X11 system.

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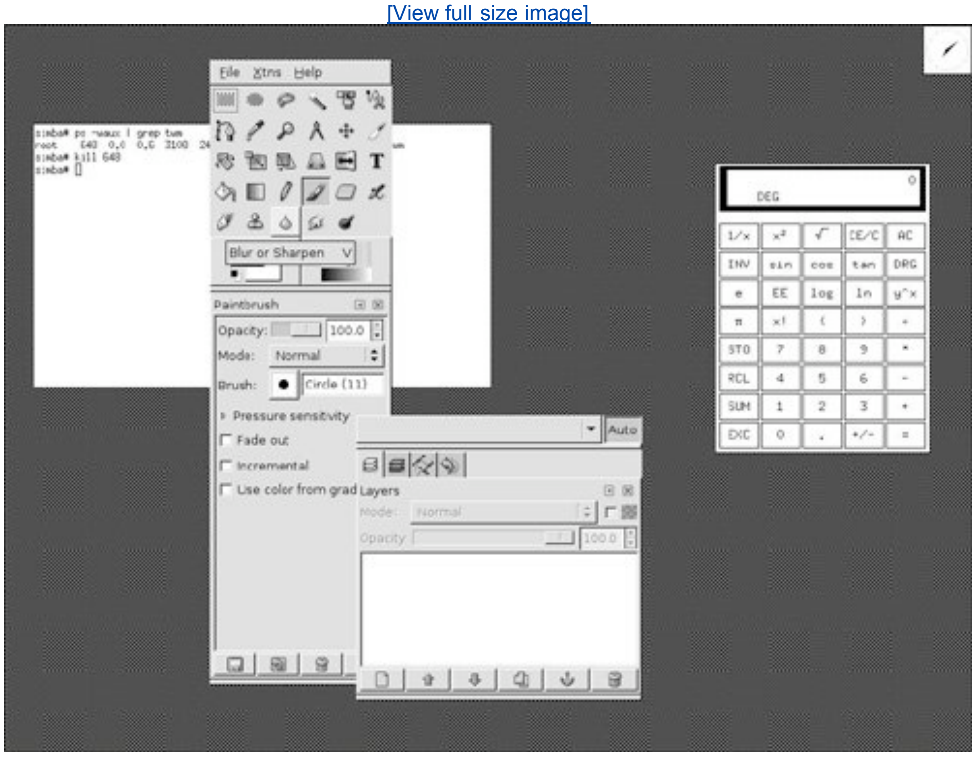
The X Server

The X Server is the underlying framework that allows graphical applications to run. By itself, the X Server is not very usefulit's just a mechanism for controlling basic window placement and application window painting, and it contains no window-management functions such as the ability to move a window by dragging it with a mouse. Figure 5.1 shows an X Server running with no window manager.

Figure 5.1. Here you see a very bland and rather useless X session, running without a window manager.

[View full size image]



```
simba# ps -waux | grep twm
root     640  0.0  0.0  3100  24
simba# kill 640
simba# []
```

Several applications are running in the X11 session shown in Figure 5.1: an `xterm` (a command shell terminal window), a clock, a calculator, and the GIMP image-processing program used to take this screenshot. Notice that the windows have no title bars or borders. They are not resizable or movable, and they cannot be minimized or maximized. Obviously, this lack of flexibility makes for a pretty useless graphical user interface. This is where the window manager comes in.

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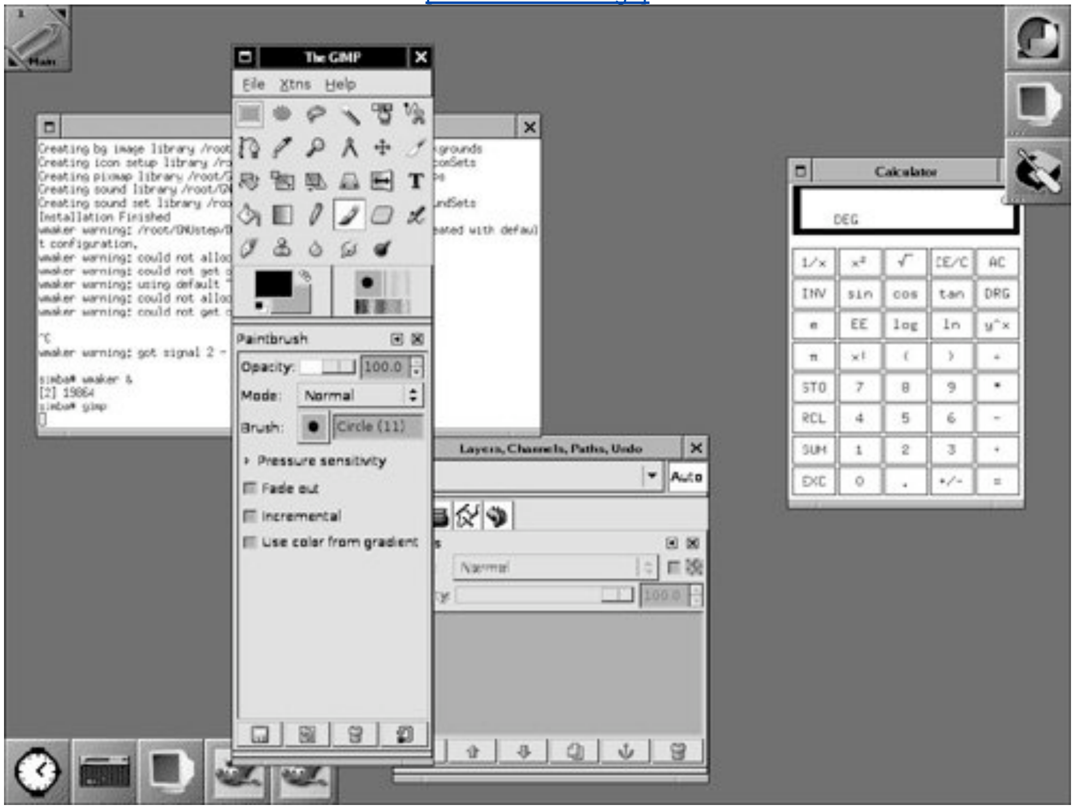
Window Managers

The window manager controls how the graphical environment looks and works. In what is perhaps the most easily visible demonstration of the dynamics of the open-source software development community, rather than a single window management system being "blessed" for FreeBSD as would occur in a commercial operating system, dozens of different window managers are available for X11, as diverse in individual behaviors as the tastes of the people using them. Most window managers support "themes" as a central feature, allowing the user to swap out interface elements for new ones, so your user experience is almost infinitely customizable even within a single window manager. If you don't like the way X11 looks or feels, you can either customize your existing window manager or switch to a completely different one.

Figure 5.2 shows the same session as Figure 5.1, but this time it is running under the Window Maker window manager.

Figure 5.2. A window manager such as Window Maker completes the user environment equation by giving you window controls and interface utilities.

[View full size image]



```
Creating bg image library /root          grounds
Creating icon setup library /r           conSets
Creating pixmap library /root/           e
Creating sound library /root/G
Creating sound set library /roo          ndSets
Installation Finished
wmaker warning: /root/GNUstep/D          eated with defaul
t configuration,
wmaker warning: could not allo
wmaker warning: could not get c
wmaker warning: using default "
wmaker warning: could not allo
wmaker warning: could not get c

^C
wmaker warning: got signal 2 -

simba# wmaker &
[2] 19864
simba# gimp
```

Paintbrush
Opacity: 100.0
Mode: Normal
Brush: Circle (11)

In Figure 5.2 you see that each of the application windows now has a title bar with controls to maximize and close it. You can resize or move a window in any window manager interface. On the right side of the desktop is a menu from which you can launch applications by clicking an icon. Right-clicking the mouse on the desktop opens another menu from which you can select various options or launch applications.

When you first configured X11 and launched your first graphical session in Chapter 2, the window manager FreeBSD chose by default was TWM, a minimalist user environment with only the most rudimentary window decorations and control options. There's not much you can do in TWMyou can launch windowed programs by typing their names at the command line in an `xterm`, you can move and resize windows, you can kill processes by clicking on them in the right way, and that's really about it. There are no icons and there's no file manager. There is no preference-setting utility. You can't even specify a background "wallpaper" image without the help of extra programs. For seasoned UNIX veterans who shun modern convenience, TWM is perfectly adequate, but if you plan on spending any significant amount of time using the X11 environment for desktop computing, you're going to find yourself wishing for the integrated features to which we've all become accustomed in modern desktop operating systems. Fortunately, to satisfy this need, FreeBSD makes available not one but *two* full-fledged user environment suites designed for this very purpose: KDE and GNOME.

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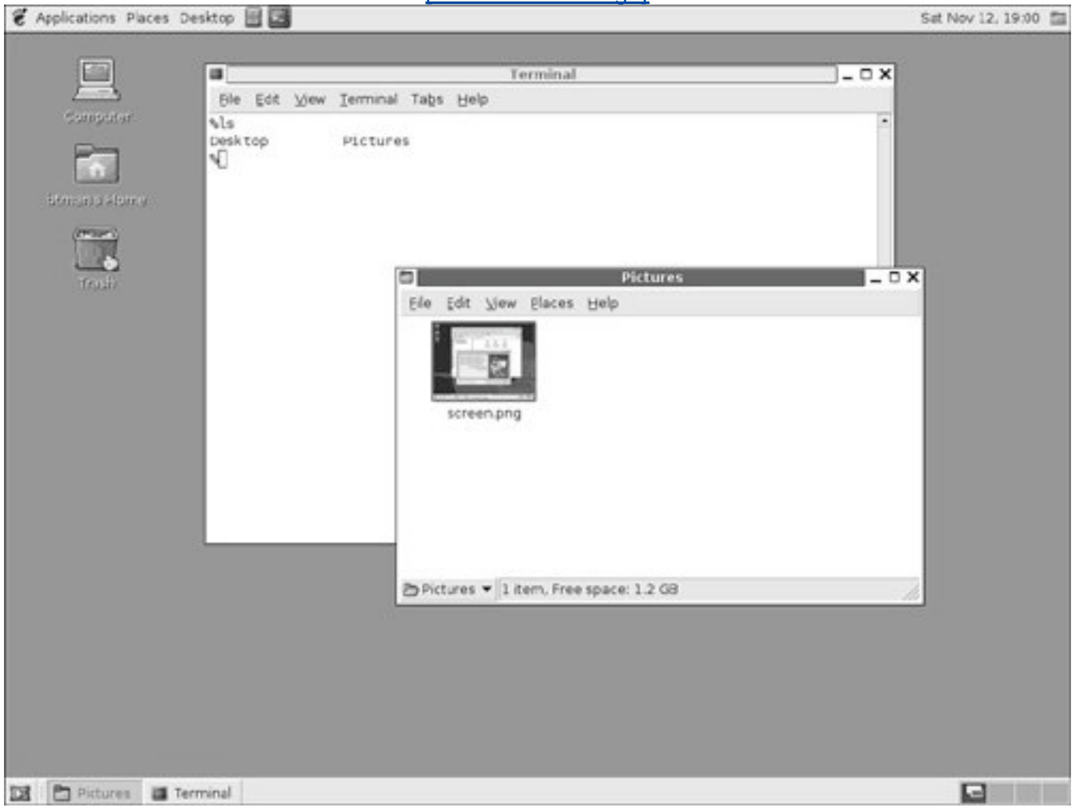
KDE and GNOME

Later in this chapter, we will discuss using window managers such as Window Maker and FVWM. However, for now, let us turn our attention to the two available user environments that best approximate the experience you'd have in Windows or Mac OS X.

As is so often the case in the open-source world, KDE and GNOME, the two most widely used and enthusiastically developed user environments for UNIX, each have their impressive advantages and their inevitable weaknesses. Both also have sets of fierce advocates within the open-source UNIX community. This book, in presenting the techniques necessary for setting up a fully immersive graphical user environment for FreeBSD, must choose one package or the other for its demonstrations; an in-depth tour of both KDE and GNOME would be largely redundant, as both provide much the same benefits to the user, with features that are analogous if not identical (both KDE and GNOME have native web browsers and office suites, for example). KDE in execution tends to provide a user experience more akin to what you might be used to in Windows, with familiar metaphors and layout (such as a Start menu and Windows-like control buttons), and at the time of this writing it has a more ambitious claim on the desktop computing world with advanced features such as text-to-speech synthesis and a password management utility. This makes KDE perhaps a more likely choice for a casual or first-time user of FreeBSD than GNOME (shown in Figure 5.3), which offers a more unique style and set of metaphors, and is also considerably more lightweight than KDE, making it more appropriate for somewhat more seasoned UNIX veterans.

Figure 5.3. GNOME, a highly customizable, complete user environment that's less Windows-like in its behaviors than KDE.

[View full size image]



Applications Places Desktop
Sat Nov 12, 19:00
Computer
btman's Home
Trash
Terminal
File Edit View Terminal Tabs Help
Pictures
File Edit View Places Help
screen.png
Pictures
1 item, Free space: 1.2 GB
Pictures
Terminal

```
%ls
Desktop        Pictures
%
```

For these reasons, and because the FreeBSD variant PC-BSD (which you might want to examine if you're interested in desktop computing rather than server applications) is built around it, this chapter will concentrate on KDE rather than GNOME. Fortunately, the setup process for KDE is similar to that of GNOME, and if you've set up one you should have little trouble setting up the other. Feel free to try both and decide for yourself which you prefer.

Both KDE and GNOME are ambitious efforts to bring nothing less than a completely realized windowing environment to UNIX and Linux, with full sets of widgets and control elements, published Human Interface Guidelines, supporting applets, and even their own native applications. Most X11 applications operate independently of the window manager you're using, and so a program such as the `xv` image viewer will work the same under FVWM as it does under Window Maker or TWM, with the exception of a different window border style. However, programs written for GNOME and KDEsuch as the Konqueror web browser or the Evolution email clientare specifically designed to run only under their respective native windowing environments.

Some of these specialized applications won't run properly or at all if you're not running the right windowing environmentfor example, text in a GNOME application might not show up because the expected font architecture isn't present if you run it under KDE. This downside, to purists, represents a lamentable departure from the traditional UNIX window-manager agnosticism that meant you could run any application under any desktop setup. However, the advanced technological underpinnings of KDE and GNOME apps mean that the freely available UNIX desktop environments are finally starting to reach the level of disciplined usability popularized by the Windows and Mac OS systems on every desktop.

Installing KDE

As extensive a program suite as KDE is, installing it is a relative breeze. The simplest method is to log in as root (or use `su` to assume root privileges), make sure you are connected to the Internet, and then type the following command:

```
# pkg_add -r kde3
```

This command connects to the FreeBSD FTP server and attempts to fetch all the required programs that make up the KDE 3.x package. This process might take an hour or more, so be patient; there are dozens of dependency packages that must be installed before KDE is complete.

Tip

You can also install packages from within the Sysinstall program, as discussed during the installation procedure in Chapter 2. Type **`sysinstall`**, and then navigate to Configure, Packages, to browse the available packages visually. The `kde3` package is in the `x11` category.

If the `pkg_add` command failsfor example, if it's unable to find the required packages on the server, or if you get an error during installation such as "Broken pipe"an alternative way to install KDE is to compile it yourself from the publicly available source code, using the ports tree (assuming you installed it during the procedure in Chapter 2). The package system and ports tree are fully discussed in Chapter 16. For now, though, all you need to do is type the following series of commands:

```
# cd /usr/ports/x11/kde3
# make
# make install
# make clean
```

After each of the `make` commands, FreeBSD fetches the latest source code for each component of KDE and begins compiling it into binary code. This process can take hours or even days, depending on the speed of your network connection and your computer hardware. Be patient and wait for each step to complete.

Note

KDE and many of its dependency packages are "interactive" ports, meaning that at some point during the configuration of each one, you'll be presented with a text menu allowing you to select and deselect certain components that you may or may not need. Don't just start the compilation process and walk awayFreeBSD might reach an interactive menu step and wait hours for you to come back to it!

Caution

A complete installation of KDE and all the components selected by default consumes over a gigabyte of disk space, and compiling all the components from source consumes at least another gigabyte. Make sure you have at least several gigabytes of free space on your `/usr` partition before attempting to compile KDE from scratch. Also, don't forget to type **`make clean`** at the end; this deletes all the source code and compiled objects that you don't need after KDE is installed.

You might choose to install the `kde-lite` package rather than the complete `kde3` suite if you want the KDE environment but not all the space-consuming component applications.

Finally, when all these steps are done, KDE is installed on your computer; all that remains is for you to configure X11 to use the KDE environment instead of the default TWM. This can be accomplished most easily by setting up FreeBSD to use the KDM login manager instead of presenting the usual textual login prompt.

Enabling the KDM Login Manager

Open up the terminal configuration file, `/etc/ttys`, in a text editor such as `ee`:

```
# ee /etc/ttys
```

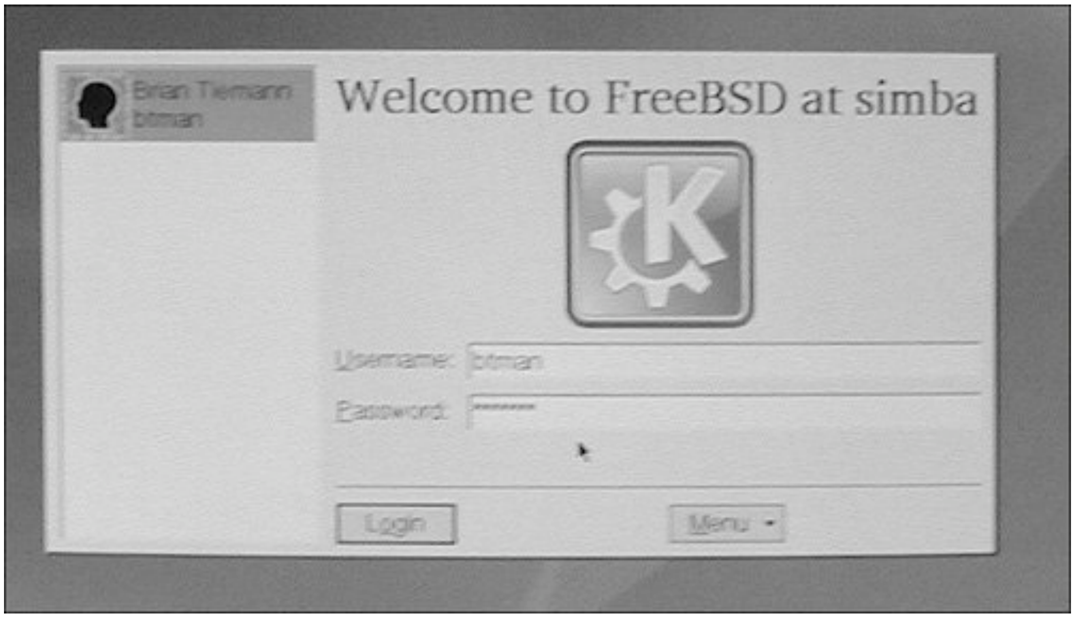
Use the arrow keys to move down to the line beginning with `ttyv8`; press Enter to create a blank line below it, and add a new line enabling KDM, the KDE Display Manager:

```
ttyv6   "/usr/libexec/getty Pc"         cons25 on secure
ttyv7   "/usr/libexec/getty Pc"         cons25 on secure
ttyv8   "/usr/X11R6/bin/xdm -nodaemon"  xterm off secure
ttyv9   "/usr/local/bin/kdm -nodaemon"  xterm on secure
# Serial terminals
```

Then press Escape and press Enter, and then press Enter again to save your changes and exit. Finally, reboot your computer by typing **`shutdown -r now`**. When your computer reboots, instead of the text login prompt, you should see a graphical login screen like Figure 5.4.

Figure 5.4. KDE's KDM login screen, providing a graphical user experience

from boot to shutdown.



Type your username in the Username box (or select your name from the user list at the left) and your password in the Password box, and then click OK or press Enter to log in to your first session with KDE.

Note

KDM doesn't allow you to log in as the root user; you have to use your own regular user account. This is a security precaution, as is the fact that you cannot set up FreeBSD to boot automatically into a user accountyou have to log in by supplying a username and password.

Note

Installing GNOME is very similar to installing KDE, with a couple of small exceptions. You can install GNOME from the packages (`gnome2` in the `x11` section) or the ports (`/usr/ports/x11/gnome2`); GNOME isn't an interactive port, and it has far fewer components than KDE, so it takes far less time to compile and install, and requires much less disk space.

To enable GDM (the login manager analogous to KDM), don't edit `/etc/ttys`; instead, edit `/etc/rc.conf`, the main system configuration file described in detail in Chapter 14, "System Configuration and Startup Scripts." Scroll to the bottom of the file and add the following line:

```
gdm_enable="YES"
```

Save the file. If you had earlier enabled KDM, edit `/etc/ttys` again to disable it by commenting out the `ttyv9` line you added (place a hash mark, `#`, at the beginning of the line). Then reboot. The system will present you with the GDM login window when it comes back up.

KDE, The K Desktop Environment

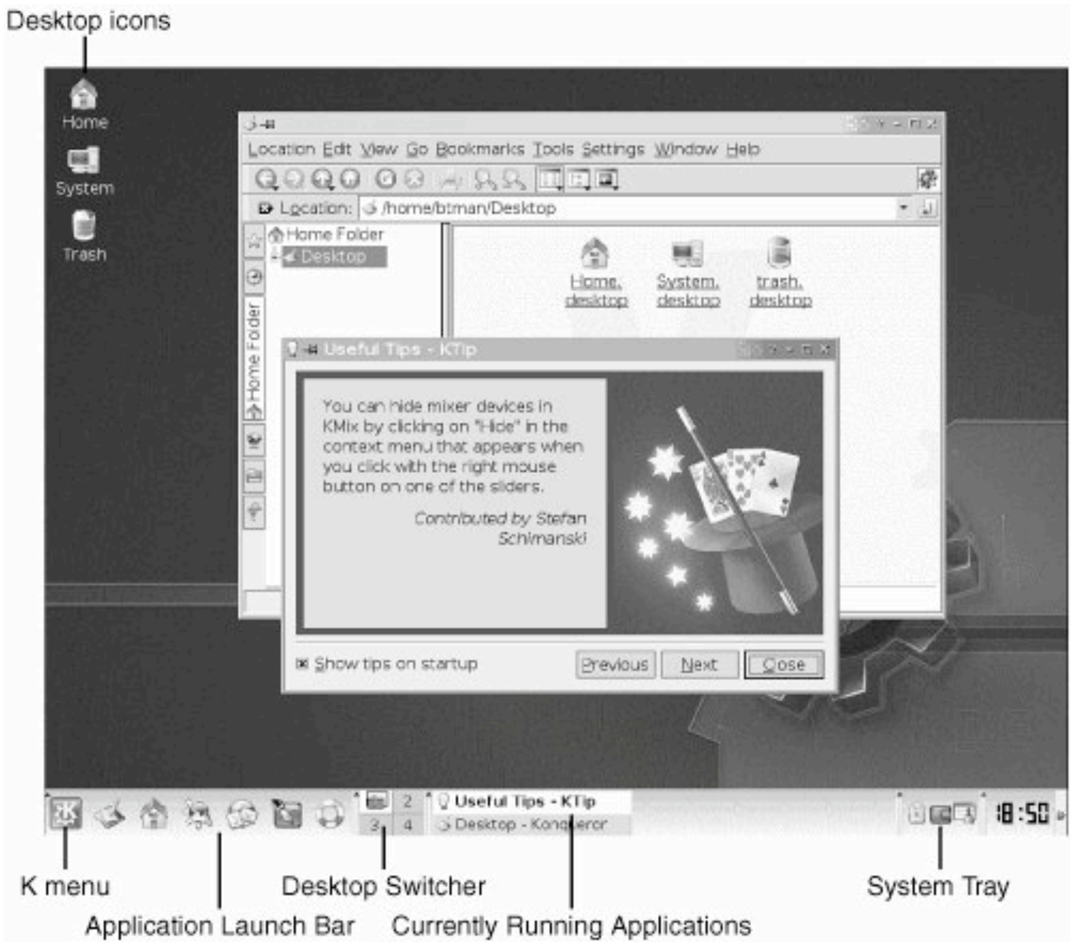
When you successfully log in to KDE for the first time, you're greeted with a five-stage "wizard" that sets up KDE according to your preferences as a user. In these screens you specify your country and language; then you choose the system behavior you want (whether KDE's windows should behave like they do in Windows, in Mac OS X, in classic UNIX, or in KDE's own style), as well as the "theme" or visual look of the various controls used in the windowing system. KDE provides you with previews and descriptions of each of these behaviors and styles, so you can get a good idea of what you want before you choose it; don't worryyou can always revisit these choices later using the KDE Control Center, available from the K menu.

After you're done with the setup process, you'll see a splash screen and progress bar that indicate the stages of startup; this usually takes longer the first time you launch KDE than in subsequent sessions. Keep an eye out for error messages that might pop up in dialog boxes; they usually indicate problems with hardware, such as an inability to open the sound system, and most often they can be safely dismissed.

After a few moments you'll find yourself at the KDE desktop, shown in Figure 5.5.

Figure 5.5. The KDE Desktop in its default configuration, with a Konqueror browser window showing local files and a tip window.

[View full size image]



You can hide mixer devices in KMix by clicking on "Hide" in the context menu that appears when you click with the right mouse button on one of the sliders.

Contributed by Stefan Schimanski

Anyone familiar at all with Windows should immediately feel more at home in KDE than in just about any other desktop environment available for UNIX. KDE is laid out to recall the Windows desktop, with a Start menu equivalent in the lower-left corner, a taskbar along the bottom, a configurable launch bar for commonly used applications, Windows-like window controls, and a combined web browser/file manager called Konqueror. (Indeed, as you'll quickly discover, almost every component of KDE has a name beginning with K. Apparently, all the K indicates is the letter preceding the L of Linux.) The icons on the desktop are laid out just like the ones in Windows XP, and even have rather the same design.

In fact, KDE even has a number of flashy features that Windows doesn't have. For example, mousing over icons in the launch bar shows you an animated pop-up window that describes the icon and what it does; mousing over an icon on the desktop or in a file browser window shows you a great deal of information about that file, including its last-modified date, ownership, permissions string, type-specific metadata, and even a preview for most file types. Launching an application puts a tiny bouncing version of the application's icon next to your mouse cursor, in what seems an homage both to the animated cursors of Windows and Mac OS X's bouncing Dock icons. Any of these features, by the way, can be turned off if they annoy you.

Note

One benefit that KDE and GNOME both provide, and which is notably absent from both Windows and Mac OS X, is that upon login it will attempt to restore your sessionthe windows that were open, the applications you were running, and the files that you'd had openin the state it was in when you last logged out.

It would be a mistake to say that KDE is self-explanatory if you've used Windows; inevitably, there are a number of potentially confusing differences between KDE and Windows, and although simply exploring the menus will teach you a great deal, the basics are important to understand.

Manipulating Files and Folders

KDE's equivalent of the Windows Explorer is a browser called Konqueror; like Microsoft Internet Explorer, it's both a web browser and a filesystem navigation system. If you single-click either the Home or System icons on your desktop, a Konqueror window opens to show you the contents of the item you selectedHome leads to your home folder (`/home/btman` in my case), and System leads to the root of the filesystem (`/`). In the KDE paradigm, you can think of directories in the filesystem as "folders," as they're called in other desktop operating systems; each one has an appropriate folder icon that you can double-click to navigate deeper into the filesystem. Some folders have special icons, such as your Home folder (a house) and Desktop, which contains all the items that appear on your desktop. In this respect, KDE behaves very much like Mac OS X.

Konqueror gives you three navigation modes, accessible using icons in the toolbar of the navigation window:

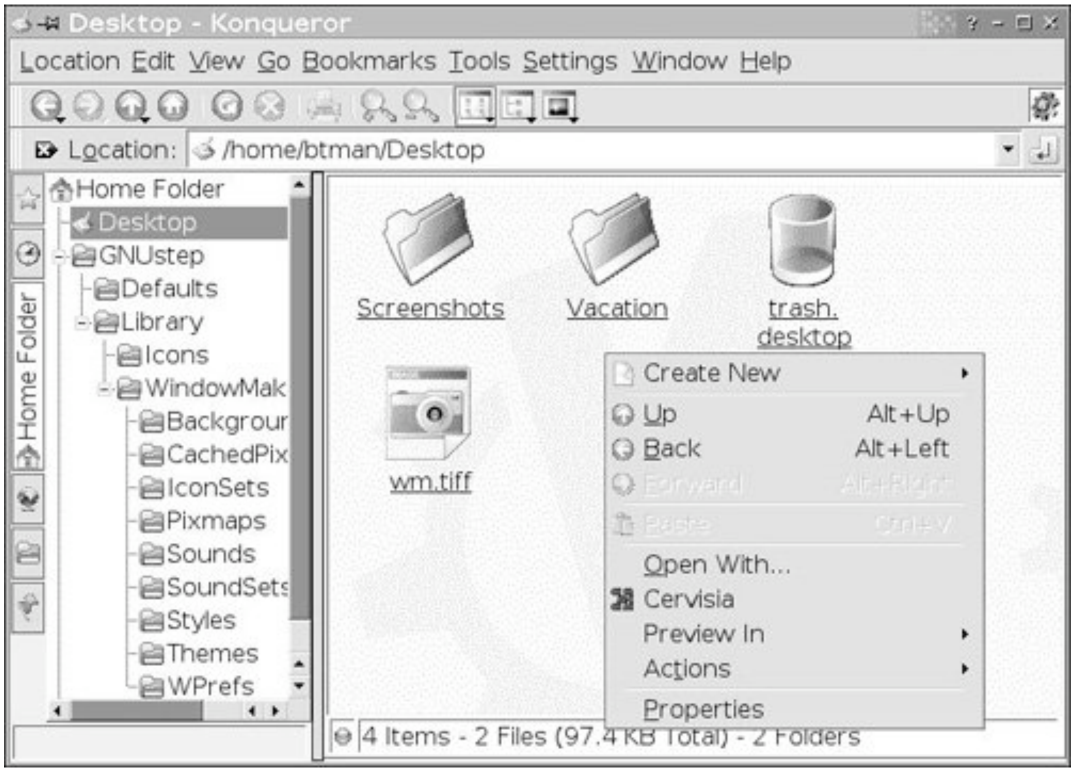
- *Icon view* Files and folders are represented as icons, and can be arbitrarily placed in a window or sorted according to name, date, and other criteria.
- *Tree view* Using an expandable "tree" hierarchy similar to the one in Windows, you can expand folders in-place to view their contents.
- *Photobook view* Previewable files are shown in a vertical column at the right; clicking on one shows a preview of its contents in the middle of the window, which you can zoom to any magnification level and scroll back and forth using custom icons that appear in the toolbar when you're in this mode.

Tip

Several other useful view modes are available in the View, View Mode menu, including MultiColumn view (similar to Mac OS X's Column view) and Info List View (which shows useful details such as the number of lines and characters in text files). Experiment with these view modes to determine what works best for you, and in what areas of the system.

Right-click on the desktop or the background of a folder window. A contextual menu, much like the one in Windows (see Figure 5.6), gives you the capability to create new folders, text files, HTML documents, or documents associated with any of the KDE applications, links, or other items.

Figure 5.6. A Konqueror file browser window showing a folder in Icon view and the rightclick contextual menu.

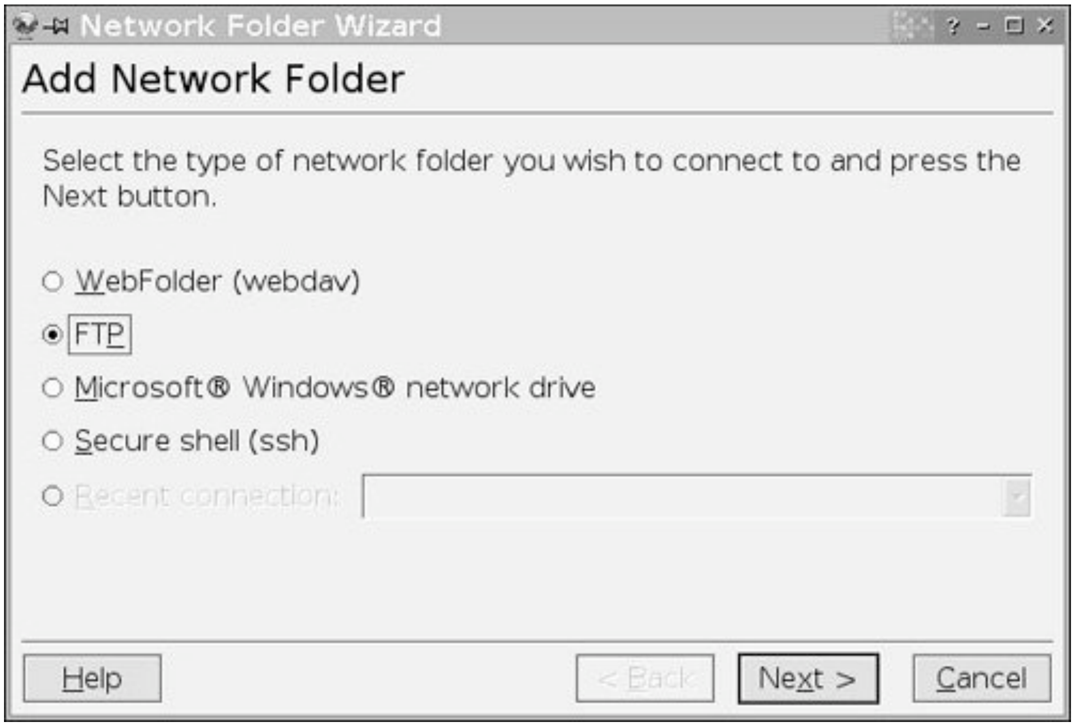


On the left of the Konqueror window is a vertical series of shortcut icons; this list of icons, called the SideBar, includes Bookmarks, History, Home Folder, Root Folder, and Services. These icons take you directly to commonly traveled locations, or give you a means to retrace your browsing steps to find out where you've been. You can add folders into this bar to extend its usefulness as with the Finder Sidebar in Mac OS X: right-click in the SideBar, and then choose to add either a Folder, a Bookmarks pane, or a Web SideBar Module (a way to load a web page into the left-hand pane of the Konqueror file browser window). After the new item is created, right-click on it to customize its name, icon, and destination URL.

Browsing Files on Remote Volumes

KDE has an integrated remote volume browser that you can use to connect to shared resources on the network, whether they're WebDAV servers, FTP servers, Windows shares, or SSH connections. Open the K menu; under Internet, select KNetAttach (Network Folder Wizard). This wizard's first screen is shown in Figure 5.7.

Figure 5.7. The Network Folder Wizard, giving you access to commonly used remote volumes.


Network Folder Wizard

Add Network Folder

Select the type of network folder you wish to connect to and press the Next button.

- ○ WebFolder (webdav)
- ● FTP
- ○ Microsoft® Windows® network drive
- ○ Secure shell (ssh)
- ○ Recent connection:

Choose the type of remote volume you want to connect to and click Next; fill out the required authentication information when prompted. When you connect, you're given the opportunity to save the connection; if you do, you can then select it from the Recent Connection menu the next time you open the wizard.

Using the Network Folder Wizard is probably the first time you'll encounter the KDE Wallet, which is a password archival system similar to the Keychain in Mac OS X. Whenever you connect to a password-protected resource (such as a remote folder or a secure website), KDE prompts you to keep the password you enter; this password gets stored in the Wallet. The first time you save a password, KDE requires you to enter a password to secure the Wallet itself. After you've done this, the Wallet is automatically opened when you log in, and it automatically supplies the passwords to the secure services that request them.

Caution

Although the Wallet is secured with your password so that nobody else can access it when it's locked, it is automatically unlocked at the time you log in to KDE; this means that if the computer is in a shared environment, someone else can sit down at your unattended login session and gain access to your unlocked Wallet passwords. If you have any concerns about the trustworthiness of anyone who might have the opportunity to use the computer without your knowing, it's better to avoid the Wallet and instead simply memorize your passwords.

Switching Desktop Workspaces

In the middle of the taskbar at the bottom of the screen is a four-pane Desktop Switcher. A common feature to nearly all X11 window managers, a desktop (or workspace) switcher lets you work within a virtual desktop that's several times bigger than your actual screen spacefour times, in KDE's case. All the windows you open automatically appear in your primary workspace, which is synonymous with your screen; but if your screen starts getting too cluttered, don't start closing windowssimply switch to another workspace. Just click on one of the other three desktop icons, and you'll switch to a new, clean desktop, free of windows. New windows you open while in a workspace other than your primary one stay in that workspace; the desktop icons show you rudimentary outlines of the windows on each one, reminding you of where your windows are even though they're off where you can't see them.

Right-click in the title bar of any window and choose To Desktop to send that window to a different workspace.

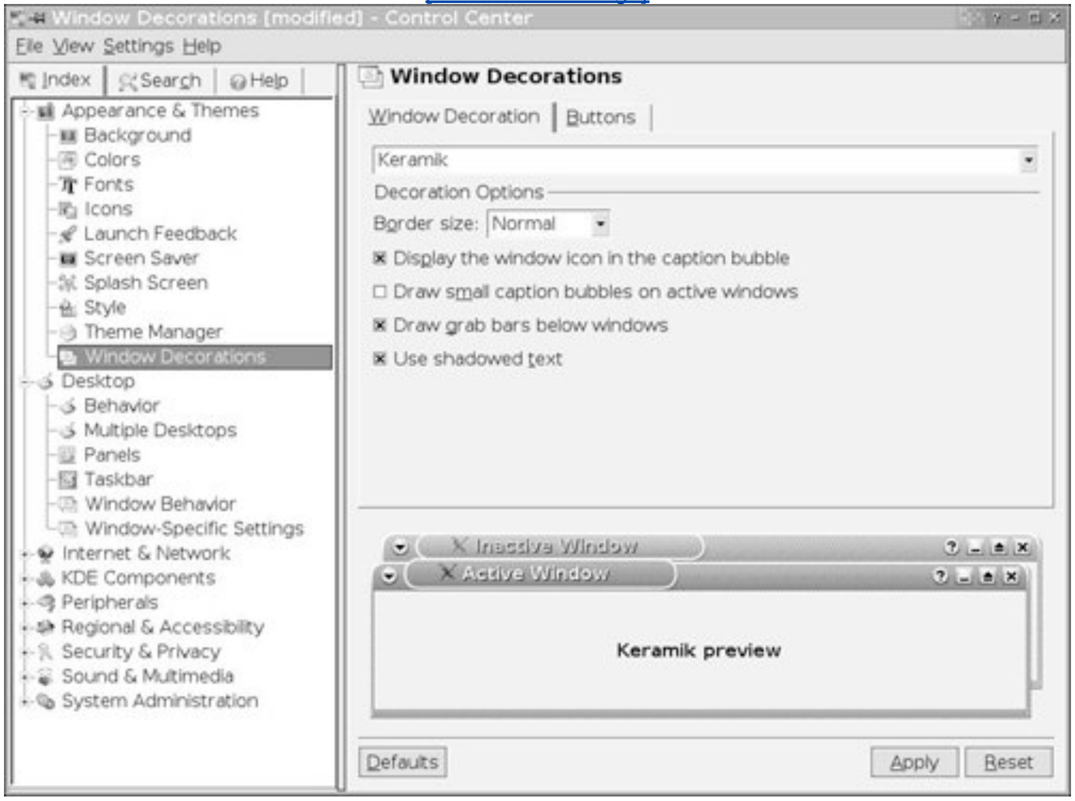
Changing KDE's Look and Feel

Like any good X11 window manager, KDE provides a near-infinite range of modifications you can make to ensure that your desktop is entirely unique. Far from being limited to the five or six themes you saw in the personalization wizard when you first launched KDE, you have access to a huge number of fully developed themes and piecemeal stylistic customizations that you can mix and match to your taste.

Open the K menu and choose Control Center. This opens the full-screen configuration browser shown in Figure 5.8.

Figure 5.8. The KDE Control Center, where all manner of configuration changes are made.

[View full size image]



Keramik

Decoration Options

Border size: Normal

☒ Display the window icon in the caption bubble

☐ Draw small caption bubbles on active windows

☒ Draw grab bars below windows

☒ Use shadowed text

Under the Appearance & Themes heading, browse all the various sections that allow you to customize how

KDE's interface elements appear: from the Background (where you can add any wallpaper image you choose) to the Theme Manager and Window Decorations sections, you'll be experimenting and tinkering for hours before you find just the look you're after.

After you're done customizing KDE's look and feel, it's worthwhile to look through some of the rest of the sections available in the Control Center. This application gives you access to all the aspects of system behavior that you'd find in the Control Panels of Windows, and even a bit more. You can configure your network settings and perform user management all from within KDE using these tools. The rest of the book, being more focused on remotely accessible system administration than the tools available in a graphical console session, will be discussing such topics from the standpoint of editing the necessary text files and running commands from the shell; but if you're more comfortable working within KDE for these tasks, you'll find that most of the common aspects of system administration are covered quite well in the KDE Control Center.

KDE Applications

KDE's major claim to fame, beyond just its familiar-feeling desktop metaphor, is the sheer number of component applications that are installed along with it. Just look through the submenus of the K menu to see how many apps are available in each of the categories: dozens, many of which are functionally equivalent to desktop applications costing hundreds of dollars in the commercial computing world, or at least aim to fulfill the same needs.

Note

It should be noted that KDE's built-in applications also usually leave a lot to be desired, in terms of their end-user quality and useful feature sets. Fortunately, the open-source community has stepped up to the challenge and provided better alternatives in almost every category. See Chapter 6, "Working with Applications," for more details on these.

Complete coverage of all the applications that make up KDE would entail a whole book unto itself. Indeed, this chapter's topic is limited to the essentials of working within the X11 system, and productivity and leisure applications are covered in Chapter 6, thus, here we will list only a few of the most important KDE apps that you'll find yourself using on a daily basis.

- *Konqueror* More than just a file browser, it's also a fully capable web browser with all the cutting-edge features today's Internet users demand. Mac OS X users will be interested to note that Konqueror is based on the same HTML rendering engineKHTMLthat Apple adopted as the back-end for its Safari browser.
- *KOffice* A feature-rich office suite comparable in capabilities to Microsoft Works (or, to a certain extent, Office). Although its documents aren't interoperable with the ones from Microsoft Word, Excel, PowerPoint, and so on, KOffice's applicationsamong which are KWord, KSpread, KPresenter, Kivio, and the Photoshop-like Kritagive users the power to produce professional documents that get the job done every bit as well as their commercial counterparts. (Demanding users will probably want a more ambitious office suite, such as OpenOffice.org, which is discussed in Chapter 6.)
- *KEdit* An excellent, feature-rich text editor. Editing your configuration files might prove to be far easier in KEdit than in command-line editors where you're limited to keyboard navigation and input.
- *KMail* A full-featured, HTML-based email application comparable to Outlook or Apple Mail, with all the modern spam-control and organizational features we expect in this modern age.
- *Quanta* A web development suite complete with imagemap editing tools and WYSIWYG layout.
- *KDevelop* A full-fledged Integrated Development Environment (IDE) for C/C++. (Look into Eclipse for

a still more highly polished IDE.)

This is only the tip of the iceberg; there's plenty more in each of KDE's application menus, including games and frivolitiescertainly the most important part of any desktop environment worth what you pay for it.

Logging Out of KDE

When you're done with your session, be sure to log outyou can configure KDE to lock your screen saver with a password, protecting your personal information, but if the computer is shared with others, you want them to be able to log in when you're not around. Select Log Out from the K menu and choose to End Current Session (returning to the KDM login window), Turn Off Computer, or Restart Computer.

PREV NEXT

PREV NEXT

Working with Window Managers

Suppose you don't want to burden your computer with the behemoth that is KDE, flashy though it might be. Suppose, instead, that you want your desktop UNIX experience under FreeBSD to be a minimalist affair, taking up as little as possible of the precious processing power your machine has, yet giving you the capability to work with modern graphical applications just as easily as you can under Windows.

Before KDE and GNOME, there were window managers. These simple programs, as lightweight as possible (so as to avoid putting undue processing load on the thin clients in computing clusters where they were run), served only the limited purpose of letting you move windows around within your X11 session. There were no menu systems associated with most window managers; there were no elaborate theme managers or screen savers, and certainly no office applications or file browsers. You couldn't view your files as icons even if you wanted toand you certainly couldn't move them around on your desktop. The desktop used to be nothing more than a space for your windows. The brief experience you've had already with TWM should give you enough of a flavor for what was, at the time that X11 was first being developed, all anyone in the desktop UNIX world wanted.

Times have changed, though. KDE and GNOME have shown that bringing a full-fledged, Windows-like user environment to UNIX is no impossible feat. Now that that has been proven, though, traditional window managers are off the hook, as it werethey no longer have to feel the pressure to provide features that we expect out of commercial desktop operating systems. That being the case, they can focus on what they do best: offering maximum configurability with a minimum of resource consumption and obtrusiveness.

As you saw in the beginning of this chapter, window managers take hold of existing windows and wrap their own window decorations and widgets around them. The windows themselves are managed by X11, the X Server; the window manager gives them the ability to move and interoperate, while X11 handles the back-end tasks of painting their contents. Because the X Server and the window manager are independent processes, you can try a window manager by simply killing the old one and starting a new oneall within the same X11 session.

Installing Window Managers

Some popular window managers, among the dozens currently in use, include the following:

- *TWM* A veteran of the old school; minimalist, quirky, and supremely lightweight. The default window manager for FreeBSD until you try some others.
- *Window Maker* A NeXTSTEP clone, offering workalikes for NeXT's innovative Dock and Preferences utility.
- *FVWM* Easy on the eyes, with support for translucency, thumbnailing, and antialiasing.
- *XFce* A clone of Sun's CDE interface, with its traditional utility bar and easy configuration utilities in modular form.
- *Blackbox* A minimalist interface that nonetheless gives users a very aesthetically pleasing look and feel and great customizability. As a bonus, it was also developed on FreeBSD.

Each of these window managers, as well as dozens more, is installable from within the `x11-wm` section of the packages, or in the ports in `/usr/ports/x11-wm`.

To get an idea of what each window manager is capable of, visit its website; each window manager has a site that's listed in the `pkg-descr` file within its port directory. Nearly every window manager's home site has a gallery of screenshots and a list of features, and describes the goal of the project, whether it's to offer the smallest memory footprint possible, or to emulate the Amiga OS, or to be the most customizable desktop environment in history. Most window managers are pretty small, though, and naturally they're all free and open-source, so it doesn't hurt to install a few so you can try them all out at one sitting.

Tip

See the "Window Managers for X" site at http://www.xwinman.org for screenshots and comparisons of all the most popular X11 window managers available today.

Choosing a Default Window Manager

When your session is managed by a minimalist window manager, you don't generally have a login manager such as KDM or GDM that launches at boot time and provides its own authentication window. Instead, each user starts up an X11 session by typing **`startx`** at the command prompt. This command reads a file called `.xinitrc` in your home folder; this file contains a command that launches the window manager of your choice. You have to supply that command, and create the file if it doesn't exist already.

After you've decided on what window manager you want to use, you can make sure it's the one you always get when you run `startx` by putting it into the `.xinitrc` file using a text editor such as `ee`. Type **`ee .xinitrc`**, and then add this line to invoke FVWM as your window manager:

```
exec fvwm
```

Save the file. From now on, when you type **`startx`**, your X11 session will start up using FWVM. Simply change this file's contents to change which window manager you want.

Note

KDE and GNOME, because of their more complex natures, have slightly nonintuitive command names you must invoke if you want to launch them from the `startx` command rather than from KDM or GDM. For KDE, use the following command in `.xinitrc`:

```
exec startkde
```

For GNOME, use the following:

```
/usr/X11R6/bin/gnome-session
```

The `.xinitrc` file is a shell script. You can take advantage of this fact to set up a whole session environment to execute every time you launch X11, as described in Chapter 7, "Advanced X11 Configuration."

PREV NEXT

PREV NEXT

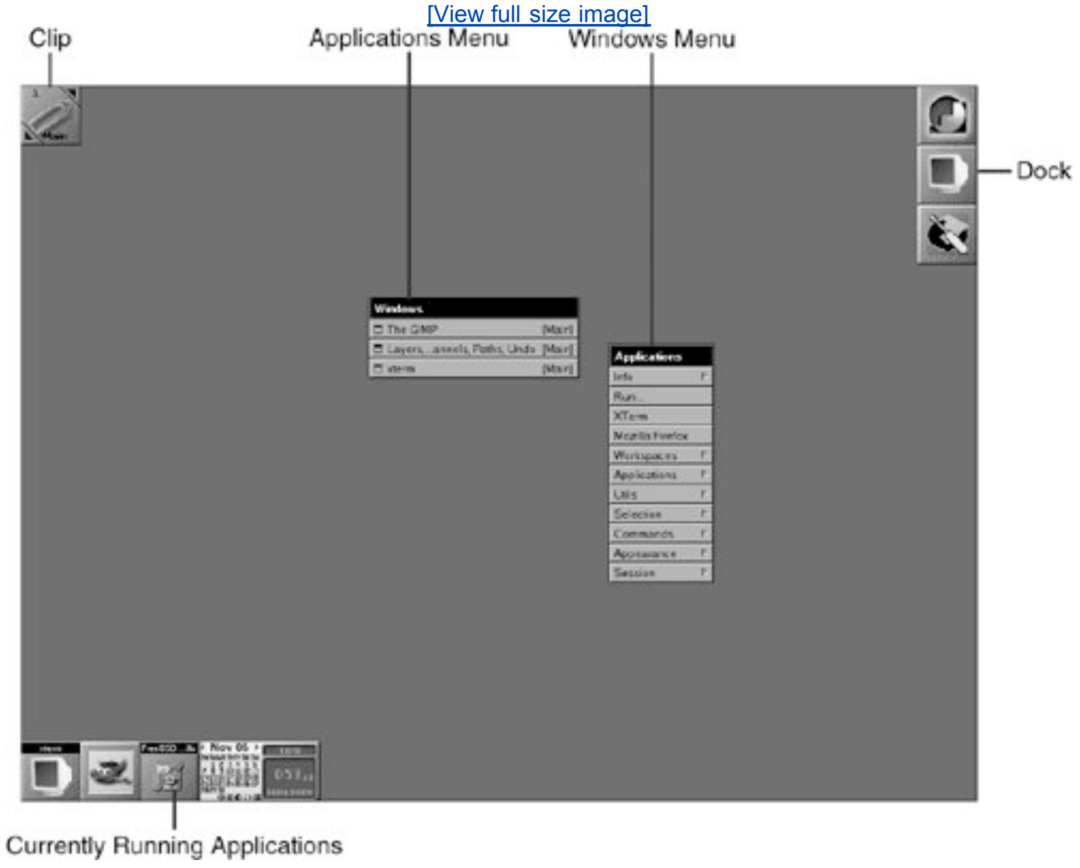
The Window Maker Window Manager

To demonstrate some of the features that are common to most lightweight window managers, we'll now look at Window Maker, one of the most popular desktops for more advanced users who prefer to avoid all the bells and whistlesand their attendant heavy processor and memory loadof environments like KDE and GNOME.

Window Maker is designed to recall the appearance and function of the now defunct desktop for the NeXTSTEP operating system, which many hail as one of the most innovative and functional desktops ever designed, and which became the basis years after its heyday for Mac OS X. Many of the features we know today as "Mac features," such as the Dock of Mac OS X, originally appeared in NeXTSTEP, and are thus replicated in Window Maker. Figure 5.9 shows a Window Maker desktop.

Figure 5.9. The Window Maker desktop isn't a full-featured user environment like KDE, but it does have many efficient features for using your X11 applications.

[View full size image]



The following list describes the main features of the Window Maker desktop:

- The column of buttons along the right side of the desktop is known as the *Dock*. If you've used Mac OS X, the Dock should be a familiar sight, though it might appear more primitive than Apple's modern iteration. Although you can't arbitrarily place icons on the Window Maker desktop like you can in Windows or KDE, you can place square tile-like buttons for launching commonly used applications onto the Dock. The main advantage the Dock offers over arbitrary icons is that it is never covered up, even when windows are maximized. Your application buttons are thus always available. In addition to application launchers, you can also place "mini-programs" on the Dock. The calendar/clock shown in the figure is an example of one of these mini-programs. You learn more about the Dock in "Working with the Dock," later in this chapter.

- You can think of the icons for currently running applications as being similar to the Windows taskbar. Double-clicking an icon, for example, will restore a window that has been minimized.

- The Applications menu is similar to the Start menu in Windows. This menu is accessed by right-clicking a blank area of the desktop.

- The Windows menu opens a list of currently running windows. Clicking an entry will bring that window to the foreground and also make it the active one. This menu is accessed by clicking the middle mouse button on a blank area of the desktop. (For those with two-button mice, the Windows menu is accessed by clicking the left and right buttons at the same time.)

- The Clip in Window Maker allows you to move between multiple virtual desktops that are active at the same time, and all these desktops can be displaying different windows and applications. Clicking the arrows on the Clip button allows you to "page" back and forth between the various desktops.

Working with Windows

Window Maker, like every window manager, provides its own paradigm for window control buttons. All the controls you expect are there; you just have to know which ones do what. Fortunately, the icons for each control are usually pretty clear in meaning, and Window Maker is no exception.

Moving and resizing windows works pretty much the way we've all become accustomed after decades of experience with Windows and Mac OS desktops: click and drag the title bar to move a window; click and drag the window's borders to resize it. Clicking the icon at the left end of the title bar will minimize the window to an icon at the bottom of the screen. (You double-click the minimized icon to restore the window.) Clicking the x icon at the right end of the title bar closes the window. Double-clicking the title bar itself will roll up the window so that only the title bar is displayed (an effect known as *WindowShade*). You can double-click the title bar again to restore the window. If you want to maximize the window or perform various other window-manipulation functions, you can right-click the title bar to open a menu of options.

Tip

Notice the Close and Kill options when you right-click the title bar. What is the difference? The Close option closes the window normally. It performs the same function as clicking the x icon at the right end of the title bar. The Kill option, however, sends a `kill` signal to the program running in the window. This can be useful for terminating a misbehaving application that is not responding to the Close command. However, Kill should only be used if Close has failed. Close terminates the application gracefully and allows it to do all of its normal tasks before closing (such as asking whether you want to save any files that have been edited). Kill simply squashes the application immediately. This can sometimes result in lost data or orphaned runtime files (which can interfere with the application if you run it again) because applications can't perform their normal shutdown tasks when terminated in this manner. That's why Kill should be used only as a last resort.

Window Maker Menus

As mentioned previously, Window Maker menus can be accessed by clicking a blank area of the desktop. Right-clicking opens the Applications menu, whereas middle-clicking (or clicking both the left and right buttons on a two-button mouse) opens the Windows menu. If you open a menu and then decide you don't want to select any of its options, you can close the menu by clicking the same mouse button somewhere on a blank spot of the desktop.

Normally, the menu will disappear after you have made a selection from it. However, if you want the menu to stay on the desktop, you can left-click its title bar. When you have done this, the x icon will appear at the right end of the title bar, which allows you to close the menu. Both main menus and submenus can be "pinned" to the desktop by leftclicking their title bars.

Working with the Dock

The Window Maker Dock is the bar of buttons along the right side of the screen. One of the functions of the Dock is for holding application launcher buttons. It's quite easy to add an application tile to the Dock. A running application will have an icon placed at the lower-left part of the screen. To add this icon to the Dock, simply hold down the left mouse button and drag the icon below the last button currently on the Dock. When you have it in the correct location, a white border will appear around the icon. Release the mouse button and a new button will be created in the Dock. Double-clicking this new button will launch the application. If you later decide you don't want the launcher anymore, simply click and hold down the left button and drag the launcher off the Dock to a blank area of the desktop. Release the mouse button, and the launcher will disappear.

You can rearrange the order of the buttons on the Dock by dragging them around. Note that you should only drag them up or down, though. Dragging a button to the left will result in that launcher being removed.

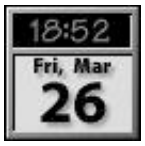
To change the properties of a launcher button on the Dock, right-click it and hold down the mouse button to open a pop-up menu. Move the mouse to the Settings menu option and then release the mouse button. This will open the Docked Application Settings dialog, which allows you to customize the launcher's look and functions, such as indicating that the associated application should be launched upon login, or whether the application button should be "locked" (prevented from being deleted by being dragged off the Dock).

If you want to move the Dock to a different location on the screen, simply click and hold down the left mouse button on the top button of the Dock and then drag. This action moves the entire Dock. You can move the Dock up and down the right side of the screen, or you can move it to the left side of the screen, if you prefer.

Installing and Using Dock Applications

A number of applications are designed specifically for running in the Window Maker Dock. These applications include a clock/calendar, network traffic monitors, system performance monitors, and a CD player. Figure 5.10 shows `wmCalClock`, an example of a Dock application.

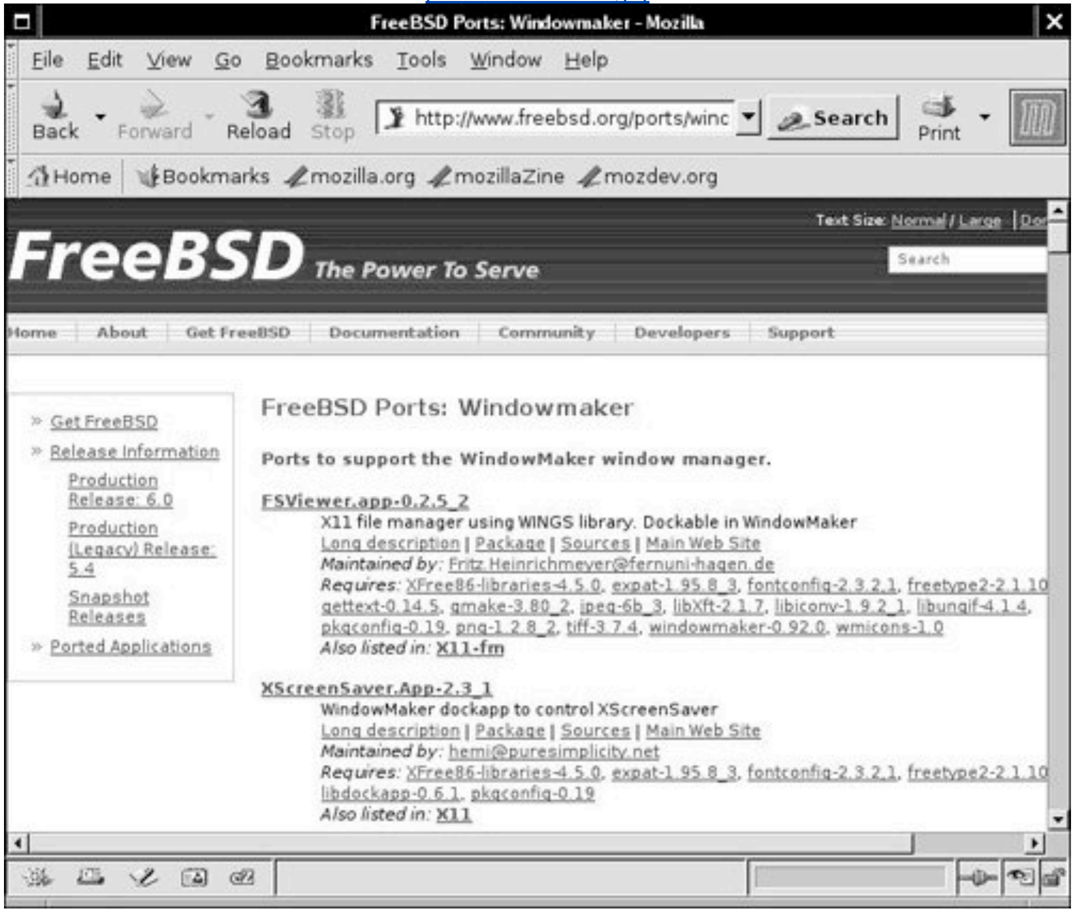
Figure 5.10. The clock/calendar `wmCalClock` is an example of an application specifically designed for running in the Dock.



A fair number of Dock applications (DockApps) are available in the FreeBSD ports collection (see Chapter 16 for information on installing software from the FreeBSD ports collection). There is no ports category for Window Maker DockApps; rather, DockApps are scattered throughout the collection depending on each one's purpose. However, you can visit the page for Window Maker's logical grouping of ports, as seen in Figure 5.11, to see all ports that have to do with Window Maker listed in one place; the direct URL for this page is http://www.freebsd.org/ports/windowmaker.html.

Figure 5.11. A section of the web page showing ported applications available for the Window Maker Dock.

[View full size image]


FreeBSD Ports: Windowmaker - Mozilla
File Edit View Go Bookmarks Tools Window Help
Back Forward Reload Stop
http://www.freebsd.org/ports/winc
Search
Print
Home Bookmarks mozilla.org mozillaZine mozdev.org
Text Size: Normal / Large
FreeBSD The Power To Serve
Search
Home About Get FreeBSD Documentation Community Developers Support
» Get FreeBSD
» Release Information
Production Release: 6.0
Production (Legacy) Release: 5.4
Snapshot Releases
» Ported Applications

FreeBSD Ports: Windowmaker

Ports to support the WindowMaker window manager.

FSViewer.app-0.2.5_2
X11 file manager using WINGS library. Dockable in WindowMaker
Long description | Package | Sources | Main Web Site
Maintained by: Fritz.Heinrichmeyer@fernuni-hagen.de
Requires: XFree86-libraries-4.5.0, expat-1.95.8_3, fontconfig-2.3.2,1, freetype2-2.1.10 gettext-0.14.5, gmake-3.80_2, jpeg-6b_3, libXft-2.1.7, libiconv-1.9.2_1, libungif-4.1.4, pkgconfig-0.19, png-1.2.8_2, tiff-3.7.4, windowmaker-0.92.0, wmicons-1.0
Also listed in: X11-fm

XScreenSaver.App-2.3_1
WindowMaker dockapp to control XScreenSaver
Long description | Package | Sources | Main Web Site
Maintained by: hemi@puresimplicity.net
Requires: XFree86-libraries-4.5.0, expat-1.95.8_3, fontconfig-2.3.2,1, freetype2-2.1.10 libdockapp-0.6.1, pkgconfig-0.19
Also listed in: X11

Tip

Dockapps.org (http://www.dockapps.org) is an independent site that keeps track of DockApps for Window Maker. If you find a DockApp here that you want to install, look for it in your system's ports collection using `locate`. For example, to find wmCalClock, try the following commands:

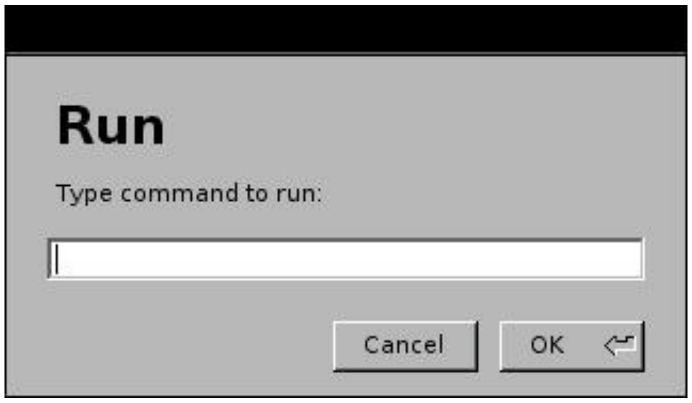
```
# locate wmCalClock

# locate -i wmcalclock
/usr/ports/x11-clocks/wmcalclock
```

Ahait's in the x11-clocks section.

If you find one that interests you, note the line that reads `Also listed in`. For example, in Figure 5.11, `FSViewer.app-0.2.5_2` is shown at the top of the page. The description of this application tells you that `FSViewer.app` is also listed in X11-fm. It turns out that the category `misc` is in the FreeBSD ports collection, and this is where you can find the `FSViewer.app` application.

Window Maker DockApps can be installed like any other application (see Chapter 16 for information on how to do this). After a DockApp has been installed, you can start it by right-clicking the desktop to open the Applications menu and then selecting the Run option. This opens the Run dialog shown in Figure 5.12.

Figure 5.12. The Run dialog allows you to start an application by entering its name.



In the Run dialog, type the name of the application you want to start and click OK. The DockApp will start as a minimized icon that appears at the bottom of the desktop, and which you can move to the Dock if you intend to reuse it.

After you have the application installed in the Dock, you can configure it so that it starts automatically each time you start Window Maker. To do this, first produce the Docked Application Settings dialog (right-click the application's icon and choose Settings). Select the Start When Window Maker Is Started option and then choose OK to close the dialog. From now on, the DockApp will start automatically each time you start Window Maker.

Tip

Many DockApps have customizations available that are dependent on the individual applications. Often these are in the form of options supplied to a program when it is started. Many DockApps will install manual pages. To access them, type **`man`** at the console command prompt, followed by the name of the command (for example, **`man wmCalClock`**).

Customizing Window Maker

You can customize various aspects of Window Maker to your liking. For example, you can change the desktop background, the color scheme, and much more. The following sections explain how to perform these and other customizations in Window Maker.

Changing the Desktop Theme

The desktop *theme* affects the color scheme as well as the desktop background. To change the theme, right-click the desktop to open the Applications menu and then select Appearance. From the Appearance menu, choose Themes to produce a list of available installed themes. To apply a new theme, simply click it in the list.

Changing the Style

You can also change the color scheme used for window borders, title bars, and menus as well as the Dock. This is referred to as the *style*. To change the style, right-click the desktop to open the Applications menu. Then click Appearance and then Styles. Window Maker has many available styles.

Customizing the Desktop Background

You can customize the desktop background in several ways. For example, you can select one of several solid colors, a color gradient, or an image that you want to use as the desktop background. If you have a custom image that you want to use as a background, you should place it in your home directory under the following subdirectory:

```
GNUstep/Library/Window Maker/Backgrounds
```

After you have placed the image in this subdirectory, right-click the desktop to open the Applications menu. Then click Appearance and then Background to open a list of possible backgrounds. The custom image you added to the subdirectory will appear in the Backgrounds list. (See Chapter 8, "Working with the Shell," if you need help with copying or moving files.)

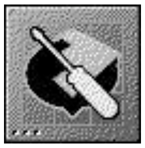
Tip

If the image you select is too small to cover your entire desktop, Window Maker will tile multiple copies of it to fill the available space. Of course, if your image is a photograph, tiling is probably not desirable. To avoid this, you should make sure the image is the same size as your desktop resolution. For example, if your desktop resolution is set to 1024x768, you should use the same size for the photograph. You can use any photo-editing program to resize the image. If you don't have a photo-editing program, a powerful oneGIMPis available for free in the `graphics` category of the ports collection.

The Preferences Utility

You can use the Preferences utility to make further configuration changes in Window Maker. To access the Preferences utility, double-click the utility's Dock button, shown in Figure 5.13.

Figure 5.13. Click the utility's launcher button to open the Window Maker Preferences utility.



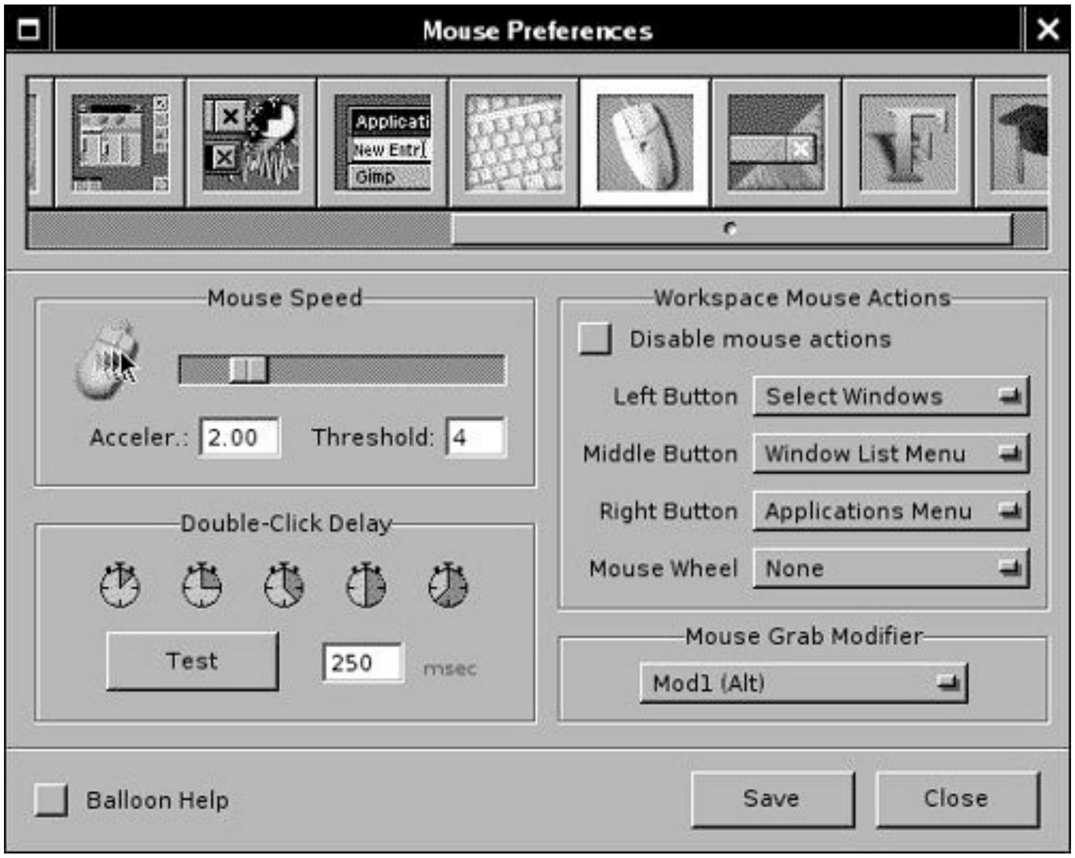
At the top of the Preferences utility window is a row of buttons you can click to access configuration preference settings. Use the scroll bar beneath this row to display the remaining buttons. In the bottom-left corner of the Window Maker Preferences utility window is a check box labeled Balloon Help. Check this box and then move your pointer over the various buttons to see pop-up descriptions of what configuration options are available for each button. In some cases, the picture on a button might not help you much if you aren't familiar with Window Maker.

Configuring Window Maker Preferences

Configuration preferences are arranged into categories, each one with its own icon in the toolbar of the Preferences utility window. Scroll left and right to reach all the possible configuration categories. For example, scroll to the right to display the button with a mouse icon on it. Click that button to open the Mouse Preferences panel, shown in Figure 5.14, which allows you to configure your mouse.

Figure 5.14. Configure the mouse in this dialog. Among other things, you can set the speed of the mouse and how much delay is allowed between double-clicks.

[View full size image]



Mouse Speed

Acceler.: 2.00 Threshold: 4

Double-Click Delay

250 msec

Workspace Mouse Actions

Disable mouse actions

Left Button: Select Windows

Middle Button: Window List Menu

Right Button: Applications Menu

Mouse Wheel: None

Mouse Grab Modifier: Mod1 (Alt)

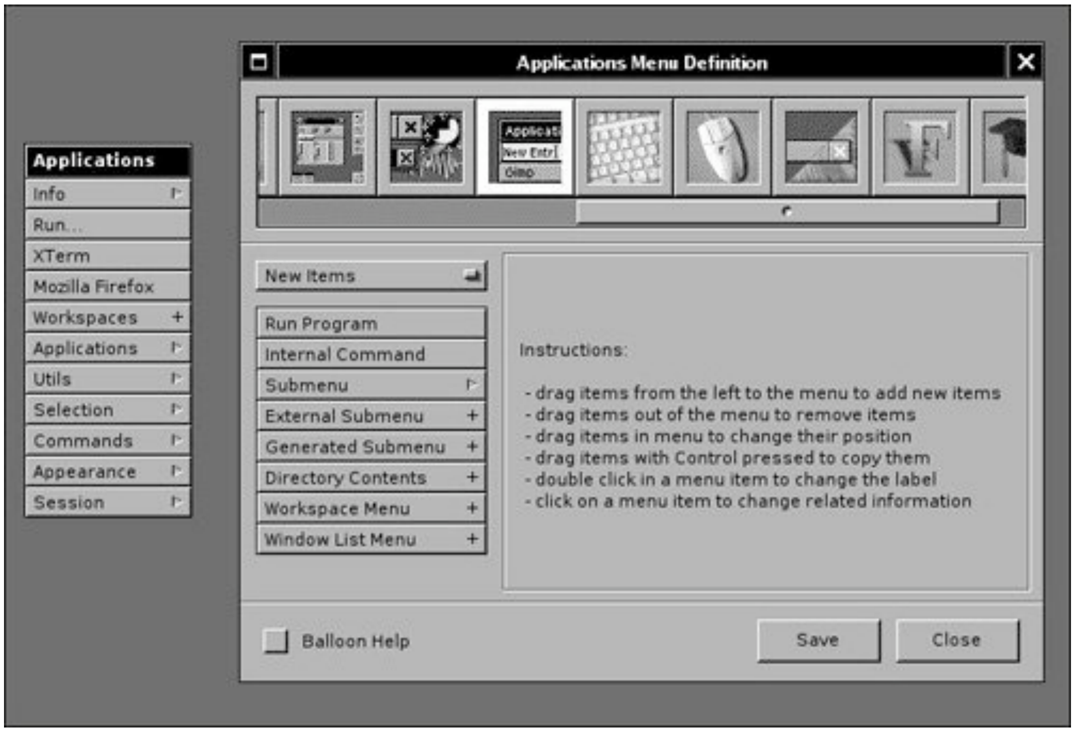
Here's another option you might be interested in: Click the button that looks like the title bar of a window (shown to the right of the Mouse Preferences button in Figure 5.14). Here, you can create a custom color scheme in case none of the default schemes suit your taste.

Customizing the Applications Menu

You can customize the Applications menu from within the Preferences utility. To do so, click the button that shows part of the Applications menu (if you have the Balloon Help box checked, the pop-up description for this button reads "Edit the menu for launching applications"). This will open the dialog shown in Figure 5.15.

Figure 5.15. Click the Applications Menu button (outlined in white when selected) to open the Applications Menu Definitions dialog. Use the options in this window to configure the Applications menu.

[View full size image]



Instructions:

- drag items from the left to the menu to add new items
- drag items out of the menu to remove items
- drag items in menu to change their position
- drag items with Control pressed to copy them
- double click in a menu item to change the label
- click on a menu item to change related information

This process is fairly straightforward and is explained in the Instructions list in the right pane of the dialog. You can drag items from the New Items list in the dialog and drop them where you want them on the Applications menu. A dialog will open asking you to specify the name of the item, the program to load, and so on. If you want to remove an item from the Applications menu, you can drag it off the menu.

Quitting Window Maker and X11

Recall that Window Maker is only an overlay on top of X11, and that X11 itself is just a graphical shell running on top of the command-line core of FreeBSD. When you log out of Window Maker, X11 quits as well, and you are returned to the command prompt.

Right-click on the desktop area to open the Applications menu and choose Exit from the bottom of the menu. Click OK to confirm that you want to exit your session. After Window Maker quits and X11 terminates, you should again see the text screen with the command prompt where you originally started X11.

If you're shutting down your computer, you can now issue a `shutdown` command as described in Chapter 4, "Booting and Shutting Down FreeBSD."

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Chapter 6. Working with Applications

IN THIS CHAPTER

No matter how robust and efficient an operating system might be, it's of little interest unless you can run useful applications on it. Fortunately, even on a free operating system like FreeBSD, you can get thousands of top-notch applications that cost you no more money than what you paid for FreeBSD itself (that is, nothing). This is the case whether you're using the computer as a desktop workstation or a rack-mounted serverthe applications available for either purpose are in many cases well-developed, full-featured equivalents of any of the best software packages you'll find in the commercial software world, and they showcase the best strengths of the open-source computing community in their robustness, security, and easy availability for no charge.

This chapter discusses how to use the applications you'll be working with most often for common desktop computing tasks such as text editing, word processing, graphics manipulation, email, and web browsing. These applications are generally not installed as part of FreeBSD itself, but most of the applications that are integrated with the KDE or GNOME desktop environments are installed along with them (see Chapter 5, "Working with the X Window System"). Where applicable, text-based equivalents of the graphical applications used under KDE or GNOME will be discussed; you'll need to know how to edit text or read email even on a system that doesn't have X11 installed.

FreeBSD provides a mature and polished mechanism for installing third-party software (for more information on installing applications, see Chapter 16, "Installing Additional Software"). Some top-end software packages, such as the OpenOffice.org suite, are every bit as polished and full-featured as their commercial counterparts, and come with their own installation procedures, help systems, and technical support avenues. Beyond that, however, you'll run into one of the downsides of open-source software: because each package is written by someone different and none of it (with some notable exceptions) comes from a software company with a vested interest in customer service, it's often lacking in accurate or useful documentation, and technical support is all but nonexistent (unless you consider asking questions on web-based user forums to be "technical support"). Running desktop applications under FreeBSD can be very rewarding and give you far more bang for your buck than an expensive suite of commercial applications, but you'll need to be prepared to put up with the inevitable shortcomings of open-source applications that are never quite "complete" the way that commercial software is.

Note

In addition to the thousands of native FreeBSD applications, FreeBSD can also run most Linux applications through its Linux compatibility module. This gives you a very wide variety of applications to choose from for virtually any purpose, including commercial software developed and released in binary form for Linux. If you find you need to run a Linux application and you didn't enable Linux compatibility during the installation of the system, simply add the following line to `/etc/rc.conf` and then reboot the system:

```
linux_enable="YES"
```

Of course, this chapter cannot even begin to cover the entire range of applications available for FreeBSD, but it does give a good sampling of some of the more popular applications within a range of categories. Feel free to explore additional software packages not discussed in this chapterlook around in the ports collection (`/usr/ports`) and refer to Chapter 16 for more information about installing anything that looks interesting. It doesn't cost anything, so you've got nothing to lose!

Note

This chapter covers applications for workstation use. It does not cover server applications such as web servers, FTP servers, and email servers. If you are looking for information on setting up services such as these, you should read the appropriate chapters in Part V of the book, "FreeBSD Networking," that cover the services you are interested in configuring.

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Running GUI and CLI Applications

There are two kinds of applications you'll be using under FreeBSD: *GUI (Graphical User Interface)* applications, which run within the context of an X11 user environment such as KDE or GNOME, and *CLI (Command Line Interface)* applications, which run in text mode and operate within a terminal window or the system console.

CLI applications are the most commonly used in the UNIX world; they include text editors such as `ee` and `vi`, email programs such as Pine, and textual web browsers such as Lynx. When you run a CLI program, you type its name at a shell prompt, and the program generally takes over the entire context of your terminal, whether it's the full screen of the system console, a terminal window invoked within your X11 session, or a Telnet or SSH session where you're accessing the FreeBSD system from a remote computer. Local or remote terminal windows in a desktop GUI (such as an SSH client on a Windows machine) can be resized to any dimensions, and a CLI program running within that window will generally resize its workspace to fit; but the default size for a terminal window, and the size of the physical console screen, is 80 columns wide by 25 lines tall. The program dominates your shell session until you quit it, at which point it returns you to the shell prompt.

Tip

If you're working at the local console, remember that you can switch from one virtual terminal to another by pressing Alt+F2, Alt+F3, and so on. This can be very useful if you need to perform command-line operations in one screen while simultaneously editing a file or reading your email in another one.

Note

Your *path* is a list of directories, specified in your shell configuration file (`.cshrc` or `.profile`), that tells the shell where it should look for programs whose name you type at the command line. Your path, by default, contains directories such as `/usr/bin`, `/usr/sbin`, and `/usr/local/bin`; because most third-party applications get installed into `/usr/local/bin`, the shell will find them there if you simply type a program's name at the prompt. However, if a program you want to run isn't found in any of the directories in your path, you need to launch it by specifying its entire path, for example:

```
# /home/frank/myapp
```

For safety reasons, your path by default does not include your home directory or the current directory (denoted with a dot or period). To execute a program located within the current directory, such as a shell program you're writing, use the `./` prefix:

```
# ./myscript.sh
```

Refer to Chapter 9, "Customizing the Shell," for more information about the shell configuration files.

A GUI application can be launched in any of several ways, depending on what kind of desktop GUI you have. The simplest way to invoke a GUI application in an X11 session is to type the program's name at a shell prompt within a terminal window (such as KTerm in KDE); when you do this, the program creates its own window within the desktop environment, along with its own menus and palette windows if necessary. The terminal window from which you launched the program, however, becomes useless until you exit the program; keyboard input is suspended and ignored, and the shell prompt doesn't reappear until you use the program's Exit function or press Ctrl+C at the command line (this key combination usually terminates any program you executed at that command line).

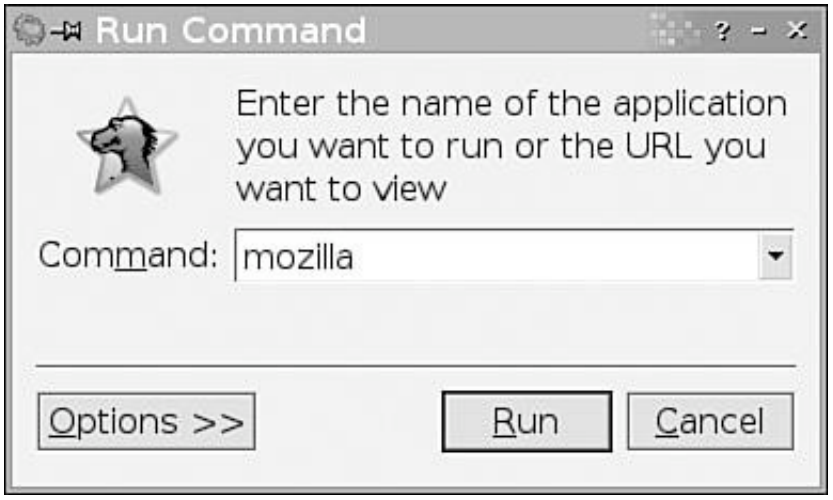
A more elegant way to launch GUI applications from a terminal window is to use the `&` character after the program's name; this tells the shell to detach from the process you're executing, place it in the background, and return to an interactive prompt:

```
# mozilla &
```

This syntax allows you to keep working within your terminal window while launching new, independent GUI applications that aren't tied to it and don't depend on the terminal window remaining open.

These techniques are useful if you're using a plain window manager such as Window Maker, as discussed in Chapter 5. If you're using KDE or GNOME, however, you have a couple of additional, even better ways to launch GUI applications. KDE and GNOME both have facilities for adding programs, along with their icons, into the K menu (in KDE) or the Applications menu (in GNOME), so that you can navigate graphically to them in their appropriate categories and launch them just as you would in Windows. If the program you want to launch isn't found in these menus, though, you can use KDE's Run Command function, found in the K menu and shown in Figure 6.1, to specify a program by name and run it independently, free of any terminal windows. GNOME's equivalent function is available in the Applications menu and called Run Application. Other window managers, such as Window Maker, have the same functionality as well, although the vocabulary varies (in Window Maker it's Run...).

Figure 6.1. The Run Command dialog box in KDE. The equivalent function in GNOME is Run Application.


Run Command

Enter the name of the application you want to run or the URL you want to view

Command: mozilla

Tip

Both GNOME and KDE include the facility to add a command launcher to the quick-access panel, which can allow you to launch your applications even more directly.

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Working with Text

Text editors are among the most commonand essentialapplications. You'll need to know how to edit text to accomplish just about any of the tasks described throughout the rest of this book, and it's a good idea to find a text editor that you like as early as possible in your FreeBSD career.

Unlike a word processor, a text editor simply works on plain-text files (which, in FreeBSD, can be denoted with any kind of filename, with any kind of extensionnot just `.txt`). It does not have the ability to store font changes, styles, margins, or any other such information in the document because plain-text files don't support such formatting information. Plain-text files make up a great deal of the FreeBSD system, from configuration files to documentation; you'll be working with them all the time. Here are some common uses for a text editor:

- *Editing system configuration files* FreeBSD, like most other versions of UNIX, relies heavily on text-based configuration files to control system behavior. To edit these files, you will need a text editor that can write a plain-text file. Word-processing applications, such as KWord or OpenOffice, are overkill for such basic functionsaside from the fact that they require a graphical desktop environment such as KDE or GNOME, they also tend to save files in formats other than plain text, which makes them unreadable to the system when it needs to launch applications or boot. (The system configuration files and how to interact with them will be covered in Chapter 14, "System Configuration and Startup Scripts.")

- *Creating or modifying programming source code* You will use a text editor to write the code that tells the computer what you want it to do. Although in many languages this code will be converted to machine language by a program called a *compiler*, your original instructions are still written in plain text. These instructions are called *source code*. Chapter 10, "Shell Programming," and Chapter 11, "Introduction to Perl Programming," introduce two popular programming languages in FreeBSD in which you would use a text editor to write the code.

- *Creating or modifying web pages* Web pages are written in HTML, which stands for *HyperText Markup Language*. Although there are many GUI-based, WYSIWYG (What You See Is What You Get) programs available for designing web pages, the end result is still a plain-text file with formatting control tags that the web browser understands. Many people still choose to write web pages by hand in a plain-text editor because it gives them total control over all the features of HTML. In addition, you would use a text editor to write PHP code, JavaScript, and other such extended features of web design that allow you to give your pages interactive content.

- *Sophisticated typesetting* Some very feature-rich typesetting languages are available for FreeBSD. Like HTML, typesetting languages generally use plain-text files with special formatting tags in them to control the layout and appearance of text. Although the word processor has largely replaced these languages (the word processor is easier to work with, and it shows you what the output will actually look like), there are still situations in which you might want or need to use a typesetting language for a particular task. TeX and its extended macro package LaTeX might interest you if you are a scientist or engineer because of their extremely sophisticated mathematical equation-formatting capabilities.

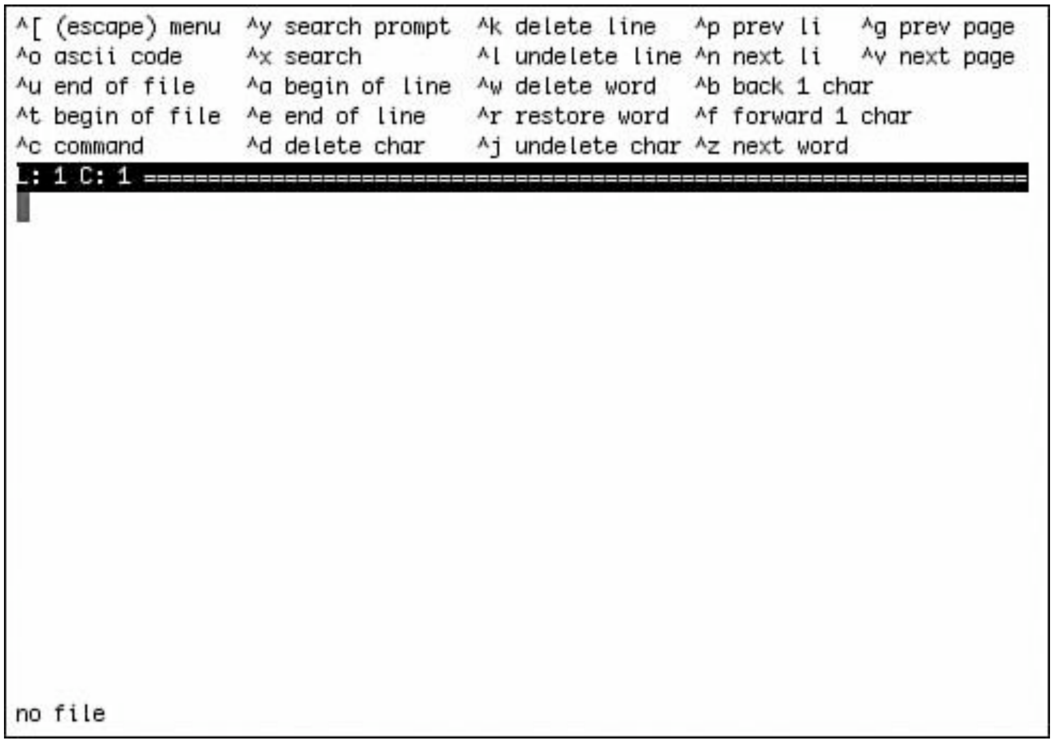
In the following sections, we'll look in detail at some of the built-in text editing solutions available in FreeBSD, namely the `ee` and `vi` editors. After that, we'll look at a couple of more modern graphical text editors that are part of the KDE or GNOME user environments.

Using `ee` (Easy Editor)

`ee` (Easy Editor) is installed by default as part of FreeBSD. As its name indicates, the Easy Editor is a basic text editor that is designed to be easier to work with than some other traditional UNIX text editors.

`ee` can be invoked either by simply typing **`ee`** at the command line or by typing **`ee`** followed by the name of a file you want to edit. Figure 6.2 shows a sample `ee` session with a blank document.

Figure 6.2. A sample `ee` session. You can use the key combinations shown at the top of the screen to access various features.



```
^[ (escape) menu  ^y search prompt  ^k delete line   ^p prev li   ^g prev page
^o ascii code     ^x search         ^l undelete line ^n next li   ^v next page
^u end of file    ^a begin of line  ^w delete word   ^b back 1 char
^t begin of file  ^e end of line    ^r restore word  ^f forward 1 char
^c command        ^d delete char    ^j undelete char ^z next word
L: 1 C: 1 ===================================================================










no file
```

Using `ee` Key Combinations

The caret (`^`) in each of the listed key commands means the Ctrl key. Most of the options in the menu are self-explanatory, but there are a few that deserve greater discussion. Table 6.1 shows these options and their meanings.

Table 6.1. Ctrl Key Options in `ee`

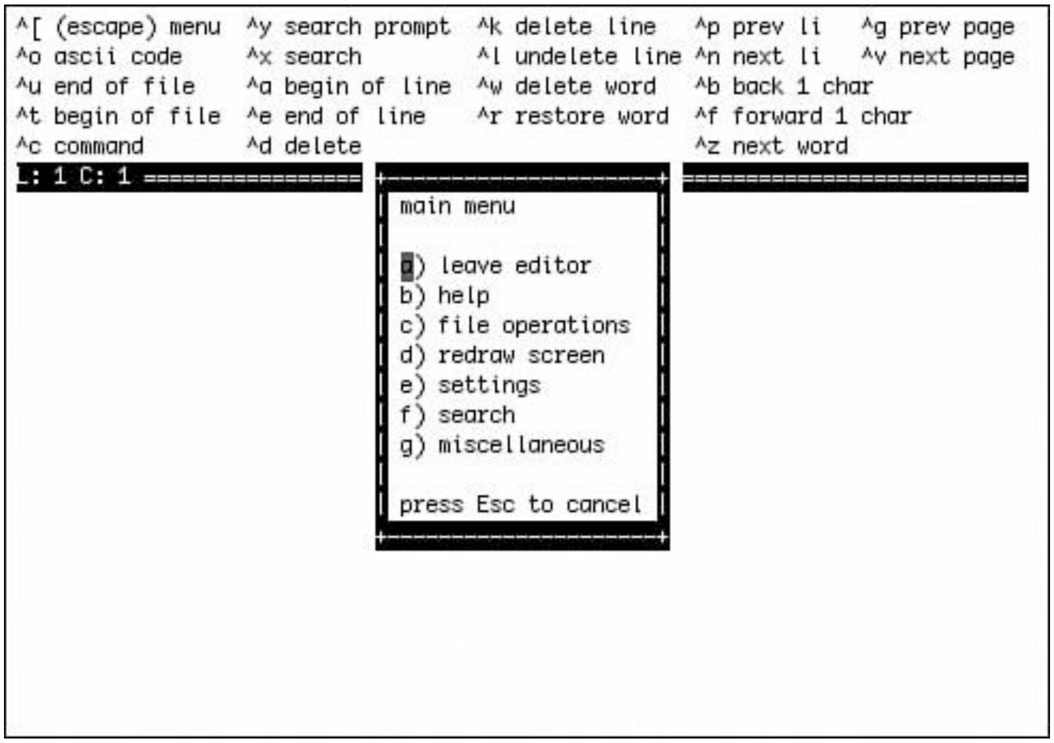
Key Combination	Action
Ctrl+O	Invokes a prompt where you can enter an ASCII value. Useful for inserting special characters that do not exist on the keyboard and require their ASCII values to be entered directly.
Ctrl+C	Changes the top menu and also invokes a prompt at the bottom of the screen where you can type one of the commands listed at the top. Simply press Enter to leave the prompt without entering a command.
Ctrl+Y	Invokes a search prompt. Here, you can type an expression to search for in the file. When you press Enter, the first occurrence

	of the expression after the current location of the cursor will be found.
Ctrl+X	Repeats the previous search done with Ctrl+Y, causing `ee` to find the next occurrence of the expression.
Ctrl+G and Ctrl+V	As the menu says, these will move forward and backward one page at a time. You can also use the Page Up and Page Down keys on your keyboard to accomplish the same thing. Ctrl+G and Ctrl+V exist in case you are on a terminal that does not have Page Up and Page Down keys.

Setup and Configuration of `ee`

If a file called `.init.ee` exists in your home directory, `ee` will read the configuration options in this file each time it starts. You can create this file by hand, or you can choose setup options from the `ee` setup options list. To access this list, press Esc within `ee` to open the main menu, shown in Figure 6.3. Press E to select the Settings menu or use the down arrow to highlight the Settings option in the menu and then press Enter to open the modes menu (see Figure 6.4).

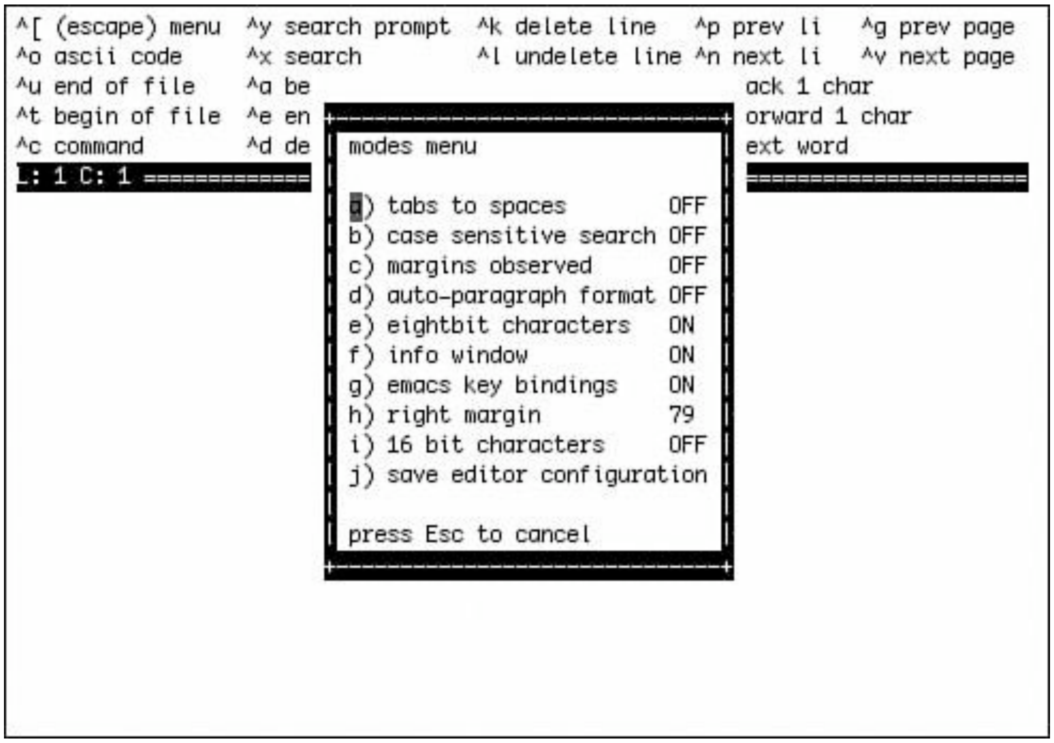
Figure 6.3. The main menu in `ee`.



```
^[ (escape) menu  ^y search prompt  ^k delete line   ^p prev li    ^g prev page
^o ascii code     ^x search         ^l undelete line ^n next li    ^v next page
^u end of file    ^a begin of line  ^w delete word   ^b back 1 char
^t begin of file  ^e end of line    ^r restore word  ^f forward 1 char
^c command        ^d delete                          ^z next word
L: 1 C: 1 =================+---------------------+==========================
                           | main menu           |
                           |                     |
                           | a) leave editor     |
                           | b) help             |
                           | c) file operations  |
                           | d) redraw screen    |
                           | e) settings         |
                           | f) search           |
                           | g) miscellaneous    |
                           |                     |
                           | press Esc to cancel |
                           +---------------------+
```

Figure 6.4. If you choose the Settings option from the `ee` main menu, you

open this list of setup options.



```
^[ (escape) menu  ^y search prompt  ^k delete line   ^p prev li    ^g prev page
^o ascii code     ^x search         ^l undelete line ^n next li    ^v next page
^u end of file    ^a be                                ack 1 char
^t begin of file  ^e en +------------------------------+ orward 1 char
^c command        ^d de | modes menu                   | ext word
L: 1 C: 1 ============= |                              | ======================
                        | a) tabs to spaces        OFF |
                        | b) case sensitive search OFF |
                        | c) margins observed      OFF |
                        | d) auto-paragraph format OFF |
                        | e) eightbit characters   ON  |
                        | f) info window           ON  |
                        | g) emacs key bindings    ON  |
                        | h) right margin          79  |
                        | i) 16 bit characters     OFF |
                        | j) save editor configuration |
                        |                              |
                        | press Esc to cancel          |
                        +------------------------------+
```

In the Modes menu, shown in Figure 6.4, you can toggle an option on or off by pressing the letter corresponding to the option, or by using the arrow keys to highlight the desired option and then pressing Enter.

Table 6.2 shows the various setup options and what they do.

Table 6.2. The `ee` Setup Options

Option	Description
Tabs to Spaces	Off by default. This converts hard tabs into the equivalent number of spaces. It is useful for some programming languages where whitespace is significant (for example, Python and FORTRAN).
Margins Observed	Off by default. When this option is on, `ee` wraps at the right margin and starts a new line automatically. When it is off, wrapping does not occur unless a new line is inserted manually.
Info Window	On by default. When this option is on, the top part of the screen shows the window with the listing of key commands. When it is off, this window is not displayed. You should probably leave this option on until you are familiar with the various key commands.
Right Margin	The column at which the right margin is set. By default, it is set for the width of a standard 80-column terminal display.
16 Bit Characters	This controls how 16-bit characters are handled (whether they are handled as two 8-bit characters or one 16-bit character). You shouldn't have to worry about this option unless you are using a

character set that uses sixteen bits per character, such as Unicode.

The final option in the menu, Save Editor Configuration, writes the configuration information to the file `.init.ee`. When you choose to save the configuration information, you will be asked whether you want to write the configuration file to the current directory or to your home directory. If you write it to your home directory, the configuration will be the default configuration for all files you create and open in `ee`. If you write it to the current directory, the settings will override the default settings from the configuration file in the home directory any time `ee` is started from the directory you're in.

The `vi` Editor

`vi` was one of the first editors developed for UNIX-like operating systems. To this day, it is still one of the most powerful editors available, and it comes standard on virtually every UNIX-like operating system. It has also been ported to several non-UNIX systems, including Microsoft Windows and OS/2. Unfortunately, `vi` also has a reputation among newbies for being notoriously arcane and difficult to learn. Unlike in editors such as `ee`, you can't just navigate with the arrow keys to a point in the file and start typingyou have to know certain kinds of editing modes and key combinations to accomplish the tasks you're used to in more modern editors.

So why learn `vi`? There are two primary reasons, really. The first is that you can be virtually guaranteed that `vi` will be available on any UNIX-like system you might ever have to work on. If you find yourself working on an unfamiliar Linux or UNIX system in the future, and you need to edit a text file, `vi` might be the only editor you will have available.

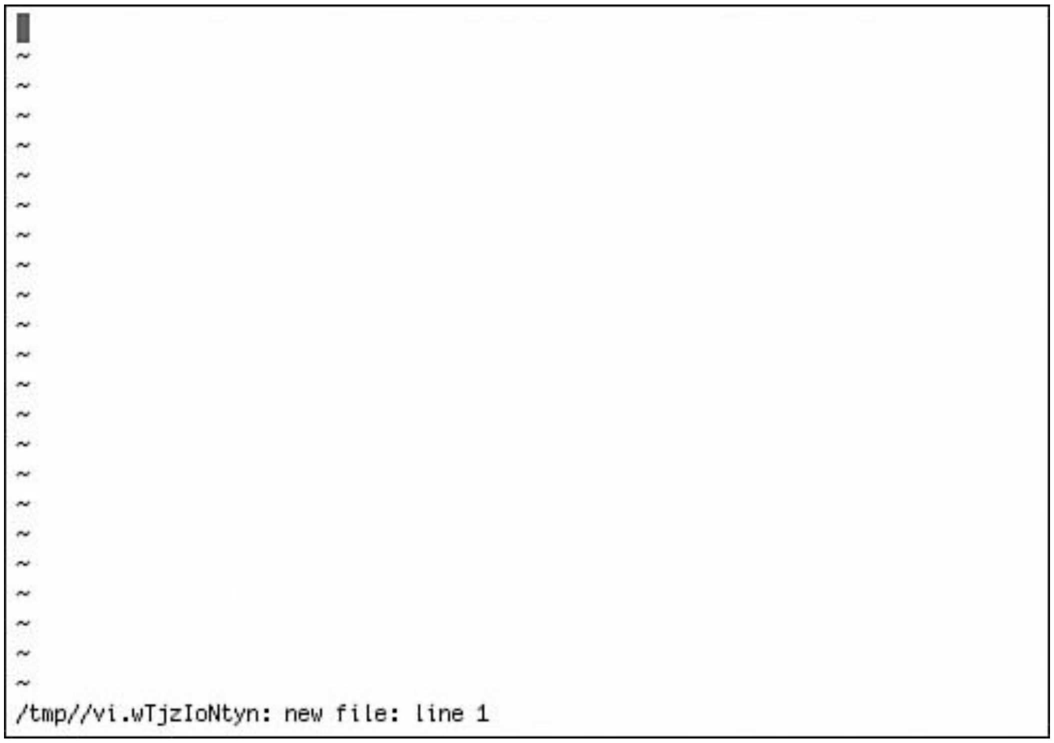
The second reason for learning `vi` is that once you have learned its various keystrokes and commands, you'll find it to be a very powerful editor. If you are a touch typist, it is also an extremely fast way to workit's designed so that you don't have to remove your hands from the home keys to access most `vi` commands.

Tip

A third reason to learn `vi` is that its key command structure crops up in lots of unexpected places throughout FreeBSD. For example, if you're using `less` to page through a file, you can use `vi`'s search commands to navigate it and look for particular text strings. You'll also find that `vi` uses many of the same conventions as appear in regular expressions, such as `$` for the end of a line. This will help keep your mind tuned to the proper mode if you program in Perl or other languages that use regular expressions.

To start `vi` with an empty file, type **`vi`**. To start `vi` and load a file for editing, type **`vi`** followed by the filename. If the filename you specify doesn't already exist, `vi` will assume that this is a new file. Figure 6.5 shows a `vi` session with a new file ready for editing.

Figure 6.5. The `vi` editor, ready to edit a new file. The status line at the bottom of the screen gives information about the file being edited; note the temp file location.



```
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
~
/tmp//vi.wTjzIoNtyn: new file: line 1
```

Looks rather plain and boring, doesn't it? One of the first things you may notice if you start trying to type text is that `vi` does nothing except beep at you; it doesn't insert any of the text you are typing. You may also hit certain keys and see strange-looking messages on the status line at the bottom of the screen. This is because `vi` has different modes of operation, and you don't start out in one where typing does any good.

When `vi` first starts, it is in *command mode*, in which keypresses are interpreted as commands to the editor rather than as text to be inserted into the document. To switch into the mode in which you can enter text into the document, you must press the A, I, or O key, or use Shift to invoke their alternative command meanings, depending on where you want the text to appear in the document:

- The `a` command stands for *append*. In this mode, the text you type will be inserted after whatever character the cursor is currently on.
- The `A` command (Shift+A) puts the cursor at the end of the current line and lets you begin entering additional text.
- The `I` command stands for *insert*. In this mode, the text you type will be inserted before whatever character the cursor is currently on.
- The `o` command stands for *open*. This will cause a new line to be inserted after the line the cursor is currently on. Then, the cursor will move to the new line, and `vi` will enter insert mode, allowing you to enter text on the new line.
- The `O` command (Shift+O) is like `o`, except that it puts a blank line above the line the cursor is on and lets you insert text into it.

Note

In `vi`, key commands are differentiated on the basis of capitalization because they're intended to be combined with other keypresses in sequence to create a complex command that can be written out (for example, `75G`). Thus, for example, when you see a reference to "the `q` command", it means to press Q by itself; but a reference to "the `Q` command" means for you to press Shift+Q. These two commands have very different meanings!

If you want to get back into command mode after entering text-entry mode, press the Esc key. By default, `vi` will beep when entering command mode.

Tip

Remember that if you are trying to enter text and `vi` simply keeps beeping at you or doing other unexpected things, you are probably in command mode. Press A, I, or O to enter textentry mode. Also, if you are ever unsure what mode you are in, simply press Esc to move into command mode (if you are already in command mode, it will have no effect). You can then press A, I, or O to enter text-entry mode. If you mistakenly pressed keys in command mode and caused errors in your document, you can often press U to undo them.

Moving Around in `vi`

In text-entry mode, you can usually use the arrow keys and the Page Up/Page Down keys to move around. However, `vi` is designed with specific editing functions in mind, not the ad-hoc freedom you might be used to in more WYSIWYG-style text editors. This means there are many other movement keys available in command mode than just the arrow keys; they're all described in Table 6.3.

Table 6.3. The Movement Keys Available from `vi`'s Command Mode

Command	Action
`h`	Moves the cursor left one character
`j`	Moves the cursor down one character
`k`	Moves the cursor up one character
`l`	Moves the cursor right one character
`w`	Moves the cursor forward one word
`b`	Moves the cursor back one word
`e`	Moves the cursor to the end of the next word
`0`	Moves to the beginning of the line
`$`	Moves to the end of the line
`)`	Moves to the beginning of the next sentence
`(`	Moves to the beginning of the previous sentence
`}`	Moves to the beginning of the next paragraph
`{`	Moves to the beginning of the previous paragraph

`G`	Moves to the bottom of the current document
`^`	Moves to the first character in the line that is not a space
`H`	Moves the cursor to the first line on the screen
`L`	Moves the cursor to the last line on the screen

Note that each of the commands in the table (with the exception of `G`) uses the unit of one, by default. The command `j` moves the cursor down one line, `k` moves it up one line, `w` moves one word to the right, and so on. You can modify the default behavior by typing a number before the command. For example, the following line causes the cursor to move down five lines instead of one line:

```
5j
```

The following line causes the cursor to move to the 75th line in the current file that is being edited:

```
75G
```

The following line causes the cursor to move to the line that is five lines up from the bottom of the screen:

```
5L
```

This syntax works for all of the commands in Table 6.3, except for the `^` command, which moves to the first non-space character in the document.

Tip

If you enter a number followed by one of the previous commands, and `vi` seems to do nothing except beep, it probably means you entered a number out of the viable range. For example, if you enter **`560G`** to move to line 560, and the document has only 557 lines, `vi` will simply beep at you, indicating that it can't perform the requested function. Unfortunately, no error message will be printed telling you what exactly is wrong.

Other Movement Keys

In addition to the cursor-movement keys described previously, there are also some key combinations that are related to scrolling the screen (Table 6.4 lists them).

Table 6.4. Scrolling in `vi`

Key Combination	Action
Z then Enter	Moves the line the cursor is on to the top of the screen
Z then -	Moves the line the cursor is on to the bottom of the screen
Z then .	Moves the line the cursor is on to the center of the screen

Ctrl+U	Scrolls up one-half screen
Ctrl+D	Scrolls down one-half screen
Ctrl+F	Scrolls forward one full screen
Ctrl+B	Scrolls backward one full screen
Ctrl+E	Scrolls down one line
Ctrl+Y	Scrolls up one line

Text-Editing Commands

Modifying existing text is where using `vi` gets particularly tricky. The Backspace and Delete keys will not do what you might expect. Instead, you will have to use various keystrokes from `vi`'s command mode in order to delete text in the manner to which you're accustomed or to overwrite existing text. Table 6.5 lists the various text-editing commands available in `vi`.

Table 6.5. Commands for Text Editing in `vi`

Command	Action
`D`	Deletes the text from the cursor position to the end of the line.
`dd`	Deletes the entire current line.
n`dd`	Here, n is the number of lines you want to delete. For example, 5dd will delete the current line, as well as the next four lines.
`p`	Pastes the contents of the memory buffer (which might have been "cut" to there with a deletion command or copied with a "yank" command, which is discussed a little later).
`r`*c*	Here, *c* is a character. This will replace the character under the cursor with the character that follows `r`.
`R`	The text typed after `R` will overwrite the current text, starting at the cursor position until you press Esc to get back into command mode.
`S`	Deletes the current line and begins inserting text in the now-blank line.
`x`	Deletes the character under the cursor and moves the character to the right over to close the gap.
`X`	Deletes the character before the cursor and moves the characters on the right to close the gap.
`~`	Changes the case of the letter under the cursor.
`J`	Joins the current line with the previous line and removes the resulting blank line.

File Operations and Exiting `vi`

Several `vi` commands relate to loading and saving files. Table 6.6 shows the various command sequences available for these actions.

Table 6.6. File Operations in `vi`

Command	Action
`ZZ`	Saves changes to the current file and then exits.
`:wq`	Saves changes to the current file and then exits (the same as `ZZ`).
`:w`	Saves changes to the current file.
`:w!`	Saves changes to the current file, overwriting a file of the same name if it already exists.
`:q`	Quits `vi`. If there are unsaved changes, `vi` complains and does not quit.
`:q!`	Quits `vi` even if there are unsaved changes. All unsaved changes will be lost.
`:e` *`filename`*	Loads the specified file into `vi` for editing. If the specified file does not exist, a new file will be created.
`:e!`	Loses all changes and reloads the saved file from the disk.

Caution

Note that the `!` option on the end of several of the commands in Table 6.6 is a stronger variant of another command without the `!`. Usually it means to suppress warnings and take whatever action you're requesting without complaint. For example, `:q!` will exit `vi` immediately without asking first whether you want to save any changes. Use the `!` option with care.

Searching and Replacing Text in `vi`

Several commands are available for performing a search-and-replace operation in `vi`. Table 6.7 lists these commands and their actions.

Table 6.7. Search and Replace Commands in `vi`

Command	Action
`/pattern`	Here, *pattern* is what to search for. `vi` searches forward in the file for the first occurrence of the specified *pattern*.
`/` or `n`	Repeats the last search, finding the next occurrence of the pattern in the file.
`?pattern`	Here, *pattern* is what to search for. `vi` searches backward in the file for the first occurrence of the specified *pattern*.
`?`	Repeats the last search, finding the previous occurrence of the *pattern* in the file.

`%`	Moves to the matching parenthesis or brace for the one that the cursor is currently on. This is useful to programmers.
`:s/pattern1/pattern2`	Replaces each occurrence of *pattern1* with *pattern2* on the current line.
`:%s/pattern1/pattern2`	Replaces every occurrence of *pattern1* with *pattern2* in the entire file.

Tip

Many of these commands are similar to how the `less` pager worksyou can use `vi` search commands when reading system documentation with `less`.

This table doesn't include a few other search-and-replace functions that aren't often used. The operations listed in the table are the ones you will probably use most often.

Copying, Cutting, and Pasting Text in `vi`

To copy text to a buffer in `vi`, use the `y` command. This command, in popular `vi` parlance, "yanks" text into the buffer. Table 6.8 shows the various ways the `Y` command can be used.

Table 6.8. `yank` Commands in `vi`

Command	Action
`yw`	Yanks the word that the cursor is currently on into the buffer.
`y$`	Yanks from the current cursor position up to the end of the current line into the buffer.
`yy`	Yanks the entire current line into the buffer.

After you have yanked text into the buffer, you can paste it anywhere in the document by moving to the appropriate location and then using `p` or `P` to "put" the text. The `p` command places the text into the document after the cursor, whereas `P` places the text into the document before the cursor. After you have "put" the text, it continues to remain in the buffer. You can use `p` or `P` again to copy the text to another location in the document.

If you want to cut instead of copy, use one of the deletion commands. For example, `5dd` will cut the current line as well as the next four lines, as well as copying them into the buffer. They can than be pasted into the document in another location by using `p` or `P`.

Caution

`vi` stores only the last text that was yanked or deleted. In other words, if you use `dd` to delete a line of text, and you later use `yy` to copy a line of text, the text from the `dd` operation will be overwritten in the buffer with the text from the `yy` operation. This means the text from the `dd` operation will no longer be available, nor will you be able to undo the delete.

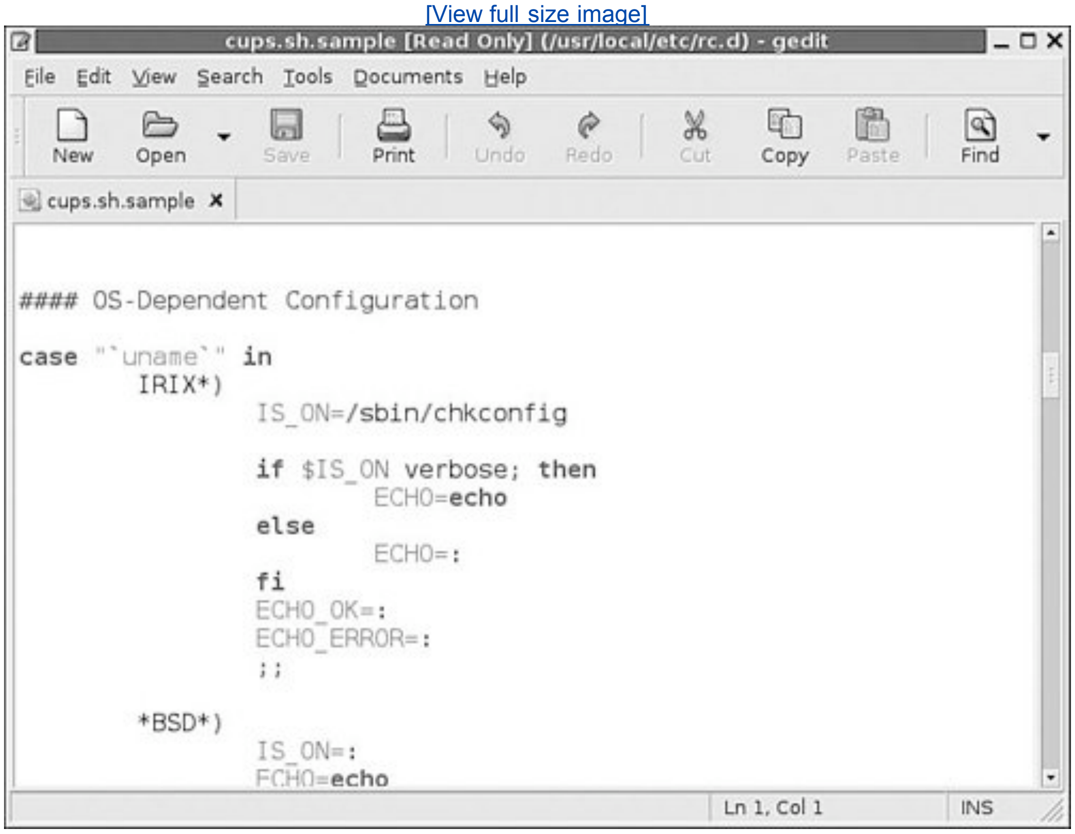
vi has many more powerful features that cannot be covered here without making this into a vi textbook. When you get to know vi, you'll recognize it as a very powerful editor that offers a fast and reliable way to edit documents. If you would like to learn more about vi, a few books are available on the subject, including *Learning the vi Editor* and *vi Editor Pocket Reference*, both available from O'Reilly.

Editing Text Graphically in KEdit or gedit

KDE provides a fully functional text editor, similar to Notepad in Windows, called KEdit. This program can be found in the Editors submenu of the K menu. Similarly, GNOME provides a Notepad-style text editor called gedit, found in the Accessories submenu of the Applications menu, and labeled simply Text Editor. gedit is shown in Figure 6.6.

Figure 6.6. gedit, the built-in text editor in GNOME. Its equivalent in KDE is KEdit.

[View full size image]


cups.sh.sample [Read Only] (/usr/local/etc/rc.d) - gedit
File Edit View Search Tools Documents Help
New
Open
Save
Print
Undo
Redo
Cut
Copy
Paste
Find
cups.sh.sample
Ln 1, Col 1
INS

```
#### OS-Dependent Configuration

case "`uname`" in
        IRIX*)
                IS_ON=/sbin/chkconfig

                if $IS_ON verbose; then
                        ECHO=echo
                else
                        ECHO=:
                fi
                ECHO_OK=:
                ECHO_ERROR=:
                ;;

        *BSD*)
                IS_ON=:
                ECHO=echo
```

Operating either of these text editors is very similar to working with Notepad in Windows: you use the File menu to perform operations such as opening and saving files, and you use the Edit menu (and its associated keyboard shortcuts) for operations such as copying and pasting text you select with the mouse. As shown in Figure 6.6, these editors even provide functionality that you won't have seen in Notepadgedit, for example, automatically renders parts of recognizable program files (such as shell scripts) with boldface and differently colored text, even though this special formatting isn't saved in the plain text of the file. This formatting is of special importance to programmers, for whom having variables shown in one style of text and flow-control statements in another is very helpful.

Note

If you're running KDE or GNOME as a non-root user (as you should be), you'll find that you can't directly edit system configuration files that are owned by root. In KDE you can get around this by opening up the Options pane of the Run Command dialog box and turning on the Run as a Different User check box, where you can specify root's username and password so you can edit the file with root privileges (which apply only to that KEdit process). GNOME doesn't have this functionality, however; you have to either run GNOME as root (which is dangerous), or simply save your edited files in a location where you have write access, and then use `su` in a terminal window to assume root privileges and move the edited file back into its proper location. The inconvenience of this workflow is why even KDE or GNOME users often prefer to use CLI-based text editors to work on system configuration files.

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Office Applications

Just because you're using an open-source operating system doesn't mean you have to do without the productivity applications you've come to depend on under Windows. After a long period when office applications that could adequately stand in for the commercial but indispensable Microsoft Office were in short supply, today there are several excellent open-source office suites that provide all the functionality of Microsoft Office and more.

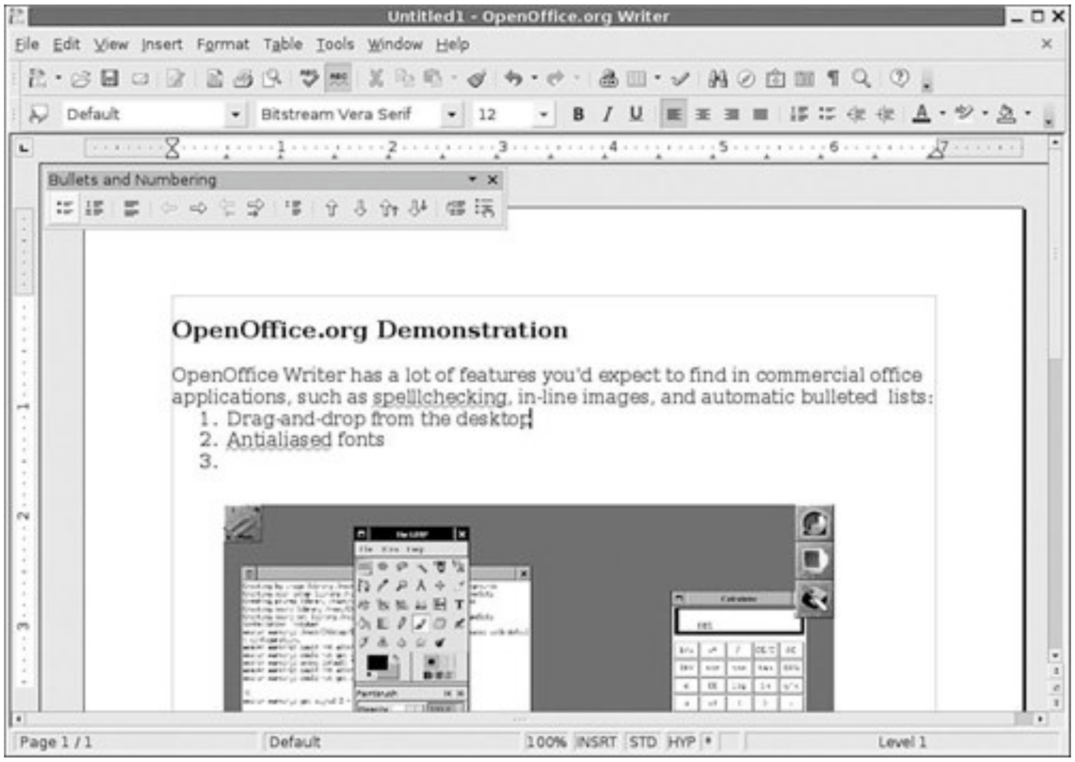
If you're using KDE, the built-in office suite, KOffice, contains eleven component applications including KWord, KSpread, KPresenter, and Kivio, which correspond in functionality to Word, Excel, PowerPoint, and Visio. KOffice also includes Krita, a full-featured Photoshop-style painting program, and several other component applications that won't be found in Microsoft Office. The KOffice applications can be found under the Office submenu in the K menu.

GNOME users have to install office applications separately, but they're there just the same: AbiWord, a Word-like word-processing application; Gnumeric, a spreadsheet; and GNOME-DB, a database access architecture. AbiWord is available in the `editors` category of the FreeBSD ports or packages, and Gnumeric is found in the `math` section. There aren't any other component applications for GNOME Office, though, and you might find yourself wanting to try the KOffice components (most of which will run under GNOME), or our third option for office suites on FreeBSD.

OpenOffice.org (that's the suite's name, not just the location of its website) is the latest evolution of Sun's StarOffice suite, made fully open-source and based on emerging interoperability standards. OpenOffice.org 2.0, the newly released current version, contains six component applications: Writer, Impress, and Calc, which correspond to Word, PowerPoint, and Excel; as well as Math (a mathematical equation editor), Draw (a vector drawing and diagramming program similar to Visio), and Base (a database back-end). Figure 6.7 shows Writer in action.

Figure 6.7. OpenOffice.org Writer, an excellent open-source Microsoft Word workalike with many unique features.

[View full size image]



OpenOffice.org Demonstration

OpenOffice Writer has a lot of features you'd expect to find in commercial office applications, such as spelllchecking, in-line images, and automatic bulleted lists:

1. Drag-and-drop from the desktop
2. Antialiased fonts
3.

OpenOffice.org 2.0 is available in the `editors` category of the ports or packages, as well as on the software CDs packaged with this book. If you're downloading it over the Internet, you'll probably want to opt for the package version because the full source tarball is 262MB and will take a very long time to compile. If the package is not available through the `pkg_add -r openoffice-2.0` command, go to the OpenOffice.org website and follow the links to download the FreeBSD version, and then use `pkg_add` *`package-filename`* to install it.

Interoperability

The question on everybody's mind when it comes to open-source office applications, naturally, is file-format interoperability. It's one thing to have a great word-processing application or full-featured spreadsheet for creating and printing out your own files, but what good is it if you can't open documents sent to you by your coworkers, or create documents that they can read in Microsoft Word, Excel, and PowerPoint?

All three of the office suites discussed here are acutely conscious of this perennial sticking point. OpenOffice.org has standardized on a format called OpenDocument, an XMLbased and extensible architecture approved by OASIS (a body formed to develop standards for XML-based data formats in office documents). The goal of both OASIS and OpenDocument is to make it so that future word-processing, spreadsheet, and other kinds of mission-critical office documents are never tied to a single application, but can interoperate from one application to another without any loss of functionality. Companies such as IBM have endorsed OpenDocument and are in the process of bringing out commercial applications that support it. Microsoft, which to date has controlled the file formats for Word, Excel, PowerPoint, and other office applications of which it is the de facto standard gatekeeper, has been (understandably) reluctant to endorse OpenDocument, preferring to promote a semi-open XML-based document standard of its own; but Microsoft is a sponsor of OASIS, so there will undoubtedly be tension and disagreements over the issue for the foreseeable future. This issue is open and fluid at the time of this writing, and you should check the OpenOffice.org website for the latest news regarding the fortunes of the OpenDocument format.

Meanwhile, all of the office applications described in this chapterKOffice, GNOME Office, and

OpenOffice.orgsupport the reading of Microsoft Word or Excel documents. Writing documents in Microsoft's formats, however, is less well supported. OpenOffice.org boasts fully Microsoft-compatible output in Writer, Calc, and Impress, as does AbiWord. Gnumeric, however, can only import Excel files, not export them. And the KOffice applications, such as KWord and KSpread, currently only have filters that support importing Microsoft Office documents, and can't yet write them. (See http://koffice.org/filters for the latest information on KOffice's interoperability status.)

Because interoperability is its chief focus and its most standout feature, OpenOffice.org (which is available for all commercial platforms, not just UNIX) might well be your best bet if you need to use a Microsoft Officecompatible office suite in your work, no matter what desktop environment you use.

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Creating and Editing Images with GIMP

Several graphics programs and image-editing programs are available for FreeBSD, such as `bitmap` for creating background patterns and mouse pointers and Xfig for drawing figures and illustrations. KDE and GNOME also come with simple image-editing programs, such as KolorPaint, a Microsoft Paint clone, and Kritaa full-featured Photoshop-style applicationis part of KOffice. GIMP, however, is the most significant and full-featured graphics program in the open-source world today.

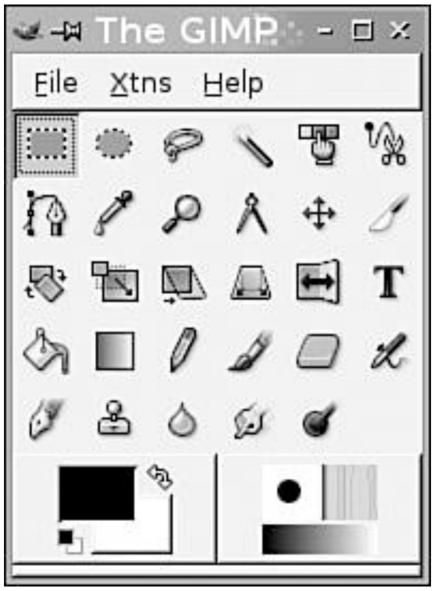
GIMP, which stands for *GNU Image Manipulation Program*, is a freely available imageediting program maintained by the GNU project. It has many advanced features, such as layers, filters, paths, and support for tablet input. It's intended to provide a free alternative to Adobe Photoshop, and thus most of GIMP's features and terminology will be familiar to you if you're familiar with Photoshop. Getting used to the layout of GIMP, however, may take some time.

GIMP recognizes most popular image formats, including BMP, GIF, JPEG, PNG, PCX, and TIFF. GIMP can also read PostScript files, and even read and write Photoshop's PSD format.

GIMP is available in the FreeBSD ports collection or packages under the `graphics` category. After you have installed GIMP, you can simply type **`gimp`** from a terminal window within an X11 session, or you can use the Run Application or Run Command windows as noted earlier in this chapter.

Figure 6.8 shows the main control panel for GIMP, in its simplest form, without any extended palettes or additional windows.

Figure 6.8. The main control panel for GIMP enables you to select the various tools available in GIMP, as well as load and save files.

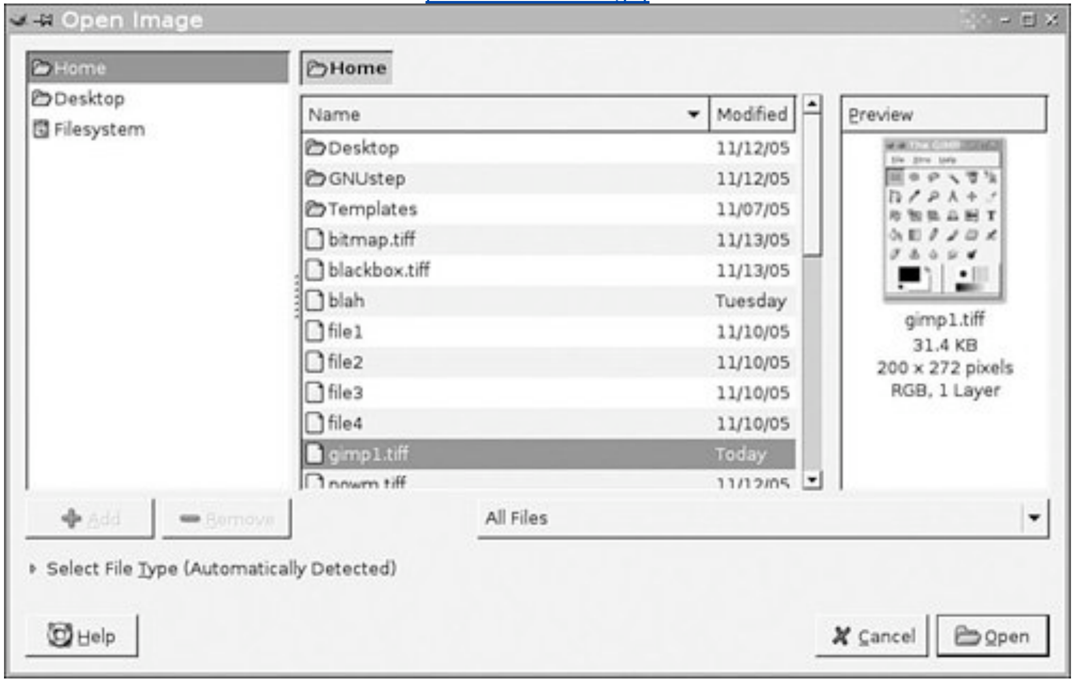


The File menu is usually your starting point in GIMP. Here, you can open an existing file, create a new file, or acquire an imageeither from a screen shot or from a supported scanner, if installed.

Figure 6.9 shows the Open Image dialog box in GIMP. It begins in your home directory, from which you can navigate to the location of any existing image file; select one and its preview appears in the rightmost pane. You can use the Select File Type drop-down menu to see all the kinds of files GIMP can open.

Figure 6.9. Opening a file in GIMP. The file browser has built-in previews and file-type filters.

[View full size image]



Name	Modified
Desktop	11/12/05
GNUstep	11/12/05
Templates	11/07/05
bitmap.tiff	11/13/05
blackbox.tiff	11/13/05
blah	Tuesday
file1	11/10/05
file2	11/10/05
file3	11/10/05
file4	11/10/05
gimp1.tiff	Today
nowm.tiff	11/12/05

gimp1.tiff
31.4 KB
200 x 272 pixels
RGB, 1 Layer

After your image window is open, whether you're creating a new file or modifying an existing one, you can use the wide array of brushes and editing tools (most of which are modeled on their Photoshop counterparts) to edit the image. Use layers to edit parts of the image non-destructively, and paths to make smooth curves that you can then "stroke" with a line of your chosen style. Finally, save the file using GIMP's default XCF format, or use Photoshop's PSD format to create a file that Photoshop users can open and that contains all the layer and path information you created. In the Save Image dialog box, specify the output file type by simply including the appropriate extension in the filename; for example, to save the image as a TIFF file, name the file *image.tiff*.

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Audio Applications

The sound and multimedia support in FreeBSD has become quite good in recent years, after a long period of barely existing at all. Today it supports a wide range of popular sound cards, whether add-on devices such as Creative's SoundBlaster series, or integrated motherboard sound chipsets such as NVIDIA's nForce series. If you have one of these or many other common sound cards, chances are good that FreeBSD supports it natively. Even if FreeBSD does not have native support for your sound card, the commercial sound drivers from a company called 4Front Technologies might support it. Sound drivers for FreeBSD 6.x (and earlier versions) are available for $49 at the company's website at http://www.opensound.com, and there are free trial versions available as well.

Enabling Sound Support

In the default configuration, FreeBSD has no active audio subsystem. Sound support is available in a collection of kernel modules, one for every type of popular sound card. You'll need to load the appropriate kernel module to enable sound support for your system. The sound drivers are all located in `/boot/kernel`, and they all begin with the `snd_` prefix. If you can't tell at a glance whether your model of sound card matches any of the inscrutably named kernel modules, refer to the online FreeBSD Handbook's section on supported hardware at http://www.freebsd.org/releases/6.0R/hardware-i386.html#SOUND (adjust the address to match your FreeBSD release) to match up your sound card model with an appropriate kernel module. For example, a SoundBlaster Audigy 2 card is supported by the `snd_emu10k1` driver.

Tip

If you still aren't sure what driver to use, or you can't find your sound card listed under any of the supported kernel modules on the Handbook site, you can try using the generic `snd_driver` module. This is a meta-driver that loads all the sound drivers into the kernel at once, and it might make your sound card work. It's better to find out for sure what driver to use, thoughhaving lots of kernel modules loaded at once is a great way to destabilize your system. Use the `cat /dev/sndstat` command after loading the drivers to find out which one is actually being used.

After you've found out what sound driver to use, add it to your `/boot/loader.conf` file to cause it to be loaded at boot time:

```
snd_emu10k1_load="YES"
```

Then reboot the system. If you don't want to reboot, you can use `kldload` to load the kernel module immediately:

```
# kldload snd_emu10k1
```

Then use the `kldstat` command to verify that the sound driver was loaded.

After you have enabled the appropriate sound driver and rebooted, type **`dmesg | more`** to check the `dmesg` output from the kernel. Look for information indicating that your sound card was correctly detected on system boot. For example, the `dmesg` output on my system contains the following lines:

```
sbc0: <Creative SB AWE64> at port 0x220-0x22f,0x330-0x331,0x388-0x38b irq 5 drq
1,5 on isa0
pcm1: <SB16 DSP 4.16> on sbc0
```

This output shows that FreeBSD detected a SoundBlaster AWE 64, and gives the memory addresses and IRQ that the card is occupying. Use the `cat /dev/sndstat` command to find out further status information on your card and ensure that the system has recognized it properly.

If FreeBSD doesn't seem to find your sound card, you might want to try to get sound working using the 4Front sound drivers. Once again, they can be obtained at http://www.opensound.com.

Tip

To speed up the boot process, you might choose to compile your card's sound driver into the kernel, rather than making FreeBSD load it dynamically every time you boot up. To do this, add the following two lines to your kernel's configuration file, `/usr/src/sys/i386/conf/MYKERNEL`:

```
device sound
device "snd_emu10k1"
```

Use the appropriate sound driver in the second line. Then recompile the kernel as described in full detail in Chapter 18, "Kernel Configuration." Note that if you build sound support into the kernel, it might conflict with the 4Front sound drivers if you bought them; be sure to remove them from the `/boot/loader.conf` file if you had them enabled there.

Note

Generally, in FreeBSD, only one application can produce sound output at once; if one application has opened the sound device, you might receive an error such as can't open `/dev/dsp!` If this occurs, try using `fstat | grep /dev/dsp` to find out if an application that you left running (or that another user is running) has hold of the sound output device.

Using the Mixer

The next step in setting up sound, once the kernel's sound support has been loaded, is to use the *mixer* to set up the proper sound output levels for various audio sources and frequency ranges. You should be able to access the FreeBSD mixer from the command line. From a shell prompt or terminal window, type the command **`mixer`** and press Enter. Your system will output something similar to the following:

```
Mixer vol      is currently set to  75:75
Mixer bass     is currently set to  50:50
Mixer treble   is currently set to  50:50
Mixer synth    is currently set to  75:75
Mixer pcm      is currently set to  75:75
Mixer speaker  is currently set to  75:75
Mixer line     is currently set to  75:75
Mixer mic      is currently set to   0:0
Mixer cd       is currently set to  75:75
Mixer igain    is currently set to   0:0
Mixer ogain    is currently set to  50:50
```

This shows what levels (in percentage values ranging from 0 to 100) each audio device in the system is set to. The numbers separated by colons represent the left and right stereo channels of each sound component.

Most of the items in the list are self-explanatory, but a few of them deserve some more attention:

- `Mixer vol` is the master volume for all the audio devices.
- `Mixer pcm` is the device through which most audio is played. This will control the volume of WAV files, MP3s, Real Audio files, and so on.
- `Mixer synth` controls the volume of the synthesizer. This generally affects MIDI files.
- `Mixer cd` controls the volume of audio CDs.
- `Mixer line` controls the volume of a device connected to the line in the jack on a sound card.
- `Mixer igain` controls the input gain level.
- `Mixer ogain` controls the output gain level.

To make changes to any one of the levels, you can type **`mixer`**, followed by the name of the device and the desired level. For example, the following will set the CD output volume to 90 percent on both the left and right channels:

```
# mixer cd 90
```

If you want to set the left and right channels to different values, you need to include both values, separated by a colon. For example, the following will set the CD volume to 100 percent for the left channel and 80 percent for the right channel:

```
# mixer cd 100:80
```

At system boot time, most of the mixer values will default to 75 percent. If you want to have different default values at system boot, there are two ways to accomplish this.

The first way is by creating a startup file in `/usr/local/etc/rc.d`. In the file, simply include a list of the desired mixer commands. You can name the file anything you want. For example, you might call the file `mixerset`. Here is an example of what the file might contain:

```
mixer vol 80:80
mixer cd 90:90
mixer pcm 50:50
```

As root, create this file in the directory `/usr/local/etc/rc.d` and save it as `mixerset`, for example. Next, make the file executable by issuing the following command:

```
# chmod u+x mixerset
```

The commands inside this file will now be run at each system boot and cause the mixer to be set to the desired values.

Tip

If the preceding steps are unclear to you, see Chapter 8, "Working with the Shell," and Chapter 14 for more information on these topics.

The second way you can change the default mixer values is by adding commands to your login script (see Chapter 11 for further details). Open either `.profile` or `.login`(depending on your shell) in your favorite text editor and add the mixer commands that you want to set. For example, you might want to add the following lines to the file:

```
mixer vol 80:80
mixer cd 50:50
mixer pcm 90:90
```

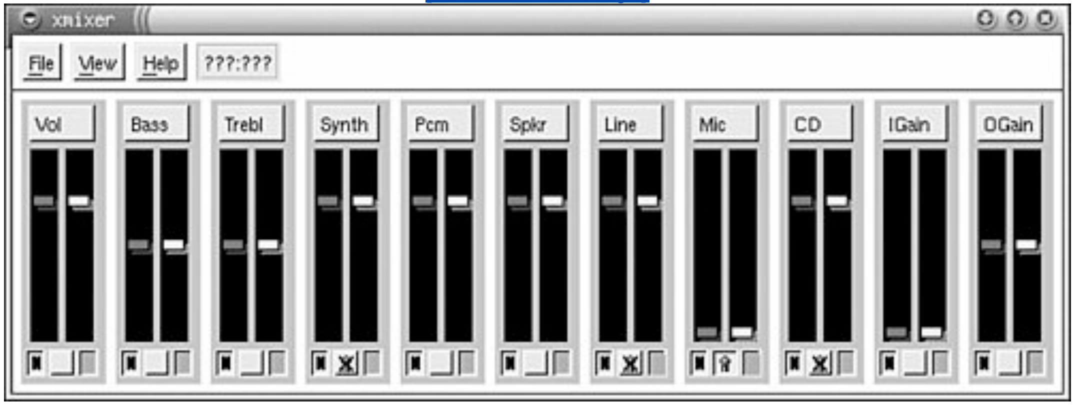
Unlike the changes made to the startup file, these do not need to be made as root, and they also will not take effect at system boot. They will take effect as soon as you log in to the system. The benefit of this method is that if more than one person uses this system, each person can create his own customized set of mixer settings to suit his listening preferences. Each time that user logs in to the system, his custom mixer settings will be applied.

Mixers in X11

If your tastes run toward the graphical, several X11-based interfaces to the mixer are available, including KMix for KDE and GMix for GNOME, both of which are standard components of their respective desktop environments. Figure 6.10 shows the desktop-agnostic `xmixer`, which is available in the FreeBSD ports or packages in the `audio` section.

Figure 6.10. `xmixer`, a graphical front-end for manipulating the sound driver's recognized channels.

[View full size image]



Using the familiar Windows-like icons in `xmixer`, you can graphically manipulate the left and right channels (or both locked together) of any of the audio output channels that FreeBSD recognizes. You can also disable certain channels if you don't need them or want them to be muted.

MP3 Playback Under X11 with XMMS

Now that you have the audio device configured properly, you will probably want to play some sounds with it. Yes, your MP3 collection will work with FreeBSD. XMMS, the X Multimedia System, is a Winamp clone for FreeBSD and other UNIX-like systems. It is available in the FreeBSD ports or packages in the `multimedia` category.

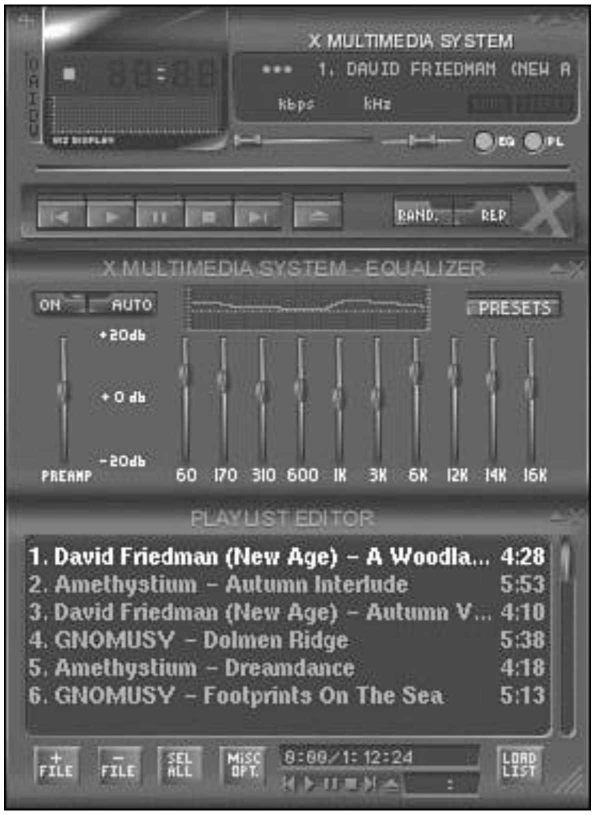
Note

KDE has its own built-in media player, Noatun. You might prefer to use this utility instead of XMMS if you're running KDE. On GNOME, on the other hand, you can play back MP3, Ogg Vorbis, and other types of audio files using the included Totem Movie Player.

After you have XMMS installed, you can start it with the command `xmms`, either issued at a shell prompt in a terminal window or at the Run Command dialog box (or equivalent). You can also create menu entries or desktop shortcuts for it, if you use it often enough.

Figure 6.11 shows XMMS with the mixer and playlist windows also open.

Figure 6.11. The XMMS MP3 player. Windows users who have used Winamp will be quite comfortable with XMMS because its controls are virtually identical.



1. David Friedman (New Age) - A Woodla... 4:28
2. Amethystium - Autumn Interlude 5:53
3. David Friedman (New Age) - Autumn V... 4:10
4. GNOMUSY - Dolmen Ridge 5:38
5. Amethystium - Dreamdance 4:18
6. GNOMUSY - Footprints On The Sea 5:13

0:00/1:12:24

Yes, it even supports Winamp skinsand you don't even have to unzip them first. Simply place your zipped Winamp skins in the directory `.xmms/Skins` located in your home directory. Click the icon at the very upper-left corner of XMMS; then select Options, Skin Browser from the pull-down menu. This will open a dialog box in which you can select the desired skin.

Tip

In order for you to be able to use zipped skins, you will have to have the `unzip` program installed. It can be installed from the FreeBSD ports or packages and is located in the `archivers` category.

In addition to Winamp skins, a large number of XMMS skins are available at http://www.xmms.org/skins.php. Like the Winamp skins, they can simply be copied into the `.xmms/Skins` directory and do not need to be unzipped first.

XMMS skins are normally distributed as gzipped tar files with a `.tar.gz` extension. This is a popular archive format for UNIX-like systems that is similar to ZIP files.

XMMS also supports various visualization and audio effect plug-ins. Many of these are available as FreeBSD ports in the `multimedia` category.

Note

You can create your own MP3 or Ogg Vorbis files from your CD collection using any of several CD-ripping applications available for the command line, X11, or KDE/GNOME. KDE comes with KAudioCreator, and GNOME has Sound Juicer, both of which will look up CD track information from an online database and apply them to your imported tracks as you encode them. For full music management functionality, though, look into Amarok (for KDE), which serves as an excellent music and playlist manager with many advanced features that even iTunes doesn't have, or Songbird, a cross-platform iTunes-style music database with a Linux version that FreeBSD should be able to run under Linux compatibility.

PREV NEXT

PREV NEXT

Networking Applications

Numerous networking applications are available for FreeBSD. This section will concentrate on web browsers, email, and FTP applications.

Web Browsers for X11

In FreeBSD, you have your choice of several excellent web browsers, all of them featuring advanced functionality such as tabbed browsing and pop-up blocking, making them demonstrably better in many ways than the standard offerings on Windows. At the heart of the web browser universe is the Mozilla family of browsers, dating back to the opensource transition made by Netscape when it was forced to concede defeat on the consumer desktop to Microsoft Internet Explorer. In the ensuing several years, the dedicated core Netscape development team and the many thousands of contributing developers around the world brought out the Gecko rendering engine, the Mozilla browser (and Netscape 6/7, its commercial counterpart), and finally Firefox, the cross-platform browser that has attained widespread respect that the Netscape team hadn't seen since 1996. Gecko has at the same time found its way into the back-end of many alternative browser projects, including Epiphany, the web/desktop browser built into GNOME.

At the same time, alternative browsers based on newer, faster rendering engines were being developed, such as Konqueror (KDE's built-in browser), founded on the KHTML rendering engine. KHTML is so efficient and complete that it forms the basis for Safari, Apple's browser built into Mac OS X.

If you're using KDE, you might want to use Konqueror as your browser; if you're on GNOME, Epiphany might be your choice. However, for either of those desktop environments, or if you're using a plain window manager, running Mozilla or Firefox is a choice you probably won't regret.

Note

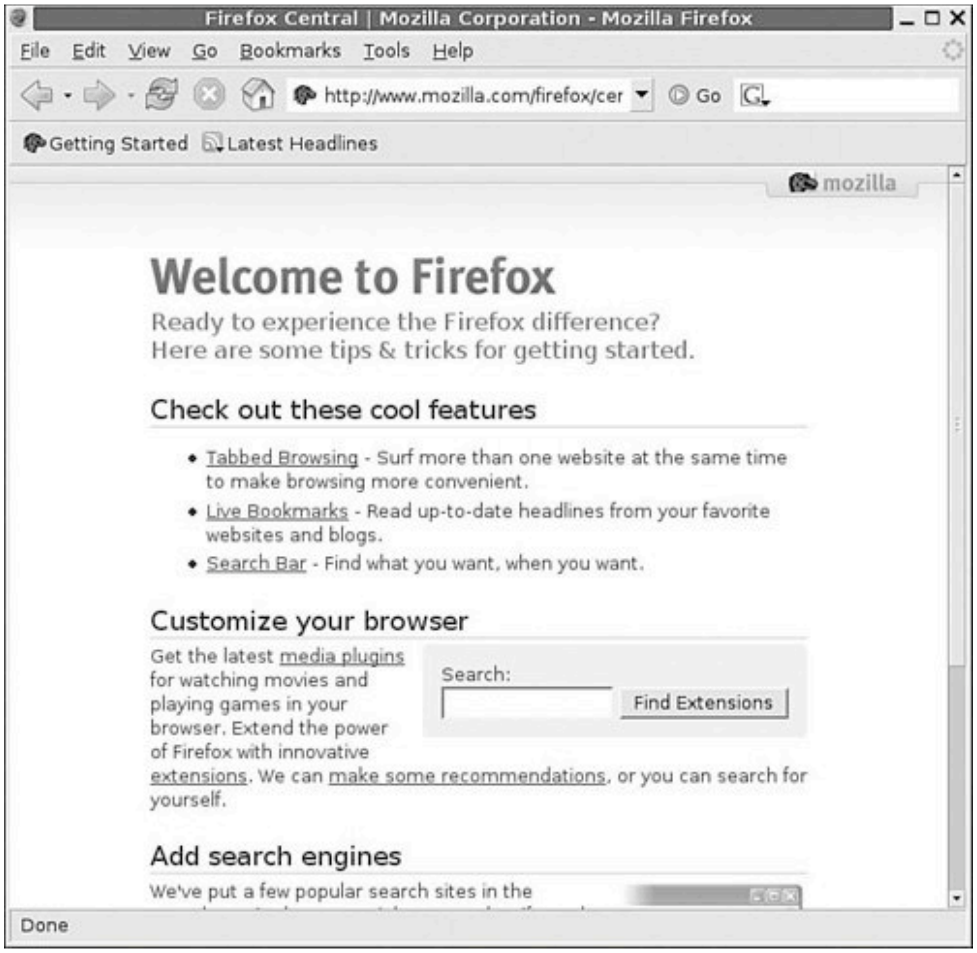
Because Firefox is a cross-platform browser that you can use on Windows or Mac OS X as well as on FreeBSD, you can stick with it on all your computers no matter what operating systems they're running; you can also use a centralized bookmark system like del.icio.us to ensure a consistent browsing experience on all platforms.

Both Firefox and Mozilla are available as ports or packages in the `www` category. Once installed, you start the browser with the `mozilla` or `firefox` command (as appropriate) or by choosing it from the menu of applications in KDE or GNOME.

When you first launch Firefox, it gives you the opportunity to import your preferences, bookmarks, and other information from an earlier installation of Netscape or Mozilla. Choose the appropriate option and click Next to be guided through the process of importing your data if necessary. When you're done with that, you're ready to use Firefox (shown in Figure 6.12), with all the modern features that have made it so popular on all platforms.

Figure 6.12. The Firefox web browser. Click the circular flower pattern at the right end of the menu bar to see how to use some of Firefox's more interesting features.

[View full size image]


Firefox Central | Mozilla Corporation - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://www.mozilla.com/firefox/cer
Go
Getting Started
Latest Headlines
mozilla
Search:
Find Extensions
Done

Welcome to Firefox

Ready to experience the Firefox difference?
Here are some tips & tricks for getting started.

Check out these cool features

- Tabbed Browsing - Surf more than one website at the same time to make browsing more convenient.
- Live Bookmarks - Read up-to-date headlines from your favorite websites and blogs.
- Search Bar - Find what you want, when you want.

Customize your browser

Get the latest media plugins for watching movies and playing games in your browser. Extend the power of Firefox with innovative extensions. We can make some recommendations, or you can search for yourself.

Add search engines

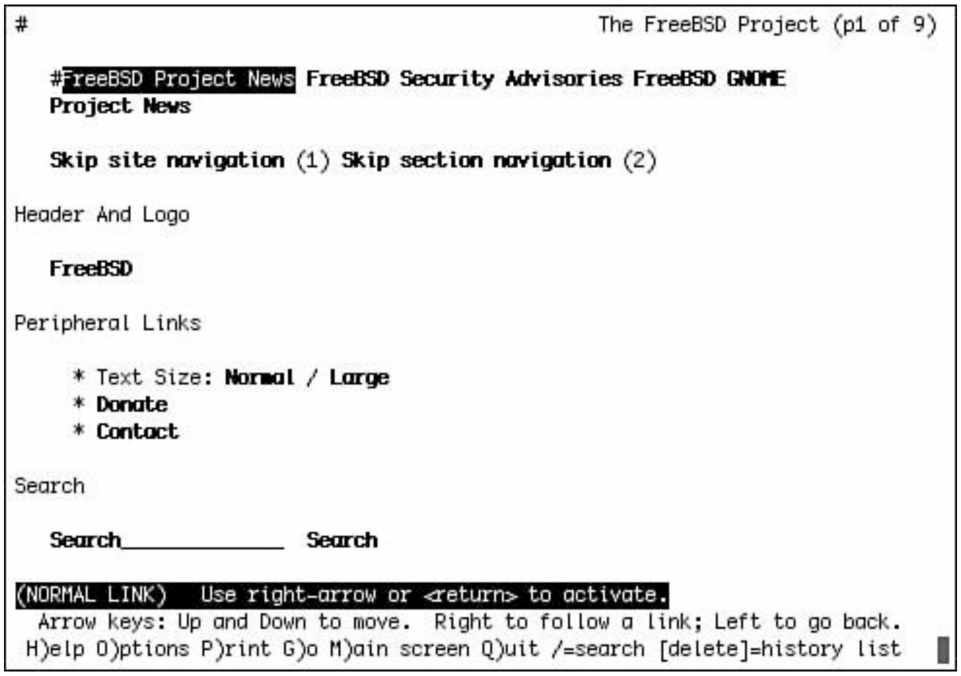
We've put a few popular search sites in the

Firefox's extensive configuration options are available by selecting Edit, Preferences. You can modify many aspects of Firefox's appearance and behavior, including how it handles your saved browsing history, passwords, form information, and cookies.

The Lynx Web Browser

Lynx is a CLI web browser that runs in text mode and has no graphical capabilities. It attempts to render web pages in as close as possible a format to how they would appear in a graphical browser. It's getting more and more difficult to navigate the Web with Lynx these days because it does not support images, frames, JavaScript, CSS, Flash, or any of the other technologies that make today's web what it is. Because many sites are using images as links and not making use of `ALT` tags, this can cause navigational problems in Lynx that are difficult or impossible to get around. However, Lynx is still an indispensable tool for downloading important files or getting crucial information from utilitarian sites such as download repositories or documentation archives, particularly if you're on a system that doesn't have X11 installed. Figure 6.13 shows Lynx with the (now rather Lynxunfriendly) FreeBSD website loaded into it.

Figure 6.13. The FreeBSD website in Lynx.



```
#                                        The FreeBSD Project (p1 of 9)

   #FreeBSD Project News FreeBSD Security Advisories FreeBSD GNOME
   Project News

   Skip site navigation (1) Skip section navigation (2)

Header And Logo

   FreeBSD

Peripheral Links

     * Text Size: Normal / Large
     * Donate
     * Contact

Search

   Search______________     Search

(NORMAL LINK)   Use right-arrow or <return> to activate.
  Arrow keys: Up and Down to move.  Right to follow a link; Left to go back.
 H)elp O)ptions P)rint G)o M)ain screen Q)uit /=search [delete]=history list
```

Lynx can still work on quite a few sites, although navigation is not always easy. Use the Up and Down arrow keys to move between links in the browser window, and the Right and Left arrows to navigate forward (using the selected link) and backward. The spacebar is the equivalent of Page Down. Type **`G`** to change to a different website; you will be asked to enter a URL after typing G. Q quits Lynx when you're done.

Lynx can be installed from the ports or packages (in the `www` category). For more information on Lynx, including customization options, refer to the `man lynx` page.

Tip

Lynx is gradually being replaced by more full-featured textual browsers, such as `w3m` and `links`, both available in the `www` category of the ports or packages. Both these browsers make a game attempt at rendering elements such as frames, tables, and menus, which are beyond the ambitions of Lynx.

FTP

FTP (File Transfer Protocol) is a time-honored and reliable method of transferring files between systems. Windows users might be familiar with FTP only as a way to download software from a central distribution server; but as the owner of a FreeBSD system, you'll be able to set up your machine as an FTP server for two-way file-transfer that requires a minimum of hassle. (See Chapter 27, "Configuring an FTP Server," for more information.)

Using FTP to download (or upload) files is a utilitarian endeavor that has never inspired much development effort for GUI-based applications in the open-source world. The traditional way to transfer files over FTP is the old-fashioned way: on the command line, using the `ftp` program.

To start an FTP session, type **`ftp`** followed by the name of the server you want to connect to. For example, to connect to the FreeBSD FTP server, you would type the following:

```
# ftp ftp.freebsd.org
```

After you have done this, and assuming the connection is successful, you will eventually see something like the following:

```
Connected to ftp.freebsd.org.
220 ftp.FreeBSD.org NcFTPd Server (licensed copy) ready.
Name (ftp.freebsd.org:btman):
```

You might be connecting to a private FTP server, where you need to have a user account established, or a public server where you can log in anonymously. If it's a private server, enter your account name at the `Name` prompt and press Enter, and then enter your password when prompted. If it's a public server, however, enter the special username **`anonymous`**. You'll see the following further prompt:

```
331 Guest login ok, send your e-mail address as password.
Password:
```

Public FTP servers use the password as a means of logging who's accessed the system, and they ask that you use your email address as your passwordit's an entirely voluntary matter to give your real email address. Either enter your real address or a fake one as your password. Note that the password will not echo to your screen.

After you have logged in, you may get a welcome message and finally something that looks similar to the following:

```
Remote system type is UNIX.
Using binary mode to transfer files.
ftp>
```

At the prompt, you can use many of the same shell commands that you use at your local shell to navigate through the FTP server. (See Chapter 8 for details on how to work with shell commands.) Table 6.9 provides a list of some of the most commonly used commands in an FTP session.

Table 6.9. Commonly Used FTP Commands

Command	Action
`ls`	Lists the directory contents of the remote host.
`cd`	Changes the directory on the remote host.
`pwd`	Displays the current directory you are in on the remote host.
`lcd`	Changes the directory on the local host. (Only available in some FTP client programs.)
`binary`	Transfers files in binary mode (this mode should be used for anything other than plain-text).
`ascii`	Transfers files in ASCII mode (this mode should be used only for plain-text, and then only if necessary). The purpose of ASCII mode is to translate end-of-line characters in text files from the format used on the source host to the format used on the destination host. If you're transferring files from UNIX to Windows or vice versa, ASCII mode is important; but between UNIX machines, no translation is necessary, so it doesn't matter.
`put` *`filename remotename`*	Copies *`filename`* to the remote host. *`filename`* is assumed to be in the current directory unless a path is specified. If no destination file is specified, the file will be placed in the current directory in the remote host and have the same name as the local file. (This command works only if you have permission to write to the directory on the remote machine.) *`remotename`* is optional; if specified, the file is renamed to that name on the remote host.

`mput file1 file2`	Copies multiple files in a list to the remote host. The files will be placed in the current directory on the remote host. (This command works only if you have permission to write to the directory on the remote machine.)
`get filename localname`	Copies a file from the remote host to the local system. If no path is specified, the file is assumed to be located on the current directory on the remote host. If no destination file is specified, the file will be copied to the local system using the same filename. *localname* is optional; if specified, the file is renamed to that name on the local host.
`mget file1 file2`	Gets multiple files in a list from the remote host. The files will be placed in the current directory on the local system. This can also take `*` as a wildcard to get all files in a directory matching a specification.
`mkdir dirname`	Creates a directory called `dirname` on the remote machine (assuming you have permission to do so).
`rmdir dirname` or `rm dirname`	Removes the directory called `dirname` on the remote machine (assuming you have permission to do so).
`del filename`	Deletes the file `filename` from the remote machine (assuming you have permission to do so).
`bye` or `quit`	Closes the connection with the remote host and quits the FTP program, returning you to the shell prompt.

You can also type **`help`** at the `ftp>` prompt to get a list of available commands. Type **`help`** followed by one of the commands in the list to get a short description of what that command does. Here's an example:

```
ftp> help
Commands may be abbreviated.  Commands are:

!               features        mls             prompt          site
$               fget            mlsd            proxy           size
account         form            mlst            put             sndbuf
append          ftp             mode            pwd             status
ascii           gate            modtime         quit            struct
bell            get             more            quote           sunique
binary          glob            mput            rate            system
bye             hash            mreget          rcvbuf          tenex
case            help            msend           recv            throttle
cd              idle            newer           reget           trace
cdup            image           nlist           remopts         type
chmod           lcd             nmap            rename          umask
close           less            ntrans          reset           unset
cr              lpage           open            restart         usage
debug           lpwd            page            rhelp           user
delete          ls              passive         rmdir           verbose
dir             macdef          pdir            rstatus         xferbuf
disconnect      mdelete         pls             runique         ?
edit            mdir            pmlsd           send
epsv4           mget            preserve        sendport
exit            mkdir           progress        set
ftp> help mdir
mdir             list contents of multiple remote directories
ftp>
```

For more information on using FTP, read the manual page for FTP by typing **`man ftp`** at the shell prompt. You might also want to read the sections in Chapter 8 on file-manipulation commands because the commands used in FTP are similar.

Listing 6.1 shows what a sample FTP session might look like.

Listing 6.1. A Sample FTP Session

[View full width]

```
# ftp ftp.freebsd.org
Trying 62.243.72.50...
Connected to ftp.freebsd.org.
220 ftp.FreeBSD.org NcFTPd Server (licensed copy) ready.
Name (ftp.freebsd.org:btman): anonymous
331 Guest login ok, send your complete e-mail address as password.
Password:
230-You are user #113 of 1000 simultaneous users allowed.
230-
230 Logged in anonymously.
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> ls
502 Unimplemented command.
227 Entering Passive Mode (62,243,72,50,247,103)
150 Data connection accepted from 12.104.153.15:4481; transfer starting.
drwxr-xr-x   3 ftpuser  ftpusers       512 Oct 12 09:27 pub
drwxr-xr-x   3 ftpuser  ftpusers       512 Oct 12 10:48 sup
226 Listing completed.
ftp> cd pub/FreeBSD/tools
250 "/pub/FreeBSD/tools" is new cwd.
ftp> get gunzip.exe
local: gunzip.exe remote: gunzip.exe
227 Entering Passive Mode (62,243,72,50,245,41)
150 Data connection accepted from 12.104.153.15:4542; transfer starting for gunzip.exe
   (37178 bytes).
100% |*************************************| 37178      42.41 KB/s    00:00
226 Transfer completed.
37178 bytes received in 00:00 (42.38 KB/s)
ftp> bye
221 Goodbye.
#
```

If you would rather work with a graphical FTP client in X11, several GUI-based FTP client applications are available in the `ftp` category, including several that integrate with KDE (such as Kasablanca) and several that work under any desktop (such as `ftpcube`), and some that operate equally well in both modes (such as `gftp`). These full-featured FTP clients generally support SSL/TLS encryption, multiple threads, site management (bookmarks), and drag-and-drop file transfers. As convenient and user-friendly as these applications are, though, most UNIX users still fall back on the trusty CLI FTP client for all their day-to-day file-transferring needs.

Email Applications

Email was one of the earliest applications for the Internet, and it's still the most popular and necessary. There is no shortage of email clients available for FreeBSD, of both the CLI and GUI varieties. As a FreeBSD administrator, you'll need to install email client applications not just for yourself, but for any users you might allow to use your systemthey might choose to use a command-line email client like Pine right on the FreeBSD server instead of a GUI-based client on their Windows machines. This section will look at some of the more popular email clients available both for the shell and for X11.

Tip

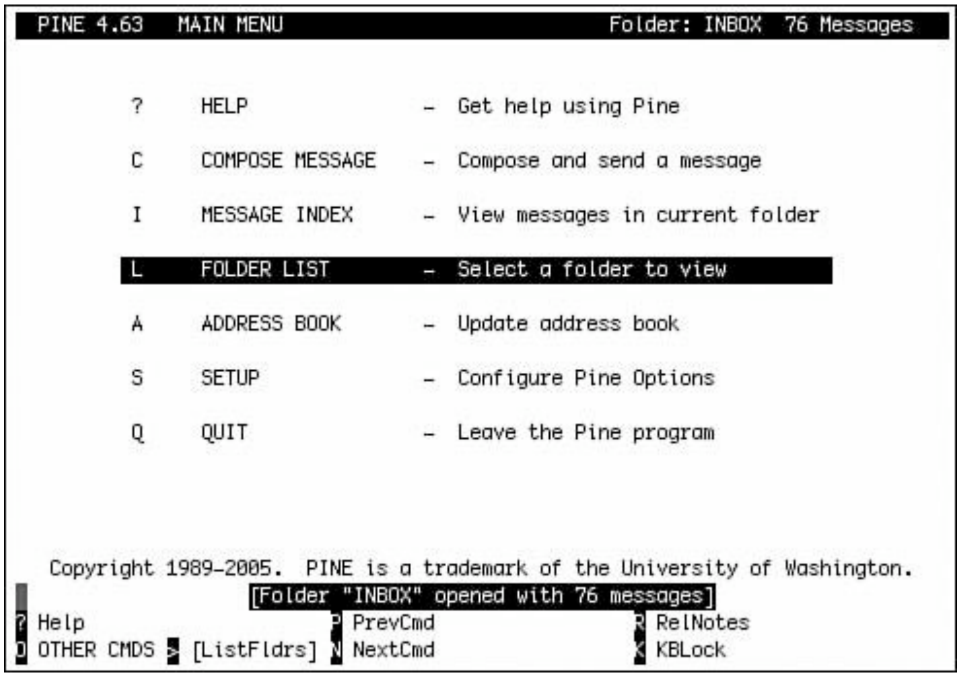
In addition to having an Internet connection configured and working properly, you will also need to have a Mail Transfer Agent (MTA) such as Sendmail configured and working properly before you can use some of these email clients. In addition, if you need to retrieve your mail from a POP3 or IMAP server at your ISP, you will also need to have Fetchmail configured. Not all the clients listed here will require this because some can transfer mail on their own; but if you're ambitious and a UNIX purist, you might still choose to use Fetchmail in concert with a local MTA. This setup allows much greater flexibility in dealing with email because it uses FreeBSD's native mail-handling system, allowing the shell or utilities such as `xbiff` to notify you when you have new email. These features will not work if you use the mail client's built-in mail-handing functions. See Chapter 25, "Configuring Email Services," for details on how to set up and configure FreeBSD to send and receive email.

Pine

Pine is a text-based email and news client that was designed with nontechnical UNIX users (for example, university students) in mind. Because of its comparative ease of use and the fact that it's shell-based, any number of remote users who log in on a remote terminal can efficiently manage their email without having to maintain any heavyweight email client applications on their own computers.

Pine is available in the FreeBSD ports or packages in the `mail` category. Figure 6.14 shows the main menu of Pine.

Figure 6.14. Pine is menu-driven and can be navigated with the arrow keys or by pressing the letter in front of any menu entry.



```
  PINE 4.63   MAIN MENU                         Folder: INBOX  76 Messages


          ?     HELP               -  Get help using Pine

          C     COMPOSE MESSAGE    -  Compose and send a message

          I     MESSAGE INDEX      -  View messages in current folder

          L     FOLDER LIST        -  Select a folder to view

          A     ADDRESS BOOK       -  Update address book

          S     SETUP              -  Configure Pine Options

          Q     QUIT               -  Leave the Pine program



   Copyright 1989-2005.  PINE is a trademark of the University of Washington.
                         [Folder "INBOX" opened with 76 messages]
? Help                     P PrevCmd                R RelNotes
O OTHER CMDS > [ListFldrs] N NextCmd                K KBLock
```

Unfortunately, Pine has a reputation of being poorly programmed and having a lot of security problems. Although all the known problems have currently been fixed, many security experts believe that there are many more security holes in Pine that have not yet been discovered. Some even place the likely number of undiscovered holes in the thousands. You will also be warned of these potential security issues with Pine when you install the port. If you do decide to make Pine available to your users, you should make sure your users are aware of the potential security hazards involved in using Pine.

If security is a high-level concern on your system (for example, if you have confidential data on the system that these users have access to), it is probably best to forbid the use of Pine altogether (in other words, don't install Pine, or uninstall it if it is already installed). Your users may have fits, but in some situations, security may be more important than user convenience. Other mail programs are available that your users can use (one popular alternative, Mutt, is discussed in the next section). Although they may not be as easy to use as Pine, these programs are generally much more secure.

Caution

Although it is generally a bad idea to open any email while logged in as root, it is even more so with Pine. This is because of the nature of some of the potential holes in Pine that might allow someone to execute arbitrary code on your system as the user running Pine simply by sending a maliciously corrupted email header to that user (even root). It is a much better idea to forward root's mail to a normal user account and then read the email using that account instead. Instructions on email forwarding can be found in Chapter 25.

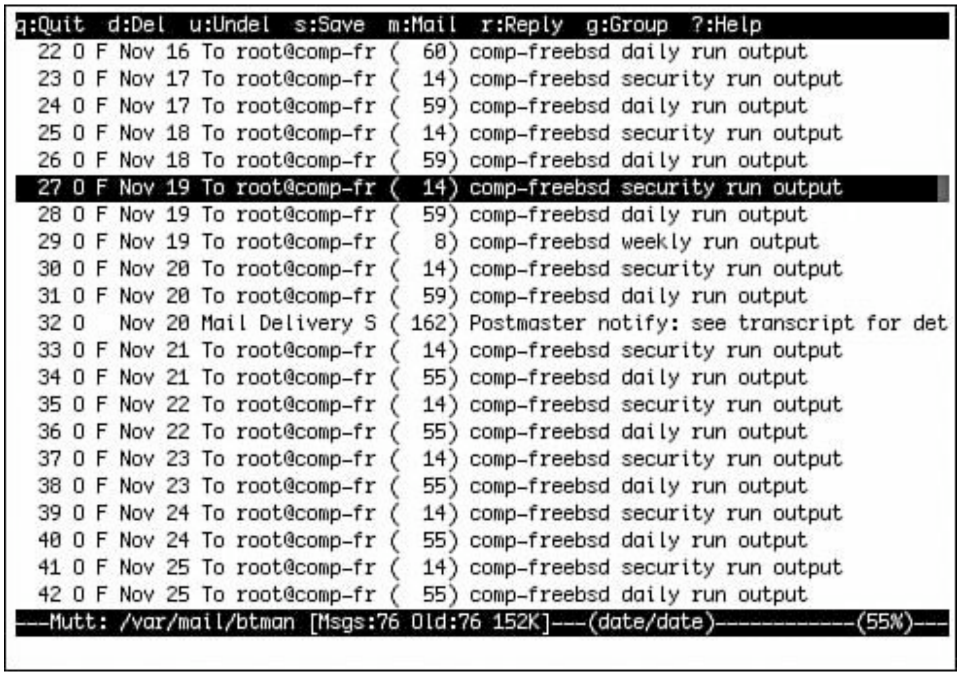
Tip

You might not want to use Pine for email, but there's still an excellent reason to install it: it comes with the `pico` text editor, which is Pine's internal mechanism for message composition but also included as a separate program. Many users choose `pico` over `ee`, `vi`, or any other CLI text editor, for its straightforward and efficient keystroke-driven interface and its handy auto-justification function.

Mutt

Mutt is another text-based email client for FreeBSD and other UNIX-like operating systems. It is available in the FreeBSD ports or packages in the `mail` category. Figure 6.15 shows the main screen of Mutt.

Figure 6.15. Although it does not have the simple menu-driven interface of Pine, Mutt is much more secure than Pine and is also more configurable.



```
q:Quit  d:Del  u:Undel  s:Save  m:Mail  r:Reply  g:Group  ?:Help
  22 O F Nov 16 To root@comp-fr (  60) comp-freebsd daily run output
  23 O F Nov 17 To root@comp-fr (  14) comp-freebsd security run output
  24 O F Nov 17 To root@comp-fr (  59) comp-freebsd daily run output
  25 O F Nov 18 To root@comp-fr (  14) comp-freebsd security run output
  26 O F Nov 18 To root@comp-fr (  59) comp-freebsd daily run output
  27 O F Nov 19 To root@comp-fr (  14) comp-freebsd security run output
  28 O F Nov 19 To root@comp-fr (  59) comp-freebsd daily run output
  29 O F Nov 19 To root@comp-fr (   8) comp-freebsd weekly run output
  30 O F Nov 20 To root@comp-fr (  14) comp-freebsd security run output
  31 O F Nov 20 To root@comp-fr (  59) comp-freebsd daily run output
  32 O   Nov 20 Mail Delivery S ( 162) Postmaster notify: see transcript for det
  33 O F Nov 21 To root@comp-fr (  14) comp-freebsd security run output
  34 O F Nov 21 To root@comp-fr (  55) comp-freebsd daily run output
  35 O F Nov 22 To root@comp-fr (  14) comp-freebsd security run output
  36 O F Nov 22 To root@comp-fr (  55) comp-freebsd daily run output
  37 O F Nov 23 To root@comp-fr (  14) comp-freebsd security run output
  38 O F Nov 23 To root@comp-fr (  55) comp-freebsd daily run output
  39 O F Nov 24 To root@comp-fr (  14) comp-freebsd security run output
  40 O F Nov 24 To root@comp-fr (  55) comp-freebsd daily run output
  41 O F Nov 25 To root@comp-fr (  14) comp-freebsd security run output
  42 O F Nov 25 To root@comp-fr (  55) comp-freebsd daily run output
---Mutt: /var/mail/btman [Msgs:76 Old:76 152K]---(date/date)------------(55%)---
```

Mutt got its name because it is known as "the mongrel of mail clients." This is because it is a relatively new mail client that attempts to combine the best features of Elm (a very old email client that is not widely used anymore) and Pine (which was designed to be much easier to use than Elm). Mutt has many users who would agree that the client successfully fulfills these goals.

Mutt is a very complex program with a rich set of features, and it's still under active development today. Its use and configuration is beyond the scope of this book. The Mutt website, located at www.mutt.org, has very good online documentation and reference manuals that explain the use and configuration of this powerful program.

`uuencode` and `uudecode`

A brief word on `uuencode` and `uudecode` is in order here. `uuencode` (UNIX-to-UNIX Encode) is a method of converting binary files to plain-text so that they can be sent through email, because SMTP (the Internet's standard mail delivery protocol) can only handle plain-text data. Without `uuencode` and other forms of encapsulation of binaries, email with attachments or included images wouldn't be possible.

Often, the email client will handle encoding and decoding of the attachments automatically; Pine, for instance, will detect attached files and present them as links so you can save them directly instead of making you decode them yourself. However, it doesn't always work out quite so well. Sometimes, you may receive an email that has an attachment that the mail client doesn't decode properly, and it appears as several hundred lines of what appears to be garbage text. It will look something like the following:

```
begin 644 gunzip.exe
M35HZ`4D````"`.I6___/6H`````.`,4('````$Q:.3'_\8X&W"<F_S9(`/M&
M`'_XN&\#'E"X9"+[F@(%FO__!X/$#,N058OL@^P$N"0'B7^,1OR,7OZX!`?=
M#B;_^\7X#A3HQ?@*%`[HH?_K'\(AD,1>_(/&!-MW<.,"_#>X(-GX#@S@)O]W
MBP<F"T<"==2+Y5W+D/V4`U-KD/U8SV*0^!%HD/@/E/@1=*<6E/@?N'C>@J/X
M$8BC^`\H]7#NGONEY/@.$+C>ML'N^`X(N,_N^!#A[O@0Z^[X$/)=_^[X$/CN
M^!`#".[X#E[U"E=6QT;Z$!\`107?C48(%L-'^P;[FE(#QP4&",,@WB"C/B&)
```

These are what the first several lines of a uuencoded file may look like. The `begin` line contains the name of the file that this file will be saved to when uudecoded.

To decode the file, save the attachment (or email message) that contains the garbage text to a file in the directory where you want to decode it. For example, suppose you save the file as `program.txt`. You can now use the following command to decode the file:

```
# uudecode program.txt
```

This will decode the file and write the contents to whatever filename is given in the encoding. In this example, the command would produce an output file called `gunzip.exe`.

If you need to encode a file, you can do so with a command like the following (assume that the file you want to encode is called `gunzip.exe`):

```
# uuencode gunzip.exe gunzip.exe > gunzip.txt
```

The three arguments in the preceding command are the name of the file you want to encode (in this case `gunzip.exe`), the name of the output file that should be produced when the file is decoded (usually this will be the same as the input file, as in this example), and a redirect of the output to a file called `gunzip.txt`, which will contain the encoded file. The `>` character tells the shell to redirect the output to whatever destination is on the right side of it. If you do not do this, the output will be sent to the screen instead. This allows the output to be piped directly into a mail program, for example, if you want to send the encoded file to someone, as in this example:

```
# uuencode gunzip.exe gunzip.exe | mail -s "Here's that program you wanted"
asmith@somewhere.com
```

See Chapter 8 for more information on input/output redirection and pipes.

Tip

Other kinds of encoding, such as Base64, are even more common than `uuencode` these days. If you receive a Base64-encoded file in email, you might need another program such as UUDeview (available in the `converters` section of the ports or packages) to decode it.

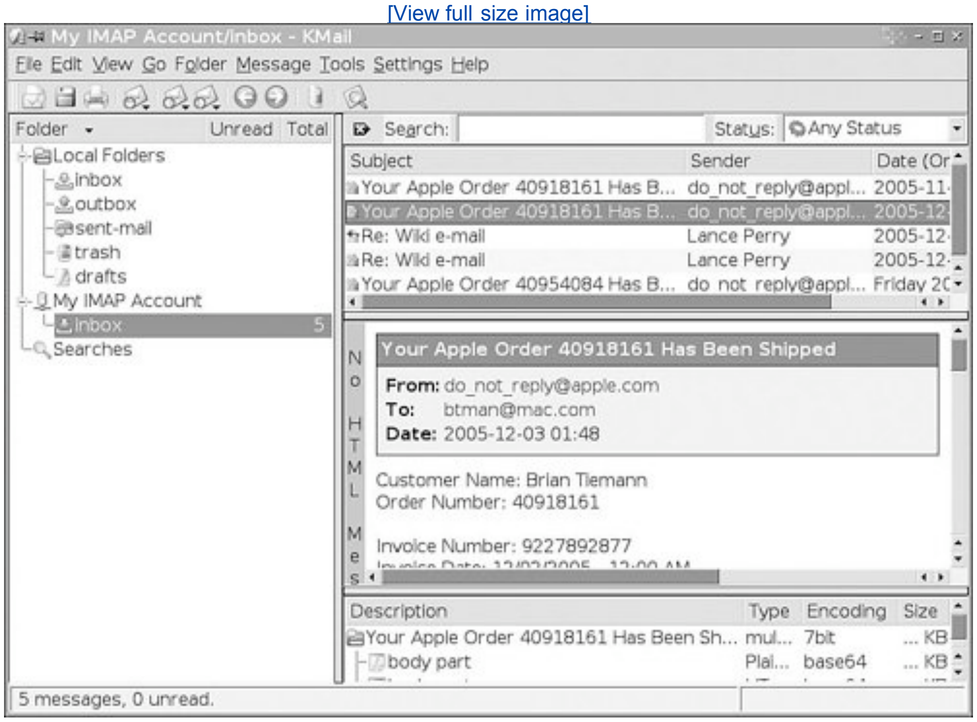
GUI Email Clients

With the rise of modern full-featured email clients for Windows and Mac OS X that get their mail through POP or IMAP, it's inevitable that these kinds of applications would eventually come to the correspondingly full-featured desktop environments of KDE and GNOME. If you want such features as spam control, address-book integration, WYSIWYG message composition, graphical attachments, drag-and-drop folder interaction, multiple accounts and identities, message filtering rules, and other such modern niceties, a graphical email client is a must.

If you're using your FreeBSD machine as a workstation and you have a POP or IMAP account from which you're accustomed to getting your email, there are several options available to you, depending on your choice of desktop. KDE users will want to use KMail, as shown in Figure 6.16. GNOME users can use the built-in Evolution, or might opt for Balsa, a third-party application that must be installed separately, but which is designed with GNOME in mind. Finally, Thunderbird, the email client developed in tandem with Firefox and by the same people, is an excellent and full-featured choice for users of any desktop environment.

Figure 6.16. KMail, a full-featured and modern email client for KDE.

[View full size image]



Subject	Sender	Date (Or
Your Apple Order 40918161 Has B...	do_not_reply@appl...	2005-11
Your Apple Order 40918161 Has B...	do_not_reply@appl...	2005-12
Re: Wiki e-mail	Lance Perry	2005-12
Re: Wiki e-mail	Lance Perry	2005-12
Your Apple Order 40954084 Has B...	do_not_reply@appl...	Friday 20

Your Apple Order 40918161 Has Been Shipped

From: do_not_reply@apple.com
To: btman@mac.com
Date: 2005-12-03 01:48

Customer Name: Brian Tiemann
Order Number: 40918161

Invoice Number: 9227892877

Description	Type	Encoding	Size
Your Apple Order 40918161 Has Been Sh...	mul...	7bit	... KB
body part	Plai...	base64	... KB

PREV NEXT

PREV NEXT

Working with Java Applications

For a full-featured web experience, and in order to use many cross-platform applications, you'll likely want to install Java. This "virtual machine" programming environment created by and licensed from Sun Microsystems is distributed free of charge through the FreeBSD Foundation website (http://www.freebsdfoundation.org/downloads/java.shtml) and can be installed using the pkg_add command after downloading each appropriate file, as follows:

```
# pkg_add diablo-jdk-freebsd6-1.5.0.06.00.tbz
# pkg_add diablo-jre-freebsd6-1.5.0.06.00.tbz
```

The FreeBSD ports collection includes a whole `java` category full of applications and programming utilities that you can use within the Java environment that results from this installation, and web pages that include Java programs will work as intended.

As of this writing, the latest stable release of the Java Development Kit (JDK) and Java Runtime Library for FreeBSD is 1.5. If you need earlier versions (for compatibility, for example), you can install the ports named `jdk15` (or `jdk14` or `jdk13`), which predate the official license agreement between the FreeBSD Foundation and Sun, and therefore are based on a much more cumbersome installation procedure than is possible with the official JDK/JRE 1.5 release. Most users will want to stick with the official licensed software from the FreeBSD Foundation rather than mess with the earlier ports.

Note

The Java compiler is itself written in Java, making it possible for you to write Java applications on any platform that has the JDK/JRE installed on it, including FreeBSD.

Installing Java Applications

Many Java applications aren't included in the ports collection. However, because Java applications by their very nature are portable and binary-compatible, you can install and run in FreeBSD any application written in Java, without having to compile it. Installation procedures vary depending on the application, so refer to the `README` files and other documentation that came with the application for instructions.

Java applications sometimes come as compressed Java archives. These archives have a `.jar` extension. You can uncompress Java archives by typing **`java -jar`** followed by the name of the compressed file.

Running Java Applications

Java applications need to be run with the aid of the Java Runtime Engine. To start a Java application, invoke the `java` program followed by the name of a Java class file. Many applications contain multiple class files, but the documentation that comes with the application will tell you which class file to start. Java class files have a `.class` extension.

Sometimes Java applications come in a compressed format. These applications can be run in their compressed form and uncompressed on the fly. In this situation, the Java interpreter should be invoked with the `-jar` option.

Note

A detailed discussion of Java is beyond the scope of this book. For more information on Java, visit the Java website at http://java.sun.com. If you are interested in learning Java programming, many good books are available on the market today, including *Sams Teach Yourself Java 2 in 21 Days*.

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Chapter 7. Advanced X11 Configuration

IN THIS CHAPTER

Chapter 4, "Booting and Shutting Down FreeBSD," Chapter 5, "Working with the X Window System," and Chapter 6, "Working with Applications," discussed some basics of the X Window System (X11). X11 is a very powerful server framework that can do much more than provide the basic desktop functionality that has been covered so far. Depending on your computing environment, you might find yourself needing to take advantage of the versatility and advanced features for which X11 was originally designed, such as in a clustered computing deployment where a central X11 server displays windows on remote client computers over the network. Similarly, if you have multiple UNIX users in a cluster or sharing a single computer, each one needs to be able to configure her X11 session to her own liking, using the X11 configuration files that each user can configure. This chapter looks at these and other advanced features of X11, starting with techniques for optimizing the graphical performance of your video card and display hardware.

Configuring X11 with the `xorgconfig` Script

During the initial setup of FreeBSD you performed in Chapter 2, "Installing FreeBSD," you used the full-screen `xorgcfg` program to set up a basic hardware configuration for your X11 server. Because of the variety of video cards and displays in the world today, and because X11 configuration is in many ways more art than science, it's entirely possible that `xorgcfg` alone was not able to get X11 set up properly for your computer. Perhaps you couldn't get X11 to run at any higher resolution than 640x480, or perhaps you can't do any better than 8-bit color (256 colors). Perhaps you couldn't find an appropriate video driver in the `xorgcfg` database, and you had to guess. Or, perhaps, X11 won't start at all, and keeps cycling between several flickery or unstable graphics modes and never finds one that's stable.

There's another configuration script in Xorg that might help: `xorgconfig`. This tool is a linear script that asks you a series of questions and configures X11 based on the answers you provide; it's more difficult to use than `xorgcfg`, and much of it seems to duplicate the questions `xorgcfg` asks, but it does have a significantly better set of video chipsets and drivers from which to choose, and it might do a better job recommending an appropriate combination of refresh rates and color depths for your hardware.

Caution

Improper use of this tool when configuring video settings could actually cause physical damage to your hardware. Although most modern monitors have built-in protection circuits and will shut themselves down if you try to drive them with a refresh rate higher than they support, some monitors will try to display the screen at the specified refresh rate, even if the monitor's hardware is not capable of handling it. The result could destroy your monitor.

Caution

The `xorgconfig` program will overwrite your existing `xorg.conf` file. If you have a working `xorg.conf` file and you want to experiment with a new configuration, you should back up your existing file first. The file is located in `/etc/X11/xorg.conf`. Make a copy of this file to `/etc/xorg.conf.bak` (or some similar name) before continuing. This way, you can restore your previous configuration easily if your new configuration does not work by simply copying the backup file back to `/etc/X11/xorg.conf`.

You will need to be root to use this program. As the root user, type **`xorgconfig`** at the command prompt and press Enter. You will see a screen like the following:

```
This program will create a basic xorg.conf file, based on menu selections you
make.

The xorg.conf file usually resides in /usr/X11R6/etc/X11 or /etc/X11. A sample
xorg.conf file is supplied with Xorg; it is configured for a standard
VGA card and monitor with 640x480 resolution. This program will ask for a
pathname when it is ready to write the file.

You can either take the sample xorg.conf as a base and edit it for your
configuration, or let this program produce a base xorg.conf file for your
configuration and fine-tune it.
Before continuing with this program, make sure you know what video card
you have, and preferably also the chipset it uses and the amount of video
memory on your video card. SuperProbe may be able to help with this.
```

```
Press enter to continue, or ctrl-c to abort.
```

After you have read the information, simply press Enter to continue. The first thing you will be asked to configure is your mouse.

Caution

Double-check your typing when entering values in `xorgconfig`. The program is not very forgiving of mistakes and typos. If you accidentally make a wrong entry and don't catch it before you have pressed Enter, there is no way to back up and fix it. You will have to press Ctrl+C to exit the program and then start over again completely.

Configuring the Mouse

Caution

PS/2 mice are notoriously finicky in many ways. A common problem is that the motherboard and operating system won't recognize a mouse that you plug in after the machine has been booted; but a more serious risk is that the motherboard might short out if you unplug the mouse while the machine is running. Always be sure to have all your non-USB devices plugged in before booting the computer, and leave them connected for the duration.

The mouse-configuration screen of `xorgconfig` looks like this:

```
First specify a mouse protocol type. Choose one from the following list:

 1. Auto
 2. SysMouse
 3. MouseSystems
 4. PS/2
 5. Microsoft
 6. Busmouse
 7. AceCad
 8. GlidePoint
 9. IntelliMouse
10. Logitech
11. MMHitTab
12. MMSeries
13. MouseMan
14. ThinkingMouse
The recommended protocol is Auto. If you have a very old mouse
or don't want OS support or auto detection, and you have a two-button
or three-button serial mouse, it is most likely of type Microsoft.

Enter a protocol number:
```

Simply enter the number representing the type of mouse you have and press Enter. In most circumstances, and with most standard PS/2 or USB mice, selecting 1 (Auto) is the best solution, especially if you were able to get your mouse working using the Auto setting in Sysinstall or `xorgcfg`. If you weren't, here are some guidelines for determining what type of mouse you have:

- If your mouse has a nine-pin, D-shaped connector where it plugs into your computer, it is a serial mouse. Use either 3, 5, 10, or 13. Note that most serial mice will work with either 3 or 5 and that all newer Logitech mice will use either 5 or 13. Option 10 is only for extremely old Logitech mice. (Do yourself a favor and spend 15 bucks on a modern PS/2 mouse.)
- If your mouse has a small round connector that plugs in next to the keyboard plug, it is a PS/2 mouse. Any PS/2 mouse should use option 4. Even if you have a Microsoft mouse, you should use 4 if it has a PS/2 connector. The Microsoft mice options listed are only for serial mice.
- If you are installing FreeBSD on a laptop or notebook computer, the built-in pointing device will probably work with option 4 because it is most likely running on an internal PS/2 port. This includes touchpads and trackpoint-style pointing devices.

After you have entered the number for the type of mouse you have and pressed Enter, you will be asked the following:

```
If your mouse has only two buttons, it is recommended that you enable
Emulate3Buttons.

Please answer the following question with either 'y' or 'n'.
Do you want to enable Emulate3Buttons?
```

The first line of this message really should read "If your mouse has only two buttons, it is *required* (rather than *recommended*) that you enable Emulate3Buttons." Most window managers in X11 make use of all three buttons on the mouse, and some (such as Window Maker) depend on the middle button for accessing important menus. If you have a two-button mouse, you need to answer Y here; doing so will cause clicking both mouse buttons at the same time to emulate clicking the middle button on a three-button mouse.

You will then be asked to give the name of the device the mouse is on:

```
Now give the full device name that the mouse is connected to, for example
/dev/tty00. Just pressing enter will use the default, /dev/sysmouse.

Mouse device:
```

If you selected Auto for the mouse type, or if you were able to use your mouse properly when configuring it in Sysinstall or `xorgcfg`, just press Enter here to use the default system mouse driver. Otherwise, unless you have symlinked the actual device your mouse is on to `/dev/sysmouse`, you will need to enter the name of that device here. Table 7.1 shows guidelines on what you should enter, depending on what type of mouse you have.

Table 7.1. Device Names for Various Mouse Types

Mouse Type	Mouse Device
PS/2 mouse (or laptop)	`/dev/psm0`
Serial mouse on COM 1	`/dev/cuad0`
Serial mouse on COM 2	`/dev/cuad1`
Serial mouse on COM 3	`/dev/cuad2`
Serial mouse on COM 4	`/dev/cuad3`
Bus mouse	`/dev/mse0`

Enter the corresponding mouse device name at the prompt and then press Enter.

Selecting the Keyboard

The next screen will ask you to select the type of keyboard you have:

```
Please select one of the following keyboard types that is the better
description of your keyboard. If nothing really matches,
choose "Generic 104-key PC"

  1  Generic 101-key PC
  2  Generic 102-key (Intl) PC
  3  Generic 104-key PC
  4  Generic 105-key (Intl) PC
  5  Dell 101-key PC
  6  Everex STEPnote
  7  Keytronic FlexPro
  8  Microsoft Natural
  9  Northgate OmniKey 101
 10  Winbook Model XP5
 11  Japanese 106-key
 12  PC-98xx Series
 13  Brazilian ABNT2
 14  Acer AirKey V
 15  ACPI Standard
 16  Azona RF2300 wireless Internet Keyboard

Enter a number to choose the keyboard.
```

Tip

On some systems, you might not be able to see the top part of the keyboard list. If this is the case, you will need to press Enter several times until you have cycled through the entire list and returned to the beginning.

Notice that although only 16 keyboard types are immediately visible, there are actually 93 specific keyboard models listed in `xorgconfig` at the time of this writing, and the list of available keyboard layouts is too long to fit on one screen. Press Enter to see the next screenful of layouts. If you press Enter again at the end of the list, the display returns to the beginning of the list.

If you have a U.S. keyboard, select 1 or 3 here and press Enter. You will then be asked to select the layout by language:

```
  1  U.S. English
  2  U.S. English w/ ISO9995-3
  3  U.S. English w/ deadkeys
  4  Albanian
  5  Arabic
  6  Armenian
  7  Azerbaijani
  8  Belarusian
  9  Belgian
 10  Bengali
 11  Bosnian
 12  Brazilian
 13  Bulgarian
 14  Burmese
 15  Canadian
 16  French Canadian
 17  Croatian
 18  Croatian (US)
```

```
Enter a number to choose the country.
```

Again, press Enter to scroll through the 90 available region-specific layouts. U.S. users will likely want to choose 1. You're then asked the following:

```
Please enter a variant name for 'us' layout. Or just press enter
for default variant
```

There's generally no need to enter anything special here; just press Enter to proceed to the next question:

```
Please answer the following question with either 'y' or 'n'.
Do you want to select additional XKB options (group switcher,
group indicator, etc.)?
```

Enter N here unless you want to remap some keys. If you do want to remap some keys (or you just want to see what remapping options are available), press Y. This action presents a couple of menus in which you can do various things, such as make the Caps Lock key into a Ctrl key (useful for Emacs gurus) or swap the Caps Lock key with the Ctrl key. Enter the number of an option you want to perform and then press Enter. If you want to exit the menu without doing anything, simply press Enter without selecting a number first.

Configuring the Monitor

In this section of the configuration program, you configure various aspects of your monitor, including the horizontal and vertical refresh rates.

Caution

The next few questions in the configuration are the parts that could potentially damage your monitor if you don't configure them correctly. Make sure you do not select frequency ranges higher than your monitor can support. Consult your monitor documentation for more information on the refresh rates that your monitor can support.

You first see this screen:

```
Now we want to set the specifications of the monitor. The two critical
parameters are the vertical refresh rate, which is the rate at which
the whole screen is refreshed, and most importantly the horizontal sync rate,
which is the rate at which scanlines are displayed.

The valid range for horizontal sync and vertical sync should be documented
in the manual of your monitor.

Press enter to continue, or ctrl-c to abort.
```

Press Enter at this message to continue. If you haven't done so already, take this opportunity to locate the manual for your monitor (or look up its specifications online) and determine its vertical and horizontal sync ranges. Even LCD monitors have sync frequencies. One excellent resource for finding the specifications of popular monitors from all manufacturers is located at http://www.monitorworld.com/Monitors/.

Tip

If you can't find the sync information in your monitor's manual, and you can't find an entry in the MonitorWorld.com database, there's one more method you can try. If you've used this monitor in Windows, or if you can hook it up to a Windows machine, you can determine the refresh rate by looking at the Display Properties panel; select the Settings tab, click Advanced, and then click the Monitor tab to see what refresh rates Windows knows about for your monitor.

When you've found what your monitor's horizontal sync range is, look it up in the list presented by the script:

```
You must indicate the horizontal sync range of your monitor. You can either
select one of the predefined ranges below that correspond to industry-
standard monitor types, or give a specific range.

It is VERY IMPORTANT that you do not specify a monitor type with a horizontal
sync range that is beyond the capabilities of your monitor. If in doubt,
choose a conservative setting.

    hsync in kHz; monitor type with characteristic modes
 1  31.5; Standard VGA, 640x480 @ 60 Hz
 2  31.5 - 35.1; Super VGA, 800x600 @ 56 Hz
 3  31.5, 35.5; 8514 Compatible, 1024x768 @ 87 Hz interlaced (no 800x600)
 4  31.5, 35.15, 35.5; Super VGA, 1024x768 @ 87 Hz interlaced, 800x600 @ 56 Hz
 5  31.5 - 37.9; Extended Super VGA, 800x600 @ 60 Hz, 640x480 @ 72 Hz
 6  31.5 - 48.5; Non-Interlaced SVGA, 1024x768 @ 60 Hz, 800x600 @ 72 Hz
 7  31.5 - 57.0; High Frequency SVGA, 1024x768 @ 70 Hz
 8  31.5 - 64.3; Monitor that can do 1280x1024 @ 60 Hz
 9  31.5 - 79.0; Monitor that can do 1280x1024 @ 74 Hz
10  31.5 - 82.0; Monitor that can do 1280x1024 @ 76 Hz
11  Enter your own horizontal sync range

Enter your choice (1-11):
```

If you know the exact horizontal frequency range that your monitor can support, select 11 to enter the range manually. Otherwise, select a predefined range that *does not exceed* the range you know your monitor is capable of. In other words, make sure you select a *narrower* range than you know the monitor can handle, to ensure you won't be pushing it beyond its limits.

After you have selected one of the predefined entries or entered your monitor's horizontal sync range, press Enter to move to the next screen, where you will be asked to set the vertical refresh rate:

```
You must indicate the vertical sync range of your monitor. You can either
select one of the predefined ranges below that correspond to industry-
standard monitor types, or give a specific range. For interlaced modes,
the number that counts is the high one (e.g. 87 Hz rather than 43 Hz).

 1  50-70
 2  50-90
 3  50-100
 4  40-150
 5  Enter your own vertical sync range

Enter your choice:
```

Once again, it is very important that you do not select a refresh rate higher than your monitor can handle; otherwise, you may cause damage to your monitor. If you know the vertical refresh rate for your monitor, select 5 and then enter the refresh range for your monitor. Otherwise, you can select one of the first four predefined ranges, again making sure it doesn't exceed the range you know the monitor can handle from its experience with Windows. Press Enter after you have made your selection to continue on to the next screen:

```
You must now enter a few identification/description strings, namely an
identifier, a vendor name, and a model name. Just pressing enter will fill
in default names.
```

```
The strings are free-form, spaces are allowed.
Enter an identifier for your monitor definition:
```

This is the information that will show up in the `xorg.conf` file that the program will generate after you have finished entering all the values. All you're doing here is defining some labels to help you decipher the option blocks in the configuration file; the names don't have to conform to any particular standard. You can just press **Enter** here to let `xorgconfig` use default names such as `My Monitor`.

Configuring the Video Card

Next, you will be given some information about configuring the video card. Press Y after you have read the informational screen; this gives you access to Xorg's complete card database. It will look like the following:

```
 0  * Generic VESA compatible                          -
 1  * Generic VGA compatible                           -
 2  * Unsupported VGA compatible                       -
 3  ** 3DLabs, TI (generic)             [glint]        -
 4  ** 3Dfx (generic)                   [tdfx]         -
 5  ** ATI (generic)                    [ati]          -
 6  ** ATI Radeon (generic)             [radeon]       -
 7  ** ATI Rage 128 based (generic)     [r128]         -
 8  ** Alliance Pro Motion (generic)    [apm]          -
 9  ** Ark Logic (generic)              [ark]          -
10  ** Chips and Technologies (generic) [chips]        -
11  ** Cirrus Logic (generic)           [cirrus]       -
12  ** Cyrix MediaGX (generic)          [cyrix]        -
13  ** DEC TGA (generic)                [tga]          -
14  ** Intel i740 (generic)             [i740]         -
15  ** Intel i810 (generic)             [i810]         -
16  ** Linux framebuffer (generic)      [fbdev]        -
17  ** Matrox Graphics (generic)        [mga]          -
Enter a number to choose the corresponding card definition.
Press enter for the next page, q to continue configuration.
```

Once again, there are far more cards listed in the database than can fit on one screen566 at the time of this writing. Press Enter to get to the next page. When you reach the end of the list, pressing Enter will start the list over at the first page.

If you can't find your exact video card make and model number in this list, simply press Q to quit. Don't select a model just because its name sounds familiarmodels that have similar names do not necessarily have similar hardware or capabilities. However, the beginning of the list contains nearly 30 "generic" video drivers that you can select if your specific model isn't listed. For example, if you have an ATI Radeon 9200, and that particular ATI card model isn't in the list, simply scroll to the beginning of the list and choose option 6, which is a generic driver for all Radeon cards. If all else fails, choose option 0 or 1 to select a generic VESA or VGA driverit won't have a lot of capabilities, but it will be almost sure to work.

If you do find the make and model of your video card in the list, enter its number and then press Enter. You will then receive information about the video card you selected. Here's an example:

```
Your selected card definition:

Identifier: Matrox Millennium G400
Chipset:    mgag400
Driver:     mga
Do NOT probe clocks or use any Clocks line.

Press enter to continue, or ctrl-c to abort.
```

After you press Enter to continue, you are asked to give some more information about your video card, starting with the amount of RAM it contains:

```
Now you must give information about your video card. This will be used for
the "Device" section of your video card in xorg.conf.

It is probably a good idea to use the same approximate amount as that detected
by the server you intend to use. If you encounter problems that are due to the
used server not supporting the amount memory you have, specify the maximum
amount supported by the server.

How much video memory do you have on your video card:

 1  256K
 2  512K
 3  1024K
 4  2048K
 5  4096K
 6  Other
 6  8192K
 7  16384K
 8  32768K
 9  65536K
10  131072K
11  262144K
12  Other

Enter your choice:
```

The amount of video memory defines the resolution and color bit depth that your card will be able to support. Be sure you know the correct amount of video RAM available on your card; if you set this value too low, you won't be able to use some of the higher-resolution modes or take advantage of full color depthbut if you set it too high, X11 might try to set the card to a mode that it can't support. This won't damage the card, but it will take extra time each time you start X11 as it tries the invalid mode and falls back to a less ambitious one.

Most modern video cards have 32MB or more of video RAM; this is enough so that 24-bit color (16.7 million colors) is possible even at the highest resolutions. The `xorgconfig` script lets you directly specify as much as 262144KB, which corresponds to 256MB of video RAM. If you know you have a different amount from any of the listed options, choose 12 and specify the number manually. Remember to use kilobytes; multiply the number of megabytes by 1,024 to get the number of kilobytes to enter.

Press Enter to continue on to the next screen:

```
You must now enter a few identification/description strings, namely an
identifier, a vendor name, and a model name. Just pressing enter will fill
in default names (possibly from a card definition).

Your card definition is Matrox Millennium G400.

The strings are free-form, spaces are allowed.
Enter an identifier for your video card definition:
```

If you selected a video card type from the card list, there will already be a suggested identification/description string listed here. I suggest that you accept the default that is given. If you couldn't find your card in the list, enter a brief description of your video card here and then press Enter.

Depending on whether or not you selected a card definition from the database, you will be presented with a different set of questions. Read the appropriate upcoming section, depending on whether you did or did not select a card definition from the database.

Selecting a Card from the Database and Saving the Configuration File

If you selected a card definition from the database list, you will be presented with a menu of currently configured video modes. The following shows an example of what this might look like:

```
For each depth, a list of modes (resolutions) is defined. The default
resolution that the server will start-up with will be the first listed
mode that can be supported by the monitor and card.
Currently it is set to:

"1280x1024" "1024x768" "800x600" "640x480" for 8-bit
"1280x1024" "1024x768" "800x600" "640x480" for 16-bit
"1280x1024" "1024x768" "800x600" "640x480" for 24-bit

Modes that cannot be supported due to monitor or clock constraints will
be automatically skipped by the server.

 1  Change the modes for 8-bit (256 colors)
 2  Change the modes for 16-bit (32K/64K colors)
 3  Change the modes for 24-bit (24-bit color)
 4  The modes are OK, continue.

Enter your choice:
```

You will probably want to make some changes here because, by default, X11 will start up in a resolution of 640x480, which is so small as to be virtually unusable. If you have a 17-inch monitor, you will probably want to go with at least 1024x768, and you may want to go even higher, depending on your needs. You'll be able to edit these settings at any time to adjust your display's resolution after you've used X11 enough to know how much screen real estate you'll need.

Tip

Of course, if you have an LCD monitor, you'll want to disable all video resolutions except for your monitor's native resolution. LCD monitors in interpolated resolutions usually look pretty bad.

You will also want to decide what color depth to use. As a general rule, the higher the color depth, the better. If you have a small amount of video RAM, though, color depth and resolution may be a tradeoff. In general, you will not notice a difference in most applications between 24-bit and 16-bit color; however, the difference between 16-bit and 8-bit color is the difference between comfortable, seamless work and a constant barrage of palette shifts and dithered gradients. Although personal preference has to be the governing factor, here are my recommendations:

- If the resolution you want to run does not allow more than 8-bit color (256 colors), it is probably better to reduce the resolution to a level that allows 16-bit color. However, if getting more than 256 colors requires you to reduce the resolution to a value lower than 1024x768, you should really consider getting a newer video card.
- If the resolution you want to run allows 16-bit color but does not allow 24-bit color, it is probably not worth reducing the resolution to allow 24-bit color. In most cases, unless you are doing something in which the number of colors is extremely important (such as graphics processing), you are not likely to notice the difference between 16-bit and 24-bit color.

After you have decided on the default color depth you want to use, you will want to make changes to the mode line for that color depth (unless you plan on running 640x480 resolution by default, in which case you do not have to make any changes).

Enter the number for the series of modes you want to adjust and then press Enter. For example, if you plan to run 24-bit color by default, you would select 3 in the sample screen given previously. This will take you to a screen similar to the following.

```
Select modes from the following list:
 1  "640x400"
 2  "640x480"
 3  "800x600"
 4  "1024x768"
 5  "1280x1024"
 6  "320x200"
 7  "320x240"
 8  "400x300"
 9  "1152x864"
 a  "1600x1200"
 b  "1800x1400"
 c  "512x384"
 d  "1400x1050"

Please type the digits corresponding to the modes that you want to select.
For example, 432 selects "1024x768" "800x600" "640x480", with a
default mode of 1024x768.

Which modes?
```

Select the number corresponding to the default resolution that you want to use when X11 first starts up. For example, if you want X11 to start in 1024x768 resolution by default, select 4.

If you want to be able to switch between different resolutions, you can enter multiple numbers here, in a combined string. The first number will be the default resolution, and the numbers listed after that will be cycled through in the order they are listed when you issue the command to change the screen resolution (generally Ctrl+Alt plus either the + or key on the numeric keypad). For example, if you want the default resolution to be 1024x768, the next resolution in the cycle to be 800x600, and the final resolution in the cycle to be 640x480, you would enter **`432`** here.

Most people are not in the habit of changing the resolution on their screens at all once they have it initially set up. If you've never changed the screen resolution on your Windows or Macintosh system, chances are you won't in FreeBSD, either. Unless you anticipate having to flip back and forth between various resolutions for some reason, you can probably just set one resolution here.

Tip

While you're still experimenting with your X11 settings here, it might be a good idea to specify at least one "safety" resolution, such as 640x480 (option 2). This allows X11 to fall back to that resolution if it can't put your system into the resolution you want, for instance if you specified the wrong sync frequencies for your monitor or the wrong amount of video RAM. You can always remove this resolution option later by editing `xorg.conf` manually.

When you have selected the resolution(s) that you want for this color depth, press Enter to continue. You will then be asked about virtual screens:

```
You can have a virtual screen (desktop), which is screen area that is larger
than the physical screen and which is panned by moving the mouse to the edge
of the screen. If you don't want virtual desktop at a certain resolution,
you cannot have modes listed that are larger. Each color depth can have a
differently-sized virtual screen

Please answer the following question with either 'y' or 'n'.
Do you want a virtual screen that is larger than the physical screen?
```

A virtual screen that is larger than the physical screen (a traditional X11 feature that isn't widely supported in the Windows/Mac world) means that your monitor, which may be limited in resolution, only displays a subset of X11's desktop area; you'll be able to pan across the virtual screen by moving your mouse to the edges of the displayed area.

Note

For many users, virtual screens are more annoying than their utility is worth, as working with them can be very clumsy and inefficient; most users avoid the feature unless forced by a limited video card to use a very low resolution (such as 640x480). However, for users with limited visual acuity, the feature can be a godsendit lets you use a low, very readable screen resolution to make text large and legible, and lets you pan around the screen to see the entirety of the desktop, in a passable emulation of the Zoom feature in Mac OS X (itself designed for accessibility purposes).

If you do decide that you want a virtual screen, you will be asked for the resolution you want the screen to be. Select the desired resolution and press Enter.

If you decide you do not want a virtual screen, you will be taken back to the mode line configuration screen shown earlier. The newly updated screen, with its currently configured mode lines, is shown here:

```
For each depth, a list of modes (resolutions) is defined. The default
resolution that the server will start-up with will be the first listed
mode that can be supported by the monitor and card.
Currently it is set to:

"1280x1024" "1024x768" "800x600" "640x480" for 8-bit
"1280x1024" "1024x768" "800x600" "640x480" for 16-bit
"1024x768" for 24-bit

Modes that cannot be supported due to monitor or clock constraints will
be automatically skipped by the server.

 1  Change the modes for 8-bit (256 colors)
 2  Change the modes for 16-bit (32K/64K colors)
 3  Change the modes for 24-bit (24-bit color)
 4  The modes are OK, continue.

Enter your choice:
```

Notice that the mode lines for 24-bit color have changed. It now has only 1024x768 resolution.

Unless you plan to run multiple color depths, you can leave the other color depths alone. If you do plan to switch between color depths, simply select the number for the next color depth you want to configure and repeat the previous steps to configure the resolutions for that color.

When you have finished configuring all the modes you want to configure, select 4 (`The Modes Are OK, Continue`) to move on to the next section.

You will then be asked to specify the default color depth you want to use:

```
Please specify which color depth you want to use by default:

  1  1 bit (monochrome)
  2  4 bits (16 colors)
  3  8 bits (256 colors)
  4  16 bits (65536 colors)
  5  24 bits (16 million colors)

Enter a number to choose the default depth.
```

Simply select the number for the color depth you decided on earlier and then press Enter.

After you have selected the desired color depth, you will be asked whether you want to save the changes:

```
I am going to write the xorg.conf file now. Make sure you don't accidentally
overwrite a previously configured one.
```

```
Shall I write it to /etc/X11/xorg.conf?
```

Select Y to write a new `xorg.conf` file. If you already have an `xorg.conf` file, it will be overwritten with the new file.

After you have selected Y and pressed Enter, `xorgconfig` will respond with the following:

```
File has been written. Take a look at it before running 'startx'. Note that
the xorg.conf file must be in one of the directories searched by the server
(e.g. /etc/X11) in order to be used. Within the server press
ctrl, alt and '+' simultaneously to cycle video resolutions. Pressing ctrl,
alt and backspace simultaneously immediately exits the server (use if
the monitor doesn't sync for a particular mode).

For further configuration, refer to the xorg.conf(5) manual page.
```

At this point you're done with the script and will be returned to the command prompt. Your `xorg.conf` file has been written and its operation is ready to test. Skip ahead to the section "Testing the X11 Setup."

Configuring a Card That Is Not in the Database and Saving the Configuration File

If you did not select one of the cards from the card list database (if you pressed Q instead of choosing a listed card driver), the first question you will be asked is how much video memory your card has:

```
Now you must give information about your video card. This will be used for
the "Device" section of your video card in xorg.conf.

It is probably a good idea to use the same approximate amount as that detected
by the server you intend to use. If you encounter problems that are due to the
used server not supporting the amount memory you have, specify the maximum
amount supported by the server.

How much video memory do you have on your video card:

 1  256K
 2  512K
 3  1024K
 4  2048K
 5  4096K
 6  8192K
 7  16384K
 8  32768K
 9  65536K
10  131072K
11  262144K
12  Other
Enter your choice:
```

If you know how much video RAM your card has, choose it from the list or enter it manually (in kilobytes) by choosing option 12. Otherwise, you can proceed by specifying an unrealistically high number, such as option 9 (64MB); this number doesn't directly affect the card's configuration, but tells `xorgconfig` what display resolutions and color depths it should offer you. You can always edit the X11 configuration file, after you're done with this script, to use video modes that don't tax your video card's capabilities or call your bluff.

```
You must now enter a few identification/description strings, namely an
identifier, a vendor name, and a model name. Just pressing enter will fill
in default names (possibly from a card definition).

The strings are free-form, spaces are allowed.
Enter an identifier for your video card definition: blah
```

You're now asked to enter a card identifier. Because you didn't select a card model, this identifier is important for future diagnostics; enter a label that describes your card as best you can.

The next screen asks you what default color depth you want to use:

```
Please specify which color depth you want to use by default:

  1  1 bit (monochrome)
  2  4 bits (16 colors)
  3  8 bits (256 colors)
  4  16 bits (65536 colors)
  5  24 bits (16 million colors)

Enter a number to choose the default depth.
```

Select the number corresponding to the default color depth you want and press Enter. You will then be asked whether you want to save the changes:

```
I am going to write the xorg.conf file now. Make sure you don't accidentally
overwrite a previously configured one.

Shall I write it to /etc/X11/xorg.conf?
```

Select Y here to write the configuration file. This will overwrite any existing configuration file you may have. After you have written the changes, `xorg.conf` will respond with the following message and then exit:

```
File has been written. Take a look at it before running 'startx'. Note that
the xorg.conf file must be in one of the directories searched by the server
(e.g. /etc/X11) in order to be used. Within the server press
ctrl, alt and '+' simultaneously to cycle video resolutions. Pressing ctrl,
alt and backspace simultaneously immediately exits the server (use if
the monitor doesn't sync for a particular mode).

For further configuration, refer to the xorg.conf(5) manual page.
```

By default, X11 will start in 640x480 resolution. You will probably want to change this to a higher resolution. You will need to edit the `xorg.conf` configuration file manually in order to do so. The `xorg.conf` file is covered in the next section.

PREV NEXT

Understanding the xorg.conf File

Like most other components of FreeBSD, the X11 configuration is controlled by a configuration file that is in plain text. The primary X11 configuration file is located in /etc/X11 and is called xorg.conf. This is the file that is created or modified by xorgcfg (the menubased interface for X11 configuration you used back in Chapter 2) and also by xorgconfig (the text-based configuration script that was covered in the previous sections of this chapter). These configuration tools have made X11 configuration much easier than it used to be when the files had to be created and edited entirely by hand.

However, there are still some situations in which you might need to make changes to the configuration file by hand. For example, if your video card was not listed in the card database, you might need to make manual changes to this file to fine-tune it to your card's capabilities. Another situation in which you may need to make changes by hand is if you want to make changes to aspects of X11 that xorgconfig doesn't address, such as the acceleration or speed settings for the mouse. If you simply want to make one or two minor changes to X11, it may be desirable to edit the file by hand rather than go through a complete configuration with xorgconfig.

To make changes to the xorg.conf file, first make a backup copy of the file so that it will be easy to undo your changes if they cause problems. For example, you might want to copy /etc/X11/xorg.conf to /etc/X11/xorg.conf.bak. After you have a backup copy, open the file /etc/X11/xorg.conf in your favorite text editor (see Chapter 6 if you need information on how to use one of the text editors included with FreeBSD).

xorg.conf Syntax

The xorg.conf file is divided into several sections. Each section relates to a specific device or configuration issue, and begins with the keyword Section followed by the section name in quotes. Each section ends with the keyword EndSection. The body of the section is indented for easy readability. Comments, or lines that are ignored by X11, begin with a pound sign (#). The following is an example of a section in the xorg.conf file:

```
Section "Module"

# This loads the DBE extension module.

    Load        "dbe"   # Double buffer extension

# This loads the miscellaneous extensions module, and disables
# initialization of the XFree86-DGA extension within that module.
    SubSection  "extmod"
      Option    "omit xfree86-dga"   # don't initialize the DGA extension
    EndSubSection

# This loads the font modules
    Load        "type1"
#    Load        "speedo"
    Load        "freetype"
#    Load        "xtt"

# This loads the GLX module
#    Load       "glx"
# This loads the DRI module
#    Load       "dri"

EndSection
```

The comments before this section are not shown, but in the xorg.conf file, they explain what the section is for. In this case the Module section loads dynamic modules when the server starts to support various components of the system. For example, the part of this example that begins with # This loads the font modules loads dynamic modules to support various types of fonts. In this case, the first Load line loads a module that supports Adobe Type 1 fonts. The second active Load line loads the freetype module, which is a freely available module that allows X11 to use commercial TrueType fonts.

In addition to main sections, there are also subsections that can be embedded within the sections. These begin with the keyword SubSection followed by the name of the subsection in quotes, and end with the keyword `EndSubSection`. Like the main sections, they are also indented for readability purposes.

The next few sections of this chapter take a look at the various sections and subsections in the `xorg.conf` file.

Section `"Module"`

The `Module` section is where modules can be dynamically loaded to support X11 components such as various font types. Dynamically loaded modules are not a part of the X binary; instead, these modules are loaded as needed when X11 starts. The advantage of dynamically loaded modules is that they are loaded only if they are needed. Modules that are not needed are not loaded and therefore do not waste memory and system resources. For example, if you don't have any TrueType fonts on your system, there is little point in having TrueType font support in X11, and you can comment out the `Load "freetype"` line.

Modules that are to be loaded begin with the keyword `Load` followed by the name of the module in quotes. For example, the following line loads the module that supports TrueType fonts:

```
Load "freetype"
```

Section `"Files"`

This section is similar to the X11 `PATH` environment variable. The `Files` section tells X11 where in the system it can expect to find various required files.

The only portion of this section you may ever want to modify is that which tells X11 where to look for fonts. Each one of the font directories begins with the keyword `FontPath`, followed by a directory enclosed in quotation marks. For example, the following line is where the Adobe Type 1 fonts are located:

```
FontPath   "/usr/X11R6/lib/X11/fonts/Type1/"
```

This is the directory in which you would install new Adobe Type 1 fonts that you may download or purchase. Details on X11 fonts will be covered later on in this chapter, in the section titled "Working with Fonts."

If you do add new font directories, the name of the directory is not really important. For example, there is nothing that says that Adobe Type 1 fonts have to be stored in a directory called `Type1`. This convention is just followed to make it easier for you to guess what types of fonts are in a directory.

Section `"ServerFlags"`

The `ServerFlags` section of the file contains some global options that control the behavior of X11. Some of the available options are present in the configuration file generated by `xorgconfig` and include comments about what they do. All the options are commented out by default.

All the options in this section begin with the keyword `Option`, followed by the option in quotes. For example, the following line will disable the Ctrl+Alt+Backspace sequence that kills the X Server immediately:

```
Option "DontZap"
```

The following subsections discuss some (though not all) of the options available in `ServerFlags` you're most likely to use.

Option `"NoTrapSignals"`

If this option is uncommented (enabled), X11 will not exit cleanly when there is a problem. Instead, it will write a core dump file. This can cause problems with the console not working correctly after X11 has terminated incorrectly.

You should probably leave this line commented out unless you are experiencing consistent X Server crashes. In that case, uncommenting this option creates a core dump file that is invaluable for troubleshooting purposes. Even if you are not a programmer and cannot make heads or tails of the dump file, it will be an important piece of evidence if you want to file a bug report with the Xorg project developers.

Option `"DontZap"`

If this option is uncommented, you will not be able to kill the X Server by using the Ctrl+Alt+Backspace key combination. You should definitely not uncomment this line until you have tested your X11 configuration and are sure it is working correctly. This option is helpful if you're setting up a kiosk or a public computer where it's important that users not have the ability to exit from the running application or escape from the X11 session.

Option `"DontZoom"`

If this option is uncommented, it will disable video mode switching using Ctrl+Alt++ and Ctrl+Alt+ (on the numeric keypad). By default, these key combinations will allow you to cycle between different video modes if you have configured multiple video resolutions.

About the only reason for uncommenting this would be if you have programs that require these key combinations for some other use. In this case, uncommenting this line will prevent the X Server from intercepting the combination and causing the video modes to switch in the middle of your work.

Option `"DisableVidModeExtension"`

If this option is uncommented, it will prevent the `xvidtune` program from making any changes to the video system. If this is a multiuser system, it may be a good idea to uncomment this line to prevent users from being able to use `xvidtune` because the improper use of `xvidtune` can damage your monitor. Note that if the line is uncommented, `xvidtune` can still be loaded. But you will not be able to make any changes to the video system with it.

Most of the other options in this section that are present in the configuration file generated by `xorgconfig` should probably be left alone.

Other Options Not Present by Default for Section `"ServerFlags"`

Several other options may be of interest that are not present in the default configuration file generated by `xorgconfig`. We are not going to discuss all of them here, but many of the more useful ones are listed. If you want to add any of these following options, simply add the line in bold text to the `ServerFlags` section in `xorg.conf`:

- **`Option "AllowMouseOpenFail"`** By default, if the X Server cannot communicate with the mouse or other pointing device, the server will not start and will exit with an error. Adding this line will allow the server to start, even if the mouse or other pointing device cannot be accessed.

  Unless you are trying to use X11 without a mouse or other pointing device, there is probably no reason to change this option.

- **`Option "BlankTime" "`*`n`*`"`** This option will cause the screen to go blank after the number of minutes represented by *n*. If this option is not present, the default is 10 minutes.

- **`Option "StandbyTime "`*`n`*`"`** This option will cause the monitor to go into standby mode after the number of minutes represented by *n*. If this option is not present, the default is 20 minutes.

  This option is not supported by all video drivers, and it only works with monitors that support DPMS power-saving features. The `Monitor` section of `xorg.conf` (discussed later in this chapter) must explicitly specify that the monitor can support DPMS for this feature to apply.

- **`Option "SuspendTime" "`*`n`*`"`** This option will cause the monitor to go into suspend mode after the number of minutes represented by *n*. If this option is not present, the default is 30 minutes.

This option is not supported by all video drivers, and it only works with monitors that support DPMS power-saving features. The `Monitor` section of `xorg.conf` (discussed later in this chapter) must explicitly specify that the monitor can support DPMS for this feature to apply.

- **`Option "OffTime" "n"`** This option will turn the monitor off after the number of minutes represented by *`n`*. If this option is not present, the default is 40 minutes.

  This option is not supported by all video drivers, and it only works with monitors that support DPMS power-saving features. The `Monitor` section of `xorg.conf` (discussed later in this chapter) must explicitly specify that the monitor can support DPMS for this feature to apply.

- **`Option "NoPM"`** This option will disable some events that relate to power management. By default, power management is enabled on systems that can support it. You should need to add this option only if you are experiencing strange problems that seem to be related to power-management events.

A few other options can be included in this section, but they are less commonly used. If you are interested in some of the other options available, see the `man` page for `xorg.conf`.

Section **`"InputDevice"`**

This section is where the input devices are configured. There can be multiple `InputDevice` sections in the configuration file. Usually there will be at least two: one for the keyboard and one for the mouse or other pointing device.

`InputDevice` sections have several keywords associated with them. The first is the `Identifier` keyword. It is followed by a name that identifies this device. X11 doesn't really care what you call the device, but it is best to use a descriptive name that defines it well enough for your own purposes.

The second is the `Driver` keyword. It is followed by the name of the driver for this device, in quotes. The most common drivers are `"keyboard"` and `"mouse"`, but there are a few others such as `"microtouch"` for a touch screen.

The final part of the `InputDevice` section consists of options for the device.

The following sections look at the two most common `InputDevice` sectionsthe keyboard and the mouseand discuss some of the option lines available for configuring them.

Configuring the Keyboard Options

Here is an example of the first part of the `InputDevice` section for the keyboard:

```
Section "InputDevice"

    Identifier   "Keyboard1"
    Driver       "kbd"
```

You can choose from a number of available options for controlling keyboard behavior. Here are some of the most commonly used of these options:

- `Option "Protocol"` If this option is omitted or commented out, the default value of `"Standard"` will be used. There is probably no reason to change this.

- `Option "AutoRepeat" "x y"` This option controls the repeat rate of the keys on the keyboard. The number represented by *`x`* is the delay in milliseconds before the key starts repeating. The number represented by *`y`* is the number of times per second that the key will repeat.

  The default is 500 milliseconds before the key starts to repeat, and 30 times per second that it will repeat.

- `Option "XkbRules" "xorg"` This option determines the way various aspects of the keyboard are interpreted. In most cases, you should leave this set to `"xorg"` unless you chose an atypical keyboard type in the `xorgconfig` script.

- `Option "XkbModel" "pc104"` If you have a 105-key Windows keyboard, this will be `"pc105"`. If you have a 101-key keyboard that does not have the Windows keys, it will be `"pc101"`. These values will also work for laptops. Even though laptops usually have fewer keys, they generally have ways of emulating the additional keys.
- `Option "XkbLayout" "us"` This will usually be set to `"us"`. If you are using the Japanese PC-98 platform, you will want to change it to `"nec/jp"`. Again, running `xorgconfig` is probably the best way to set this option for your needs.
- `Option "XkbOptions" "ctrl:swapcaps"` If this line is uncommented, it will cause the Caps Lock key to become a Ctrl key and the left Ctrl key to become a Caps Lock key. You may want to uncomment this line if you are an Emacs guru (Emacs relies heavily on the Ctrl key) or if you are used to a UNIX keyboard layout in which the Ctrl key is placed in the position where the Caps Lock key is found on PC keyboards.

Configuring Mouse Options

Here is an example of the first part of the `InputDevice` section for the mouse:

```
Section "InputDevice"

# Identifier and driver

    Identifier  "Mouse1"
    Driver      "mouse"
    Option "Protocol"    "Auto"
    Option "Device"      "/dev/sysmouse"
```

The following subsections describe some of the most commonly used options.

- `Option "Protocol" "`*`protocol`*`"` In this option, *`protocol`* represents the type of mouse that your system has. This option is required, and the X Server will not work if it is not present.

  Many users will be able to get away with specifying Auto here to have the X Server automatically attempt to determine the protocol the mouse uses. This usually causes no problems these days; but if it does, several other options are available. A few of the more useful protocol types follow:

  - The `Logitech` protocol is used only by very old Logitech serial mice. If you have a newer Logitech serial mouse, use the `Microsoft` or `MouseMan` protocols.
  - Use the `PS/2` protocol for any PS/2 mouse, no matter who the manufacturer is. You have a PS/2 mouse if the mouse connector is a small round one.
  - If you have a laptop or notebook system, the built-in pointing device (such as a touchpad or trackpoint) will probably work with the `PS/2` protocol.

    I suggest that you try using `Auto` first and then change it only if your mouse is not detected or is not working properly.

- `Option "Device" "`*`devicename`*`"` This option specifies what device the mouse is driven by. The option is required, and the X Server will not work if this option is missing.

  Table 7.1 (earlier in this chapter) lists some of the common device names where your mouse may be located.

  Note that *`devicename`* in this option should be replaced with the mouse device.

- `Option "Buttons" "`*`n`*`"` In most cases, the number of buttons on the mouse will be automatically detected; if they are not, this option can be used to tell the X Server how many buttons are on the mouse.

  Here, *`n`* represents the number of buttons the mouse has. The most common values are 2 and 3, although numbers up to 5 are supported. If you happen to have a mouse with five buttons on it, go for it.

- `Option "Emulate3Buttons"` This very important line allows a two-button mouse to emulate a three-button mouse. If you have a two-button mouse, you will want to uncomment this line because X11 makes extensive use of all three mouse buttons.

  If you do uncomment this line, the middle mouse button is emulated by pressing the left and right mouse buttons at the same time (a "chord").

- `Option "Emulate3Timeout" "`*`n`*`"` If the `Emulate3Buttons` option is enabled, this option will control the number of milliseconds that can elapse between clicking the left and right mouse buttons before X11 will no longer interpret the action to be a middle click. In other words, both the left and right mouse buttons must be pushed within this time frame in order for the action to be interpreted as a middle click. Here, *`n`* is the number of milliseconds that can elapse.

  If this line is not present and the `Emulate3Buttons` option is enabled, the default `Emulate3Timeout` value will be 50 milliseconds.

Section `"Monitor"`

This is where you configure the horizontal and vertical refresh rates for your monitor. It consists of the `Identifier` keyword followed by a name in quotes to identify this monitor. The name you choose is not very important.

Two other keywords are required to be present in this section: `HorizSync` and `VertRefresh`. You learn more about them in the following sections. A few other options can be used with the `Monitor` section, but they are not as common. For full details on all the available options, see the `man` page for `xorg.conf`.

`HorizSync`

`HorizSync` is the horizontal sync rate in kilohertz that the monitor supports. It can be specified in several ways:

- As a range This is normally the method used to configure multisync monitors (and virtually all CRT monitors are multisync these days). For example, `HorizSync 44-76` would be used for a monitor that can support horizontal refresh rates ranging from 44 to 76 kilohertz.

- As a single value If you have a fixed frequency monitor that supports only one frequency, it is simply listed after `HorizSync` (for example, `HorizSync 35.2`).

- As a list of frequencies If your monitor supports several fixed frequencies, you can supply a list of the fixed frequencies that it supports, separated by commas (for example `"HorizSync 31.5, 35.2"`).

- As multiple ranges of frequencies If your monitor supports more than one range of frequencies but has a gap in the middle that it does not support, you can list multiple ranges (for example, `"HorizSync 15-25, 30-50"`).

`VertRefresh`

The `VertRefresh` keyword lists the vertical refresh rate your monitor can support. It can take its value in any of the same formats that the `HorizSync` keyword can use.

Caution

Supplying values for `HorizSync` and `VertRefresh` that are outside the range of what your monitor can support can damage or destroy your monitor. Be extremely careful that you do not supply values outside the supported range. See your monitor's documentation or check the manufacturer's website (or the http://www.monitorworld.com/Monitors/database) for technical specifications to find the values your monitor can support.

Section "Device"

This section is where you configure your graphics adapter (video card). Like most other sections, it begins with the keyword `Identifier`, followed by a name in quotes to identify the device.

The `Driver` keyword is also required, followed by the name of the driver for your card in quotes. For example, if you have an NVIDIA TNT2, the line would look like this:

```
Driver "nv"
```

If you have a supported video card, it is much easier to go through `xorgconfig` (explained earlier in this chapter) to set up the graphics device than to do it manually in the `xorg.conf` file. However, if for whatever reason you need to or want to do it manually, a full list of the supported cards, along with the driver that should be used to support each card, is available at http://wiki.x.org/wiki/VideoDrivers or in Appendix B, "Hardware Compatibility Lists."

The other keyword that is most commonly used here is the `VideoRam` keyword to specify how much video RAM the video card has. For example, if your video card has 16MB of RAM, the line would look like this:

```
VideoRam 16384
```

As you learned earlier, the amount of video RAM is specified in kilobytes; in binary math, a kilobyte is actually 1,024 bytes. Be sure to multiply your card's megabyte value by 1,024 to get the value you have to specify in the configuration file.

Some more options are available for graphics devices, but most of them will not be needed for most video cards. See the man page for `xorg.conf` for full details on all the available options.

Also, you will probably want to have a look at the web page located at http://x.org/X11R6.8.2/doc/RELNOTES3.html#9 to see whether there are any notes regarding your particular type of video card and any specific options you need to supply for it.

Tip

If you cannot find a driver for your video card, all may not be lost. You might be able to get the card working with the VESA driver. VESA is a generic Super VGA specification that a lot of cards support to some extent. If you have to use this driver, the accelerated features of your card will not be fully supported, and nor will all the resolutions and color depths that your video card can handle. But it's better than nothing, and it may allow you to use a card for which there is no driver currently available for X11. If you end up using this alternative, check the supported card database often because support for new cards is being added on a regular basis.

Section "Screen"

The `Screen` section is where a monitor is combined with a graphics card to make a "display" construct that will work with the X Server. It starts with the `Identifier` keyword that contains a name enclosed in quotes, identifying this particular combination of monitor and video card. There can be multiple `Screen` sections present in the `xorg.conf` file, but there must be at least one. The first one encountered will be the one that is used unless specified otherwise in the `ServerLayout` section.

After you have specified an identifier for the `Screen` section, you also must specify the `"`*`devicename`*`"`, `"`*`monitorname`*`"`, and `DefaultDepth` "*`n`*" keywords. Other available options are rarely used; see the man page for `xorg.conf` for details on these options.

- `Device "`*`devicename`*`"` This is the name of the graphics device (video card) that should be used for this screen configuration. Here, *`devicename`* is whatever string appears in the Identifier section of the graphics device that you set up earlier in the file.

- `Monitor "`*`monitorname`*`"` This is the name of the monitor that should be used for this screen configuration. Here, *`monitorname`* is whatever string appears in the Identifier section of the monitor that you set up earlier in the file.

- `DefaultDepth "`*`n`*`"` This is the default color depth that should be used for this screen configuration. Valid values for n are 8, 16, and 24, assuming your video card supports all three color depths.

SubSection `"Display"`

After you have configured the `Screen` section, you will need to configure the `Display` subsection(s) for the screen, to specify the resolutions and cycle order for each available color depth. There must be at least one `Display` subsection for the default color depth, or the X Server will not start. However, there can be more than one `Display` subsection, one for each color depth.

The first line in the subsection will be the keyword `Depth` followed by the color depth that this subsection is for. Here is an example of what the first two lines of this subsection might look like:

```
Subsection "Display"
    Depth       24
```

The third line that is required here is a mode line. It is simply the keyword `Modes` followed by a list of the resolutions you want to have supported. The first resolution listed will be the default. The resolutions listed after that will be cycled through when the Ctrl+Alt++ and Ctrl+Alt+ key combinations (using the keypad) are used. Note that this may not work on some systems.

Here is a sample mode line:

```
Modes "1024x768" "800x600" "640x480"
```

In this example, the default resolution will be 1024x768 for this color depth. Pressing Ctrl+Alt++ or Ctrl+Alt+ will cause X11 to switch to 800x600 and 640x480, in order.

X11 allows you to have a virtual screen that is larger than the resolution you have configured. For example, you can have your screen resolution set to 800x600 and have a virtual screen size of 1024x768. This was discussed in a previous section of this chapter when we talked about configuring X11 with the `xorgconfig` program.

If you decide that you want to use a virtual screen, you can use the `"Virtual `*`resolution`*`"` option to configure the resolution the virtual screen should be. For example, `"Virtual 1024x768"` will set the virtual screen size to 1024x768. If the actual screen resolution is lower than this, only part of the screen will be visible. To see the portions of the screen that are not visible, you will need to drag the mouse pointer off the edge of the screen. This will scroll the screen left, right, up, or down, depending on which edge of the screen you are interacting with.

Some other options are available here but are not commonly used. For a list of all the options available in the `Display` subsection, see the `man` page for `xorg.conf`.

Section `"ServerLayout"`

The `ServerLayout` section is optional. If it does not exist, the first screen listed and the first keyboard and mouse input devices listed will be used. If the `ServerLayout` section does exist, it is used to select from among multiple screen entries and keyboard and mouse entries to be used during your X session.

The `Identifier` keyword is required, and it is followed by a string in quotes that gives this server layout a name. Here are some of the other items commonly used in the `ServerLayout` section:

- `Screen "`*`screenname`*`"` This is the screen configuration that should be used for this device. Here, *`screenname`* is the name listed in the `Identifier` keyword for the `Screen` section that is to be used for this server layout.

- `InputDevice "`*`keyboardname`*`" "CoreKeyboard"` This determines which keyboard entry should be used for this server layout. Here, *`keyboardname`* is the name listed in the `Identifier` keyword for the `Keyboard` section you want to use.

The `CoreKeyboard` option that follows sets this keyboard to the default keyboard.

- `InputDevice "`*`mousename`*`" "CorePointer"` This is like the `Keyboard` entry, except that it determines the mouse entry that should be used for this server layout. Once again, the `CorePointer` option that follows sets this mouse to the default mouse.

`Option` lines can also be included in the `ServerLayout` section. If they are included and they conflict with options listed in other sections, the options listed here will override the other options.

Other options are available for all aspects of the `xorg.conf` file, but most of them are rarely used. Once again, see the man page for `xorg.conf` for full details of all the available configuration options.

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Testing the X11 Setup

After you have finished with `xorgconfig` and/or hand-edited the `xorg.conf` file and saved your changes, you are ready to test the X Server.

Type **`startx`** at the command line to start the X11 system. If all goes well, your screen will go blank for a moment, and you should soon see a checkered background with a small x in the middle, as you saw in Figure 2.13 in Chapter 2. The x is the mouse pointer. After a few more seconds, the window manager should come up, the mouse pointer should turn into a more familiar white or black arrow, and you should be able to move the mouse around on the screen.

If you can't move the mouse or if X11 seems to start but then quits with an error message, double-check your `xorg.conf` file to make sure you have everything configured properly.

Caution

If you start X11 and your screen appears to be garbled, or you hear a high-pitched whine coming from your monitor, *immediately* turn your monitor off and press Ctrl+Alt+Backspace to kill the X Server. Either one of these symptoms indicates that you are probably driving the refresh rate of your monitor higher than it can tolerate, and the flyback transformer in your monitor is getting ready to fry. After you have killed the X Server, reconfigure the sync rates and resolutions for your monitor in `xorg.conf` or with the `xorgconfig` script.

If you type **`startx`** and your monitor goes blank and then seems to turn off or go into a suspend mode (the power light changes color, starts blinking, or you can hear the static on the monitor discharging), it probably means you have driven your monitor past the specs it can tolerate. Press Ctrl+Alt+Backspace to kill the X Server. This should restore your screen and give you the command prompt back. Then, reconfigure your refresh rates and resolutions in `xorg.conf` or with the `xorgconfig` script, specifying less ambitious resolution settings, before trying again.

After you have a working X11 setup, you may want to make some customizations to the way it works. The next section covers your personal `.xinitrc` file in your home directory.

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Your Personal `.xinitrc` File

Individual users don't have to worry about the configuration of the X Server; it's handled at the root level of the system, running as a daemon when queried by clients (window managers). The window managers are user processes, and each user has the ability to choose a window manager to suit his or her taste, regardless of the hardware-limited resolutions you've defined in the `xorg.conf` file.

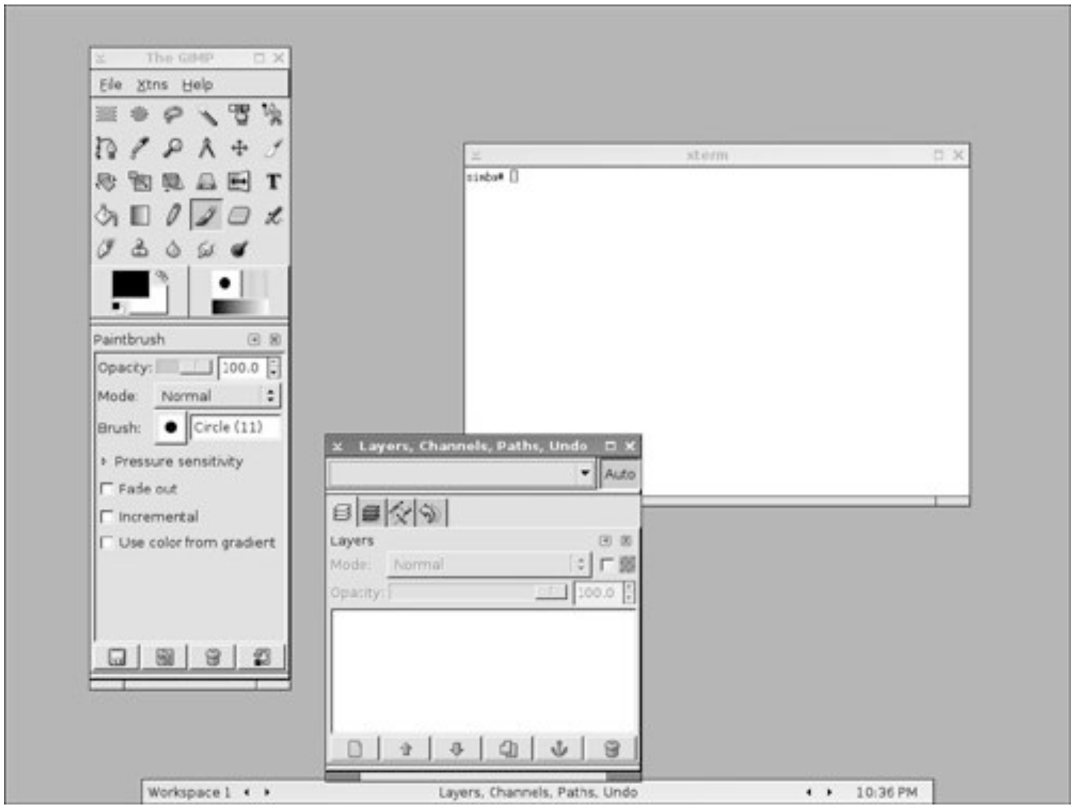
Each user controls how his X11 session looks and acts using a shell script file in his home directory called `.xinitrc`. One of the most common setup attributes controlled by this file is which window manager is to be invoked to handle the client end of X11's clientserver architecture during your X session. You also can use this file to control which applications start automatically every time you run X11, the background color of the screen, and the display of a background image. Each of these operations involves making changes to your personal `.xinitrc` file, as you learn in the sections that follow.

Changing the Window Managers

Many window managers are available in the `x11-wm` category of the FreeBSD ports tree or packages. One popular window manager only briefly mentioned previously is Blackbox, which is shown in Figure 7.1. See Chapter 16, "Installing Additional Software," for information on how to work with the FreeBSD ports collection.

Figure 7.1. Blackbox is a very small and fast window manager. It contains few frills and takes up very few system resources.

[View full size image]



Blackbox is an ideal minimal window manager for users who don't want the window manager to get in the way. It is also ideal for systems that are low on resources. Blackbox is a common window manager used on servers. However, the instructions in this section apply to any window manager you install.

Note

KDE and GNOME both behave somewhat differently from regular window managers. If you want to invoke KDE when you run startx, instead of using the KDM login manager, use this line in `.xinitrc`:

```
exec startkde
```

For GNOME, use the following:

```
/usr/X11R6/bin/gnome-session
```

After you have installed a new window manager from the ports or packages, you must edit your personal `.xinitrc` file to use it. Open the `.xinitrc` file located in your home directory in your favorite text editor. If the file does not already exist, it will be created.

In this case, all you want to do is tell X11 what window manager to use, so you only need to add one line to the file. For Blackbox, here's the line to add:

```
exec blackbox
```

Each window manager has its own executable name; look in the `pkg-plist` file in any window manager's port directory to find out what the executable is called, and use it in place of `blackbox` here. After you have added the appropriate `exec` command to the `.xinitrc` file, save the file and exit the editor; the next time you start X11, you will be placed in the new window manager.

Configuration of window managers other than Window Maker (discussed in Chapter 5) is beyond the scope of this book. See the web page for your chosen window manager for more information; the website is usually listed in the port's `pkg-descr` file. (In the case of Blackbox, see http://blackboxwm.sourceforge.net/).

Note

Many other window managers are available for use with X11, and can be installed from the FreeBSD ports collection under the `x11-wm` directory.

For more information, including screen shots of the more popular window managers, see http://www.xwinman.org.

Starting Applications Automatically

Remember that `.xinitrc` is a shell script, executed at launch time when you run `startx`. That means you can include anything in it that you want executed whenever you start X11, including certain X applications such as xterm windows or commonly used productivity apps.

Any applications that you want to start automatically should be added before the window manager is invoked, and should end with an ampersand character (`&`). (Note that there should be a space before the ampersand.) This way, they start in the background and detach from the shell executing the script, allowing it to proceed to the next command. If you don't end each command with an ampersand, it will start in the foreground, blocking the script from ever reaching and launching the window manager.

Here is an example of an `.xinitrc` file that starts an X terminal window and an X clock along with the Blackbox window manager:

```
xterm &
xclock &
exec blackbox
```

Many of the programs you can execute within an X session are instrumented with options that let you define exactly where and how they appear. For example, to specify an `xterm` window of 80 columns by 25 lines, positioned at 100 pixels from the left edge and 50 from the top, use this line:

```
xterm -geometry 80x25+100+50 &
```

Many other X11 programs can be invoked with similar arguments; see their `man` pages, usually under the `-geometry` option, for details.

Setting a Background Color or Background Image

Many window managers and desktop environments such as Window Maker and GNOME have the built-in capability to set their own background colors or background images. However, some of the simpler window managers, such as FVWM and wm2, do not. You can set the background color or background image by calling external programs from the `.xinitrc` file, as explained in the following subsections.

Setting the Background Color

By default, X11 has a rather ugly checkered background that seems as though it's designed to be as hard on the eyes as possible. The program `xsetroot` allows you to set the background color to a solid color or to a tiled bitmap from an image. There is a text file that lists all the available named colors located in `/usr/X11R6/lib/X11/rgb.txt`. Here is an example of how the background color can be set to a solid color:

```
xsetroot -solid ForestGreen
```

Try typing this command from an `xterm` window to set the background to forest green.

If you want this change to be permanent, you can add this command to your `.xinitrc` file before the window manager starts. For example, the following line will set the background color to forest green and then start the `twm` window manager:

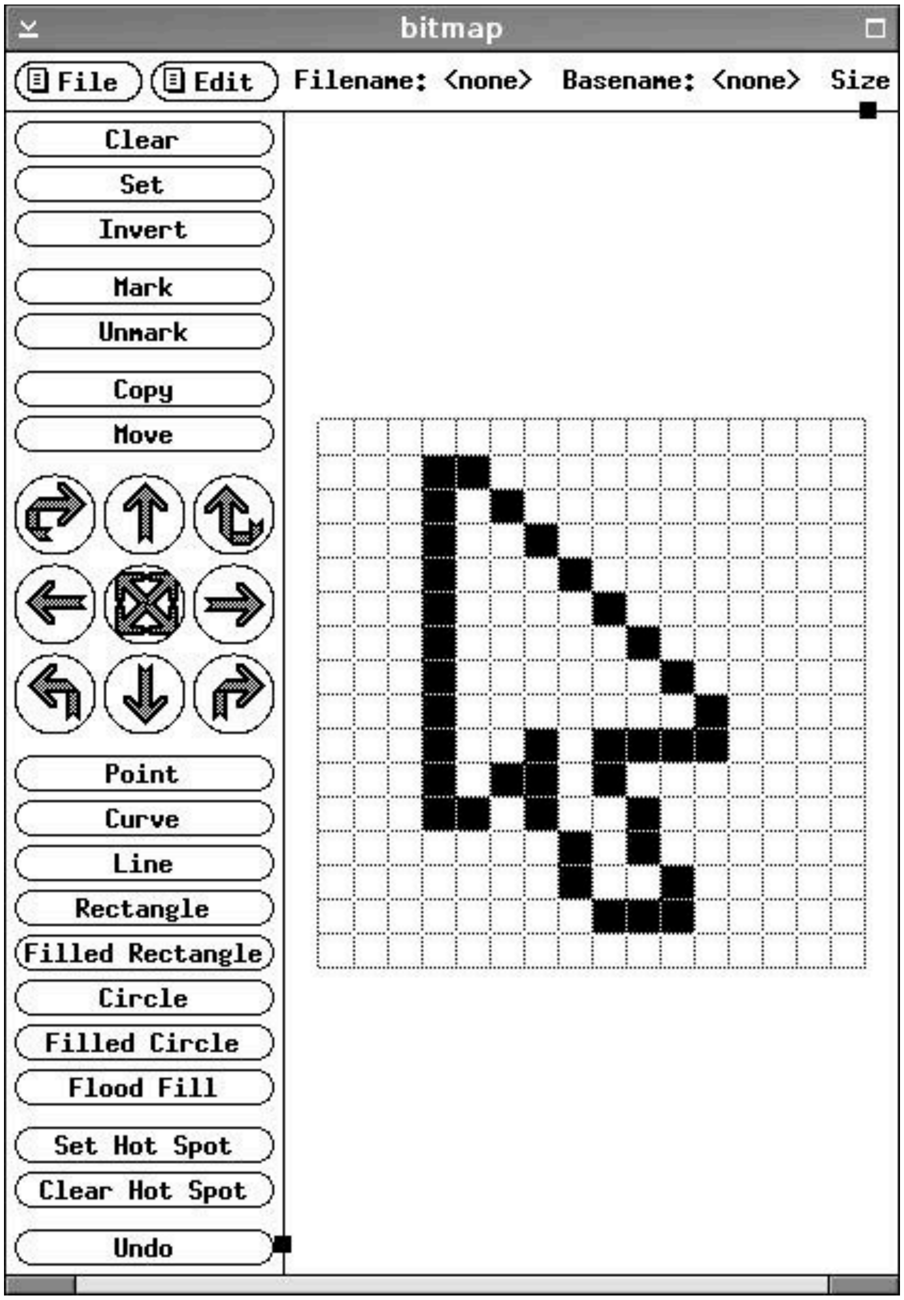
```
xsetroot -solid ForestGreen &
exec twm
```

The color you use must be a valid color that is listed in the `rgb.txt` file, and if the color has a space in it, the name of the color must be enclosed in quotation marks.

In addition to setting the background color or pattern of the desktop, `xsetroot` can also change the appearance of the mouse pointer. See the `man` page for `xsetroot` for details on how to configure bitmapped backgrounds and also how to change the mouse pointer using a custom bitmap.

You can create your own bitmaps to use as the background and as the mouse pointers with the `bitmap` program, which is installed as part of X11. Figure 7.2 shows the `bitmap` program.

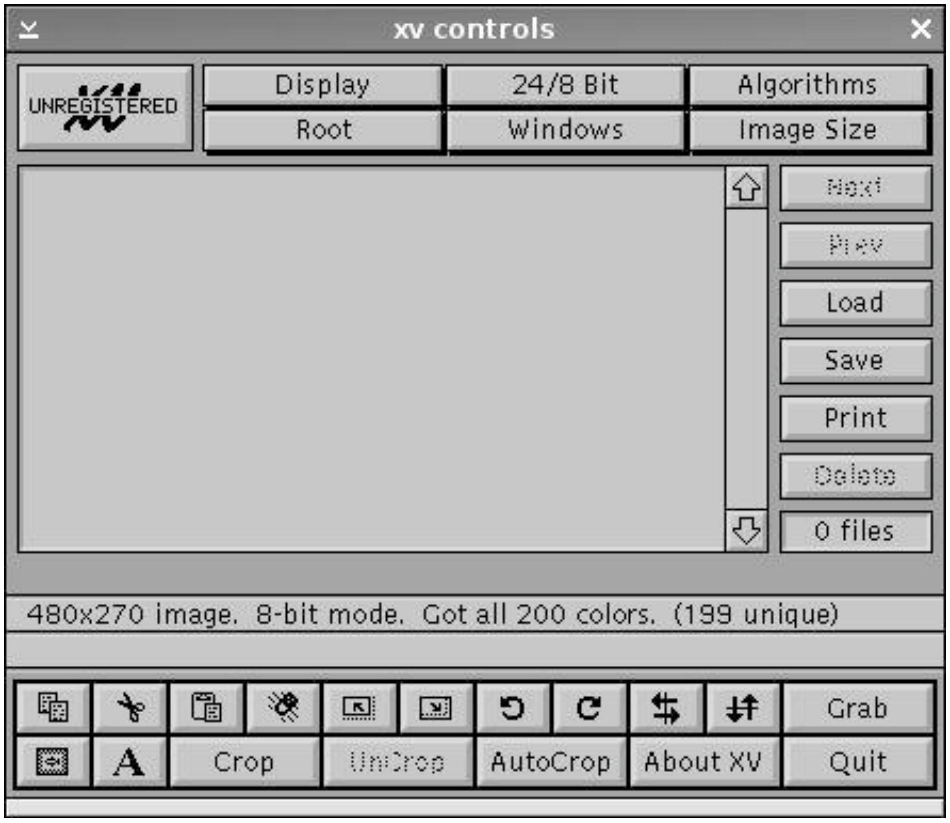
Figure 7.2. The `bitmap` program, which can be used to create bitmaps for use as background patterns and mouse pointers with `xsetroot`.



Configuring a Background Image

X11 does not come with any program that allows you to set a full-size "wallpaper" image in your desktop background. However, there is an image-viewing program called `xv` that is traditionally used for this task. `xv` is available in the ports collection under the `graphics` directory. Figure 7.3 shows `xv` running in interactive mode.

Figure 7.3. `xv` can do far more than just set the background image in X11. It is also a fullfeatured image viewer that can be used interactively.



`xv` supports most common image formats, including GIF, JPEG, BMP, and PNG, and you can use a picture in any one of these formats as a background image.

The following command is an example of how `xv` can be used to load an image as a background image for X11:

```
xv -root -quit /hone/btman/images/myimage.jpg
```

This command tells `xv` to load the image `myimage.jpg` onto the root window (which is the background of the window manager). It also tells `xv` that it should quit as soon as it has loaded the image. (This gets around the need to append an ampersand to the command line if you include it in your startup script.)

In order to have this image loaded as the background each time you start X11, you could do something like the following in your `.xinitrc` file:

```
xv -root -quit /home/foobar/images/myimage.jpg
exec twm
```

Some of the other options you may want to use with `xv` when using it to load background images include `-max`, which will cause the image to be resized and take up the entire available screen size, and `-maxspect`, which will cause the image to be resized to take up the entire available screen size within the limits of maintaining the proper aspect ratio of the image.

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Working with Fonts

Sooner or later, you will probably want to install additional fonts in X11 for your applications (such as GIMP).

Although X11 supports several types of fonts, the most commonly installed are Adobe Type 1 and TrueType. Both are extremely popular because they are supported by Windows and Macintosh, as well as newer versions of Xorg. Thousands of Type 1 and TrueType fonts are available free for download from various places on the Internet. Also, commercial fonts are available for purchase in both formats, and X11 can use them regardless of whether they're packaged as "Windows" or "Mac" fonts.

Because these are the most commonly used font types, the following sections describe their use and configuration.

Checking the `xorg.conf` File for Font Support

The first thing you will need to do is make sure the `xorg.conf` file contains the proper modules to support the fonts you want to use. The `xorg.conf` file was covered in detail under the section "Understanding the `xorg.conf` File," earlier in this chapter. You need to check the file `/etc/X11/xorg.conf` for the appropriate `Load` line under the `Module` section.

This line is necessary to support Adobe Type 1 fonts:

```
Load "type1"
```

This line is necessary to support TrueType fonts:

```
Load "freetype"
```

The preceding lines need to be located under the following heading in `xorg.conf`:

```
Section "Modules"
```

You also need to make sure an appropriate font directory exists in the `Files` section to hold the new fonts. Look for the lines in `xorg.conf` that begin with `FontPath`. If you are installing a TrueType font, I suggest that you add the following line after the last `FontPath` statement in the file to hold all your TrueType fonts:

```
FontPath "/usr/X11R6/lib/X11/fonts/TrueType/"
```

After you add this line, save the file and then exit the editor.

Creating the Directories and Installing the Fonts

Now, you must create the directory, if it doesn't already exist. As root, issue the following command:

```
mkdir /usr/X11R6/lib/X11/fonts/TrueType
```

This command creates the directory for the TrueType fonts.

Note

You may notice that X11 is one subsystem that doesn't obey the traditional FreeBSD separation between the `/usr/local` subtree and the rest of the system, discussed in detail in Chapter 12, "The FreeBSD Filesystem." When you install additional fonts for use in X11, it's a good idea to create a location for them within the design of the FreeBSD filesystem, such as `/usr/local/X11/fonts` (with appropriate subdirectories for different font types), and then use additional `FontPath` lines in `xorg.conf` to tell X11 to look for your fonts there. That way, if you have to perform a backup or transfer your system's data to a new installation, your downloaded and purchased fonts will be safely stored along with everything else in `/usr/local`.

When you have a directory for the fonts, copy the font files for the fonts you want to add into the appropriate directory. Type 1 fonts should be copied into `/usr/X11R6/lib/X11/fonts/Type1`, and TrueType fonts should be copied into `/usr/X11R6/lib/X11/fonts/TrueType`. The fonts only need read access, so you may want to change the permissions on the fonts so that they only have read access for everyone. You can do this with the following command:

```
# chmod 444 fontname
```

Here, *`fontname`* is, of course, the name of the font file you just installed. (Make sure you are currently in the right font directory. If you need help with basic shell commands and navigation through the directories, see Chapter 8, "Working with the Shell.")

Next, you must run a couple of programs to set up the fonts correctly.

To set up TrueType fonts, you need the program `ttmkfdir`. It is available in the FreeBSD ports collection under the directory `x11-fonts`. To set up Adobe Type 1 fonts, you need the program `type1inst`, also available in the FreeBSD ports collection under the `x11-fonts` directory (its port name is `p5-type1inst`, as it's a Perl package). See Chapter 16 for information on how to install software from the ports collection.

After you have copied the fonts to the appropriate directory, make sure you are in that directory and type one of the following commands at the command prompt.

For TrueType fonts:

```
# ttmkfdir > fonts.scale
```

For Adobe Type 1 fonts:

```
# type1inst > fonts.scale
```

You now must run just one more command: the `mkfontdir` command recognizes the new fonts and adds them to the font configuration file. To set up scalable fonts, such as Type 1 and TrueType, you need to run the command with the `-e` option. Once again, make sure you are in the directory to which you copied the fonts and then issue the following command from the prompt:

```
# mkfontdir -e /usr/X11R6/lib/font/encodings
```

Next, restart X11 (if you are currently in it), and your new fonts should be available for use.

Note

Whenever you add new fonts to the system, you must repeat `ttmkfdir` or `type1inst`, followed by the `mkfontdir` procedure.

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Using Remote X11 Clients

In the separable client-server architecture of X11, applications can be run on a central host and have their output and input redirected to a remote host, as is common in clustered computing environments or college campuses. Using a remote client can be useful, for example, if there's a collaborative graphical application hosted on a high-powered server and you need to be able to control it from a workstation that may not be powerful enough to run it. Another example of where this setup is useful is if the central application is very expensive and only licensed for one installation, but you need to be able to access it from any X11-capable client computer on campus; X11 makes this system possible and transparent, not to mention cost-effective. In a way, this remote use is similar to simply using SSH to log in to a remote system and then run a text-based application. The application is actually running on the server; the output and input are just being sent to your system. X11 extends this concept to graphical applications as well as text-based applications. However, this capability is disabled by default and needs to be enabled before it can be used.

The confusing aspect of using remote clients is that the terms *client* and *server* are reversed when dealing with X11. In networking terminology, you think of a "client" as being a host that runs applications located on another system known as a "server." In X11, however, the server is running on the local system, and the client is located on a remote system. Basically, a client in X11 is any program that runs under the X11 system. To make things even more confusing, your X Server may be running a client located on a remote system, which is actually a server. For example, you might load a graphical database administration client located on a remote system onto your X Server. In this case, your client is located on a remote system, but the remote system is a database server.

In order for any of this to work, the system on which you want to display the output of and control the input of the remote X11 application must be running an X Server. However, the X Server does not have to be on the same type of system. The X Server can be running on another FreeBSD system, a Linux system, a Solaris system, or a Mac OS X system. The system doesn't even have to be a UNIX-based system. There are X Servers available for Windows that can display remote X applications running on FreeBSD. Right now, the large majority of them are commercial, but an X server package for Windows, Cygwin/X, is available at http://x.cygwin.com/, and so you should be able to take part freely in the distributed X experience even from a Windows machine.

By default, your X Server will not allow remote applications to be displayed on your screen. There are a few common ways to allow this. The most common, but also the least secure, is by using `xhost`.

Using `xhost` to Allow Remote Applications to Be Displayed

`xhost` will allow remote applications running on a different system to be displayed locally on your system and take their input from your system. To see the current `xhost` configuration settings, type **`xhost`** with no arguments. Here is what the default `xhost` configuration will return:

```
# xhost
access control enabled, only authorized clients can connect
```

In this case, only applications being run on remote systems that appear in this system's authorization list will be allowed to be displayed on this system. Also, the list is currently empty, meaning that no clients are currently authorized to send their display to this system.

If you want to be able to run remote applications on the host named `lion`, you need to add it to the authorization list. To do this, you use the following command:

```
# xhost +lion
lion being added to access control list
```

If you type **xhost** now without any arguments, the system responds with this:

```
access control enabled, only authorized clients can connect
INET:lion.example.com
```

The remote host `lion`which, in the context of our earlier examples, might be a mainframe in a lab across campus running a super-expensive CAD or rendering applicationcan now display its X11 applications on your local system.

The problem with this setup is that anyone who has an account on `lion` can send the display of its applications to your system, whether you want them to or not. This can be a major security problem in an environment with untrusted users. It's therefore not a good idea to use `xhost` in these environments; other methods are available that are more secure. These are discussed briefly later in this chapter.

Also, if you do use `xhost`, it is probably a good idea to authorize a host only just before you need it and then remove the authorization as soon as you are done working with the remote application. To revoke authorization from a host, you can use a command like the following:

```
# xhost -lion
lion being removed from access control list
```

The remote host `lion` can no longer display applications on this system.

There is also a way to completely disable access control in `xhost` so that any clients can connect to the system at will. This is probably never a good idea because it is a serious security hazard. But if for some reason you want to do it, you can use the following command:

```
# xhost +
access control disabled, clients can connect from any host
```

To enable access control again, type **xhost** `-`. The system responds with this:

```
access control enabled, only authorized clients can connect
```

Caution

Because of the security hazards involved with `xhost`, at a minimum you will want to have a firewall configured that blocks unauthorized users from outside the internal network from accessing the ports that `xhost` uses. `xhost` uses ports 6000 through 6063. See the "Enabling and Configuring the Firewall" section of Chapter 30, "Network Security," for more information on configuring a firewall.

After you have configured the system to allow a remote application to display on it, you need to connect to the remote system and start the application. You can do this through Telnet, SSH, or `rlogin` (though be aware that Telnet and `rlogin`, being unencrypted communication methods, expose you to terrible security risks).

Tip

If you are connecting to the remote system by using an X Server running on Windows, make sure you use the Telnet or SSH application included with your X Server software. Because the Windows Telnet application knows nothing about the X Server, it does not work correctly for the procedures described in the following sections. Also, as mentioned earlier, it's unencrypted and thus a grave security risk.

Starting a Remote Application

To start an application on the remote host and have it display its output on the local system, you need to set the `DISPLAY` environment variable on the remote host to your local system. You can do this from the SSH session. In your connection window to the remote host, you can usually use something like the following to start a remote application and display it on your system (this example assumes that your local host is named `simba`):

```
# DISPLAY=simba:0; export DISPLAY
# xcalc &
```

This code is for a Bourne-style shell (that is, `sh`, `korn`, or `bash`). If you are using a C shell (`csh` or `tcsh`), replace the first line with the following:

```
# setenv DISPLAY simba:0
```

This code should start an `xcalc` on the remote host and display the output on your screen.

The `DISPLAY` environment variable has the following syntax:

```
DISPLAY=hostname:display#:screen#
```

Here, *`display#`* is almost always set to 0, and you can usually eliminate *`screen#`* unless you are on a system that has multiple screens attached to it.

Tip

Make sure you enter the information in the SSH window that is connected to the remote host. Entering the information on a local `xterm` window will not have the desired effect.

Other Client Access Controls

There are other ways to control which hosts can display applications on the local host. Some of these ways are more secure than using the `xhost` method described here. The other methods and their configuration are beyond the scope of this book. However, you might want to read the `man` page for `Xsecurity` to get you started. (Note that this name is case-sensitive when you try to access the `man` page.)

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Using the XDM Graphical Login Manager

You've already seen (in Chapter 5) how to use the graphical login managers built into the KDE and GNOME systems, KDM and GDM. These login systems provide a nice, seamless, graphical experience from startup to shutdown of your system, making sure users logging in on the local console can enter their KDE or GNOME sessions securely, without having access to the command-line shell. KDM and GNOME can even be configured to launch users' X11 sessions under other user environments or window managers than KDE or GNOME. However, these methods might not produce the desired effect, if you want to ensure that all users of the system have the ability to completely control their X11 sessions, including their `.xinitrc` startup scripts, using window managers other than KDE or GNOME.

XDM is the traditional graphical login manager for the X11 system, independent of any window manager or environment the user might choose. When it is run at system startup, it displays a graphical login prompt rather than the text-based login prompt at the console. The graphical login prompt is similar to a Windows 2000/XP login screen, and operates the same as KDM or GDM, but with a lot less flash and polish. It's also customizable with your own bitmaps if you want to get creative.

If you want to use XDM in your X11 sessions, you should edit a file called `.xsession` in your home directory. This file is the XDM equivalent of the `.xinitrc` file that the console login uses. It should contain the command to start your desired window manager, as well as the commands to start any applications you want to run automatically at boot time. All the commands in the `.xsession` file should end with an ampersand (`&`) so they start in the background. The following is what a sample `.xsession` file could look like:

```
exec wmaker
xterm &
```

This would start the Window Maker window manager and also start an xterm automatically after login.

Note that unlike the `.xinitrc` file, the `.xsession` file needs to be executable; otherwise, it will not work. Other than that, the two files can be the same; you can save yourself some aggravation by simply making `.xsession` a symbolic link to `.xinitrc`, and then setting `.xinitrc` executable:

```
# ln -s .xinitrc .xsession
# chmod +x .xinitrc
```

You can run XDM manually by typing **`xdm`** at the command line instead of `startx`; but this isn't an especially good idea for two reasons:

1. It doesn't really get you any additional convenience; you end up having to log in twice, once at the command line and again in XDM.
2. If you're worried about console security, it doesn't help at all, as anyone can come up to the machine and press Ctrl+Alt+Backspace to kill XDMand then they'll be dropped to your logged-in root shell.

A better solution is to have XDM launch automatically at boot time, the same way that KDM or GDM does (as you saw in Chapter 5). Setting up XDM is very similar to setting up KDM: you need to edit the `/etc/ttys` file, and enable the already present `ttyv8` line to invoke XDM automatically.

```
ttyv5   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv6   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv7   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv8   "/usr/X11R6/bin/xdm -nodaemon"  xterm   on  secure
ttyv9   "/usr/local/bin/kdm -nodaemon"  xterm   off secure
# Serial terminals
```

Be sure that the fifth field is set to `on`. At the same time, if you'd previously configured KDM (as in this example), disable it by setting its fifth field to `off`.

Save the file and reboot the system. XDM should start automatically on the next system boot. If killed, it will just launch itself again, preventing users from being dropped to your root shell.

XDM is very configurable, and details of its configuration are beyond the scope of this book. See the `man` page for information on the various configuration files available to configure XDM.

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Part III: FreeBSD on the Command Line

In This Part

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Chapter 8. Working with the Shell

IN THIS CHAPTER

Part I, "Introduction to FreeBSD," walked you through the installation and setup of FreeBSD, and Part II, "FreeBSD on the Desktop," covered the graphical user environments (GNOME, KDE, and other window managers) that help make FreeBSD run like the desktop operating systems available in the consumer market. Although a user can do great things within the graphical world of X11, so far this book has given only minimal attention to the more austere and direct method for unlocking the true power of UNIX: the *shell*.

This chapter introduces several shells available for FreeBSD, gives a feature comparison of the various shells, and then shows how to work with the shell, harnessing the power of input/output redirection and pipes to work with your data in a more direct and flexible manner than is possible any other way.

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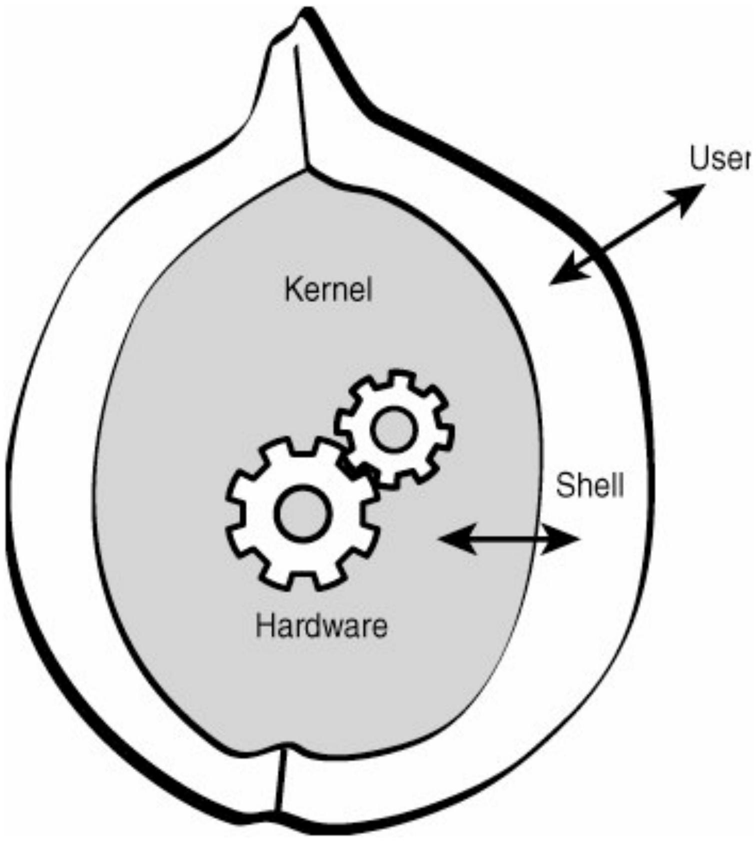
Introducing the Shell

The UNIX shell is the command-line interface between the user and the operating system *kernel*, which is the process-executing core of the operating system. If you have worked with MS-DOS, you can think of the shell as being similar to the DOS prompt, where you type commands to work with your files and the data in them. In a looser sense, you could also think of the Windows or Macintosh desktops as being shells, because even though they're a lot more flashy and specialized than the command-line interfaces they replaced, they fulfill the same purpose to you as a user: they interpret your commands and communicate them to the operating system's kernel. The shell acts as a translator, rendering human language into machine language that the kernel can understand. The shell also translates machine language from the kernel into language that humans can understand. When you log in to FreeBSD, a shell program is executed on your behalf, and when you type commands you're actually working within that shell program. Without a shell, you wouldn't even be able to type anything.

The terminology of the "shell" and "kernel" describe a metaphor for the operating system in which the innermost functions of software, which are the only ones capable of accessing the computer's hardware, are protected from interference by users who might potentially execute unsafe code. These users are thought of as existing in an "outer" layer, further away from the hardware than the kernel, and this separation is deepened in UNIX by having users run with a lower level of *permissions* (see Chapter 13, "User, Groups, and Permissions") than the kernel. The shell is the interface between these two discrete layers of the operating system, the shield around the sensitive core of the "nut" that is FreeBSD. Its job is to give youthe usera safe, structured way to access the kernel and the hardware devices it controls. As a command interpreter, the shell takes your commands and translates them into processes that access files and devices through the kernel. It should prevent you from executing unsafe code that could crash the kernel, and it helps you find and execute the programs that run the system.

Figure 8.1 shows the relationship between the system hardware, the kernel, the shell, and the user.

Figure 8.1. The relationship between the hardware, kernel, shell, and user.



You learn about the role of the kernel in detail in Chapter 18, "Kernel Configuration." For now, simply be aware that the kernel is a special piece of software that controls and regulates all the interactions of other software (and the actions of users) with the computer's hardware. Normally, you do not need to concern yourself with the kernel because it is transparent to the user, does its job in the background, and is "out of sight, out of mind."

In UNIX, the term *shell* refers almost exclusively to command-line interface (CLI) shells, which hardly look like software programs at all: all you see, when you're working with a shell, is a prompt and the text you type (and the output of the programs you run). The shell itself is so minimal in appearance that it's difficult to tell at a glance what makes one shell different from another. This chapter, however, will demonstrate how important some of those subtle differences can be.

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Choosing a Shell for FreeBSD

A lot of different shells are available for FreeBSD, ranging from bare-bones models to some that are loaded with features. Some shells are very strict as to the command syntaxes they accept, and insist that you type everything correctly; other shells allow you to repeat and edit previously used commands and automatically expand command lines with the Tab key. This chapter doesn't cover all shellssuch an undertaking would be nigh impossiblebut rather looks at some of the more popular ones. All shells listed here can be installed from the ports (in `/usr/ports/shells`) or packages, as described in Chapter 16, "Installing Additional Software."

The Bourne Shell (`sh`) and POSIX

The earliest shell still in common use is the Bourne shell, commonly known as `sh`. The original Bourne shell was developed at Bell Labs by Steven Bourne for the AT&T UNIX operating system. FreeBSD, like many other versions of UNIX, has replaced the Bourne shell with an enhanced version called the POSIX shell. This version provides a number of features that the original `sh` did not, such as rudimentary command-line editing and access to previously executed commands (done in `vi` edit mode, invoked by typing **`set -o vi`**). However, for daily use, `sh` is a pretty limited shell, and most users will want to switch to a more advanced shell (`sh` is the default shell assigned by FreeBSD to new users; see Chapter 13 for more on configuring the default shell).

The strength of `sh` is its flexibility. Accepting your typed commands is hardly its only function; its much more widespread use is as a scripted command interpreter. You can feed a *script* filea list of commands (known as a *batch file* in the MS-DOS world)to an `sh` process, and `sh` will run the script and execute its contents, automating even the most complex of command-line operations. Shell scripts can entail a lot more than merely lists of commands, too; with flow control, variables, and case-based processing, shell scripting is its own full-fledged programming language, and you'll learn how to harness it in Chapter 10, "Shell Programming." Although few people use `sh` for their day-to-day user interface, it still forms the basis for a huge number of shell scripts that you can invoke as commands within FreeBSD.

The C Shell (`csh`)

The C shell is the traditional BSD shell. The researchers at Berkeley saw all the limitations the original UNIX Bourne shell had, so they created their own shell in the process of developing the BSD operating system. The C shell is so named because its own shell programming syntax looks a lot like the C programming language. The C shell has many enhancements over the Bourne shell owing to its interactive nature, including job control and command history. It also supports a logout script file, a program that executes when you exit the shellsomething most Bourne shells (`sh` and its descendants) don't have.

The C shell also supports a configuration file that gets read every time a new subshell that is not a login shell is started (the original Bourne shell does not support this).

The C shell is the opposite of the Bourne shell in that it is great for interactive use but absolutely terrible for shell programming. Some programmers insist on writing shell programs in the C shell, but because of its more cryptic and demanding syntax, this can be an exercise in frustration and futility; thus, virtually all shell programs in FreeBSD are written in the `sh` programming language rather than the incompatible `csh` one.

Although the C shell is great for interactive use and has been very popular, it is somewhat dated, and better choices are available for an interactive shell.

Note

Modern versions of FreeBSD have replaced the original C shell with the `tcsh` shell. In fact, the C shell (`csh`) is often just a link to the `tcsh` shell. You'll learn more about that shell later in this section.

The Korn Shell (`ksh` or `pdksh`)

Not to be outdone by Berkeley, AT&T released the Korn shell in 1986. This shell was written by David Korn, and it was AT&T's answer to the C shell. The Korn shell is backward-compatible with the Bourne shell. Like the C shell, it supports job control, command history, command aliases, and a configuration file for subshells. The Korn shell goes even further, though, and includes a number of very useful enhancements for shell programmers, such as extensibility with new commands and syntax compatibility with many other shells and command interpreters. The Korn shell has been very popular and is included with most commercial versions of UNIX these days (not FreeBSD, however).

`pdksh` is a public domain version of the Korn shell. This is the version you can get for FreeBSD by installing it from the ports collection, as you'll learn in Chapter 16.

Users who are familiar with `vi` and Emacs will like the Korn shell, but users new to UNIX will probably prefer the `bash` shell (discussed next).

The Bourne Again Shell (`bash`)

The Bourne Again shell is a Bourne-compatible shell developed by the Free Software Foundation (FSF). The `bash` shell is the default shell on virtually all Linux distributions. Like the Korn shell, its Bourne compatibility means it can be used to run `sh` scripts. In usage it is similar to the Korn shell but adds even more features, including built-in help, intuitive command-line editing and history editing that use the arrow keys (simply press up and down to navigate your previously issued commands, and press left and right to edit your current command in-line), extremely powerful history functions, and more environment variables than you can shake a stick at.

The only real problem with `bash` is that it is not standard software on most commercial UNIX versions. Because of this, shell programs written specifically for `bash` can be less portable across different versions of UNIX than programs written for the Bourne shell.

The `tcsh` Shell

The `tcsh` shell is an enhanced version of the C shell. (What does the *t* stand for? It refers to TENEX, an operating system for the DEC PDP-10, whose command-line behavior `tcsh` originally was intended to mimic.) It adds many new features to the C shell, including filename completion and command-line editing with intuitive editing controls like in `bash` (it uses the arrow keys). `tcsh` also has some nice features that even `bash` doesn't support, including the capability to watch your back by recognizing potentially dangerous commands and then asking whether you're sure you want to continue (for example, "Are you sure you want to delete ALL files?").

`tcsh` is a great shell for interactive usein many ways, it's even better than `bash`. Unfortunately, it is still plagued by many of the problems of the C shell when it comes to shell programming. Again, though, almost nobody writes shell scripts in `csh` style, and so `tcsh`'s shortcomings in the shell programming arena don't have much bearing on its usability as a daily user-interface shell.

The `zsh` Shell

The Z Shell, or `zsh`, is a shell designed to cover all the bases. Its basic design is Korn-like, and it incorporates all the popular features of both `bash` and `tcsh` (and it attains a large size and memory footprint because of it); but its unique features such as advanced globbing (filename matching), command line editing, and key binding makes it a favorite for hard-core UNIX users, especially those accustomed to the binding-rich Emacs editor.

Which Shell to Choose?

Which shell, then, should you choose? For most of this chapter, it doesn't really matter. Most of the standard FreeBSD commands work the same way under all shells. It is only when you want to start performing advanced tasks, such as changing shell variables, setting aliases, and writing shell programs, that the differences between the shells really become apparent. In day-to-day use, you'll find that some of the features of more advanced shells (such as the ability to recall your previously issued commands using the arrow keys, and to complete command names with the Tab key) are crucial to your ease of use and peace of mind. This means using `pdksh`, `bash`, or the shell endorsed by FreeBSD`tcsh`.

If you don't plan to do any shell programming, `tcsh` (which in FreeBSD is the same thing as `csh`) is a fine choice. If you are interested in learning shell programming, choose `pdksh` or `bash` because you won't have to unlearn anything when you start programming, and all the commands you learn for operating within the shell can be applied directly to programming within it. For most of this chapter, command-line demonstrations will be shown using `bash`, which lays the groundwork for the shell programming discussed in Chapter 10.

Changing Your Shell

The default shell for the root user in FreeBSD is `csh` (actually `tcsh`). If you're not running as root, however, you might have a different shell assigned. To see what shell you are currently running, type the following command, where `foo` is your login name and `#` is the command prompt:

```
# grep foo /etc/passwd
```

Don't worry if you don't know what this command line means. You'll understand it and far more before you are done with this chapter. The command returns a line that looks something like the following:

```
foo:*:1001:1001::Foo Bar:/home/foo:/bin/csh
```

The line on your screen will probably be different from this one. For now, all you need to worry about is the last field (the one that reads `/bin/csh` in the example). This is your default shellin this case, the `csh` shell. Your result will probably have one of the following values:

- `/bin/sh` The POSIX Bourne shell.
- `/bin/csh` The C shell, which is actually a *hard link*, or alias, to the `tcsh` shell. If your shell is `/bin/csh`, you are actually running `tcsh`.
- `/bin/tcsh` The `tcsh` shell.
- `/usr/local/bin/ksh` The Korn shell.
- `/usr/local/bin/bash` The bash shell.

Suppose you want to switch to another shell, for example the Bourne Again Shell, `bash`. To install `bash`, choose it from the packages on the included DVD (in the `shells` category) or build it from the ports, as described in Chapter 16. After it has been installed, log out and back in to register that `bash` is now a command that you can run.

To run the `bash` shell, simply type **`bash`** at the command prompt to begin a new session using the `bash` shell. This instance of `bash` is actually running within your original `csh` session, and you'll return to `csh` when you quit `bash`. In Chapter 9, "Customizing the Shell," you'll see how to permanently change your shell, so that `bash` is what is executed as soon as you log in, instead of `csh`.

Caution

Unlike DOS, Windows, and VMS, UNIX and FreeBSD are case-sensitive. For example, the names `Grep`, `grep`, and `greP` are completely unrelated to each other as far as FreeBSD is concerned. This is a common source of errors for newcomers. If you are getting `No such file or directory` errors when you type commands in this chapter, make sure you are capitalizing your commands exactly as they're written.

You'll notice that the command prompt changes when you run the new shell. This is because different shells have different default styles for their prompts. If you're running as root (under `csh`), and your computer is called simba, you'll see the prompt change like this when you run bash:

```
simba# bash
root@simba#
```

The # prompt character traditionally denotes that you're running as root (to remind you of your potentially dangerous capabilities). If you're running as a regular user, csh uses the % character, and bash uses $, so these two lines would look like this:

```
%bash
btman@simba$
```

Notice that the default prompt under csh shows your computer's hostname and nothing else if you're root, and no information at all if you're not root. The default bash prompt communicates both your username and the computer's hostname, as well as indicating whether you're root or not with the final character. All this behavior can be changed, and you can read how in Chapter 9.

Getting Help in the Shell

The commands you can type in the shell are almost always the names of executable programs elsewhere in the system. Some shell commands are internal and specific to each particular shell (such as `alias`), but most commands must correspond to some installed program. The trick in using the shell efficiently is knowing which of these programs does what. That's where the built-in "manual" comes in. The manual is invoked using the `man` command, and you can find information on any known command or program like so:

```
# man ls
```

This would give you a full, browseable set of documentation on the `ls` ("list") command and all its available options. The same method will get you information and syntax for any installed program, whether it came with FreeBSD or was installed after the fact.

You can use the spacebar, the arrow keys, and the Page Up/Page Down keys to review the contents of the manual page, or press / and enter a text string to search for that string. Press Q to exit the manual.

Searching for Manual Pages

Sometimes, you might know what you want to do, but you are not sure of the name of the command to use. In this case, you can use the `-k` option to the `man` command to specify a general concept and return a list of possible commands that might help execute it. Sometimes, you have to be fairly creative about what you search for in order for `man -k` to return the results you want. For example, suppose you want to find out about commands that can search text files for certain words or phrases, and you want to show each place in the text file where a certain word or phrase occurs. You would likely assume that such commands would have "search" in their names or their descriptions. First, you might try the `man -k search` command, as shown in Listing 8.1. The output of this command is a list of all the relevant entries in the `whatis` database, a dictionary of programs and their descriptions. (The output on your system may be different depending on what software you have installed.)

Listing 8.1. Using `man -k`

```
# man -k search
apropos(1), whatis(1) - search the whatis database
bios(9), bios_sigsearch(9), bios32_SDlookup(9), bios32(9) - Interact
with PC BIO
S
bsearch(3)                - binary search of a sorted table
devclass_find(9)          - search for a devclass
device_find_child(9)      - search for a child of a device
lkbib(1)                  - search bibliographic databases
lookbib(1)                - search bibliographic databases
lsearch(3), lfind(3)      - linear searching routines
manpath(1)                - determine user's search path for man pages
res_query(3), res_search(3), res_mkquery(3), res_send(3), res_init(3),
dn_comp(3
), dn_expand(3) - resolver routines
tsearch(3), tfind(3), tdelete(3), twalk(3) - manipulate binary search
trees
Search::Dict(3), look(3) - search for key in dictionary file
```

This probably isn't what you had in mind. The results seem to be geared toward search routines for programmers using C. For your next attempt, you try searching for the keyword *pattern*, as shown in Listing 8.2, because you want a command that finds patterns in text files.

Listing 8.2. Another Attempt with `man -k`

```
# man -k pattern
gawk(1) - pattern scanning and processing language
glob(3), globfree(3)      - generate pathnames matching a pattern
grep(1), egrep(1), fgrep(1), zgrep(1) - print lines matching a pattern
lptest(1)                 - generate lineprinter ripple pattern
menu_pattern(3)           - get and set a menu's pattern buffer
```

Now *that* looks more usefulespecially the `grep` series of commands. These seem to be tools for searching for patterns within files, as you hoped. You could now type **`man grep`** to read the man page for `grep`, and you would find that indeed this command does what you need.

Command Summaries

At other times, you might know the name of a command but are not sure what it does (if you are poking around in `/usr/bin` or `/usr/games`, for example). You can use the `-f` option to `man` to get a short, one-line description of a command. For example, suppose you find the command `pom` in the `/usr/games` directory, and you want to know what it does:

```
# man -f pom
pom(6) - display the phase of the moon
```

The `(6)` at the end of the command name is the section of the manual that the command comes from.

Manual Sections

The online manuals are divided into nine sections, as detailed in Table 8.1.

Table 8.1. Manual Sections

Section	Description
1: User Commands	Information on user commands such as `ls`, `rm`, `cp`, and `grep`. This is the section you will probably use most often while working with and learning FreeBSD.
2: System Calls	Contains information on various APIs for FreeBSD. This section is primarily of interest to C programmers.
3: Subroutines	This section contains information on subroutines, also known as *library functions*. Once again, this is mostly of interest to C programmers.
4: Devices	More stuff for C programmers. Contains information on interfacing with device drivers in FreeBSD.
5: File Formats	Contains information on the formats of various system configuration files, such as the `crontab` files for the scheduling of regular jobs and the `rc` scripts for controlling system startup.

6: Games	Naturally, the most important section of the manual. This section contains instructions for playing the various games and other amusements that come with FreeBSD.
7: Miscellaneous	If your topic doesn't fit anywhere else, it will be found here.
8: System Administration	Contains information on commands related to system administration, such as `fsck`, for checking filesystems.
9: Kernel Interfaces	More information for programmers. This section contains information on interfacing with the kernel in C.

Some commands have more than one entry. For example, the `crontab` enTRy has an entry in Section 1 for the `crontab` command and also an entry in Section 5 for the format of the `crontab` file. If you don't specify a manual section when you use the `man` command, you'll get the first entry in the manual that matches what you're looking forin the case of `man crontab`, this means that you get the entry listed in Section 1, describing the command syntax. If you want to see the entry on file formats in Section 5, use `man 5 crontab`.

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Basic Shell File Manipulation

At the heart of using any operating system is the ability to work with filescopying, moving, renaming, creating, and deleting them. Modern graphical operating systems have sophisticated visual metaphors for these tasks, such as dragging file icons in and out of folders. However, on the command line, such file operations require the use of specific commands.

Most of FreeBSD's file-manipulation tools are analogous to similar tools in MS-DOS. If you've worked with MS-DOS before, most of this chapter will come fairly easily to you. If you haven't worked with MS-DOS before, some background information is necessary.

How FreeBSD Stores Files

Like most other modern operating systems, FreeBSD stores files in a hierarchal tree structure. You can think of the FreeBSD filesystem as a filing cabinet in an office, and you can think of each volume on the hard disk as a single drawer in the filing cabinet. FreeBSD's structural hierarchy is organized into multiple top-level directories, or *mount points*, where disk volumes are attached, and inside each volume are any number of directories (or "folders" as they are often known).

Directories can contain files as well as other directories. These directories and files are analogous to the folders and papers in a drawer. Windows and Macintosh systems both use this same type of filing system. The only real difference is that in Windows and Mac OS X, just as in GNOME or KDE under FreeBSD, you see a graphical representation of folders and files in a graphical file manager. From the FreeBSD command line, you see only a textual representation of these items.

When you log in to FreeBSD at the command line of a shell, you are placed in your *home directory*, which is located a few levels down from the topmost directory of the system disk. This behavior is the same as in Mac OS X and modern versions of Windows when you summon their respective command-line prompts, as both those systems manage multiple users in the UNIX style by keeping all users' home folders inside a specialized directory on the system disk. You'll learn the details of directory structures in Chapter 12, "The FreeBSD Filesystem." For now, you need only be concerned with your home directory.

Each user on a UNIX system (with certain exceptions) has his own home directory. Your home directory is like your own filing cabinet drawer or your own private "virtual hard disk." Here, you can create and delete files, copy files, move files, and create and remove directories. Your home directory is your personal space on the FreeBSD system, which no other user (except for root) can view, unless you configure parts of it otherwise. Being able to manage the files and directories in your home directory is an important skill. The next few sections take a look at the various commands available to manage your files and directories.

Listing Directory Contents

Use the `ls` command to list the contents of the directory you are in. Invoked with no options, the `ls` command produces output similar to the following:

```
# ls
Mail      letter-to-boss      program     proposal-draft
fbu       mail                program.c
```

By itself, this output is not very usefulit tells us nothing about the contents of the files, or even whether they are files or directories. `ls` supports several options to modify its default behavior. One of the most useful is the `-F` option, which provides you with more information on the type of each file in the list. Here's an example:

```
# ls -F
```

```
Mail/      letter-to-boss     program*      proposal-draft
fbu@       mail/              program.c
```

Now you know a little bit more about the entries in the list. Here is what each symbol following the various files means:

Symbol	Description
/	The item is a subdirectory of the current directory.
*	The item is an executable binary file or script.
@	The item is a link to another location on the hard disk. This is analogous to shortcuts in Windows or to aliases in Mac OS X.

Notice the executable file `program`. Unlike Windows, FreeBSD does not require a file to have a `.com`, `.exe`, or `.bat` extension to denote it as being executable. Whether a file is executable is a "permissions" bit that is stored along with the file as an attribute. You will almost never see an executable FreeBSD file with an `.exe` or `.com` extensionit's not necessary.

This list does not include all the symbols that `ls -F` can reveal. Type **`man ls`** and look at the `-F` option for a complete list.

Modern versions of the `ls` command also support the `-G` option, which tells `ls` to use different colors to denote different types of files. Not all terminals can display colors, though, and as a general rule, an `xterm` terminal window cannot display colors unless it is configured as a color `xterm`. (Do this by setting the `TERM` variable to `xterm-color`; see Chapter 9 for details on setting variables.) However, the console terminal *can* display colors by default.

By default, `ls` does not display hidden files, which are hidden by virtue of their names beginning with a period (they're also known as *dotfiles*). To display hidden files, use `ls` with the `-a` option:

```
# ls -a
.              .forward     .mailrc         ..profile      Mail
..             .hushlogin   .mysql_history  .project       fbu
.addressbook   .login       .rhosts         .login.conf    mail
.muttrc        .sh-history  .cshrc          .mail_aliases
```

Most of these hidden files are configuration files that store various types of information, such as profile information on how you want your shell set up, your address book for the mail program, and a list of the commands you have typed for the history functions of the shell. There are two main benefits to having these files hidden:

- They don't clutter up the directory during normal operation.
- It's more difficult to accidentally delete important configuration files because dotfiles are not matched by shell wildcard operators when used by themselves.

If you want more detail about the files and directories in the list, use the `-l` option, as shown in Listing 8.3.

Listing 8.3. Sample Output of `ls -l`

```
# ls -l
total 3
```

```
drwx------ 2 btman btman   512 Feb 15 16:04 Mail
lrwxr-xr-x 1 btman btman    15 Mar 20 06:55 fbu ->
/home/btman/documents/books/fbsd
-rw-r--r-- 1 btman btman   782 Mar 15 09:21 letter-to-boss
drwx------ 2 btman btman   512 Mar 24 15:12 mail
-rwx------ 1 btman btman 15221 Feb 21 18:11 program
-rw-r--r-- 1 btman btman  1571 Feb 21 17:51 program.c
-rw-r--r-- 1 btman btman  2521 Feb 25 18:51 proposal-draft
```

Each entry has six different fields of information. From left to right, they are as follows:

- *Permissions and other file attributes* The first field in the `ls -l` listing tells you the permissions and attributes of the file. This field is covered in detail in the section titled "File Ownership" in Chapter 13. For now, simply be aware that the information in this field tells you whether the file can be read, modified, or executed as a command.

- *Number of links* This field contains the number of links that exist to the file. Every regular file contains at least one link, which is to itself, and every directory contains at least two linksone to itself and one to its parent.

- *Username of the file's owner* and *Name of the file's owner group* These two fields are covered in detail in Chapter 13. For now, be aware that these fields tell you who the owner of the file is and what group the file belongs to.

- *Size of the file* This is the size of the file in bytes.

- *Last modification time* This is the date and time the file was last modified.

- *Name of the file* This is the name of the file. Files that look like the following are links:

  ```
  fbu -> /home/btman/documents/books/fbu
  ```

  In this case, the entry `fbu` is actually a link to `/home/btman/documents/books/fbu`. I can use this link any time I want to reference the directory rather than having to type the entire pathname of the directory.

The `ls` command can take numerous different options at once. For example, combine `l` (long listing), `-t` (sort by last-modified time), and `r` (sort in reverse order) to get a listing of the files in the directory sorted so that you can easily tell which files have been modified most recently:

```
# ls -lrt /var/spool/mqueue/
total 180
-rw-------  1 root  daemon  131913 Apr 19  2005 dfg3J6hRq61454
-rw-------  1 root  daemon    4436 Sep 25 18:16 dfg8Q1GmF96201
-rw-------  1 root  daemon    2922 Sep 27 08:05 dfg8RF56F87464
-rw-------  1 root  daemon     283 Sep 27 20:54 dfg8S3s6p77032
-rw-------  1 root  daemon     336 Sep 28 07:09 dfg8SE98Z23923
-rw-------  1 root  daemon     320 Sep 28 11:59 dfg8SIxUv57877
-rw-------  1 root  daemon     344 Sep 29 07:37 dfg8TEbE365707
-rw-------  1 root  daemon     360 Sep 29 10:22 dfg8THMim85609
-rw-------  1 root  daemon     306 Sep 29 11:00 dfg8TI07g90919
-rw-------  1 root  daemon     246 Sep 29 13:34 dfg8TKYvp14024
```

Moving Around the Filesystem

The `cd` command is used to "change directory" from one location to another in the filesystem. You can give it destination directory names in several forms, as shown in Table 8.2.

Table 8.2. Usage of the `cd` Command

Command	Result
`cd`	Instantly takes you to home directory.
`cd /`	Directories that begin with `/` are known as *absolute paths*. They always start at the root directory of the system (which is the very top directory). A `/` by itself takes you to the root directory.
`cd /usr/local/bin`	Takes you to the directory `bin`, located under the directory `local`, which is located under the directory `usr`, which is located under the root (top) directory.
`cd bin` or `cd ./bin`	Takes you to the `bin` directory (if there is one) located directly under whatever directory you currently happen to be in. If there is no such directory, `cd` returns an error. Directories or filenames that do not begin with `/` are relative to the current directory you are in. The `./` is not required, but can be a good habit to get into.
`cd ..` or `cd../`	The special `..` notation means the parent directory of the directory you are currently in. This takes you to the directory one level above where you are right now. The trailing slash is not required.
`cd ../bin`	Takes you to the directory `bin`, if one is located in the parent directory of the directory you are currently in.
`cd ../../bin`	Takes you to the directory `bin`, located two levels above the directory you are currently in.

Tip

Sometimes, it's easy to forget where you are in the filesystem hierarchy. The `pwd` ("present working directory") command prints the current directory on your screen. Use it whenever you need to refresh your memory about where you are. (Yes, you can set your shell prompt to show you where you are. You'll learn how in Chapter 9.)

Copying Files and Directories

Use the `cp` command to copy files from one place to another. It takes as its arguments a list of files to copy, followed by where to copy the files. If you specify more than one file to copy or use a wildcard, the destination must be a directory. A few examples are shown in Table 8.3.

Table 8.3. Usage of the `cp` Command

Command	Result
`cp file1 file2`	Copies an existing file called `file1` to a new file called `file2`.
`cp file1 /archive/`	Copies `file1` into the directory `archive`, which is a subdirectory of the root directory. (The trailing slash is not required, but it's good rigorous practiceif the directory `archive` doesn't exist,

	you'll get an error message rather than the file being copied to a new file called `archive`.)
`cp file1 mystuff/newfile`	Copies `file1` to the directory `mystuff` in the current directory. If `newfile` is the name of an existing subdirectory of `mystuff`, `file1` will be copied into the subdirectory `newfile`. If `newfile` is not a subdirectory, `file1` will be copied to the subdirectory `mystuff` and given the name `newfile`.
`cp file1 file 2 /archive/`	Copies `file1` and `file2` to the directory `archive`, located under the root directory.

Caution

By default, the `cp` command simply overwrites the contents of an existing file if you accidentally copy a file to a filename that already exists. For example, `cp file1 file2` overwrites `file2` with the contents of `file1` if `file2` already exists. You can use the `-i` (interactive) option with `cp` to cause it to ask you before overwriting any existing files.

If you want to recursively copy a directory and everything under it, including subdirectories, to another location, use the `-R` option to `cp`. Here's an example:

```
# cp -R dir1 dir2
```

This copies everything under `dir1` to a new directory called `dir2`. If `dir2` already exists, a new directory is created under `dir2` called `dir1`, and the contents are placed there. If `dir1` already exists in `dir2`, the contents of `dir1` in the current directory are added to the `dir1` directory under the `dir2` directory. Any files in the directory that have the same name are overwritten by the copies, so be careful when using the `-R` option (or combine it with the `-i` option so that you are warned before overwriting anything). Also note that the newly copied files will have the same permissions as the originals, as long as you own them. The `cp R` command ignores your `umask`, or the default permissions that are used to create new files. Use the `-p` option (`cp -Rp`) to ensure that all permissions are preserved.

Caution

Be careful that you do not accidentally insert special characters (such as space, *, ; etc) when using shell commands. For example:

```
# cp -R /* /old
```

This command recursively copies everything in the root directory to a subdirectory called `old`, which is also in the root directory. Of course, this also means that the contents of `old` are copied into a subdirectory in `old` called "`old`." The result is a loop that copies the contents of `old` indefinitely. On a fast hard disk, this can quickly fill up the entire disk.

Moving and Renaming Files and Directories

Moving and renaming items is the same operation in UNIX; the `mv` ("move") command is what you use for either purpose. Some examples are shown in Table 8.4.

Table 8.4. Usage of the `mv` Command

Command	Result
`mv file1 file2`	Renames `file1` to `file2`.
`mv /dir1 /dir2`	Renames `dir1` to `dir2`. Generates an error message if `dir2` already exists and is not empty.
`mv file1 /dir2/`	Moves `file1` into the `dir2` directory, which is located under the root directory.
`mv file1 /dir2/file2`	`file1` is moved into the `/dir2` directory and renamed `file2`.

Deleting Files and Directories

To delete files, use the `rm` ("remove") command. With no options, `rm` deletes the list of files it is given on its command line. It does not delete directories. If you want to delete a directory and everything under that directory, use the `-R` option with `rm`. Table 8.5 shows some examples of using the `rm` command.

Table 8.5. Usage of the `rm` Command

Command	Result
`rm file1`	Deletes `file1`.
`rm file1 file2`	Deletes `file1` and `file2`.
`rm -R dir1`	Deletes the directory `dir1` and everything under it.

Table 8.6 shows a list of some (but not all) of the other options supported by the `rm` command.

Table 8.6. Options for Use with the `rm` Command

Option	Result
`-f`	Causes `rm` to force the deletion without asking questions, even if the file is marked read-only. Use this option with care.
`-i`	Prompts before deleting each file. Useful when using `rm` with wildcards (more on that later) or with the `-R` option.
`-P`	Overwrites files three times with random patterns of data before deleting. This is useful for deleting sensitive files because it reduces the chance that they can be recovered with the `W` option.
`-W`	Attempts to undelete a file that was previously deleted with the `rm` command. This only works in certain circumstances, so don't depend on it.

Creating and Removing Directories

The `mkdir` command is used to create a directory. If you don't specify a path on the command line, `mkdir` will assume that the directory should be created as a subdirectory of the current directory. For example, type **`mkdir workdocs`** to create a new directory called `workdocs` in whatever directory you are currently in. To create a whole path of directories at once, use the `-p` option; for example, **`mkdir -p workdocs/chapters/chapter1`** creates not just the `chapter1` directory, but also `chapters` and `workdocs` if they don't already exist.

Use the `rmdir` command to remove directories. `rmdir` will only remove a directory if it is empty. Used with the `-p` option, it removes a directory and its subdirectories, provided that the subdirectories are also empty. If you need to remove directories that have files in them, use the `rm -R` command instead.

The `touch` Command

The `touch` command serves two primary purposes: It can be used to create an empty file, and it can be used to modify the last access or last modification time of an existing file. Its basic format is

```
touch filename
```

where *`filename`* is the name of the file you want to create or modify.

The `touch` command supports a few options that control how the last accessed or last modified times are set. See the `man` page for `touch` for full details.

Creating Links

As mentioned briefly earlier, you can create files or directories that are links that point to other places in the filesystem. This is useful to avoid having to type long pathnames or having to navigate through many sublevels of folders from the GUI. You can think of links as being similar to shortcuts in Windows. There are a few important differences, though, which you will look at in the following sections. The two kinds of links are *hard links* and *soft links*. Let's look at hard links first.

Hard Links

A hard link is a directory entry that points to the same inode (physical location on the hard disk) as another file. There is actually only one file, but two or more directory entries point to the same physical data on the hard disk.

By default, the `ln` ("link") command creates hard links. Here's an example:

```
# ln /home/btman/documents/books/fbsd/file1.txt ./file.txt
```

This creates an entry in the current directory called `file1.txt` that points to the same location on the hard disk as `/home/btman/documents/books/fbsd/file1.txt`. I can now access the same file by using either directory entry (presumably I would create a link like this so I only have to type `vi file1.txt` after I log in to edit this file rather than `vi documents/books/fbsd/file1.txt`). If I now use `ls -l` on this link, it will look something like the following:

```
-rw------- 2 btman users 26896 Mar 25 19:18 file.txt
```

This looks like any other plain old file, right? That's because it *is* a plain old normal file, for all practical purposes. The only visual cue you have that this is a link is seeing the number `2` after the permissions string. This indicates that two directory entries are pointing to this inode (physical location) on the hard disk. Any changes I make to this file or its directory entry will affect the other directory entries that point to this same location. For example, if I change the permissions on this entry, the original directory entry in `/home/btman/documents/books/fbsd/file1.txt` will reflect the changes as well. The modification time here reflects the same modification time as the original directory entry. The size also reflects the size of the original directory entry.

If I delete the original directory entry in `/home/btman/documents/books/fbsd/file1.txt`, the directory entry will be removed, and the link count will be decremented by one to show the change. However, the file still exists because there is another link pointing to that same location on the hard disk (the link you created). The file will not actually be deleted until all its hard links have been removed and the link count is decremented to zero.

Hard links have two important limitations:

- They cannot be used to link directories.
- They cannot cross filesystem boundaries (for example, you cannot create a link from within `/usr` to a location in `/var`).

If you need to link a directory or cross a filesystem boundary, you will have to use a soft link.

Soft Links

Soft links (also called *symbolic links* or *symlinks*) are similar from a user's perspective to shortcuts in Windows or aliases in Mac OS X. Unlike hard links, a soft link is a separate file that has its own inode on the hard disk. The soft link is simply a "stub" file that contains a pointer to another file. Use the `-s` option with `ln` to create a soft link. Here's an example:

```
# ln -s /home/btman/documents/books/fbsd/file1.txt file.txt
```

If you use `ls -l` on this file, it will look something like this:

[View full width]

```
lrwxr-xr-x 1 btman users 31 Mar 25 19:56 file.txt -> /home/btman/documents/books/fbsd
   /file1.txt
```

Notice the differences between this version and the hard link:

- The permissions do not indicate the permissions of the target file to which the link refers. Also, you cannot change the attributes of a soft link (permissions, owner, or group). You must do this by manipulating the target file.
- The link count is only one instead of two. This is because the soft link is an actual file that points to the other file. It is not simply a directory entry that points to a location on the hard disk (as a hard link is).
- The file size is lying to us. The size listed here is the size of the file containing the linknot the size of the target file it points to.
- The file modification time is also deceiving. It tells us the time the *link* was last modified, but it tells

us nothing about the time the target file was last modified.

- The filename tells us the name of the file that this file points to (after the `->` symbol).

Also, unlike with a hard link, if you delete the original file that a soft link points to, the file's data blocks are removed and the link becomes an orphan that no longer works. However, if you delete the link with `rm`, the target file remains untouched.

Tip

If you are trying to access a file and you keep getting `No such file or directory` errors, and yet when you do an `ls`, the file is clearly there, you are probably trying to use a soft link that has become an orphan, meaning that its target (or parent) no longer exists. Use the `-l` option to `ls` and see whether the file is a soft link. If it is, check to see whether the file it points to actually exists. Note that deleting or even simply moving a file can cause its soft links to become orphans.

Which style of links to use is as much a matter of style as of technical best practices. You might want to use hard links if you are pointing to a file located on the same filesystem as the one you are currently on because hard links have the advantages of providing you with information about the actual files and of not becoming orphans if the original files are deleted or moved. However, if you need to link to a directory or link to a file that is located on a different filesystem, you must use soft links. It's also a lot easier to detect a soft link using `ls`, and they're generally more versatile and easier to understand than hard links.

Note

Hard links also have one other advantage over soft links: They don't take up an inode. This may not seem like a huge issue, but there's a fixed number of inodes available on the hard disk, and it's possible to run out of inodes if you have a lot of very small files on the disk, even if you have lots of space left on the hard disk. When you run out of inodes, no more files can be created until you have deleted some files and thus freed up some inodes.

Universal Options

Many (but not all) of the file-manipulation commands available in FreeBSD support the options shown in Table 8.7. Before using these options, though, be sure to check the `man` page for proper syntaxsome commands might use certain well-known option names for unusual purposes!

Table 8.7. Universal Options for Most Shell Commands

Option	Result
`-i`	Runs in interactive mode, prompting you before taking action on each file if that action would cause damage to an existing file.
`-v`	Is verbose about what the command is doing. In other words, the command prints messages on the screen for each operation it performs.
`-q`	Is quiet (the opposite of verbose); the command doesn't print any status messages as it runs.
`-f`	Forces the action without asking, even if the file permissions prohibit the

action (for example, this action could be used to delete a file without asking whether the file is set to read-only, assuming that you have write privileges in the directory where the file is located).

Caution

As you may have noticed, most UNIX commands that deal with file and directory manipulation will pretty much do whatever you tell them to do without asking any questions, even if the action will destroy existing files. UNIX doesn't hold your hand like Windows or DOS does. UNIX assumes you know what you are doing when you tell it to do something. Because of this, if you aren't completely sure of what you are doing (for example, if you aren't sure whether there might be existing files of the same name in a directory you are copying another directory to), it's often a good idea to use the `-i` option with many of these commands. This way, you will be prompted before the command does anything that will damage existing files.

Meta-characters and Wildcard Operators

All the previously mentioned commands also support meta-characters and wildcards. These allow you to match one or more unknown characters.

Caution

DOS users: Before you get any ideas of skipping this section because you think you know all about wildcards, remember that UNIX and FreeBSD wildcards do *not* behave like DOS wildcards. Part of this is because the period (`.`) is just another character in a filename as far as UNIX is concerned. UNIX gives no special treatment to the period like DOS does. This means that although `del *` would do virtually nothing in DOS, `rm *` will delete *every visible file* in the current directory in UNIX! Be careful with UNIX wildcards, especially if you are used to how wildcards behave in DOS.

You can use three primary wildcard operators in FreeBSD. These wildcard operators are shown in Table 8.8.

Table 8.8. Wildcard Operators

Operator	Meaning
`?`	Matches any single unknown character. For example, `file?.txt` will match the files `file1.txt`, `file2.txt`, and `fileA.txt`. However, it will not match `file10.txt` or `fileAB.txt`.
`*`	Matches any number of unknown characters. For example, `f*` will match the files `f`, `foo`, `file`, `file1.txt`, `file2.txt`, `fileA.txt`, `file10.txt`, and `fileAB.txt`.
`[]`	Matches a range of characters. (This operator is explained in the following section because it requires more detail than can fit well in this table.)

Matching Ranges of Characters

You can match ranges of characters by enclosing them in brackets. For example, `file[1-3]` will match `file1`, `file2`, and `file3`, but not `file4`. This also works with characters: `file[a-c]` will match `filea`, `fileb`, and `filec`.

Tip

When dealing with ranges of characters, it is important to remember that the matching is based on the ASCII number value of the character. For example, `file[A-b]` will match `fileA` and `fileb`, but it will also match `fileB`, `fileC`, `fileD`, `fileE`, and so onall the way up to `fileZ`. This is because uppercase letters come before lowercase letters in the ASCII chart. Therefore, any time you specify an uppercase letter as the starting point for the match and a lowercase letter as the ending point, all the uppercase letters between the one you specify and the letter *Z* will also be matched. Refer to http://www.lookuptables.com/ for more information on ASCII values.

You can also match one of several characters simply by including them in a list. For example, `file[1234]*` will match any file beginning with `file1`, `file2`, `file3`, or `file4`, no matter what follows it. Notice that this example combines two wildcard operators, which is perfectly legal.

Finally, you can use the logical `NOT` operatoran exclamation point (`!`) in `bash`, a caret (`^`) in `tcsh`with wildcards. For example, `file[!1234]*` will match all files that begin with `file` *except* `file1*`, `file2*`, `file3*`, or `file4*`.

Caution

Be extremely careful when using wildcards with commands such as `rm` because it is easy to make disastrous mistakes. For example, suppose you accidentally type `rm note *` when you meant to type `rm note*`. The shell interprets the space as an argument separator. Therefore, this simple typo of putting a space between `note` and the asterisk changes this command from "remove all files beginning with `note`" to "remove the file `note` and then remove *all* other files in the directory!" So, double- and triple-check your typing when using wildcards with commands such as `rm`. (Better yet, use the `-i` option to force `rm` to prompt you for each deletion.) Also, quadruple-check when using the `R` (recursive) option, which can result in complete destruction of your system if used improperly.

Tip

One trick you can use when working with wildcards and potentially destructive commands is to use the wildcard with the `ls` command, instead of the command you're really going to use, as a harmless "dry run" before executing the final command. Then, to execute the real, potentially destructive command, simply press the Up arrow to recall the harmless `ls` version from your command history, and change only the command name. It pays to take all the precautions you can when it comes to avoiding dangerous typos!

Notes on Filenames

It is all right to include spaces in files, but if you do you will need to place the filenames in quotes so as to tell the shell to interpret the filename as one argument, not two separate files, or to use the backslash (`\`) to "escape" the space characters and force them to be interpreted literally. A common practice, and the one I recommend, is to use underscores in filenames instead of spaces. This makes them easy to read and also eliminates the need to quote filenames. Also, for similar reasons, avoid using filenames with special charactersyou'll thank yourself later if you ever need to access those files.

Caution

One serious problem with filenames that contain spaces is that they can cause you to accidentally delete files that you did not intend to delete. For example, suppose you have three files: the first is named `business`, the second is named `letter`, and a third is named `business letter`. Suppose you want to delete the file `business letter`, but you forget to quote the filename when issuing the `rm` command. Remember that the shell interprets a space as an argument separator unless it is quoted. Therefore, forgetting the space when issuing this command will result in the files `letter` and `business` being deleted, but the file `business letter` will be left untouched. This is *not* what you intended to happen. This is another good argument for not using spaces in filenames, although this is also a good example of a case where modern shells' filename completion features (which properly escape the spaces) can both save you time and protect you from typos.

Dealing with Funky Filenames

Most filenames in UNIX are of a simple, predictable form: alphanumeric characters, upper-and lowercase, and no spaces. However, this is just a convention; UNIX fully supports filenames that contain all kinds of special characters, including spaces, quotes, parentheses, and other odd symbols that you would normally only expect to see on Windows or Macintosh files, where command-line manipulation of filenames is unnecessary. The only character that is not allowed in UNIX filenames is the forward slash (`/`).

However, although most UNIX programs will only create files with well-behaved names, files that originate on Windows or Macintosh computers might end up (via FTP or other methods) on your FreeBSD machine with spaces or other unusual characters in them, and you will need to know how to deal with them.

For example, here is a directory listing that contains several files with funky names:

```
*               File\1.txt       file4.txt         file6.txt
File 1          file"3".txt      file5.txt
```

These filenames are for demonstration purposes only. Don't create filenames like this in practice!

The first special case here is the file `*`. How can you remove this file? If you are new to UNIX, your first reaction might be simply to type **`rm *`**, which would remove a file named `*`, right? Well, it will certainly remove this file, but the shell interprets the asterisk as a wildcard character. Because of this, it will remove this file and also every other file in the directory! This is obviously not what you want to happen.

The shell provides an "escape" character for cases such as this one: the backslash (`\`). It tells the shell that it should interpret the next character in the string as a normal character instead of giving it the special treatment it might otherwise receive. In this case, then, the command `rm -i \*` would remove the offending file while leaving the other characters untouched.

The second problematic file is `File\1.txt`. In this case, the filename itself contains the escape character, the backslash. Typing **`rm File\1.txt`** will result in `File1.txt: No such file or directory` because you've merely told the shell to treat the character `1` as a normal characterwhich it would have done anyway.

The solution here is to simply escape the escape character itself, like this:

```
# rm -i File\\1.txt
```

Next you come to the file named `File 1`. The shell interprets spaces as argument separators, so `rm File 1` will not remove this file. Instead, this command will attempt to remove two files: one named `File` and the other named `1`. In order to get the shell to interpret the string as a single argument, you need to quote it. In this case, `rm -i "File 1"` (or `rm -i File\ 1`) will do the trick.

So what about `file"3".txt`? Once again, if you simply try `rm file"3".txt`, you will see `file3.txt: No such file or directory`. This is because the shell interprets `"` as a special character. Once again, you need to escape it with the backslash. The command `rm -i file\"3\".txt` will do the trick, although being clever with quote marks (`rm -i 'file"3".txt'`) will also work.

Tip

Notice that the `-i` option to `rm`, which prompts for confirmation before deleting the file, is used in all the previous examples. This is a good habit to get into when trying to remove files with unpredictable names. This way, you can be sure the command you are issuing will actually have the effect you intend it to have, and it won't delete some files you don't want deleted.

Where Did I Put That File Again?

It happens to all of us. Once in a while we create files or save files and then we simply can't remember where we put them. For situations such as this, FreeBSD provides the `find` command, which has a somewhat nonstandard syntax. Here is an example of how to use it:

```
# find . -name "lostfile*"
```

This command will find all files beginning with the name `lostfile` that are in the current directory or any directory within the current directory. Note that a search done from the root directory will check every subdirectory on the entire systemeven subdirectories located on other disks or across NFS mounts. This can take quite some time on large disks. There are various options to control how far into the directory hierarchy `find` will go, and whether it will traverse filesystems or only look on the current filesystem. You can also use `find` to search for files based on criteria other than name, such as the owner, group, and size. See the `man find` page for full details on this command.

A related command, called `locate`, does not actually search for the file but instead searches a database list of files on the system. Because of the database back-end, `locate` is many times faster than `find`. The drawback is that there could be files on the system that the `locate` database doesn't know about and won't find. Depending on the system, the `locate` database is usually updated once a day or sometimes once a week (you can control the frequency of the updates; see the `man locate` and `man updatedb` pages for more details).

That covers the bulk of what you need to know to manipulate files from the command line. Although this part of the chapter didn't cover all the available commands, you now know about the ones you are likely to use on a regular basis, and you know where to look for additional documentation. For more information on each of these commands and their options, see their respective `man` pages.

PREV NEXT

Text-Related Commands

One of the original design goals of UNIX at AT&T was the easy processing of text data. UNIX and FreeBSD include a large number of commands for processing text data from the command line. This chapter doesn't cover every available text command, but you'll learn how to use the most useful ones. With a few judiciously applied commands invoking small but flexible command-line text-processing utilities, you can take a bare text file and extract information from it like a sorcerer.

Counting Lines, Words, and Characters

Use the `wc` command to count the number of lines, words, and characters in a text file. With no options, this command gives all three. For example, the following tells me that there are 1,160 lines, 7,823 words, and 51,584 characters currently in the text file that contains this chapter of the book:

```
# wc chapter08
    1160    7823   51584 chapter08
```

`wc` supports the `-l` option to only display the number of lines, the `-w` option to only display the number of words, and the `-c` option to only display the number of characters. These options can be combined to control what information `wc` displays.

Viewing Text Files: Less is More

Once two separate commands, `more` and `less` are now just two different names for the most commonly used tool for viewing text files in UNIX. You can use the `less` (or `more`) command to display text files on your screen, one screen at a time. In addition, you can search the file you are currently viewing for text strings, and you can scroll back and forth through the file by any number of lines you specify or by simply using the arrow keys.

Table 8.9 shows some examples of commands that can be used in `less`.

Table 8.9. Commands Allowed Within the `less` Program

Command	Usage
`/pattern`	If you replace *`pattern`* with the pattern you want to search for, `less` will find the specified pattern in the file.
Space or `f`	Scrolls forward one screen. If you type a number before pressing the spacebar, `less` will scroll forward that number of lines.
`b`	Scrolls back one screen. If you type a number before typing `b`, `less` will scroll back that number of lines.
Up and down arrows	Moves up and down, respectively, one line at a time in the file.
`# g`	If you replace `#` with a number and then type **`g`**, `less` will move to that exact line in the file.
`# %`	If you replace `#` with a number between 0 and 100, `less` will move to a new location that represents that percentage of the file.

`G`	Jumps to the end of the file.
`q`	Quits the `less` program.

These are probably the most common options you will use with `less`. Many more options are available, however. The `man` page for `less` is nearly 2,000 lines long. See this page for more information on the other options and commands that `less` offers (and note, too, that `man` uses the `less` interface to view the manual pages).

Viewing Only the Top or Bottom of a Text File

If you want to see only the first few lines or the last few lines of a file, you can use the `head` or `tail` commands.

By default, `head` and `tail` show the first 10 and last 10 lines of the file, respectively. You can change the number of lines that will be displayed by using the `n` option followed by a number (for example, `tail -100 log.txt`).

For the `tail` command, you can use the `f` option to have it continually update the display with new lines as they are appended to the end of a file. This can be useful for monitoring a log file and any new messages written to it in real-time.

Searching for Patterns

A hallmark of UNIX is the ability to search rapidly through a collection of files for a particular bit of textsomeone's name, a command you're trying to remember, a function in a program, or the name of a service in a log file. With standard UNIX commandline tools, these kinds of searches can be executed with great efficiency.

You can use the `grep` series of commands to search for patterns in text files. Three different `grep` commands are available. There is plain-old `grep`, which simply searches for patterns and basic regular expressions; there is `egrep`, which can search for extended regular expressions (which employ a large suite of special wildcards to define variable patterns); and there is `fgrep`, which searches for fixed strings (strings that must be matched literally, without wildcards). Some earlier UNIX manual pages also referred to `fgrep` as "fast `grep`" because it was supposed to be faster than regular `grep`. In reality, though, `fgrep` is almost always slower than regular `grep`. Most `man` pages these days no longer refer to `fgrep` as fast `grep`.

Suppose you want to search the file `textfile` for the pattern `cat`. In its simplest form, `grep` looks like this:

```
# grep cat textfile
```

This command searches through every line of the file `textfile` and prints each line where the pattern `cat` is matched. Note that the command matches a pattern and not a word. This means that in addition to *cat*, the words *catnip*, *catbird*, *catfish*, and *concatenate* would also be matched because they all contain the string `cat`. If you only want to match the actual word *cat*, enclose the string in quotes and include spaces on each side, like this:

```
# grep " cat " textfile
```

Note, however, that this only matches occurrences of `cat` in the middle of a sentence; if `cat` appears at the beginning or end of a line, or it's followed by a period, this `grep` command won't match it. Adjust your search pattern to your needs accordingly.

Some common options to `grep` include `-i` to perform a noncase-sensitive search, `-c` to suppress the display of matching lines and print the number of times the match occurred instead, `-n` to display the line number of the line in front of each line where a match occurs, and `-v` to reverse the operation and print only lines that do not match the specified pattern.

The extended regular expression matching of `egrep` is beyond the scope of this chapter, but regular expressions will be covered in detail in Chapter 10.

Sorting Text in a File

Sometimes, you might want to view the text in a file sorted into a certain order. For example, you might want to take a list of names and perform an alphabetical sort, or list of expenses and sort the lines numerically. You can use the `sort` command for this. By default, this command sorts based on ASCII value, and it does not ignore leading whitespace. Some of the common options are shown in Table 8.10.

Table 8.10. Options for Use with the `sort` Command

Option	Result
`-d`	Sorts using "telephone book" sorting, which ignores anything other than letters, digits, and blanks when sorting.
`-b`	Ignores leading whitespace in lines when sorting.
`-f`	Folds lowercase letters into uppercase letters when sorting. This has the effect of creating a case-insensitive sort.
`-n`	Sorts according to the numeric value of a field.
`-t`	Changes the field separator that `sort` uses to indicate the end of a field and the beginning of the next field. By default, `sort` uses whitespace to separate fields.
`-u`	If there are identical lines in the input to be sorted, this option displays only one of the lines in the sorted output.
`-r`	Reverses the output of the sort.
`-o`	Sends the results to an output file instead of to the screen. The name of the desired file should be supplied after `-o`. This option has the same basic effect as redirecting the output to a file (there'll be more on input/output redirection later in this chapter).

If given more than one file on its command line, `sort` will concatenate the two files. If you use the `-m` option when supplying multiple files, `sort` will work faster by merging them together. However, for the `-m` option to work properly, each input file should already be individually sorted.

Replacing Strings Using `tr`

You can use the `tr` ("translate") command to search a text file for each occurrence of a certain string and replace it with a new string. The basic form of the command is as follows:

```
# tr "a-z" "A-Z"
```

This command would replace all lowercase letters with uppercase letters. By default, `tr` gets its input from standard input (which is normally the keyboard) and sends its output to standard output (which is normally the screen). This is not very useful in most cases, so normally `tr` is used with input and output redirection. You will learn more about input and output redirection later, but here is the basic form of `TR` to make it receive input from a file and also direct output to a file:

```
# tr "a-z" "A-Z" < file1 > file2
```

This command will read `file1`, replace all lowercase letters in the file with capital letters, and store the new file in `file2`.

You can also use the `-d` option with `tr`. In this case, `TR` will simply go through the file and delete each occurrence of a specified character. For example, the following will delete each occurrence of either uppercase *A* or uppercase *B* from `file1` and store the results in `file2`:

```
# tr -d "AB" < file1 > file2
```

The `TR` command is extremely flexible. When used with the proper pipes, redirections, and options, it can address a great many text-manipulation tasks that users have all too frequently written Perl scripts for, not realizing they're reinventing the wheel.

Showing Only Certain Parts of Lines in Text Files

Sometimes, you might be interested in only a certain part of a line in a filejust the first half of each line, for instanceor you might want to divide up each line at commas or tab characters and print out only the third field of each. You can use the `cut` command to cut only certain fields or parts thereof from a file for display. For example, suppose you have a text file named `phone.txt` that contains the following simple address book:

```
Doe, John~105 Some Street~Anytown~NY~55555~123-555-1212
Doe, Jane~105 Some Street~Anytown~NY~55555~123-555-1212
James, Joe~251 Any Street~Sometown~CA~51111~321-555-1212
```

If you only want to see the first five characters of each line, you can use `cut -c 1-5 phone.txt`, in which the argument to `c` (`1-5`) specifies a list of character positions, which in this case is characters 1 through 5. This results in the following:

```
# cut c 1-5 phone.txt
Doe,
Doe,
James
```

A more useful application of `cut` is to cut only certain fields from a line with regular delimiters. The following command will return the first field from a set of lines delimited by tabs:

```
# cut -f 1 phone.txt
```

By default, `cut` expects fields to be separated with tab characters. However, you can change the field separator to any character you want. In this case, our address book text file doesn't use tab characters as field separatorsit uses tildes (`~`). You can specify which delimiter character you want to use with the `-d` option:

```
# cut -f 1 -d "~" phone.txt
Doe, John
Doe, Jane
James, Joe
```

Here, you have told `cut` to display only the first field, and you also told it that fields are delimited by tildes (`~`). Because the first tilde comes after the name, the command lists only the name of the person and leaves out the rest of the information.

Similarly, you can get a listing of all the users on your system by using `cut` on the `/etc/passwd` file:

```
# cut -f 1 -d ":" /etc/passwd
frank
bob
alice
joe
simba
lee
```

Formatting Text with `fmt`

The `fmt` command formats text into nice 65-character lines (by default). This is most useful for preparing a text file to be sent through email, but it can be used for other simple formatting tasks as well. Here's an example:

[View full width]

```
Until he extends his circle of compassion to include all living things, man will not
    himself find peace.
-- Dr. Albert Schweitzer
```

The first line contains 105 characters, which is too long to display on one line of a character-based display (and even some graphical displays if the resolution is low). The result is that either the mail-reading program will break the line in an odd place (such as in the middle of a word) or the text will go off the right end of the screen, forcing the reader to scroll right to read the rest of it. (If you've ever gotten one of those email messages that looks like it is just one long line, the mail program is not breaking the lines properly for display.)

The `fmt` command will save us. Its typical use is simple, as follows:

```
# fmt quote.txt
Until he extends his circle of compassion to include all living
things, man will not himself find peace.
-- Dr. Albert Schweitzer
```

This output could then either be redirected to a mail program or to a file that could then be mailed.

Here is an example that makes it easier to see the results of the `fmt` command:

```
Until he extends
his
circle of
compassion to
include all living
things
man
will not himself
find peace

-- Albert Schweitzer
```

It will look like this after being run through `fmt`:

```
Until he extends his circle of compassion to include all living
things man will not himself find peace

-- Dr. Albert Schweitzer
```

This section has presented some of the most useful commands for working with text. By combining these various commands, you can perform some rather sophisticated tasks, such as analyzing web server logs for trends. Of course, these commands have their limits. When you run into them, you might want to look into `sed` and `awk` for text processing. Both `sed` and `awk` are beyond the scope of this chapter (whole books exist on both subjects, such as *sed & awk* published by O'Reilly), but you should be aware that they exist on your FreeBSD system and can be used to handle some very sophisticated text-processing tasks.

So, how can you combine the commands we've used to do more useful things? That's where pipes and input/output redirection come in to play.

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Pipes and Input/Output Redirection

One of the things that makes UNIX so powerful is the fact that output from one command can be used as the input to another command, and the final output can be redirected to other places than just the screen. You can get a listing of files or the output of a program, pipe it into `grep` to filter out irrelevant lines, and then send it through `fmt` to process it for easy readingall on the same command line. These kinds of tasks are very frequently useful in system administration tasks such as log file processing and filesystem auditing. For example, `ls` would normally display the directory list to the screen, but it can easily have that output redirected to a file, like this:

```
# ls > filelist.txt
```

This will create a text file called `filelist.txt` that contains the directory list of the current directory. This is known as *output redirection*.

If the directory list is too long to fit on the screen, you can pipe its output to the `less` program, like this:

```
# ls | less
```

You may recall that the `less` command displays text sent into it one screen at a time. This will prevent the directory list from scrolling off the screen before you get a chance to read it.

What if I want to mail the Albert Schweitzer quote to someone? Rather then type the quote into an email message, you can send the file that contains the quote as the input to the `mail` command. There are actually two ways you can do this, and both have the same effect. First, you can use the `cat` ("catenate") command, which would normally print the file to the screen and pipe the output to the `mail` program, like this:

```
# cat quote.txt | mail useraddress
```

The following command uses input redirection to accomplish the same thing:

```
# mail useraddress < quote.txt
```

In this case, you have told the `mail` command that instead of getting the message to send from the keyboard, it should get the message from the file `quote.txt`. Although both these commands accomplish the same thing, the second one is more efficient because it doesn't have to call the `cat` program. Instead, it lets the shell handle redirection.

You can do both input and output redirection in the same command. For example, the `TR` command you used previously tells `TR` to get its input from `file1` and send its output to `file2`:

```
# tr "a-z" "A-Z" < file1 > file2
```

Tip

If you ever get confused about whether to use `<` or `>`, remember that the arrow points in the direction the data is going.

You can combine multiple pipes into a single command:

```
# cut -f 1 -d " " access.log | sort | uniq -c | more
```

This is a quick-and-dirty way of extracting useful information from an NCSA-compliant web server log file. Specifically, this information extracts field 1, which contains the network address of each hit, pipes it to `sort`, and then pipes the sorted output to `uniq -c`. This counts the number of occurrences of identical lines and then displays each unique line, preceded by the number of times that line was repeated, and then pipes the output to `more` so that you can read it without it scrolling off the screen. Specifically, this command tells me how many hits each network address generated on my web server.

You can also combine pipes and input/output redirection:

```
# cut -f 1 -d " " /var/log/httpd-access.log | sort | uniq -c > hits.txt
```

This is the same as the first command, except it records the information in a file instead of displaying it on the screen.

The creative use of pipes and input/output redirection is where the power of FreeBSD is really unleashed. (You can make the previous command more useful using `awk`, but you will have to wait until Chapter 10 to learn how.)

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Command Completion and History Editing

Now that you have seen some of the basic commands available at the command line, let's examine a few of the advanced features of the more modern shells.

If you're not sure whether `bash` (or any program) is installed on the system, you can easily figure it out by taking advantage of the built-in command-completion features of `tcsh`, `bash`, and other feature-rich shells. Type enough of the command name for it to be uniquethe first two or three letters, just to see how this worksand then press Tab. If you've entered enough of the program name for it to be uniquely determinable, the rest of the command will complete itself.

If you haven't specified enough of the program name for the shell to figure out what you want, you will get a "bell" signal (which will beep at you or give you another kind of alert, depending on your terminal program). You can then get a listing of all possible completions to the command, either by pressing Tab again (in `bash`) or by using Ctrl+D (in `tcsh`):

```
# bas [Tab]
basename   bash     bashbug
```

Caution

Ctrl+D is also the keystroke for deleting the character to the right of the cursor as well as for logging out of a `tcsh` session (if entered on a blank line). So be careful!

Tab-completion also works on filenames:

```
# ls show [Tab]
showchars.cgi*    showfavepics.cgi* showprofile.cgi*  showuploads.cgi*
showcomments.cgi* showpopular.cgi*  showrequests.cgi*
```

History editing is also a fundamental feature of the advanced shells. As you enter commands, each one is held in a buffer for the duration of your current login session, up to a limit set in your shell configuration file (100 by default in `tcsh`). You can scroll up and down through the commands you've entered with the up and down arrow keys; then you can either press Enter to re-execute whatever command you've selected or edit the command with the other arrow keys to correct mistakes or alter the desired result.

Each command is also entered into a history file in your home directory: `.history` for `tcsh` and `.bash_history` for `bash`. This allows your command history to span even beyond your current login session, back into previous ones; however, although the history file is readable only by its owner, you might consider it a security risk. After all, do you really want to have a file sitting around with a record of all the commands you've entered? If that's the case, the history file can safely be deleted without any detrimental effects other than commands from previous login sessions not being available in scrollback. You can delete your history file by entering **`rm ~/.history`** or **`rm ~/.bash_history`**, depending on the shell you're using. You can even have this occur automatically by adding the appropriate `rm` command to your `.logout` or `.bash_logout` file, as described in Chapter 9.

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Chapter 9. Customizing the Shell

IN THIS CHAPTER

Regardless of whether or not you choose to operate your FreeBSD system through the X11 GUIparticularly as an administratoryou're going to have to deal with a shell. A shell gives you all the flexibility you need to accomplish even the most complex tasks but also dictates a user experience that's arcane at best. In this chapter, we'll make ourselves at home in the shellcomfortable enough to use it as a programming environment as well as an everyday user interface.

We've already talked about the basics of the shell and what you can do with it back in Chapter 8, "Working with the Shell." That chapter introduced the shell as a command-line interface, discussed the various shells you can use in FreeBSD and what kinds of commands are available in the shell for controlling the system. Now, we'll be looking at the shell itself in more detail and examining how it applies to the multitudes of users you might be supporting on your system and how to customize it to your taste.

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Adding Shells to the System and Making Them Available

Most users will probably be satisfied with the default FreeBSD shell, `/bin/tcsh` (the same as `/bin/csh`). It provides command-line editing, tab completion, history navigation, and the rest of the advanced shell features missing in the more rudimentary shells. However, the fact that FreeBSD defaults to `tcsh` rather than `bash` (which is commonly used in Linux) reflects the subtle philosophical differences between the BSD tradition and the System V structure (which accounts for much of the architecture of Linux), an argument as old as UNIX itself. These philosophical differences used to mean a lot more than they do today. Commercial flavors of UNIX generally fall into one camp or the other and haven't changed materially in years; between Linux and FreeBSD, though, the more significant philosophical difference is between the GNU and BSD license structures. That's where we see the roots of Linux's preference for `bash` and FreeBSD's preference for `tcsh`.

Because `bash` is a GNU-oriented program, and because Linux tends to prefer software developed under the GNU General Public License (GPL), `bash` is the default Linux shell. The feature sets of `bash` and `tcsh` are quite similar, but these features are accessed in different ways, and the configuration process and runtime behavior of the two shells differ subtly. If you are used to Linux, you may want to install `bash` in order to remain in a familiar environment. On the other hand, you might be a seasoned UNIX user who comes from a system in which your shell was `ksh` or `zsh`. Installing and using these shells is no problem, as you'll learn in the next section of this chapter.

Note

Bourne-style shells, of which `bash` is an example, are preferred by shell programmers because they're immediately compatible with any shell script you might find in the system; you can execute a shell script under `bash` just as easily as under `sh`. You can't do the same thing with C shells (`csh` or `tcsh`) because their programming syntax is very different. However, the reality of UNIX today is that shell scripts generally call their own interpreters by specifying them in their first lines (for example, `#!/bin/sh`), and the shell you use to execute the script is thus immaterial. That's why you'll have very few difficulties if you choose to stick with `tcsh` as your default shell in FreeBSD.

The remaining sections of the chapter examine both `tcsh` and `bash`, showing the differences in configuration and usage for each one. For additional shells, you're on your ownyou'll need to install the shells and read their `man` pages for details.

Installing Shells from the Ports or Packages

The preferred way to install software on FreeBSD is through the ports or packages, which is described in detail in Chapter 16, "Installing Additional Software." That chapter explains how to use the ports collection and the packages for all your software-management needs. This section, however, covers the most basic commands and procedures for installing new shells.

Installing from Packages

The most visual way to install a new shell is through Sysinstall and its interface to the package manager. Run `sysinstall`, select Configure, and then choose Packages. Select your installation mediumCD/DVD if you have the FreeBSD installation DVD handy, or FTP otherwise.

After you've received the package list, go into the `shells` subsection and scroll through the list of available shells. Press the spacebar to place an x on each shell you want to install. Press Tab to select the OK button and press Enter once you're done selecting shells to install, and you'll be returned to the main package selection screen. Use the right-arrow key to select Install and then press Enter. Then select OK at the confirmation screen showing the selected packages.

The software will now download automatically and install itself. Once it's done, exit out of Sysinstall by returning to the Exit option at the top of the Configuration menu; then choose Exit Install from the bottom of the screen. The shell (or shells) you've selected are now installed. You can verify that they're installed by looking in `/usr/local/bin` and by reading the `man` page for the shell you've installed (for example, `man bash`).

An even simpler way to install a packaged shell is straight from the command line, like this:

```
# pkg_add -r bash
```

If all goes well, just this single command should fetch and install the port from the central FreeBSD FTP server. If, however, you have a problem accessing the package repository, or the requested package is not available, you can instead compile it directly from the ports; to do this, go into the `/usr/ports/shells` directory, find the port directory corresponding to the shell you want to install, and then build it from downloaded source code as detailed in Chapter 16.

Note

You may need to type **`rehash`** (if you're using `tcsh`) to force the shell program to reread your shell configuration files and the available programs in your path after installing any new programs; otherwise, you won't be able to access those programs unless you log out and then back in.

The `/etc/shells` File

A very important system file that you'll need to know about when working with shells is `/etc/shells`. This file contains the names of the installed shells on the system, listed with their full paths. The following is an example of `/etc/shells` on a working system with three extra shells installed:

```
# cat /etc/shells
# $FreeBSD: src/etc/shells,v 1.5 2000/04/27 21:58:46 ache Exp $
#
# List of acceptable shells for chpass(1).
# Ftpd will not allow users to connect who are not using
# one of these shells.

/bin/sh
/bin/csh
/bin/tcsh
/usr/local/bin/bash
/usr/local/bin/zsh
/usr/local/bin/ksh
```

The purpose of `/etc/shells` is to specify the shell programs that you, the administrator, consider "valid." The `chsh` program (which we'll discuss shortly) won't allow a regular user to change his default shell to any program that you have not listed in `/etc/shells`. This safeguard allows you to ensure that a user cannot change his default shell, which executes upon login, to a program that isn't designed to be used as one. Especially problematic are *setuid* programs, or programs that run with the effective UID of the user that owns them (as described in Chapter 13, "Users, Groups, and Permissions"). If a setuid program is owned by root, it can execute any action with root's privileges; it's clearly not desirable for a user to be able to attain these privileges simply by logging in.

A user's shell is specified in the `/etc/master.passwd` user database, in the tenth field of the user's record (or the seventh field in `/etc/passwd`). Here's an example:

[View full width]
```
/etc/master.passwd:
btman:*:$1$LXZkCuzD$7Oa8LyRgbjYOb.XrXiBad.:1001:1001::999066364:0: Brian Tiemann:/home
   /btman:/usr/local/bin/ksh

/etc/passwd:
btman:*:1001:1001::Brian Tiemann:/home/btman:/usr/local/bin/ksh
```

If that field's value (`/usr/local/bin/ksh` in this example) is set to a shell that appears in `/etc/shells`, the user is allowed to log in using services such as FTP. If not, she is denied. Also, `/etc/shells` is used to generate the list of available shells that you can assign to a user during the `adduser` process, which we cover in Chapter 13.

An entry is added automatically to `/etc/shells` each time you install a shell through the ports or packages, as described earlier. Note that although only the administrator (root) can change a user's shell to a program not listed in `/etc/shells`, a user can log in as a shell user whether or not the assigned shell appears in `/etc/shells`. The `shells` database also controls access to the system via FTP. A common trap is for an administrator to install a shell without using the ports or packages (thus not adding an entry to `/etc/shells`) and then to switch another user to that new shell (because the administrator is allowed to do so). The regular user can use Telnet or SSH to get to the machine without any trouble, but as soon as he tries to FTP to it, he will be inexplicably denied access. The solution to this is simply to make sure the user's shell is listed in `/etc/shells`. Always use the ports or packages to install shells properly; this will help you avoid such pitfalls.

Using Alternative Shells

Any user can change his assigned shell at any time. The reasons for doing this are myriad: The user might be accustomed to Linux and `bash`, as described earlier, or have a highly customized shell environment from another system that is only in a certain shell's configuration format (as we'll discuss shortly). Regardless of the reason, changing a user's shell is pretty easy.

Changing Your Shell While Logged In

The simplest way to use an alternate shell is simply to run it from within your existing shell. If your default shell is `tcsh`, and you want to use `bash` (assuming that `bash` is available on the system), just type **`bash`** to open a new `bash` environment within your `tcsh` session, as shown here:

```
# bash
bash-2.04#
```

Now, when you log out, you'll have to do it twiceonce to exit the `bash` process and again to exit the original `tcsh` process. When your login shell program exits, you are disconnected from the system.

Changing Your Default Shell

Running a secondary shell from within your default one every time you log in can get tedious. Although you can do it automatically by adding the command for the second shell into your `.login` file (an initialization script that runs when the shell is started, as you'll learn in "`tcsh/csh` Files: `.cshrc`, `.login`, and `.logout`," later in this chapter), this still means you're running a shell within a shell, which isn't very elegant. Fortunately, any user can change his or her shell to any program listed in `/etc/shells`. The `chsh` (change shell) program is used for this task. This program differs in its behavior from platform to platform. On some platforms, such as Linux, `chsh` is a command-line, interactive tool that prompts for new values one by one. In FreeBSD, however, `chsh` is really the same program as `chpass`, `chfn`, and other user-management tools. They're all hard links to each other, and they all have the same function.

The behavior of `chsh` (and its identical siblings) is to open your user information in a text editor and allow you to change the values in any of the available fields. The editor used by default is `vi`, although this can be overridden by setting the `EDITOR` environment variable to the name of a different program, such as `ee` or `pico`. (We'll talk about environment variables in the upcoming section "Shell Initialization Files.")

To change your own shell, simply type **`chsh`**. If you're root, you can modify another user's shell by supplying that user's login as the argument. Here's an example:

```
# chsh frank
#Changing user database information for frank.
Shell: /bin/csh
Full Name: Frank Allen
Office Location:
Office Phone:
Home Phone:
Other information:
~
~
```

Using `vi` is no easy feat for a beginner; there are whole books just on its usage, even though the program's design is quite utilitarian. For now, let's concentrate on the necessary commands you'll need for changing the user's shell.

Part of what makes vi so challenging is that its internal commands are so arcane and must be entered so exactly that it's easy to get to a point at which crucial data has been accidentally deleted or mangled and can't be retrieved. If you make a mistake, press Escape, and then enter a colon (**:**), followed by **q!**, and then press Enter, which will force an exit without saving changes:

```
~
~
:q!
```

Let's say you want to change Frank's shell permanently from /bin/csh to /usr/local/bin/bash. Once you're in the vi screen, obtained by typing **chsh frank**, use the arrow keys to move to the beginning of the word csh, immediately after the second slash (/).

You can't just start deleting and typing; that's not how vi works. Instead, type **c** (for "change") and then **w** (for "word"). A dollar sign ($) will appear at the end of the word you're changing:

```
Shell: /bin/tcs$
```

Type **bash** in place of the word csh and then press Esc to exit change-word mode. Now the shell is /bin/bash. The next step is to place the cursor on top of the first slash, just before bin, and type **i** (for "insert") to get a usable cursor. Enter **/usr/local** and then press Esc. The shell string should now be /usr/local/bin/bash.

Now, enter a colon (**:**) to go into the in-program command line and then follow it with **w** (for "write"). Press Enter to save the file. Finally, type **:q** and press Enter to quit.

The file you've now written is actually a temporary file in /etc. If your changes are valid, they will be read from that file and automatically rebuilt into /etc/master.passwd and /etc/passwd. From now on, every time the user in question logs in to the system, the login will be under /usr/local/bin/bash rather than /bin/csh.

Non-Shell Programs as Shells

It's possible to set a user's shell to a program that isn't specifically designed to be a shell; programs such as /sbin/nologin, for example, do nothing but print out a text banner and exit, thus preventing a user from logging in (a just punishment for a user who's violated the rules of the system). Also the user might prefer to use some programs tailored to command-line interaction with services other than the UNIX filesystem (such as the gaming client TinyFugue).

You can set a nonexistent program as a user's shell to prevent the user from logging in at all. You can even set a user's shell to /usr/bin/mail (the shell-based mail reader) if you want, although this will mean that the user can't do anything but read mail. On the other hand, this might be the server policy you decide to set.

The chsh program will warn you if you specify a shell that doesn't exist, but it will still dutifully write it into the user database. There's nothing wrong with having a user's shell set to a nonexistent program; it simply means that the user won't be able to log in. Remember, a login shell works as follows:

- If the program can be successfully executed and attached to a pty (pseudo-terminal), the login will be successful and will not end until the shell program terminates and releases the pty.
- If the shell program can't be executed, nothing will bind to the pty, and the user won't get a command line. Instead, the user gets an error. Depending on the terminal program, the error might take the shape of a password-authentication error or a protocol failure error. In a command-line Telnet session, the error might result in an explicit failure to execute the shell program after displaying the various login banners, as shown here:

  ```
  FreeBSD/i386 (simba.example.com) (ttyp2)
  ```

```
login: frank
Password:
Last login: Sun Nov 13 23:38:17 from 172.21.17.1
Copyright (c) 1992-2005 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 1989, 1991, 1992, 1993, 1994
        The Regents of the University of California. All rights reserved.

FreeBSD 6.0-RELEASE (GENERIC) #0: Thu Nov 3 09:36:13 UTC 2005
--------------------------------------------------------------------------
Welcome to the system! Today's news: nothing.

You have mail.
login: /usr/local/bin/foosh: No such file or directory
Connection closed by foreign host.
```

You can leverage FreeBSD's behavior of displaying the general login banners before executing a user's shell. For instance, if you have a troublesome user or group of users who have violated system policy in some way (such as by cracking), you can prevent them from logging in by setting their shells to a nonexistent program and giving an explanation of a systemwide policy enforcement change in `/etc/motd`. This "message of the day" file is a regular text file that the system displays as a banner to every user immediately after accepting his or her password, and before determining whether the user's shell is valid, as shown in this example. Edit `/etc/motd` in your favorite text editor to reflect anything you want all your users, including ones without valid shells, to read upon login.

Note

Because of the various methods of accessing a UNIX system, you might or might not be able to rely on the `/etc/motd` user-notification system to fulfill regulatory requirements. If you are required by law or policy to notify your users of changes to terms of use such as privacy policies, you are strongly encouraged to run your notification system past a lawyer.

An even more useful (and correct) method is to set the user's shell to a program that isn't really a shell but merely a program that prints out informative text. `/sbin/nologin` is a built-in program that you can set as a user's shell to disable her login. This shell script prints out a single line of text and then exits. The line of text is short and sweet:

```
You have mail.
This account is currently not available.
Connection to simba.example.com closed.
```

Notice that `/sbin/nologin` executed, attached to the `pty`, exited properly, and released the `pty`. The fact that it never presented any kind of interactive command line doesn't make it any less valid as a shell. This method of disabling an account works for any terminal program, whether connecting via terminal or SSH, and it involves no errors or warnings. It's very elegant and extensible.

You can, in fact, assign any program as the shell, regardless of whether the program is interactive. You can make your shell `/bin/ls` or `/usr/bin/finger`, if you like. More usefully, you can create your own script or program to execute when a certain user logs in. This way, you can set up interesting services on your system, such as a customized "library" system in which guests can log in and interact with a menu, execute a certain limited set of commands, or simply get a screenful of information. The possibilities are endless!

Caution

A word of warning is in order: If you write a login handler for the purpose of providing custom services in C or another language in which you have to allocate your own buffer space, beware of potential buffer overflows! These are the most common types of security holes found in network services; if an attacker is able to find and exploit a buffer overflow in a program you devise yourself, and there is any way for the program to run executable code as root (for example, if it's a setuid program owned by root), your system belongs to that attacker. Be very careful in this area, and make sure you know how to program securely before writing any custom program to handle incoming connections.

PREV NEXT

Shell Initialization Files

It's now time to discuss how to customize your shell to do what you want. You can create aliases to simplify common commands, you can automatically execute certain programs every time you log in, you can set various environment variables to your taste, and much more. These tasks are handled in the shell initialization and configuration files, which exist both at the global and per-user levels.

Because `tcsh` and `bash` have completely different sets of configuration files, we will cover them both sequentially. FreeBSD includes systemwide and default per-user config files for both shells so that you can switch from `tcsh` to `bash` on a system basis if you really want to (although this is rarely necessary).

Note

When a new user is created, default shell config files are copied from `/usr/share/skel` (the `dot` prefix on each of the files is dropped) into the new user's home directory. If you like, you can copy these default files into `/usr/local/share/skel`, modify them to your taste, and then alter the `/etc/adduser.conf` file to copy its default "dotfiles" from this new location. Use this technique to make a global, preemptive change to all users' default shell configurations before they're even created.

`tcsh/csh` Files: `.cshrc`, `.login`, and `.logout`

The first file that `tcsh` (or `csh`) looks at when it is executed is the systemwide config file, `/etc/csh.cshrc`, followed immediately by `/etc/csh.login`. Note that in FreeBSD, both these files exist, but their contents are commented out (see Listing 9.1).

Listing 9.1. The Global `/etc/csh.cshrc` and `/etc/csh.login` Files

```
# cat /etc/csh.cshrc
# $FreeBSD: src/etc/csh.cshrc,v 1.3 1999/08/27 23:23:40 peter Exp $
#
# System-wide .cshrc file for csh(1).

# cat /etc/csh.login
# $FreeBSD: src/etc/csh.login,v 1.21 2004/06/06 11:46:27 schweikh Exp $
#
# System-wide .login file for csh(1).
# Uncomment this to give you the default 4.2 behavior, where disk
# information is shown in K-Blocks
# setenv BLOCKSIZE      K
#
# For the setting of languages and character sets please see
# login.conf(5) and in particular the charset and lang options.
# For full locales list check /usr/share/locale/*
#
# Read system messages
# msgs -f
# Allow terminal messages
# mesg y
```

This listing shows that these config files don't really do anything, but they could if you so chose. Any change you make in either of these files, such as enabling `mesg` (terminal messages) globally, is applied globally (for all users running `csh` or `tcsh`, at least). The change is overridden only if set differently by the individual user config files, which function similarly to systemwide ones and are read immediately afterward from the user's home directory (`.cshrc`, followed by `.login`).

The default `.cshrc` file, which comes from `/usr/share/skel/dot.cshrc`, does a number of generally useful things to set up the shell environment. For example, it creates several aliases to shorten commands:

```
alias h         history 25
alias j         jobs -l
alias la        ls -a
alias lf        ls -FA
alias ll        ls -lA
```

It sets the search path for programs:

[View full width]
```
set path = (/sbin /bin /usr/sbin /usr/bin /usr/games /usr/local/sbin /usr/local/bin /usr
   /X11R6/bin $HOME/bin)
```

It sets various environment variables that control the behavior of many different shell tasks:

```
setenv  EDITOR  vi
setenv  PAGER   more
setenv  BLOCKSIZE       K
```

And a few other things are set as well. You can look at the `.cshrc` file in your own home directory to see them all.

The `.login` file, which is read next, is where the user can place any programs he wants to run every time he logs in. For example, the `fortune` program is provided in the default `.login` file (from `/usr/share/skel/dot.login`) and is encapsulated in an existence-test conditional, so that a random witticism or FreeBSD usage tip is emitted every time the user logs in:

```
[ -x /usr/games/fortune ] && /usr/games/fortune freebsd-tips
```

You (the administrator) or the user can also specify certain things to happen whenever the user logs out. For instance, you might write a script to clean out any temporary files owned by the user in `/tmp`; you could put a call to this script into `/etc/csh.logout`, which in its default state has no material contents:

```
# cat /etc/csh.logout
# $FreeBSD: src/etc/csh.logout,v 1.3 1999/08/27 23:23:41 peter Exp $
#
# System-wide .logout file for csh(1).
```

The logout process will also read a `.logout` file in the user's home directory if it exists, but there is no such per-user file installed by default.

Note

The files shown in this section are the ones run by `tcsh` when it is executed as a login shell. There are various other circumstances under which `tcsh` can be runfor example, as a non-login shell executed in order to run a C shell script, invoked from the interpreter line of the script. In this case, the `.login` and `.logout` files (and their systemwide equivalents) are ignored.

bash Files: .profile, .shrc, and .bash_logout

If you've chosen to use bash rather than tcsh as your shell, it will operate in much the same way: it will first read the systemwide config and initialization files and then proceed to the per-user ones. First comes /etc/profile, which (like /etc/csh.cshrc) is materially blank but contains a few examples for options you might decide to enable, as shown in Listing 9.2.

Listing 9.2. The Global /etc/profile File

```
# cat /etc/profile
# $FreeBSD: src/etc/profile,v 1.14 2004/06/06 11:46:27 schweikh Exp $
#
# System-wide .profile file for sh(1).
#
# Uncomment this to give you the default 4.2 behavior, where disk
# information is shown in K-Blocks
# BLOCKSIZE=K; export BLOCKSIZE
#
# For the setting of languages and character sets please see
# login.conf(5) and in particular the charset and lang options.
# For full locales list check /usr/share/locale/*
# You should also read the setlocale(3) man page for information
# on how to achieve more precise control of locale settings.
#
# Read system messages
# msgs -f
# Allow terminal messages
# mesg y
```

Notice that /etc/profile combines the functionality of both /etc/csh.cshrc and /etc/csh.login. It's the only bash-related global file in the system; there is no systemwide logout script for bash.

The next file for bash is the user's .profile file, which primarily sets various environment variables (including PATH) and exports them in the Bourne shell style:

[View full width]

```
# remove /usr/games and /usr/X11R6/bin if you want
PATH=/sbin:/bin:/usr/sbin:/usr/bin:/usr/games:/usr/local/bin:/usr/X11R6/bin:$HOME/bin;
    export PATH

# Setting TERM is normally done through /etc/ttys. Do only override
# if you're sure that you'll never log in via telnet or xterm or a
# serial line.
# Use cons25l1 for iso-* fonts
# TERM=cons25;  export TERM

BLOCKSIZE=K;    export BLOCKSIZE
EDITOR=vi;      export EDITOR
PAGER=more;     export PAGER

# set ENV to a file invoked each time sh is started for interactive use.
ENV=$HOME/.shrc; export ENV
[ -x /usr/games/fortune ] && /usr/games/fortune freebsd-tips
```

The second-to-last line sets the ENV variable to the .shrc file, also in the user's home directory. This is then read in sequence with `.profile`. Its purpose is to define command aliases similar to their counterparts in `.cshrc`, as well as a few other optional things, such as customizing the prompt, that are commented out by default:

```
# some useful aliases
alias h='fc -l'
alias j=jobs
alias m=$PAGER
alias ll='ls -laFo'
alias l='ls -l'
alias g='egrep -i'

# # be paranoid
# alias cp='cp -ip'
# alias mv='mv -i'
# alias rm='rm -i'

# # set prompt: ``username@hostname$ ''
# PS1="`whoami`@`hostname | sed 's/\..*//'`"
# case `id -u` in
#       0) PS1="${PS1}# ";;
#       *) PS1="${PS1}$ ";;
# esac

# search path for cd(1)
# CDPATH=.:$HOME
```

As with `.logout` for `tcsh`, `bash` will read and execute a `.bash_logout` file if it's present (but no such file is installed by default). This functionality is designed for users' convenience rather than administrators' security; there are many ways in which a user can exit the shell, and there's no guarantee that the logout script will be properly executed every time.

Note

These are the files "sourced" (that is, read as configuration files) by `bash` if it's executed as a login shell. If it's used as a non-login shell, though, the file it reads is `.bashrc` rather than `.profile`. This file doesn't normally exist in FreeBSD.

PREV NEXT

Customizing Your Shell Environment

You've seen a few examples already, in both `tcsh` and `bash` style, of how to customize the way your shell works through the use of the default suggested settings in the shell config files. These can serve as perfectly valid examples of how to extend your shell's functionality. There are a few extra things you can do on your own, though. Also, some available options aren't clearly demonstrated in the default files. We'll look at how to accomplish these customizations in `tcsh` and in `bash`. In most cases, these are built-in shell commands that can be issued either from the command line directly or from within any of the shell configuration files.

Note

Full details on a large number of available built-in commandssome of which appear in `csh`/`tcsh`, some of which appear in `sh`/`bash`, and some of which appear in bothcan be found in `man builtin`.

Customizing `tcsh`

The following sections describe some of the common user-environment enhancements available for `tcsh` users.

Creating Aliases

The most common shell customization is to create an *alias*. This customization substitutes the first word of a command with whatever surrogate command string you choose to replace it with. Aliases can greatly simplify your work, especially if there are certain complex commands that you find yourself using on a regular basis. The simplest alias is of the type seen in `.cshrc`:

```
alias ll            ls -lA
```

This alias, as you would expect, replaces a command such as `ll /usr/local` with `ls -lA /usr/local`. But what if you want to perform argument substitution as well, reformatting the command's parameters according to what you enter each time? You can do that with the extremely versatile and equally convoluted command-line parsing syntax of `tcsh`. The `man tcsh` page explains this in full detail, but for our purposes, simply note that the first argument to a command in an alias assignment can be referred to as `\!:1`, and further arguments can be indicated as `\!:2`, `\!:3`, and so on. Therefore, you can create an alias like the following:

```
alias lookup   grep \!:1 /etc/passwd
```

This customization allows you to enter commands such as `lookup frank` to extract a user's information. The `unalias` command allows you to remove an alias, as shown here:

```
unalias lookup
```

Customizing the Prompt

You can customize your prompt's appearance by setting the `prompt` shell variable. You can embed the output of any command, for example the `hostname` or `pwd` commands, by enclosing them in backticks (as is done in Perl scripts). You can also echo the "command number" variable, which specifies a numbered entry in the shell's editable history with the ! character. The following example is a fairly complex one that incorporates all these tricks, plus the use of sed (a "stream editor" text processor that operates noninteractively on text fed to it at any time) to shorten the output of hostname to its first element:

```
# set prompt="{`whoami`@`hostname | sed 's/\..*//'`:!} "
{root@www:23}
```

Another use of the prompt shell variable is to reflect the directory you're currently in, which can be echoed using the pwd (present working directory) command:

```
# set prompt="{`pwd`:!} "
{/usr/local/etc:24}
```

Note that these examples show commands being issued at the shell prompt, so as to show you their immediate effect on the prompt's style; if you incorporate a set prompt command into your .cshrc file, it will take effect every time you log in.

Customizing the Command Path

The command path is the list of locations where tcsh is configured to look for programs whose names you type as commands. Setting the command path in tcsh involves setting the shell variable path (we'll cover shell variables and environment variables in a moment) to an array in which each command directory is listed in a long string within parentheses. You can't add elements to the parenthesized array "on the fly." You have to add the new path element to the string and reissue the entire set command, which is why the path is best set from within one of the config scripts rather than from the command line. The syntax specifies a list of pathnames in parentheses, separated by spaces. This example shows a modified set path statement that adds the hypothetical directory /usr/local/mystuff to your command path:

[View full width]

```
set path = (/sbin /usr/sbin /bin /usr/bin /usr/local/bin /usr/contrib/bin /usr/X11R6/bin
   /usr/local/sbin /usr/games . /usr/local/mystuff)
```

Customizing Character Mappings

Another useful built-in tool is stty. This tool allows you to redefine various character mappings, a practice you might find very useful in cases where your terminal program sends unexpected characters to your programs. This is most commonly seen in confusion between "delete" and "backspace" characters or in line-delimiter characters. The first step is to see what's currently set for the characters:

```
# stty -a
speed 38400 baud; 60 rows; 80 columns;
lflags: icanon isig iexten echo echoe -echok echoke -echonl echoctl
        -echoprt -altwerase -noflsh -tostop -flusho pendin -nokerninfo
        -extproc
iflags: -istrip icrnl -inlcr -igncr ixon -ixoff ixany imaxbel -ignbrk
        brkint -inpck -ignpar -parmrk
oflags: opost onlcr -ocrnl -oxtabs -onocr -onlret
cflags: cread cs8 -parenb -parodd hupcl -clocal -cstopb -crtscts -dsrflow
        -dtrflow -mdmbuf
cchars: discard = ^O; dsusp = ^Y; eof = ^D; eol = <undef>;
        eol2 = <undef>; erase = ^?; intr = ^C; kill = ^U; lnext = ^V;
        min = 1; quit = ^\; reprint = ^R; start = ^Q; status = ^T;
        stop = ^S; susp = ^Z; time = 0; werase = ^W;
```

Pay particular attention to the cchars listing, where the key combinations for certain terminal commands are displayed. Now, if you want to set your "erase" character to ^H (Ctrl+H), specify it in just that two-character form:

```
stty erase ^H
```

Other tcsh Tips

A useful trick for users of shared systems is what's known as "watch" mode. When you log in, this mechanism will tell you who else is logged in to the system. To do this, use the following sequence in your `.cshrc` file:

```
set watch=(1 any any)
set who="%n has %a %l from %M."
```

One thing about `tcsh` that you'll likely want to disable is the `autologout` shell variable, which is set by default to 60 minutes. This variable closes your connection if you leave the terminal idle for more than an hour. You can disable `autologout` easily enough with this config file line:

```
unset autologout;
```

Finally, if you set any of these built-in customization variables by editing the configuration scripts, you don't have to log out and back in to incorporate them; you can use the `rehash` built-in command to force a reread of all the config scripts.

Customizing bash

The following sections describe some of the common user-environment enhancements available for `bash` users.

Creating Aliases

Aliases in `bash` work a bit differently from those in `tcsh`. The alias and substitution text are separated by an equal sign (`=`) rather than a space or tab. Also, there is no mechanism for performing argument substitution as there is in `tcsh`, so the `lookup` alias we created for `tcsh` can't be created in `bash` without more extensive gymnastics. Here's a simple `bash`-style alias, to be placed in your `.profile` file:

```
alias ll='ls -laFo'
```

Customizing the Prompt

Setting your prompt in `bash` can get interesting. Because `bash` doesn't implement shell variables in the same parsed way that `tcsh` does, the best it can really do is to set the "primary" and "secondary" prompts as environment variables (`PS1` and `PS2`), from which the shell reads the strings it displays to you. To get the "email-address-style" prompt you saw earlier in `tcsh`, use the following code (note the backslash behind the `!` character, which doesn't have the same special meaning as it does in `tcsh`):

```
# PS1="{`whoami`@`hostname | sed 's/\..*//'`:\!} "
{root@www:17}
```

Similarly, to get a prompt that reflects the present working directory, use the following:

```
# PS1="{`pwd`:\!} "
{/root:18}
```

Place one of these commands into your `.profile` file to change your prompt's style for every login session.

Customizing the Command Path

Setting the command path in `bash` involves setting the `PATH` environment variable. In this context, it's a colon-separated string of pathnames; in the default `.profile` file, this string is combined with an `export` statement to publish the variable into the environment:

[View full width]

```
PATH=/sbin:/bin:/usr/sbin:/usr/bin:/usr/games:/usr/local/bin:/usr/X11R6/bin:$HOME/bin;
   export PATH
```

To add directories to your path, separate out the commands into three separate lines, as follows:

```
PATH=/sbin:/bin:/usr/sbin:/usr/bin:/usr/games:/usr/local/bin: /usr/X11R6/bin:$HOME/bin
PATH=$PATH:/usr/local/mystuff
export PATH
```

This technique ensures that the standard, out-of-the-box command path can be kept in sync with changes in the system, and your personal additions to the path can be maintained separately.

The need to export your variables is something we'll talk about in the next section.

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Shell and Environment Variables

One of the biggest differences between `tcsh` and `bash` lies in the way they each handle variables. You have two kinds of variables to work with: shell variables and environment variables (you'll learn more about these variables in Chapter 10, "Shell Programming"). Let's take a look at how the variable types differ and where they're used.

Environment Variables

No matter which shell you're using, you always have *environment variables* (variables containing values that travel with you throughout your login session and are propagated to any program spawned from within that session). Environment variables dictate the behavior of certain programs that you run. For instance, the `chfn` program launches the text editor specified in the `EDITOR` environment variable, and the `TERM` variable tells the shell how to format text to display properly on your screen. The `BLOCKSIZE` variable controls what the output numbers in commands such as `du` and `df` signify (kilobytes, half-kilobytes, or whatever the value of the variable is). A program doesn't have to be a login shell to have access to environment variablesevery program has access to the same set of variables as the program that spawned it.

Whichever shell you're using, you can view all your environment variables using the `printenv` command, as shown in Listing 9.3.

Listing 9.3. Sample Output of the `printenv` Command

```
# printenv
PATH=/sbin:/usr/sbin:/bin:/usr/bin:/usr/local/bin:/usr/contrib/bin:/usr/X11R6/bin:.
MAIL=/var/mail/btman
BLOCKSIZE=1k
FTP_PASSIVE_MODE=YES
USER=btman
LOGNAME=btman
HOME=/home/btman
SHELL=/bin/tcsh
SSH_CLIENT=192.168.173.230 50095 22
SSH_TTY=/dev/ttyp0
TERM=vt100
HOSTTYPE=FreeBSD
VENDOR=intel
OSTYPE=FreeBSD
MACHTYPE=i386
SHLVL=1
PWD=/home/btman
GROUP=users
HOST=simba.example.com
REMOTEHOST=192.168.173.230
PATHSET=true
EDITOR=vi
VISUAL=pico
```

Environment variables don't follow any hard-and-fast rules; there are certain traditional variables that every program expects to be able to read, such as `USER` and `PATH`, but you can make up any variable that you want and set it to any arbitrary value, for any purpose you might dream up. To set an environment variable from within the shell, you would use one of two syntaxes, depending on the shell you're using. To set a hypothetical variable called `COLOR` to `gold` in `tcsh`, enter the following:

```
# setenv COLOR gold
```

In `bash`, you have to first set the variable in the local session context and then export it to the shell's environment, as shown here:

```
# COLOR=gold
# export COLOR
```

Note that an environment variable must have a value; it can't simply exist in the environment with a null or undefined value.

Shell Variables

In addition to environment variables, another separate set of variables are available to your login session. These variables, called *shell variables*, apply only to the current login session and have no bearing on any other processes. They're comprehensible only to the shell process itself. In programming terms, shell variables exist in the "local" context, whereas environment variables exist in the "global" context and can be inherited by other programs.

Shell variables in `tcsh` are traditionally named in lowercase, and shell variables in `bash` are traditionally named in uppercase, but this is not required. You can view shell variables using the `set` command. Setting a shell variable in `tcsh` is also done, not surprisingly, with `set`. It's possible to set a shell variable in `tcsh` without assigning a value to it:

```
# set history=100
# set noclobber
```

In `bash`, you simply set the variable without exporting it:

```
# VISUAL=pico
```

You can also remove a variable with `unset`, as shown here:

```
# unset autologout
```

Shell and environment variables, as well as the way their inheritance properties interact and apply to shell scripting techniques, will be described more fully in Chapter 10, where you will learn how to take your interaction with the shell to the next level: writing shell programs.

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Chapter 10. Shell Programming

IN THIS CHAPTER

In Chapter 8, "Working with the Shell," you saw how to operate the shell interactively at the command line. To the casual user, the shell looks like nothing more than a prompt where you can type commands and launch bigger, more useful programs. What you may not have realized is that a powerful programming language is built right into the shell, and when you're at the shell prompt you're actually in the middle of a "program" that you're writing line by line with every command you type. More usefully, you can write a shell script (which you might know as a "batch file," though shell scripts are far more powerful) full of commands that you would otherwise have to issue manually, creating a program you can then run at your discretion. You can use shell programming to do everything from automating a repetitive list of commands to writing sophisticated interactive programs that process text data to storing and retrieving information in simple databases.

The modular design of the FreeBSD operating system allows you to call any FreeBSD command from within a shell program. And if you can't find a FreeBSD command to do what you want, you can string commands together into *pipelines* to create new commands. As you learn in this chapter, pipelines take the output from one command and use it as the input for another command. FreeBSD has hundreds of these modular commands that each serve a small but highly specialized purpose. In this chapter, you learn how to write a simple shell program and how to use variables, arithmetic, and loops in shell programming. You also learn how to use conditional statements, file descriptors, and many of the advanced techniques of shell programming to perform a number of important tasks in FreeBSD.

Shell programs offer commands for searching text files, combining text from two files into a single file, formatting text in columns, cutting only certain fields from text files, counting characters, words, and lines in a file, performing math operations, doing file backups, compressing and uncompressing files, and much more. If you can't find a command or pipeline that does what you want, chances are you can find a free program available on the Internet that you can use in your shell program. You'll find all the important techniques you'll need for taking full advantage of the flexibility of shell programming in this chapter.

Why Shell Programming Matters to You

Shell programming is sometimes shunned in favor of scripting in Perl and other interpreted languages, and thought of as simply a glorified version of DOS batch programmingbut as a UNIX administrator, you'll find that being able to write and interpret shell scripts is a central skill. True, in its simplest form, shell programming is like DOS batch programming in that you can use it to execute a list of commands stored in a file that could also be executed from the command line. However, the shell programs you might write can have far greater flexibility and sophistication than a simple DOS batch program, and shell scripting has certain unique advantages even over languages such as Perl or C.

Here are the top seven reasons why every FreeBSD user should learn shell programming:

- It's easy to learn. If you work with the FreeBSD command line on a regular basis, you probably are already familiar with many of the commands you can use in your shell programs.
- For many tasks, you can develop a shell program in 5 or 10 minutes that would take hours or even days to develop in C or some other programming language.
- It can save you hours of tedious work. For example, why go through 100 text files manually to make a single change when you can write a shell program with a `for` loop that will do it automatically?
- It will teach you many new and more efficient ways to work with FreeBSD. You will discover useful commands you never knew existed as well as ways to do things you wouldn't ever otherwise have discovered. You might even learn to like the FreeBSD command line better than the X11 GUI or even Windows. Why spend money to buy a new program to perform a certain task when you can string a few FreeBSD commands together in a pipeline to accomplish the same thing?
- Don't like the way an existing command works? You can write a new one in a few minutes with shell programming. One of the things that makes FreeBSD so powerful is the "do it your own way" philosophy. There are many ways to achieve the same end, and no one way is necessarily the best way.
- It is perhaps the ideal first programming language because it allows you to concentrate on learning programming logic and other key techniques while working with commands you may already be familiar with and that provide immediate useful results.
- Shell programming is a skill that's applicable throughout the UNIX world, so it will benefit you whether you're using FreeBSD, Linux, Solaris, Mac OS X, or any other UNIX variant.

Furthermore, some of the most crucial components of FreeBSD are actually shell scripts, including (but not limited to) the resource configuration scripts in `/etc` and the start/stop shell scripts that control third-party daemon programs, which live in `/usr/local/etc/rc.d` (as you will see in Chapter 14, "System Configuration and Startup Scripts").

Having a thorough grounding in shell scripting will make it much easier for you to understand how those scripts work, and therefore to come up with clever solutions to problems that might arise with your configuration. Shell scripting is like having a jack in your trunk: Most of the time, it's just there taking up space. But when you suddenly get a flat tire, you find yourself very glad you took the time to stow it there.

It's to your advantage to take the time to understand the shell, how it interprets commands, how to send the output of one command down a pipeline to use as the input for another command, and the hundreds of specialized FreeBSD commands you'll use to develop the commands that make up your shell scripts. You can start that learning process by working with a simple shell program, as you do in the section that follows.

Note

The first part of this chapter covers only commands that are available in all Bourne-type shells. The second part covers the enhanced features of the Korn and POSIX shells, such as FreeBSD uses. If you need to write shell programs that will be run on other systems and you cannot say for sure what shells will be available there, it is best to stick with the commands available in all Bourne shells. If you don't, your programs might not work on other systems that have an older Bourne shell.

Note

This chapter does not cover C shell scripting at all. Although it is possible to write shell scripts using the C shell, its programming syntax is a lot more limited than the incompatible one found in Bourne-style shells, and lacks a lot of very useful shell-scripting features (including functions and swapping `STDOUT` and `STDERR`). If you're using a C shell (`csh` or `tcsh`) for your login sessions and you plan to do a lot of shell programming, you might want to consider switching to `bash` (the modern iteration of the Bourne shell) for better session compatibility and ease of testing.

Tip

There is a lot more to shell scripting than a single chapter can cover. If you are interested in learning more about shell scripting, refer to *Teach Yourself Shell Programming in 24 Hours*, available from Sams Publishing, for more information.

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A Simple Shell Program

The first rite of passage for any aspiring programmer is to write the classic "Hello World!" program. Here is one way to write it in the Bourne shell programming language. Enter the text shown in Listing 10.1 into your favorite text editor (the line numbers in this code are for reference only; don't include them when you enter the code).

Listing 10.1. A Basic Shell Program

```
1.  #!/bin/sh
2.
3.  # The legendary Hello World program
4.  # As implemented in the Bourne shell programming language.
5.
6.  echo
7.  echo "Hello World!"
8.  echo
9.  exit 0
```

Save this program as a file called `hello`. (Remember, in UNIX the filename extension doesn't matter and is not required.) Next, you need to make the file executable. You can do this with the following command:

```
# chmod u+x hello
```

This command gives the owner of the file permission to execute it. If you're concerned about security, you might want to use the following command instead:

```
# chmod 700 hello
```

This ensures that only you can access the file in any way, and other users can't even read it. See Chapter 13, "Users, Groups, and Permissions," for more information.

Tip

Traditionally, shell scripts have the extension `.sh` so that anyone can quickly tell in a directory listing that a certain file is a shell script. The extension is not necessary, however, and in some cases you might want to leave it out to make the commands easier to type (you can't just omit the extension as with `.exe` files in DOS). If you're writing a shell script for end users who have no knowledge of what the `.sh` extension means, you can safely leave the extension off, as in this example.

Next, execute the file. The following sequence shows the command you type as well as the output of the program:

```
# ./hello

Hello World!
```

Note

You have to prefix the name of the command with `./`, indicating that the command is a program located in the current directory (`.`) rather than in one of the locations specified in your path, such as `/usr/local/bin`. It's possible to add the current directory (`.`) to your path as described in Chapter 9, "Customizing the Shell," but it's not a particularly good idea, especially as rootyou don't want to make it too easy to accidentally execute any old program you have lying around. They might not all be safe to run as root, after all!

Note

Because shell scripts are interpreted, you don't necessarily have to make them executable in order to run them, or even have the interpreter line at the top. If you prefer, although this method is less conveniently "encapsulated" than the previous method, you can run the script as an argument to `/bin/sh` itself. This way you can run the program even if the script is not set executable or does not contain the interpreter line:

```
# sh hello
```

Understanding the Shell Script, Line by Line

Now let's look at the lines in the sample shell program in detail and see what each one does:

- Line 1 This line contains the magic character sequence `#!`, which tells the executing shell that what follows is a script that should be interpreted by the program named after `#!`. In this case, it tells FreeBSD that it should use the Bourne shell interpreter `/bin/sh` to interpret the remainder of the script. If this were a Perl script, you would use `/usr/local/bin/perl`. For a Python script, you would use `/usr/local/bin/python`, and so on.
- Lines 2 and 5 These are simply blank lines. The shell ignores whitespace unless it is quoted (more on that later). It is a good idea to use whitespace to make your program more readable.
- Lines 3 and 4 These are comments. Comments are lines in a shell program that begin with a `#` character and are entirely ignored by the interpreter. They are used for the benefit of the programmer who needs to revisit a complicated program he wrote six months ago and try to figure out what it does again, or for another user who needs to know how certain parts of the code operate.
- Line 6 The `echo` command takes whatever data it receives as an argument and echoes it to `STDOUT` ("standard output", which is normally the screen). This output can be redirected, however, so that `echo` sends the output somewhere else, such as to a file. In this case, `echo` by itself simply prints a blank line on `STDOUT`, making the script's output more readable.
- Line 7 The `echo` command here prints the string `Hello World!` to `STDOUT`. The quotes tell the interpreter that everything inside them should be interpreted as a single argument (that is, the shell

should interpret the string as one long parameter instead of many separate parameters separated by spaces). Without the quotes, the shell will interpret the whitespace as an argument separator. In this case, the quotes would not have been strictly necessary, but you will see later on in the chapter why quoting is important. It's a good idea to get into the habit of quoting strings such as these.

- Line 8 The `echo` command here prints a blank line again.
- Line 9 The `exit` command exits the program and returns an exit status to the invoking program. (This is normally your login shell, but it could be another program, such as another shell script, possibly being called automatically at a scheduled time.) An exit status of 0 indicates that the program terminated normally. An exit status of anything other than 0 indicates that an error occurred. You have the option of specifying any exit code you want (at any time in the program) so as to communicate various runtime conditions to the invoking shell, which then determines what action it should take next based on the success or failure of your shell script.

In a program this short, setting the exit status isn't really necessary. If the exit status is not implicitly set, the exit status returned will be the exit status of the last command that was run in the script. It is best to be aware of the exit status, though, because it will become important as you start to write larger and more complex shell programs. Later in this chapter, you will see how the exit status of a command can be used in a shell script to make automatic decisions about the next action that should be performed. However, setting the exit status should not generally be necessary; if a script is written properly, it will exit with a status of 0 on its own. Otherwise, it will have inherited an error condition from one of its lines, and you as the programmer should address this rather than masking the true status with an `exit` statement.

Using the `printf` Command

The previous program could also have been written using `printf` commands instead of `echo`. The `printf` command performs a similar function, but it allows far more control over how its output is formatted. The example in Listing 10.2 shows how the program could be rewritten using `printf` instead of `echo`.

Listing 10.2. Using `printf` Instead of `echo`

```
#!/bin/sh

# The legendary Hello World program
# As implemented in the Bourne shell programming language.

printf "\nHello World!\n\n!"
```

If this program is run, the output it produces will look exactly the same as the previous program's. This, however, is only where the demonstration of `printf` begins.

If you have ever programmed in C or Perl before, the syntax of the `printf` command will look familiar to you. The backslash (`\`) is an *escape character* that normally indicates that the character immediately following it should be interpreted literally (as with quotation marks or spaces), but in certain combinations it takes on entirely different special meanings. In this case, `\n` is a newline character. This is why you could eliminate the two `echo` commands that inserted blank lines when you use `printf`, because now you can embed the newlines directly into the string you want to print. At the end of the string, you used two newline characters because `printf` does not automatically insert a newline at the end of a printed string; thus you want two newlines to get a blank line in your output. Here's an example in which `printf` doesn't automatically insert a blank line at the end:

```
printf "Hello "
printf "World!\n\n"
```

These two lines in a shell script would produce the output "Hello World!", even though they are given as separate statements. This is because `printf` does *not* automatically output a newline (which in UNIX implies a carriage return) at the end of a statement, the way `echo` does. If you had used `echo` in the previous two lines instead of `printf`, "Hello" and "World!" would appear on separate lines. This gives some indication of how much more control `printf` gives you over your program's output than `echo`; you have to be more explicit about what you tell it, but it can be configured with far more flexibility.

The `printf` command supports the formatting characters outlined in Table 10.1.

Table 10.1. Formatting Control Characters from `printf`

Formatting Characters	Description
`\a`	Rings the terminal's bell. In the old teletype days, this rang an actual bell on the teletype machine. These days, it usually beeps the computer's speaker.
`\b`	Prints a backspace character.
`\f`	Prints a form-feed character (the screen is cleared, or in printed output, the current sheet is ejected and a new one loaded).
`\r`	Prints a carriage return (the cursor returns to the beginning of the line but does not move down to the next line). The result is that the previous output on the line will be overwritten by whatever comes after `\r`.
`\n`	Prints a newline character (which moves the cursor to the beginning of the next line).
`\t`	Prints a tab character.
`\v`	Prints a vertical tab character, which is equivalent to a linefeed without a carriage return.
`\'`	Prints a single-quote character.
`\"`	Prints a double-quote character.
`\\`	Prints a backslash.
`\`*`num`*	Prints the ASCII value of the octal 1-, 2-, or 3-bit value *`num`*. You will probably never need to use this option in a shell program.

Of course, simply being able to echo prewritten messages to the screen is not very useful. You need the program to be able to give you different output depending on what data it has received. This is where variables come in.

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Variables

In algebra, you learned that you can use letters to stand for unknown quantities in algebraic equations, and that these letters are called *variables*. In programming, the concept is pretty much the same, although programming variables can hold strings (strings of characters) as well as numbers.

You work with two types of variables in shell programming: shell variables and environment variables. The primary difference is that *environment variables* are available to other scripts or programs that you call from inside your shell program, whereas *shell variables* are available only to the script itself.

Variables in shell programming are *loosely typed*; they do not have to be declared or typeset before they can be used, whereas in other programming languages they do. All variables in shell programming are stored as strings.

Variable Assignment

In its most basic form, a variable can be set from the command line in the following manner:

```
myVar=5
```

The value `5` is now stored in the variable `myVar`. To access the information stored in a variable, precede the variable name with a dollar sign (`$`). For example `echo ${myVar}` will print `5` to `STDOUT`, which as you recall is normally the screen.

Note

Variable assignment is one place where whitespace *does* matter. The statement `mvar=5` will assign the value `5` to the variable `myVar`. The statement `myVar = 5` will produce an error because the shell will try to interpret `myVar` as a command name to execute rather than as a variable assignment.

The curly braces are optional but can help to improve code readabilitythey make variable names easier to spot when you are quickly scanning code. It's up to you whether you want to use the braces.

The value of a variable can also be assigned to another variable. Here's an example:

```
myVarB=$myVar
```

This line assigns whatever is in `myVar` to the variable `myVarB`. If `myVarB` already contains something (for example, the number 5), that value is overwritten by the new assignment.

In addition, it is also possible to assign the output of a command to a variable or read input from `STDIN` ("standard input," which is normally the keyboard) and store it in a variable. You will see how to do this later in the chapter.

Creating an environment variable is pretty much the same as creating a shell variable. The only difference is that it must be *exported* from your script's context before it becomes part of the environment. This is done with the `export` statement, as shown in this example:

```
MYVAR=5
```

```
export MYVAR
```

This creates a shell variable named `MYVAR` and then exports it so that it is an environment variable that is available to other shells started from within this shell.

Variable Names

Variable names are case-sensitive and can contain letters, numbers, and underscores. The variable name cannot begin with a number, though, and it is best to avoid beginning variable names with an underscore. Use descriptive names to make program code easier to read. For example, it is much easier to guess what a variable named `avg_rainfall` probably contains than to guess what a variable named `xyz123` might contain.

Caution

You cannot use words that are already the names of shell commands as variable names; nor can you use any of the "reserved words" that have special meaning in shell scripting, such as `if` and `case`.

Tip

By convention, local variables use lowercase letters, and environment variables use uppercase letters. However, some people prefer to use a mixture of lowercase and uppercase letters in local variables to make them stand out from other shell commands, which are almost always in all lowercase.

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Interacting with the User

You now know how to assign variables to contain different data; but without input from the user, your variables won't ever change. The shell provides a way for you to get input from `STDIN`. Normally, this input will be typed in by the user (or received from a file if `STDIN` has been redirected). The command that can read input from a user is `read`. Listing 10.3 shows a slightly modified version of the "Hello World!" program that reads some input from `STDIN`, which is normally the keyboard, and then acts on that input.

Listing 10.3. Reading Input from `STDIN`

```
1.  #!/bin/sh
2.
3.  # Modified Hello World program that accepts input from keyboard
4.
5.  echo
6.  echo -n "Please enter your name: "
7.  read name
8.  echo
9.  echo "Hello, ${name}!"
10. echo
```

When run, this program does the following:

```
Please enter your name: Brian
Hello, Brian!
```

Notice these three important lines in the preceding program:

- Line 6 A new option to the `echo` command is introduced. The `-n` option suppresses the newline character that would normally be sent at the end of the `echo` statement. This causes the cursor to remain on the same line after `Please enter your name:`.
- Line 7 The `read` command accepts input from `STDIN` (in this case, the keyboard). The user can enter a string of text here. When Enter is pressed, `read` takes whatever the user entered and stores it in the variable `name`. The `read` command implies quotes; therefore the entered string is stored in the variable exactly as the user enters it with all whitespace preserved.
- Line 9 The `echo` command is used to insert the contents of the variable `name` into the string beginning with `Hello`, and ending with the exclamation point; then, once the final string is composed, it sends the string to the screen. Once again, the curly braces are optional.

The `read` command can take multiple variables as arguments. When it does, whitespace is the delimiter that separates what goes into each variable. Listing 10.4 shows an example.

Listing 10.4. Using Multiple Variables with `read`

```
1.  #!/bin/sh
```

```

echo
echo -n "Enter three numbers separated by spaces or tabs: "
read var1 var2 var3
echo
echo "The value of var1 is: ${var1}"
echo "The value of var2 is: ${var2}"
echo "The value of var3 is: ${var3}"
echo
```

Here is a sample run of the preceding program:

```
Enter three numbers separated by spaces or tabs: 557 2024 57240

The value of var1 is: 557
The value of var2 is: 2024
The value of var3 is: 57240
```

It doesn't matter how much whitespace you use in the input from the keyboard. When assigning multiple variables, `read` interprets any amount of whitespace as an argument separator to determine what should go in each variable.

If `read` gets fewer arguments than there are variables in its list, the remaining variables after the argument list runs out will not be assigned. On the other hand, if `read` gets more arguments than it has variables, whatever arguments are left over will be assigned to the last variable in the list. For example, here is another run of the program that gives `read` more than three arguments:

```
Enter three numbers separated by spaces or tabs: 1 2 3 4 5 6 7 8 9 0
The value of var1 is: 1
The value of var2 is: 2
The value of var3 is: 3 4 5 6 7 8 9 0
```

Handling Command-Line Arguments

You can also get information from the user by reading arguments included on the command line. The shell automatically stores up to nine command-line arguments in special internal variables. No programming is required to actually read the argumentsyou just need to address the variables `$1` through `$9`. The FreeBSD POSIX shell also allows additional arguments that can be accessed with `${10}`, `${11}`, and so on. But this should be avoided if the program will need to run on other systems because the traditional Bourne shell can only handle `$1` tHRough `$9`. The variable `$0` contains the name of the program itself, the variable `$@` contains a list of all the arguments, and the variable `$#` contains the number of arguments that were passed to the program. Listing 10.5 shows an example.

Listing 10.5. Command-Line Arguments in a Script

```
#!/bin/sh

echo
echo "The name of the program is: $0"
echo "The total number of arguments received is: $#"
echo "The complete argument string is: #@"
echo "Your first name is: $1"
echo "Your last name is: $2"
echo
```

And here is a sample run:

```
# ./yourname Brian Tiemann

The name of the program is: ./yourname
The total number of arguments received is: 2
The complete argument string is: Brian Tiemann
Your first name is: Brian
Your last name is: Tiemann
```

Note

The POSIX shell that FreeBSD uses also supports the `getopts` command, which provides a more versatile way of handing command-line arguments with a shell program. We will discuss this command when we talk about the advanced features of Korn shell programming. If you are writing Bourne shell programs (that use `sh`) for other UNIX platforms, however, it is best to avoid the use of `getopts` because it is not a standard part of the traditional Bourne shell and may cause the program not to work on some systems.

Command Substitution

Among other things, *command substitution* allows you to run a command and assign the output to a variable. The command to be run should be enclosed in backward quotes (`). Be careful not to confuse this character with the single quote. The backward quote character typically shares a key with the tilde (~) character on the keyboard. Here's an example of the backward quote used to enclose a command:

```
todaysDate=`date`
```

This example runs the `date` command and assigns its output to the variable `todaysDate`. You can then access the information in this variable just as you would with any other variable.

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Arithmetic in Shell Programs

Although the original Bourne shell has no built-in arithmetic handlers, arithmetic can still be done using command substitution along with the `expr` command. Here's an example:

```
var3=`expr var1 + var2`
```

This adds the values contained in `var1` and `var2` together and then stores the result in `var3`. Note that the arguments and the operator must be separated by whitespace. `expr var1+var2` will not have the intended result.

The `expr` command can do only very simple mathit can handle only integer arithmetic. Entering floating-point numbers will cause an error. Changing the order of operations with parentheses is not supported. Division that does not return an integer value will have the decimal portion dropped. For example, `5 / 2` is `2` as far as `expr` is concerned. If you want to retrieve the remainder of a division, you can use the modulus operator (`%`). For example, `expr 5 % 2` will return `1` (`5 / 2 = 4` remainder `1`).

Characters that have special meaning to the shell must be escaped. For example, `expr 2 * 2` will not work because the shell interprets the `*` as a wildcard operator. For the operation to work, the multiplication operator (`*`) must be escaped like this: `expr 2 \* 2`. This protects it from the shell's interpreting it as having a special meaning.

`expr` can also evaluate true/false expressions. If the expression is true, `expr` returns a 1. If the expression is false, `expr` returns 0. Here's an example:

```
expr 2 + 2 = 4 + 1
```

This command returns `0` (the equation is false).

This next example returns `1` (the equation is true):

```
expr 2 + 2 = 3 + 1
```

`!=` will reverse the sense of the equationit means "is not equal to." So, for example, the equation `expr 5 != 3` will return `1` (true).

`expr` can, of course, also evaluate less than/greater than comparisons. Once again, because the `<` and `>` characters have special meaning to the shell, they must be escaped when used with `expr` to make sure they retain their mathematical meanings. Comparisons are true/false evaluations just like the "equal to" operator. If the expression is true, `expr` returns `1`. If the expression is false, `expr` returns `0`. For example, `expr 5 \> 4` returns `1` (the expression is true). Greater than or equal to (`\>=`) and less than or equal to (`\<=`) evaluations are also supported.

`expr` is not limited to comparing numbersit can also compare strings. For example, `expr "The quick brown fox jumps over the lazy dog" = "The quick brown fox jumps over the lazy dg"` will evaluate to `0` (the expression is false unless the strings are exactly equal).

Although `expr` is great for simple shell scripting, as mentioned previously, its capabilities are rather limited. If you need to do floating-point math, work with complex expressions that change the order of operations, and so on, you can use a command called `bc`, which is a programming language in itself designed for working more flexibly with math than can be done in the basic shell language. It's possible to embed expressions into your shell program and feed them to `bc`. The program in Listing 10.6 uses `bc` to compute both the circumference and the area of a circle. Note that the argument to `bc` is `l`, the lowercase letter *L*. This option defines the standard math library for `bc`.

Listing 10.6. Using `bc` to Compute the Circumference and Area of a Circle

```
1.  #!/bin/sh
2.
3.  # The Following program computes both the circumference and the area
4.  # of a circle.
5.
6.  pi="3.14159265"         # Assign the value of pi to a variable.
7.
8.  # Tell the user what the program does and ask them for the radius of
9.  # the circle.
10.
11. echo
12. echo "This program computes both the circumference and the area of"
13. echo "a circle."
14. echo
15. echo -n "Please enter the radius of the circle: "
16. read radius
17.
18. # Now we will use bc to compute the answers and store them in variables.
19.
20. circumference=`echo "$radius*$pi" | bc l`
21. area=`echo "$radius^2*$pi" | bc l`
22.
23. # Last, we display the answers to the user and exit.
24.
25. printf "\n\nThe circumference is:\t$circumference\n"
26. printf "The area is:\t\t$area\n\n"
```

Most of the concepts used in this program have already been explained, in the sections "Variables" and "Interacting with the User." Therefore, rather than go through the program line by line, we'll just cover the concepts that are new and/or important to the operation of the program:

- Line 6 This line assigns a reasonably accurate value of Π to a variable called `pi`. I point this out because it shows good programming practice. You could just as easily have typed the number `3.14159265` each time you needed to use Π in the program.

  But assigning this irrational number to a variable serves two primary purposes. First, it simply makes the program more readable, minimizing the number of long numeric strings that would have to appear. Second, it makes the program much easier to maintain. If you later decided that you needed more precision for the value of Π, you would only have to change one number where you assign the value to the variable `pi`. If you had used the actual number each time in the program when you needed it, you would have to find and change each occurrence of Π when you decided you need more precision. This practice also aids in debugging; keeping all your variable declarations in one place and referring repeatedly back to it means that a typo will cause a problem much earlier and allow you to fix it much more directly.

- Line 16 As shown earlier, the `read` command gathers data from `STDIN`. In this case, you read the value typed by the user and store it in the variable `radius`.

- Line 20 Line 20 uses command substitution and a pipe to compute the circumference of the circle and store the value in the variable `circumference`. Because `bc` does not accept expressions directly on the command line, you need to use the `echo` command to echo the expression you want computed and then pipe the output of `echo` to `bc`.

- Line 21 This line is similar to line 20. The caret (`^`) in the expression is the `bc` exponent operator. In this case, it raises the value stored in `radius` by the power of 2 (you may recall from geometry that the area of a circle is obtained by squaring the radius and then multiplying by pi). You do not need to use parentheses to change the order of operation because, as you may recall from algebra, exponents have higher precedence than multiplication. Therefore, you can be assured that the exponent will be evaluated before the multiplication is done.

- Lines 25 and 26 These lines display the results to the user. I used `printf` here because it gives me a nicer layout than `echo`. The use of the `\t` expression creates tabs and causes the numbers to line up in a nice column.

This is only a very simple use of `bc`. `bc` is quite powerful and can do much more than the examples you've seen here. See the `man` page for `bc` if you are interested in learning more about its capabilities, both inside shell scripts and in standalone programs.

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Loops

Sometimes you might want an operation to repeat until a certain condition becomes true (or until a certain condition is no longer true). This is where looping statements come into play. The Bourne shell supports three different looping constructs for these situations. These are the `while` loop, the `until` loop, and the `for` loop. You will look at each one separately.

The `while` Loop

The `while` loop takes a test condition as an argument, and repeats the statements inside the loop as long as the condition that is being tested is true. In other words, whatever is enclosed in the loop keeps being executed over and over until it causes a change in the program's variables such that the test condition becomes false. If the condition is already false the first time it is evaluated, the loop will never be executed. For example, the program in Listing 10.7 uses a `while` loop to count to 20 and display the numbers on the screen.

Listing 10.7. Using the `while` Loop

```
1.   #!/bin/sh
2.   # Count from 1 to 20
3.   i=1
4.   while [ $i -le 20 ]
5.   do
6.   echo $i
7.   i=`expr $i + 1`
8.   done
```

This program introduces a few new concepts:

- Line 3 This line simply assigns the variable `i` the initial value of `1`. `i` is a variable that is universally understood to be a loop-control counter; as with its usage in summation in mathematics, *i* typically stands for *increment*. This is one case where you can get away with not using a descriptive variable name.

- Line 4 The `while` command contains the condition to test enclosed in brackets. The bracket is actually a shorthand notation for a command called `test`, which takes two operands and an operator used to compare them. You will use this command a lot in shell scripting.

  Unfortunately, the `test` command uses a somewhat strange syntax. `-le` in this example means "is less than or equal to." So this means the loop will repeat as long as the variable `i` is less than or equal to 20. For mathematical evaluations, Table 10.2 shows all the operators that this command supports.

Table 10.2. Mathematical Operations for the `test` Command

Option	Action
`-eq`	Returns true if operand 1 is equal to operand 2
`-ne`	Returns true if operand 1 is not equal to operand 2

`-gt`	Returns true if operand 1 is greater than operand 2
`-ge`	Returns true if operand 1 is greater than or equal to operand 2
`-lt`	Returns true if operand 1 is less than operand 2
`-le`	Returns true if operand 1 is less than or equal to operand 2

- Line 5 The `do` statement indicates that everything after this should be done for each iteration of the loop. All statements located between the `do` statement and the `done` statement are considered part of the loop.
- Line 6 Prints the current value of the variable `i`.
- Line 7 Uses command substitution with the `expr` command to increment the value of `i` by 1 and then assign the new value back into `i`.
- Line 8 The `done` statement indicates the end of the loop. At this point, the program jumps back up to the `while` statement, and the test condition is evaluated again. If `i` is still less than or equal to `20`, the statements inside the loop are repeated again. If `i` is greater than `20`, the loop exits and control passes to the first statement after the `done` statement (in this case, line 9, which simply exits the program with a `0`, or successful status).

Notice that the statements inside the loop are indented. This makes it easy to pick out the statements that are part of the loop when quickly scanning the program's source code. The shell ignores the indentation, so you could have written this program without using it. I recommend you always indent loops, though, using tabs or a specified number of spaces, to make them easier to find when quickly scanning program source code.

Tip

The space between the bracket (`[`) and the condition to be tested is mandatory, as is the space immediately before the final bracket (`]`). Failing to include either one will cause an error. For example,

```
[ $VarA -gt 5 ]
```

will work, but

```
[$VarA -gt 5]
```

will cause an error.

The `until` Loop

The `until` loop is the opposite of the `while` loop. It performs the operations inside the loop as long as the condition being tested is *not* true. When the condition being tested becomes true, the loop exits. If the condition is already true the first time it is evaluated, the loop will never be executed.

The `while` loop and the `until` loop are very similar. Usually, you can use either one in a program and achieve the same results simply by modifying the condition that is tested for. For example, the counting program that used the `while` loop can be rewritten to use an `until` loop by making only two changes in line 4:

```
4.  until [$i -gt 20 ]
```

This program performs the same function performed by the earlier program that uses the `while` loop. The only difference is that now the loop repeats until the value of `i` is greater than `20`, whereas before it repeated while the value of `i` was less than or equal to `20`. The result is exactly the same, however.

Logical `AND`/`OR` Statements in `while` and `until` Loops

Both the `while` loop and the `until` loop can also work with logical `AND`/`OR` statements. A logical `AND` statement, indicated with the symbol `&&`, will be carried out if and only if *both* conditions are true. A logical `OR` statement (`||`) will be carried out if *either* condition is true. The code example in Listing 10.8 shows a logical `AND` statement, which will execute the `while` loop only if both statements ("`$VarA` is equal to 1" and "`$VarB` is greater than 7") are true; the second statement is not true, so the loop will not execute.

Listing 10.8. Using a Logical `AND` Statement

```
#!/bin/sh

# Demonstrate logical AND
VarA=1
VarB=5
while [ $VarA -eq 1 ] && [ $VarB -gt 7 ]
do
    echo "VarA is equal to 1 and VarB is greater than 7"
done
```

In this example, the `echo` statement will not be executed. Because the `while` loop in this case requires both conditions to be true, the test fails and returns a `0` (false).

The code example in Listing 10.9 is identical to the one in Listing 10.8, except you have changed the `while` test to a logical `OR` statement. Now, only one of the conditions needs to be true. Therefore, because `VarA` will always be equal to `1` in this program, the `while` statement will continuously execute in an endless loop (until you press Ctrl+C).

Listing 10.9. Using a Logical `OR` Statement

```
#!/bin/sh

# Demonstrate logical AND
VarA=1
VarB=5
while [ $VarA -eq 1 ] || [ $VarB -gt 7 ]
do
    echo "VarA is equal to 1 and VarB is greater than 7"
done
```

The for Loop

The for loop is different from the while and until loops. Instead of evaluating a true/false test condition, the for loop simply performs the statements inside the body of the loop once for each argument it receives in a list. When creating a for loop, you supply it a variable. Each iteration of the for loop changes the value of the variable to the next argument in the list. The for loop continues until the argument list has been exhausted, at which point the loop exits and the program proceeds to the next command. The program in Listing 10.10 uses a for loop along with the bc command you learned about earlier to print the square root of all numbers from 10 through 20:

Listing 10.10. Using the for Loop

```
1.   #!/bin/sh
2.   # Print square roots of 10 - 20
3.   for num in `jot 10 10 20`
4.   do
5.      square_root=`echo "scale=5; sqrt($num)" | bc l`
6.      echo $square_root
7.   done
```

The output from this program is as follows:

```
3.16227
3.31662
3.46410
3.60555
3.74165
4.00000
4.12310
4.24264
4.35889
4.47213
```

Note these important lines in the preceding program:

- Line 3 This line of the program contains the for loop. It introduces a new command called jot, which can do many useful operations with numbers, including printing a string of numbers and generating random numbers. In this case, you have used jot to print a string of 10 numbers, starting with number 10 and ending with the number 20 (10 10 20). The for loop assigns each one of these values to the variable num in sequence and then performs the statements in the body of the loop for each value.
- Line 5 This line uses the bc command to compute the square root of the value stored in num. The scale=5 statement tells bc that the output should be scaled (truncated) to five significant digits after the decimal point. Notice also the semicolon after the scale statement. Semicolons can be used in place of a newline to separate multiple statements on the same line. The sqrt function of bc takes a number in parentheses and returns the square root of that number. Because the shell expands the variable to the value it contains, bc actually receives the number contained in the variable rather than the name of the variable itself. Finally, at the end of line 5, the output is piped to the bc command itself. The -l option tells bc to preload the math function library, which contains the sqrt function.

The shift Command

The `shift` command is similar to the `for` loop. You can use a `while` loop along with `shift` to run a loop once for each command-line argument you give when invoking a shell program.

As you'll recall from the previous discussion, command-line arguments are stored in numbered variables starting at `$1` and going to `$9`. The `shift` command shifts the variables one position to the left each time it is run. This means that each time `shift` is encountered, the information currently stored in `$1` "falls off" the end; the information currently stored in `$2` is moved to `$1`, and so on up the list. Listing 10.11 shows an example.

Listing 10.11. Using the `shift` Command

```
1.   #!/bin/sh
2.   # This program demonstrates the use of shift.
3.   while [ $# -ne 0 ]
4.   do
5.       echo "The value of \$1 is now $1."
6.       shift
7.   done
8.   echo
```

And here's a sample run:

```
# ./shift1 a b c d e
The value of $1 is now a.
The value of $1 is now b.
The value of $1 is now c.
The value of $1 is now d.
The value of $1 is now e.
```

Here are the notable lines in this program:

- Line 3 This line starts a `while` loop. You will recall from the "Handling Command-Line Arguments" section that the magic variable `$#` contains the number of command-line arguments. This `while` loop continues as long as the value of `$#` is not equal to zero. When the value of `$#` is equal to zero, all the command-line arguments have been used up, and the loop ends.
- Line 5 This line prints the current value of `$1`. Note that to actually print the literal string `$1` on the screen, you have to escape the `$` character with a backslash to prevent the shell from giving `$` a special meaning.
- Line 6 When the `shift` command in line 6 is run, the variables are shifted one position to the left. `$1` "falls off" the end and is no longer available, `$2` becomes `$1`, `$3` becomes `$2`, and so on.

One of the most common applications of `shift` (and `for` loops) is in shell programs that accept a list of filenames as command-line arguments and then perform a group of operations on each file specified on the command line.

The `true` and `false` Statements

The sole purpose of the `true` and `false` statements in shell programming is to return a value of true (`0`) or false (`1`), respectively. You can use these statements to create infinite loops. As long as there is some condition that can break a program out of an infinite loop, it can be useful to write code that creates one. This is how programs are designed that run continuously and listen for input, such as web servers. The example in Listing 10.12 shows a program that will loop indefinitely.

Listing 10.12. Creating an Infinite Loop with `true`

```
1.  #!/bin/sh
2.  # The following program loops indefinitely.
3.  while true
4.  do
5.      echo "This line will print forever."
6.  done
7.  echo "This line will never print since the program will"
8.  echo "never get past the loop."
9.  exit 0      # The program will never exit cleanly since it will
10.             # never get to this point.
```

Obviously, this chapter cannot show you the output of this program because it would go on forever. Line 3 tests for a true condition. And because the argument it tests (`TRue`) will never return a value of false, the loop will repeat indefinitely. Lines 7, 8, 9, and 10 will never be executed because the program can never get past the loop. (To end this program, press Ctrl+C on your keyboard.)

Breaking the Loop

Sometimes, you might want to break out of a loop before the condition necessary to exit the loop has occurred, and then proceed with the rest of the script. There are two statements that can be used to break a loop without ending the program. The first is the `break` statement, and the second is the `continue` statement.

The `break` Statement

The `break` statement will terminate a loop immediately when it is encountered, regardless of whether the condition required to exit the loop has been met. Listing 10.13 shows a slight modification to the previous "endless loop" program.

Listing 10.13. Breaking Out of a Loop

```
#!/bin/sh
# The following program loops indefinitely.
while true
do
    echo "This line will print forever... But..."
    break
done
echo
echo "The break statement in the loop causes the loop"
echo "to terminate immediately and go the first statement"
echo "after the loop."
```

Here's the output of this program:

```
This line will print forever... But...

The break statement in the loop causes the loop
to terminate immediately and go to the first statement
after the loop.
```

In a more complex implementation, you could have a loop that waits for some kind of input to be entered from the user's console or from the network; the loop could test continuously for the existence of a file or the value of a variable, and if that condition becomes true, a break could end the loop. Usually it is considered more elegant to write loops whose exit conditions are constructed to react properly on the right kind of input and to avoid a break when possible. In sufficiently complex programs, however, a break can be just what you need to get out of a jam.

The `continue` Statement

The `continue` statement causes the loop to immediately jump back to the top and reevaluate the test condition. Any remaining statements in the loop are not executed. Listing 10.14 is another example that uses the "endless loop" program with a slight modification.

Listing 10.14. Restarting a Loop Before It Has Ended

```
#!/bin/sh
# The following program loops indefinitely.
while true
do
    echo "This line will print forever."
    continue
    echo "But this line will never print even though it is inside"
    echo "the loop because the preceding continue statement"
    echo "causes the loop to jump back to the top and reevaluate"
    echo "the test."
done
echo "This line will never print since the program will"
echo "never get past the loop."
exit 0       # The program will never exit cleanly since it will
             # never get to this point.
```

This program will indefinitely output "This line will print forever." The rest of the `echo` statements inside the loop will never be printed because the `continue` statement preceding them causes the loop to immediately jump back to the top and reevaluate the test condition.

Conditional Statements

Conditional statements execute if and only if a certain condition or conditions are true. They generally come in three forms: `if` statements, `case` statements, and logical `AND`/`OR` statements. These are very fundamental and useful constructs in programming; flow control depends on them (executing certain blocks of code depending on the outcome of a condition), as does the ability of a program to behave correctly upon receiving certain expected arguments (which would be handled by `case` statements).

`if` Statements

`if` statements test numerical expressions given in brackets (which, as you saw earlier, are a shorthand for the `test` command). If the test condition is true, the statements inside the `if` block are executed. If the condition is false, one of two things can happen:

- Nothing. The statements inside the `if` block are not executed, and the program continues as if they were not even there.
- If an `else` statement is included inside the `if` block, the statements will be executed if the condition is false. In other words, this technique can be used to write "Do this if the condition is true, or do this if the condition is false, but don't do both" procedures in programs.

For example, the program in Listing 10.15 uses an `if` statement to test the number of command-line arguments given to the program. If the command-line arguments are one or more, the program performs the operations inside the `then` block. If no command-line arguments were supplied, the program exits without doing anything.

Listing 10.15. Using an `if` Statement

```
#!/bin/sh
# ifprog: Demonstrate one way to use if statements.
if [ $# -ge 1 ]
then
     echo "You supplied $# command line arguments."
fi
echo
echo "Program exiting..."
echo
```

And here are two sample runs:

Run 1:

```
# ./ifprog file1 file2 file3
You supplied 3 command line arguments.

Program exiting...
```

Run 2:

```
# ./ifprog
```

```
Program exiting...
```

The `if` statement in line 3 checks to see whether the number of command-line arguments supplied is one or greater (using the magic variable `$#`, which stores the number of command-line arguments). If it is, the statements between `then` and `fi` are executed. ("`fi`" is `if` spelled backward. It marks the end of the `if` block.) If it isn't, the statements inside the `if` block are skipped and the program jumps to the first statement past `fi`, which in this case simply informs the user that the program is exiting.

Using an `else` Statement

You could make this program more user-friendly by including an `else` statement that tells the user how to properly use the program rather than simply having it exit without doing anything, as it currently does. Listing 10.16 shows the revised example. Note that the operand in line 3 is a number one, not a lowercase *L*.

Listing 10.16. A More User-Friendly Way to Use `if` Statements

```
1.  #!/bin/sh
2.  # ifprog: Demonstrate one way to use if statements.
3.  if [ $# -ge 1 ]
4.  then
5.       echo "You supplied $# command line arguments."
6.  else
7.       echo "Usage: $0 file1 file2..."
8        echo
9        exit 1
10. fi
11. echo
12. echo "Program exiting..."
13. echo
```

Now, if the number of command-line arguments is less than one, the program will perform the `else` statements and give the user a usage message (remember that `$0` contains the name of the command that was invoked). Notice also line 9, which tells the program to exit immediately and sets the exit status to 1 (which indicates the program terminated with errors). Statements 1014 will never get executed if the program runs the `else` statements.

The `then` part of the `if` statement is required, but the `else` part is optional. As you have seen, the `then` part of the `if` statement performs an action if the expression tested by `if` evaluates to true. Sometimes, however, you might want to perform an action only if the expression evaluates to false and to do nothing if the expression evaluates to true. You can do this by using a colon as a placeholder. Here's an example:

```
if [ $myVar -gt 5 ]
then
    : # Do nothing and continue after end of if block
else
    # Statements to execute if condition is false go here.
fi
```

Using an `elif` Statement

Sometimes you might want to test for two or more different conditions and perform a different action, depending on the results. The `elif` statement (an abbreviation for "else if") accomplishes this.

When `elif` statements are used, the program will go through the `if` statement. If it evaluates to true, its actions will be performed and then program flow will jump to the first statement after the end of the `if` block (where `fi` is located). If it evaluates to false, the first `elif` is checked. If it is true, the statements inside it are executed and flow jumps to the end of the `if` block. If it is false, the second `elif` statement is evaluated, and so on.

Basically, evaluations are done until the program reaches an expression that evaluates to true. If none of the conditions evaluate to true, either nothing happens or the statements inside `else`, if present, are executed. Listing 10.17 uses much of what you have learned up to this point, including `if`, `elif`, and `else` to play a simple number-guessing game. Note that line 10 uses `jot`, a little command-line random-number-generating tool. The arguments in this case to its `r` option are the number of results to return (`1`), the lower bound (`1`), and the upper bound (`$up_limit`).

Listing 10.17. A Simple Number-Guessing Game

```
1.  #!/bin/sh
2.  # Number guessing game
3.  clear
4.  guess_count=1    # Initialize the guess counter to 1
5.  echo
6.  echo "Number guessing game written in Bourne shell script."
7.  echo
8.  echo -n "Enter upper limit for guess: "
9.  read up_limit
10. rnd_number=`jot -r 1 1 $up_limit`    # Get a random number
11. echo
12. echo "I've thought of a number between 1 and $up_limit."
13. echo
14. echo -n "Please guess a number between 1 and $up_limit: "
15. read guess
16. # Check the guess against the random number.
17. while true
18. do
19.     if [ $guess -gt $rnd_number ]
20.     then
21.         echo
22.         echo "Your guess was too high. Please try again."
23.         guess_count=`expr $guess_count + 1`
24.         echo -n "Please guess a number between 1 and $up_limit: "
25.         read guess
26.     elif [ $guess -lt $rnd_number ]
27.     then
28.         echo
29.         echo "Your guess was too low. Please try again."
30.         guess_count=`expr $guess_count + 1`
31.         echo -n "Please guess a number between 1 and $up_limit: "
32.         read guess
33.     else
34.         break
35.     fi
36. done
37. # We get to this point when the player guesses the correct number.
38. echo
39. echo "Correct!"
40. echo
41. echo "You guessed the number in $guess_count guesses."
42. echo
```

Here's a sample run:

```
Number guessing game written in Bourne shell script.

Enter upper limit for guess: 10
I've thought of a number between 1 and 10.
```

```
Please guess a number between 1 and 10: 5

Your guess was too low. Please try again.
Please guess a number between 1 and 10: 8

Your guess was too high. Please try again.
Please guess a number between 1 and 10: 7

Correct!

You guessed the number in 3 guesses.
```

Most of the concepts in this program should be familiar to you by now:

- Line 3 Simply clears the screen.
- Line 4 Initializes a variable `guess_count` to store the number of guesses the player has made and sets the initial value to 1.
- Lines 23 and 30 These increment the value of the variable `guess_count` by 1 for each incorrect guess made.
- Line 10 Uses command substitution with the `jot` command to assign a single random number between 1 and whatever the player entered as the upper limit for the guess to the variable `rand_number`.
- Line 17 Starts an infinite loop.
- Line 19 Checks to see whether the number the player entered is greater than the random number that the program picked. If it is, the player is informed of that, the `guess_count` variable is incremented by 1, and the player is asked to pick another number. After the player has picked another number, it is stored in the variable `guess` and the `while` loop starts over.

  If the number the player guessed is not greater than the random number the computer picked, the `elif` statement is evaluated to check whether the number is lower. If it is, the player is informed of this, the `guess_count` variable is incremented by 1, and the player is asked to try again. After the player has entered a new number, the `while` loop starts over.
- Line 33 Finally, if neither condition is true, the `else` statement is executed (you did not need to perform a test here because if the number is neither higher nor lower, it must be equal). The `else` statement here simply breaks out of the infinite loop, and program flow passes to the first statement after the `done` statement.
- Lines 39 and 41 The statements at the end of the program simply tell the user he guessed the correct number and then inform the user how many guesses it took him to get the correct answer by displaying the value of `guess_count`.

Like loop tests, `if` tests also support the logical `AND` (`&&`) and logical `OR` (`||`) tests to perform actions if and only if both conditions are true, or if one of any number of conditions is true.

`case` Statements

If you need to test the same variable for multiple conditions, there is a more efficient and cleaner way of doing it than with `if` statements. The `case` statement takes a variable as an argument and then uses statement blocks to determine what to do, depending on the value of the variable. Listing 10.18 uses `case` statements to create a random quote generator.

Listing 10.18. Using `case` to Generate Random Quotes

```
1.  #!/bin/sh
2.  # Random quote generator.
3.  quote_num=`jot -r 1 1 5`
4.  case "$quote_num" in
5.     1) echo
6.        echo "\"Until he extends his circle of compassion to include"
7.        echo "all living things, man will not himself find peace.\""
8.        echo "-- Albert Schweitzer"
9.        echo ;;
10.    2) echo
11.       echo "\"With regard to excellence, it is not enough to know, but"
12.       echo "we must try to have and use it.\""
13.       echo "-- Aristotle"
14.       echo ;;
15.    3) echo
16.       echo "\"Imagination is more important than knowledge. Knowledge"
17.       echo "is limited. Imagination encircles the whole world.\""
18.       echo "-- Albert Einstein"
19.       echo ;;
20.    4) echo
21.       echo "\"It is not the strongest of the species that survive, nor"
22.       echo "the most intelligent, but the one most responsive to change.\""
23.       echo "-- Charles Darwin"
24.       echo ;;
25. esac
```

Once again, you use `jot` in line 3 to generate a random number between 1 and 4. The `case` block begins on line 4. The syntax is `case` *`variable`* `in`, where *`variable`* is the name of the variable that the tests should be performed on. Line 5 begins the first test. Everything to the left of the parenthesis indicates the condition that `case` tests for. Like the `if` statement, `case` stops at the first match it comes to, executes the statements that go with that match, and then jumps down to `esac` (which is "case" spelled backward). The end of the statements that go along with each condition is marked with a double semicolon, which can be on a line by itself, or can be placed on the same line as the last statement, as is done in the previous example.

The `case` statement also accepts shell wildcards. Here's an example:

```
case "$myVar" in
   a) #statements to do for a
      ;;
   b) #statements to do for b
      ;;
   *) #statements to do for anything else
      ;;
esac
```

The previous code will check to see whether `myVar` is equal to *a* or *b*, and perform the appropriate statements if it is. If it is not, the last test is a wildcard that will match anything. So, if `myVar` is not equal to *a* or *b*, the last group of statements (for example, printing an error message) will be performed.

Other wildcards supported by `case` include `?`, which works the same way it does in the shell (as you saw in Chapter 8), and the pipe character (`|`), which allows `case` to accept a range of options. For example, `Y | y)` will accept either *Y* or *y* as a match for a test. You can also enclose multiple characters in brackets to match a range of characters. For example, `[Yy]|[Yy][Ee][Ss])` will accept either *y* or *yes* as a match in any combination of upper- or lowercase letters.

CGI Programming

You've probably seen websites that have features such as random quotes that display on the page at each load or a random picture that changes each time the page is reloaded. The program in Listing 10.18 that used `case` to display the quotes is one way to do this. This is called a CGI program, and it is a way for the web server to run external programs and then send the output of those programs over the Internet to a browser. Chapter 26, "Configuring a Web Server," covers CGI programming in much greater detail.

Logical `AND`/`OR` Conditionals

Logical `AND`/`OR` conditionals can serve as a shorthand way of doing `if` statements. They use the exit status of the first command to determine whether to run the second command. Here's an example of a shell command that packs a lot of programming meaning into a single command line:

```
# tar cvfz backup.tar.gz documents/2004/* && rm -r documents/2004
```

This command basically says, "If the first operation is successful, perform the second operation. If the first operation is not successful, do not perform the second operation." In other words, "You have to perform A and B. If A cannot be performed, do not perform B." In this case, it will attempt to use the `tar` command to archive all the files in the directory `documents/2004` into a file called `backup.tar.gz`. If the archive operation is successful (the `tar` command exits with `0`), the operation after `&&` will also be performed, which removes the directory `documents/2004`. If the archive operation is unsuccessful (the `tar` command exits with some number other than `0`), the operation after `&&` will not be performed (obviously, you do not want to remove the directory if you were unable to successfully archive it).

The `||` is the `OR` operator. It basically says, "If you cannot perform A, perform B. But do not perform B if A is successful." Here is an example:

```
# tar cvfz backup.tar.gz documents/2000/* || echo "Archive operation failed."
```

In this case, if the archive operation is successful (`tar` exits with `0`), the statement after `||` will not be executed. If, however, the archive operation fails (`tar` returns an exit status other than `0`), the statement after `||` will be executed, and an error message will be printed to the screen.

Exit Status

Most programs in FreeBSD return an exit status when they terminate. The exit status is usually `0` if successful, and some number other than `0` if something went wrong. Some programs will return a general error of `1`, and some will return a different number depending on the particular problem. The meanings of specific error codes can usually be found in each program's `man` page.

The exit status of the last program that ran is stored in the magic variable `$?`. Here are a couple of examples:

```
# ls > /dev/null
# echo $?
0

# ls -2 /dev/null
ls: illegal option -- 2
usage: ls [-ABCFGHLPRTWabcdfgiklnoqrstu1] [file ...]
# echo $?
1
```

The first example, a command that exits normally, will set the magic variable `$?` to `0` (the output of the `ls` command was redirected to `/dev/null` for brevity in the example). The second example, however, supplies an illegal option to `ls`. The command fails with an error message, and `$?` is set to `1`.

Tip

If you do a lot of programming, you might want to change your shell's prompt to include the `$?` token, so you can always see the exit status of the previous command right in your prompt.

You can use this exit status to make automatic decisions in your shell programs. The previous logical `AND`/`OR` example already introduced this technique to an extent. It showed how the success or failure of one command can determine whether the next one is executed. The logical `AND`/`OR` statement used in the previous section could also have been written as an `if` statement, like this:

```
if tar cvfz backup.tar.gz documents/2004/*
then
    rm -r documents/2004
else
    echo "Archive operation failed"
fi
```

This example combines the two examples from the previous section. The `if` statement reads the exit status of the `tar` command. If the exit status is `0`, the `then` statements are performed, and the directory that was archived is removed. If the exit status is some number other than `0`, the `then` statements are not performed, and the `else` statements are performed instead.

Another useful application of this property is with the `test` command. You've already seen how to use the `test` command with mathematical expressions. Another useful application of `test` is to check for the existence of `AND`/`OR` properties of a file, as in this example:

```
if [ -f program.conf ]
then
```

```
    : # do nothing
else
    touch program.conf
fi
```

This example checks for the existence of the file `program.conf`. If the file exists, `0` is returned and the `then` statement is executed. In this case, the `then` statement does nothing. (The colon tells it to do nothing; the rest of the line is a comment.) If the file does not exist, `1` is returned and the `else` statement is performed, which uses the `touch` command to create the file.

The `test` command can test for more than just the existence of a file. It can also test the attributes and type of a file. Table 10.3 is a list of all the options for the `test` command and what they mean.

Table 10.3. Testing File Attributes in Shell Programs

Option	Action
`-f`	The file exists and is a normal file.
`-d`	The file exists and is a directory.
`-s`	The file exists, and its size is greater than zero.
`-r`	The file exists and is readable.
`-w`	The file exists and is writable.
`-x`	The file exists and is executable.

Setting Exit Status

Most of the scripts in this chapter have set the exit status using the `exit` statement, and by now you have a pretty good idea of what the exit status is used for. If you do not specifically set the exit status, your program will return the exit status of the last command that ran. When you do set the exit status, whatever you set will be stored in the `$?` variable, just like the exit status of any other program. Also, just like any other program, the exit status of your shell program can be read by other programs to make a decision about what to do next. This can be useful if you are calling a shell program from another shell program, for example.

Also, remember that you are not limited to just `0` and `1` for exit statuses. You can put `exit` statements at many different points in the program, testing for various error conditions and returning a different exit status value (a nonzero, positive number) for each one. You can use several different exit statuses in the same program to communicate different error conditions, and then the invoking program (for example, your login shell or another shell script) can interpret them and act accordingly. Here is an example of some code that uses multiple exit statuses:

```
if [ -r program.conf ]
then
    : # do nothing
else
    exit 1
fi
if [ `touch /tmp/program.lock` ]
then
    : # do nothing
else
    exit 2
fi
# main program statements here
exit 0
```

The preceding example first checks to see whether it can read the file `program.conf`. If it can, the program continues to the next `if` test. If it can't, the program exits immediately with an exit status of `1`. If the program was able to read the `program.conf` file, it will then attempt to create the `/tmp/program.lock` file. If it can, the program continues. If it can't, the program exits immediately with an exit status of `2`. Finally, assuming that both operations succeed, the program will continue with the main part of the program and then exit with a status of `0`, which universally means "success." This program could be called from another program and then return its exit status to that program. The invoking program could then make decisions based on the exit status it received from this program.

Exit Traps

As you know, programs in FreeBSD can be terminated by sending them various "kill" signals and with various combinations of keyboard commands, such as the universal "interrupt" signal, Ctrl+C. (See the "Terminating Misbehaving Processes" section of Chapter 15, "Performance Monitoring, Process Control, and Job Automation," for more on the `kill` command and its numeric signals.) The problem with this is that if, for example, a program creates temporary runtime files, and the user interrupts the program with Ctrl+C before it has finished running, the program will not clean up after itself and will leave its temp files laying around on the disk, thus wasting space.

Fortunately, the shell provides a way to trap these types of interrupts. Listing 10.19 shows a short sample program that demonstrates the use of trapping interrupts.

Listing 10.19. A Program that Traps Interrupt Signals

```
#!/bin/sh
# Program that demonstrates trapping interrupts
trap `echo "Interrupt received. Quitting." 1>&2` 1 2 3 15
echo -n "Enter a number: "
read num
exit 0
```

This program sets a trap for interrupt signals 1, 2, 3, and 15. The actions performed by the trap are located between the single quotes. If you run this program and press Ctrl+C at the prompt that asks you to enter a number, it will send signal `2` (`INT`) to the program, setting off the trap and causing the message `Interrupt received` to be printed. Then the program will exit.

You also can use the `echo` command in the task of shell output redirection. The `1>&2` in the `echo` statement redirects the output of the `echo` command to `STDERR` ("standard error," which often means the screen, but can also be set to append to log file) instead of `STDOUT`. This separates status messages from meaningful data output, and ensures that the output of the command will not accidentally be sent down a pipe to another command or redirected to another location along with the rest of the program's output. It is a good idea any time you create error messages to send the output to `STDERR` with `1>&2`.

Normally, of course, you would use the traps to perform simple tasks such as cleaning up stray temp files and removing locks. If you need to do a lot of things in a trap, it is better to make the trap a function (functions will be covered later in the chapter).

If you want to prevent the user from being able to exit the program with Ctrl+C, you can set a trap and leave the action null, like so:

```
trap `` 2
```

This line causes signal `2` to be completely ignored.

Your program can have more than one trap, and different things can be done depending on how the program has exited. A trap for signal `0` will be set off on all exits, normal or otherwise. A trap for other signals will be set off only when one of those signals occurs. Table 10.4 provides a list of the most common signals you might want to trap.

Table 10.4. Common Interrupt Signals and Their Actions

Interrupt Signal	Action
`0`	Exit
`1`	`HUP`Session hang-up (or disconnect)
`2`	`INT`Interrupt (Ctrl+C)
`3`	`QUIT`Quit (Ctrl+\)
`15`	`TERM`A normal `kill` command

Note

You can trap signal 15 (the default signal sent by the `kill` command). You can also trap most other signals that can be sent by the `kill` command. However, you cannot trap signal 9 (`SIGKILL`). `SIGKILL` is used as a last resort to terminate a program when all other methods have failed. Therefore, it cannot be trapped and cannot be ignored.

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Functions

Functions are predefined groups of statements that can be called with a single command. They can almost be thought of as mini-programs inside other programs. Using functions in your shell programs can make your life a lot easier for two reasons. First, if you need to perform a complex operation in multiple places in your program, you can simply type the name of the function rather than having to retype all the code each time you need to perform the operation. Secondly, if you later decide you need to make the operation work differently, you only have to change the function rather than go through the code and change it every place it is used. The example in Listing 10.20 demonstrates how a function is created; it shows a simple function that cleans up temp files after a shell program exits. It then shows how to call the function.

Listing 10.20. Using a Function

```
#!/bin/sh
on_exit() {
    rm -rf /tmp/myprogram.*
    mv logfile logfile.old
    mail foo@bar.com < report.txt
}
trap on_exit 0 1 2 3 15
```

This function is given a name (`on_exit`), followed by parentheses and a left bracket. Everything between the two brackets is the body of the function. The function can then be called as if it were a program, simply by using its name. As stated previously, functions can almost be thought of as mini-programs inside other programs. Any time you type the name of this function, the statements between its brackets will be performed.

There is one important difference between calling a function and calling another program, though. The function is run in the current shell, whereas a separate program starts in a subshell. This means that a function can modify the variables and environment variables in the program that calls it. But a separate program called from inside a shell program cannot modify any of the variables or environment variables in the calling program.

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Filehandles

Filehandles are symbolic IDs for files and pseudo-files that are set up each time the kernel starts a process. These numbers are what the process uses to write output and read input. Three filehandles are opened by default:

Filehandle	Meaning
F.H. 0	`STDIN`. This is where standard input comes from. This is normally the keyboard, but it can be redirected to read from a file or some other source.
F.H. 1	`STDOUT`. This where standard output goes. It is normally the screen, but as you have seen it can be redirected.
F.H. 2	`STDERR`. This is where standard error messages go. Once again, this is normally the screen, but it can also be redirected.

Filehandles can be used in shell programs to make your programs both more efficient and easier to write. The `exec` command can be used to open a filehandle other than one of the default ones so as to redirect your program's output to it.

Suppose you have a program that wants to write a lot of lines to a file. Normally you would have to use output redirection (the `>` operator) on every single `echo` or `printf` command, opening a filehandle and closing it for each command. Listing 10.21 shows an example of how directly addressing filehandles can make your programs both easier to write and more efficient.

Listing 10.21. Using Filehandles to Redirect Output

```
1.  #!/bin/sh
2.  # open a filehandle on F.H. 1 (STDOUT)
3.  exec > testfile.txt
4.  # echo some stuff to STDOUT which will now go to the file testfile.txt
5.  echo "Line 1 of the file"
6.  echo "Line 2 of the file"
7.  echo "Line 3 of the file"
8.  echo "Line 4 of the file"
9.  echo "line 5 of the file"
10. exit 0
```

The `exec` statement in the second line of the preceding code example causes `testfile.txt` to be opened as a stand-in for `STDOUT`. As a result, all the `echo` lines are set to the file `testfile.txt` instead of to the screen, even though the output is not redirected in the `echo` statements. If you have a lot of things that need to be written to a file, this is more efficient for the operating system than using shell redirection with every single command, as well as being far easier to code.

This is also very useful when opening filehandles for `STDIN` and using `read`. Listing 10.22 shows an example.

Listing 10.22. Using a Filehandle for Input

```
#!/bin/sh
# open a file descriptor on F.D. 0 (STDIN)
exec < testfile.txt
while read string
do
    echo $string
done
```

Assuming that you still have the file `testfile.txt` from the previous example, this example will output the following:

```
Line 1 of the file
Line 2 of the file
Line 3 of the file
Line 4 of the file
Line 5 of the file
```

What's so great about this? It demonstrates the important concept of using a filehandle with `read`, enabling your script to read a multiline file and act on each line individually. Because the filehandle is not closed between each call to `read`, `read` remembers the last line it read and moves the pointer to the next line in the file. This way, `read` will read each line of the file in sequence automatically.

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Debugging Shell Scripts

If you write shell scripts of any complexity at all, sooner or later bugs are going to creep in. Although there is no full-fledged debugger for the shell, it does provide some primitive debugging capabilities in the form of being able to trace each action that is performed. You turn on tracing by adding `-xv` to the end of the `#!/bin/sh` line in your script, so it looks like this:

```
#!/bin/sh -xv
```

The `x` switch means for the shell to print every command, preceded by a plus sign (`+`), to `STDERR`. The `v` switch puts the shell in verbose mode. This has the effect of causing the script to write out everything it does to the error filehandle so that you can debug more easily.

This works best if you pipe the output to `more` or `less` so that it doesn't scroll off the screen faster than you can read itand also if you redirect both `STDOUT` and `STDERR` to the same place so that you can see both the output of the script and the errors. Listing 10.23 shows a simple example; enter it into a file called `xvtest` and set the file executable:

Listing 10.23. A Simple Demonstration of Tracing

```
#!/bin/sh -xv
# Demonstrate the use of tracing in shell script debugging
result=`echo "2 * 12 / (2 + 2)" | bc`
echo $result
exit 0
```

To execute this program so that you will see both `STDOUT` and `STDERR` and pipe the output to `more`, use the following command to invoke the program:

```
# ./xvtest 2>&1 | more
```

Tip

Piping the output to `more` (or `less`, which is the same thing) is only useful when the script is non-interactivewhen it requires no user intervention. Another technique, one that lets you debug interactive scripts, is to pipe the output instead into the `tee` program to redirect `STDOUT` and `STDERR` into a file, which you can then read in another terminal with `less` (press shift + F while in `less` to have it automatically show new data arriving at the end of the file).

The program will produce the following output:

```
#!/bin/sh -xv
# Demonstrate the use of tracing in shell script debugging
result=`echo "2 * 12 / (2 + 3)" | bc`
+ echo 2 * 12 / (2 + 3)
+ bc
+ result=4
```

```
7.  echo $result
8.  + echo 4
9.  4
10. exit 0
11. + exit 0
```

You can now see everything that this program did. The lines with plus signs (`+`) in front of them are the results of actions in the program. For example, line 3 in the preceding example assigns the results of a calculation to the variable `result`. Lines 4, 5, and 6 show the actions that were taken. Line 4 shows the `echo` command, line 5 shows the execution of `bc`, and line 6 shows the variable assignment, where `4` is assigned to the variable `result`.

This example also shows how variable expansion works. Notice lines 8, 9, and 10. In line 8, the `echo` statement is read. In line 9, the variable is expanded so that the `echo` statement becomes `echo 4`. Then, in line 10, the actual output of the `echo` statement is produced.

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Advanced Features of Korn Shell Scripting

The Korn shell, which can be installed separately as discussed in Chapter 8, contains some advanced features that can make shell programming easier and more powerful, such as built-in arithmetic and arrays. You should think carefully before using these features in a script, however, because virtually every UNIX system can run a Bourne shell script, but Korn shell scripts won't run unless the Korn shell is installed and available. If such a script is highly specializedrequiring the advanced features of the Korn shelland will be run only on your local system or on systems that have the Korn shell available, using this script won't present any problems. If you are writing a shell script for public consumption, however, or if this script will run on multiple systems within your organization and you cannot be sure which shells will be available on those systems, you are better off sticking to plain-old Bourne script, or looking ahead to Perl (see Chapter 11, "Introduction to Perl Programming").

That being said, this section will cover some of the advanced features of Korn shell scripting.

Tip

Most of the techniques given in this chapter also apply to the POSIX shell that FreeBSD ships with as `/bin/sh`. However, you definitely should not use these in a `/bin/sh` script if the script will be run on other systems that do not use a POSIX shell as `/bin/sh`. Because of the `#!/bin/sh` at the beginning of the script, the other system will try to run the script anyway. But it will bomb as soon as it hits code that it doesn't understand because that code is not part of the Bourne shell syntax.

Tip

Note that the `bash` shell can also run most scripts written for the Korn shell. You will, of course, need to change the first line in the script to point to the `bash` shell instead of the Korn shell. For example, in FreeBSD you would change `#!/usr/local/bin/ksh` to `#!/usr/local/bin/bash`. If you wanted to run the script on a Linux system where bash is installed by default in `/bin`, you would change the line to `#!/bin/bash`. A more general technique is to use `#!/usr/bin/env bash`, which will work equally well for all systems.

Obtaining and Installing the Korn Shell

Before you can write shell programs for the Korn shell, you need to install a copy of the Korn shell on your system. The Public Domain Korn shell (`pdksh`) is available for FreeBSD both on the DVD as a package under `shells` (which can be installed from Sysinstall or from the command line) and also in the ports tree under `/usr/ports/shells/pdksh`. To tell your program to run with the Korn shell, replace `#!/bin/sh` at the top of your shell program with `#/usr/local/bin/ksh`. The Korn shell is completely backward-compatible with Bourne, so any script that was written for a Bourne shell will also run under the Korn shell. The reverse is not true, however: you cannot run a Korn shell script under Bourne.

When you have the Korn shell installed, take a moment to review some of the advanced features that make programming in the Korn shell easier, more powerful, and more efficient.

Built-in Arithmetic

The Korn shell has built-in arithmetic. This means you do not need to call the `expr` program to do arithmetic in Korn as you do in Bourne. However, like `expr`, Korn shell arithmetic is limited to operations on integer numbers. Because it is an internal function, however, it can perform these operations much faster than `exec`.

There are two ways to access the built-in arithmetic functions of the Korn shell. The first is with the `let` statement. Here's an example:

```
let x=7+5
```

This line assigns 12 to the variable `x`.

The other method is by enclosing the expression in double parentheses, as shown here:

```
((x=7+5))
```

This can be more readable than using `let`. It is also more readable for mathematical comparisons than using the `test` command in Bourne shell syntax because it allows you to use the familiar mathematical notations `<` and `>` rather than `-lt` and `-gt`. Also, unlike with `expr`, characters that would have special meaning to the shell do not have to be escaped. In Korn, you can write `((5 * 3))` rather than `expr 5 \* 3`, for example.

Korn shell arithmetic supports the common mathematical operators shown in Table 10.5.

Table 10.5. Korn Shell Math Operators

Operator	Description
`+`	Addition
`-`	Subtraction
`*`	Multiplication
`/`	Division
`%`	Modulus (returns the remainder of a division)
`>`	Greater than
`<`	Less than
`>=`	Greater than or equal to
`<=`	Less than or equal to
`==`	Equal to
`!=`	Not equal to
`&&`	True if both expressions are non-zero
`||`	True if either expression is non-zero
`=`	Assigns the expression on the right to the expression on the left
`+=`	Adds the expression on the right to the variable on the left and then stores the result in the variable
`-=`	Subtracts the expression on the right from the variable

	on the left and then stores the result in the variable
`*=`	Multiplies the expression on the right by the variable on the left and then assigns the result to the variable
`/=`	Divides the expression on the right by the variable on the left and then assigns the result to the variable
`%=`	Divides the expression on the right by the variable on the left and then assigns the remainder to the variable

Arrays

The Korn shell also supports arrays. An *array* (also often described as a *list*) is a variable that contains multiple elements, each of which contains a separate value. Arrays are useful for grouping related elements together.

You can think of an array as a box with different compartments in it. Each compartment has a number. You could access the various compartments by giving the name of the box, followed by the compartment number.

Use the `set` command to load an array. For example, suppose you want to create an array called `temperature` that contains the average temperature for each month of the year for a given area. The following command will do the trick (the `A` option effectively sets the parameter, or name, of the array to `temperature`):

```
set -A temperature 57 52 58 61 63 65 71 70 68 66 64 62
```

This will create an array called `temperature` with 12 elements in itone for each month of the year. If you are following along on your system, simply enter the preceding command from a Korn shell command prompt for now (if you need to start a Korn shell, you can do so by typing **`ksh`** or **`pdksh`** at the prompt).

To access the various elements in the array, you use a subscript appended onto the end of the array name. Elements in the array start at `0`, and wildcards are accepted. Here are some examples of how this works:

```
ksh$ echo ${temperature[0]}
57
ksh$ echo ${temperature[11]}
62
ksh$ echo ${temperature[*]}
57 52 58 61 63 65 71 70 68 66 64 62
ksh$
```

Arrays can contain up to 512 elements (`0511`).

If you want to change the value of only one element in an array, you can do so by referencing the element in a variable assignment. To set the value of the first element to `55`, do the following:

```
temperature[0]=55
```

Here are a couple of points to note regarding arrays:

- Unlike with scalar variables, the curly braces are not optional when referencing the arraythey're mandatory. `echo $temperature[1]` will not have the desired result. It must be written as `echo`

`${temperature[1]}`.

- Arrays cannot be exported as environment variables.

You could have created a separate variable for each month, of course, but the program shown in Listing 10.24 shows how using arrays instead can save a lot of programming time.

Listing 10.24. Arrays in a Korn Shell Script

```
1.  #!/usr/local/bin/ksh
2.  # Demonstration of arrays and computing average temperature.
3.  set -A temperature 57 52 58 61 63 65 71 70 68 66 64 62
4.  i=0
5.  printf "\nMonth\t\tTemperature\n\n"
6.  while ((i < 12))
7.  do
8.          (( month = $i + 1 ))
9.          printf "$month\t\t${temperature[$i]}\n"
10          (( total_temp += ${temperature[$i]} ))
11.         (( i += 1 ))
12. done
13. avg_temp=$(( total_temp / 12 ))
14. echo
15. echo "Average temperature for whole year: $avg_temp"
16. echo
```

Here's the output of this program:

```
Month           Temperature

1               57
2               52
3               58
4               61
5               63
6               65
7               71
8               70
9               68
10              66
11              64
12              62

Average temperature for whole year: 63
```

This may look scary at first, but really there isn't much new here other than the syntax, which is a little different from what you're accustomed to using in Bourne shell scripting. There is also some new logic in this program that you haven't used before, but it will make perfect sense after you look at how the program works:

- Line 1 Notice the difference here: this shell script starts with `/usr/local/bin/ksh`. If you accidentally put `#!/bin/sh` here instead, the program will not run, and you will get strange errors.

- Line 3 This line uses the `set` command to load an array named `temperature` with 12 numbers, each of the numbers being an average temperature for one month.

- Line 4 This simply initializes the loop counter to zero.

- Line 6 This line starts a loop that will continue as long as `i` is less than 12.

- Line 8 This line creates a new variable called `month` and sets the value to whatever is in `i`, incremented by 1. This is used in the output of the program to print the number of the current month. Why do you have to add 1 to `i`? Because `i` is currently set to 0, and it is what you will use to get the first element out of the `temperature` array. Because array element numbers start with 0, your elements in the `temperature` array are numbered from 0 to 11. But this is not what you want for your month number display, so you simply add 1 to the current value of `$i` for each iteration of the loop.

- Line 9 This line prints the current value of `month`, followed by two tab characters and then a single element from the `temperature` array. Notice that you use variable substitution here. The value of `i` is expanded to the number stored in `i`, and this is used as the element to retrieve from the array.

- Line 10 This line takes whatever value is currently in the variable `total_temp`, adds the number stored in the array element of `temperature` represented by `i` to it, and then stores the new value in `total_temp`, overwriting the old value. It keeps a running sum of all the temperatures added together, which will be used later to compute the average temperature.

- Line 11 This adds 1 to the current value of `i`. So, for example, on the second iteration of the loop, `i` will now be set to `1` instead of `0`, and therefore the second element of the array will be printed as well as added to `total_temp`. This is the last statement in the loop. If `i` is still less than `12`, the loop will repeat.

- Line 13 After the loop has completed, the average temperature is computed by taking the sum of all the temperatures stored in `total_temp` and dividing by `12`. The new value is assigned to `avg_temp`.

- Line 15 The average temperature for the entire year is printed.

Note

According to the program, the average temperature for the whole year was 63. This is a good example of how the shell's arithmetic can only handle integers. The actual average temperature for the whole year is 63.083333, but because the shell cannot handle floating-point math, it drops the decimal portion and just prints `63`. If you needed more precision here, you could use the `bc` command to do the calculation, as you saw in Listing 10.6, to compute the circumference and area of circles with π.

Do you see how this program saved us some work? Rather than having to go through each month manually, you were able to use a loop that increments a variable and automates the task of getting the value for each month. If you had used separate variables to store the temperatures, this task would have required a good deal more code than you used here.

Note

If you want some good practice, see if you can modify the previous temperature program to use a `for` loop instead of a `while` loop. Here is a hint: Remember that the array can accept the `*` wildcard to show all the elements in the array.

Command Substitution

The Korn shell also supports a cleaner form of command substitution than the Bourne shell. Rather than putting commands in backquotes, you can use a syntax like the following:

```
todayDate=$(date)
```

The old style is also still supported. Which one you use in Korn shell scripts is mostly a matter of personal preference.

Using `getopts`

The `getopts` command offers a better way of handling command-line arguments than the simple Bourne-style syntax used earlier in the chapter. It allows you to use the standard option syntax of `-option` that most other FreeBSD commands use. It also allows for better handling of arguments to the options.

The general syntax of the `getopts` command looks like this:

```
getopts options variable
```

Here, *`options`* is the list of valid options that can be supplied, and *`variable`* is the name of the variable in which those options should be stored. If an option letter ends with a colon, it can also take a value. That value will be stored in the special variable `$OPTARG`. Another special variable, named `$OPTIND`, stores the value of the current argument being worked on.

The `getopt` command executes once for each option it is supplied with. If used with the `while` loop, the loop will execute once for each command-line argument supplied. The following shows an example of how the `getopt` command syntax works:

```
getopts abc:d: myVar
```

With this command, the valid options that `getopts` recognizes are `a`, `b`, `c`, and `d`. In addition, options `c` and `d` are followed by a value that will be stored in the variable `$OPTARG`. The option itself is stored in `MyVar`.

A simple sample script using `getopts` appears in Listing 10.25. Note that this script will run under FreeBSD's `/bin/sh` as well, butagainbeware of other systems whose `/bin/sh` isn't POSIX and doesn't support `getopts`.

Listing 10.25. Using `getopts` to Handle Command-Line Arguments

```
#!/usr/local/bin/ksh
# Demonstrates the use of getopts.
for i in 1 2 3 4
do
  getopts abc:d: myVar
  echo "$myVar, $OPTARG"
done
```

Let's assume that you have saved this script as a program called `test.pdksh`, and you invoke it as follows:

```
# ./test.pdksh -a -c foobar -b -d blah
```

Note that the order in which you specify the arguments does not matter. The output looks like this:

```
a,
c, foobar
b,
d, blah
```

If you omit any arguments, the myVar variable will be set to the question mark (?). The getopts command is run as many times as there are arguments. The first time it is run, myVar will contain a. The second time it is run, myVar will contain c, and the variable $OPTARG will contain the string foobar. Using these variables and the previously mentioned $OPTIND variable, the getopts command can be used for decision-making in shell programs using the same procedures used throughout this chapter (loops, conditionals, and case statements, for example).

Chapter 11. Introduction to Perl Programming

IN THIS CHAPTER

Perl is an interpreted programming language, particularly suited for text processing, that is widely used for such tasks as system administration and CGI scripting for active web content. Its name officially stands for *Practical Extraction and Report Language* (although several variants exist, some tongue-in-cheek). Perl was written by Larry Wall as a replacement for `awk`, and has grown into a framework of modules created and maintained by an immense network of independent developers. Wall is still Perl's chief architect and is currently (as of this writing) working on the newly redesigned Perl 6.

It's almost impossible to work in the UNIX world or on the Internet in general today without at least some understanding of the Perl language. Despite many structural inconsistencies and quirks, Perl has managed to become the *de facto* tool for writing quick but versatile programs for just about any purpose. Like shell scripts, Perl programs don't have to be compiled in order to run, and its free-form syntax-checking and its built-in data typing and memory management eliminate many of the headaches of programming in more traditional compiled languages such as C. Perl can thus be used quite effectively with very little programming expertise.

This chapter covers some of the basics of Perl so that you can take advantage of its strengths without having to know enough about programming to be limited by its weaknesses. The chapter is aimed at users who have had some working experience in FreeBSD already and are familiar with the basics of shell scripting (from Chapter 10, "Shell Programming"); it discusses Perl in just enough detail to provide a useful base for writing simple scripts and CGI programs and understanding the concepts in some of the more complex scripts that currently exist. This foundation in the subject will help you teach yourself further Perl techniques by example, using the Perl-based utilities available in FreeBSD or any prewritten tools you might download.

Note

Many, many large books have been written on the subject of Perl. Its usefulness in today's world is so vast, its presence so ubiquitous, and its structure so complex that even those who can claim mastery of Perl are frequently surprised by hidden quirks or tricks that the language can accomplish. You'll learn more about some excellent Perl books and other resources at the end of this chapter.

Perl in FreeBSD

Although a concerted effort has been made to eliminate them in favor of shell scripts or compiled programs, some of the programs that make up FreeBSD's core installation are actually Perl scripts. The rest are generally compiled binaries, built from source code written in C, C++, or a number of other popular languages. These binaries cannot be read by a human or easily decompiled back to source form. Perl code, on the other hand, does not need to be compiled. It exists as plain text, easily readable and editable, and is run with the help of the Perl interpreter, `/usr/local/bin/perl`.

Note

Until FreeBSD 5.0, Perl was included by default in the core operating system. For a variety of reasons, it is no longer in `/usr/bin` as part of a newly installed system and must be installed from the ports (`/usr/ports/lang/perl5`) or as a package (**`pkg_add -r perl5`**).

Chapter 10 described how to write scripts using the shell interpreter `/bin/sh` by specifying the name of the interpreter on the first line of the script. Perl scripts work the same way. The difference is that whereas shell scripts are primarily useful as "batch programs" (in MS-DOS parlance) that execute sequences of system commands as they would be entered on the command line with simple variable substitution and flow control, Perl is a fully functional programming environment that allows you to write programs as complex as web servers or database-management systems. Because they're interpreted rather than compiled, Perl programs tend to be slower in execution (especially to start) than their C counterparts, although C programs typically take longer to develop properly. Perl's primary strengths are in string processing and text handlingfeatures that are far more difficult to work with in C. Therefore the ideal application for a Perl program is as a system-utility script (such as `adduser`, which until recently was a Perl script) or a CGI program that performs string manipulations and operations on files. Perl can be less efficient at doing heavy-duty mathematics than a well-designed C or C++ program. For this reason, some Perl modules (such as the MD5 hashing module) contain core mathematical components written in C for speed.

Although the parts of FreeBSD itself that used to be Perl-based are not so any longer, Perl is still widely found in third-party applications such as Majordomo, the popular mailing list manager, and SpamAssassin, the mail filtering suite. In a live FreeBSD system, you will probably run into Perl programs at least as frequently as you will shell scripts, so it's important to know how to work with them.

Strengths of Perl

Perl strikes a balance between the ease of use of shell scripting (a high-level approach) and the versatility of C programming (a low-level approach). The result is a language that allows you to use variables of many different data typesincluding data structures, importable objects, associative arrays, multidimensional arrays, and I/O handleswithout having to worry about casting variables from one type to another, allocating and freeing memory, predeclaring variables, dereferencing pointers, prototyping functions, and performing a number of the other onerous tasks associated with programming in C, including compiling binaries.

Perl gives you extreme freedom to do what you like without getting bogged down in the convoluted and bug-prone details of low-level programming. The high-level tools that make Perl what it is are largely responsible for Perl's vast acceptance as the language of choice for CGI programming and server-side web applications, a field that has grown explosively over the years due to the increase in e-commerce.

The specific purpose of Perl is to provide superior string-manipulation tools: pattern matching, string replacement and translation, regular expressions, and a structure that makes it very straightforward to read and write text files using native arrays of strings. There is no need in Perl to declare a variable as being a string, an integer, a character, or any other type. Perl recognizes variable types in a cascading structure of appropriateness, assigning the necessary memory to each variable as it is modified and applying operators appropriately according to the variable's type.

In Perl we have what is arguably the best mixture of ease of use and programming power in any widely used language. Its syntax is extremely lax and flexible, letting you get away with many minor mistakes that other languages would punish severely. It's extensible (with thousands of importable library modules available throughout the Internet), it's well-documented and well-supported, and it's available everywhereon dozens of different platforms. You can be sure that a Perl script will operate the same no matter where you run itwhether it's on Linux, Mac OS X, IRIX, Windows, or FreeBSD.

Weaknesses of Perl

Perl was never designed to be the general-purpose language it has become. It started life as a string-processing language, and over the years more and more functionality has been heaped upon it. The result is that text-processing remains extremely fast and efficient in Perl, but it does so at the expense of structural elegance. Although Perl's strengths are very significant assets indeed, Perl is not widely regarded as a model of ideal language design.

Although Perl's laxness lets the programmer get away with many types of mistakes, this has the effect of encouraging sloppy code (much as a standards-lax web browser will encourage invalid or incompatible HTML code). Perl accepts syntax that resembles C, BASIC, Fortran, or even common English in some cases. Although this gives the language great flexibility, it also means that Perl code that's perfectly natural to one programmer might be unreadable to another. Perl's structure allows many different ways to do any given task; this results in a learning curve that grows much steeper after the initial easy introduction to the language, and it means that unless certain coding practices are enforced, Perl programs can be a severe challenge for multiple programmers to maintain. Perl is in many ways the "black sheep" of the programming language community.

Python and Post-Perl Programming

Many new projects have attempted to fill in for Perl's shortcomings since its meteoric rise to prevalence. Many, such as REBOL, Java, and Ruby, have been under development since Perl gained critical mass in the server-programming world. The frontrunner, however, is a language dating back to about the same time as Perl's beginnings: Python.

Python is an even more object-oriented language than Perl, and it has a much more regimented syntax. No C-style brackets are used; instead, tab indentations are significant, greatly simplifying the hierarchical nesting of flow-control blocks. Python also uses dotted-object hierarchies and tightly structured modules (or *dictionaries*), providing a much more direct and extensible interface to objects than Perl can.

Whereas Perl programs are compiled with each runtime, Python generates compiled bytecode (a `.pyc` file) at the first run of a program, which speeds up execution on subsequent occasions. This is partially necessary because, as with all object-oriented programming environments, the trade-off is speed for structure. Because of its strict object-oriented nature, in which syntactic structure and a single method of doing things are paramount to its design, Python programs are potentially less susceptible to bugs than is Perl. Python also is easier to maintain because it is less prone to "spaghetti code." Python lacks many text-processing capabilities, though, which is the area where Perl shines the most.

Although Python is not a part of the core FreeBSD system, it is available from the ports collection, in `/usr/ports/lang/python`. Its proponents continue to gain strength and credibility, and Python may eclipse Perl as the dominant interpreted programming language before too much longer.

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Fundamentals of Perl Scripting

A Perl script is effectively similar to a shell script, such as those explained in Chapter 10. The first line (known as the *interpreter line*) tells the shell which interpreter to use to run the rest of the script's contents:

```
#!/usr/local/bin/perl
```

Or, to avoid compatibility issues on systems that might have Perl installed in a different location, a more portable interpreter line would be as follows:

```
#!/usr/bin/env perl
```

The rest of the script, as in shell programming, is made up of variable assignments, flow-control blocks and loops, system calls, and operations on I/O handlesto name a few fundamental parts of a script's anatomy. Here's a simple example:

```
#!/usr/bin/env perl

$string = "Hello world!";
$hostname = `hostname`;
if ($hostname eq "uncia") {
  print $string."\n";
  print `date`;
}
```

Notice the use of C-style curly brackets to delimit the `if` block, rather than the "`if`/`fi`" and "`case`/`esac`" syntax of shell scripting. Also as in C, each statement is terminated by a semicolon (`;`), allowing you to use multiline statements in most cases. The whitespace between the statements and operators is also optional: "`$a = 1`" is just as valid as "`$a=1`". Perl's syntax much more closely resembles that of a simplified version of C than that of the shell language. Think of Perl as a cross between shell scripting and C, incorporating the best features of both.

A Perl script doesn't need to be compiled. This makes debugging very easy: Just edit the file, make a change, run it again, see what new errors there are, and edit it again. The Perl interpreter does the "compiling" at runtime, and it doesn't write out any compiled bytecode. This makes Perl slower than full-fledged Cwhich is why almost all critical system functions are written in Cbut it's fine for scripts that aren't especially time- or performance-sensitive.

Tip

While you learn Perl and during development of your programs, you might want to use `perl -c` in the interpreter line, which enables more verbose syntax checking and helps greatly in debugging.

To run a Perl script, you have to set it as executable. This is done with the `chmod` command:

```
# chmod +x myscript.pl
```

Now, to run the script, you would use the `./` prefix to specify the script in the current directory because you most likely won't have "`.`" (the current directory) in your path, especially as root:

```
# ./myscript.pl
Hello world!
Sat Apr 28 15:29:17 PDT 2001
```

Note

Because Perl scripts are interpreted, you don't necessarily have to make them executable in order to run them, or even have the interpreter line at the top. If you prefer, although this method is less conveniently "encapsulated" than the previous method, you can run the script as an argument to `perl` itself. This way you can run the program even if the script is not set executable or does not contain the interpreter line:

```
# perl myscript.pl
```

Note

Perl has several options that can be used either in the interpreter line or at the command line to alter its behavior. The `-w` switch, for example, turns on warnings in which the Perl interpreter informs you of improperly written code that can execute but isn't deterministically correct. This option is so widely relied upon that *not* using it is seen as poor form. You can use the `w` switch in either of the following ways if you want to ensure that the code you write is "proper":

```
# perl -w myscript.pl
```

or

```
#!/usr/bin/perl w
```

Variables and Operators

A variable in Perl is a *scalar*, an *array*, or an *associative array* (or *hash)*, which are three different ways of storing pieces of data. This data can take the form of a number (expressed in any of several different ways), a string of text, or other various types of what are known in Perl as *literals*pieces of data, such as `3` or `car`, whose meanings are exactly as represented. A scalar variable (the most common kind) has a name beginning with the dollar sign (`$`).

The nice thing about Perl is that you never have to worry about whether a number is an integer, a float, a short, a long, or whatever. You also don't need to treat a string as an array of characters, a pointer to a string in memory, or anything like that. Perl handles all that stuff internally. You don't even have to convert strings to numbers, or vice versa. Perl will recognize if a string has only numbers in it and allow you to multiply it by a number or apply any mathematical operators to it. Everything from the first nonnumerical character in a string onward is dropped, so `123blah` would be treated by numerical operators as `123`, and `blah` would be treated as zero.

Operators are available to modify these variables. There are the mathematical operators you'd expect: `+`, `-`, `=`, and so on. C-style incrementation operators are available (`++` and `--`) as are space-saving composite mathematical operators (`+=`, `-=`, `*=`, and so on). Extra operators include exponentiation (`**`), modulus (`%`), and the comparison operators used in conditional clauses (`>`, `<`, `=>`, `=<`, `==`, and `!=`). Strings can be concatenated with the dot operator (`.`) or repeated any number of times using the string repetition operator (`x`).

Perl makes use of more operators than you are ever likely to need to know about. Full coverage of these operators could fill an entire book, but Table 11.1 lists the purposes of some of the common operators you're likely to use when writing scripts for use in FreeBSD.

Table 11.1. Numeric Operators

Operator	Meaning	Usage	Value of `$c`
`+`	Addition	`$c = $a + $b;`	`7`
`-`	Subtraction	`$c = $a - $b;`	`1`
`*`	Multiplication	`$c = $a * $b;`	`12`
`/`	Division	`$c = $a / $b;`	`1.333...`
`=`	Assignment	`$c = $a;`	`4`
`+=`	Implicit addition	`$c += $a;`	`$c + 4`
`++`	Incrementation	`$c++;`	`$c + 1`
`**`	Exponentiation	`$c = $a ** $b;`	`64`
`%`	Modulus	`$c = $a % $b;`	`1`
`.`	Concatenation	`$c = $a . $b;`	`43`
`x`	Repetition	`$c = $a x $b;`	`444`
`>`	Greater than		
`<`	Less than		
`>=`	Greater than or equal to		
`<=`	Less than or equal to		
`==`	Equal to		
`!=`	Not equal to		

Here are a few simple lines of Perl that show the use of variables, literals, and operators:

```
$a = 5;
$a++;
$b = $a ** 2;
$c = "test" . $b;
print "$c";
```

This block of code would print out the string `test36`. First `$a` is assigned to 5; then it is incremented to 6. Next, `$b` is assigned to `$a` squared, or 36. Then, `$c` is assigned to the string test with `$b` appended. Finally, `$c`, whose value now is `test36`, is printed to the screen. If that's clear to you, you understand the building blocks of Perl.

Scalars, Arrays, and Associative Arrays

Variables can be used individually or in arrays of arbitrary numbers of dimensions. You've already seen scalar variables, such as `$a`, `$b`, and `$c`, in the previous example; a scalar variable contains a single number or string. But each of these variables travels separately, and there will be times when you will need to work with groups of associated pieces of data. This is where arrays come in:

```
@array1 = ("blah",5,12.7,$a);
@array2 = ($a, $b, $c);
```

An array has the same kind of naming conventions as a scalar variable, except that it begins with an "at" sign (`@`) instead of a dollar sign. As these examples show, an array does not need to be declared with a certain size or contain only a consistent type of data. Arrays can contain numbers, strings, other arrays, or whatever you like.

You can access an element of an array using square brackets. The third element of the previous `@array1` array, a scalar value, would be `$array1[2]`. Remember that array element numbering begins at zero!

You will also see elements of arrays addressed with the `@` prefix instead of `$`. This prefix indicates that you can address a "slice" of an array by specifying more than one element (for example, `@array1[1,2]`). This example is really an array in itself with two elements. If you say `@array1[2]`, you're talking about a slice with one element, which is effectively the same thing as a scalar variable, and it works the same way. However, for consistency's sake, you may want to keep in mind that the "preferred" method is `$array1[2]`the prefix of the variable determines what kind of variable it is.

You can use the various array operators, essentially built-in functions, to set up your arrays in any way you like. Arrays are often also called *lists*. In that context, you can think of an array in "stack" terminology, which gives you the `push()`, `pop()`, `shift()`, and `unshift()` operators. These operators are listed in Table 11.2, where `@array1` undergoes each of them in turn.

Table 11.2. List Operators

Operator	Function Result	Syntax
`push()`	Adds a value to the end of a list.	`push(@array1,"test"); @array1 = ("blah",5,12.7,6,"test")`
`pop()`	Removes a value from the end of a list and returns it.	`$d = pop(@array1); @array1 = ("blah",5,12.7,6), $d = "test"`
`unshift()`	Adds a value to the beginning of a list.	`unshift(@array1,"test"); @array1 = ("test","blah",5,12.7,6)`
`shift()`	Removes a value from the beginning of a list and returns it.	`$d = shift(@array1); @array1 = ("blah",5,12.7,6), $d = "test"`

Tip

You can accomplish each of these operations by setting the output of the operator to a new array, or even to the same array. Therefore, by writing `@array3 = push(@array1,"test")`, you can create a new array with the new lengthened contents, leaving the original array (`@array1`) untouched.

A further useful array function is `sort()`. For instance, `sort(@array1)` would arrange all the elements in lexicographical order, treating them as strings. You can specify an alternate sorting algorithm of your own construction to extend the functionality of the `sort()` routine to do whatever you like. For instance, if you create a subroutine called `numerically()` that sorts two arguments in numerical order, you can use the following:

```
sort numerically (@array1)
```

Tip

Custom sort subroutines (you'll learn about creating subroutines later) can be used to sort lists of elements based on any criteria you like, either by comparing members of data structures or by performing complex calculations on the values to be compared before evaluating them. A simple numerical sort routine can be reduced to the single operator `<=>`, so you can numerically sort `@array1` like this:

```
sort <=> (@array1);
```

Arrays are especially useful when you're working with relational data, either through interfaces to real databases or simply delimited text files such as `/etc/passwd`. Using arrays is how you would access the individual lines in a file that you've read in from standard input. We'll be looking at how that's done a bit later in the chapter.

Tip

You can get the size of an array by accessing it in "scalar context." The easiest way to do this is to assign the list to a scalar variable:

```
$size = @array1;
```

Now, `$size` is equal to 4.

An array can be created from a scalar string using the `split()` function. This will divide up the string based on whatever delimiter you specify, omitting the delimiter from each of the new array's elements:

```
$mystring = "Test|my name|Interesting data|123";
@mydata = split(/\|/,$mystring);
```

In the first line, `$mystring` is assigned to a string of four different chunks of text, separated by the pipe character (`|`). In the second, the `split()` function separates the string into four parts, removing the pipe characters on which the string was split, and assigns the parts to elements of the `@mydata` array.

Note that slashes are used to delimit the delimiter expression, and you have to escape the pipe character (`|`) with a backslash to make sure it's evaluated as a delimiter and not the "alternative" operator, which will make sense a little later, in the section on regular expressions. In any case, `@mydata` now contains the strings `Test`, `my name`, `Interesting data`, and `123` as its elements.

A special kind of array is an *associative array*; this is equivalent to a hash table in which the different values in the array are stored as key/value pairs. The prefix for an associative array is the percent sign (`%`), but each value of the array is a scalar, so you use the scalar prefix (`$`) to refer to the individual elements. Here's how you set up an associative array:

```
$assoc1{key1} = "value1";
$assoc1{key2} = "value2";
```

You can then use any of several associative array operators on the array as a whole:

```
@myvalues = values(%assoc1);
while (($mykey,$myvalue) = each(%assoc1)) {
  print "$mykey -> $myvalue\n";
}
```

Associative arrays are very useful in applications such as CGI programming, in which all the variables from HTML forms are sent to the server and read into an associative array based on the form field names. You'll see more about CGI programming in Chapter 26, "Configuring a Web Server."

Flow Control

One thing that qualifies Perl as a full-featured programming environment rather than a simple batch scripting language is its complete set of flow-control structures. These are what allow you to create complex data-flow paths and iterations in your programs.

`if/elsif/else`

The most common control structure is the `if` block:

```
if ($a == 5) {                    # If $a equals 5...
  print "It's 5\n";
} elsif ($a > 5) {                # Otherwise, if $a is greater than 5...
  print "Greater than 5\n";
} else {                          # In all other cases...
  print "Must be less than 5\n";
}
```

Note

Note that the conditional clause (`$a == 5`) must use the *equality operator* (`==`) rather than the assignment operator (`=`). The `==` operator and other comparison operators (listed in Table 11.1) can always be used in conditionals. But if the items you're comparing are strings, you can use the string equivalents: `eq` for `==`, `lt` for `<`, `ne` for `!=`, and others.

foreach

Another common flow-control player in Perl is `foreach`, which allows you to iterate over all the elements in an array. Here, the `foreach` statement divides `@buffer` into its component elements, assigns each one to `$line` for the duration of the loop it controls, and allows you to use it as many times as there are members in the array:

```
foreach $line (@buffer) {
  print $line;
}
```

If you omit the optional variable name that refers to the element the loop is looking at (`$line` in this example), use the default `$_` variable name to refer to the current element. It's a good idea to specify a variable name here in order to prevent confusion when you're using multiple nested `foreach` loops.

for

Perl also has a standard `for` loop, which is almost identical to the `for` loop in C. The purpose of `for` is simply to iterate a specified number of times rather than over the elements of an array. The `for` loop is controlled by an iteration variablegenerally one that isn't used anywhere else in the scriptthat is iterated automatically by `for` until it reaches your specified limit. Its arguments, as in C, are separated by semicolons. These include the name of the iteration variable, the incrementation operation, and the end condition. Here's an example:

```
for ($i; $i++; $i<100) {
  print "$i\n";
}
```

This sample `for` loop will print out 100 lines, numbered from `0` to `99`. The first argument sets up `$i` as the iteration variable, and the second says that `$i` should be incremented upward once. The `for` loop will execute unless the condition specified in the third argument is false, which in this example occurs once `$i` has reached 100.

while/until/do

Finally, we have the `while` loop, which acts like a simplified version of `for` without the iteration variable. It has a conditional statement as its argument, which is evaluated every time the loop begins, and it keeps executing until the condition is false. Here's an example:

```
while ($i < 100) {
  $i += 5;
  $j++;
}
print "$j\n";
```

This loop will execute 20 times, and the output of the `print` statement will be `20`.

A variant of `while` is `until`, which has effectively the opposite meaning: It keeps executing *until* the conditional is true. The following example has the same effect as the previous `while` loop:

```
until($i == 100) {
  $i += 5;
  $j++;
}
print "$j\n";
```

This is very seldom used; most Perl programmers instead just use `while` loops with the exit condition set appropriately to the situation (which is generally easier to understand anyway).

Another way to use `while` or `until` is via the `do...while` or `do...until` construct. This guarantees that the loop will execute at least once, and the `while` or `until` conditional is evaluated at the end, rather than the beginning. Here's an example:

```
do {
  $i += 5;
  $j++;
} while ($i < 100);
print "$j\n";
```

Backquotes (`` ` ``) enable Perl to execute any command as you would at the command line or within a shell script. Simply enclose your command in backquotes, and Perl will execute it using `/bin/sh`, waiting until the spawned process quits before proceeding. What's more, the output from the backquoted command is available as the return value, so you can put it into a variable for later use. Here's a commonly used example:

```
$date = `date`;
```

Note that this returned string generally has `\n` at the end, so you can use `chomp()` to snip it off, either on a separate line or by enclosing the original assignment as an expression:

```
chomp($date = `date`);
```

Caution

Be aware that Perl won't necessarily know your command path. Commands called by your script might work for you on your own machine, but if you put the script on another system, it might fail because the commands you're trying to run in backquotes can't be found. The best defense against this is to specify the full path to each invoked command:

```
@who = `/usr/bin/who`;
```

One way to keep control over externals that must be called from your scripts is to define their paths in variables at the beginning of a script. Declaring these variables in an easy-to-find section helps other users locate and maintain them:

```
$who = "/usr/bin/who";
```

The variable `$who` can then be used in backticks to invoke the `who` program. *Be very careful!* An error that puts the wrong value into `$who`, or an attack that does so maliciously, means the script will be executing someone's arbitrary commands instead of the harmless `who` command.

Command-Line Arguments

You can pass practically as many arguments as you want on the command line to a Perl program. These arguments, separated by whitespace (unless enclosed in quotes), are placed at runtime into the `@ARGV` array and are available for any kind of use:

```
# ./myscript.pl test "My String" 123
```

`$ARGV[0]` is now `test`, `$ARGV[1]` is `My String`, and `$ARGV[2]` is `123`. This also works on CGI programs, as you will see in Chapter 26. If you specify a URL with arguments separated by `+` characters (the usual way of passing arguments to CGI programs), `@ARGV` will be populated the same way:

```
http://www.example.com/myscript.cgi?test+My%20String+123
```

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A Simple Perl Script

The script in Listing 11.1 uses most of the techniques covered thus far in the chapter, as well as a few that haven't been covered (and that's about all it does). This script is available on the included Disc 3 as `simpledemo.pl`.

Listing 11.1. Simple Demo Perl Script (`simpledemo.pl`)

```
#!/usr/bin/env perl

# <STDIN> is an I/O handle referring to the standard input. In this context,
# we're using it to read in text input from a prompt. The chomp operator removes
# any trailing newline/return characters from the end of the input.
print "Please enter your name: ";
chomp ($name = <STDIN>);

srand;   # Initialize the random number generator
@namelist = ("Bob","Jane","Frank");
@colorlist = ("green","red","blue","yellow");
foreach $testname (@namelist) {
  # You can select any random element of an array by using the rand() operator
  # on it.

  $colors{$testname} = $colorlist[rand(@colorlist)];
}
while (($name,$color) = each(%colors)) {
  print "$name: $color\n";
  undef ($n);    # The undef() function undefines a variable. Works like NULL.
  do {
    $color = @colorlist[$n+1];
    $n++;
  } until ($color eq "blue");
}
```

Advanced Perl Techniques

Now, it's time to move on to some of the more interesting things you can do with Perl in FreeBSD. These include file access, functions, modules, andPerl's hallmarktext-processing capabilities. The following sections take a look at each of these topics.

Text Processing

Perl's primary strength and original purpose, as mentioned earlier, is text processing. Perl evolved from simpler text-processing tools whose efficiency came from their use of regular expressions.

A *regular expression* (also often called a *regexp* or *regex*) is a very highly developed way of specifying a pattern to seek in a text stream. You can use regexps to do simple searches on strings, or you can modify one to include such constraints as the beginning or end of a line, groups of certain characters, included strings of arbitrary length, or any of a number of occurrences of any pattern.

Regexps are part of many different tools in FreeBSD and other UNIX-based systems, especially the pattern-matching tool `grep` and its variants. Perl gives you the same kind of flexibility as you have in `grep` but embeds it in a full-featured programming environment. This is something that almost all other languages lack. For instance, in C you have to copy strings back and forth in memory and seek through them character by charactera rather painful and inelegant process.

Searching with Regular Expressions

The simplest regexp pattern is a text string. To seek for a regexp in a string, use the `=~` operator and enclose the regexp in slashes:

```
if ($string =~ /abc123/) { ...
```

This can be simplified even more if you're receiving a text string already, such as from the "diamond" operator (`<>`), which allows you to loop through a text file specified on the command line (we'll look at this in the next subsection). If this is the case, and you already have a `$_` variable (the "default" variable, which you read about back in the section titled "`foreach`"), you can search on it implicitly:

```
if (/abc123/) { ...
```

Note

The default variable (`$_`) is a useful shortcut, but its use is frowned upon because of how easy it is to lose track of what it means in multiple nested loops. It's always better coding practice to assign a named variable to the current value in a loop.

That's all well and good. But what about searching for a more complex pattern? For example, you can modify the pattern so that `abc123` will match only if it appears at the beginning of the line. This is done with the `^` anchor, as shown here:

```
/^abc123/
```

The end-of-line anchor, `$`, is interpreted as such only if it's at the end of the regexp. Otherwise, it's treated as a variable name prefix. Using these two anchors together, you can change your pattern to only match if `abc123` is the whole line, with nothing else on it:

```
if (/^abc123$/) { ...
```

These are only the most basic of the regexp pattern controls. You can embed `[abc]` to specify a character "class" consisting of any of the three letters `a`, `b`, or `c`. You can use quantifiers immediately after any character, class, or grouping to specify how many times it can appear in sequence. Table 11.3 shows a summary of these patterns (and not a complete one, at that).

Table 11.3. Regular Expression Syntax Operators

Pattern	Explanation
Text	
`.`	Any single character
`[abc123]`	Any of the characters in the group `abc123`
`[^abc123]`	None of the characters in the group `abc123`
`[a-g]`	All characters between `a` and `g`, inclusive
`abc1|abc2`	Alternative: `abc1` or `abc2`
`(abc123)`	Grouping (for use with quantifiers or alternatives, or back references)
Quantifiers	
`?`	0 or 1 of the preceding text
`*`	0 or *n* of the preceding text (*n* > 0)
`+`	1 or *n* of the preceding text (*n* > 1)
`*?`	Forces `*` to the minimal match (anti-greediness quantifier)
`{m}`	Exactly `m` repetitions of the preceding text
`{m,n}`	`n` through `m` repetitions of the preceding text
`{m,}`	`m` or more repetitions of the preceding text
Anchors	
`^`	Start-of-line anchor
`$`	End-of-line anchor
`\b`	Word boundary
`\B`	No word boundary
Escape Codes	
`\`*X*	Escapes (treats as a literal) any character *X* that does not match an existing escape code; for example, `\.` matches a period, instead of "any

	character"
`\r`	Carriage return
`\n`	Line feed
`\f`	Form feed
`\t`	Tab
`\d`	Digits (equivalent to `[0-9]`)
`\w`	Word characters (equivalent to `[a-zA-Z0-9_]`)
`\s`	Whitespace (equivalent to `[\r\t\n\f]`)
`\D`	Not digits
`\W`	Not words
`\S`	Not whitespace
`\###`	ASCII character `###` (in octal)
`\cX`	Ctrl+`X` character (where `X` is any character)

What's more, you can also add various switches to the end of the pattern, after the final slash, to change the sense of the match. An `i` makes it a case-insensitive search (for example, `/abc/i`).

Note

A word on precedence: When grouping within a regexp, parentheses have the highest precedence, followed by multipliers, and then anchors, and then alternatives.

Regexps can be made as complex as the most obfuscated code you've ever seen in your life. Perfecting a well-crafted regexp that does some incredibly obscure task can be one of the most satisfying parts of the UNIX lifestyle.

Changing Text with Translation Operators

Of course, what's a search without the ability to replace? Perl has several built-in translation operators: the "substitution" operator (`s///`), the "transliteration" operator (`tr///`), and explicit string-manipulation functions such as `substr()`.

To do a substitution, you will still use the `=~` operator, but this time as an assignment operator rather than as a comparison. The argument to it is the `s` operator, and then a regexp, and then the replacement string, and finally any options. These are all separated by slashes, as shown here:

```
$mystring =~ s/^test[0-9]/foo/g;
```

Here's a more useful example, which translates angle brackets into HTML escape sequences to display them literally in a web page:

```
$myhtml =~ s/</&lt;/g;
$myhtml =~ s/>/&gt;/g;
```

The g at the end means *global*, and it tells the substitution operator to do a "replace all"that is, to change every occurrence of test1, test2, and so on to foo. If this is omitted, only the first match in the string will be substituted.

One of the more useful explicit text-processing functions is substr(). Its full usage is covered, along with all the other built-in functions, in any good Perl reference book. As a quick summary, it takes a string, an offset, and a length and then returns just that substring. Here's an example:

```
$mystring = "cat and dog";
$newstring = substr($mystring,0,3);
```

$newstring is now cat. This is cool enough as it is, but substr() really comes into its own when used in conjunction with index(). This function will return the point in a string where a given substring appears:

```
$mystring = "cat and dog";
$newstring = substr($mystring,index($mystring,"cat"),index($mystring,"dog"));
```

This would assign "cat and" to $mystring, including the trailing space.

You can also use rindex instead of index to search for the last occurrence of a token; this is useful for capturing the base name and extension of a file that might be uploaded through a CGI web form:

```
$basename = substr($filename,0,rindex($filename,"."));
$ext = substr($filename,rindex($filename,".")+1,255);
```

Using Filehandles to Work with Files

Perl has access to the same basic data-flow filehandles you saw in Chapter 10: STDIN, STDOUT, and STDERR. What's more, Perl's control over filehandles that point to real files is very extensive and can be harnessed to make your programs juggle files toward any purpose you need. You can open a file, read it into an array, and write out a new one, or even do all this to many files at once, through the use of filehandles.

The simplest filehandle is the "diamond" operator, which doesn't really have a permanent filehandle at allit's just a way to treat an incoming file (or set of files) from the command line as an input filehandle for as long as there are lines in the file to read. To use the diamond operator, use a loop like the following:

```
while (<>) {
  print $_;
}
```

Then, run your program with one or more filenames on the command line:

```
# ./myscript.pl file1.txt file2.txt ...
```

This will have the effect of printing out all the contents of the specified files, much in the way that cat would. This way of operating on a file's contents is convenient and quick. However, it's also pretty limited; the diamond operator is really a "degenerate case" of a true filehandle. Let's look at some properly specified ones to see what they can really do.

A filehandle name by convention is in all caps. It is created with the open() command, and afterward you can read from it, print to it, and close it. Here's how to open a file and print it out line by line:

```
open (FH,"/path/to/file1.txt");
while ($thisline = <FH>) {
  $i++;
  chomp ($thisline);
  print "$i: $thisline\n";
}
close (FH);
```

It's possible for Perl to fail to open the file, either because it doesn't exist, its permissions don't allow you to read it, or any other of a number of reasons. You can trap for failures opening the file by using the `die` operator; if the evaluation of an expression falls through to `die`, it will print its argument (if any) to standard output, and the script will quit. Here's the most common way `die` is used with opening files:

```
open (FH,"/path/to/file1.txt") || die ("Can't open file1.txt!");
```

Writing to files is a bit more complex because there are so many different ways you can do it. The thing to remember is that you can write to any kind of handle you can use on the command line, which includes the overwrite (`>`) or append (`>>`) redirector, or even the `|` (pipe) into a program. This is useful for, say, having your script write its output into an email message (note the simplified method of stepping through the `@contents` array and printing each line):

```
open (FH,">/path/to/file2.txt");
print FH $_ foreach (@contents);
close (FH);

open (MAIL,"| /usr/sbin/sendmail -oi -t");
print MAIL "From: me\@somewhere.com\n";
print MAIL "To: you\@somewhereelse.com\n";
print MAIL "Subject: Check it out!\n\n";
print MAIL $_ foreach (@contents);
close (MAIL);
```

Caution

Remember that when specifying `@` characters in text strings (in email addresses, for instance), you need to precede them with backslashes to prevent Perl from treating them as array identifiers. If you don't, the script will fail with an error.

The filehandle goes as an argument to `print`; it's important here to realize that this argument is assumed to be the built-in filehandle `<STDOUT>` (standard output), unless a different one is specified. There is also a `<STDIN>` handle. To set the default input/output filehandle, use the `select()` function:

```
select (FH);
```

This way, you won't have to write `print FH` every time. However, you'll need to switch it back to `STDOUT` when you're done with `FH`.

Directories have corresponding `opendir()` and `readdir()` functions; you can open a directory and read its contents into an array, like this:

```
opendir (DIR,"/path/to/dir");
@files = sort readdir (DIR);
closedir (DIR);
```

Using what you've seen so far, you can now do some pretty interesting stuff. For instance, you can open up /etc/passwd, grab all the entries that have a UID greater than 1,000, and print out their usernames and full names:

```
#!/usr/bin/env perl


open (PASSWD,"/etc/passwd") || die ("Can't open passwd file!");
while ($line = @passwd) {         # For each member of @passwd...
  @userdata = split(/:/,$line);  # Split on colons and assign to @userdata
  if ($userdata[2] > 1000) {  # If the UID is greater than 1000...
    print "$userdata[0]: $userdata[4]\n";
  }
}
```

A useful tool already! This is what makes Perl so popular. There's very little effort involved in producing programs that make your life measurably easier.

Functions

Perl has hundreds of built-in functions, many of which you've already seen. These functions cover pretty much any general-purpose necessity of programming, especially once you know how to include Perl modules that expand your available functions as much as you want. However, there will come the time in your more complex Perl programsespecially programs that span multiple Perl scripts, such as server-side CGI suiteswhen you will want to define functions of your own (which Perl calls *subroutines*) to accomplish your common tasks.

You can define functions anywhere in your script that you want; they don't need to have already been "declared" in order to work. For neatness' sake you might choose to put your function definitions at the end, or you might want to put them all inline, or at the topit doesn't matter.

Let's say you want to be able to pass an arbitrary number of values to a function and have it add them together. The syntax for this would be as follows:

```
sub sum {
  $mysum += $_ foreach (@_);
  $mysum;  # This line evaluates $mysum and thus sets the function's
           # return value
}
```

The function would then be called with its name prefixed with the ampersand character:

```
$newsum = &sum(45,14,2134,89);
```

The @_ variable refers to the argument list, much in the same way that @ARGV represents the arguments passed to the program itself from the command line. For a more "traditional" style of function, the kind that most other languages have (which accept a certain number of named variables), you can do something like this:

```
sub printname {
  ($name, $number, $passwd) = @_;
  print "$name/$number" if ($passwd);
}
```

Functions bring up a common hornets' nest of issues surrounding "global" and "local" namespaces. The rule about Perl is that there are normally no local functionsthey're all globally defined (unless you use the object-oriented syntax that underpins the Perl module system and will be briefly discussed a little later). Any variables that you define in a function are global, unless you say otherwise (for example, with the `local()` operator). The `@_` array is already local; each time you call a function, its argument array is created as a brand-new local copy. Using `local()`, you can do the same with other variables, too, and have them be relevant only within the function and discarded when it's done:

```
sub sum {
  local($mysum);
  $mysum += $_ foreach (@_);
  $mysum;  # This line evaluates $mysum and thus sets the function's
           # return value
}
```

The `my` operator does the same thing, and it is more common nowadays. You can use `my` to specify a list of local variables:

```
my ($mysum, $name, $hash);
```

"Strict mode" is an option you can invoke in your scripts to ensure that unsafe constructs and data flows are restricted, and it bears fundamentally upon global and local variables and functions. (You invoke strict mode with the statement `use strict` at the top.) If you're running in "strict mode," Perl will complain unless you've properly specified your local variables within every function, and it won't let you use variables unless they're declared in a `my` statement. Keeping things tidy in memory isn't as big a deal in Perl because Perl programs tend to execute and quit without hanging around for a long time, but good code style does dictate practices such as these.

Perl Modules

Every good language has shared libraries of some sort, and Perl is no exception. In fact, Perl's libraries (called *modules*), which are chunks of nonexecutable Perl code with `.pm` extensions (for "Perl scripts module"), have grown up as a very distributed Internet-wide grass-roots effort, much in the same way that FreeBSD's ports collection has grown. The ports and Perl modules do play an interrelated part, as a matter of fact, which we'll get to in a moment.

You can put Perl code into a `.pm` file in the same directory as your script (for instance, `mylib.pm`) and then call it using the `use` operator, minus the `.pm` extension:

```
use mylib;
```

Perl's support structure in FreeBSD is installed in `/usr/local/lib/perl5`. There aren't any Perl modules in there, though; it's up to you to install any modules you need in the course of your system's life, and those go into `/usr/local/lib/perl5` as well. This directory forks in two directions, with `man` pages in one (named for the current version of Perl, such as `5.8.6`) and the actual modules in the other (`site_perl`). Inside this (one more level down) are various directories containing module groupings for any module set you've installed. There's also an `i386-freebsd` directory, which contains precompiled C code that some Perl modules use for performance reasons (mathematics-heavy algorithms, for example).

Working with Modules

Modules come in groups, with a prefix and the module name separated by a double colon (`::`), as in C++ scoping. For example, `Net::Telnet` is the name of the Perl module that contains Telnet capabilities, and `Net::DNS` provides name-server lookup functions. These are kept in `/usr/local/lib/perl5/site_perl/5.8.6`, in the `Net` directory, as `Telnet.pm` and `DNS.pm`.

This directory is in Perl's search path. To bring a module into your script, use the `use` operator, like so:

```
use Net::Telnet;
```

Now, any function specified in that module can be used in your script as if you defined it within the script itself, simply by prepending an ampersand (`&`) to its name.

Note

Some Perl modules require you to declare which functions in the module you're going to use. For example, the `Image::Info` module has numerous subroutines for manipulating images, but suppose I only want to use two: `image_info` and dim. I would declare these using the `qw()` operator, which lets me specify an array of strings separated by spaces (it stands for "quoted words"):

```
use Image::Info qw(image_info dim);
```

This isn't the only way to do this, as is the case with so much else in Perl; if you only want to declare one subroutine, you can simply quote its name:

```
use Image::Info 'image_info';
```

How do you find out which functions are in a module? By using `perldoc`, that's how. This utility works in a similar fashion to `man`, and assuming that you've installed your modules properly (for example, through the ports, as you'll see in a moment), you can look up any module's documentation the same way you'd specify it in a script. Listing 11.2 shows part of the documentation for the `Image::Size` module.

Listing 11.2. Sample Documentation for a Perl Module

```
# perldoc Image::Size

Image::Size(3) User Contributed Perl Documentation Image::Size(3)

NAME

       Image::Size - read the dimensions of an image in several
       popular formats

SYNOPSIS
           use Image::Size;
           # Get the size of globe.gif
           ($globe_x, $globe_y) = imgsize("globe.gif");
           # Assume X=60 and Y=40 for remaining examples

           use Image::Size 'html_imgsize';
           # Get the size as "HEIGHT=X WIDTH=Y" for HTML generation
           $size = html_imgsize("globe.gif");
           # $size == "HEIGHT=40 WIDTH=60"

           use Image::Size 'attr_imgsize';
           # Get the size as a list passable to routines in CGI.pm
           @attrs = attr_imgsize("globe.gif");
           # @attrs == ('-HEIGHT', 40, '-WIDTH', 60)

           use Image::Size;
```

```
            # Get the size of an in-memory buffer
            ($buf_x, $buf_y) = imgsize($buf);
```

Documentation of this type will generally give you usable and accurate prototype code that you can insert into your scripts, as well as a complete listing of all available functions.

Perl Modules and the Ports Collection

The "correct" way to install Perl modules is with the ports collection, as described more fully in Chapter 16, "Installing Additional Software." Go into `/usr/ports` and look through the various subdirectories. You'll see many ports beginning with `p5-`. These are Perl modules that have been codified into proper FreeBSD ports. (Package versions of most of them exist, too.) Many modules have compiled C components as well as multiple supporting modules and documentation, so it's definitely important to make sure everything gets installed in the proper place. The ports make sure of that.

The port for `Net::Telnet` is `/usr/ports/net/p5-Net-Telnet`, and that's the naming scheme for all of thema dash substituted for the double colon. Some port categories have dozens of Perl modules, all of them added to the ports out of repeated usefulness.

This distributed model allows Perl to be infinitely extensible while remaining fairly unencumbered in its default installation.

To install a module from the ports, simply build it as you would any portusing `cd` to change to its directory and then running `make` and `make install`. Perl modules have a built-in `make test` target that tunes and evaluates how well the module will work on the system; this is run implicitly with the ports' `make` target.

You can use `pkg_info` and `pkg_version` to check which Perl modules you have installed; this is much easier than remembering to look in `/usr/local/lib/perl5`. The rest of the package tools work as well; you can use `pkg_add` to install a Perl module from its tarball, if you like, and use `pkg_update` to refresh it when a new version comes out.

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Useful Perl Resources

Because Perl is so widespread, it's little wonder that there are so many resources for it available in as many formats as you might want. Nearly everyone involved in content provider work on the Internet needs to have some familiarity with Perl, so computer bookstores do a brisk trade in books on the subject, and the most cursory or off-topic of searches on the Web will turn up discussions between Perl hackers on how to do this or that.

The following sections list some of the more centralized and "official" sources of Perl information.

Websites

If you need a Perl reference, the first stop should be the Web. It's not as direct or definitive as a book, but if you don't have such a book, you're sure to find your answer on the Web in at least some form.

www.perl.org

www.perl.org is the "Perl Mongers" website, an independently run source of information and advocacy references. There are mailing lists you can join as well as affiliated websites, such as www.perldoc.com, the centralized Perl documentation database.

www.perl.com

The "official" Perl site, run by O'Reilly, is an aggregation of Perl news, tutorials, and discussions about all kinds of details of working with Perl. This is probably the most complete site for everyday Perl happenings, if not necessarily for definitive reference.

Books

Just about every Perl hacker has one of the popular O'Reilly Perl reference books on hand; for complete and easy-to-follow reference, these books are hard to beat.

The "Camel" Book

Programming Perl, Third Edition is the complete Perl reference book, written by Larry Wall (the father of Perl), Tom Christiansen, and Jon Orwant (O'Reilly, 2000). Nicknamed for the camel on the cover, which has become synonymous with Perl as a visual logo, this book is frequently revised to cover the most recent developments in the Perl world, and it's widely accepted as the "definitive" work on the subject. One of its best features is an alphabetized function reference, an indispensable section.

The "Llama" Book

Learning Perl, Fourth Edition, by Randal L. Schwartz and Tom Phoenix (O'Reilly, 2005) is the "camel" book's little brother; the llama is its icon. It discusses the basics of Perl (essentially the same topics covered in this chapter) in enough detail and with an engagingenough style to cover pretty much all you'll need to get you to where Perl is no longer a foreign language to you.

Perl Developer's Dictionary

Perl Developer's Dictionary by Clinton Pierce (Sams Publishing, 2001, ISBN: 0672320673) is a comprehensive reference of all Perl functions, and one of the most complete texts on the subject available today. It's ideal for the more advanced Perl hacker who needs reference on syntax and usage more than tutorials on how Perl works.

Teach Yourself Perl in 24 Hours

This step-by-step, entry-level guide, also by Clinton Pierce (Sams Publishing, 2002, ISBN: 0672320355), gives you a running start into putting Perl to practical use very quickly. Also, *Teach Yourself Perl in 21 Days* (Sams Publishing, 2002, ISBN: 0672322765) takes the tutorial to the next level of depth with lots of concrete examples.

The CPAN

The CPAN (Comprehensive Perl Archive Network) is where all the Perl modules across the Net are pulled together and made public. This also applies to binary distributions, scripts, and other tools, as well as source code for the brave of heart. Its primary usefulness, though, is for its comprehensive module list; if there's a module you want to install that isn't in the ports collection, you'll find it here, as well as all kinds of documentation that will help you use it.

The CPAN's central site is at http://www.cpan.org. The CPAN's purpose is to provide numerous worldwide mirrors of its resources so that everyone will have quick access to it; you can use the "CPAN sites" list and map to find a mirror close to you and bookmark it for later reference.

You should also bookmark http://search.cpan.org, which offers a lightweight and efficient mechanism for finding a module based on your search terms, or documentation for a module you're working with.

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Part IV: System Administration

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Chapter 12. The FreeBSD Filesystem

IN THIS CHAPTER

To understand how FreeBSD operates, it is essential to have a clear idea of how the system manages files as well as the critical differences between FreeBSD's method and those of other operating systems.

Files in any operating system are catalogued and accessed using a *filesystem*, which is a particular architecture and set of interfaces between the kernel and the system's stored data. There are at least as many filesystems in existence as there are operating systemsquite a lot more, as a matter of fact, because any single operating system can use several different filesystems at once, as long as its kernel supports them all. Filesystems have cryptic and abbreviated names that sometimes, but not always, indicate what system they're a part of; Linux typically uses Ext2FS or Ext3FS (as well as a couple of other alternatives such as ReiserFS), Windows 2000/XP uses NTFS, Mac OS X primarily uses HFS+, and Windows 95/98/Me use VFAT, the MS-DOS filesystem. There are a great many more filesystems in use throughout the computing world, each with its own particular technical advantages or intended uses.

FreeBSD uses the BSD Fast Filesystem (FFS), which replaced the original UFS (*Universal* or *Unix Filesystem*, depending on who you ask). Many of the tools discussed in this chapter (such as `mount`) refer to UFS as the default filesystem type for FreeBSD, but this isn't really the case. The original, "true" UFS was used only in very early BSD-style UNIXes and has been replaced by FFSa completely different filesystemin FreeBSD. Incorrect as it is to do so, the names are often used interchangeably.

FFS is commonly used in FreeBSD, OpenBSD, NetBSD, and others, including Mac OS X (whose foundation, called Darwin, is based on FreeBSD and the core BSD distribution). This information will be useful to know later in this chapter when we discuss mounting filesystems from other operating systems.

Note

A fuller reference and discussion of the filesystem types used in the computing world can be found at http://www.faqs.org/docs/Linux-HOWTO/Filesystems-HOWTO.html.

In this chapter, you'll see how the FreeBSD filesystem is laid out, how to attach (or *mount*) hard disk partitions to it in appropriate locations, how to work with CD-ROMs, floppy disks, and network-based filesystems, and how to monitor how much disk space is being used on any of them. You'll also learn about maintenance techniques such as the `fsck` command, which ensures efficiently running disks, and setting quotas for disk usage by users.

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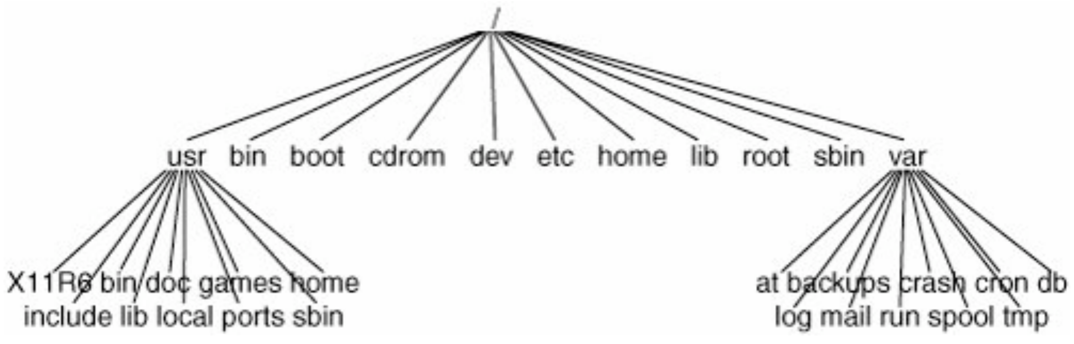
The FreeBSD Directory Structure

If you have used any UNIX or UNIX-like operating system, FreeBSD's directory structure will undoubtedly look familiar to you (see Figure 12.1).

Figure 12.1. The FreeBSD filesystem, showing part of the hierarchical structure beginning at the root directory (`/`).


/
usr bin boot cdrom dev etc home lib root sbin var
X11R6 bin doc games home
include lib local ports sbin
at backups crash cron db
log mail run spool tmp

However, there are some key differences between the FreeBSD filesystem and the ones used by Linux, Solaris, and other UNIXes. For users coming from a Windows or classic Macintosh background, the directory structure can be extremely cryptic. As with much in the UNIX realm, the original reasons for such things as the quirky traditional naming scheme have been lost in the mists of time, but this chapter tries to shed a little light on the FreeBSD filesystemenough, at least, to help you become familiar with its quirks so you can comfortably use the system.

Table 12.1 lists the key elements of the FreeBSD filesystem. Issue the command **`ls -F /`** and you will see the top-level view of the FreeBSD filesystem, including the listed items and probably a few more which may vary depending on your specific installation and version of FreeBSD. In this table, as with the output of the `-F` flag on the `ls` command, directories are indicated with a following slash (`/`), symbolic links with an at (`@`) sign, and executables with an asterisk (`*`).

Table 12.1. Key Elements of the FreeBSD Filesystem

Directory	Purpose
`bin/`	Statically linked binaries (self-contained programs that do not depend on shared library modules stored separately) are contained here. These can be used even when you're doing an emergency boot and don't have access to any filesystems other than `/`, which might not be mounted under such circumstances. Programs in `/bin` are generally user-oriented programs and commands that don't affect the system in general, whereas the ones in `/sbin` are administrative programs that might alter the system's behavior (hence the "s" prefix).
`boot/`	This directory contains the *kernel*, which is the master executable of the system. The kernel manages all the devices and handles networking, along with a host of other tasks. See Chapter 18, "Kernel Configuration," for more information. `/boot` also has configuration files and executables that are used during boot.
`compat@`	This is a symbolic link to directory structures that provide compatibility with other operating systems, such as Linux. In many installations this directory is empty.

`dev/`	This is a special directory. Files in here are mostly *devices*, which are special file types that give programs an interface into any devices the kernel supports. `/dev` is actually a mount point where the device filesystem, `devfs`, is usually mounted.
`etc/`	Long ago, this was merely a directory for random files that didn't fit elsewhere. It is now where most systemwide configuration files go, including your user (password) databases and startup scripts.
`home@`	This is possibly a plain directory or a symbolic link to `/usr/home`, depending on your installation. All regular users' home directories are contained here. If you intend to have a lot of users on your system with a lot of space-consuming data, make `/home` into a symlink pointing to `/usr/home` so that the users' data goes into the `/usr` partition rather than the much smaller root partitionor carve out a dedicated partition for `/home` (see Chapter 20, "Adding Hard Disk Storage").
`mnt/`	An empty directory that's provided for your convenience as a mount point if you need to mount another disk.
`proc/`	Contains the process filesystem (`procfs`) and is an interface to the process table. It's used for convenience by some programs but is not essential to the operation of the system (it's usually not mounted in modern systems).
`rescue/`	Contains a set of hard-linked programs that provide a "mini-FreeBSD" environment during system installation and emergencies when running in standalone mode.
`root/`	The `root` user's home directory. It's not in `/home` for security reasons, and to ensure that it will be available during an emergency boot.
`sbin/`	Contains system binaries that are statically linked. These programs differ from the ones in `/bin` in that they generally are used to alter the system's behavior, whereas the `/bin` programs are simply user tools.
`sys@`	A link to the kernel sources (if you installed them).
`tmp/`	Contains temporary files. Any user can write files into this directory. If you set `clear_tmp_enable="YES"` in `/etc/rc.conf`, the contents of `/tmp` will be deleted at every startup.
`usr/`	The UNIX System Resources directory, the gateway to the rest of the system. Contains dynamically linked programs, user files, and programs you installed yourself. In upcoming chapters, you'll spend most of your time here. Subdirectories of `/usr` are carefully delineated according to their purpose; the most important subdirectory for you as a FreeBSD administrator will be `/usr/local`.
`var/`	Contains *variable files*. These include runtime files used by programs, log files, spool directories, databases, and other items that change with the normal operation of the system and its applications.

There are some important differences between the FreeBSD directory structure and that of similar operating systems, such as Linux. FreeBSD's structure is tightly controlled, and the clearest rule is this: *Anything installed by the administrator goes into the directory structure under `/usr/local`*. Although other systems might allow user-installed programs the freedom to install files wherever they want, FreeBSD maintains strict structural guidelines in its ported programs and packages to ensure that all your own installed files are kept inside the `/usr/local` structure (see "Introduction to Packages," in Chapter 16, "Installing Additional Software"). Although a program might, by default, put its libraries in `/var/lib` and its configuration files into `/etc`, FreeBSD patches (modifies) the installation scripts so that the files would go into `/usr/local/lib` and `/usr/local/etc`, respectively. In fact, all configuration files for any software you might install will go into `/usr/local/etc`. If the program installs a startup script to be launched on boot, the script is placed in `/usr/local/etc/rc.d`. Anything in that directory is run at boot time, after the scripts in the analogous `/etc/rc.d` (the base system's startup scripts) are run.

Note

The FreeBSD filesystem hierarchy is designed to conform as closely as possible to the Filesystem Hierarchy Standard (FHS), although this standard was developed in a Linux-centric manner and includes some conventions shunned by FreeBSD (such as the practice of putting web content files in `/srv`). A full discussion of the FHS, including explanations of many of the cryptic abbreviations, can be found at http://en.wikipedia.org/wiki/Filesystem_Hierarchy_Standard.

The advantage of a structure this carefully controlled is that a FreeBSD system is relatively easy to maintain, and it's especially easy to re-create on a new machine (if you're upgrading to new hardware, for instance). Theoretically, you could copy the entire `/usr/local` directory tree from one machine to another, and everything would work the same on both machines. This is a risky proposition, however, and any such operation is likely to hit any number of unforeseen snagsfor example, any well-used system is likely to have been tweaked in certain subtle ways that aren't re-created if you simply transfer `/usr/local` to the new machine. Still, this kind of system portability is an ideal toward which FreeBSD strives.

An obvious disadvantage of FreeBSD's regimented structure, though, is that if you're trying to port a program from Linux or Solaris to FreeBSD, you might experience some pain in fixing the expected paths. For instance, if you have programs written in Python on Linux, in which the Python interpreter is installed as `/usr/bin/python`, the programs will not run on FreeBSD because Python is not part of the base installation and is therefore installed as `/usr/local/bin/python` by the ports or package system. You can easily fix this problem for one or two files by modifying their interpreter lines that specify where to find Python, but migrating an installation with hundreds of such programs can quickly become painful. In the interest of cross-platform compatibility, it may turn out to be simplest to violate FreeBSD's structural guidelines by making the symbolic link `/usr/bin/python` to point to `/usr/local/bin/python`, so that the ported program works right away.

Tip

A convenient way to get around the problem of interpreters such as Perl and Python being installed in different locations on different systems is to use an interpreter line such as `#!/usr/bin/env python` instead of `#!/usr/local/bin/python`.

You can find a more detailed description of FreeBSD's filesystem by entering **`man hier`**.

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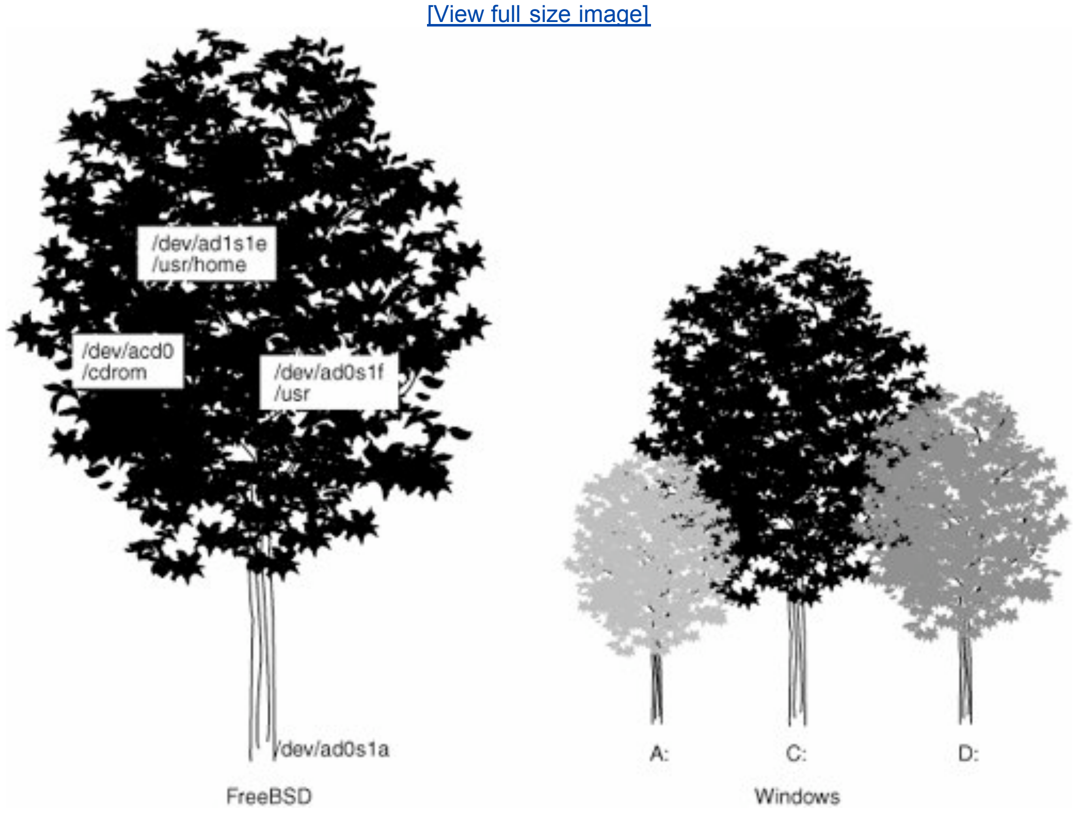
Monitoring Filesystem Usage

FreeBSD's filesystem is a single large directory hierarchy beginning at `/`, the root level. Each partition of your hard disk (or disks) is assigned its own local hierarchy, and the partitions are attached to FreeBSD's filesystem structure at different designated *mount points*. To keep an eye on how much disk space is being used by your data, you need to look at each mounted filesystem in turn, beginning at each one's mount point.

The idea of mount points is an aspect of UNIX-style operating systems that is quite foreign to Windows users. In Windows/DOS, each disk in your system is assigned a drive letter (such as `C:`), and each drive has its own independent filesystem. For example, a machine with two hard drives and a CD-ROM drive might have `C:`, `D:`, and `E:` drives between which the user can switch. In UNIX, there is only one systemwide directory structure, and all disks in the system are mounted at different points in the structure, at the administrator's discretion. An appropriate analogy would be that a Windows system resembles an orchard, with a row of similar trees, whereas a UNIX system is more like a single large tree, with smaller trees grafted onto its trunk and branches. All the grafted elements on the UNIX "tree" form a single hierarchical structure (see Figure 12.2).

Figure 12.2. Diagrams of the FreeBSD (UNIX) and Windows filesystem structures, using the "tree" analogy.

[View full size image]



The advantage of this type of structure is that it's really easy to add more disk space to your system. To increase the pool of storage available to some part of the hierarchy, you just mount a new disk or partition there (as you'll learn later in this chapter). However, a corresponding disadvantage is that it's much harder in a filesystem like this to move the entire contents of a disk wholesale to another disk. In Windows or Mac OS, you can move your entire system to a new larger disk with a simple drag-and-drop operation because each disk is a separate filesystem. This task is more cumbersome in FreeBSD. The hierarchical structure is better suited to a server machine with a long lifetime on the same hardware than to a desktop computer where the data often outlives the hardware.

The `df` (Disk Free) Command

Using the `df` (disk free) command is the most direct way of finding out the status of your system's disk usage. A `df` reading is part of every daily status check (more on this in Chapter 15, "Performance Monitoring, Process Control, and Job Automation," in the section "Using the Periodic Task Scheduler"), and it nicely encapsulates all the relevant information about your different filesystems and their respective device names.

When you enter the command `df`, you get output similar to this:

```
Filesystem  1K-blocks     Used    Avail Capacity  Mounted on
/dev/ad0s1a    128990    74314    44358    63%    /
devfs               1        1        0   100%    /dev
/dev/ad0s1f    257998       44   237316     0%    /tmp
/dev/ad0s1g   8027686  1990866  5394606    27%    /usr
/dev/ad0s1e    257998    30586   227694    14%    /var
```

Each disk slice or partition is regarded as a "filesystem" and can be mounted at any point in the directory structure. The preceding output shows that this system has four BSD partitions on its main IDE disk (`/dev/ad0`) and that they are mounted at `/`, `/tmp`, `/usr`, and `/var`. This is the default setup for a FreeBSD installation. Note that the `/` filesystem has only about 128MB allocated to it and that `/var` and `/tmp` each have about 256MB; all the rest of the disk is allocated to `/usr`. This means that the system defaults expect very little to be placed into the directories other than `/usr` or `/var`, and still less to go into `/var`.

The numbers in the `df` output will not necessarily calculate out the way you might expect. The figures you see are subject to a number of delays and estimations due to caching and other issues. They are as accurate as possible in a system where this information must be gathered on an ongoing basis from many constantly changing sources.

Caution

Allocating a small `/var` partition can be dangerous because log files traditionally go into `/var/log`, and log files are notorious for growing out of control. Many administrators choose to move `/var` to `/usr/var` and create a `/var` symlink to point to it. We will discuss the pros and cons of different styles of partitioning in Chapter 20.

The `du` (Disk Usage) Command

Aside from the `df` command, you also need to have a more specific method for monitoring disk usage, especially if you're running a network server and you have a lot of users, any of whom might suddenly dump gigabytes of data into their home directories. For this, the tool of choice is `du` (disk usage). Here's an example:

```
# du -h -d 1 /home/
 23M    /home/bob
  9K    /home/fred
 31K     /home/alice
1.5M     /home/tom
664K     /home/pat
```

The `du` command tells you the size, recursively, of every directory below the one you're currently in (or the one you specify on the command line). You can specify the `-d` switch along with a number, which tells `du` to recurse only down to that depth (a necessity unless you want to be flooded with output); the `h` switch (for "human readable") formats the sizes of the directories into kilobytes and megabytes. You can also use the `-s` option, which forces "summary" mode. In this mode, you only get a single line of output, listing the aggregate size of everything in the directory you specified. You can find more options to `du`, including controls for the way it handles symbolic links, in `man du`.

All this, of course, places the burden of watching the filesystems on you, the administrator. Wouldn't it be great if you could rely on the system to keep tabs on these things for you? Fortunately, you canwith *quotas*, which you'll learn about in "Setting and Enforcing User Disk Usage Quotas," later in this chapter.

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Mounting and Unmounting FreeBSD Filesystems

Now, we will discuss how the versatility of UNIX-style filesystems can really shine. Let's say your system outgrows its single disk (`/dev/ad0`), and you install another disk as the primary slave so that it appears as `/dev/ad1` (a SCSI disk would be available as `/dev/da0`, and so on). After you partition and label the disk (a procedure that is described in detail in Chapter 20), you have one or more new filesystems you can add to your system's directory structure at any point, like grafting a new branch onto the trunk of a tree.

The `mount` Command

Suppose, for instance, you have a system in which you have been adding new users left and right, and they keep uploading large files into their home directories. You notice (through the use of `df` and `du`) that the `/usr` partition is almost full, almost entirely because of the growing `/usr/home`. What you want to do is add another pool of storage space and dedicate it to your users and their home directories.

Caution

The instructions in this section are best followed when your system is in single user mode, so that no remote users or applications disturb the filesystems you're working on. Be sure to work directly at the system's console rather than from a remote terminal, and boot your system in single user mode (choose option 4 at the loader screen) before you start reconfiguring your filesystems.

You therefore buy a new 400GB disk and divide it into three BSD partitions within the single FreeBSD slice; they are available as `/dev/ad1s1e` (10GB), `/dev/ad1s1f` (50GB), and `/dev/ad1s1g` (300GB). You make the third partition the largest because it's the one you want to make into the new home for your users; the other two partitions are chunks of space you want to add to other parts of the system. But for now, all you're interested in doing is turning `/home` into a new 300GB partition for nothing except users' home directories.

Right now, `/home` is most likely a symbolic link to `/usr/home`, so you will first want to use `rm /home` to get rid of the symlink. (The actual `/usr/home` directory that the symlink points to is not touched by this command.) If `/home` in your system is not a symlink but is instead a plain directory, use something like `mv /home /home.old` to move it temporarily out of the way for this process.

Now, create a mount point for the new filesystem. Mount points (also known as *nodes*) must be plain directories. They don't need to be empty, but after a device is mounted on a non-empty directory, whatever was originally located in that directory will no longer be accessible. To have the files and the mounted filesystems simultaneously accessible, union filesystems are needed, but this feature is not fully supported as of this writing. Therefore, to create the new mount point, issue `mkdir /home`.

You're now ready to mount the new filesystem. For standard FreeBSD filesystems, you do this with the `mount` command. Your 300GB partition is labeled `/dev/ad1s1g`, so give the following command:

```
# mount /dev/ad1s1g /home
```

If the command executes without any errors, you should be able to use the new filesystem immediately. Check `df` to see if it worked:

```
Filesystem  1K-blocks     Used    Avail Capacity  Mounted on
/dev/ad0s1a    128990    74314    44358    63%    /
```

```
/dev/ad0s1f     257998        44   237316      0%    /tmp
/dev/ad0s1g    8027686   1990866  5394606     27%    /usr
/dev/ad0s1e     257998     30586   227694     14%    /var
procfs               4         4        0    100%    /proc
/dev/ad1s1g   39245453         0 39245453      0%    /home
```

The `/home` partition is now mountedit looks like it's ready to go! You can now move the files from `/usr/home` (or `/home.old`, depending on where your home directories have been sitting in the interim) into the new `/home` filesystem, and your users will be free to upload to their hearts' content.

It isn't always this easy, however. Mounting filesystems is one of the areas of system administration that has the most potential pitfalls for the unwary. You may get the error message "Incorrect super block," for instance, or you may get an even less informative message, such as "Invalid argument." These messages usually stem from improperly specifying the name of the device on the `mount` command line; the device naming conventions used by the FreeBSD labeling system can lead to serious confusion. A filesystem might be labeled as `/dev/ad1s1e` or `/dev/ad1s1`, depending on whether it is being addressed in "slice mode" or "dedicated mode," and certain device names with suffixes can be interchangeable with shorter names. This disk geometry esoterica is discussed thoroughly in Chapter 20.

The `mount` command has the `-f` option, which will force a mount operation even in circumstances where it might otherwise fail. However, if a filesystem won't mount, it's usually for a good reason. It's a much better idea to find the cause for any error and fix it rather than use the `-f` option. Some of these causes might include an unformatted disk, a filesystem of an unrecognized type, or a "dirty" filesystem that was not shut down properly. In the latter case, the filesystem might have some inconsistencies that must be repaired using `fsck` (as you learn in "Checking and Repairing Filesystems with `fsck`," later in this chapter) before the filesystem can be mounted.

One other useful argument to note is the `options` field, in which you can specify any code words (flags) from a large list of code words, separated by commas. Most useful are the ones specifying whether the filesystem is read-only or read/write; it is read/write by default, but you can use the `-r` or `rdonly` option to make it read-only. See `man mount` for a full list of `mount` options.

You also use `mount` whenever you insert a CD-ROM, DVD, or floppy disk into the system; if you don't, you won't be able to access the media. See "Mounting and Unmounting CD-ROM and Floppy-Based Filesystems" later in this chapter for more information.

Note

Mounting filesystems is typically something that only the root user can do. This isn't a big deal for hard disk partitions (you don't want regular users mucking around with your filesystem hierarchy while the system is running), but it can present problems if you're using FreeBSD as a console user under KDE or GNOME, and you want to mount a CD-ROM or audio CD. This intricacy will be covered later in this chapter.

The `umount` Command

There will also come the time when you have to "unmount" a filesystem; the command for this is `umount` (rather than `unmount`). To unmount the `/home` filesystem, issue the following command:

```
# umount /home
```

You can also use `umount /dev/ad1s1g` to accomplish the same result, or even `umount -a` to unmount everything except for the root filesystem.

Unmounting filesystems is a much simpler procedure than mounting them, with only one major complicating factor: For a filesystem to be unmounted, it must be quiescentin other words, it cannot be in use by the kernel, any daemon, or any user process. This means that to unmount filesystems such as `/usr` and `/var`, you will almost certainly have to be in single-user mode. For the `/home` partition in the example in the previous section, any connected users will likely be working in their home directories, so they will have to be kicked off the system before `/home` can be unmounted. The shell, keeping current tabs on your present working directory, makes whatever filesystem you're in "busy." This factor leads to the most common surprise most users find when first experimenting with `mount` and `umount`: *You can't be inside a filesystem you're trying to unmount!* If you are, you'll get a "Device busy" error message. To be safe, be in the habit of entering `cd /` before you attempt to unmount a filesystem.

Like `mount`, `umount` has the `-f` option to force an unmount. But again, it's best to avoid using it unless absolutely necessary; filesystem operations have the potential to destabilize the system if done in a messy manner.

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Mounting and Unmounting Filesystems from Other Operating Systems

The techniques you've just learned are all well and good for standard FreeBSD filesystems. But what if you need to mount a disk from a Linux box or from a Windows 98 or XP machine? You can do that. FreeBSD supports the filesystems listed in Table 12.2 in the `GENERIC` (default) kernel.

Table 12.2. Filesystems Supported in the GENERIC Kernel

Filesystem	Name
FFS	Berkeley Fast Filesystem
MFS	Memory Filesystem
NFS	Network Filesystem
MSDOSFS	MS-DOS Filesystem
CD9660	ISO 9660 (CD-ROM) Filesystem
PROCFS	Process Filesystem

There is also support for the filesystems shown in Table 12.3, but they need to be compiled into a custom kernel in order to work (see "Compiling and Installing the Custom Kernel," in Chapter 18).

Table 12.3. Additional Available Filesystems

Filesystem	Name
FDESC	File Descriptor Filesystem
HPFS	OS/2 Filesystem
NTFS	Windows NT Filesystem
NULLFS	NULL Filesystem
NWFS	NetWare Filesystem
PORTAL	Portal Filesystem
SMBFS	SMB/CIFS Filesystem (Windows)
UMAPFS	UID Map Filesystem
UNION	Union Filesystem
CODA	CODA Filesystem
EXT2FS	Ext2 Filesystem (Linux); also includes Ext3FS
REISERFS	ReiserFS Filesystem (Linux)

Some of these latter filesystems are more stable than others, and some lack critical features (for instance, some of these filesystems can only be mounted read-only; you can't write new data to them). As you saw earlier, union filesystems are available as an option, but they are only partially in a working state (and can damage your system). Therefore, it is not recommended that you use them unless absolutely necessary. EXT2FS and NTFS support is also given a caveat about completeness and stability. Filesystems that are not built in to the `GENERIC` kernel, in general, are not included for a reason.

The ideal circumstance for a filesystem type that isn't part of the existing kernel is to be available as a kernel module in `/boot/kernel`, as many of the filesystems listed in the preceding tables are. If the filesystem is available as a kernel module, it will be automatically loaded when you try to mount the filesystem. At the time of this writing, these available module-driven filesystems include Ext2FS, ReiserFS, FDESC, CODA, PORTAL, NWFS, NULL, NTFS, UNION, SMBFS, and some others that are already compiled into the `GENERIC` kernel and are provided in `/boot/kernel` for compatibility.

If you're mounting a filesystem (MSDOSFS, for example) that is supported in the default kernel, or if you decide to accept the risks and plunge ahead with mounting a filesystem that isn't initially built in, you'll find that FreeBSD does provide some handy tools for doing the actual mounting. The following tools are available in `/sbin` (although their names may vary according to your version of FreeBSD):

```
mount_cd9660     mount_linprocfs   mount_nfs4       mount_portalfs    mount_std
mount_devfs      mount_mfs         mount_ntfs       mount_procfs      mount_udf
mount_ext2fs     mount_msdosfs     mount_nullfs     mount_reiserfs    mount_umapfs
mount_fdescfs    mount_nfs         mount_nwfs       mount_smbfs       mount_unionfs
```

Each of these variations on `mount` corresponds to one of the supported filesystems and operates in the same way as `mount`. The idea is that these `mount_*` tools serve as an extension to the `-t` option to `mount`. The `-t` option recognizes only a couple internal filesystem types; if you give it an unrecognized argument, it will execute the corresponding self-contained command from the preceding list. For example, if you use `mount -t nfs /mnt`, the tool will actually execute `mount_nfs /mnt`. Knowing this, it is often easier simply to run the latter tool directly.

Note

As a further note on the stability and completeness issues regarding the not fully supported filesystem types, you should read the `man mount_*` pages. Each one gives a good account of what is deficient in that filesystem's support. For example, `man mount_ntfs` discusses the lack of full write capabilities and support for compressed files, and `man mount_union` warns about the feature's limited functionality and potential to damage data. Be informed!

Mounting a Windows/MS-DOS Filesystem

Let's first look at mounting a Windows 98 disk, which will be MSDOSFS for FreeBSD's purposes. The command you use for this operation is `mount_msdos`. This command can take some special options that we do not need to cover fully here. Examples are `-W` and `-L`, which control the locale-based character mapping for the long filenames associated with FAT32/VFAT filesystems. For this example, you can use the default settings, which assume that the ISO 8859-1 encoding will be used and that you will read and write to the filesystem as root:

```
# mount_msdosfs /dev/ad1s1 /mnt
```

Note

Bear in mind that what DOS and Linux systems call *partitions* are called *slices* in FreeBSD, to avoid confusing them with traditional BSD partitions (which are subdivisions of slices). The slice number is the *s* in the device name, thus `s1` indicates the first slice, or MS-DOS partition. MS-DOS partitions don't contain any subpartitions, such as the BSD partitions `a` through `g`; therefore, because your Windows 98 filesystem on `/dev/ad1s1` is effectively using a slice rather than a partition, you can address it simply by its slice number rather than specifying additional suffixes, as when mounting standard FreeBSD filesystems where you use `/dev/ad1s1g`.

You only get four MS-DOS partitions on a disk, but you can also use "extended DOS partitions," which are the MS-DOS and Linux way of doing subpartitions. If you're using an extended DOS partition, you may get an "Invalid argument" error. If this happens, note that extended DOS partitions are numbered beginning with 5, so your device name will be `/dev/ad1s5`.

You can perform additional tricks when mounting an MS-DOS filesystem, such as mounting it as a non-root UID/GID, mounting it with a permissions mask for controlling users' access to the filesystem's contents, listing it with long filenames (instead of short "8.3" filenames), and so forth. Refer to `man mount_msdos` for the full documentation on these options.

Tip

A Windows floppy disk contains filenames that can be in the standard MS-DOS "8.3" short format or in the Windows 95/98 long format, which is derived from metadata in the filesystem. If you mount a Windows floppy disk using `mount_msdos`, FreeBSD attempts to find any of these long filenames on the disk. If it finds any, it uses that format to list and interact with the files. However, if it finds none of these long filenames but does find short ones, it will use the short format. To force `mount_msdos` to use the long format, use the `-l` option. The `-s` option forces the use of the short format.

Mounting a Linux Filesystem

Most Linux systems use Ext2FS (or Ext3FS, which is also handled by FreeBSD's Ext2FS kernel module). Because EXT2FS support is not built into the `GENERIC` kernel, this task can involve an extra step.

If you have to mount a Linux disk for temporary work, such as copying files off it in a one-time operation, you can simply mount the disk using the `mount_ext2fs` command, which automatically loads the `ext2fs.ko` kernel module and adds temporary support for the Ext2FS filesystem to FreeBSD. This is very convenient, but it has the side effect of leaving the kernel module loaded after you're done with your work, and in general it's a little less safe to rely on loading a kernel module (which might destabilize the system or cause a crash) than to have Ext2FS support built into the kernel. If you intend to interoperate with Linux disks on a regular basis, you should build a custom kernel with Ext2FS support enabled.

Chapter 18 discusses the steps involved in compiling and installing a custom kernel; the line you want to add to your custom kernel configuration file (preferably at the end of the block of `options` lines) is the following:

```
options      EXT2FS
```

After your system is up and running with the new kernel, you can use the following command:

```
# mount_ext2fs /dev/ad1s1 /mnt
```

Other than the issues surrounding kernel support and automatically loading the kernel module when needed, `mount_ext2fs` behaves almost identically to standard `mount`, so the surprises should be minimal.

Using `fdisk` to Gather Partition Information

You can determine what filesystem you're working with by using the `fdisk` command. Here's an example:

```
# fdisk /dev/ad1
******* Working on device /dev/ad1 *******
parameters extracted from in-core disklabel are:
cylinders=1247 heads=255 sectors/track=63 (16065 blks/cyl)

Figures below won't work with BIOS for partitions not in cyl 1
parameters to be used for BIOS calculations are:
cylinders=1247 heads=255 sectors/track=63 (16065 blks/cyl)

Media sector size is 512
Warning: BIOS sector numbering starts with sector 1
Information from DOS bootblock is:
The data for partition 1 is:
sysid 131,(Linux filesystem)
    start 63, size 2104452 (1027 Meg), flag 0
        beg: cyl 0/ sector 1/ head 1;
        end: cyl 130/ sector 63/ head 254
The data for partition 2 is:
sysid 130,(Linux swap or Solaris x86)
    start 2104515, size 787185 (384 Meg), flag 0
        beg: cyl 131/ sector 1/ head 0;
        end: cyl 179/ sector 63/ head 254
The data for partition 3 is:
sysid 131,(Linux filesystem)
    start 2891700, size 17141355 (8369 Meg), flag 0
        beg: cyl 180/ sector 1/ head 0;
        end: cyl 1023/ sector 63/ head 254
The data for partition 4 is:
<UNUSED>
```

For each partition (or slice, as FreeBSD has it), there's a "sysid" number. 131 corresponds to an EXT2FS Linux filesystem, and 165 is FreeBSD. Everything else `fdisk` recognizes can be found by perusing `/usr/src/sbin/i386/fdisk/fdisk.c`, where the partition IDs are given in hexadecimal values.

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Mounting and Unmounting CD-ROM and Floppy-Based Filesystems

Now that you've had some experience mounting different foreign filesystems, it should be a snap moving on to CD-ROMs and floppy drives. CD-ROMs usually are mounted as CD9660 filesystems, but floppies generally are either FFS (the FreeBSD standard) or MSDOS.

Mounting CDs and Floppies

For CD-ROMs, the main trick is to determine the device name. IDE drives will be of the form `/dev/acd0c`, SCSI drives will be of the form `/dev/cd0c`, and miscellaneous types of nonstandard drives have other prefixes. As for the suffix, use `c` to indicate that you are addressing the entire disk in "dedicated" mode. Here's an example:

```
# mount_cd9660 /dev/acd0c /cdrom
```

Tip

See http://www.freebsd.org/doc/en_US.ISO8859-1/books/handbook/disks-naming.html for the current reference to disk names.

Mounting CD-ROMs in a GUI Environment

One drawback of the UNIX system architecture is that you need to be the root user to mount CD-ROMs. This usually isn't a problem if you're using the command line at the physical console; but if your FreeBSD machine is a desktop workstation, especially if it has multiple users, your KDE or GNOME login will be using a regular user account, not the root account. This is an important security consideration, as it mitigates the risk of potentially destructive system operations being executed as root; but it also means mounting CD-ROMs is a lot more difficult. The procedure for enabling regular users to mount CD-ROMs in KDE involves tweaking a lot of permission settings on your user accounts and on your CD-ROM drive device, enabling a kernel permissions adjustment, and even adding user-level mount points and corresponding entries to `/etc/fstab`. The full procedure is outlined at http://www.bsdguides.org/guides/freebsd/beginners/kde_cd_icons.php; note, though, that even with this configuration in place, only one user at a time can have the CD-ROM drive mounted, and another user won't be able to access it until the user who mounted it unmounts it.

After you have your system's permissions set up properly, mounting CD-ROMs in KDE or GNOME is quite seamless. Just navigate to the system's drives in a filesystem window and click or double-click the CD-ROM drive icon. The desktop environment automatically mounts the disc in the background and launches a navigation window to let you browse its contents.

Mounting a floppy disk is fairly straightforward. Use the device name `/dev/fd0` (the zero specifies your first floppy drive). The kernel also contains a confusing entry for `fdc0`, which refers to the actual ISA floppy disk controller device, but `fd0` and `fd1` are the device names for the drives that hang off the controller. Here's how to mount a UNIX floppy disk:

```
# mount /dev/fd0 /floppy
```

An MS-DOS floppy can be mounted in a similar fashion:

```
# mount_msdosfs /dev/fd0 /floppy
```

Be careful: Floppy disks can be write protected and CD-ROMs are physically read-only, but FreeBSD does not check at mount time whether they are writable! If you mount a write-protected floppy without specifying the `-r` or `rdonly` option, you will get I/O errors whenever anything tries to write to the diskand what happens as a result can vary with the stability of whatever program is doing the writing. Anything from a simple console error message to a complete hang of the system can occur. Therefore, if you must mount a write-protected floppy or CD-ROM from the command line, make sure you specify the `-r` or `rdonly` option to prevent programs from even *trying* to write to it!

Unmounting CDs and Floppies

The other tricky thing about CD-ROMs and floppies is that because they are removable devices, there exists the potential to remove the disk while the system still thinks it is mounted. Windows (for comparison's sake) dynamically mounts and refreshes the devices whenever they are accessed for reading or writing, and Mac OS X keeps track of such things by having disk mounting and physical insertion/ejection controlled entirely by software, making the user's actions interdependent with the software's state. FreeBSD (and other *x*86 UNIXes) do not have the latter luxury or the former sophistication, so you must shoulder the burden of making sure the system's impression of its mounted disks is an accurate one.

Most CD-ROM drives lock their trays when the operating system has a disk mounted because they have soft-eject mechanisms that are aware of the media's state in the operating system. Such a drive will not respond when you press the Eject button until you have unmounted the device. Floppies, however, can be mechanically ejected on a whim, and even CD-ROMs can be ejected through determination and the use of a paper clip. If a mounted device is ejected without being properly unmounted, and some program tries to read from or write to the device, the same kind of system destabilization can occur as described previously.

The bottom line is this: Always remember to use `umount /cdrom` or `umount /floppy` before ejecting a disk. Your system will thank you.

Other Removable Media

The field of removable media is becoming more complex every day, with USB and FireWire-based external media and rewritable CD and DVD drives coming into the market at an ever-increasing pace. Zip drives and their relatives have been around for some time, and though they're beginning to disappear from the market, you might still have a use for them. FreeBSD supports parallel port Zip drives as the `vp0` device and USB Zip drives as the `umass` device. But dozens of new devices are in development, and each will offer its own complications in writability, removability, and mountability. Your understanding of mounting and unmounting CD-ROMS and floppies, however, can help prepare you for dealing with other removable media devices in FreeBSD.

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Understanding the `/etc/fstab` File

You may be wondering whether there is a shortcut to all this mountinga way to program "recipes" for all the mountable devices on a systembecause chances are that all the flexibility offered by the `mount` tools will become less useful over the lifetime of a system. After you figure out the commands and esoteric device names needed to mount your second IDE hard drive, your NFS volume from across the network, your MS-DOS floppy, and your SCSI CD-ROM, do you really have to remember those commands every time you want to mount them? No, there is indeed a better way: the `/etc/fstab` file.

Let's take a look at the file now, using `cat /etc/fstab`:

```
# Device                Mountpoint      FStype  Options         Dump    Pass#
/dev/ad0s1b             none            swap    sw              0       0
/dev/ad0s1a             /               ufs     rw              1       1
/dev/ad1s1f             /tmp            ufs     rw              2       2
/dev/ad0s1g             /var            ufs     rw              2       2
/dev/ad0s1e             /usr            ufs     rw              2       2
/dev/acd0               /cdrom          cd9660  ro,noauto       0       0
/dev/fd0                /floppy         msdos   rw,noauto       0       0
proc                    /proc           procfs  rw              0       0
/dev/ad1s1g             /home           ufs     rw              2       2
```

This file (which will vary according to your system's configuration) tells the system everything it needs to know about a given mount point: what device attaches to it, what filesystem type to expect, the mount options, and in what order it should perform filesystem checks when the system is booted. The `fstab` file is closely interrelated with the `mount` command. Used in conjunction, these two tools can make filesystem management a relative breeze.

The main function of the `fstab` file is to give the system a profile of mounted devices that can be activated automatically at boot time. With all your mount points specified in the `fstab` file, you can issue the command `mount -a` to mount them all (which is what happens during bootup). When the system goes through its filesystem checks during bootup, it runs `fsck -p` to "preen" the filesystems, making sure they are all marked "clean" (you'll learn more about the `fsck` actions in "Checking and Repairing Filesystems with `fsck`," later in this chapter). The system then runs `mount -a -t nonfs` to mount all filesystems listed in `/etc/fstab` except for NFS volumes.

Beyond this function, though, is an even more convenient effect of this setup. After a mount point is specified in `/etc/fstab`, you no longer need to remember the `mount` command necessary to bring it online; now, the only thing you have to know is the name of the mount point:

```
# mount /home
```

This command reads in all the necessary information about `/home` from the `fstab` file. It knows that the device you want is `/dev/ad1s1g`, that it's a UFS (well, FFS) filesystem, and that you want it mounted read/write. Similarly, to mount a CD-ROM, all you need to enter is the following:

```
# mount /cdrom
```

Now the process of mounting disks is starting to look almost user-friendly!

The `noauto` option on the `/cdrom` and `/floppy` entries tells `mount` that these filesystems should not be mounted at boot time. As with NFS resources, there is no guarantee that a CD-ROM or floppy disk will be available when the system boots, so the `noauto` option prevents `mount` from spending pointless time trying to mount a disk that isn't there. It doesn't prevent you from easily mounting it later, however. The preceding `mount` command is all you need.

You can specify any of the command-line `mount` options in the fourth column of the `fstab` file that are applicable to the filesystem in question. For instance, any options listed in `man mount` can be used, as well as anything in the filesystem's `man mount_*` page if it's a nonstandard filesystem type.

The fifth column in the `/etc/fstab` file contains the dump level numbers. These numbers are for the benefit of the `dump` command, which is a venerable UNIX backup utility that operates based on priority levels. You call for a backup at a specified dump level; the dump level number tells `dump` at what level to trigger a backup for each filesystem. For example, filesystems with a dump level number of `1` are backed up only when the dump level is `1` or lower (a dump level of `0` indicates a full backup of all filesystems). Note that specifying `0` in `/etc/fstab` omits that filesystem from ever being dumped.

The sixth, or rightmost, column in `/etc/fstab` is the `Pass#` field. The pass number is a flag for `fsck`; numbers above `0` indicate the order in which the filesystems should be checked. The root filesystem has a pass number of `1`, meaning that it is checked first; mounts with a pass number of `2` are checked next, in as concurrent a manner as the hardware permits. A pass number of `0` means that the filesystem should not be checked; this is what you want for CD-ROMs, floppies, swap partitions, and other resources that can't become corrupted (or devices where it doesn't matter if they do become corrupted).

A fuller discussion of backup and restoration procedures can be found in Chapter 21, "FreeBSD Survival Guide," in which `dump` will be covered in more detail, along with other backup/mirroring methods such as CVSup.

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Checking and Repairing Filesystems with `fsck`

The `fsck` (Filesystem Consistency Check) program is the equivalent of Microsoft ScanDisk and other disk utilities, at least as far as its role in the boot process and its interactive nature go. The `fsck` program runs at boot time just before mounting the filesystems out of `/etc/fstab`, to make sure that all the filesystems are "clean" and eligible for mounting. This is the "preen" mode that is called for with the `-p` option. But `fsck` also exists to repair any inconsistencies that it finds and to clean filesystems that have not been marked "clean" by a proper shutdown method.

The most likely place you'll encounter `fsck` is at boot time, no matter what role it plays in your life. In the happiest circumstances, it runs invisibly just after all the devices have been identified, and all you see on the console are a few lines like this:

```
/dev/ad0s1e:
103469 files, 858450 used, 9066025 free
(25777 frags, 1130031 blocks, 0.3% fragmentation)
```

Note

Don't worry about the "fragmentation" figure that `fsck` prints out. It looks pretty dire, but be aware that even fragmentation of 2 to 3 percent (which is the highest you'll likely see) is miniscule compared to the kind of fragmentation that occurs under Windows. It is not unusual to see a DOS/VFAT disk with 50 percent or more fragmentation; that is why defragmenting utilities sell so well in the desktop market. UNIX filesystems, however, are designed with mechanisms to keep related sectors together on the fly, so fragmentation is kept to a minimum. You won't ever need to defragment a UNIX hard drive. See "Blocks, Files, and Inodes," later in this chapter, for a closer look at the mechanics of data storage and fragmentation.

You might run into trouble, however, if the system has not been shut down cleanlyif power has failed or someone has hit the power switch without running `shutdown` first. UNIX filesystems keep track of their structural information by writing that metadata to the disk in a synchronous manner, which may take multiple write cycles. If the system goes down while it's in the middle of the write sequence, the metadata becomes corrupted, and the filesystem cannot be used until it is made consistent again. This is what `fsck` is for.

If a filesystem is brought up in this "unclean" state, `fsck` drops into its investigative mode. It then walks through the filesystem block by block, examining the metadata and making sure it is consistent. This can take a very long time, depending on the size of the filesystem and the speed of the disk. When `fsck` finds an inconsistency that it cannot repair automatically while guaranteeing data integrity (see `man fsck` for details), `fsck` prompts you about whether you want to fix it. In most cases, you do. However, if you are being prompted, it's most likely that the inconsistency is so severe that you will have lost some datausually the file or files being written at the time of the crash, which tends to mean that data loss is fairly small.

After `fsck` finishes running, you may be dropped to a `#` prompt. Type **`boot`** to continue booting or **`reboot`** to go through the entire boot process again. Going through a reboot might be a good idea, just to make sure it will come up cleanly without intervention. You don't want to lock the server in a cabinet and drive away, only to have it not come up the next time it crashes.

Boot time is not the only place for `fsck`, though. You also can run it from the command line at any time on mounted filesystems, although it's a bad idea to do so when the system is fully up and running! It's important that the filesystem in question not be changing while you're trying to give it a consistency check. If you have to run `fsck` on one of your system's main disk partitions, take the precaution of dropping to single-user mode:

```
# shutdown +5
```

This command closes down multiuser mode five minutes after you issue the command. Naturally, everything from this point on has to be done at the physical console. You can't remotely administer the system in single-user mode!

Tip

You can also shut down the system immediately, rather than after a pause, with the **`shutdown now`** command.

With the system in this quiescent state, you can now use `fsck` to your heart's content. This may be necessary if during runtime you find a message in your `dmesg` output (part of the daily monitoring scripts that get sent to `root`) that says it found a bad inode or file descriptor, and you want to go directly to the root of the problem without rebooting. After you run `fsck` on one or all of your devices (use syntax such as **`fsck -p /dev/ad1s1g`**), you can then simply exit from the single-user shell (type **`exit`**) to bring up the rest of the multiuser system.

One case in which it is safe to use `fsck` while still in multiuser mode is when you're trying to mount a second disk with a noncritical or new filesystem that you're attempting to add. The `fsck` that runs at boot time will only check the filesystems that are listed in `/etc/fstab`. Rather than adding the new device to the `fstab` file and rebooting, you can simply try to mount the device. If the mount fails, telling you that you need to run `fsck`, do so with the syntax shown previously. Then try mounting the disk again. This mount can be done safely in multiuser mode because nobody will be writing to a device that hasn't yet been mounted.

Note

FreeBSD's `fsck` is similar in functionality to that of the `fsck` used on similar operating systems; however, it does lack one or two nice interface features, such as the progress bar on the Linux `fsck`. Be assured, though, that the core features behave almost exactly the same way.

Journaling Filesystems and Soft Updates

Many different solutions to the synchronous-write issues that lead to fragmentation and lost file pointers have been developed. You hear a lot these days about *journaling* (or logging) filesystems like Ext3FS and Journaled HFS+, for example, which keep a log of all write operations before they are executed. This log dramatically speeds up `fsck` because it no longer needs to comb the entire filesystemit knows where the inconsistencies are and how to fix them.

FreeBSD does not include support for journaling filesystems; what it does have, though, is *Soft Updates*. Whereas journaling filesystems work by maintaining a log file of write actions, Soft Updates (which is built into the `GENERIC`, or default, kernel ever since FreeBSD 4.5, and is enabled on all newly created disk partitions) provides a different technique that offers the same kind of benefits. Soft Updates uses precalculated, ordered writes to eliminate the need for an external log; at the same time, Soft Updates protects the integrity of the metadata to provide filesystem consistency as good as or better than that offered by journaling. It has performance advantages over journaling as well; a filesystem can be brought up immediately at boot time, and the consistency checking is done afterward through the use of automated snapshots in a background task.

Soft Updates can be enabled on any or all of your filesystems. A toggle option in the Disk Label Editor (the utility you use to divide your disk into subpartitions and assign them to different mount points, as discussed in the section "Creating the Disk Labels," in Chapter 20) lets you set Soft Updates on whichever partitions, or filesystems, you wish. Soft Updates is particularly effective when used on filesystems that contain frequently changing data, such as `/var` and `/usr`.

An optional daemon called `diskcheckd` supports Soft Updates. Installable from the ports or packages, `diskcheckd` runs in the background and performs periodic filesystem integrity scans, thus dramatically reducing the reliance on `fsck` at boot time and the risks associated with abrupt shutdowns. The configuration file is `/usr/local/etc/diskcheckd.conf`; see `man diskcheckd` for instructions for and examples of using this file. Any errors that `diskcheckd` finds are logged through the `syslogd` service, described in the section "The System Logger (`syslogd`) and the `syslog.conf` File," in Chapter 14, "System Configuration and Startup Scripts." While `diskcheckd` is running, you can use `ps` to view its progress:

```
# ps -ax | grep diskcheckd
  251  ??  Ss     0:00.28 diskcheckd: ad0 13.26% (diskcheckd)
```

You can find more information on Soft Updates and comparisons between it and journaling filesystems at http://www.mckusick.com/softdep/ and http://www.ece.cmu.edu/~ganger/papers/CSE-TR-254-95/.

Using `fsck` to Recover a Damaged Super Block

Chances are that you'll never have to use this technique. However, according to Murphy's Law, the best way to ensure a certain kind of disaster never happens is to prepare for it.

A common kind of filesystem corruption is a damaged super blockthe block that contains the critical data for a device's filesystem. This corruption occurs when the system, for whatever reason, cannot read the device's *super block*, located on sectors 16 through 31 at the beginning of the device. The super block is such an indispensable part of a filesystem that FreeBSD keeps an alternate super block at the beginning of every cylinder group. This way, if your main super block becomes corrupted, dozens of backups throughout the device are available for you to use. The first alternate is always at block 32, and the rest are at regular intervals throughout the disk, but are much less easily predictable.

Let's say you try to mount a filesystem that you know is otherwise validfor example, a removable hard disk that worked the last time you had it in the machine. Upon issuing the `mount` command, you get the following error:

```
/dev/ad1s1h on /mnt: Incorrect super block
```

As dire as the situation sounds, it is easily dealt with by using `fsck`:

```
#  fsck /dev/ad1s1h
** /dev/ad1s1h
BAD SUPER BLOCK: MAGIC NUMBER WRONG
LOOK FOR ALTERNATE SUPERBLOCKS? [yn] y
USING ALTERNATE SUPERBLOCK AT 32
** Last Mounted on /home2
** Phase 1 - Check Blocks and Sizes
** Phase 2 - Check Pathnames
** Phase 3 - Check Connectivity
** Phase 4 - Check Reference Counts
** Phase 5 - Check Cyl groups
148 files, 15660 used, 7038840 free (208 frags, 879829 blocks, 0.0%
fragmentation)
UPDATE STANDARD SUPERBLOCK? [yn] y
***** FILE SYSTEM WAS MODIFIED *****
```

FreeBSD makes dealing with a "damaged super block" error easy. Other platforms make you use command-line options to specify where the alternate super block is that you want to use, but the one at 32 is really the only one you know for sure is there. Using `fsck` in this manner, the first available alternate super block is copied over the primary one, and you should be able to mount the filesystem cleanly.

Note

You can determine where all the super blocks on the device are (if you're really interested) by using the `newfs` utility, with the `-N` parameter (which prints out the filesystem's stats without actually making any changes to the disk). Here's an example:

```
# newfs -N /dev/ad1s1h
Warning: 2672 sector(s) in last cylinder unallocated
/dev/ad1s1h: 14558608 sectors in 3555 cylinders of 1 tracks, 4096 sectors
 7108.7MB in 223 cyl groups (16 c/g, 32.00MB/g, 7936 i/g)
super-block backups (for fsck -b #) at:
32, 65568, 131104, 196640, 262176, 327712, 393248, 458784, 524320, 589856,
655392, 720928, 786464, 852000, 917536, 983072, 1048608, 1114144, 1179680,
1245216, 1310752, 1376288, 1441824, 1507360, 1572896, 1638432, 1703968,
1769504, 1835040, 1900576, 1966112, 2031648, 2097184, 2162720, 2228256,
2293792, 2359328, 2424864, 2490400, 2555936, 2621472, 2687008, 2752544,
2818080, 2883616, 2949152, 3014688, 3080224, 3145760, 3211296, 3276832,
3342368, 3407904, 3473440, 3538976, 3604512, 3670048, 3735584, 3801120,
3866656, 3932192, 3997728, 4063264, 4128800, 4194336, 4259872, 4325408,
4390944, 4456480, 4522016, 4587552, 4653088, 4718624, 4784160, 4849696,
4915232, 4980768, 5046304, 5111840, 5177376, 5242912, 5308448, 5373984,
5439520, 5505056, 5570592, 5636128, 5701664, 5767200, 5832736, 5898272,
5963808, 6029344, 6094880, 6160416, 6225952, 6291488, 6357024, 6422560,
6488096, 6553632, 6619168, 6684704, 6750240, 6815776, 6881312, 6946848,
7012384, 7077920, 7143456, 7208992, 7274528, 7340064, 7405600, 7471136,
7536672, 7602208, 7667744, 7733280, 7798816, 7864352, 7929888, 7995424,
8060960, 8126496, 8192032, 8257568, 8323104, 8388640, 8454176, 8519712,
8585248, 8650784, 8716320, 8781856, 8847392, 8912928, 8978464, 9044000,
9109536, 9175072, 9240608, 9306144, 9371680, 9437216, 9502752, 9568288,
9633824, 9699360, 9764896, 9830432, 9895968, 9961504, 10027040, 10092576,
10158112, 10223648, 10289184, 10354720, 10420256, 10485792, 10551328,
10616864, 10682400, 10747936, 10813472, 10879008, 10944544, 11010080,
11075616, 11141152, 11206688, 11272224, 11337760, 11403296, 11468832,
11534368, 11599904, 11665440, 11730976, 11796512, 11862048, 11927584,
11993120, 12058656, 12124192, 12189728, 12255264, 12320800, 12386336,
12451872, 12517408, 12582944, 12648480, 12714016, 12779552, 12845088,
12910624, 12976160, 13041696, 13107232, 13172768, 13238304, 13303840,
13369376, 13434912, 13500448, 13565984, 13631520, 13697056, 13762592,
13828128, 13893664, 13959200, 14024736, 14090272, 14155808, 14221344,
14286880, 14352416, 14417952, 14483488, 14549024
```

As you can see, plenty of backups are available, but all except for the one at 32 are at odd locations. `fsck` does all the dirty work for you. However, it does let you specify a certain super block if you don't want to let it pick one automatically. For example, `fsck -b 2490400 /dev/ad1s1h` is the command to use the super block at sector 2490400.

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Setting and Enforcing Disk Usage Quotas

Remember those users from earlier in the chapter who wouldn't stop uploading files and forced you to buy a new disk to accommodate them? Suppose you decided that you didn't want any single user to be able to use more than 100MB without special permission from you. You can set this limit with quotas.

Quotas are not built into the `GENERIC` kernel. To enable them, you have to add the following line to your custom kernel configuration file (`/usr/src/sys/i386/conf/CUSTOM`, copied from `GENERIC`, as discussed in Chapter 18):

```
options         QUOTA
```

See "Creating a Custom Kernel Configuration File," in Chapter 18 for information on building a custom kernel. You also can make use of a couple switches in `/etc/rc.conf` to enable support for quotas when the system is brought up. To use those switches, add these lines:

```
enable_quotas="YES"
check_quotas="NO"
```

The first line turns on quota support globally. The second line tells the system to skip a long, time-consuming consistency check (`quotacheck -a`) at boot time, which ensures that the quota database is properly synchronized. If you want to enable this check, change the second line to `"YES"` or remove the line altogether (`"YES"` is the default).

The last step is to turn quotas on (or off) per filesystem. This is done in `/etc/fstab` by adding the `userquota` option and/or the `groupquota` option to the fourth field in each filesystem on which you want to enforce quotas. Here's an example:

```
/dev/ad0s1f     /var    ufs   rw,userquota               2      2
/dev/ad0s1e     /usr    ufs   rw,gropquota               2      2
/dev/ad1s1g     /home   ufs   rw,userquota,groupquota    2      2
```

After making all these changes, reboot the system. Now that you're armed for battle, you're ready to start assigning quotas to users. You can assign them user by user (which is hardly practical on a high-load server) or you can set one user's quota and then use it as a prototype to apply the same settings to a range of user IDs. To set the quota for that first user, you'll need to use the built-in `edquota` utility, which lets you edit the attributes as a text file (much like `chfn`, which you learn about in Chapter 13, "Users, Groups, and Permissions"). The text editor that `edquota` uses is whatever is specified in your `EDITOR` environment variable. The default installation specifies `vi`, but you can choose a more user-friendly text editor, such as `pico` or `ee`, by using a command such as `setenv EDITOR pico`. Here's an example of setting a user's quota ("hard" and "soft" limits will be discussed later):

```
# edquota -u bob
Quotas for user bob:
/usr: blocks in use: 65, limits (soft = 50, hard = 75)
        inodes in use: 7, limits (soft = 50, hard = 60)
/var: blocks in use: 0, limits (soft = 50, hard = 75)
        inodes in use: 0, limits (soft = 50, hard = 60)
```

After this user's quota has been set up, you can then clone the settings throughout your system, as follows:

```
# edquota -p bob 1001-9999
```

This will apply the same quota settings to the entire range of UIDs specified, even those that haven't been created yet!

Note the difference between blocks and inodes. Both limits will be enforced. The term *blocks* refers to the total space used (in 1KB units), and *inodes* can be understood to mean "files."

Soft and Hard Limits

A word or two about hard and soft limitsand the grace periodare in order here:

- A *hard limit* is strictly enforced. If a user's disk usage reaches the hard limit, the system will not permit any more space to be allocated to that user.
- A *soft limit* does not prevent the user from creating more files or using more space; instead, it triggers a timer for the *grace period*, which is seven days by default (but can be changed using **`edquota -t`**). After this grace period expires, the soft limit is enforced the same way as a hard limit. This allows users to use more than their allocated space (up to the hard limit) for brief periods of time. If the user's disk usage drops below the soft limit, the grace period is reset.

After you have set these limits, you can view them as follows:

```
# quota bob
Disk quotas for user bob (uid 1015):
Filesystem  blocks   quota   limit   grace    files    quota   limit   grace
/home       1812     20000   40000             37        0       0
```

The `quota` command shows the quota information for the user specified as the final argument, or for the current user if that argument is omitted. If the user is over either of these limits, an asterisk (`*`) will appear after the number of blocks or files by which the user is exceeding the limit, and the `grace` column will report the amount of time left before the soft limit is enforced. Here's an example:

```
# quota bob
Disk quotas for user bob (uid 1015):
Filesystem  blocks   quota   limit   grace   files    quota   limit   grace
/home       28121*   20000   40000   6days    189       0       0
```

Note

To make sure that quotas are running properly, use the **`mount`** command with no arguments. The following is output from `mount` on a system in which the `/home` partition is using quotas:

```
/dev/ad0s1a on / (ufs, local)
/dev/ad0s1e on /usr (ufs, local)
procfs on /proc (procfs, local)
/dev/ad1s1g on /home (ufs, local, with quotas)
```

If you don't see the `with quotas` flag, the filesystem was not properly mounted with quotas. Check `/etc/fstab`, `/etc/rc.conf`, and your kernel configuration and then try rebooting if everything looks correct.

Quotas can be turned off easily enough in one of three ways:

- Globally, by setting `enable_quotas="NO"` in `/etc/rc.conf` and then rebooting.
- Per filesystem, by editing `/etc/fstab` and then rebooting.
- Per user, by using `edquota` and setting the hard and soft limits to zero. Then, you could use `edquota -p` to propagate these settings throughout a range of UIDs, if you want.

Filesystem management isn't an easy task, but once you have a firm grasp of the concepts, the versatility of UNIX filesystems becomes readily apparent. Multiuser operating systems like FreeBSD bring up all kinds of issues that don't exist on desktop systems, such as handling multiple filesystem types, monitoring usage, and enforcing quotas, but these features are what separates UNIX from its less-capable contemporaries. We will continue this discussion into the area of formatting and labeling new disks in Chapter 20.

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Blocks, Files, and Inodes

The different ways of looking at data on a disk can get fairly confusing, but the details are important for understanding how to read the output of tools such as `df` and `fsck`. Let's take a closer look at how storage is divided up and used.

The data block is a unit of data storage; the default size for a data block is 8,192 bytes. A block is divided into eight fragments of 1,024 bytes each. A file that does not take up an entire data block is stored in fragments and shares that block with other files. This process is actually what `fsck` is referring to when it reports fragmentation.

However, if a file that is currently sharing a data block with another file grows to the point where it will no longer fit in the current block, FreeBSD moves the entire file to a different block. In the same circumstance, Windows simply fragments the file into an adjacent block. FreeBSD's approach ensures that for files smaller than 8,192 bytes, all the fragments for a single file are always stored in one data block. It also ensures that a file of any size is stored across as few different blocks as possible. You will never have a small file that has fragments in more then one data block. This, of course, improves access time, and it prevents fragmentation from getting to the dizzy levels seen in consumer-grade operating systems.

A "file" really just provides a way of looking at an *inode*, which is the fundamental grouping of related data that we think of as a file. This model is necessary for a true multiuser operating system to be able to share files efficiently. Here is all the information that is contained in an inode:

- The type of file and the access modes
- The user ID and group ID of the owner
- The size of the file
- The time the file was last accessed and modified, and the inode changed
- The number of data blocks used by or allocated to the file
- The direct and indirect pointers to these data blocks

FreeBSD accesses data blocks with pointers located in the inodes. There are 12 direct pointers, each of which can access one block. This allows direct access to a file up to 96KB. In addition, there are three levels of indirect pointers: single, double, and triple. These pointers are what allows FreeBSD to support files of extremely large sizes, spanning huge numbers of blocks.

The *single* indirect pointer refers to a filesystem block that contains pointers to data blocks. The filesystem block contains 2,048 additional addresses of 8KB data blocks, thus allowing access to a file up to 16MB in size. The *double* indirect pointer refers to a filesystem block containing 2,048 addresses that each point to a filesystem block containing a single indirect pointer, and each one of those 2,048 single indirect pointers refers to a filesystem block containing 2,048 addresses of 8KB data blocks. This allows access to a file up to 32GB in size. Finally, the *triple* indirect pointer contains 2,048 addresses that each point to a filesystem block containing a double indirect pointer. 2,048 double indirect pointers times 2,048 subsequent single indirect pointers times 2,048 8KB data blocks allows the triple indirect pointer to access a file that is 70TB (terabytes) in size! FFS limits the maximum file size to 1TB, though, so don't get too excited.

Chapter 13. Users, Groups, and Permissions

IN THIS CHAPTER

Users and file permissions are the concepts that form the central pillars of a UNIX system. Working within a system that is designed for multiuser operation imposes many more rules and restrictions than you experience when administering single-user desktop systems. This is a safety feature as much as a matter of privacy: not only can each user hide his files and sensitive data from the prying eyes of other users, but each user is also restricted from altering parts of the system that he does not himself own. This protects the components and configuration of the operating system itself from being harmed by the actions of casual users, whether maliciously or accidentally.

A true multiuser operating system is one where every process is owned by a particular user identity, each of which has a certain level of privileges with which those processes can be executed. You might already be familiar with operating a desktop computer in a multiuser context; however, even in the modern server-class iterations of Windows, user privileges play a somewhat different role than in FreeBSD. Let's look at why this is the case, using Windows' incremental development to illustrate by contrast how user permissions are used in FreeBSD.

Traditional desktop operating systems, such as Windows 95/98/Me and classic Mac OS, gave the impression of being multiuser operating systems; however, strictly speaking, they were not. What they used, instead, were simply *profiles*, or ways of presenting data according to each user's preferences. Any potentially system-altering action the user wanted to take on the local machine, such as reading and writing files, installing programs, or shutting down the computer, was permitted because there was only one "user" with absolute control over the machine. Access to network resources was done on a "guest user" basis, without the user or the machine participating in any true authentication with a domain controller or its equivalent.

Windows NT, 2000, and XP, as server-class operating systems with a need for greater data security and stability than their predecessors, have taken successive steps toward becoming true multiuser operating systems like FreeBSD. Each user in the system has a separate account and a set of permissions that control access to files, printers, and other resources. Windows and FreeBSD both have the concept of a "root" user, or administrator, who has absolute power over the local machine. Both systems have groups (enabling sets of users to have the same access to certain resources) and different layers of accessibility. (In fact, Windows-style permissions have such complexityinheritance upward, inheritance downward, domain users versus local users, and up to three accounts with administrative powerthat even the most experienced user can get swamped.) However, even with all the recent advances that bring Windows' multiuser feature set near to that of UNIX, the two systems still come from very different remote-accessibility and administration traditions that continue to influence how each one's permissions models work, leading to many fundamental differences that persist today.

Note

Mac OS X, a true UNIX operating system, has a multiuser architecture similar to FreeBSD'sexcept that it's designed not to allow you to run a user session with root privileges. Instead, administrative actions are executed under the `sudo` model, where the system prompts you to enter your password to authenticate yourself as a user who's allowed to attain administrative privileges (and not just someone who happened to sit down at a logged-in user's session). The system then retains this elevated level of privileges for the duration of whatever administrative action you're performing.

The `sudo` model is a far safer way of administering a system than running as root all the time, and you should consider installing the `sudo` program (in the `security` category of the ports or packages) and using it instead of running as root wherever possible. Set up the `sudoers` file as directed in the `man` page for `sudo`, to restrict access to the command to authorized users. Then, prefix a command with **`sudo`** to be prompted for the root password and have the command executed as root.

Although modern versions of Windows feature integrated graphical terminal-server software, the traditional method for using and administrating a Windows system is to do so at the console, with the user sitting in front of the actual computer. Indeed, because of the high network overhead and potential security implications of graphical terminal server software, many administrators still tend to prefer using the console, where the complex user interface doesn't suffer from network lag. In the case of servers in which user privileges are important, network applications running on Windows typically consist of two portions: a *server*, which handles all the central processing and is running at all times, and a *client*, which must be installed on a remote computer and accesses the server application through whatever functions are programmed into the client. A web browser accessing a server is a prime example of this, as is an email client accessing POP or IMAP mail or calendaring data. The web or email server application runs only under its own restrictive permissions, and each user accessing the application from a remote computer is bound by those same restrictions and can't directly affect any files on the server. If data must be divided among users and kept private and secure, that division is typically handled within the application itself, not by the operating system.

FreeBSD and other UNIX-style operating systems, by contrast, thrive on ad-hoc remote accessibility. Although client-server applications are as common in the UNIX world as under Windows, in UNIX it's far more crucial for remote users to be able to access the entire operating system through terminal connections (such as Telnet or SSH), which provide a user with a command-line shell interface over the network. Shell access is very lightweight and does not require any more than the most rudimentary of client applications, which are often already installed as part of the client operating system. As you have already seen, a shell gives a user the ability to issue any FreeBSD commands she wants, rather than just what commands are permitted by the specialized client software for a particular application, and the simple textual interface isn't as sensitive to network-related sluggishness as a graphical remote-access client that has to transmit all kinds of information about the movements of the windowing system. The upshot of this is that beyond the usual client-server applications like web servers and email, your FreeBSD machine will likely be accessed from many remote locations and by many different users at once, all using terminal programs to run shells on the server itself, issuing all kinds of different commands to directly modify files on the server. On FreeBSD systems, therefore, user and group permissionswhich protect critical system files and provide user data privacy during this ad-hoc accessplay a much more important part in an administrator's life than they would on a Windows system, in which the administrator can always predict which applications will be running and how they might affect the system.

Caution

SSH (Secure Shell) is an encrypted, or "scrambled," form of remote terminal connection. It provides all the functionality of Telnet (the traditional clear-text terminal application), with added security to prevent eavesdroppers from viewing terminal traffic such as your password or sensitive system data. Today, SSH is preferred and encouraged in almost all circumstances, and Telnet should only be used when SSH is not an option. We will cover SSH in more detail in Chapter 30, "Network Security."

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Introduction to Users and Groups

The users and permissions model that FreeBSD and most UNIXes use is fairly simple and single-layered. There are only two types of users: regular users and the super-user, or "root." Regular users are subject to user permissions that restrict what they can do; only the super-user is free of these restrictions. Other permissions models (such as that of Windows 2000/XP) involve more complex layering, which is intended to facilitate certain system functions, such as authentication services and system-level processes. The simpler model of FreeBSD requires you to do a few more gymnastics when it comes to tasks such as setting up a web server with proper permissions to protect it from unauthorized access by shell users (covered in Chapter 26, "Configuring a Web Server"). However, the alternativea more complex permissions systemmore than likely means a less secure system, because there's so much more that can go wrong.

Note

A more complex permissions modelAccess Control Lists, or ACLsis available in FreeBSD if you choose to use it; it's discussed later in this chapter. ACLs let you designate certain resources as being accessible by a specified list of users, rather than making you use groups and permissions masks.

Every regular user on a FreeBSD system has limited permissions and a place to dwell (a home directory). When you connect to the FreeBSD machine remotely, it's generally as a regular user rather than root, and you're placed into your home directory where you're surrounded by files that you can modify only because you own them. To gain elevated status, you need to promote yourself to the super-user using the `su` command (or the preferred `(su -`, which simulates a full root login complete with environment variables). This prompts you for the root password, which is the "key to the kingdom" and the most important piece of information you'll have to remember in maintaining your system. After you gain root access, you have as much freedom to createor destroyanything on the computer as you would on a single-user Windows machine.

Caution

Any time you are logged in as root, you should cultivate a heightened sense of security consciousness, a wariness that someone malicious could be eavesdropping to get the kind of access that you have. The root password should never be transmitted over the network in clear-text, and it should be changed every few months as a rule (see Chapter 30 for more details). You cannot be too careful with this vital piece of information.

In order to execute the `su` command, you need to be a member of an elite group called "wheel." Although FreeBSD has only regular users and the super-user, the wheel group effectively creates a special class of regular usersthose who are allowed to *become* root (using `su`). You can use `su` and this special class to delegate administrative responsibility to others that you trust.

Note

FreeBSD differs slightly from most distributions of Linux and many other UNIX-based operating systems in that it does not allow you to connect directly to the system (via Telnet or SSH) as root. This is a security measure. To gain root access, you must connect as a regular userspecifically, a user who is a member of the wheel groupand use the `su` command to promote yourself to super-user status. This means that the root password alone will not give anyone access to your system; that access also requires a user's password who is in the wheel group. A determined hacker will find ways to discover both of these passwords, but the added step is a significant deterrent.

If you really, *really* must turn off this feature and make FreeBSD allow direct root access, you can do so by editing the file `/etc/ttys` and adding the keyword `secure` in the field to the right of `network` in the first few entries in the `Pseudo terminals` section:

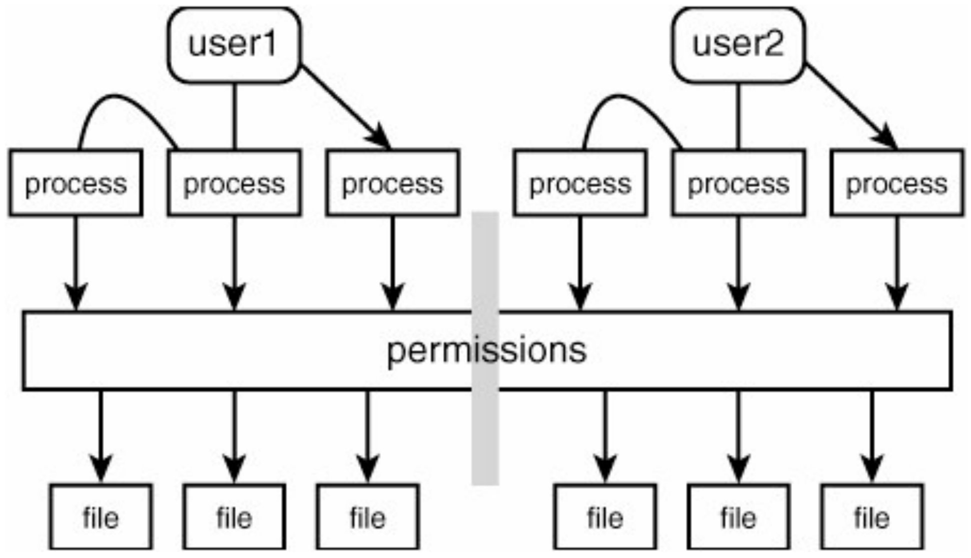
```
ttyp0   none                    network      secure
ttyp1   none                    network      secure
ttyp2   none                    network      secure
```

This is, however, considered an extremely risky maneuver, and not one you should use if you can possibly stand simply logging in as yourself and using `su`.

Another kind of distinction among regular users is between actual login users (people who connect to the system) and automated users (such as `bin`, `operator`, `daemon`, `nobody`, and others). These user accounts exist in order to "own" certain system processes and server applications. It is important to realize that processes, just like files, are each owned by some user, and all processes are bound by their users' permissions when interacting with files and other processes. This ensures that system processes that create files do so under the limited permissions of their owner users, rather than as root (which can be dangerous and insecure).

Users never really access their files directly. Everything a user does to his files by giving commands is effectively done by executing processes running with the user's assigned permissions. Those processes then operate on files and other processes, as illustrated in Figure 13.1. The processes owned by `user1` can only operate on the files and processes owned by `user1`; permission would be denied if any of those processes tried to change any of `user2`'s files or processes in any way. In the simplest setup, each user can change only those files and processes that he owns.

Figure 13.1. A user executes processes, which then operate on files and other processes.



Imagine what would happen if `user1` were the super-user. That user's processes would have absolute power over any other user's files and processes. If one of `user1`'s processes is, for instance, a program that reads a configuration file and then modifies items in the system specified in that file, suppose an unauthorized user managed to modify the configuration file in a malicious way. `user1'`s program would be then vulnerable to any such misconfiguration, and depending on its capabilities, could completely ruin the system. This is why most system processes, except those that are absolutely trusted, run under the ownership of one of the automated pseudo-users instead of running as root.

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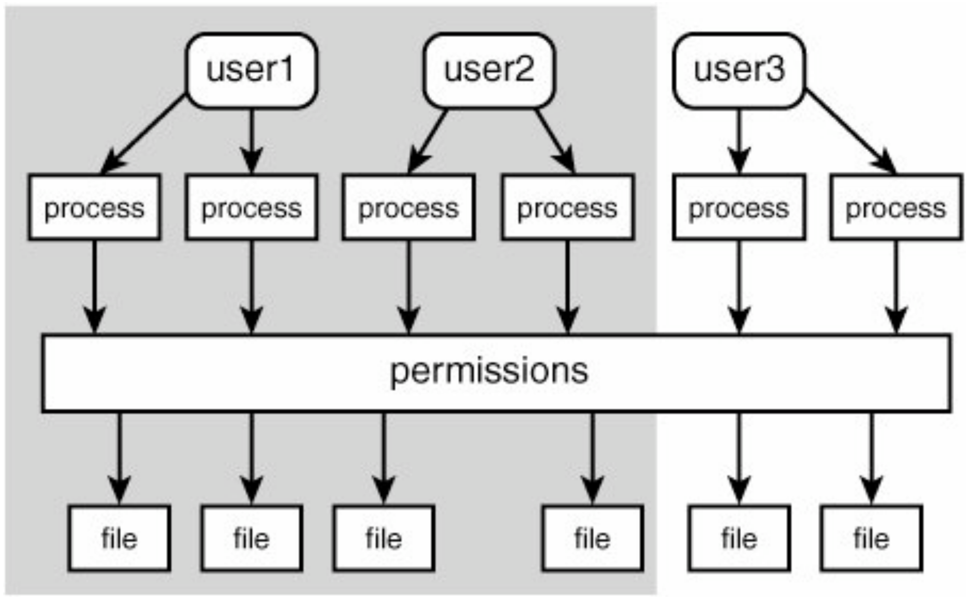
Why Use Groups?

Every user belongs to some primary group, generally a group that has the same name as the user and the user as its only member. This can be changed as you see fit; for instance, you might decide to have all users belong to the "users" group as their primary group. However, having a different group for every user gives you more flexibility. It's also a more secure model. More information on unique "personal" groups and why they're useful can be found in `man adduser`.

Each user can also belong to any other groups in the system, such as other users' "personal" groups, the wheel group, or any other group you create (by adding the user to the `/etc/group` file, as you'll see later). However, the super-user is the only one who can control who belongs to what groups.

We have discussed the purpose of the wheel group: to indicate a special clique of users who have the privileges to use `su` to gain root access. Other applications for groups are geared toward granting special privileges to certain users. In the most general case, a group exists to give one user the same permissions on a set of files or processes as another userfor example, to enable different engineers working on a software project to modify the source code files in a single central location, as illustrated in Figure 13.2. It wouldn't be very desirable if the two users had to share an account or tell each other their passwords; groups enable the two users to "own" the same group of files, with both users having the same permissions to operate on these files.

Figure 13.2. Two users in a group working on the same set of files. These files are still protected from other users.



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File Ownership

This brings us to our file ownership model. All UNIXes have the same kind of ownership structure: Every file and directory is owned by both a *user* and a *group*. As you will see in a moment, this does not necessarily mean that either the user or the members of the group have any particular permissions to access the file or directory. Ownership does come into play, though, in conjunction with the permissions settings that indicate what the owner user and other users can do with the file.

Let's take a look at the permissions and ownership details of a set of files (see Listing 13.1). Here we use the `-l` option to `ls` to give a detailed listing, and we use the `-a` option to show all files, including "hidden" ones (those whose names begin with a dot).

Listing 13.1. Set of Files Showing Ownership and Permissions

```
# ls -la /home/frank
total 3126
drwxr-xr-x   3 frank     frank      512 May 12  2000 .
drwxr-xr-x  52 root      frank     9216 Mar  7 13:37 ..
-rw-r--r--   1 bob       frank   291090 Jan 23  2000 1.bmp
-rw-rw-r--   1 bob       bob       2703 Dec 22  1998 contents.html
-rw-r--r--   1 frank     frank     3657 Jan  9 14:11 file.txt
-rw-r--r--   1 bob       frank    92195 Sep 11 21:31 1.uu
drwxr-xr-x   2 root      frank      512 Jan  2 14:19 files
drwxr-xr-x  12 root      wheel     1024 Feb 18  1999 more-files
```

Seems pretty crypticbut it really isn't. In this chapter, you'll learn how to decode strings such as `drwxr-x`, which define the *mode* of a file (the parameters that define who can access it and in what manner).

There are three modes of owner permissions on a file (or directory): *user*, *group*, and *others*. There are also three modes of access: *read*, *write*, and *execute*. These six pieces of information, referred to as *bits*, define the permissions on a file. For instance, a file's permissions configuration might tell us that the user who owns the file can read and write to it, but members of the group that own the file can only read from it, and anybody else in the system can also only read from it. (This is the default file mode.) Similarly, a file's permission mode can tell us that anybodyuser, group, or otherscan read or execute the file (running it as a program) but that only the user and group owning it can write to it. Literally any combination is possible. We'll look in more detail at the permission modes and discuss how to set them a little later in this chapter.

For now, it is necessary to realize that a user can only read her own files if those files have their permissions set so that the user can read them. Similarly, the necessary permissions must be in place if members of the owner group are to read the files. Most of the time, this is indeed the case; it is important to recognize, though, that ownership and permissions are not inextricably tied together.

Note

A user can delete a file owned by another user, *if that file is in a directory owned by the first user*. The `rm` (remove) command will prompt for whether the user wants to override the file's ownership and permissions, and proceed, as shown here:

```
# ls -l tempfile
-rw-r--r--  1 root  wheel  0 Aug  7 21:44 tempfile
# rm tempfile
override rw-r--r--  root/wheel for tempfile? y
```

Using `chown` to Change File Ownership

As the super-user, you have the ability to change which users own any files on the system. Only the super-user can do this; regular users cannot "give" their files to another user or "take" them from another user. If they could, it would sort of defeat the purpose of users and file ownership.

The command to change ownership is `chown` (change owner):

```
# chown bob file.txt
```

This command changes the *user* ownernot the group ownerof the file `file.txt` to the user `bob`. The file used to be owned by `frank`, but now Bob can read and write to the file, whereas Frank can no longer write to it.

You can also use `chown` on a directory:

```
# chown bob /home/frank
```

This command, when used on a directory, operates on the "`.`" entry you saw earlier in Listing 13.1. This special filename is a pointer that refers to the current directory, whereas the "`..`" entry refers to the parent directory (this behavior is the same as in MS-DOS). Looking back at the permissions on the `/home/frank` directory, you can see that it is writable only by its user owner (you know this by the `w` bit in the third position, and nowhere else, in the permissions string); therefore, `bob` is now the only one who can create and delete files in the directory. He can, however, modify any file that he owns in any directory. This interrelation between ownership and permissions will be made clearer in Table 13.1.

Table 13.1. Anatomy of the Permissions String

Place	Value(s)	Meaning
1	`d`, `-`	Indicates whether the item is a directory or (if `-`) a plain file.
2	`r`, `-`	Indicates (if `r`) that the item can be read by its owner.
3	`w`, `-`	Indicates (if `w`) that the item can be written (modified) by its owner.
4	`x`, `-`, `s`	Indicates (if `x`) that the item can be executed/searched by its owner, or (if `s`) that it will be executed in `setuid` mode.
5	`r`, `-`	Indicates (if `r`) that the item can be read by members of its owner group.
6	`w`, `-`	Indicates (if `w`) that the item can be written (modified) by members of its owner group.
7	`x`, `-`, `s`	Indicates (if `x`) that the item can be executed/searched by members of its owner group, or (if `s`) that it will be executed in `setgid` mode.
8	`r`, `-`	Indicates (if `r`) that the item can be read by any user other than its owner.
9	`w`, `-`	Indicates (if `w`) that the item can be written (modified) by any user other than its owner.
10	`x`, `-`, `t`	Indicates (if `x`) that the item can be executed/searched by any user other than its owner, or (if `t`) that it's a "sticky" directory where a

user can't delete files he doesn't own.

Tip

There's a useful option to `chown` that you as an administrator will need to know: `-R`. This makes `chown` act recursively, meaning that if you run it against a directory, the function will operate on the current directory, all files within the directory, and all files in all subdirectories below it. You'll need to use `chown` if you have to re-create an account, for example, and need to transfer ownership of all the user's files. Here's an example:

```
# chown -R bob /home/frank
```

Using chgrp to Change File Group Ownership

Now that you know how to use `chown`, it's a simple matter to understand the use of `chgrp`, a very similar command. Its purpose is to change the group owner rather than the user owner of a file or directory, and it works exactly the same way:

```
# chgrp users contents.html
```

After this command is issued, the permissions for `contents.html` will look like this:

```
-rw-rw-r--   1 bob       users  2703 Dec 22  1998 contents.html
```

Because both the user and group owners have write permissions (the `w` bit is in the third and sixth positions), you've just created a situation in which any member of the "users" group can write to the file just as `bob` can.

FreeBSD, by default, creates a new group for every user, so there will be a `bob` group as well as a `bob` user, and Bob belongs to it as his primary group. By default, all the user's files are created with the user and group owners set to `bob`. Now, if another user (for instance, `frank`) belongs to the `bob` group, he can write to those files. You now have a file-sharing mechanism in which both Bob and Frank have the same level of control over the files.

Tip

Using `chgrp` is really just another way of executing `chown`; if you prefer, you can use the following syntax:

```
# chown bob:users contents.html
```

This changes the ownership on `contents.html` to the `bob` user and the `users` group, whereas the following will change the group owner only:

```
# chown :users contents.html
```

Both `chown` and `chgrp` support the `-R` option, described previously, in the same way.

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File and Directory Permissions

Refer to the files in Listing 13.1. It's now time to examine the permissions strings for these files and directories more carefully. The first thing you should notice is that for directories, the first bit in the string is a `d`. This is simply a flag and doesn't really indicate permissions that can be controlled; this flag is, however, a useful means of distinguishing between files and directories.

The rest of the bits in the string are fairly straightforward: three groups of three, showing respectively the read, write, and execute permissions for the user owner, the group owner, and all other users. For instance, `contents.html` (with the permissions string `-rw-rw-r--`) is readable and writable by both the user and group owners, and all other users can only read it. Table 13.1 describes all 10 fields in the permissions string and what their possible values mean.

Note that a directory must have the "execute" bit set in order for its contents to be viewable; for directories, viewing a directory's contents or moving into it counts as "executing" it.

The Relationship Between File and Directory Permissions

Table 13.2 shows the relationship between a user, a group to which the user belongs, and the permissions that the directory offers to the user and group, depending on its mode.

Table 13.2. Capabilities Granted by the Various Types of File Permissions

	Directory Writable by User	Directory Writable by Group	Directory Writable by Other
Create file	Yes	Yes	No
Delete file owned/writable by user	Yes	Yes	No
Delete file owned/writable by group	Yes	Yes	No
Delete file owned/writable by other	Yes	Yes	No
Rename file owned/writable by user	Yes	Yes	No
Rename file owned/writable by group	Yes	Yes	No
Rename file owned/writable by other	Yes	Yes	No
Modify file owned/writable by user	Yes	Yes	Yes
Modify file owned/writable by group	Yes	Yes	Yes
Modify file owned/writable by other	No	No	No

Any time you try to delete (`rm`) a file for which you do not have write permissions, you'll see a prompt similar to the following:

```
# rm file.txt
override rw-r--r-- bob/users for 1.uu? y
```

Note that you still might not have permission to delete the file! The override prompt appears any time you try to delete a file that isn't yours, regardless of whether you'll be successful if you type `y`. You can suppress the override prompt with `rm -f`.

A file that can be deleted can be renamed because you use the `mv` (move) command to rename a file in FreeBSD, and `mv` operates by copying the file and then deleting it. A file that can be read can be copied.

Beyond the standard permissions that apply to the user, group, and others, a few additional file modes have special meanings. You'll learn about these modes in the following sections, which discuss mechanisms for changing file permissions.

Using `chmod` to Change File and Directory Permissions

Now that you know how to read permissions on a file or directory, it's time to learn how to set them. The command for setting permissions is `chmod` (change mode). A file's permissions set is often referred to as its *mode*.

The `chmod` command can operate in two waysnumerically or symbolicallydepending on your preference.

Changing Modes Numerically

The most direct way to change permissions is by setting a three-digit, octal (base-8) number that uniquely specifies the permissions for each type of ownership. Each digit refers to a certain ownership mode that controls the permissions corresponding to the user, group, and others, respectively (you'll learn about a fourth digit later in this section). You can grant a single permission bit to a file or a combination of the available bits. A mode digit is constructed by adding together the numbers corresponding to the permission bits you want to grant. The available bits are shown in Table 13.3.

Table 13.3. Permissions Mode Bits and Their Meanings

Bit	Meaning
`0`	No permissions
`1`	Execute (for directories, search)
`2`	Write
`4`	Read

Using this scheme, you can specify a mode of "read and write" with `6`, a mode of "read and execute" with `5`, or a mode of "read, write, and execute" with `7`.

Combine these digits into a three-digit number indicating the three different user contexts of the permissions, and you've got a numeric way of specifying the standard permissions for a file. Table 13.4 shows a few common examples.

Table 13.4. Some Complete Numeric Permissions Modes

Mode	String	Meaning
`755`	`-rwxr-xr-x`	Read/write/execute by user; read/execute by group and others
`644`	`-rw-r--r--`	Read/write by user; read-only by group and others
`600`	`-rw-------`	Read/write by user; no access for group and others

Note

The textual permissions string is derived from the binary representation of the octal permissions. For example, `755` octal is `111101101` binary; if you "and" this number with the full permissions string `rwxrwxrwx`, you get `rwxr-xr-x`. Here you can see why permission attributes are referred to as "bits"it's because they literally are, with a 0 or 1 value indicating whether each field applies.

You can then apply the permissions to a file or directory, like so:

```
# chmod 755 testscript.sh
```

But that's only three of the four digits available in FreeBSD's permissions system. The fourth, "most significant" (leftmost) digit controls some extra features that address specific behaviors of files and directories under special circumstances. Here are the bits that make up this fourth digit and what they do:

- `0` Indicates normal permissions.
- `1` The sticky bit. This can only be set (with any effect) on directories, making them into "append-only" directories to which files can only be added, not deleted. Within a directory with this bit set, a regular user can only delete or rename files if he owns them *and* if he has write permissions for the directory. This does not apply to executable files.
- `2` Set group ID (setgid). If this bit is set on an executable file, it will be executed with the effective group permissions of the file's group owner rather than those of the user executing it. A file can only be made `setgid` by the super-user.
- `4` Set user ID (setuid). If this bit is set on an executable file, it will be executed with the effective user permissions of the file's user owner rather than those of the user executing it. A file can only be made `setuid` by the super-user.

This fourth digit is the highest-value digit (in other words, the leftmost one), so in the earlier example where we showed what the permissions of `755` mean, we could have used the equivalent value `0755`. We use the same method to construct the value for that digit as we do for the other digits, so the value `3755` would create a directory with the sticky bit and the `setgid` bit set, in addition to the regular `755` permissions.

Changing Modes Symbolically

The octal numeric permissions system is designed for the utmost efficiency in access and storageit's a direct reflection of how the permissions bits are stored in the filesystem, and thus it's optimized for being read by a computer, not a human. As clever and efficient as this system is, it's helpful to have a method for setting modes that's easier for us mere mortals to remember. Fortunately, we have a symbolic method for doing just that.

Instead of giving `chmod` a number, you can give it between one and three alphanumeric flags in a single string. This string can be formatted in a number of ways, but we'll briefly cover the most common usages here.

Note

See `man chmod` for complete coverage of the flexible syntax of `chmod` and its symbolic modes.

Table 13.5 shows some examples of symbolic modes. Each is made up of a string of characters. The first character or substring specifies the ownership mode(s), the second character indicates the modification you're making (`+`, `-`, or `=`), and the third is the permission bit(s) you're applying.

Table 13.5. Symbolic Permissions Modes

Mode String	Meaning
`go+w`	Adds "write" permissions to the group owner and others.
`+x`	Adds "execute" permissions for everyone.
`o-r`	Removes "read" permissions for others.
`ugo=rw`	Sets "read" and "write" permissions for everyone.
`a=rw`	Same as `ugo=rw`. The `a` refers to "all" fields.
`+t`	Adds the sticky bit (super-user only).
`+s`	Adds both the `setuid` and `setgid` bits (super-user only).

To set the file `file.txt` so that it is "group writable," use the following command:

```
# chmod g+w file.txt
```

This symbolic method lends itself more readily to memory than the numeric method, and it will probably be a much easier way for you to perform most of your typical `chmod` operations.

Tip

The `-R` option works on `chmod`, too, the same as with `chown` and `chgrp`.

PREV NEXT

Access Control Lists (ACLs)

The Access Control List (ACL) is an advanced permissions scheme that gives you tighter control over who can and cannot access files and directories. Instead of just allowing or denying access based on the owner, group, and everyone else, you can now grant access to individual specified users and groups. You can also set a maximum permission mask for the users and groups that are granted access through an ACL that will override the actual permissions given by the ACL.

ACLs are usually not necessary for desktop workstation users, and they're also seldom used in typical Internet server applications. However, in cases where complex group ownership is necessary, such as in a research environment where different lab groups must be able to contribute to a common pool of data, ACLs can provide the necessary level of granularity in permissions in a way that's simply not possible with traditional UNIX permissions.

For an ACL to work, the kernel must be properly configured with support for UFS extended attributes. If you are using a FreeBSD installation that was newly created using FreeBSD 5.0 or later, your kernel is up-to-date and you don't need to make any modifications to the kernel or create any support files for UFS extended attributes; skip ahead to "Enabling ACLs on Your Mounted Filesystems." However, if you're using an old version of FreeBSD or one whose filesystems were created prior to FreeBSD 5.0, you should read the next two sections to see how to add the necessary kernel and filesystem support for ACLs.

Configuring the Kernel to Support ACLs

There are two versions of the UFS (FFS) filesystem: UFS1 and UFS2. UFS2, which was made the default format for newly created filesystems in FreeBSD 5.0, contains built-in support for UFS extended attributes, which are necessary for ACLs to work. UFS1, however, requires that the kernel be modified to support the extended attributes. If your installation of FreeBSD was created prior to FreeBSD 5.0, you need to add the appropriate options and rebuild the kernel.

To see whether your kernel has UFS Extensions enabled, look for the following lines in your kernel configuration file. Unless you have already built a custom kernel, your kernel configuration file will be `/usr/src/sys/i386/conf/GENERIC` on an Intel x86-based system (adjust the `i386` portion accordingly, otherwise). The following lines should be present in order for the ACL feature to work:

```
options       UFS_EXTATTR
options       UFS_EXTTR_AUTOSTART
options       UFS_ACL
```

If these options are already present in your kernel configuration file, you don't need to do anything. If they are not present, you will need to add these options and then build a new kernel. See Chapter 18, "Kernel Configuration," for full details on how to configure, build, and install a new kernel.

Tip

Further documentation on the kernel modifications necessary for ACLs can be found in the source tree, in the `README.*` files in `/sys/ufs/ufs`.

After you have installed the new kernel and rebooted, you will need to configure the filesystems you want to use the ACL with.

Configuring UFS1 Filesystems to Use ACLs

On UFS1 filesystems (those created using FreeBSD versions prior to 5.0), you need to use the `extattrctl` command to set up the support files for the extended attributes necessary for ACLs. You must set up these support files on each filesystem where you want to use an ACL. For example, to enable an ACL on the filesystem mounted as `/usr`, follow this procedure:

1. As the root user, create the directories `/usr/.attribute` and `/usr/.attribute/system` (using the `-p` option to create them both at once):

    ```
    # mkdir -p /usr/.attribute/system
    ```

2. Change to the newly created `/usr/.attribute/system` directory (`cd /usr/.attribute/system`) and then run the `extattrctl` command to initialize the ACL attributes on the filesystem:

    ```
    # extattrctl initattr -p /usr 388 posix1e.acl_access
    ```

    On large filesystems, this command can take several minutes to complete, so be patient as the command generates the backing files needed to support the ACL feature.

3. When the first command has finished executing, run the `extattrctl` command one more time with another filename as the argument:

    ```
    # extattrctl initattr -p /usr 388 posix1e.acl_default
    ```

    Once again, on a large filesystem, this command can take several minutes to complete, so be patient.

4. Reboot the system or remount the filesystems in question for the changes to take effect. After you have done so, the ACLs for the filesystem will be enabled.

    ### Caution

    The files created by the commands in the ACL-enabling process can be extremely large, possibly taking up several gigabytes of disk space on large filesystems. Make sure you have plenty of free disk space before running the commands.

Enabling ACLs on Your Mounted Filesystems

Whether you have modern UFS2 filesystems that natively support ACLs or older UFS1 filesystems that you had to configure manually in the preceding sections, the final step in preparing your system to use ACLs is to tell the `mount` program to use them when mounting the disk partitions at boot time. To do this, edit the `/etc/fstab` file and add the flag `acls` to the options on each filesystem you want to use ACLs with:

```
/dev/ad0s1f    /usr    ufs     rw,acls    2     2
```

Reboot the system to enable these changes. You can also use the `acls` flag when mounting a filesystem manually:

```
# mount -o acls /dev/ad0s1f /usr
```

Getting Information About Current ACL Settings

Use the `getfacl` command to obtain information about existing ACL settings on files or directories. For example, on a newly created file named `acltest.txt` with no ACL set and with default `644` permissions, issuing **`getfacl acltest.txt`** will return the following:

```
#file:acltest.txt
#owner:0
#group:0
user::rw-
group::r--
other::---
```

The first line simply shows the name of the file. The next two lines show the UID and GID, respectively, of the owner and group the file belongs to (in this case, the file is owned by root and wheel). The final three lines show the current permissions on the file. Notice that "other" does not have any permissions on this file.

Setting the Maximum Permissions Mask

The *maximum permissions mask* controls the maximum permissions that will be given to any user or group added to the ACL list. Note that the mask applies only to users and groups that are given access to the file or directory with an ACL entry; the mask doesn't affect the owner's permissions. It also does not affect the permissions that the default group has, nor does it affect the permissions of the rest of the users on the system. For anyone not listed in an ACL entry, the standard file access permissions apply.

The `setfacl` command is used to add, modify, or delete entries from the ACL list. The syntax is:

```
# setfacl action permissions filename
```

where *action* is a flag specifying the action that should be performed (adding an entry, modifying an entry, deleting an entry, and so on), *permissions* is the string representing the ACL permissions that should be set, and *filename* is, of course, the name of the file or directory that the ACL should be applied to. The following example adds an ACL maximum permissions mask of "read" to the file `acltest.txt`:

```
# setfacl -m m::r acltest.txt
# getfacl acltest.txt
#file:acltest.txt
#owner:0
#group:0
user::rw-
group::r--
mask::r--
other::---
```

In the `setfacl` command, the `-m` option means that you want to add or modify the ACL entry. The `m::` specifies that you want to set a mask, and the `r` simply means "read." If you want to also set the mask to allow write permissions, you would use `m::rw`. The last argument is, of course, the name of the file you want this operation to be performed on.

After you have set the mask, `getfacl` displays the same information it displayed the first time, but this time it shows that there is a mask set.

Adding a User or Group to an ACL

The strength of an ACL is that it allows you to specify more than one rule for a given permission context. For example, even though standard permissions on `acltest.txt` might state that only the owner (root) gets read access and all other users have no access, an ACL can specify explicit privileges for users or groups other than the owner, as you will see here.

To add a user or group to an ACL, you once again use the `setfacl` command. For example, to give the user `frank` read access to the file `acltest.txt`, you can use the following command:

```
# setfacl -m u:frank:r acltest.txt
# getfacl acltest.txt
#file:acltest.txt
#owner:0
#group:0
user::rw-
user:frank:r--
group::r--
mask::r--
other::---
```

As you can see, an entry has been added to the ACL for the user `frank` (users specified by name in ACLs are listed in the field between the first pair of colons). This user will now have read access to the file, even though the standard file permissions would not normally give it to him.

So, what happens if you try to give the user write permissions as well as read permissions? The following command would give `frank` both read and write permissions on the file:

```
# setfacl -m u:foobar:rw acltest.txt
# getfacl acltest.txt
#file:acltest.txt
#owner:0
#group:0
user::rw-
user:frank:rw-
group::r--
mask::rw-
other::---
```

The `getfacl` output shows that `frank` was indeed given write permissions to the file. Notice also that the mask has been updated automatically to give a maximum permission of read and write. If this behavior is undesirable (in other words, you do not want the mask to be updated), use the `-n` option when setting the ACL. For example, the following command sets an ACL that gives the user `frank` read and write access to the file:

```
# setfacl -n -m u:foobar:rw acltest.txt
```

This command won't update the mask, however, even if the current mask does not allow write access. See `man setfacl` for a discussion of what exactly this means about how the permissions will be applied under varying circumstances.

Tip

The order of the options is important. The `-n` option must come before the action option (in this case, `-m`). If you reverse the order of the two options, you will get the following error:

```
setfacl: acl_from_text() failed: Invalid argument.
```

Caution

Remember that if you set a new ACL without using the `-n` option, the maximum permissions mask will automatically be updated to allow the permissions. For example, if the mask is currently set to allow maximum permissions of read-only, and you add an ACL for a user that allows read and write, the mask is updated automatically to allow both read and write privileges. Always remember to use the `-n` option if you do not want this to happen.

Tip

When the `-n` option is not used and the mask is automatically updated, it will increase the permissions if a new ACL is added that has greater permissions than the mask currently allows. The mask will also automatically be lowered to the maximum permissions needed to support all the entries in the ACL. For example, if you delete an ACL entry that allows read and write access to a certain user, and after you delete this entry there are no other entries left that require write access, write access will automatically be removed from the mask. Just as you can use the `n` option to prevent the automatic raising of the mask, you can use the option to prevent the automatic lowering of the mask.

After giving `frank` read and write access to the file, your ACL should now look like this:

```
#file:acltest.txt
#owner:0
#group:0
user::rw-
user:frank:rw-
group::r--
mask::rw-
other::---
```

If you want to change your mask back so that it allows maximum ACL permissions of read-only, use the following command:

```
# setfacl -m m::r acltest.txt
```

If you then run the `getfacl` command again, you get the following output:

```
#file:acltest.txt
#owner:0
#group:0
user::rw-
user:frank:rw-                # effective: r--
group::r--
mask::r--
other::---
```

Notice that the user `frank` still has read and write permissions listed. However, because of the mask, frank's effective permissions are read-only.

You can also add several ACLs with a single command line by separating them with commas. Here's an example:

```
# setfacl -n -m u:frank:rw,u:guest:r,g:visitors:r acltest.txt
```

This command gives read and write access to the user frank, read access to the user guest, and read access to the group visitors. In addition, the use of the -n option prevents the mask from being updated, even if the current mask doesn't allow some of the permissions you assign in this statement.

Denying Access with ACLs

Just as an ACL can be used to allow users and groups to have access to a file or directory that they otherwise could not access, it can also be used to deny access to users and groups that otherwise would have access. For example, the following command creates an ACL entry for the user frank that contains no permissions:

```
# setfacl -m u:frank: acltest.txt
```

In this case, the user frank is denied all access to the file acltest.txt, even if frank is a member of the group that owns the file and that group has access to the file. The ACL overrules the standard file permissions and denies the user access, even if the standard file permissions would allow him access.

It's important to realize, however, that denying access on an individual user basis is far less secure than simply denying access by default and then enabling access for trusted users. It's always possible, after all, that a user you're trying to block might be able to access the system through another account that isn't blocked by the ACL.

Deleting ACL Entries

Use the -x option with setfacl to delete an ACL entry. For example, the following command removes the entire entry for the user frank:

```
# setfacl -x u:frank: acltest.txt
```

Use the -b option to remove all the ACL entries on the file. Here's an example:

```
# setfacl -b acltest.txt
```

For more information on the capabilities of ACLs, including the capability to set default ACLs for directories, see the man pages for getfacl and setfacl.

PREV NEXT

Adding and Removing Users

Now that we have covered permissions and ownership, we need to turn our attention to expanding the system's user base to include more users and groups.

Use the `adduser` script to add users to the system. This program differs somewhat in workflow from the `adduser` and `useradd` scripts you might be accustomed to using on a Linux system, but it accomplishes the same thing. You must be root (or use `sudo`) in order to run `adduser`.

Setting Up `adduser` Defaults

Before using `adduser` to add any users, you should first run it with the `-C` option to create a configuration file that defines its default behavior, setting up the standard policies for the users you'll be adding. You can specify users' options (such as shells, member groups, and password behaviors) at the time you create each one, but having a predefined config file with default settings makes this job a lot easier. Listing 13.2 shows an initial run of `adduser -C`.

Listing 13.2. Configuring the `adduser` Script

```
# adduser -C
Login group []:
Enter additional groups []:
Login class [default]:
Shell (sh csh tcsh bash nologin) [sh]: csh
Home directory [/home/]:
Use password-based authentication? [yes]:
Use an empty password? (yes/no) [no]:
Use a random password? (yes/no) [no]: yes
Lock out the account after creation? [no]:
Pass Type  : random
Class      :
Groups     :
Home       : /home/
Shell      : /bin/csh
Locked     : no
OK? (yes/no): yes
Re-edit the default configuration? (yes/no): no
Goodbye!
```

The default setting for each option is shown in brackets, and pressing Enter will accept the default. In this sample run of `adduser -C`, I specified a few non-default settings, specifically the `csh` shell (which is the same as `tcsh`), and to have the script create a random password for each new user. At the end of the script, the file `/etc/adduser.conf` is written, and you can edit it further with a text editor if you want, or simply run `adduser -C` again to change its default settings.

Some settings, such as the login group, are best left blank, as they will be filled in with the username when you add an actual user. The same goes for the home directory setting (`/home/`); in this case, it defines the base directory where users' home directories will reside, each one named with the appropriate username.

Adding a User with `adduser`

After you've set up your default settings for `adduser`, you can use it to start adding users to the system with minimal input from you. Listing 13.3 shows a sample run of the script.

Caution

Usernames must be 16 characters in length or fewer, and cannot contain any special characters other than the ones in the brackets: [-_.]. Convention dictates that usernames should only contain lowercase letters and numbers, but capital letters are accepted in FreeBSD. However, you should bear in mind that other systems might not be so lenient, and a username with capital letters on your FreeBSD system might not work on another system the user wants to join. Similarly, commonly used protocols such as SMTP expect lowercase usernames, and mixed-case names might cause problems in email. You might want to standardize your usernames on the traditional lowercase-only format just to make sure they don't run into any nasty surprises. Similarly, some other flavors of UNIX (including older versions of FreeBSD) only allow usernames up to 8 or 12 characters in length; you might want to discourage users from choosing longer usernames for compatibility's sake, even though FreeBSD accepts them.

Listing 13.3. A Sample `adduser` Session

```
# adduser
Username: joe
Full name: Joe User
Uid (Leave empty for default):
Login group [joe]:
Login group is joe. Invite joe into other groups? []:
Login class [default]:
Shell (sh csh tcsh bash nologin) [csh]:
Home directory [/home/joe]:
Use password-based authentication? [yes]:
Use an empty password? (yes/no) [no]:
Use a random password? (yes/no) [yes]:
Lock out the account after creation? [no]:
Username    : joe
Password    : <random>
Full Name   :
Uid         : 1002
Class       :
Groups      : joe
Home        : /home/joe
Shell       : /bin/csh
Locked      : no
OK? (yes/no): yes
adduser: INFO: Successfully added (joe) to the user database.
adduser: INFO: Password for (joe) is: cwwqAuSpwd0rYG
Add another user? (yes/no): no
Goodbye!
```

Pressing Enter after every prompt accepts the default value, which was defined in `/etc/adduser.conf` after your configuration run. You can specify any non-default setting you want for a given user (as long as the option is offered in the parentheses), and your choice won't affect the default setting in the config file for future users.

If you like, you can create a text file called `/etc/adduser.msg` that will be emailed to the new user at the new local account. The user is able to read it the first time she logs in to the system and runs a mail program (more on reading mail can be found in Chapter 25, "Configuring Email Services"). This is an excellent way to send out a "welcome" message to all newly added users, explaining the rules of the system and pointing out a few helpful tips. However, the `adduser.msg` file won't be mailed out to users by default, and `adduser -C` doesn't let you specify that it should; to enable `adduser` to send out the message file, you have to manually edit `/etc/adduser.conf` and add the following line:

```
msgflag=yes
```

If you chose to have `adduser` create random passwords for each user (as in this example), take special note of the line at the end of its run where it tells you the password it generated. You'll need to copy down this password (in this case, `cwwqAuSpwd0rYG`) and inform the user of it, in as secure a manner as possible (preferably over the phone or in person). The user can then use the `passwd` command to change his password to something of his choice the next time he logs in.

Note

If you don't choose to have `adduser` generate random passwords for each user (or accept blank ones, which is inadvisable), you'll be prompted twice to enter a password for the user. Choosing a good, secure password is a key skill in any Internet application and particularly so when it comes to administering a UNIX server. Good passwords are at least six characters long and contain a mixture of letters, numbers, and special characters. Don't use words that can be found in the dictionary, and especially don't fall into the trap of doing something easy like using the username as the password. Further discussion of ways to improve password security, including setting up password expiration intervals and enforcing password obscurity, can be found in Chapter 30.

At the end of the script, after you enter **`yes`** at the `OK?` prompt, `adduser` creates the user's account and sets up his home directory. The following "dotfiles" (which are only visible if you use the `-a` option on `ls`) are copied into it from `/usr/share/skel`:

```
.cshrc          .login_conf      .mailrc          .rhosts
.login          .mail_aliases    .profile         .shrc
```

These files, which configure the behavior of the user's shell and other applications, are explained in more detail in the section titled "Shell Initialization Files," in Chapter 9, "Customizing the Shell." If you want to modify their behavior so that each new user gets a customized version of a dotfile (for example, to add a helpful alias to a certain systemwide command you've installed), modify the original source file. For example, `/usr/share/skel/dot.cshrc` becomes `.cshrc` in a new user's directory.

Note

Each user and group has a numeric equivalent to its name, user ID (UID), and group ID (GID). This ID is listed in the ownership information of a file or directory and is used to control processes. If you remove a user from the system, that user's files become owned by the UID number that the user left behind.

Use the `finger` command to see that the user has been added successfully:

```
# finger joe
Login: joe                              Name: Joe User
Directory: /home/joe                    Shell: /bin/csh
Never logged in.
Mail last read Wed Dec 7 12:40 2005 (PST)
No Plan.
```

Removing a User with `rmuser`

Removing a user is a fairly simple matter. The command here is `rmuser`, which takes the username as an argument (`adduser` does not), as shown in Listing 13.4.

Listing 13.4. A Sample `rmuser` Session

```
# rmuser joe
Matching password entry:

joe:*:1008:1008::0:0:Joe User:/home/joe:/bin/csh

Is this the entry you wish to remove? y
Remove user's home directory (/home/joe)? y
Removing user (joe): mailspool home passwd.
```

The line about the "matching password entry" describes the database in which all the user information is kept, which brings us to our next topic.

The `/etc/passwd` and `/etc/master.passwd` Files

User information is kept in a file called `/etc/passwd`. All UNIX-flavored operating systems have an `/etc/passwd` file, but the file's specific role differs from platform to platform. For some systems, `/etc/passwd` is the sole repository of user information (including passwords). In these cases, adding a user requires only that you add a line to the file using a text editor. More modern operating systems, though, use a "shadow passwords" structurea way of storing the encrypted password strings not in `/etc/passwd`, but in a different file that is readable only by root. This file's name varies, depending on the platform. On some systems, it's `/etc/shadow`; on others, it's `/etc/security/master.passwd`. On FreeBSD, it's `/etc/master.passwd`.

Both `/etc/passwd` and `/etc/master.passwd` will be very important to you as a FreeBSD administrator. These files are both simple text databases, containing a line for each user with fields delimited with colons (`:`). The files contain the username, the user ID, the group ID of the primary group, the home directory, the login shell, and the full name (which also has embedded comma-delimited fields such as Office Location, Office Phone, and Home Phone).

The permissions on `/etc/passwd` are `0644`; on `/etc/master.passwd`, they're `0600`. (Both files are owned by root.) This security scheme means that any user can access the information in `/etc/passwd`, but root is the only one who can see into `/etc/master.passwd`, which differs from `/etc/passwd` only in that it contains the users' encrypted passwords in the second field. Passwords are encrypted in FreeBSD using a hash scheme based on the MD5 algorithm. Here are examples of each:

```
/etc/passwd:
joe:*:1008:1008:Joe User:/home/joe:/bin/csh

/etc/master.passwd:
joe:$1$32iknJXS$TnJUJj9LzYGwWRZonOu/I0:1008:1008:Joe User:/home/joe:/bin/csh
```

These two files aren't the only ones that store user information, though. Flat text databases are fine for a fairly small number of users, but as the user base grows, the need for a faster, hash tablebased lookup database becomes more and more obvious. On a system with thousands of users in a linear text database, looking up a user's information can take a significant amount of timewhile the user is waiting to log in!

This is why FreeBSD also has `/etc/pwd.db` and `/etc/spwd.db`. These files are hash tables in `db` format, corresponding to the "insecure" `/etc/passwd` and the "secure" `/etc/master.passwd`, respectively. They also have the same permissions as their corresponding clear-text files. These files provide a fast lookup mechanism for large user databases, and they're generated by the `pwd_mkdb` program automatically every time you alter a user's information with the `chfn`, `passwd`, or `adduser`/`rmuser` commands. All of FreeBSD's component programs and many third-party applications get their user information from `/etc/pwd.db`.

Note

A *hash table* is a software construct in which a piece of data can be looked up quickly by jumping directly to its location in a file, which is calculated based on a known algorithm, instead of searching for it linearly. For example, it would take forever for you to look up a word in the dictionary by starting at Page 1 and looking at every word to see if it matches; but because you know the algorithm called "alphabetical order," you can jump directly to the place in the dictionary where you know the word will be found. Hash table files, like `/etc/pwd.db` and other similar lookup databases, work the same waythey just need to be stored in a special format that also describes the algorithm necessary for searching them.

Speaking of which, the `chfn` (change full name) command is the tool you use to change a user's information. Like the `edquota` command we examined in the last chapter, `chfn` operates by invoking the editor specified in your `EDITOR` environment variable (`vi`, by default). You can then modify any of the text fields. Upon saving and exiting, the `/etc/master.passwd` file is rewritten, and `pwd_mkdb -p` is automatically run to rebuild the other three files.

It is important to understand that `/etc/master.passwd` is truly the "master" user database file. Any change made in that file is propagated to the `/etc/passwd` file and the hash databases when you run `pwd_mkdb -p`. One example of how to use this to your advantage is if you want to rebuild a user list or port one from another FreeBSD machine. To do this, you can simply place the new `master.passwd` file into `/etc` (or anywhere within the `/` partition) and then issue the following command:

```
# pwd_mkdb -p /etc/master.passwd.new
```

This example assumes that your new user database file is in `/etc` as `master.passwd.new`. (You can simply overwrite `master.passwd` with a new file of the same name, but it's safer to keep it separate until you run `pwd_mkdb`.) The `/etc/master.passwd` file is replaced with your new file, and `/etc/pwd.db`, `/etc/spwd.db`, and `/etc/passwd` are rebuilt from it. The `-p` option tells `pwd_mkdb` to generate a new `/etc/passwd` file; if this is omitted, `/etc/passwd` is left unchanged. You will probably want to use `-p` at all times to keep the two files synchronized.

The `/etc/group` File

Groups are handled in much the same way as userswith a text database in `/etc`. But because groups normally don't have passwords, there is no need for special security on the `/etc/group` file (the group equivalent of `/etc/passwd`), other than having it writable only by root.

The following is a sample line from `/etc/group`. Note that there are only four fields: the group name, a "dummy" field (in which passwords would go if they existed), the group ID, and then a comma-separated list of the users in the group:

```
wheel:*:10:root,bob,frank
```

There is no hash database for `/etc/group` because the file's information generally is referenced much less frequently than the information in `/etc/passwd` and because most systems have far fewer groups than users. FreeBSD's policy of creating a personal group for every user, however, makes that latter point moot. Future development may produce a hash file for groups, if it proves to be necessary.

Managing Groups

Without passwords, user access, and a hash file to worry about, adding a group to the system is much easier than adding a user. You can simply open the `/etc/group` file in any text editor and create a new line in the format listed earlier (make sure to give the new group a group ID that has not yet been used). A typical workflow is to duplicate an existing group line and then modify the name and GID fields to make them unique.

New groups are added automatically by the `adduser` script when it creates unique per-user groups. The group IDs typically match the corresponding user IDs, but that is not a requirement. You will most likely only be interested in adding systemwide groupsfor example, for tasks such as running a web server or a database back-end. These groups generally ought to have group IDs in the range of 100 to 1000. The numbers above 1000 are usually used for unique per-user groups, to match the corresponding user IDs, which begin by default at 1001. The numbers under 100 tend to be populated by system groups that are part of the core operating system, and you shouldn't use any old unused number because a software package you install later might want to use that number for its own application group.

To add a user to a group, type the user's name into the fourth field. If there are already usernames in the fourth field, separate them with commas, as shown previously. You can remove a user just as easilysimply delete the name.

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User Management Using NIS

If your FreeBSD machine is on a corporate or university network with centralized user management, it's likely that there is a NIS (Network Information Service) server available that you can use. This service (also known as YP, or Yellow Pages) provides user and group information to any subscribed machine, allowing all UNIX users throughout the network to be registered and managed on a single central server.

Note

In many modern networks, LDAP and Active Directory are replacing NIS as the standard method for centralized user management. It's possible, though not particularly straightforward, to join a FreeBSD machine to an Active Directory network using the Samba package; see http://web.irtnog.org/howtos-orig/freebsd-winbind/view for the necessary procedure.

You might want to add users to your FreeBSD system in such a way that they can log in using their established NIS usernames and passwords, rather than making them use local accounts on your system with separately managed passwords and user information. To do this, you first must register your machine as a client of the NIS server by adding the following two commands to your `/etc/rc.conf` file, using your own network's domain name in the `nisdomainname` variable:

```
nisdomainname="example.com"
nis_client_enable="YES"
```

Then either restart the computer, or start the NIS domain client manually with the following command:

```
# /etc/rc.d/nisdomain start
Setting NIS domain: example.com.
```

Check to see that your system found a NIS server using the `ypwhich` command:

```
# ypwhich
olympus.example.com
```

If `ypwhich` returned the correct name of your network's NIS server, you're ready to start adding NIS users.

Edit `/etc/master.passwd` in your favorite text editor, and add a line for each NIS user with a `+` sign in front of the username and all of the fields blank except for the last two:

```
+fred::::::::/home/fred:/bin/csh
```

Save the file and run `pwd_mkdb -p /etc/master.passwd` to rebuild the hash databases. Now use `finger` to verify that the user has been added properly:

```
# finger fred
Login: fred                               Name: Fred Hudson
Directory: /home/fred                     Shell: /bin/csh
Never logged in.
No Mail.
No Plan.
```

If `finger` returns the correct user information, the newly added user should be able to log in to your FreeBSD system using his NIS username and password. The UID and GID of the user are inherited from the NIS server, and all files created by the user are owned by that UID/GID combination, rather than by any IDs under the local system's numbering scheme.

Tip

If a NIS user tries to change his password using the `passwd` command on the FreeBSD machine, it will transmit the changed password back into the NIS system so that it's updated at the central server.

Removing a NIS user follows the same procedure as removing a regular user: you use the `rmuser` command, and specify the user's regular username, without the `+` sign indicating that it's a NIS account:

```
# rmuser fred
Matching password entry:

fred:*:20441:101::0:0:Fred Hudson:/home/fred:/bin/csh

Is this the entry you wish to remove? y
Remove user's home directory (/home/fred)? y
Removing user (fred): mailspool home passwd.
```

Note that the matching password entry is the one inherited from the NIS server, not the dummy one from your own `master.passwd` file. The user is now no longer part of your system, but he's still registered in the central NIS database.

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Chapter 14. System Configuration and Startup Scripts

IN THIS CHAPTER

You saw a brief discussion of the process of starting up your FreeBSD system in Chapter 4, "Booting and Shutting Down FreeBSD." That chapter gave a basic description of what's going on behind the scenes during each cryptic phase of startupenough to enable you to boot the system under standard operating conditions. In this chapter we will expand on the earlier rudimentary coverage to give you a fuller understanding of what each startup phase does and how to control it.

You might have come to FreeBSD from a Linux background; if so, you'll already be familiar with the mechanics of a UNIX-style system startup procedure. However, there are a number of aspects of FreeBSD's startup process that might be unfamiliar even to a veteran. For example, you won't have the handy `fsck` progress meter or the neatly formatted check boxes for each launched component that are available in some distributions of Linux, and the FreeBSD boot manager operates quite differently from GRUB and LILO (the boot loaders widely used in Linux). Neither does FreeBSD have the large variety of selectable *run levels* that Linux and Solaris have (where the system can be brought up into any of several different modes, with more or fewer services running, usually for the purpose of troubleshooting or administrative tasks). Because FreeBSD's startup model is simpler and more direct than on these other systems, it can be easier to understand and maintainbut it also has pitfalls and complexities that other platforms lack. With a little exploration, though, you'll soon have FreeBSD's startup process fully analyzed and under control.

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Understanding the FreeBSD Startup Process

FreeBSD's bootstrapping (startup) process is the means by which the system's kernel is first located within its BSD partition and slice on your hard disk, and then launched in the manner necessary to activate all your hardware devices and make the system available to users. Accomplishing all this is more difficult than it soundsit's far from a straightforward procedure. Because of the way that PC hardware works, with bootable hard drive partitions governed by the BIOS (Basic Input/Output System) software located on a chip on the motherboard, FreeBSD must launch itself in several stageseach stage having a very limited function and scope, and each executing one crucial step before passing off control to the next stage.

As you'll learn in Chapter 20, "Adding Hard Disk Storage," the hard disk is divided into partitions (which FreeBSD refers to as "slices"); the BIOS can only look for a Master Boot Record (MBR) in one of these partitions, rather than in the secondary partitioning scheme known as "BSD partitions" (where the FreeBSD kernel is located). The BIOS can't address the kernel directly and has no knowledge of how to launch it even if it couldthere are several levels of increasingly complex addressing schemes in between. This means that at each level of the architecture dictated by legacy PC hardware standards, there must exist a FreeBSD *boot block*a small chunk of executable code that has the ability to look one level deeper into the boot process, understanding the architecture of the next stage and knowing how to launch the next boot block. This process continues stage by stage until the kernel is finally located and launched. Chances are that you won't ever need to know the details of how these boot stages work, but knowing them can't hurtespecially if you're trying to figure out why something went wrong!

When you first power on the machine, the first thing FreeBSD does is run the hardware checks and probes that are specified by the BIOS and the CMOS configuration. This part of the startup process depends entirely on your hardware configuration. In it, your RAM is checked, any SCSI controllers you might have installed are activated and tested, and you're given the opportunity to reconfigure your BIOS. This stage doesn't have anything to do with FreeBSDit occurs the same way whether you've got FreeBSD installed on your hard disk, Windows, or even no operating system at all.

Moving Through the Boot Process

After the BIOS prints a table showing the hardware data it has collected, it reads the Master Boot Record (MBR) of the primary disk for the first and most rudimentary boot block. It is the job of this and the next two boot blocks to find and run the *loader*, which configures and loads the kernel. Each boot block is sequentially a little more complex than the previous one. The first two are limited to 512 bytes in size (by the standardized sizes of the MBR and of the boot sector of a given slice), so they are both very simple. Here are each of the boot blocks and their functions:

- Boot block 0 (`boot0`)This preliminary boot block is what sits in the MBR, like LILO, and (if the FreeBSD boot manager is installed) lists the available slices (the F-key commands that follow) from which you can choose what you want to boot:

  ```
  F1 FreeBSD
  F2 Linux
  F3 ??

  Default: F1
  ```

  You can press the appropriate F-key to select the slice you want or else just wait for several seconds, in which case boot block will choose the default selection and continue.

- Boot block 1 (`boot1`)This a very simple program that runs from the boot sector of the slice you selected in `boot0`, and its job is to use a stripped-down version of `disklabel`, the program that divides a slice up into BSD-style partitions (this functionality is covered thoroughly in Chapter 20) to find and run `boot2` in the appropriate BSD partition. There is no user-interface portion to `boot1`.

- Boot block 2 (`boot2`)Finally, we reach a boot block that has enough elbow room to have the necessary complexity to read files on the bootable filesystem. In earlier versions of FreeBSD, this boot block used to provide a prompt so you could tell it where to load the kernel from, if not from the default location in the root partition. Now it automatically runs a program called the loader, which gives you control over the kernel's options through a full-screen textual menu.

- LoaderYou can find this program in the `/boot` directoryand that's where `boot2` finds it, too. It reads the `/boot/defaults/loader.conf` and `/boot/loader.conf` configuration files and loads the kernel and modules specified there. (The `/boot/loader.conf` file contains the overrides to `/boot/defaults/loader.conf`, in a similar fashion to the way `/etc/rc.conf` works, which we cover later in this chapter.) Refer to Figure 4.1 in Chapter 4 to see the available menu options in the loader.

  The loader counts down 10 seconds while it waits for you to press a key and select a boot option; if you don't do anything, it boots the kernel in its default mode, with all drivers and functionality intact. Several other menu options are available, however, which allow you to control more precisely your kernel's boot behavior. You can boot in Safe Mode (with a limited kernel missing many potentially conflicting drivers) or single-user mode, using options in the menu itselfor, if you choose option 6, Escape to Loader Prompt, you can interact with the loader in a commandline environment that gives you still more flexibility. At the loader prompt you can boot a different version of the kernel, boot from CD-ROM or DVD, load and unload kernel modules manually, view the contents of files, or perform a number of other tasks (see `man loader` for details). Most of the time, you'll be booting your computer in its default configuration, so you don't even need to touch the computer at the loader stage; it will boot automatically without any user interaction. Suppose, however, that you want to load a certain kernel module (`/boot/kernel/portal.ko`) at boot time, rather than waiting until the system has completely booted. You also want to view the currently loaded kernel modules. You can perform these actions at the loader's `ok` command prompt, as follows:

  ```
  ok load portal.ko
  /modules/portal.ko text=0x1d18 data=0x1f4+0x4 syms=[0x4+0x8d0+0x4+0x6bf]
  ok lsmod
   0x100000: kernel (elf kernel, 0x355be4)
   0x455be4: /boot/kernel.conf (userconfig script, 0x4c)
   0x456000: portal.ko (elf module, 0x3eb0)
  ```

  Typing **?** at the `ok` prompt gives you a list of available commands. The two you just saw are `load`, which loads modules into the kernel, and `lsmod`, which lists the currently loaded modules. This command can be very useful during troubleshooting or if you use kernel modules that must be loaded in a specific order. For further details on the options available at the loader command line, consult `man loader`.

This concludes the boot block phase of the bootstrapping process. FreeBSD has successfully run each piece of code that leads along the path to the bootable kernel, and the final phase of the boot process is where the complete FreeBSD system starts to come into play. That's where the kernel loads itself into memory, probes its available devices, and runs the resource configuration scripts that construct a working environment and start up the various system services. The remaining steps are as follows:

1. After the loader transfers control to it, the kernel begins to probe all the devices it can find, and the results of each probe are echoed to the screen. This is the time when you will see many cryptic messages in bright white filling the screen. These lines are logged into the kernel message buffer, which you can read with the `dmesg` command if you need to see what the kernel had to say about a certain device.

2. After the kernel loads, it passes control to the `init` process, the final stage in the startup procedure. This is signaled by the `Automatic reboot in progress` message, which involves `init` running the global resource configuration script (`/etc/rc`). This script first uses the `fsck` program to check all the filesystem devices in `/etc/fstab` for consistency, as discussed in Chapter 12, "The FreeBSD Filesystem."

3. If `fsck` finds no problems it cannot correct on its own, it will mount all the filesystems (using `mount -a -t nonfs`) and continue running the rest of the startup processes. If `fsck` finds an unresolvable problem with the disks, it will exit to single-user mode for you to run `fsck` manually and repair the damage. (You will need to run `/sbin/mount -a` to mount your filesystems in read/write mode if you need to make changes to any files.) Exit the single-user shell to continue rebooting into multiuser mode.

Finally, if all goes according to plan, you get a login prompt, and the system is up and ready for use. This whole process usually takes no more than a minute.

Securing the Boot Process

Of concern to the security-conscious administrator is the fact that by default, if you choose to boot into single-user mode (option 4 in the loader menu, or `boot -s` at the loader command prompt), you are not prompted for a password, and the system comes up automatically with full root access. If you're sharing the machine with anyone else, such that this person can sit down in front of the machine and physically reboot it if he wants to, this constitutes a grave and gaping security hole.

Fortunately, it's easy to plug this hole. In `/etc/ttys`, which contains terminal settings for the various access methods (the console, virtual terminals, serial terminals, and network [pseudo] terminals), you can change the setting on the `console` line from `secure` to `insecure`:

```
console none                    unknown off insecure
```

This tells the system to treat the console as an insecure access point and to present a challenge (login prompt) to anyone who tries to boot into single-user mode. The root password is required in order to pass this challenge point.

Note

The `console` terminal method is only used in single-user mode. When you're booting into full multiuser mode, multiple virtual terminals are available at the physical terminal (you can switch between them with Alt+F1, Alt+F2, and so on). These terminals always present a login prompt. The `secure` and `insecure` settings in this case control whether you can log in as root or whether you're required to log in as a regular user and then use `su` to gain root access.

If others have access to the physical terminal (even if you've secured the single-user console), you have a second security hole to plug. This security weakness results from the fact that Ctrl+Alt+Delete causes the system to reboot, whether or not you're logged in as root, or even logged in at all. The three-finger-salute works even at the login prompt. Allowing this kind of access is appropriate in some situations (a rack-mounted server in a trusted machine room, for example), but not in others. To disable it, you'll need to add an option to your kernel configuration and rebuild the kernel:

```
options         SC_DISABLE_REBOOT
```

Other important considerations in securing your FreeBSD machine's operating environment are to make sure that it can't be booted from any device other than the primary hard drive (to protect against, for example, someone booting it from a CD-ROM or an external hard drive), and to protect the BIOS with a password. Of course, if unauthorized persons have physical access to the machine, you can't ever completely protect it; the best policy is to ensure that the operating environment is secured against all unauthorized access.

For a detailed discussion of kernel options and configuring your kernel, see Chapter 18, "Kernel Configuration."

What Can Slow Down the Boot Process?

You should allow about a minute after leaving the loader menu before you see the login prompt signaling the end of the boot process. There's usually no reason for it to take any longer than thisbut there's always the possibility that something is going wrong and needs to be corrected. Because of the scripted, serial nature of the boot process and the verbose console messages emitted during startup, it's fairly simple to see where it's hanging. Two common culprits are Sendmail and `httpd` (Apache); in both cases, the associated slowness results from a network connectivity problem or misconfiguration.

Both Sendmail and Apache have to figure out your machine's hostname. To do this, they need to perform a reverse lookup against the domain name server (DNS) configured in `/etc/resolv.conf`. (TCP/IP setup will be covered thoroughly in Chapter 23, "Configuring Basic Networking Services.") This lookup will have to time out for every configured name server before it fails and allows the startup process to proceed. Network timeouts are often fairly long, which is why networking is the most common cause of boot hang-ups. One solution to this problem is to make sure the name server listed first in `/etc/resolv.conf` is reachable from your FreeBSD machine. This ensures that Sendmail and Apache will be able to determine the machine's hostname and start up without delay. If this configuration is not possible, list **`127.0.0.1`** (`localhost`) as the first name server and disable the rest.

Incidentally, this potential slowdown is why `init` uses the `nonfs` mount type (`mount -a -t nonfs`) when doing its initial "preen" to see whether it can safely go into multiuser mode. NFS, the Network Filesystem, has an astonishingly long timeout period, and a process waiting for that timeout to elapse can be almost impossible to kill. The `nonfs` option on the `mount` command, which you learned about in Chapter 12, avoids mounting NFS resources until later, in the resource configuration phase, so that it can come up properly in multiuser mode without user intervention.

However, `init` does mount all filesystems later in `/etc/rc`, including NFS ones. Any NFS resources that you configured for automatic mounting in `/etc/fstab` (for example, without the `noauto` option) have the potential to freeze the system for a long time when the `/etc/rc` script reaches that point. Therefore, don't auto-mount NFS resources at boot unless you're sure they'll always be available to your machine on the network!

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Resource Configuration Scripts

After `init` has been started, the remaining startup tasks in the systemthe ones that start all the services and operating system processesare handled by the *resource configuration* scripts. These scripts are compartmentalized based on their functions, and are all kept inside the `/etc/rc.d` directory.

The `/etc/rc.d` Directory

The resource configuration scripts in the modern versions of FreeBSD are all kept inside `/etc/rc.d`. Each shell program in this directory is a resource configuration script, a program that starts up a specific component of FreeBSD according to the system's configuration. Some of these scripts are called recursively from other programs; some do nothing in the out-of-the-box configuration; and some, written to address certain unusual configurations and deployments, will probably never even be run on your system. All executable files in the directory are run automatically by `init`, harnessed through the master `/etc/rc` script.

You'll probably never need to edit any of the scripts in `/etc/rc.d`they're all designed to handle the dirty work of launching certain infrastructural services or daemons, and they take their configuration information from other sources, such as the `/etc/rc.conf` file. All you should ever need to modify are the configuration files, never the scripts themselves.

Tip

You can write your own resource configuration scripts to handle services or components that aren't part of the standard FreeBSD system, and if you put them in `/etc/rc.d`, they'll runbut a much better place to put them is in `/usr/local/etc/rc.d`, the "local" equivalent of `/etc/rc.d` (in other words, the directory that's set aside for resource configuration scripts that you install yourself). Scripts in `/usr/local/etc/rc.d`, such as the startup scripts installed along with many third-party software packages, are executed automatically after all the `/etc/rc.d` scripts have been run. Keeping them separate from the `/etc/rc.d` scripts makes it much easier to restore your system from a backup, or cleanly migrate your system's configuration to a new machine, if such needs should arise.

A utility called `rcorder` is used by `/etc/rc` to define the specific execution order for the resource configuration scripts. To see the order in which they're executed, type **`rcorder /etc/rc.d/*`** (this lists the files in the execution order defined by the keywords and prerequisite scripts listed in the headers of each of the files). Scripts with no prerequisites are executed first; then they're followed by the scripts that depend on the earlier scripts having been run already. See the `PROVIDE`, `REQUIRE`, and `KEYWORD` lines in each script; refer to `man rcorder` to see a fuller discussion of how they work, and `man rc` for more details on how `rcorder` is used to sort FreeBSD's resource configuration files.

Table 14.1 lists many of the more important resource configuration files in a stock FreeBSD 6.x system.

Table 14.1. Resource Configuration Scripts

Script Name	Description
`/etc/rc`	The master resource config script, which reads the configuration settings from `/etc/rc.conf` and then executes the scripts in `/etc/rc.d`.
`/etc/rc.subr`	An included script that defines subroutines used in the many scripts that reside in `/etc/rc.d`.
`/etc/defaults/rc.conf`	`init` reads in this file early in its execution to fill in its laundry list of tasks to do.

/etc/rc.conf	This is the file you edit to override the defaults set in /etc/defaults/rc.conf. This should be the *only* resource config file in /etc that you edit!
/etc/rc.d/	Resource Configuration for Daemons. Several dozen launch scripts in this directory are executed in the order defined by the rcorder utility. Most of these scripts' functions can be easily determined from their names; fsck runs the disk checks, named starts the name server, usbd activates the USB subsystem, and so on.
/usr/local/etc/rc.d/	Directory trees /usr/local/X11R6/etc/rc.d/ containing any new startup scripts you write (or are installed automatically when you add third-party software).

Note

FreeBSD versions prior to 5.0 kept their resource configuration files in the /etc directory, each one with an rc. prefix. If you're working with a FreeBSD version early in the 5.x series, where the files might not be completely migrated to the new structure from an earlier 4.x installation, you have the option to use the old-style structure. In your /etc/rc.conf file, turn off the rc_ng (RC Next-Generation) option, and FreeBSD will use the /etc/rc.* files rather than the /etc/rc.d/* files to control its startup procedure. Here's how:

```
rc_ng="NO"              # Set to YES to enable new-style rc. Experimental.
```

This technique can ease the transition to FreeBSD 5.x or 6.x if you don't want to risk destabilization from the new startup script structure. However, there is no reason to turn off the rc_ng option on a new installation, and indeed in FreeBSD 5.2 and later the option does not exist.

The /etc/defaults/rc.conf File

The resource configuration scripts are controlled by global system settings that are specified in either of two places: /etc/defaults/rc.conf and /etc/rc.conf. The former of these files is a part of the system and shouldn't be modified; the latter is the global configuration file that's yours to edit, and whose settings control all variations in system behavior from how it runs in its default configuration.

Take a look through some of the resource configuration scripts (such as /etc/rc.d/named) using your favorite text editor. You'll see that each one is completely automated; it works by checking whether certain variables are defined that control system configuration or whether certain files exist. If those variables or files are present, it executes a predefined, abstracted launch loop, which takes its parameters from those variables and files. Nothing in /etc/rc itself, or any of the standard scripts, should be edited. In other operating systems, the system startup process is altered and extended by making changes to the resource configuration scripts themselves; in FreeBSD, though, the model is to automate and abstract as much as possible of the process and centralize the control files that specify the parameters.

In earlier versions of FreeBSD, the only configuration file was /etc/rc.conf. It contained all the variables that /etc/rc and related scripts would need in their default states, and any modifications to the system would be made to the global config file. This arrangement quickly became unmanageable, however, as the list of available variables grew and the role of the file expanded. An administrator upgrading the system would painstakingly have to merge the old rc.conf with the new onehardly an improvement over just editing /etc/rc in the first place.

Therefore, the solution was to create a directory called /etc/defaults and put a copy of rc.conf, with all the default settings filled in, into it. Now, /etc/rc.conf still exists, but as an overlay whose contentsif presenttake precedence over the settings in /etc/defaults/rc.conf. For example, if the setting named_enable="NO" appears in /etc/defaults/rc.conf, you would turn on the named server not by changing that file, but by adding named_enable="YES" to /etc/rc.conf. This latter setting overrides the default setting in the previous file. FreeBSD will run even with an empty /etc/rc.conf file, but typical overrides that you'll be using are for the networking configuration (IP address, hostname, gateway address, and so on) and for running daemons such as Sendmail and sshd.

Let's look at a typical block in /etc/defaults/rc.conf, as shown in Listing 14.1.

Listing 14.1. Excerpt from /etc/defaults/rc.conf

```
# named. It may be possible to run named in a sandbox, man security for
# details.
#
named_enable="NO"                # Run named, the DNS server (or NO).
named_program="/usr/sbin/named" # path to named, if you want a different one.
named_flags="-u bind"            # Flags for named
named_pidfile="/var/run/named/pid" # Must set this in named.conf as well
named_chrootdir="/var/named"     # Chroot directory (or "" not to auto-chroot it)
named_chroot_autoupdate="YES"    # Automatically install/update chrooted
                                 # components of named. See /etc/rc.d/named.
named_symlink_enable="YES"       # Symlink the chrooted pid file
```

Using /etc/defaults/rc.conf, you can find what /etc/rc will do by default when it comes to each service with a launch script in /etc/rc.d. In the case of named, the default behavior is to not run it at all.

Typically, variables in /etc/defaults/rc.conf are grouped into blocks like in this example, with similar prefixes keeping them related and with a single "YES"/"NO" variable serving as a "master switch" at the top of the block. If the variable is set to "NO", generally none of the rest of the variables will matter; if it is set to "YES", all variables apply unless commented out. Commented lines are usually provided as examples to demonstrate a possible alternative usage, as with these lines in the syslog block:

```
syslogd_flags="-s"            # Flags to syslogd (if enabled).
#syslogd_flags="-ss"          # Syslogd flags to not bind an inet socket
```

The /etc/rc.conf File

Let's say you do want to run named. In the simplest case, all you have to do is edit /etc/rc.conf (the "overrides" file) and add the following line anywhere in the file:

```
named_enable="YES"
```

The rest of the named_* variables in /etc/defaults/rc.conf do not need to be copied into the overrides file. Remember, every variable in the "defaults" file is loaded into memory by init, and they only matter if the "master switch" for that block has been turned to "YES". In that case, the default variables will be used in the execution loop in the appropriate script in /etc/rc.d to launch whatever process is controlled by the block you're working on (in this case, named).

Caution

As you tinker with /etc/rc.conf, it's a very good idea to keep a backup copy on hand so that you can easily back out to a known working system configuration. Create a backup file by simply copying your existing file before you begin working on it (this sample filename incorporates the current date so you can accurately retrace your steps):

```
# cp /etc/rc.conf /etc/rc.conf.backup.20060127
```

To switch back to the backup version, copy or move (rename) it back to its original name:

```
# mv /etc/rc.conf.backup.20060127 /etc/rc.conf
```

Alternatively, whenever you change a line in /etc/rc.conf, duplicate the line and comment out the old one, unaltered. That way you can always go back to the original settings if your new ones don't work.

You can use these other variables for fine-tuning, though, and override them just as easily. Let's say your name server program is a customized version called mynamed. Let's also say that you've created a bind user and group, intending that the name server should run as this user and group so it won't be susceptible to as many permissions-related vulnerabilities. To handle that, all you need to do (assuming that mynamed has the same behavior and command-line options as named) is add these two lines to /etc/rc.conf:

```
named_program="mynamed"
named_flags="-u bind -g bind"
```

Just for curiosity's sake, you can examine the appropriate launch script to find out what init is doing with these variables. A script isn't executed unless the corresponding _enable variable is set to "YES"; assuming you've enabled the service by turning on this variable, you can look through the launch script (in this case, /etc/rc.d/named) to read what's involved in the startup process for that service.

The end of that script has these lines of code:

```
load_rc_config $name
# The following variable requires that rc.conf be loaded first
#
required_dirs="$named_chrootdir"        # if it is set, it must exist
pidfile="${named_pidfile:-/var/run/${name}/pid}"

run_rc_command "$1"
```

The commands in these lines are subroutines that are defined in /etc/rc.subr, which also sets up the architecture by which the name of the service is mapped to the name of the appropriate launch script. For example, the rc.subr script already ensured that the value named has been assigned to the variable $name, so the first line of this code means that the command load_rc_config named is being run. This routine simply loads in the settings from /etc/rc.conf. Next, a variable called required_dirs is set to whatever value was defined in the named_chrootdir variable, whether you set it explicitly in /etc/rc.conf or let it use the default setting in /etc/defaults/rc.conf. Then another variable, pidfile (a file keeps track of the process ID for the service while it's running), is set either to the value of the named_pidfile variable if you defined it, or to /var/run/named/pid. Finally, the subroutine run_rc_command is called, with a standardized argumentreplacing the $1 variableof start. If you examine the /etc/rc.subr file and look at the definition of the run_rc_command subroutine, you'll find that it uses the standardized variables required_dirs and pidfile in its loop that finally launches the named daemon.

All this convoluted abstraction is difficult to follow unless you're skilled at tracing nested shell programs; but once you understand how certain standardized variables are passed back and forth and harnessed to launch each configured daemon, you can see that the benefits for FreeBSDallowing it to add new services and configure them in a single neat locationare readily apparent.

Note

See Chapter 10, "Shell Programming," for a tutorial on shell scripting, which will help you in reading the resource configuration scripts.

The most typical variables that appear in /etc/rc.conf are the TCP/IP configuration parameters. Because these are different for every system, FreeBSD can't very well specify them in the defaults. Listing 14.2 shows a typical /etc/rc.conf just after a new FreeBSD installation (your installation will vary, perhaps significantly).

Listing 14.2. A Newly Installed /etc/rc.conf

```
# -- sysinstall generated deltas -- # Sat Oct 23 02:17:22 2004
# Created: Sat Oct 23 02:17:22 2004
# Enable network daemons for user convenience.
# Please make all changes to this file, not to /etc/defaults/rc.conf.
# This file now contains just the overrides from /etc/defaults/rc.conf.
linux_enable="YES"
sendmail_enable="YES"
sshd_enable="YES"
portmap_enable="NO"
nfs_server_enable="NO"
inetd_enable="NO"
ifconfig_fxp0="inet 64.41.131.10 netmask 255.255.255.0"
defaultrouter="64.41.131.1"
hostname="simba.somewhere.com"
usbd_enable="YES"
```

These variables were all written by Sysinstall during your initial installation of the system, and the "YES" or "NO" settings reflect the answers you gave to the series of questions in the post-installation configuration section covered in Chapter 2, "Installing FreeBSD." Some of these variables are, in fact, redundant with the settings in the defaults file; still, it can be useful to have them in the overrides file as well, because many of these features (such as the NFS server) now have a one-touch toggle control, in case you want to change your mind about them later.

Note

Many third-party applications, particularly network servers and databases, are installed with their own startup scripts (which reside in `/usr/local/etc/rc.d`) that depend on variables in `/etc/rc.conf` in order for them to run. For example, if you install the MySQL database server, you have to add `mysql_enable="YES"` to `/etc/rc.conf` before MySQL will start properly at boot time. In most cases this change is made automatically during the port or package installation (see Chapter 16, "Installing Additional Software"); but in case it doesn't, that's one possible reason why it might be failing. Check the installed startup script for the application to see if it seems to be looking for an `_enable` variable that you might need to add yourself.

Many programs, when you install them, will have to install a way for themselves to start up at boot time; `/etc/rc.conf` is not, however, the place for these programs. This file is supposed to be touched only by you, the administrator, and by the Sysinstall program when it makes changes to the core system. Another structure, the `/usr/local/etc` hierarchy, is in place for the startup scripts and configuration files of user-installed programs (ports and packages) and for any scripts that `/etc/rc` and friends do not know about.

The `/usr/local/etc` and `/usr/local/X11R6/etc` Directories

As you learned in Chapter 12, anything installed by the administrator goes into `/usr/local`. This is as true of startup scripts as it is of programs and shared libraries. The `/usr/local/etc` directory is the "local" equivalent of `/etc` (*local* referring to "this specific machine" as opposed to the generic components and settings found on all FreeBSD machines), and into it go all the configuration files installed by programs that you choose to install, rather than the ones controlled by the FreeBSD base system distribution.

Note

It's important to note that the difference between the `/etc` files and the `/usr/local/etc` files is *not* just that the former are "noneditable" and the latter are "editable." Just as most of the files in `/etc` should not be tampered with, many of the ones in `/usr/local/etc` also contain no user-serviceable parts or are designed not to need any modification by you in order to function (although the directory also contains customizable configuration files for installed programs). The distinction is that `/etc` controls the base systemfor example, only those programs that are always part of a FreeBSD installation. The files in `/usr/local/etc` control programs that you install after the fact, from the ports collection or from packages (which you'll learn about in Chapter 16). `/usr/local/etc` also doubles as the location for any startup scripts you write and add to the system (in its `rc.d` subdirectory).

The main local configuration directory, `/usr/local/etc`, contains configuration files that administrators edit to tune their programs' behaviors. You learn more about configuring ports and packages in Chapter 16. Here, however, we're interested in the `rc.d` (Resource Configuration for Daemons) subdirectory, which works in much the same way as `/etc/rc.d`.

`init` turns its attention to `/usr/local/etc/rc.d` after it has run through all the `/etc/rc.d` scripts. Any executable files within the directory that end in `.sh` are executed in lexicographical order. Examples of files that are installed in here include `apache.sh`, `mysql-server.sh`, and `samba.sh`. These scripts are custom-built as part of their corresponding ports or packages, and each one is tuned to take a `start` or `stop` argument, like their counterparts in the tightly controlled `/etc/rc.d` system. When `init` runs each script during the boot process, it uses the `start` argument. Note that you can just as easily run these scripts yourself during runtimefor instance, to start a newly installed service without rebooting:

```
# /usr/local/etc/rc.d/apache.sh start
```

Some ports or packages install with a secondary suffix of `.sample` (for example, `samba.sh.sample`). This suffix appears (masking the `.sh` suffix) because the program has to be properly configured before it can run successfully. The Apache web server, for instance, will run immediately after installation without any further modification to its config files (although you will no doubt be modifying them anyway). Apache, therefore, installs an `apache.sh` file, which could run the program cleanly if you executed it right then. However, the Samba network sharing server must be tuned first before it will run on your machine; if you ran its startup script right after installing it, it would fail to start the daemon. You need to make the necessary configuration changes and rename the script to remove the `.sample` extension before it will be run on startup by `init`.

The `/usr/local/X11R6/etc` directory (which is created if you install any third-party ports or packages for X11) is analogous to `/usr/local/etc`, except it is specifically tasked to X11-based programs, including GNOME panels, graphical tools, games, window managers, and so on. This directory also has an `rc.d` subdirectory, and scripts in it are executed immediately after the ones in `/usr/local/etc/rc.d`.

Note

The local startup-script directories are configurable. You can override this `rc.conf` line to add more directories if you need to:

```
local_startup="/usr/local/etc/rc.d /usr/X11R6/etc/rc.d" # startup script dirs.
```

Creating Scripts to Run Programs on System Boot

It is perhaps a bit optimistic to imagine that you will never need to have the system perform any startup tasks that are not tied to any of the carefully crafted ports/packages or the core system. You may want to run a custom daemon that you wrote yourself, for example, or clear out a common file-sharing directory every time the system boots. To do this, you can write your own shell script and put it into `/usr/local/etc/rc.d`.

Recall that `init` expects every script in the `rc.d` directory to be able to handle the `start` argument. Also, each script's name has to end in `.sh` in order to be run automatically. The following is a sample script from the `man rc` page:

```
#!/bin/sh
#
```

```
# PROVIDE: foo
# REQUIRE: bar_service_required_to_precede_foo
# BEFORE:  baz_service_requiring_foo_to_precede_it
# KEYWORD: FreeBSD

. /etc/rc.subr

name="foo"
rcvar=`set_rcvar`
command="/usr/local/bin/foo"
extra_commands="nop hello"
hello_cmd="echo Hello World."
nop_cmd="do_nop"

do_nop()
{
        echo "I do nothing."

}

load_rc_config $name
run_rc_command "$1"
```

This sample script (which you can tune to your own needs by filling in the appropriate names and special subroutines suitable to your program) uses the `/etc/rc.subr` script to handle the `start` and `stop` arguments for when the script is invoked by `init`. You might call this file `foo.sh`. Make sure it is set executable (**`chmod +x foo.sh`**)!

Technically, the program doesn't actually have to be a shell script; you can write it in Perl if you want, or even C or anything else that will run, as long as it has an `.sh` extension. Writing the program in anything other than a shell script is fairly bad form, though. You shouldn't have to try to fool the system! For more on shell scripting, consult Chapter 10.

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The `inetd` Daemon and the `inetd.conf` Configuration File

Although there are a fair number of daemons in the base system that have `.conf` files in the `/etc` directory, the most important (and sensitive) one you will have to deal with is `inetd`, the "super-server." The job of `inetd` is to listen for connections on a specified set of network ports and fire off the appropriate server process when a request comes in.

For instance, `inetd` is in charge of Telnet connections; if your system allows Telnet, you can open a connection to it and receive a login prompt without any `telnetd` process running on the server beforehand. Every time the system receives a connection request on port 23, it creates a new `telnetd` process to handle the connection. Executable programs that run out of `inetd` (and other similar daemons) are located in `/usr/libexec`. These programs are not generally part of your command path and are not supposed to be run from the command line; instead, they are spawned from within another process and passed certain resources (such as environment variables and network connections).

Note

The use of `inetd` eliminates the need for a "master" `telnetd` process running as root, which is a situation that could be particularly dangerous if a security vulnerability were to be uncovered in `telnetd`. Many daemons, including `sshd`, `httpd` (Apache), and Sendmail, do run in this standalone mode rather than being called out of `inetd`. The master process (running as root) listens for the new connections and spawns new processes, owned by an unprivileged user, to handle each transaction. This allows for greater flexibility and speed in the program, at the expense of a centralized security risk. `inetd` also runs as root, so it is just as dangerous if `inetd` is compromised. The more daemons that run as root, the more possibilities there are for security holes to be found.

During installation (in Chapter 2), you were given the option to enable `inetd`, and if so, to edit the `/etc/inetd.conf` file to your taste. If you did this, you remember that all the services listed in the configuration file were commented out and disabled by default. You had to specifically enable any services you wished to be run out of `inetd`. Indeed, modern versions of FreeBSD subtly encourage you not to use `inetd` if possible; after all, some of the most notoriously insecure network services (such as Telnet and FTP) are traditionally run from `inetd`, and if you can get along without them, so much the better. However, if you're running a public server, chances are that you'll need (or at least want) to enable services such as FTP, POP, and IMAP to accommodate the needs of your users.

Note

There are generally better, more secure alternatives to the clear-text services traditionally run from `inetd`; most of them tend to be standalone daemons, including third-party FTP and mail servers, often with available encryption. For more information on tuning your system for optimal security, see Chapter 30, "Network Security."

If you want to use `inetd`, make sure the following line is in your `/etc/rc.conf` file:

```
inetd_enable="YES"
```

Table 14.2 shows some of the most popular services that are traditionally run through `inetd`. None of these are enabled by default, but you might find it necessary to enable some of them, according to your system's needs.

Table 14.2. System Services Traditionally Run from `inetd`

Service	Description	Port(s)/Resources Used

ftp	File Transfer Protocol	Port 21/TCP
telnet	Remote terminal	Port 23/TCP
comsat	"biff" server (notifies users of incoming mail)	Port 512/UDP
ntalk	Command-line chat server	Port 518/TCP, UDP
ftp (IPv6)	File Transfer Protocol	IPv6
telnet (IPv6)	Remote terminal	IPv6
pop3	Post Office Protocol	Port 110/TCP
imap4	Interim Mail Access Protocol (server-side mail)	Port 143/TCP
smtp	Qmail (alternative to Sendmail SMTP server)	Port 25/TCP
netbios-ssn	Samba file sharing with Windows	Port 139/TCP
netbios-ns	Port 137/TCP	
finger	Lookup user information	Port 79/TCP

To enable any one of these services, simply remove the comment (#) from the beginning of the line and then restart the inetd server, as follows:

```
# ps -waux | grep inetd
root    110  0.0  0.6  1032  752  ??  Ss    11:57PM   0:00.01 inetd
# kill -HUP 110
```

inetd is one of the areas of FreeBSD without a lot of built-in automation or safety nets to prevent bad configurations. If you must enable services in /etc/inetd.conf, be aware that you're venturing into a nonstandard type of setup, and you should know what you're getting into. For instance, the cvs services come with a dire warning about a security hole that can be opened up with a misconfigured parameter. The Samba services (netbios-ssn and netbios-ns) expect to find the smbd and nmbd binaries in /usr/local/sbin, but they won't be there unless you have installed Samba from the ports or packages. (Running Samba from inetd instead of in standalone mode is a nonstandard, alternative configuration.)

Similarly, other services (such as pop3) TRy to run services installed into /usr/local/libexec. But remember, this directory is inside /usr/local, meaning that unless you explicitly installed a program into that location, it won't be there. Installing the popper port/package puts the necessary executable program into that directory, so you can enable the service in inetd. However, if you choose instead to install the qpopper port/package (another POP3 server), the executable is qpopper instead of popper, and you have to modify the line accordingly:

```
pop3   stream   tcp     nowait   root    /usr/local/libexec/qpopper      qpopper
```

Numerous other pitfalls await the unwary. Be sure not to modify the inetd services any more extensively than you really have to. The man inetd page provides a more extensive discussion of the syntax and technique of handling inetd.

The System Logger (syslogd) and the syslog.conf File

System messages are logged to files in /var/log. The mechanism that does this is called syslogd, the system logger daemon. This daemon's behaviors are set in /etc/syslog.conf, which defines various different log files for different services. Each service or "facility" that syslogd knows about (including auth, authpriv, console, cron, daemon, ftp, kern, lpr, mail, mark, news, ntp, security, syslog, user, uucp, and local0 tHRough local7) has a number of different "severity" levels for which you can control logging. These levels include, in decreasing order of severity, emerg, alert, crit, err, warning, notice, info and debug.

Each daemon or service that you run in FreeBSD can log through the predefined facilities of syslogd; for instance, Sendmail and other mail programs can use the system's syslog() routines to send out messages at various levels of severity, using the mail facility; the messages would be handled by syslogd as defined in syslog.conf.

By default, syslog.conf defines several logging rules, as follows:

```
*.err;kern.debug;auth.notice;mail.crit          /dev/console
*.notice;authpriv.none;kern.debug;lpr.info;mail.crit;news.err /var/log/messages
security.*                                      /var/log/security
auth.info;authpriv.info                         /var/log/auth.log
mail.info                                       /var/log/maillog
lpr.info                                        /var/log/lpd-errs

ftp.info                                        /var/log/xferlog
cron.*                                          /var/log/cron
*.=debug                                        /var/log/debug.log
*.emerg                                         *
```

You can interpret this to mean that all err messages from any service, debug messages from the kernel, authorization notice messages, and crit messages from mail programs will be printed out to the system console, and you will see them if you have a monitor hooked up to your FreeBSD machine. Similarly, all security-related messages go into the /var/log/security file, and all messages from mail programs at the info level go into /var/log/maillog. Almost everything else goes into /var/log/messages, the general system log file.

Certain types of messages are not merely written to log files but are sent to a variety of other types of handling mechanisms. In the default syslog.conf, for example, messages from any service at the emerg level are printed to all users at all terminals. Table 14.3 shows the possible actions for syslogd messages and the syntax for each.

Table 14.3. Syntaxes for syslogd Actions

Syntax	Action Taken
/path/to/file	Messages are written to the specified file.
@some.hostname.com	Messages are forwarded to syslogd at some.hostname.com using the syslog network service.
user1	Messages are printed to any terminal where user1 is logged in.
root,user1,user2	All specified users receive messages on all their terminals.
*	Messages are written to all logged-in users.
| "mail root"	Messages are mailed to root.

Further details on how to configure `syslogd` can be found in the `man syslogd` and `man syslog.conf` pages.

Note

Each log file in `/var/log` is rolled over according to a different set of rules. For instance, the `/var/log/maillog` file is archived and restarted every day by the `periodic` program. Other log files, such as `/var/log/cron` and `/var/log/messages`, are refreshed through other means (often internally by the programs that write to them). Archived log files are generally compressed with `bzip`. To search through old log files, use `bzcat` in conjunction with the conventional `grep`:

```
# bzcat /var/log/messages.2.bz | grep "rejected"
```

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Notes on the /etc/rc.local File

The resource configuration script /etc/rc.local was described earlier in this chapter simply as being obsolete. Administrators who used earlier versions of FreeBSD or certain Linux distributions will recognize this file. Its purpose is much the same as the /usr/local/etc/rc.d directoriesto provide you with a mechanism to extend the system's startup behavior by adding your own daemons or ad-hoc configuration changes.

The rc.d method described earlier in this chapter is the best way to run a daemon or perform some automated task upon startup. However, in some cases (such as mounting a remote server or starting a backup client), it's more expedient to have a place where you can simply execute a command line without worrying about the careful structure of the proper resource configuration system. That's what /etc/rc.local is for (although it doesn't exist in the default installation). You can create the file (with the proper interpreter line modeled after the other rc.* files) and put any set of shell commands into it, and it will be executed just before the rc.d scripts.

Support for rc.local is for backward-compatibility only, and it may eventually be removed from FreeBSD. To make sure your system supports it, check in /etc/rc.d for the existence of the local launch script, as excerpted in Listing 14.3.

Listing 14.3. Excerpt from /etc/rc.d/local Showing Support for /etc/rc.local

```
name="local"
start_cmd="local_start"
stop_cmd="local_stop"

local_start()
{
        echo -n 'Starting local daemons:'
        if [ -f /etc/rc.local ]; then
                . /etc/rc.local
        fi
        echo '.'
}

local_stop()
{
        echo -n 'Shutting down local daemons:'
        if [ -f /etc/rc.shutdown.local ]; then
                . /etc/rc.shutdown.local
        fi
        echo '.'
}

load_rc_config $name
run_rc_command "$1"
```

If this file exists, you can use rc.local to launch your ad-hoc commands at startup. If you can, though, it is still a much better idea to use the rc.d script method.

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Chapter 15. Performance Monitoring, Process Control, and Job Automation

IN THIS CHAPTER

One of the fundamental differences between a desktop operating system such as Windows and a server operating system like FreeBSD is process control. FreeBSD lets you control every single process on your system, whether trivial or crucial. Windows, by comparison, gives you control over only certain application processesand very limited control at that. The only time you ever see the process table in Windows is during an emergency, and even then there's not a lot you can do with it. In FreeBSD, awareness of the running processes is an ever-present part of administering the system.

In Windows, for example, you can press Ctrl+Alt+Delete and get a list of desktop processes, which you can terminate if you choose. That's all you can doand it's hard to tell what each of the listed processes does or how much of the system's resources it's taking up. But FreeBSD shows you all this information and gives you the ability to restart processes, alter their priority, give them a number of different types of termination signals, and moreall with complete visibility into which processes might be causing problems. To use a common analogy, desktop operating systems are like cars with the hood welded shut. FreeBSD lets you pop the hood at any time.

This doesn't mean that FreeBSD is either more arcane or less stable than GUI-based desktop platforms. Savvy administrators will never end up destabilizing the FreeBSD system through poking at the processes, nor will they have to comb through an opaque table of numbers just to perform basic system functions. As you see in this chapter, the FreeBSD process table and the tools that interact with it are an embodiment of what makes a UNIX system what it is: a fully accessible machine with all the moving parts exposed and all the nuts and bolts showing. This accessibility gives you the power to tune everything the system does, no matter how minute. That's the essence of UNIX.

This chapter discusses several process-monitoring toolsnamely `ps`, `top`, and `kill`. Some are more user-friendly than others, and some are more versatile than others. The chapter also takes a look at the `cron` program, which is a scheduler for tasks that have to happen periodicallyanother feature that separates the men from the boys, and the servers from the desktops.

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Performance Monitoring with top

The easiest-to-use of the process-monitoring utilities is top, so named because it was originally designed to list the top 10 processes currently running on the system, in descending order of CPU usage. The current version of FreeBSD's top by default shows you every process currently running in any statesomewhere around 40 processes on a freshly installed FreeBSD system.

The benefit that top provides is that it's interactive and works in real time. When you run it, it takes over your terminal and updates itself every second, giving you instantaneous information about the state of the system at that moment. You can also pass commands to top, such as the kill and renice commands (covered later in this chapter), or give it different options for filtering and sorting the processes it shows you. This makes top an immensely useful tool for reining in an out-of-control server, fine-tuning the performance of certain tasks, or simply keeping an eye on things as you work in another window.

top Output Explained

When you run the top program, you get output similar to what's shown in Listing 15.1.

Listing 15.1. Sample Output of top

```
last pid: 30283;  load averages:  0.51,  0.89,  0.87   up 52+15:48:43  11:19:03
126 processes: 1 running, 124 sleeping, 1 zombie
CPU states:  0.7% user,  0.0% nice,  2.8% system,  0.7% interrupt, 95.8% idle
Mem: 142M Active, 35M Inact, 59M Wired, 7496K Cache, 35M Buf, 4256K Free
Swap: 500M Total, 48M Used, 452M Free

  PID USERNAME      THR PRI NICE   SIZE    RES STATE  C   TIME   WCPU  COMMAND
30283 bob             1   2    0  1360K   976K sbwait 1   0:00  6.02%  qpopper
30282 root            1  29    0  2076K  1236K CPU1   0   0:00  3.14%  top
19460 mysql          11   2    0 25908K  2692K poll   0 112:20  2.20%  mysqld
  245 root            1   2    0   868K   232K select 1 177:39  0.00%  healthd
18427 root            1   2    0  7592K  5092K select 0  80:24  0.00%  named
86694 frank           1  10    0  1700K    56K nanslp 0  76:46  0.00%  elm
   86 root            1   2  -12  1296K   412K select 0   6:28  0.00%  ntpd
80717 root            1  10    0  2132K   472K nanslp 0   5:53  0.00%  telnetd
61945 root            1   2    0  1868K   360K select 0   3:29  0.00%  inetd
   80 root            1   2    0   916K   320K select 0   3:26  0.00%  syslogd
56054 root            1   2    0  2168K   584K select 0   3:12  0.00%  sshd
73772 root            1   2    0  8956K  2540K select 0   3:12  0.00%  httpd
40567 www             1   2    0  9880K  2872K sbwait 1   0:57  0.00%  httpd
40581 www             1   2    0 10008K  3796K sbwait 0   0:55  0.00%  httpd
```

By default, top shows all the system's processes (no matter who owns them), whether they're active, idle, or in "zombie" mode, and how much CPU time they're taking up. The first useful bit of information is in the second linethe number of processes. This number varies from system to system, but chances are that many more processes are currently running than can fit on your screen. You can press the I ("eye") key to switch top into displaying only the processes that are active. Because the top program is interactive, there are a number of other commands you can issue while it is running, such as the K key followed by a process ID to kill a process. We will cover these commands a little later.

The next items to notice in the top output are the "load averages," which are fairly obtuse metrics you can use to tell at a glance how busy the system is. The exact derivation of the values is from the number of jobs executed over the last 1, 5, and 15 minutes, respectively; however, it's difficult to relate this to a profile of a system running real-world applications that vary greatly in resource consumption from job to job. A load of 1 generally means that the system is processing each job as it comes in, as though each one were a single person in line at the post office; if the load is higher than 1, it means processeslike post office customersare stacking up in line and the system is becoming more congested.

Load Averages

Eventually, you will get a feel for what constitutes a high load average on your system; typically, a load should not go above 1 on a continuous basis for a server, although a desktop system with lots of graphical tools will bump it up into the 2 to 3 range (5 is considered an unsustainably high load). Certain daemons stop accepting new requests at a certain load level (for example, 12 for Sendmail). If the load reaches 20 or 30, chances are the system is in a feedback-loop situation (which can be thought of as a race condition), in which new processes are being created faster than the system can complete them. This only serves to slow it down more and drive the load higher, in what's not-so-affectionately termed a *death spiral*.

This is one of those rare times when you might have to reboot a UNIX system because a server under this kind of load can become so tightly wedged that it will never recoveror it will take so long to complete all its processes and return to normal duty that it's faster to just reboot. Either way, your remote Telnet or SSH session might be unresponsive in this condition, or you might not be running one at the time the death spiral occurs (in which case, the system probably won't be able to open a new connection for you to come to the rescue). This is when logging in to the physical consoleor even power-cycling the machine, or shutting it down physically and rebooting, as an absolute last resortmight be the only recourse.

The header block contains more information about the RAM in the system than you'll probably ever find useful. You won't find a simple "used/free" graph of all available RAM here; instead, you see the states of all chunks of memory in the fourth and fifth lines in Listing 15.1.

Note

Here is where FreeBSD's robust memory management system shows its ugly underbelly. In UNIX, there is no such thing as a simple, clear division between memory that is used and memory that isn't used. The amount of RAM you have installed in your system is a nice figure to know, but it will never have any bearing on your day-to-day usageyou can't just add up the memory requirements of every application and calculate how many such programs you can fit into the RAM you've got installed. Because UNIX's memory model is heavily dependent on *virtual memory* (free space on the hard disk used for caching inactive data from RAM, also known as *swap*), you can actually run far more applications than you'd think would normally fit into RAM. The only drawback is a decrease in speed as more data (that needs to be accessed more often) gets paged into swap. See Chapter 2, "Installing FreeBSD," for a discussion of ways to optimize your swap partition for maximum efficiency, such as putting it near the edge of the disk.

Don't look at the `Free` block and assume that it represents all the memory available in the system. That block is only the memory that hasn't yet been used at all since the system was last brought online. What you should be looking at is the `Active` block because that describes memory in use by active processesprograms that are currently running and not idle. The rest of the fields describe other states of use that may or may not be mutually exclusive, so adding up all the fields won't necessarily give you the amount of RAM you have. It will, in fact, probably add up to more.

The `Swap` fields are more straightforward. Here, data is paged in and out of the virtual memory space as needed (copied to the disk and out of RAM), and usually the only fields that `top` shows are `Used` and `Free`. The numbers here add up predictably. It's probably more useful to look at the `Swap` fields than at the actual RAM fields to see how well your system is doing; if there's a lot of data in `Swap` (50 percent or more used), it means that data has been paged in fairly recently as a result of your physical RAM being full, and you may want to consider adding more memory. A FreeBSD system rarely runs out of swap space. If it does, as with most UNIX implementations, the results will usually be benign (you'll see error messages, but the system won't destabilize). The occasional unpredictable behavior or instability will surface, however. You'll want to keep your swap as little used as possiblefor this reason and also because naturally everything runs faster in RAM than in swap.

Next, notice that the processes are listed in descending order in the `WCPU` column. This column lists how much of the CPU's cycles are being used currently by each process (using a "weighted" scale, taking into account CPU cycles in which the process was in a "resident" state). Don't expect the column to add up to 100%your CPU will only be lightly used most of the time, and most of the CPU's cycles will be unused. Take a look at the headers again; the `CPU states` line tells you how much of the processor is being used in each of the four possible states, and you can relate these values fairly closely to the percentages in the `CPU` column.

Note

Some programs are designed to use 100 percent of the CPU, unless actively throttled by the configuration. For example, Qmail (an SMTP daemon that we will cover in Chapter 25, "Configuring Email Services") or a database back-end such as MySQL might run to 100 percent of the system's capacity during heavy load. This is normal behavior and should not cause concern if the system's primary role is in running those programs.

The CPU operates in discrete cycles, many millions per second (depending on its speed). Each of these cycles is dedicated to some part of some process, and over time a process will have used enough of these cycles to add up to a number measurable in seconds. This is what the `TIME` column tells you. Don't let the colon separator fool you into thinking that it's an hours:minutes reading; the values in the `TIME` column actually represent the number of CPU seconds that the process used in system states and user states, respectively. It may take minutes or hours for a process to use enough cycles to accumulate a measurable number. If a process has a large value (such as `mysqld` in the sample output in Listing 15.1), it's usually because the process has been running for weeks or it has become a runaway and has been taking up some huge percentage of the CPU during its runtime. In the latter case, you can easily check by looking at the `WCPU` column.

The next parts of `top`'s output that you should understand are the `SIZE` and `RES` columns. `SIZE` is the entirety of a process's allocated size, including the text, data, and stack components. Because parts of these components are shared systemwide, this column is not accurate for seeing how much memory a process is using. Instead, `RES` shows the resident memory value (this column should add up to the current amount of in-use memory). Both size values are "correct" in their own way, but you should use `RES` for determining the "traditional" amount of memory a process uses, the equivalent to what it would be reported as using in Windows or classic Mac OS.

The rest of the fields in `top` are less important or are self-explanatory. The `C` column tells you which CPU a process is using if your system has more than one. `PID` is the process ID, a number that is assigned to each process upon execution, and `USERNAME` is the user who executed the process. `STATE` tells you which of the possible states a process is in, which isn't very informative unless it's `zomb` or `zombie` (which refers to a child process that has terminated but has not yet fully given up its process table space).

Using Interactive `top` Commands

You also can give `top` commands interactively to help sort through the information it gives you. Earlier in this section, you learned that you can press the I key to show only active processes. You also can press the U key to be prompted for a username; `top` then displays only processes owned by that username (use `+` as the username to show them all again). You can issue a `kill` command with the K key, which then prompts you for a PID to kill. The T key toggles whether the `top` process itself is displayed. These and other options are listed in the `man top` page.

With this feature set, `top` serves as a very good all-around summary of what's going on in the system, and it allows you to handle the majority of the process-management tasks you'll have to perform. But `top` isn't a total solution; it doesn't give you detailed information about the processes themselves, and its interactive nature keeps `top` from being a scriptable tool or something that can be used in conjunction with pipes and other programs. For these functions, you use `ps`.

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Process Monitoring with ps

Rather than being an interactive, real-time monitoring program like top, ps works a lot more like ls (hence the name). It's an instantaneous listing of all the processes that are running at the time you execute it. It provides all the information that top does as well as extra details about many of the values.

By default, if you run ps without any arguments, you will get a listing of only the processes owned by you that are attached to terminals (that is, those that have been run from a login session). A large array of command-line options can give you more widereaching results, and each can be found documented in man ps. You specify these options as follows:

```
# ps wwaux
```

This combination of options produces the following:

- Output in wide format (ww), which allows the process listing to wrap to multiple lines rather than being cropped to the width of your terminal (a single w would show only the first 132 characters)
- Usernames along with processes (u)
- All users' processes, not just your own (a)
- All processes, regardless of whether they have an associated terminal (x)

In short, this combination of options displays a list of every process on the system, with as much detail as possible.

You can filter the output in certain ways using the built-in options. For instance, eliminate the x option to show only the processes attached to users' terminal sessions, and drop the a option to show only your processes (or use -U to specify another userfor example, -U frank). Many other options of this type can be found in the man page for ps. Beyond the built-in filters, though, you will need to use ps in conjunction with grep (as you saw in Chapter 12, "The FreeBSD Filesystem") to filter based on the process name. An example is shown in Listing 15.2.

Listing 15.2. Sample ps Output, Filtered Through grep

```
# ps -ax | grep httpd
40563  ??  S      0:54.73 /usr/local/sbin/httpd
40564  ??  S      0:55.30 /usr/local/sbin/httpd
40565  ??  S      0:56.03 /usr/local/sbin/httpd
40566  ??  S      1:00.16 /usr/local/sbin/httpd
40567  ??  S      1:05.13 /usr/local/sbin/httpd
```

ps Output Explained

Listing 15.3 shows some sample output from ps -wwaux.

Listing 15.3. Sample Output from ps -waux

```
USER     PID %CPU %MEM   VSZ   RSS  TT  STAT STARTED      TIME COMMAND
root       1  0.0  0.1   724   244  ??  ILs    5:05PM   0:00.09 /sbin/init --
root       2  0.0  0.0     0     8  ??  DL     5:05PM   0:00.61 [g_event]
root       3  0.0  0.0     0     8  ??  DL     5:05PM   0:08.17 [g_up]
root       4  0.0  0.0     0     8  ??  DL     5:05PM   0:04.96 [g_down]
root       5  0.0  0.0     0     8  ??  DL     5:05PM   0:00.00 [thread taskq]
root      11 98.8  0.0     0     8  ??  RL     5:05PM  20:27.49 [idle]
root      27  0.0  0.0     0     8  ??  WL     5:05PM   0:12.44 [swi4: clock sio]
```

Processes in the output from `ps` are sorted by PID rather than any of the reported metrics (unless you used one of the special sorting options described in the `man` page). You do get most of the same information that `top` gives you, albeit in a more cryptic format and with a few slight variations.

When to Use `ps` Instead of `top`

It's generally more useful to use `top` to gather general metrics on your processes; but `ps` is intended rather for looking up PIDs of specific processes and seeing the complete command line for each one. It's quicker than `top`, and scriptable. For example, you can write scripts that extract the PID for a process from the output of `ps` and send signals to that PID, all through the use of shell commands and pipes. This is particularly helpful when you need to rein in a runaway process or change the priority on a task. These are functions that we will now review in detail.

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Terminating Misbehaving Processes

Let's say you notice the system running more slowly than you think it should; you use `su` to access root, fire up `top`, and look at the processes. Sure enough, you see something like what's shown in Listing 15.4.

Listing 15.4. Output of `top` Showing a Possible Runaway Process

```
last pid: 67469;  load averages:  8.32,  5.49,  2.47   up 53+01:04:22  20:34:42
90 processes:  1 running, 88 sleeping, 1 zombie
CPU states:  93.2% user,  0.0% nice,  0.2% system,  0.8% interrupt, 5.8% idle
Mem: 153M Active, 23M Inact, 60M Wired, 7252K Cache, 35M Buf, 5112K Free
Swap: 500M Total, 44M Used, 456M Free, 8% Inuse

  PID USERNAME      THR PRI NICE   SIZE    RES STATE  C   TIME   WCPU COMMAND
19460 frank           1   2    0 25908K  2816K poll   0 131:15 92.43% testprog
67468 root            1  28    0  2036K  1024K CPU0   0   0:00  0.20% top
  245 root            1   2    0   868K   232K select 1 178:48  0.00% healthd
18427 root            1   2    0  7592K  5124K select 0  81:01  0.00% named
```

Aha! There's your culprit: `testprog`. It seems that `frank` is running some experimental program that's perhaps not written very well, and it's taking up almost all the CPU's available cycles. Sometimes such a "runaway" process results from an infinite loop (a piece of code that never reaches a point where it can terminate) or a memory leak (the program keeps trying to grab more memory, whether it needs it or not). Chances are, the process isn't going to exit by itself cleanly; meanwhile, it's becoming more difficult for other processes to execute and terminate. This `testprog` process has to go.

Killing Processes Within `top`

To get rid of `testprog` or other runaway processes, press the K key. This brings up the "kill" prompt within `top`; this prompt is an interface to the `kill` command (or at least a simplified version of it). At the prompt, enter the PID of the offending process (`19460`, in this case). Because you're running with root privileges, the process most likely will immediately terminate, and the system will breathe freely once more. Now, you're safe to track down what happened; you'll probably want to start by sending messages to Frank and letting him know what his program did, in case he wasn't aware of how it behaved. (If he did know, you might need to lay down the law to prevent him from causing problems in the future.)

There are times when the `kill` command within `top` doesn't work, though, or you may need finer control over what signals you're sending to the processes. `top`'s `kill` function is fine for routine termination of well-behaved processes, but it's only a subset of the functionality of the command-line `kill` program, which you may need to use instead.

The Command-line `kill` Program and Its Options

Its name is slightly misleading: `kill` does a lot more than simply terminate processes. Its full charter is to be a signaling mechanism by which processes can give each other commands of a fairly wide variety. Any user can use `kill` against any of his processes, but root is the only user who can kill other users' processes.

The simplest and most common usage of `kill` is for the purpose of terminating a process:

```
# kill 12553
```

This, however, sends only a certain kind of signal to the process: the `TERM` signal. This is a universal "quit" message that all UNIX programs understand, but it isn't guaranteed to work. A number of other signals exist, too. Table 15.1 shows the more important ones.

Table 15.1. Commonly Used kill Signals

Signal	Symbolic Name	Meaning
1	`HUP`	Hang up (terminate and restart)
2	`INT`	Interrupt
3	`QUIT`	Quit
6	`ABRT`	Abort
9	`KILL`	Non-ignorable kill
14	`ALRM`	Alarm
15	`TERM`	Terminate cleanly

You can use any of these signals by specifying either the signal number or its symbol:

```
# kill -HUP 8112
# kill -9 966
```

The first command tells the process to shut itself down cleanly and restart itself with the same argumentsrereading any input files and taking on a new PID. This is useful when you've changed something in a program's config file and need to restart the process to incorporate the changes.

The second command, which should be used only in the direst need and when all other options have failed, sends a low-level "super-kill" signal that terminates the process at all costs, regardless of how stubborn the process is. (This function is equivalent to the "End Process" command in Windows.) This command makes the process quit in an unclean fashion and might leave files open or connections in an orphaned state. This command can be a lifesaver, but don't use it unless you absolutely have to (for instance, if the `kill` and `kill -TERM` commands have no effect). See http://sial.org/code/shell/tips/kill-9/ for a discussion of when `kill -9` is and is not appropriate to use.

Note

The `kill` program is not infallible; there are some occasions when even a `kill 9` will not terminate a process that has become completely unresponsive to signals. Some processes under certain circumstances can become "zombies," meaning that they never die and can't be killed. Most zombie processes just sit there and don't take up any significant system resources. However, if in some rare case you have a zombie process that is interfering with general system operation, a reboot may be the only way to clear it.

These signals are the only ones you're likely to use in everyday process control. The other signals are typically ignored by programs that aren't specifically written to respond to them.

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Making Processes "Nice"

The `kill` command is one of the process-management tools that you can use both from the command line and within `top`. You read earlier of another tool, though, that you can use to alter a process's scheduling priority. This tool is the `renice` command, which alters the priority (or "nice" level) of any currently running process.

The scheduling priority is an integer value between -20 and 20, with -20 being the highest possible priority (confusingly enough). Take a look at `top`; the values in the `NICE` column are the priorities of each process. Notice that most processes have a priority of 0. Zero priority is the default because, in most circumstances, you don't need to specify any particular priority. Still, certain services run at predefined "nice" levels to ensure they will run at a certain time or get out of the way of more important processes.

If you're not root, you can set a process to a lower priority (a higher "nice" value), but not to a higher one (a lower "nice" value).

From the command line, you can alter a process's priority to 10 using `renice`:

```
# renice 10 1442
```

Within `top`, you can press R to get the `renice` prompt. Enter a priority level between -20 and 20, followed by the PID of the process you want to change, and you can see the results in the `NICE` column. This is an easy, interactive, alternate solution to the problem caused by the `testprog` problem you saw earlier. Rather than killing the runaway process outright, you could simply set its priority to 20, which would theoretically make it back off and allow other processes to run uncontested.

The `nice` command (which is a program in `/usr/bin`, but also a built-in shell command in the `csh`/`tcsh` shell) provides a way to set the priority level of a process at the time you run it. You precede a command with `nice` and the priority level, like so:

```
# nice -10 ls
```

This starts the `ls` process with a priority level of 10.

Note

The priority level in the `nice` command is preceded by a dash, which means that positive (lower) priorities are specified as shown in the previous `renice` example. However, to specify a negative (higher) priority, you would have to use the following:

```
# nice --10 top
```

Unfortunately, though, the double-dash syntax only works in the `/usr/bin/nice` command, and not in the `nice` command built into `csh`/`tcsh` (which supersedes the system's `nice`). If you're using `bash`, the preceding syntax will work; but if you're using `csh`, you need to use the command `/usr/bin/nice --10 top` to achieve the effect described here.

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Automating Processes with the `cron` Scheduler Daemon

Now that you've seen how to manipulate processes directly, you're ready to examine how processes can be executed automatically without any intervention on your part. Automating tasks with the scheduler allows FreeBSD to perform daily security audits and system status updates, regularly update its runtime databases, flush log files, and perform as many other tasks as an administrator can think of. Some operating systems attach schedulers to individual applications (such as the Software Update tool in Mac OS X), but the advantage of FreeBSD and other UNIX-like systems is that the scheduler is an independent daemon that can run any command-line program or set of programs on any periodic schedule you can think of.

The scheduler in FreeBSD, as in most UNIX-type systems, is called `cron`. FreeBSD's `cron` program was written by Paul Vixie, and it's the standard version used in most distributions of Linux and other similar systems. Like any standalone daemon, it runs all the time and looks at its input files (called `crontab` files) each minute to see whether they have changed or contain a task it needs to execute that minute. The `cron` process itself never needs to be restarted; it will automatically read in any changes when it wakes up every minute.

A global `crontab` file (`/etc/crontab`) contains scheduled jobs executed by the system, and a special directory (`/var/cron/tabs`) enables individual users to create their own `crontab` schedule files. It can be tempting to add your own scheduled jobs to the `/etc/crontab` file, but, as with `/usr/local/etc/rc.d` versus `/etc/rc.local` (refer to Chapter 14, "System Configuration and Startup Scripts"), you really should leave `/etc/crontab` untouched (so it can be safely overwritten by later upgrades) and create new jobs in root's personal `crontab` file in `/var/cron/tabs`. You'll see how to do this in a moment.

Anatomy of a `crontab` File

Let's take a look inside a user's individual `crontab` file. Here's `/var/cron/tabs/frank`:

[View full width]
```
# DO NOT EDIT THIS FILE - edit the master and reinstall.
# (/tmp/crontab.qx7aeeMvoH installed on Mon Feb 7 11:47:00 2005)
# (Cron version -- $FreeBSD: src/usr.sbin/cron/crontab/crontab.c, v 1.19 2002/10/01 22:59
   :11 dd Exp $)
0 3 1,15 * * cat ~frank/faq.txt | mail -s "FAQ Auto-Post" mylist@testsystem.com
```

This file has one item in it: a task to send a text file into `mail` to be sent out to a mailing list. The task will be executed at 03:00 on the 1st and 15th of every month. How is this schedule specified? It's done with the first five fields of the whitespace-separated data line. (The first three lines are auto-generated comments and are not processed by `cron`.) The fields are shown, in order, in Table 15.2.

Table 15.2. Date and Time Fields in a `crontab` File

Field	Allowed Values
Minute	059
Hour	023
Day of month	131
Month	112
Day of week	07 (Sunday = 0)

For instance, to create a task (we'll use the simple `ls` for these examples) that executes every night at 1:00 a.m., use the following syntax for the five fields:

```
0      1      *      *      *      ls
```

To run the same task only on Mondays, use this:

```
0      1      *      *      1      ls
```

A task that runs at the top of every hour throughout the month of March would be specified like this:

```
0      *      *      3      *      ls
```

Any field can have multiple numbers separated by commas or can contain a range (for instance, `1-10`). You can also use an asterisk (`*`) in a field to specify every occurrence of that interval. The month and weekday (fourth and fifth) fields can also use symbolic namesthe three-letter abbreviations for month or weekday names. Names can also be listed as comma-separated strings, although they can't be used in ranges. In the fifth (weekday) field, `0` and `7` are Sunday.

Note

If you want to run a command every *n* minutes, or every *n* hours, you can do that by specifying a "step" value (for example, `*/`*n*). In the minute field, `*/5` would translate to "every fifth minute," or the equivalent of `0,5,10,15,20,25,30,35,40,45,50,55`. See `man 5 crontab` for further details on schedule formatting.

You can also use shorthand strings in place of the first five fields to specify certain oftenused schedules, as shown in Table 15.3.

Table 15.3. Examples of Symbolic Scheduling Intervals

String	Equivalent
`@reboot`	Run once, at startup
`@yearly`	`0 0 1 1 *`
`@annually`	Same as `@yearly`
`@monthly`	`0 0 1 * *`
`@weekly`	`0 0 * * 0`
`@daily`	`0 0 * * *`
`@midnight`	Same as `@daily`
`@hourly`	`0 * * * *`

You can use shorthand strings, for example, to specify a task to occur every night at midnight. The following two lines are equivalent:

```
@midnight       ls
0       0        *       *       *       ls
```

After the schedule fields, the formats of the /etc/crontab file and the individual crontab files diverge slightly. The global /etc/crontab file has an extra field before the command fielda who fieldthat specifies which user should execute and own the process:

```
1       3       *       *       *       root periodic daily
```

The command field can be as complex as you like; fill it in exactly as you would a command entered at the command line. You can even use a semicolon (;) to separate multiple commands that you want to run sequentially as part of the same automated job. It's important to note that for commands executed from /etc/crontab, cron will not assume the path of the user specified in the who fieldthere's a PATH statement at the top of the file that lists only a few basic system directories. This means you need to give the full path to any command you run that isn't in that path; otherwise, cron won't be able to find the programs to run.

If there's any output from any program executed by cron, that output is gathered into a mail message and sent to the owner of the crontab file (or the owner of the scheduled task for /etc/crontab items).

Creating and Editing crontab Files

It's easy enough for you to edit /etc/crontab as root and to add any schedule items you want. Because you should avoid editing /etc/crontab if at all possible, however, you need to understand the individual crontab files and how to create and manage them.

Because each crontab file goes into a central directory (/var/cron/tabs) and is owned by its creator with permissions 0600, a security mechanism is in place to allow users to create and edit their own files there without compromising others' files. This mechanism is the crontab program:

```
# crontab e
```

Here's how to edit Frank's crontab file if you're root:

```
# crontab -e -u frank
```

Much like the chfn and edquota tools you saw in Chapter 13, "Users, Groups, and Permissions," crontab works by invoking the editor specified in the VISUAL environment variable (or the EDITOR variable, if VISUAL isn't set). The contents of the file (minus the first three comment lines) appear in the editor. After you make your changes, save it and exit. The temporary file, which resides in /tmp while you're making your changes, is copied into /var/cron/tabs, and the header lines are added. The crontab file will be active the next time cron looks at it, at the top of the minute.

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Creating Jobs to Run One Scheduled Time with the `at` Command

Okay, so `cron` is amazingly useful for regularly scheduled tasks. However, what about a task that you only want to happen oncesomething you want to postpone until some later time when you won't be around to execute it yourself? You could do this with `cron`, setting up a `crontab` file to have an entry that runs `crontab -u` at the end to delete itself. However, there is a better way: the `at` program.

Note

As an example of how useful the `at` command can be, I used it this past summer during a road trip to Alaska. Each morning an `at` command, which I had set up in advance, posted an entry to my blog that described where on the Alaska Highway I was going to be that day. I found, however, that it wasn't as necessary as I'd expected because there's Internet access even in the Yukon these days....

The `at` program is actually made up of several commands: `at` (the job creator), `atq` (which displays pending jobs), and `atrm` (which lets you cancel pending jobs listed in `atq`). There is also a `batch` command, which is a version of `at` that will run only if the system load is less than some value (`1.5` is the compiled-in default).

When you use `at` to create a job, it reads commands, line by line, in `/bin/sh` script style. These commands can be specified either on the command line (standard input) or with a preexisting file. Either way, you simply enter the `at` command followed by a timeformatting string, which can take a number of fairly intuitive forms, as shown in Table 15.4 (a full discussion of the time-formatting options is available in `man at`).

Table 15.4. Syntax Examples of the `at` Command

Command String	Meaning
`at 10pm`	Executes at 10:00 p.m. on the current day or the next day if it's after 10:00 p.m.
`at 8:00am May 15`	Executes at 8:00 a.m. on May 15
`at midnight Jan 1 2006`	Executes on the first second of the year 2006
`at teatime tomorrow`	Executes at 4:00 p.m. the following day

After you type this string and press Enter, you are in standard input mode. Type your commands line by line, pressing Enter each time. When you finish entering commands, press Ctrl+D to exit and place the job into the queue. You can alternately create an input file beforehand and then feed it to `at`:

```
# at -f mycommands noon + 5 days
```

This reads a plain-text file called `mycommands` that contains your commands, like a batch file, and executes them using `/bin/sh` at noon five days from the time you entered the command.

You can view existing jobs with the `atq` command:

```
# atq
Date                    Owner    Queue    Job#
23:00:00 03/28/01       root     c        2
```

You can cancel jobs by ID number with the `atrm` command:

```
# atrm 2
```

Note

The way `at` jobs are executed involves the `atrun` command. The `atrun` tool runs every five minutes (in the standard FreeBSD installation), reads all pending jobs for all users, and executes all jobs whose execution time has passed. You can modify how frequently `atrun` runs by changing its entry in `/etc/crontab`, although this should not be necessary unless you need higher resolution than every five minutes.

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Controlling Access to the `cron` and `at` Commands

Scheduling is so powerful that most administrators don't necessarily want their users to be able to have complete access to the `cron` and `at` commands. As an administrator, you can control access to these commands on your FreeBSD system.

Let's say, for instance, you have a troublesome user who insists on running an IRC "eggdrop" bot, and every time you kill the process, it keeps coming back because the user has set up a `crontab` file to restart the process if it's not running (checking every hour, for example). The user doesn't respond to email. Your options are either to disable the user's account (always a possibility, unless the person is your brother-in-law or something) or to restrict the user's access to the `cron` and `at` commands. You can restrict the user's access through the `deny` and `allow` files for both programs.

The `/var/cron/allow` and `/var/cron/deny` don't exist in the default FreeBSD installation. In this condition, anybody is allowed to create `crontab` files. If you create `/var/cron/allow`, the only users (aside from root) who can create `crontab` files are the ones you listed in it (in a simple text list, one user per line). Alternatively, you can put users into `/var/cron/deny`. This approach lets everyone create `crontab` files, except for the ones listed in the file. If both files exist, `/var/cron/allow` takes precedence.

The `/var/at/at.allow` and `/var/at/at.deny` files work the same way, but the filenames are slightly different, so take note!

Caution

Be sure that these config files, if you create them, are writable only by root; issue **`chown root/var/cron/allow`** and **`chmod 600 /var/cron/allow`** commands if they are not.

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Using the Periodic Task Scheduler

The periodic command is like a souped-up version of cron. It's designed to provide a framework for executing whole directories full of shell scripts at regular intervals specified in a crontab file. In FreeBSD's default configuration, periodic is used for many housekeeping functions, controlled by a directory structure full of shell scripts located in /etc.

If you examine /etc/crontab, you will see three references to the periodic command:

```
# do daily/weekly/monthly maintenance
1       3       *       *       *           root periodic daily
15      4       *       *       6           root periodic weekly
30      5       1       *       *           root periodic monthly
```

The periodic command is invoked three times, with three different arguments: daily, weekly, and monthly. These arguments correspond to three different subdirectories of /etc/periodic. Each subdirectory, named in accordance with the three arguments, contains a number of shell programs, each of which executes a specific taskin this case, a maintenance task that the system carries out either daily, weekly, or monthly, at the specified times in /etc/crontab. In /etc/periodic/daily, for example, you will find such scripts as 100.clean-disks, 200.backup-passwd, and 999.local. Simply by existing in the subdirectories of /etc/periodic, these scripts will be run when periodic is executed with the name of their directory as an argument.

Scripts in the periodic directories are traditionally prefixed with numbers; because periodic executes scripts in lexicographical order, using numbers provides an easy way to define the order in which the scripts should be run. For example, 999.local is always the last script to run in /etc/periodic/daily.

The output of these periodic runs is gathered into a mail message and sent to root (by default). This is the origin of the daily system summary messages that your FreeBSD machine sends you each night shortly after 3:00 a.m. Reading through the periodic source directories, you will be able to see what the system is doing to generate all the disk status, user login accounting, news, UUCP, mail, and other pieces of status it throws at you every day, week, and month.

Each script in the periodic directories has individual behaviors that are defined in /etc/defaults/periodic.conf. You can examine that file to see how each script is treated, and you can override those settings by creating an /etc/periodic.conf file, which operates the same way that /etc/rc.conf does, masking the defaults set in the corresponding file in the defaults directory. You can use this technique to send the script output to a different user or to a log file, instead of to root, for instance. You can also turn on or off the output reporting for individual scripts as well as adjust many other scriptspecific variables that control how the scripts themselves operate.

Note

The /etc/periodic/security directory is special; it contains scripts that specifically address security-related tasks, such as looking for new setuid programs, accounts without passwords, and kernel firewall messages. The scripts in this directory are run in a separate process and handled differently from the normal daily maintenance scripts, in order to minimize the risk of sensitive information being gleaned by an eavesdropper. This behavior can be modified by overriding the settings in /etc/defaults/periodic.conf using /etc/periodic.conf.

You can add your own scripts to the periodic directories if you want. However, as you have seen before, it's considered safer and better form to avoid editing the global files in /etc when an alternative "local" version is available. In this case, /usr/local/etc/periodic is the location for any daily, weekly, or monthly scripts you might want to add. The scripts are executed at the same time that `/etc/crontab` runs the global `periodic` scripts. Immediately after finishing the scripts in `/etc/periodic/daily`, for example, `periodic` will run whatever it finds in `/usr/local/etc/periodic/daily`, in lexicographical order as with the global location.

Adding scripts to the `periodic` directories is a good way to schedule specific tasks to be performed on an ongoing basisfor example, a script that cleans up a temporary directory, a database backup process, or a CVSup process that synchronizes your FreeBSD sources (you learn more about synchronizing FreeBSD sources in Chapter 19, "Keeping Up to Date with FreeBSD"). It's far neater and more formal to use the `periodic` structure to handle these tasks than putting them all in a huge `crontab` file!

PREV NEXT

Chapter 16. Installing Additional Software

IN THIS CHAPTER

Up until now, we have covered topics that are largely applicable to many different types of UNIX systems. Pretty much any such system, whether commercial or open source, operates the same way regarding the filesystem structure, process automation, and general administration. What sets FreeBSD apart from its brethren (Linux and commercial UNIX software) is the model by which the administrator adds new software.

With Solaris for example, if you want to add a new piece of the software to the system, you have to find a precompiled binary for your particular platform and install it yourself (usually without the aid of installers that help you put it in the right place), because Solaris typically doesn't come with `gcc` (the standard GNU C/C++ compiler). Other systems, such as IRIX and HP-UX, do come with `gcc`, but you still have to find the source code for the program you want to install and then run its configuration script, compile it (a step that's often much easier said than done), and install it. This configuration and installation process is fairly standardized, but it's still completely voluntary and controlled by each individual software developer, so there's no guarantee that one program's installation process will work the same as another's.

Different flavors of Linux take this a step further with the concept of *packages*, which are essentially all-in-one bundles that contain the proper executable binary for your system as well as any required libraries, plus the necessary information about where to install everything as appropriate to the system's layout. The Red Hat Package Manager (RPM) system is a GNU-licensed packager that runs on many systems, including FreeBSD. Its popularity was a large part of what pushed Red Hat to the top of the Linux distributors, edging out the previous favorite, Slackware, which is now all but forgottenwhich should illustrate well how important a good packaging system can be. RPM allowed administrators to keep tabs on their installed software and to upgrade, uninstall, and add new packages with unprecedented ease.

But FreeBSD takes things to yet another level of convenience. It has its own package management system, the `pkg_*` tools, which this chapter covers in detail. FreeBSD also has a supplementary system called the *ports*. Ports allow you to compile software from its original sources with one-command simplicity and as close to a guarantee of quality as you can get in the open-source world.

Introduction to Packages

Jordan Hubbard, formerly one of the core developers of FreeBSD (now working at Apple as an architect of Mac OS X), is responsible for most of the initial work on the package system. FreeBSD's system has been adopted by NetBSD and other platforms and refined over the years, with the best of the independent development efforts being rolled back into FreeBSD.

By its simplest definition, a package system is a way of bundling up software (including config files, shared libraries, and documentation) and extracting it again onto another machine, in which its configuration will be valid enough that the software can run properly on the new machine. Early package managers did little more than direct the bundling and extraction processes. RPM and FreeBSD's packagers both have numerous additional features:

- They maintain a database on your machine that shows which software and which version of each package are installed.
- They can grab a remote installation file from an FTP site (generally, the primary distribution site).
- They keep track of dependencies or any additional packages that must be installed for the one you're installing to run.
- They can do upgrades and deinstallations as well as installations.

The major difference between the two packagers is related very closely to the different development philosophies of FreeBSD and Linux. Linux has a number of different distributions, with different versions of `glibc` (a set of core shared libraries not relevant to FreeBSD) and a nearly infinite variety of hardware on which the operating system can run. RPM package files are usually retrieved from any of thousands of developer sites all over the Web, not just a single central repository. RPM must necessarily be quite complex in order to handle all this diversityand indeed it is. Its command-line interface is fairly arcane and requires a lot of documentation to be used properly. FreeBSD, however, benefits from a centralized development model and a single supported hardware platform, so the package model can be much simpler, both in architecture and usage.

As we discussed in Chapter 12, "The FreeBSD Filesystem," the `/usr/local` hierarchy is reserved for items that you install yourself, which refers specifically to software you install from the ports and packages. Table 16.1 shows the `/usr/local` directory structure (although your installation may vary slightly, especially if you've installed software already).

Table 16.1. Directory Structure Within `/usr/local`

Subdirectory	Purpose
`bin`	Binaries (compiled programs)
`etc`	Configuration files
`include`	C `include` files, used for building new software
`info`	Various supporting types of data for building documentation
`lib`	Shared libraries
`libexec`	Supporting binaries used by other programs
`man`	Manual pages for installed software

sbin	System binaries (programs that alter system behavior)
share	Platform-independent materials (data files, documentation, and so on)

In other words, /usr/local has the same basic hierarchy as the one found directly within /usr (with the exception that man pages are found at /usr/local/man rather than /usr/local/share/man, as you might expect). FreeBSD's package system keeps anything you install in the /usr/local TRee and out of the /usr tree, thus maintaining the seamless but strict separation between base and user-installed software.

Shared Libraries and Dependencies

A *shared library* is a centralized file that provides precompiled function calls. Using a shared library, a program can access certain functions without having to have those functions built into itself. This technique, known as *dynamic linking*, reduces file size and redundancy in the executable binaries in comparison to static linking, which compiles all necessary functions into every program. Shared libraries exist on nearly all platforms, although they have different namesfor instance, Windows calls them Dynamic Link Libraries (DLLs).

FreeBSD already has a large number of shared libraries installed in the base systemenough to support all the software that's part of FreeBSD itselfand provides hooks for software that you might install later. Nevertheless, you're almost certain to run across a program that needs a shared library that doesn't exist in the base FreeBSD.

In FreeBSD, basic shared libraries are stored in /usr/lib, and any shared libraries that you install go into /usr/local/lib. All programs know automatically to look first in /usr/lib for the shared libraries they need, and they then look in /usr/local/lib (as well as a couple of other places). You can control this search path in /etc/rc.conf, as you saw in Chapter 14, "System Configuration and Startup Scripts."

Every package has a listing of *dependencies* (packages that must already be installed for the package in question to run) that includes both shared libraries and executables (programs). If a dependency isn't already installed, the package system automatically hunts it down and installs it before proceeding with the installation. If you later remove some program or library (via the package tools) that is a dependency for some other installed package, the tools tell you about this and refuse to proceed.

Obtaining Information on Installed Packages

The first step toward getting to know the packages is to explore the information about the packages you have already installed. Chances are you've installed some packages as you read earlier sections of this book, or you may have indirectly installed some as part of a custom installation (for example, if you chose to install X11 during the FreeBSD installation process). If not, don't worrythe information here will be just as useful to you later.

The tools you use to manage packages are pkg_add, pkg_delete, pkg_info, pkg_update, pkg_version, and pkg_create. Each one does pretty much what you would expect it to do; one hallmark of FreeBSD's style is to use differently named programs rather than obscure switches and parameters on the same program. Each of these tools interacts with a filesystem database at /var/db/pkg, which you can consult by simply using ls to take a quick glance at your system's package status. This repository has a directory for each installed package that includes information about the packing list (the manifest of files in the package) and the dependencies. pkg_info uses this database to print out the short descriptions of every package you currently have installed, as you can see in Listing 16.1.

Listing 16.1. Sample Output from pkg_info

```
# pkg_info
ImageMagick-6.2.2.1 An X11 package for display and interactive manipulation of
```

```
analog-6.0          An extremely fast program for analyzing WWW logfiles
apache-1.3.34       The extremely popular Apache http server. Very fast, very
arc-5.21j           Create & extract files from DOS .ARC files
aub-2.1.3           Assemble usenet binaries
autoconf-2.59       Automatically configure source code on many Un*x platforms
dict-1.10.1         Dictionary Server Protocol (RFC2229) client
elm-2.5.8           A once-popular mail user agent, version 2.5.x
emacs-21.3          GNU editing macros
```

You can also get lots of information on any single package by using its name as an argument, and even more information by adding the `-v` (verbose) switch. As with RPM, packages in FreeBSD have names with multiple parts separated by dashesthe package name, followed by the version. However, RPM files tend to be geared toward multiple platforms, and often contain the name of the intended platform in the package name. Instead, because FreeBSD is almost exclusively used on x86 hardware, a FreeBSD package file simply takes the form `name-version.tbz`. Here's an example:

```
elm-2.5.8.tbz
```

Packages are generally `.tbz` files (called *tarballs*), which is shorthand for `.tar.bz2`. Using tarballs is the traditional way of archiving a directory structure under UNIXyou first pack the directory into one file using `tar` and then compress it using `bzip`. To use tools such as `pkg_info -v`, you need to specify the full package name, including the version, as shown in Listing 16.2.

Note

FreeBSD's packages have recently been changed over to `.tbz` format from the previous `.tgz` (`.tar.gz`) format because the `bzip2` compressor achieves better results than the traditional `gzip` compressor.

Listing 16.2. Verbose Output of `pkg_info`

[View full width]

```
# pkg_info -v sudo-1.6.8.6
Information for sudo-1.6.8.6:

Comment:
Allow others to run commands as root


Description:
This is the CU version of sudo.

Sudo is a program designed to allow a sysadmin to give limited root privileges
to users and log root activity. The basic philosophy is to give as few
privileges as possible but still allow people to get their work done.

MAILING LISTS:

Please send bugs, problems, comments, etc to sudo-bugs@courtesan.com
There is a mailing list that receives announcements whenever a new
version of sudo is released.  You can subscribe to it by sending a
message to "majordomo@courtesan.com" that includes the line
"subscribe sudo-announce".  There is also a list for people working
on sudo.  The command to add yourself is "subscribe sudo-workers".

WWW: http://www.courtesan.com/sudo/
```

```
Packing list:
        Comment: PKG_FORMAT_REVISION:1.1
        Package name: sudo-1.6.8.6
        Package origin: security/sudo
        CWD to /usr/local
File: man/man5/sudoers.5.gz
        Comment: MD5:b8c9db19cbac166acac39357b92eae94
File: man/man8/sudo.8.gz
        Comment: MD5:027194bc19812c6da4ca4ed666c7c5f6
File: man/man8/visudo.8.gz
        Comment: MD5:2febf0dc710522e936e92802be2df45d
File: man/man8/sudoedit.8.gz
        Comment: MD5:115a43c18fe748f57d99650bea1ac5ad
        UNEXEC 'rm -f %D/man/cat5/sudoers.5 %D/man/cat5/sudoers.5.gz'
        UNEXEC 'rm -f %D/man/cat8/sudo.8 %D/man/cat8/sudo.8.gz'
        UNEXEC 'rm -f %D/man/cat8/visudo.8 %D/man/cat8/visudo.8.gz'
        UNEXEC 'rm -f %D/man/cat8/sudoedit.8 %D/man/cat8/sudoedit.8.gz'
        UNEXEC 'if cmp -s %D/etc/sudoers %D/etc/sudoers.sample; then rm -f
%D/etc/sudoers; fi'
File: bin/sudo
        Comment: MD5:87f016a5e538921843b48656498cff7a
File: bin/sudoedit
        Comment: MD5:87f016a5e538921843b48656498cff7a
File: etc/sudoers.sample
        Comment: MD5:f16c8ba08bf992bf3d068745395e89fd
File: libexec/sudo_noexec.so
        Comment: MD5:b618e152b00290cbcf7023dc6e58ee9e
File: sbin/visudo
        Comment: MD5:55d4f41123fb170700f5bd286af583a2
        UNEXEC 'if [ -f %D/info/dir ]; then if sed -e '1,/Menu:/d' %D/info/dir | grep -q
    '^[*] '; then true; else rm %D/info/dir; fi; fi'
Install script:
#!/bin/sh
if [ $2 != "POST-INSTALL" ]; then
  exit 0
fi
if [ -e ${PKG_PREFIX}/etc/sudoers ]; then
  echo "Will not overwrite existing ${PKG_PREFIX}/etc/sudoers file."
else
  cp -p ${PKG_PREFIX}/etc/sudoers.sample ${PKG_PREFIX}/etc/sudoers
  chmod 440 ${PKG_PREFIX}/etc/sudoers
fi
```

This listing tells you everything you need to know about the packagefrom its long description, to its dependencies, to its packing list (with the MD5 "fingerprint" `checksum` for each file, listed in its `Comment` field), and even the install script that was used during its installation, to help you track down where its component files are. Not shown in this listing is the complete `mtree` file, a map of all directories containing components for the selected package.

The information in the packing list is more than a simple list of component files: it also contains `UNEXEC` commands that are used during the deinstallation process for any package, so that if you use `pkg_delete` to remove the package, it simply executes these commands to cleanly remove all appropriate files and directories. In this example, the default `sudoers.sample` file in the `/etc` subdirectory of the script's working directory (`/usr/local`, represented by the token `%D`) is removed as part of the default packing list. Additionally, in an `UNEXEC` command, the `/usr/local/etc/sudoers` file is compared to the default `sudoers.sample` file in the same directory; if they match, you never made any changes to the `sudoers` file since installing it, and it is deleted as well. Otherwise, `pkg_delete` knows you've made your own changes to the file, and it leaves it alone. As you can see, a well-written and well-behaved package (and just about all packages are well behaved) will erase cleanly off your system when removed, leaving nary a trace of itself behind, but leaving your locally changed files untouched.

How do you know that this version of the package is current? You can determine this easily by using the `pkg_version` tool. It works only if the ports collection has been installedand it should be installed unless you're severely short on disk space. You learn more about the ports collection later in this chapter, but all you need to know for understanding `pkg_version` is that the ports collection (if kept up to date) has a listing of the current version of every package. The `pkg_version` tool compares the versions of every installed package to the version found in the ports collection, and it tells you whether your packages are up to date (see Listing 16.3).

Listing 16.3. Sample Output of `pkg_version`

```
# pkg_version -v
ImageMagick-6.1.6.8             <   needs updating (port has 6.2.2.1)
apache-1.3.34                   <   needs updating (port has 1.3.34_2)
arc-5.21e.8                     =   up-to-date with port
aub-2.0.5                       =   up-to-date with port
autoconf-2.13                   =   up-to-date with port
bash-2.04                       *   multiple versions (port has 1.14.7,2.05b.007_4)
bnc-2.9.4                       =   up-to-date with port
bulk_mailer-1.12                <   needs updating (port has 1.13)
cclient-2004d,1                 <   needs updating (port has 2004g,1)
cvsup-16.1h_2                   =   up-to-date with port
demoroniser-1.0                 =   up-to-date with port
```

Without the `-v` option, `pkg_version` wouldn't print the third column; you'd just get the icon in the second column. The version string would also not be appended to the package names in the first column. Either way, this provides you with a quick, at-a-glance method for telling where your maintenance efforts are needed.

PREV NEXT

Installing Packages

Now, you need to go out and find some software to install. The first step is to find out what's available. Just about all the software available for Linux is also available for FreeBSDnearly every piece of open-source software in the world has been made into a native FreeBSD port, and even closed-source software distributed in binary form for Linux can be installed as well (because binary compatibility allows you to do anything up to and including playing back audio/video using Linux software).

Installing from Sysinstall

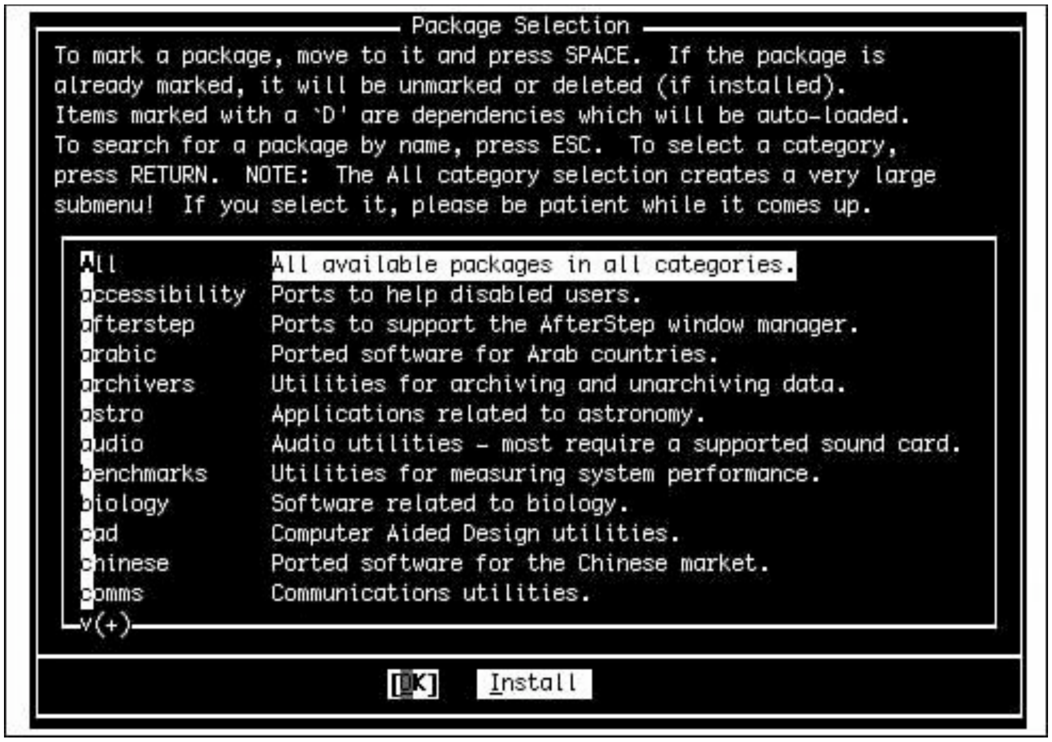
If you have the ports collection installed, you can see a categorized view of all the available software by going to `/usr/ports` and just looking around at the filesystem. Each subdirectory represents a package category of the same name, and each port directory inside it represents a software package that might be available for installation using the command-line tools. Your old friend Sysinstall, however, offers an even more direct interface.

Note

Not every port has a corresponding package available. If you try to install a package whose name you found in the `ports` directory, and it's not available in Sysinstall's menus, you'll want to build it from the ports instead. Skip ahead to "The FreeBSD Ports Tree" for more information.

From the main menu of the Sysinstall program, choose Configure and then select Packages. The Packages menu is shown in Figure 16.1.

Figure 16.1. The `Packages` menu in the Sysinstall program.



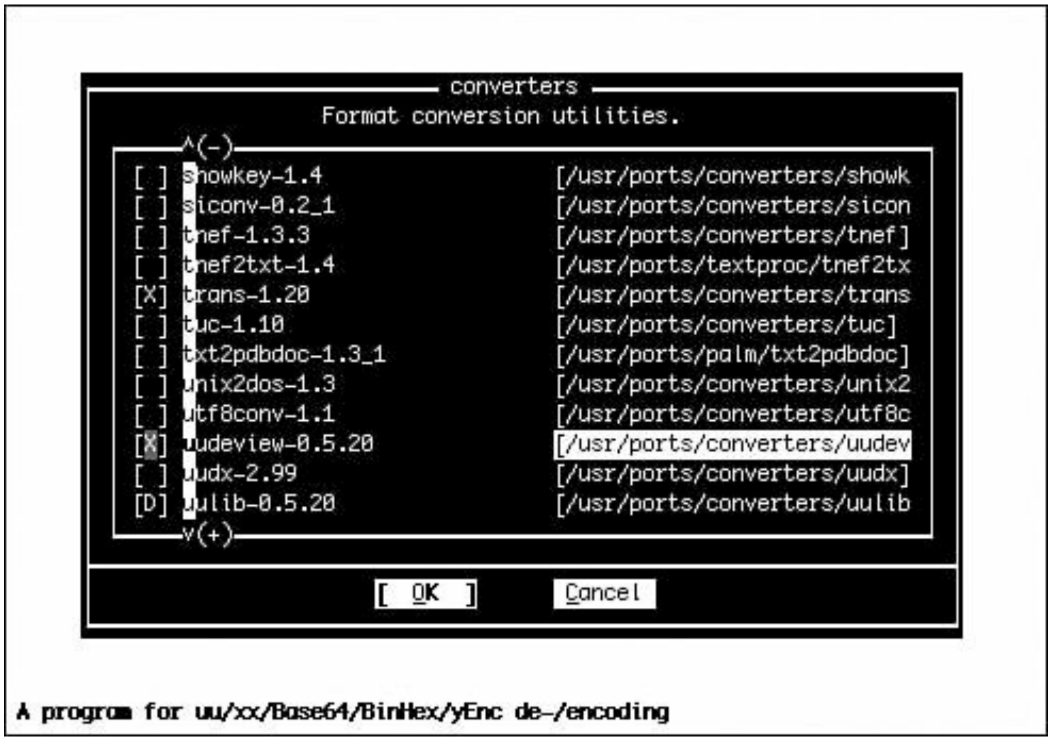
```
Package Selection
To mark a package, move to it and press SPACE.  If the package is
already marked, it will be unmarked or deleted (if installed).
Items marked with a `D' are dependencies which will be auto-loaded.
To search for a package by name, press ESC.  To select a category,
press RETURN.  NOTE:  The All category selection creates a very large
submenu!  If you select it, please be patient while it comes up.

All             All available packages in all categories.
accessibility   Ports to help disabled users.
afterstep       Ports to support the AfterStep window manager.
arabic          Ported software for Arab countries.
archivers       Utilities for archiving and unarchiving data.
astro           Applications related to astronomy.
audio           Audio utilities - most require a supported sound card.
benchmarks      Utilities for measuring system performance.
biology         Software related to biology.
cad             Computer Aided Design utilities.
chinese         Ported software for the Chinese market.
comms           Communications utilities.
v(+)
```

From there, choose CD/DVD as the installation media if you have your FreeBSD DVD handy; if not, and you're on the Net, choose FTP.

After you get the package list from whichever medium you choose, you are presented with a menu like the one shown in Figure 16.2. Scroll up and down to see the various categories, and press Enter to go into each one.

Figure 16.2. Browsing a category in the `Packages` menu.


```
 converters
 Format conversion utilities.
 ^(-)
[ ] showkey-1.4                  [/usr/ports/converters/showk
[ ] siconv-0.2_1                 [/usr/ports/converters/sicon
[ ] tnef-1.3.3                   [/usr/ports/converters/tnef]
[ ] tnef2txt-1.4                 [/usr/ports/textproc/tnef2tx
[X] trans-1.20                   [/usr/ports/converters/trans
[ ] tuc-1.10                     [/usr/ports/converters/tuc]
[ ] txt2pdbdoc-1.3_1             [/usr/ports/palm/txt2pdbdoc]
[ ] unix2dos-1.3                 [/usr/ports/converters/unix2
[ ] utf8conv-1.1                 [/usr/ports/converters/utf8c
[X] uudeview-0.5.20              [/usr/ports/converters/uudev
[ ] uudx-2.99                    [/usr/ports/converters/uudx]
[D] uulib-0.5.20                 [/usr/ports/converters/uulib
 v(+)

           [  OK  ]        Cancel

A program for uu/xx/Base64/BinHex/yEnc de-/encoding
```

A Note on Version Branches

We won't be covering FreeBSD's version-branching system until Chapter 19, "Keeping Up to Date with FreeBSD." For now, however, you should become familiar with at least a few important bits of terminology that are crucial to the proper operation of the packages and ports.

In the `Options` section of the Sysinstall program is a field to set the release name you'll be working with. Chances are you will be running a "release" version of FreeBSD (these are the versions that come on CDs). If so, the `Release Name` field will be set correctly for the version you're running (for example, `6.1-RELEASE` for the version supplied with this book). However, if you've upgraded your system to an interim point on either the `-STABLE` or the `-CURRENT` branch, this field may be set to `#.#-STABLE`, where the hash marks (`#`) stand for major and minor version numbers. That value won't work when you try to open the `Packages` menu because it tries to access a directory on the server whose name is based on the version number pulled in directly from the output of the `uname` command, which reports information on the kernel version. The corresponding directory for the packages that match your system's version doesn't necessarily have the same name as what's specified in the `Release Name` field.

Go to ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/ (and then into your appropriate platform subdirectory) to see the available release directories. If your version is `6.1-RELEASE`, the release directory you want is `i386/6.1-RELEASE`. If your system has been rebuilt from `STABLE` sources, choose the most recent `RELEASE` directory.

At the bottom of the screen shown in Figure 16.2, you'll see the one-line "short description" of each package. When you see the package you want, press the spacebar to mark it with an x. Select Cancel (press the right arrow) to exit from the category. You can browse through all the available categories this way until you've selected a long list of the packages you want; when you're done, tab to the Install button at the bottom of the screen to install them all in one fell swoop.

Note

Note that selecting **`Install`** is the only way to exit from the Package menus. If you don't select any packages for installation, you still need to select Install (and accept its dialog about there being nothing to install) in order to exit to the main Sysinstall menu.

The program now goes through the list and downloads each package, one by one, unpacking it into `/usr/tmp` and installing it using the `pkg_add` program, the commandline element to this phase of the FreeBSD package manager (which you can also use independently of Sysinstall). If a package has any dependencies, Sysinstall first finds and installs them and then returns to installing the packages you selected.

Exit from Sysinstall using the Exit Install option at the bottom of the screen. Your new packages are now installedthat's really all there is to it. The documentation (`man` pages) is all ready to use, config files are in `/usr/local/etc`, and the binaries are in `/usr/local/bin`. Type **`rehash`** to refresh the available programs that your current shell knows about (or log out and back in), and you'll be able to use the software.

As you learned in Chapter 14, some programs need to be configured before they can be used. Go into `/usr/local/etc` and check for a config file (usually of the style *`program_name`*`.conf` or *`program_name`*`.cfg`, or at least containing the program name). If the file has `.sample` at the end, you need to copy the sample file to a real, "live" config file (without the `.sample` extension) and perform some additional modifications before the program can use it. Open the file with your favorite text editor and do what needs to be done, as described in comments in the file itself or in the `man` page for the program. After you have configured the first file, check inside the `rc.d` subdirectory for similarly named startup files and deal with them in the same way if necessary.

Using `pkg_add`

Few options are available for the actual installation process in FreeBSD. Because executables, config files, and libraries are all kept in a standard centralized location, no dialog asks where you want to install a program or offers you any of the custom installation options you get in the desktop OS world. These installation limitations are perfect examples of both the more "closed-box" approach of FreeBSD, as compared to that of Linux, and the centralized distribution model for all the open-source software available for the platform.

However, there are times when you need more control over a package than you can get within Sysinstall. Examples include packages that have interactive preinstallation scripts (in which you can set options specific to that package) and situations in which the automated installation in Sysinstall fails. For times such as these, you need the `pkg_add` tool; it's used in every package installation, whether it's called directly or run by Sysinstall.

The `pkg_add` tool is designed to operate on a `.tbz` or `.tgz` file you've already downloaded (from the per-release distribution directory described earlier) or on a remote file specified by its URL. For instance, the following two procedures are roughly equivalent:

[View full width]
```
# fetch ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/6.0-RELEASE/packages/www/
   webstone-2.5.tbz
# pkg_add webstone-2.5.tbz
```

and

[View full width]
```
# pkg_add ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/6.0-RELEASE/packages/www/
   webstone-2.5.tbz
```

Of course, the latter method is much more convenient because not only does it eliminate the separate steps of downloading and installing the package, it also does all its work in `/usr/tmp` (or a similar temp directory) and cleans up after itself when it's done. The former method, however, allows you to store your source tarballs in a local directory (such as `~/tarballs`) so you can reinstall your software from them later without downloading them again.

`pkg_add` also keeps track of dependencies as if you were using it through Sysinstall. If you use `pkg_add` to add a package that has dependencies, it will automatically download and install the dependencies before proceeding. This ensures that you'll have a fully functional program after it's done working.

Tip

Use **`pkg_add -nv`** to do a "dry run" install. This shows you the steps `pkg_add` would take during the installation, without actually doing anything.

Note

`pkg_add` warns you if the compiled package was built with a dependency on another package that you have installed, but your version is older than the one the package wants:

[View full width]
```
pkg_add: warning: package 'xorg-libraries-6.8.2' requires 'pkgconfig-0.17.2', but
    'pkgconfig-0.15.0' is installed
pkg_add: warning: package 'xorg-libraries-6.8.2' requires 'freetype2-2.1.10_1',

but 'freetype2-2.1.5_1' is installed
```

If you receive warnings such as these, it's a good idea to upgrade the packages in question as soon as possible to avoid incompatibility issues.

An even more convenient way to install packages, one that does not involve your exploring through the FTP site at all, involves using the `r` option to `pkg_add`. This is the automated "remote fetching" feature, and it eliminates the need for you to know the current version number of the package you want, or even the version of your own operating system. The package manager will figure it out for you. Simply use the name of the package you want without the version number string, along with the `r` flag, and `pkg_add` will determine your platform type and release version and install the package in one step. Here's an example:

[View full width]
```
# pkg_add r webstone
Fetching ftp://ftp.freebsd.org/pub/FreeBSD/ports/i386/packages-6-release/Latest/webstone
   .tbz... Done.
```

Sometimes, a package installation finishes with a screen that gives you further instructions about how to complete the configuration. This is one benefit of installing packages from the command line rather than through Sysinstall. Another is that Sysinstall provides no feedback about the file size of any package, so you pretty much have to just let it download with no progress feedback other than data rate. If you used a browser to find the package in its FTP directory, you'll find the package size there and at least know how far you have to go when downloading.

Notes on Package Origins

The directory structure at the FreeBSD FTP site is such that each package is actually a symlink, so the file sizes aren't actually directly available if you reach them from the preceding URL. A little digging will get you the information, but it might not be worth your while.

Note that `pkg_add` does work on `.tbz` files grabbed from any location, not just the FreeBSD site. However, beware of files from "suspect" locations; adding packages is an act of trust, allowing whoever wrote the package to specify files to be placed in user-executable locations, possibly overwriting other files. (This is why regular users are generally restricted from installing packages and ports.) Viruses and Trojan horses are very uncommon in the UNIX world, but a conscientious administrator should have these potential threats in mind at all times, and especially when installing packages!

If you stick to Sysinstall, or at least to the `.tbz` files found at the FreeBSD FTP site, you can be assured that all the packages are approved for use and include an MD5 checksum to verify their authenticity, which you can usually do with the `md5` tool:

```
# md5 webstone-2.5.tbz
```

You can compare the output string from this command to the contents of the checksum file, often provided along with the package, to make sure they match before installing it.

You can also specify multiple packages, run in verbose mode, and prevent `pkg_add` from running preinstallation or postinstallation scripts. You can even prevent it from recording that it has installed the package. These options and more can be found in the `man pkg_add` page.

Removing and Updating Packages

There is no front end in Sysinstall for removing packages. You really don't need one because once a package is installed, you can specify its name directly using the commandline package management tools.

You can use `pkg_info` to see which packages you have installed, as you learned earlier. You can also simply look in `/var/db/pkg`; the directory names in there are the same as the package names. After you have the name of the package you want to delete, simply use `pkg_delete` to remove it, like this:

```
# pkg_delete pine-4.60
```

If the package has any dependencies, `pkg_delete` will detect them and refuse to proceed unless you've run it with the `-f` option to force deinstallation. It will also attempt to run any deinstallation scripts and evaluate any "require" statements; if these fail, `pkg_delete` will also fail (except if it's running with the `-f` option). As with `pkg_add`, you can use a number of other options, including verbose mode (`-v`) and "dry run" mode (`-n`).

Upgrading Installed Packages

If you attempt to install a newer version of an already installed package, `pkg_add` will exit with the following error message:

```
# pkg_add pine-4.63.tbz
pkg_add: package 'pine-4.63' or its older version already installed
```

This means you need to delete the package in question before attempting to install a newer version. First remove the package using `pkg_delete` (as described previously), and then use `pkg_add` to install the latest version of the package, either from a downloaded tarball or using the `-r` option to automatically fetch the most recent package version.

Introduction to Ports

You now know about packages and the tools FreeBSD provides for interacting with them. *Ports* offer another way for you to install software in FreeBSD. You use ports to compile software directly from the source code in an automated procedure that controls and safeguards the installation process as it allows you to grab the source directly from each program's distribution site.

As convenient as packages are, the traditional "UNIX way" of installing new software has always been to compile it yourself. The administrator finds the distribution site (using either HTTP or FTP, or in an earlier era, a tool such as Gopher or Archie), downloads the source code bundled up in a `.tar.gz` or `.tgz` (or `.tbz`) file, and unpacks it into some temporary directory. After reading the various `README` files for special instructions, the administrator usually runs a `configure` script that examines the system to check for a variety of function calls (these calls vary from platform to platform within the UNIX world) and generates an appropriate compilation script based on what calls are available for the program to use. The next step is to compile the software by running `make`an encapsulated compiler-management tool that reads its build targets and the necessary steps from a file called `Makefile` within the main source directory. After a (hopefully) clean compile, the administrator must then find the new, freshly baked executable and manually copy it into the publicly accessible location for binaries (`/usr/local/bin`, for example). In the best-case scenario, however, there is an "install" target in the makefile, so typing **`make install`** copies the proper files into (if he's lucky) the correct location.

This installation operation is (or rather, *was*) very inexact; sometimes it worked, sometimes it didn't. In the vast majority of cases it worked "sort of." Software distributed in source form usually worked fine on systems similar to the one the author was using; but trying to compile it on another platform usually resulted in at least a few minor disagreements about installation locations under the best of circumstances, or complete failures to compile in other cases. Maintenance was impossible, performance was unpredictable, and the reputation of UNIX for being arcane and difficult to use only grew stronger.

Enter the FreeBSD ports. Ports provide a way for you to compile software directly from the source in a regimented, structured, automated procedure that ensures the safety and integrity of the software you're installing while allowing you to grab the source directly from each program's distribution site (or a backup location, such as the central FreeBSD server, if the initial source fails). This means you can stay on top of the very latest developments in a piece of software without having to wait for a precompiled binary package that might not run on a heavily customized system.

Port installation also allows thousands of different pieces of software to install all their components into the proper locations in the FreeBSD filesystem without the developers even having to consider explicitly supporting FreeBSD's system structure. This is accomplished through a widespread system of port maintainers, volunteers in the FreeBSD user community who keep track of changes in their assigned ports and maintain scripts that patch a program's build and installation procedures to operate correctly with FreeBSD. When a developer updates his software, the port maintainer tries compiling it on FreeBSD and then makes whatever changes are necessary to the code patches and installation scripts that make it work smoothly with FreeBSD. A port, then, is simply these scripts and patches in a bundle, sitting in a particular spot on your FreeBSD machine, with a customized makefile that enables you to install the software simply by typing **`make install`**. No downloading; no configuring; no patching; no tweaking; no copying. All that work has been done for you.

FreeBSD's port system has been so successful it has been adopted by various other systems, particularly OpenBSD and NetBSD, and has inspired similar systems on Gentoo Linux and Mac OS X/Darwin. Its success can be attributed to two things: Its ability to keep UNIX administrators happy who prefer to compile their own software (either through security awareness or machismo), and its ability to provide the simplicity of version tracking and maintenance that the package system boasts. It's truly the best of both worlds.

The FreeBSD Ports Tree

The ports collection lives in `/usr/ports`. Go into that directory now and take a look around. What you see should resemble Listing 16.4. You'll notice that every category you saw in the Sysinstall program is here as a directory. (The list may not be 100% accurate for you because categories are reorganized on a fairly regular basis.)

Listing 16.4. Directories in /usr/ports

```
# ls -sF /usr/ports/
total 7422
    2 .cvsignore         4 deskutils/         4 net-mgmt/
   34 CHANGES           38 devel/             2 news/

    2 COPYRIGHT          2 distfiles/         2 palm/
 6768 INDEX-6            2 dns/               2 picobsd/
    4 KNOBS              6 editors/           2 polish/
   32 LEGAL              4 emulators/         2 portuguese/
  106 MOVED              2 finance/           8 print/
    6 Makefile           2 french/            2 russian/
    2 Mk/                2 ftp/               2 science/
    2 README            16 games/            12 security/
    4 README.html        2 german/            2 shells/
    2 Templates/        14 graphics/         14 sysutils/
    2 Tools/             2 hebrew/           20 textproc/
   86 UPDATING           2 hungarian/         2 ukrainian/
    2 accessibility/     4 irc/               2 vietnamese/
    2 arabic/           10 japanese/         24 www/
    4 archivers/         4 java/              6 x11/
    2 astro/             2 korean/            2 x11-clocks/
   14 audio/             6 lang/              2 x11-fm/
    2 benchmarks/       14 mail/              2 x11-fonts/
    2 biology/           6 math/              2 x11-servers/
    2 cad/               2 mbone/             6 x11-themes/
    4 chinese/          12 misc/              6 x11-toolkits/
    4 comms/             6 multimedia/        4 x11-wm/
    2 converters/       22 net/
   10 databases/         2 net-im/
```

Note

The contents of /usr/ports are by their nature independent of the branched development structure of the FreeBSD operating system. A newly released copy of the system will come with a snapshot of the ports created at the time the system was released, but it immediately becomes obsolete as soon as the ports within it are revised as new versions of the ported software come out. If you synchronize your ports tree to the central repository (as we will discuss later), it's always to whatever is current at the time you synchronize. There isn't a fixed state for the ports tree attached to each release as there is with the packages. Therefore, these sample directory listings are almost certain to differ somewhat from what is in your system. This also means that if you're trying to maintain multiple FreeBSD systems with identical software loadouts, you should avoid the ports system and use packages instead.

The first few directories (the ones beginning with capital letters, taking advantage of the UNIX convention of alphabetizing capital and lowercase initial letters separately, in accordance with the ASCII character set) are structural elements of the ports system, adjuncts that make the system work. You'll also find informative text files there, such as MOVED, which provides an up-to-date listing of recently moved or removed ports (including explanations for each of these changes). The rest of the directories are categories of ports.

Look inside one and you'll see as many as hundreds of different port directories, as demonstrated in the very partial Listing 16.5.

Listing 16.5. Some of the Ports Within a Category (Directory)

```
# ls -sF /usr/ports/audio/
total 1206
 2 HVSC-Update/                      2 mp32ogg/
 2 Maaate/                           2 mp3_check/
16 Makefile                          2 mp3asm/
 2 abcde/                            2 mp3blaster/
 2 abcmidi/                          2 mp3burn/
 2 abcselect/                        2 mp3butler/
 2 ac3dec/                           2 mp3c/
 2 adpcm/                            2 mp3check/
 2 adplay/                           2 mp3ck/
 2 afsp/                             2 mp3encode/
```

Note

Even though ports are sorted into categories by their intended functionality, their names aren't allowed to clasha port in `audio` can't have the same name as a port in `sysutils` even though they're in different directories. This is because once your ports are installed, they're all stored in a single flat database (`/var/db/pkg`) with no category divisions. The categories are only there in `/usr/ports` for your convenience in finding ports by type.

Browsing the ports in this way is less than efficient, especially in the larger categories (in this example, `/usr/ports/audio` contains 596 ports at the time of this writing). What if you know the name of a port you want to install, but you don't know what category it's in? You can use the `locate` command to find the port by name:

```
# locate uudeview
/usr/ports/converters/uudeview
```

However, until the `locate` database has been initially built (which might take a week after you first install FreeBSD), the command won't work. Use the **`/usr/libexec/locate.updatedb`** command to build the database manually so you can make use of `locate`.

Anatomy of a FreeBSD Port

Inside each port directory are a few files, totaling no more than a few kilobytes, that completely define all the tweaks and modifications that need to be made to a freshly downloaded bundle of source code for it to compile and install cleanly on FreeBSD. These files are detailed in Table 16.2 (an incomplete listingsome ports have additional files).

Table 16.2. Files in a Port Directory

File	Purpose
`Makefile`	Contains certain variables used in the build process as well as contact information for the maintainer.
`README.html`	Contains the "short description" (or comment) for the port in HTML format.
`distinfo`	An MD5 checksum used for verifying the authenticity of the

	downloaded tarball.

`files/`
`runme.sh`
`patch-aa`
`patch.ab`
	Patches that are applied to the source after it has been unpacked and support files that are FreeBSD specific; these vary greatly from port to port.

`pkg-comment`	The "short description" for the port.
`pkg-descr`	The "long description" for the port, which usually includes the URL of the developer's distribution site.
`pkg-plist`	The "packing list," which lists all the files to be installed as well as keywords telling the port system what to do when the port is deinstalled (for example, removing directories and unchanged files).

`Makefile` is the file that has the critical elements for building, configuring, installing, and maintaining a port. Listing 16.6 shows you what's typically inside `Makefile`.

Listing 16.6. A Typical Port Makefile

```
# New ports collection makefile for:    amp
# Date created:         Jun 23 1997
# Whom:                 Vanilla I. Shu <vanilla@MinJe.com.TW>
#
# $FreeBSD: ports/audio/amp/Makefile,v 1.16 2005/04/17 15:19:40 novel Exp $
#

PORTNAME=       amp
PORTVERSION=    0.7.6
PORTEPOCH=      1
CATEGORIES=     audio
MASTER_SITES=   http://www-users.cs.umn.edu/~wburdick/ftp/

MAINTAINER=     delphus@gmail.com
COMMENT=        Another mp3 player

GNU_CONFIGURE=  yes
USE_GMAKE=      yes

MAN1=           amp.1
PLIST_FILES=    bin/amp

do-install:
        @ ${INSTALL_PROGRAM} ${WRKSRC}/amp ${PREFIX}/bin
        @ ${INSTALL_MAN} ${WRKSRC}/amp.1 ${PREFIX}/man/man1

.include <bsd.port.mk>
```

The list of shell-style variables tells you what you need to know about where the source for the port comes from, what version the makefile thinks is current, and how to reach the maintainer. The `MAINTAINER` is a volunteer, usually unaffiliated with whoever develops the actual software but a contributing member of the FreeBSD community, whose job is to make sure the port compiles and installs cleanly and that the most recent version of the software is reflected in the port.

Most makefiles contain targets, such as `clean`, `install`, and `all`. Not all the makefiles in the ports have these targets explicitly defined, but what they do have is an included central makefile (`bsd.port.mk`, which lives in the `/usr/ports/Mk` directory along with other included files). This file is what contains the standardized build targets. The individual makefiles in each port serve as overrides or augmentations (much in the same way `/etc/rc.conf` relates to `/etc/defaults/rc.conf`), setting the necessary variables for the build and defining additional targets that will be used in the automated compile process.

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Installing and Removing Ports

Let's say that a port catches your eye and you decide you want to install it. Here's where it gets fun. All you have to do is move into the port's directory (using `cd`) and type **`make`**. This compiles the software. Then, you type **`make install`** to install it.

It's a simple process on the surface, but there's a lot that goes on under the hood. The `make` command actually executes a series of sequential `make` targets (described in Table 16.3). Each one depends on all the previous targets completing successfully. You can specify any of these targets directly; this will build all prerequisite targets up to and including the one you specify.

Table 16.3. The `make` Targets in a Port Makefile

Target	Action
`fetch`	Downloads the source tarball from the master site into `/usr/ports/distfiles`
`checksum`	Verifies the authenticity of the tarball using the MD5 checksum
`exTRact`	Unpacks the tarball into a `work` subdirectory
`patch`	Applies the patches from the `files` directory to the source
`configure`	Runs the `configure` script, which prepares the source for building
`build`	Compiles the source

Typing **`make extract`**, for example, will download the source file, match its MD5 checksum, and unpack it. Although there are other targets (listed in `/usr/ports/Mk/bsd.port.mk`), you won't need to use any of them under most circumstances.

After each step in the process is complete (except for `fetch` and `checksum`), a file is created in the `work` subdirectory of the form `.extract_done`. This is how the system keeps track of which steps are completed. (To see whether the `fetch` step is done, it simply checks for the existence of the tarball in `/usr/ports/distfiles`.) The `exTRact` step runs the `checksum` step implicitly. After that, the steps are sequential and independent, and they check for prerequisite steps by looking for the appropriate `.*_done` files.

If you need to make any changes to the source before compiling, you can run `make patch`, thus bringing the source up to a state where it's ready to compile, and then make whatever changes you like to the code in the `work` directory. Then, you can complete the process with `make`.

Dependencies are handled automatically by the ports, just as with the packages. Any dependencies are read from the makefile during the `fetch` or `install` phase and then downloaded, built, and installed. You will get feedback in the build output each time it encounters a dependency, regardless of whether that dependency is installed already.

After a port is installed, an entry is made in the `/var/db/pkg` database; for all intents and purposes, it is now a package. You can use the `pkg_*` tools on it to gather information and compare its version, just as with packages installed from within Sysinstall.

Tip

There is a `deinstall` target in the ports (**`make deinstall`**). This target is used when the installed port version is the same as the one in the makefilein essence, you're deinstalling exactly the same software package you installed. If you update your ports so that the version of a port (in the makefile) is higher than the installed version, you can't use `make deinstall` to delete it. Instead you have to use `pkg_delete`, the same way as you would a package.

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Updating and Maintaining Your Ports

Software changesand in the open-source community, it changes all the time. There are nearly 14,000 ports in the collection, and each one of them is undergoing development (some at much faster rates than others). A fact of system administration is that you can't install or upgrade software fast enough to keep up with the rate of development. The best you can hope to do is keep your ports collection up to date and use the built-in tools, such as `pkg_version`, to keep track of what needs to be upgraded.

Tip

If you regularly build software from the ports, you should be in the habit of reading the regularly updated `/usr/ports/UPDATING` file and skimming it for changes to ports that pertain to you. Pay special attention to the `AFFECTS:` line in each update, as it describes the particular users of various ports that will need to know about special upgrading instructions or important security notices.

Keeping Ports Up to Date with `CVSup`

To keep your ports synchronized, the best tool for the job is CVSup. In Chapter 19, you'll learn about CVSup in detail. Because CVSup is an essential tool for working efficiently with ports, it's important that you know some of its simplest usesand there really isn't much to it.

First, install the `cvsup` package, either by using the package system or by building it from the ports. In fact, it's better to use the package version because CVSup is a tool written in Modula-3, meaning that building it from source involves building several large Modula-3 dependencies, which takes forever and installs a ton of libraries that you'll probably never need for anything else. Use the package installation to get past that for now.

Note

A lot of ports have the same problem as CVSup: they require huge dependency programs, which you might not need or want on your system, to be built and installed. For instance, building a simple graphics library can cause the entire X11 system to be downloaded, compiled, and installed without your foreknowledge. For this reason, you should lean towards using the packages rather than the ports if you can help it.

The next step is to create a CVSup config file, known as a *supfile*. The purpose of this task is to update your ports, so call the file `ports-supfile`. As with other configuration files that you create for tasks that aren't part of the basic system, it's best to put this file in `/usr/local/etc`.

Listing 16.7 shows the contents of a suitable supfile for updating your ports.

Listing 16.7. A CVSup Config File for Updating Your Ports (`/usr/local/etc/portssupfile`)

```
*default  host=cvsup12.FreeBSD.org
*default  base=/usr
*default  prefix=/usr
*default  release=cvs
*default  tag=.
*default  delete use-rel-suffix

ports-all
```

The supfile has a number of tunable options, most of which you'll learn about in Chapter 19. For now, the only one you need to worry about is the `*default host=` line, which should point to one of the central FreeBSD CVSup servers. There are 18 of these servers, named `cvsup1` tHRough `cvsup18`, each one an alias for a source repository host located at some discrete location in the world. It's difficult to know where each host is without doing a host lookup (`host cvsup12.freebsd.org`) to see if the hostname to which it resolves gives a clue to its location, but it might be worth it to you to use this technique to examine each of the CVSup hosts to find the one nearest to you.

Now, run the CVSup update:

```
# /usr/local/bin/cvsup -L 2 /usr/local/etc/ports-supfile
```

CVSup connects to the selected CVSup server and begins synchronizing your ports collection. Because of the `-L 2` option (specifying the highest level of verbosity), you will see all changes between your installed version and the current one scroll by. CVSup operates by updating only files that have changed and then by updating only the changed pieces (by using `diff` patches). This allows you to update the entire ports collection while transferring only a minimum of data and using a minimal amount of bandwidth. A CVSup update can be done efficiently and quickly even over a very small network link.

Tip

If you're running CVSup within an X11 session, it will use a GUI client interface in a separate window, giving you statistics about the update process as it runs. You can disable this behavior and force CVSup to remain in CLI mode by adding the `-g` option to the command line.

After the synchronization is complete, your ports collection is current and "up to the minute." You can now run `pkg_version -v` to see which ports or packages you need to update.

You will probably want to make this synchronization process a part of your system's daily routine so that your ports will never be more than 24 hours out of date. To do this, add the preceding CVSup command to your daily `periodic` files (see "Using the Periodic Task Scheduler," in Chapter 15, "Performance Monitoring, Process Control, and Job Automation"). If it doesn't exist already, create a directory called `periodic` in `/usr/local/etc` and then another directory called `daily` underneath that. Inside the `daily` directory, create a file called something such as `100.cvsup-ports` and put these lines in it:

```
#!/bin/sh

/usr/local/bin/cvsup -g -L 2 /usr/local/etc/cvsupfile
```

Now, every night when the daily `periodic` script is executed, your ports collection will be synchronized. The output of CVSup is mailed to you in your daily system status update.

If you prefer not to get an email after every night's regular CVSup run, you can suppress its output using the `-L 0` option instead of `-L 2`; that way, the only conditions under which you'll get an email is if errors occurred.

Notes on Forbidden Ports

Sometimes a port is present in the ports collection but the system doesn't allow you to build it. This is controlled by the `FORBIDDEN` variable in the makefile. If this variable is present, whatever text string it is set to is displayed when you try to build the port, and the build process is cancelled:

```
# cd /usr/ports/databases/gnats
# make
===>  gnats-3.113.1_12 is forbidden: Security issues.
```

A port can be marked "forbidden" for many reasons. In this example, it's because the program in question has some intractable security problems that make it dangerous to install it. In other cases, a port might be forbidden because it has been made a part of the core system, and building it from the ports would be redundant and possibly ruin the system's operation. In either case, this is a good illustration of the need to keep your ports synchronized to the CVSup server as regularly as possible.

It's seldom a good idea to force the installation of a forbidden port, but it's possible to do so by simply removing the `FORBIDDEN` line from the makefile. Some forbidden ports do provide a built-in way to override the block by setting an environment variable, such as in this example of the `security/ssh` port (which no longer has this behavior, but other ports might still work this way):

```
# cd /usr/ports/security/ssh
# make
===>  ssh-1.2.27_3 is forbidden: OpenSSH is a superior version of SSH which has
been included in the FreeBSD base system since 4.0-RELEASE. This port is now
deprecated and will be removed at some point in the future. To override this
warning set the REALLY_WANT_SSH environment variable and rebuild.
```

As the instructions say, set the indicated environment variable and try again. Here's how if you're using `csh` or `tcsh`:

```
# setenv REALLY_WANT_SSH yes
```

And here's how if you're using `bash`:

```
# REALLY_WANT_SSH=yes
```

After setting the variable, run `make` again. The port should build cleanly.

Reclaiming Hard Disk Space Used by the Port-Building Process

After you're done building and installing a port, the `work` directory is still sitting there, filled with the unpacked tree of source code and compiled binary objects. This can take up a fair amount of disk space. It's always advisable to clean this directory out after installationreturning the port to its original pristine stateby running one more `make` command, this time with the `clean` target:

```
# make clean
```

This deletes the `work` directory and everything in it. It also cleans out the port directory for each dependency listed. However, it does not remove the tarball files from `/usr/ports/distfiles`; you'll have to remove these files yourself.

Tip

Unless you really need the disk space, you might want to leave the tarballs intact in the `/usr/ports/distfiles` directory. You can save a lot of time this wayif you should ever need to rebuild or reinstall a port, the system can use the file it already has, instead of having to download it again.

The beauty of ports is that if a security hole or critical bug is fixed in a port that you have installed, the ports collection might solve it by placing a patch file in the `files` directory of the port, not by bumping the revision number of the entire distribution file (and causing you to have to download a new tarball). A simple rebuild allows you to incorporate the new patch into your old sources.

Periodically, you may want to issue a top-level recursive `make clean` on the entire ports collection. There's a makefile at both the `/usr/ports` level and in each directory in the category level below it that enables you to do odd tasks such as building all the ports in a category at once (for example, building every `www` port by running `make` from inside `/usr/ports/www`). More usefully, it lets you clean every port at once, in one very long recursive process. You do this simply by going to `/usr/ports` and entering **`make clean`**. You can now go and get a sandwich if you want; like cleaning an oven, this process will be worthwhile but usually takes forever.

When a Port Will Not Build: Searching for Solutions

As convenient as the ports collection is, it's not perfectand with the amount of change that goes on in the tree, especially with so many ports (such as the ones related to GNOME and KDE) interrelated and constantly evolving, chances are that you'll run into some stumbling blocks now and then. The general failure behavior is for the compile process to exit abruptly with "`*** Error code 1`" or a similar message. When this happens, you can try a number of things.

First, make sure you're starting from a clean port. If there is a pre-existing `work` directory, it's possible that you've mixed new sources with old, resulting in an unbuildable port. Run `make clean` to start over from a clean slate.

It's also important to make sure you have the very latest ports tree available. If a port doesn't build, it's possible that it's a temporary condition that will have affected many other FreeBSD users besides yourself. A new version of the ported software might have been released since the version your ports refer to, for example, or perhaps your ports refer to a version that was newly released at the time your ports tree was installed, and some of the patches (written for a previous version) might have inadvertently become incompatible. If your ports tree is even a few days out of date, the chances are good that the port has been fixed in the meantime. Synchronize your ports tree as discussed earlier in this chapter and try building the port again (make sure you run `make clean` first).

If this doesn't work, it's time to seek outside assistance. Head to the FreeBSD website at http://www.freebsd.org and go to the Mailing Lists link, where you can search the mailing list archives for information about the port you're trying to build. Make sure you select the Ports check box as one of the search criteria. Then perform the search on the name of your port and some of the relevant text in the last few lines of the compiler output. If there's anything commonly failing that other people have noticed, you'll probably find something useful this way.

Still no luck? There's one more good recourse: the port maintainer. Look in the port's `Makefile` for the `MAINTAINER` variable, which is set to the email address of the maintainer. Send off a politely worded, undemanding email containing the last (relevant) part of the compiler output, as well as information about your system (the output of `uname -a`, for instance). The maintainer is usually a very overworked, underappreciated individual, so be sure to express your gratitude for any help!

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Upgrading a Port

If you've updated your ports tree (as described in the previous section) and the version of a port has changed, you can simply use `make install` to install it over the old version. This can be a bad idea, however, because most of the installed files will be the same from one version to another, so if you try to delete (using `pkg_delete`) an older version of the same port or package while a newer one is installed over it, you will end up deleting most of the newer version as well. If you have `pkg_version` output like the following, you're stuck with the earlier versions in your package database, unless you're willing to deinstall all versions of the package and then reinstall the current version:

```
apache-1.3.12              <   needs updating (port has 1.3.34)
apache-1.3.14              <   needs updating (port has 1.3.34)
apache-1.3.17              <   needs updating (port has 1.3.34)
apache-1.3.19              =   up-to-date with port
```

To avoid this situation, always check for a previous version of a port before installing a new one. Use `pkg_info`, `pkg_version`, or the `/var/db/pkg` structure to see what's there already. If there's an earlier version, remove it, like so:

```
# pkg_delete apache-1.3.12
```

You shouldn't have to worry about customized config files for the port. In the apache port, for example, the `pkg-plist` file contains `@unexec` commands, which compare the configuration files with the default ones installed by the port and delete them only if they match (they correspond to the `UNEXEC` commands you saw earlier in the chapter when we looked at package information with `pkg_info`). Even so, it's a good idea to back up important config files before removing a package or port, just in case.

It's not the end of the world to leave your old versions installed, though. This provides an audit trail so you can view your system's upgrade history, and it doesn't hurt anything to have the old versions around (except that if a port's component files are reorganized, the outdated files on your system will continue to hang around uselessly taking up space, and potentially confusing any other hapless administrator with whom you might be sharing duties).

Upgrading Ports with Portupgrade

To make your ports even easier to maintain and upgrade, you might want to install Portupgrade, a utility written by members of the FreeBSD team to further support the ports system. Using Portupgrade (which can be installed from the `sysutils` category), you can upgrade an installed port to a newer version with a single commandno need to research the current version, deinstall the old version, or any such trivial tasks. However, Portupgrade should be used with cautionits ease of use comes at the expense of some of the safeguards and consistency checks that make building from the ports the safest way to install software. For example, Portupgrade doesn't automatically upgrade all dependency packages or packages that depend on the one you're upgrading; you have to provide special command-line switches to make it do that (see `man portupgrade` for details). Portupgrade is intended as an expert's tool, letting you update large groups of related ports (or all your ports at once, using the `-a` option) with a single command, but only if you're fully aware of the dangerous implications of such a momentous action.

First update your ports, using CVSup. This ensures that the makefiles in the ports tree all have the most recent versions of all the ports, so you can determine which ports need to be upgraded and to what versions. Use `pkg_version` to do this:

```
# pkg_version -v
pine-4.58            <   needs updating (port has 4.64)
```

Here we see that Pine needs to be upgraded. Rather than going into `/usr/ports/mail/pine4` and typing **`make`**, **`make install`**, and **`make clean`** (and deinstalling the old version to replace it with the new one), you can simply issue the following command to perform all these steps at once:

[View full width]

```
# portupgrade pine
[Updating the pkgdb <format:bdb1_btree> in /var/db/pkg ... - 194 packages found (-0 +0) done]
```

```
--->  Upgrading 'pine-4.58' to 'pine-4.64' (mail/pine4)
--->  Building '/usr/ports/mail/pine4'
===>  Cleaning for pico-4.64

===>  Cleaning for ispell-3.2.06_13
===>  Cleaning for pine-4.64
===>  Vulnerability check disabled, database not found
/bin/sh pkg-install

. . .

===>   Compressing manual pages for pine-4.64
===>   Registering installation for pine-4.64
===>  Cleaning for pico-4.64
===>  Cleaning for ispell-3.2.06_13
===>  Cleaning for pine-4.64
--->  Cleaning out obsolete shared libraries
[Updating the pkgdb <format:bdb1_btree> in /var/db/pkg ... - 195 packages found (-0 +2) ..
    done]
```

Tip

Notice at the beginning and end of the process that Portupgrade maintains its own database of installed packages, which it uses to compare against the available ports. This database provides the ability for you to look up any given file and find out what package it came from:

```
# pkgdb /usr/local/bin/pdfopt
[Updating the pkgdb <format:bdb1_btree> in /var/db/pkg ... - 195 packages found (-0 +0) done]
ghostscript-gnu-7.07_11
```

After the process is done, use `pkg_version` again to verify that the port has been upgraded successfully:

```
# pkg_version -v
pine-4.64           =  up-to-date with port
```

Tip

You can use the **`portinstall`** command to install a new port without manually building it with the `make` command. `portinstall` is really just an alias for an install-only mode of `portupgrade`.

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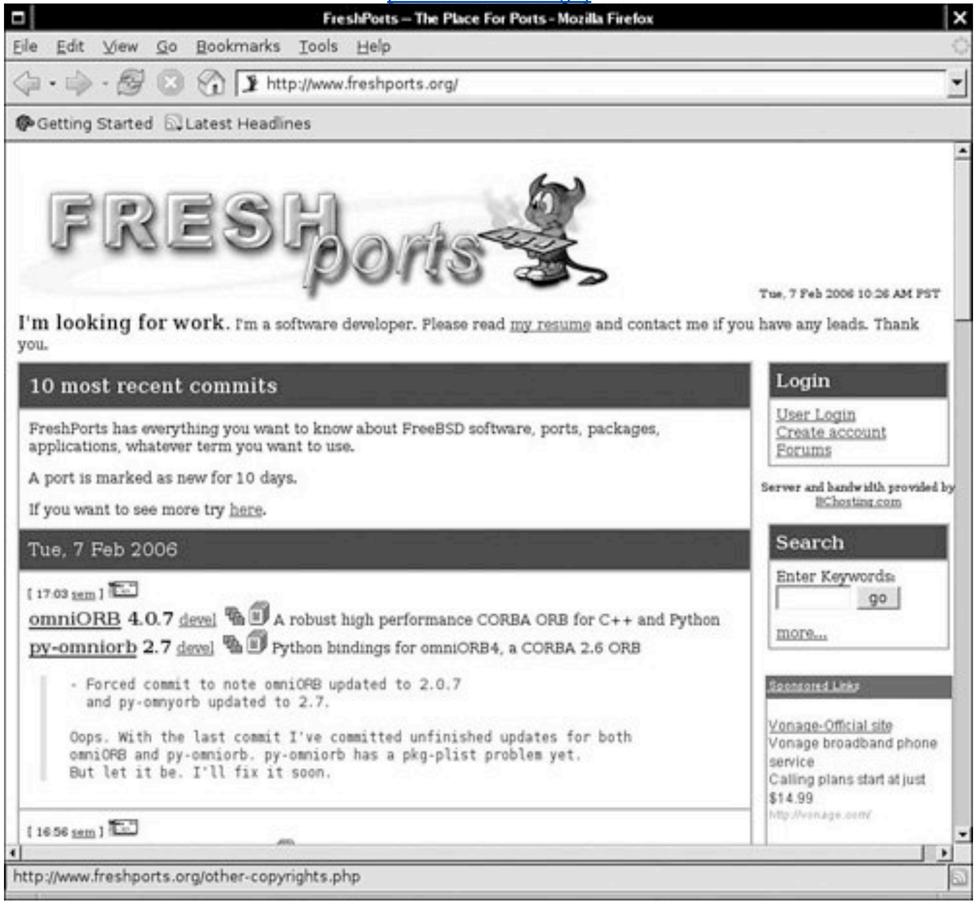
Fresh Ports

The output of the CVSup synchronization process is a useful, but hardly ideal way to keep track of which ports have changed. There's a very handy website (see Figure 16.3) that should be in the bookmarks or favorites of any FreeBSD administrator: Fresh Ports.

Figure 16.3. The Fresh Ports website (www.freshports.org).

[View full size image]



FreshPorts – The Place For Ports - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.freshports.org/

Getting Started Latest Headlines

Tue, 7 Feb 2006 10:26 AM PST

I'm looking for work. I'm a software developer. Please read my resume and contact me if you have any leads. Thank you.

10 most recent commits

FreshPorts has everything you want to know about FreeBSD software, ports, packages, applications, whatever term you want to use.

A port is marked as new for 10 days.

If you want to see more try here.

Tue, 7 Feb 2006

[17:03 sem]

omniORB 4.0.7 devel A robust high performance CORBA ORB for C++ and Python

py-omniorb 2.7 devel Python bindings for omniORB4, a CORBA 2.6 ORB

```
- Forced commit to note omniORB updated to 2.0.7
  and py-omnyorb updated to 2.7.

Oops. With the last commit I've committed unfinished updates for both
omniORB and py-omniorb. py-omniorb has a pkg-plist problem yet.
But let it be. I'll fix it soon.
```

[16:56 sem]

Login

User Login
Create account
Forums

Server and bandwidth provided by BChosting.com

Search

Enter Keywords:

go

more...

Sponsored Links

Vonage-Official site
Vonage broadband phone service
Calling plans start at just $14.99
http://vonage.com/

http://www.freshports.org/other-copyrights.php

Maintained separately from the FreeBSD project proper, Fresh Ports is a database linked to the main CVS repository for the ports collection. It constantly monitors all check-ins and lists them in reverse chronological order. You can register with the website and set up a watch list for your favorite ports. You'll be emailed whenever anything on your watch list changes, and you can view exactly what the changes are to each port so that you can determine whether the change is worth upgrading for. For instance, if a port is bumped up a version or a crucial security fix has been checked in, you may well want to upgrade; however, if the only recent change is to fix a typo in an installer error message, don't bother.

Chapter 17. Printing

IN THIS CHAPTER

Setting up a printer in FreeBSD is one of the more complex topics you will have to deal with as an administrator. In the UNIX world, and particularly in FreeBSD, printing is not as simple as installing a driver, selecting the printer from a Control Panel, and then printing, as you might be accustomed. Printing from a FreeBSD system involves setting up one or more configuration files and possibly installing *filters* (small software programs, often merely shell scripts, that translate data files into printable code) if you need to print anything more advanced than plain text. After a basic outline of the major printing processes in FreeBSD, this chapter explains how to configure the kernel, device, and communications modes, create the spool directory, install printing filters, and enable printing for your users within X11 and at the command line. The chapter also covers the administration of network printing functions, and it provides troubleshooting guidance for identifying and resolving a number of common printing problems.

Although most printers sold today connect to the computer using USB, UNIX systems such as FreeBSD are still on shaky ground when it comes to supporting that now-ubiquitous standard. UNIX-style printing is geared primarily toward serial (RS-232) and parallel port printers, and this chapter will focus on the techniques used for connecting a printer using one of these methods (many printers are still sold with parallel interfaces as well as USB ones). If you have a USB printer that you want to get working with FreeBSD, the standard print spooler techniques might work for youbut if they don't, you might want to try CUPS, a next-generation UNIX printing system covered near the end of this chapter. (IrDA and Bluetooth printing is an even more dicey proposition; Bluetooth support in FreeBSD is brand-new and barely more than experimental in its level of advancement, and IrDA isn't supported at all.)

Note

GDI printers, sometimes also called *WinPrinters*, don't work with FreeBSD at all. These printers are usually cheaper than non-GDI printers because they move some of the printer control off of the hardware and into a software driver (in much the same way that so-called "soft modems" do). These printers have disadvantages: They use more system resources because the computer's CPU has to do much of the processing, rather than letting the printer do it, and they require special drivers that are usually available only for Windows. FreeBSD is only one of many operating systems unsupported by these printers.

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How `lpd`, the Print Spooler, and the Print Queue Function in FreeBSD

`lpd` is the line printer daemon. This software runs in the background and waits for print requests. When it receives them, it sorts the requests through any relevant filters, converts the data to a different format if necessary, and sends the requests to the print queue.

A feature common to all modern operating systems, the *print queue* is an area on the hard disk where print data is stored that is waiting to be sent to the printer. Each printer connected to the system has its own separate queue and spool area. The *spool area* holds the data for you (in the order it was received, as though on a spool of thread) until it can be sent to the printer. It can hold multiple jobs from the same or different users.

When a user submits a job to be printed, it is put in the queue. The *spooler* then feeds the job to the printer when the printer is available. Jobs can have different priorities that determine in which order they will get printed. Thus the spooler and print queue act as a means for asynchronous printing, where you can create print jobs whenever you want, regardless of whether the printer is available, and the system can print them of its own accord when it's able to do so. The spooler has several advantages over simply piping data directly to the printer, as DOS used to do:

- It allows the printer to be shared by multiple users because data can be queued up to be printed, and the program that sent the data can then forget about it.
- It allows for background printing. Because a print job that's been dispatched is of no more interest to the program that dispatched it, you don't have to wait for the program to finish printing before you can continue working in it. It also means you can shut down the program after the job has been submitted to the queue without losing the print job.
- It allows for some degree of fault tolerance. If the printer has to be reset, you will not lose the jobs that are in the queue and have to resubmit them. After the printer is back online, the remaining jobs in the queue should print normally, as if nothing had happened.

Generally, the spool directories are located in `/var/spool`. Printer output is sent to a directory within `/var/spool` that corresponds to your printer, whether a parallel, serial, or USB device; the first printer on the system will normally spool to `/var/spool/lpd` or `/var/spool/output/lpd`. However, this can be changed by editing a configuration file, and you will look at how to do this later in the chapter.

Kernel, Device, and Communications Mode Configuration

The default kernel has support for the parallel and serial ports built into it, as well as basic USB support; so unless you have built a custom kernel and removed support for these ports, you shouldn't have any problems. The easiest way to check for parallel or serial support in the kernel is by checking whether it detected those ports at boot time and emitted kernel messages corresponding to them. These kernel boot messages are available throughout the computer's uptime in the file `/var/run/dmesg.boot`. Use the `grep` command to search through this file for any mention of the device corresponding to your printer: `ppc`*`N`* for parallel printers, `sio`*`N`* for serial printers, or `ulpt`*`N`* for USB printers.

Note

The *`N`* at the end of each device name indicates which device in the chain you're addressing. For example, there are four serial I/O ports in most PC-type computers, and they're numbered (like most things in UNIX) from 0 to 3. Similarly, your (likely only) parallel port controller is `ppc0`. USB printers, because they can be hot-plugged while the system is running, will echo their device names into the kernel message log at the time you connect them, and you can use the `dmesg` command to view the current kernel messages if you need to identify the device name for the USB printer you just plugged in. Note that because USB devices provide information about themselves back to the kernel, FreeBSD will usually be able to tell you about the printer's manufacturer and model, whereas parallel and serial printers are usually "black holes" to the systemit just sends data to them without knowing what's on the other end. All it can tell you about is whether it can communicate with the port itself.

The following commands show successful `grep` commands probing for parallel, serial, and connected USB printers.

```
# grep ppc /var/run/dmesg.boot
ppc0: <Standard parallel printer port> port 0x378-0x37f irq 7 on acpi0
ppc0: Generic chipset (EPP/NIBBLE) in COMPATIBLE mode
ppbus0: <Parallel port bus> on ppc0

# grep sio /var/run/dmesg.boot
sio1: <16550A-compatible COM port> port 0x2f8-0x2ff irq 3 on acpi0
sio1: type 16550A

# grep ulpt /var/run/dmesg.boot
ulpt0 at uhub0 port 1 configuration 1 interface 0
ulpt0: hp deskjet 3600, rev 2.00/1.00, addr 2, iclass 7/1
ulpt0: using bi-directional mode
```

Tip

To combine all these commands at once (and to incorporate the `^` character, which indicates the beginning of the line in a regular expression, to avoid false matches), use the following command:

```
# dmesg | grep "^ppc|^sio|^ulpt"
```

If FreeBSD responds with nothing, the kernel does not support the port in question. You will need to load a kernel module with the `kldload` command (`sio.ko` for serial, `ppbus.ko` and `lpt.ko` for parallel, and `usb.ko` and `ulpt.ko` for USB)or, for a more permanent solution, add the appropriate `device` line to the kernel configuration file and rebuild the kernel (see Chapter 18, "Kernel Configuration," for information on how to configure and build the kernel).

Configuring the Parallel Port Mode

If you're using a parallel port printer (the `lpt0` device on the `ppc0` controller), you'll need to decide what mode you want to run it in*polled* mode or *interrupt-driven* mode. Which mode you'll need depends on your printer, as some printers work better in one mode than the other; interrupt-driven mode is faster, but uses up an interrupt request (IRQ) that your system might have in short supply, and some printers are unstable in interrupt-driven mode. You can use the `lptcontrol` program to configure the mode of the parallel port. Note that you will need to be root to do this. Also, there must be a printer connected to the parallel port for `lptcontrol` to work.

The syntax of `lptcontrol` is `lptcontrol -x -d /dev/lpt0`, where `-x` is one of the options detailed in Table 17.1, depending on the mode you want to set.

Table 17.1. The `lptcontrol` Mode Options

Option	Description
`-i`	Sets interrupt-driven mode
`-p`	Sets polled mode
`-e`	Sets extended mode (whatever extended mode the printer supports)
`-s`	Sets standard mode (turns off extended mode)

If your printer and your BIOS support ECP, EPP, or other forms of enhanced parallel-port communication, you will want to use `-e` here.

Also, note that `-d` (which specifies the port device) is optional. If you do not specify a device, `lptcontrol` will use the default device, which is `/dev/lpt0`.

For example, the following command will set the first parallel port to extended mode:

```
# lptcontol -e -d /dev/lpt0
```

Maintaining Parallel Port Configuration Across Reboots

If you want these settings to be maintained across reboots, you must add the `lptcontrol` control command to one of the system startup scripts so that it is run at each system boot. The best way to do so is to create a new file in `/usr/local/etc/rc.d` that has the command in it. If you create a startup file in `/usr/local/etc/rc.d`, you will need to set the permissions on the file so that it is executable (for example, **`chmod 655 *filename*`**). See Chapter 14, "System Configuration and Startup Scripts," for more information on these techniques.

Testing Printer Port Communications

After you've determined that your kernel recognizes your printer's port, you should test its connectivity to make sure you can send data to the printer. You can use the `lptest` program to send a plain-text test page to the printer, or create a PostScript input file to test the printer's capability (if present) to print PostScript data. The printer must be turned on and you must be root for this step.

To test a parallel printer, send the prepackaged output of `lptest` to the printer device as follows:

```
# lptest > /dev/lpt0
```

For a USB printer, use the following:

```
# lptest > /dev/ulpt0
```

A test page full of standard ASCII characters should appear on the printer.

If your printer supports PostScript instructions, you can send a simple PostScript file to its device to test that capability. First create the file, as shown in Listing 17.1.

Listing 17.1. A PostScript Printer Test File

```
%!PS
100 100 moveto 300 300 lineto stroke
310 310 moveto /Helvetica findfont 12 scalefont setfont
(Hello world!) show
showpage
```

Save this file, and then send it to the printer using the cat command, using the appropriate device name for your printer:

```
# cat pstest.ps > /dev/ulpt0
```

PREV NEXT

Creating the Spool Directory and Setting Its Permissions

After you have verified that FreeBSD can talk to your printer at the most basic level, you are ready to set up the `lpd` daemon and configure the spooler. Begin by creating a spool directory for the printer. Print spool directories are normally located in `/var/spool/lpd`, although there is nothing that says you can't put them somewhere else.

Decide on a name for the printer you are configuring. You can name the printer just about anything you want, but it's probably best to use a short but descriptive name, such as `laserjet4100`. You can also create aliases to access the printer by other names.

After you have decided on a name for the printer, create a spool directory for it. Here's an example:

```
# mkdir /var/spool/lpt/laserjet4100
```

After this, you will probably want to change the owner of the spool directory and also change the permissions so that users can't snoop around and look at other people's print jobs. All print spool directories should be owned by the user "daemon" and group "daemon," and they should have read, write, and execute permissions for the user and group, with no permissions for anyone else. The following commands will correctly set the ownership and permissions on the spool directory:

```
# chown daemon.daemon /var/spool/lpd/laserjet4100
# chmod 770 /var/spool/lpd/laserjet4100
```

You have now set up the spool directory; next you'll need to set up a text filter for `lpd`.

Setting Up Text and Conversion Filters

Filters are where most of the actual work is done in printing. When `lpd` sends data to a filter, it sets the filter's `STDIN` (standard input) to the file that is to be printed and its `STDOUT` to the printer device. Conversion filters are similar to text filters except they are designed to convert non-text file formats into a format the printer can understand.

Text Filters

As its name implies, the *text filter* is the filter `lpd` uses when it receives plain text to print. Because most printers will accept plain-text data without any need for special control information, the text filter can be as simple as a shell script that uses `cat` to simply pass the raw data to the printer, or it can be as complex as a program that changes the data into a completely different format. An example of a complex filter is one that uses GhostScript, which takes raw PostScript data and changes it into a format that a non-PostScript printer can understand (see the next section for more information about GhostScript).

What is Postscript?

PostScript is a complex programming language designed to print and format graphics and text. It is device-independent, meaning that any printer that understands PostScript can render a PostScript document with no special drivers. PostScript was invented by Adobe in 1985 and is supported by a wide range of printers today. It became a widely popular language for describing text and images in files because it was so portable and device-independent (it was even used as the graphics engine for the NeXTSTEP operating system, rendering on the screen what most people would only consider sending to printers).

Unfortunately, printers that do not understand PostScript cannot print PostScript documents. (They will print out their contents as plain text, and the output is generally unreadable.) However, a freely available program called *GhostScript* can translate PostScript into a format that non-PostScript printers can understand. This allows these non-PostScript printers to emulate PostScript with software. GhostScript will be covered later in this chapter.

A very simple text filter for `lpd` would look like this:

```
#!/bin/sh
/bin/cat && exit 0
exit 2
```

The generally accepted place to store a text filter is in `/usr/local/libexec`. (You may want to call it `/usr/local/libexec/if-text`, for example.) After you have saved the file, it will also need to be made executable so that `lpd` can run it. The command **`chmod 555 /usr/local/libexec/if-text`** will do the trick.

The first line in this filter indicates that this is a shell program that should be run with `/bin/sh` (the standard shell).

Tip

If any of this is unclear to you, you might want to refer to Chapter 10, "Shell Programming," before continuing with this chapter. Setting up print filters often involves a significant amount of shell programming.

The second line simply calls the `cat` program, which by default reads data from `STDIN` and sends it to `STDOUT`. The double ampersand (`&&`) means to do both of the statements on this line, or do neither one. In other words, if the `cat` command is successful, the script will exit with status 0, which indicates success. If there is an error, the part of the line after `&&` is not performed, and the third line will be performed instead, which tells the program to exit with a status of 2. (If `lpd` receives an exit status of 2, it means the filter failed, and `lpd` will not try to print the file again.)

Setting Up Text Filters for Printing Plain-Text Files on PostScript Printers

The preceding simple filter will work fine for printing plain text on most non-PostScript printers. However, PostScript printers cannot handle plain-text data. (A PostScript printer expects input data in the form of a text program in the PostScript language that specifies control commands for text and graphics output.) If you have a PostScript printer, you will need a more complex filter that can convert the plain-text data into PostScript data.

The first thing you need to do is install a program that can convert plain text to PostScript. A program that can handle this task for you is `a2ps`, which can be found in the `print` section of the FreeBSD ports tree. (Refer to Chapter 16, "Installing Additional Software," for more information on how to install ports.) Note that three versions of `a2ps` are available. They are named based on the paper size they are intended to work with. For example, if you'll be primarily using U.S. letter paper (8.5x11"), use `a2ps-letter`.

A filter for a PostScript printer first has to be able to test whether it is receiving valid PostScript data. If it is, nothing happens, and the data is passed straight through as it was with the earlier simple text filter. If the PostScript printer is not receiving PostScript data, the filter must convert the data to PostScript before it sends it to the printer.

All PostScript data streams begin with the magic character sequence `%!`. You can write a shell script that checks to see whether the first line of the input file begins with this sequence. If it does, you have a PostScript file, and the data can be passed straight through to the printer. If it doesn't, you have a plain-text file, and the data needs to be passed through `a2ps` to convert it to PostScript before it is sent to the printer.

The shell script shown in Listing 17.2 will do the trick.

Listing 17.2. Sample Postscript Filter

```
#!/bin/sh
# Simple filter for PostScript printers

read header
ps_test=`expr "$header" : '\(..\)'`
if [ "$header" = "%!" ]
then
    # File is PostScript. Print pass through.
    Echo "$header" && cat && printf "\004" && exit 0
    exit 2
else
    # File is plain text. Convert it first.
    (echo "$header"; cat) | /usr/local/bin/a2p && printf "\004" && exit 0
    exit 2
fi
```

Save this file somewhere (/usr/local/libexec/if-ps might be a good choice). Make the file executable so that lpd can run it (**chmod 555 /usr/local/libexec/if-ps**).

This filter code reads the first line of the input it is sent by lpd and stores it in the variable header. The program then uses the expr command to get the first two characters from the file and stores them in the variable ps_test. The if statement that comes next checks what two characters are stored in ps_test. If they are %!, this is a PostScript file and the then statement is performed, which passes the raw data directly to the printer. It sends the first line, lists the rest of the input using the cat command, sends an escaped \004 with printf, and finally exits with a status of 0. The double ampersand (&&) connects the different statements and says, "Either do all of these commands or don't do any of them." If for whatever reason any part of this command line fails, none of it will be performed, and the program will exit with status 2 insteadwhich tells lpd that the data could not be printed and that it should not retry.

If the first two characters are not %!, this file is not a PostScript file, and the else statements are performed instead. The else statements in this case first echo the first line of the program and then list (using cat) the rest of the input and pipe it to /usr/local/bin/a2ps. The a2ps program does the work of converting the file into PostScript and printing out its converted output into the filter's data stream.

Finally, when all the data has been sent, an escaped \004 is sent with printf, and the program exits with a status of 0. As with the then statement, if any part fails, the program will exit with a status of 2 instead.

The a2ps program has many options, so if you will be printing plain-text files through a PostScript printer on a regular basis, I suggest you read the man page for a2ps. You can then modify the way this script calls a2ps to suit your needs and preference.

Printing PostScript Files on Non-PostScript Printers

If you have a non-PostScript printer, your problem is just the opposite of the one just described. You need to let plain text pass through to the printer, but you need to convert PostScript data to a format that your printer can understand.

If you never plan to print more than plain text, you do not need to worry about this. However, PostScript is the common denominator in UNIX and FreeBSD when it comes to printing anything other than plain text. Virtually all word processing, graphing, drawing, and graphics programs can write a PostScript file (or send it directly to the printer). Although some applications (such as the OpenOffice.org suite) may have built-in drivers for your particular printer, most UNIX applications will not. Instead, they will simply output PostScript. Because of this, your printing capabilities will be severely limited if you cannot handle PostScript.

Fortunately, a company called Aladdin makes a freely available program called GhostScript that can simulate a PostScript printer. It takes PostScript input and converts it to a form that your printer can understand.

Note

GhostScript supports a wide variety of printers. A list (which may not be all-inclusive) can be obtained at http://www.cs.wisc.edu/~ghost/doc/printer.htm.

GhostScript is available in the FreeBSD ports collection under the print category. Refer to Chapter 16 for information on installing ports.

For this procedure to work, you will need a script similar to the one described in the previous sectionexcept that the operations will be reversed. In this case, if the script detects that the data being sent is *not* PostScript data, that data will be passed straight through. If the data *is* PostScript, it will be sent through the GhostScript program to convert it to something the non-PostScript printer can understand. The script shown in Listing 17.3, taken from the online FreeBSD Handbook, will provide PostScript functionality on an HP DeskJet 500 (a non-PostScript printer).

Listing 17.3. A Sample GhostScript Filter for an HP DeskJet 500

```
#!/bin/sh
   #
   #  ifhp - Print GhostScript-simulated PostScript on a DeskJet 500
   #  Installed in /usr/local/libexec/hpif

   #
   #  Treat LF as CR+LF:
   #
   printf "\033&k2G" || exit 2

   #
   #  Read first two characters of the file
   #
   read first_line
   first_two_chars=`expr "$first_line" : '\(..\)'`

   if [ "$first_two_chars" = "%!" ]; then
       #
       #  It is PostScript; use GhostScript to scan-convert and print it.
       #
       #  Note that PostScript files are actually interpreted programs,
       #  and those programs are allowed to write to stdout, which will
       #  mess up the printed output. So, we redirect stdout to stderr
       #  and then make descriptor 3 go to stdout, and have GhostScript
       #  write its output there. Exercise for the clever reader:
       #  capture the stderr output from GhostScript and mail it back to
       #  the user originating the print job.
       #
       exec 3>&1 1>&2
       /usr/local/bin/gs -dSAFER -dNOPAUSE -q -sDEVICE=djet500 \
           -sOutputFile=/dev/fd/3 - && exit 0

       #
       /usr/local/bin/gs -dSAFER -dNOPAUSE -q -sDEVICE=djet500 -sOutputFile=- - \
           && exit 0
   else

       #
       # Plain text or HP/PCL, so just print it directly; print a form
       # at the end to eject the last page.
       #
       echo $first_line && cat && printf "\033&l0H" &&
   exit 0
   fi

   exit 2
```

This script looks complicated at first, but it isn't really that bad. The first thing the script does is to read the first line of the input, extract the first two characters, and check to see whether they are `%!`. If they are, the input data is in PostScript format, and the `then` statements are executed, which send the output through GhostScript. If they are not, the file is treated as plain text and is passed straight through.

Note

GhostScript is a very powerful program that has far more options than can be covered here. For more information on GhostScript, see the documentation at http://www.cs.wisc.edu/~ghost.

Note

FreeBSD also comes with a program called `/usr/libexec/lpr/lpf` that can act as a print filter. It has many text-reformatting capabilities, and also allows for accounting (the capability to track how many pages are printed, by what users, and so on). See the `man` page for `pac` for more details on how to use `pac` and `lpf` to keep track of users' paper and printer time usage.

Conversion Filters

As mentioned earlier, *conversion filters* are similar to text filters, except they are designed to convert input data in any of the various formats used in user applications into a format the printer can understand. Conversion filters allow you to print various types of files directly from the command line with `lpr` and avoid having to load them into a program or convert them by hand before you print them. You specify which filter to use on the command line with an option to `lpr`. (`lpr` is the command used to print files from the command line. We will cover it in detail later in this chapter.)

In the modern world, the only conversion filter options that are likely to interest you are `-d`, which specifies a file in DVI format (as used by the TeX typesetting system), and `-g`, which specifies a file that contains plotting data produced by the UNIX `plot` routines. Other conversion filter options specify file types and applications that are not included with FreeBSD, such as `-f` (FORTRAN source files), `-c` (`cifplot` files), `-n` (`ditroff`), `-t` (C/A/T typesetting commands for ancient versions of `TRoff`), and `-v` (raster images).

By default, none of these filters is installed. Also, the option letter and the filter it calls are not hard-coded into the system. Because of this, if you have no use for a `cifplot` filter, for example, it is easy to redefine the `-c` option to call some other filter that you might have installed or written yourself. Like text filters, these user-defined filters can be shell scripts that call standard UNIX programs or standalone executable programs that may be provided by manufacturers of third-party software.

The following is an example of a very simple conversion filter that converts data in the GNU `groff` typesetting system (which cannot be understood by the printer) into PostScript (which can be understood by the printer, either directly or by sending the data through GhostScript):

```
#!/bin/sh
exec grops
```

If you read the `man` page for `grops`, you will see that it is a program that converts `groff` to PostScript. In this case, the file will simply be sent through `grops` before being sent to the printer for printing.

If you want to install this filter, it should be saved in the directory `/usr/local/libexec`. (You might decide to call this filter `g2ps` or something similar because it converts `groff` data to PostScript.)

If you are planning to reassign the `lpr` option `-t` to this new filter, you'll be able to print a `groff` source file directly from the command line and have it come out looking correct on the printer. This would be done as follows:

```
# lpr -t myfile
```

Here, *`myfile`* is, of course, the name of the `groff` source file you want to print.

You learn how to configure the print system to actually use this custom filter in the following section of this chapter, where you look at setting up the `/etc/printcap` file (the file that controls how the print system behaves).

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Configuring /etc/printcap to Control Print System Functions

The /etc/printcap (printer capabilities) file is the glue that holds together all of what we have covered so far. It defines the name and aliases of a printer, what filter it uses, the conversion filters it can use, what option should be used to access the filter, where the printer spools its jobs, and more.

An /etc/printcap file already exists on your system, but all the options are commented out. Therefore, in order to make it viable, you'll need to uncomment and change or add some options.

Building the /etc/printcap File

The format of /etc/printcap is fairly simple; it contains one or more multiline entries, one for each printer you want the system to be able to use. Here is a sample entry for a PostScript printer:

```
laserjet4100|lp|local line printer:\
#        :sh:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/laserjet4100:lf=/var/log/lpd-errs:
    :if=/usr/local/libexec/if-ps:
```

The first line in this entry is divided into fields by the pipe (|) character; the first field gives the printer name, followed by any aliases you want to define in the second. In this case, the name of the printer is laserjet4100. It also has an alias of lp, which means it will be the default printer. Finally, the last field in the line is a long description of this printer.

The second line is commented out. If it is uncommented, header pages (cover pages) will be printed that give the name of the user, the name of the file, and so on. This is a good idea if you have a lot of users printing to the same printerthey can easily find which printouts are theirs when they go to pick them up.

The third line gives the information on where the printer is located. Here, :lp stands for *local printer* (as opposed to a remote printer). The printer is located on the first parallel port (/dev/lpt0). Also, :sd is the *spool directory* this printer uses, which is /var/spool/lpd/laserjet4100 (see the section in this chapter on creating and configuring the spool directory), and :lf, which stands for *log file*, is where this printer will log any errors it encounters.

The fourth line specifies the *input filter*, or text filter, that should be used with this printer. In this case, you are using the if-ps filter (which is the text-to-PostScript filter you created earlier).

Installing Conversion Filters

If you want to install any conversion filters, /etc/printcap is also where those are handled. Install them simply by adding a new line in the printer entry containing the appropriate option (listed in Table 17.2), followed by the pathname of the filter. The format is the same as the :if line for the input filter.

Table 17.2. Filter Options for /etc/printcap

Filter	Option
DVI	:df
FORTRAN	:rf
cifplot	:cf
plot	:gf

`dittroff`	`:nf`
`TRoff`	`:tf`
raster	`:vf`

Remember that these filters are not hard-coded. Therefore, if you have no use for a FORTRAN filter, for example, you can replace it with some other filter, simply by using that filter's pathname in the `/etc/printcap` file along with the option you want to assign to it.

Note

If you repurpose an `lpr` flag using the `/etc/printcap` file, you should make a change to the `man` page for `lpr` to indicate the changes you've made, for the benefit of your users who might be using the `man` page to learn how to print their files. Use the following commands to edit the `man` page:

```
# gunzip /usr/share/man/man1/lpr.1.gz
# vi /usr/share/man/man1/lpr.1
# gzip /usr/share/man/man1/lpr.1
```

Here is the line you would add beneath the `:if` line to install the `groff`-to-PostScript filter you created earlier, in place of the FORTRAN conversion filter:

```
:rf=/usr/local/libexec/g2ps:
```

Note that when you add this line, you will have to make a slight change to the `:if` line before it and add a backslash at the end. This is because `lpd` expects the entire line of information to be on one line, but the backslash escapes the newline character so that multiple lines are treated as a single line when read by the system.

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Enabling `lpd` for Command-Line Printing

After you have configured the `/etc/printcap` file, you can start `lpd`. As root, you can simply type **`lpd`** from the command line to start it. If you want to have `lpd` start up automatically each time the system boots, add the following line to `/etc/rc.conf`:

```
lpd_enable="YES"
```

You should now be able to print from the command line by following the instructions in the next section. If printing doesn't work correctly, see the troubleshooting section at the end of the chapter.

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Basic Command-Line Printing

The lpr command is used to send a file to the print spooler. At its simplest, lpr takes the form:

```
# lpr filename
```

where *filename* is, naturally, the name of the file that should be printed. You can specify multiple filenames on the command line to cause multiple files to be printed.

You have the option of specifying a printer to which you want the data to be sent; to do so, use the -P option. If you omit the -P option, lpr assumes that the default printer should be used. The default printer is determined by checking these conditions in the following listed order; the first condition that is found to be true will be used to define the default printer:

- If the PRINTER environment variable is set, lpr will use the name listed here as the default printer.
- If the LPDEST environment variable is set, lpr will use the name listed here as the default printer.
- The printer name lp is used, which should be an alias to one of the printers in the /etc/printcap file.
- If neither the PRINTER environment variable nor the LPDEST environment variable is set, and no printer has an lp alias in /etc/printcap, the print request will fail.

The lpr command also has several other options. Table 17.3 contains a list of some of the options you are likely to find the most useful.

Table 17.3. Options to the lpr Command

Option	Description
-l	Uses a filter that will print control codes and suppress page breaks.
-p	Output is formatted with pr, which formats pages into 66 lines per page with a header at the top containing the date and time the file was created, along with the page number and five blank lines at the bottom.
-P	Sends the job to a printer other than the default one.
-h	Suppresses the printing of the "burst" page, also known as the *banner* or *header page*. This has no effect if header pages are turned off by default.
-m	Sends email to you, notifying you when the print job has completed printing.
-r	Removes the file upon completion of spooling. This option should probably not be used because it will remove the file before it has successfully printed. If it is used with the -s option (described next), it won't remove the file until after it has completed printing.
-s	Uses symbolic links. Rather than copying the file to the spool directory, this option will simply create a symbolic link to the spool directory from the existing file. This allows files too large to fit in the spool area to be printed. If you use this option, be careful that you do not modify or

	delete the file before it has finished printing.
`-#n`	Here, *n* is the number of copies of each file that should be printed. (This feature can be disabled.)
`-J job`	Here, *job* is the name of the job that should be printed on the banner page. By default, it will be the name of the first file that is specified.
`-T`	Specifies the title string that `pr` should use on the header at the top of the page. By default, this will be the filename. This option only applies if the `-p` option has also been used.
`-i n`	Here, *n* represents the number of columns by which the printed output will be indented.
`-w n`	Here, *n* represents the page width in columns. This only applies if the `-p` option has also been used.

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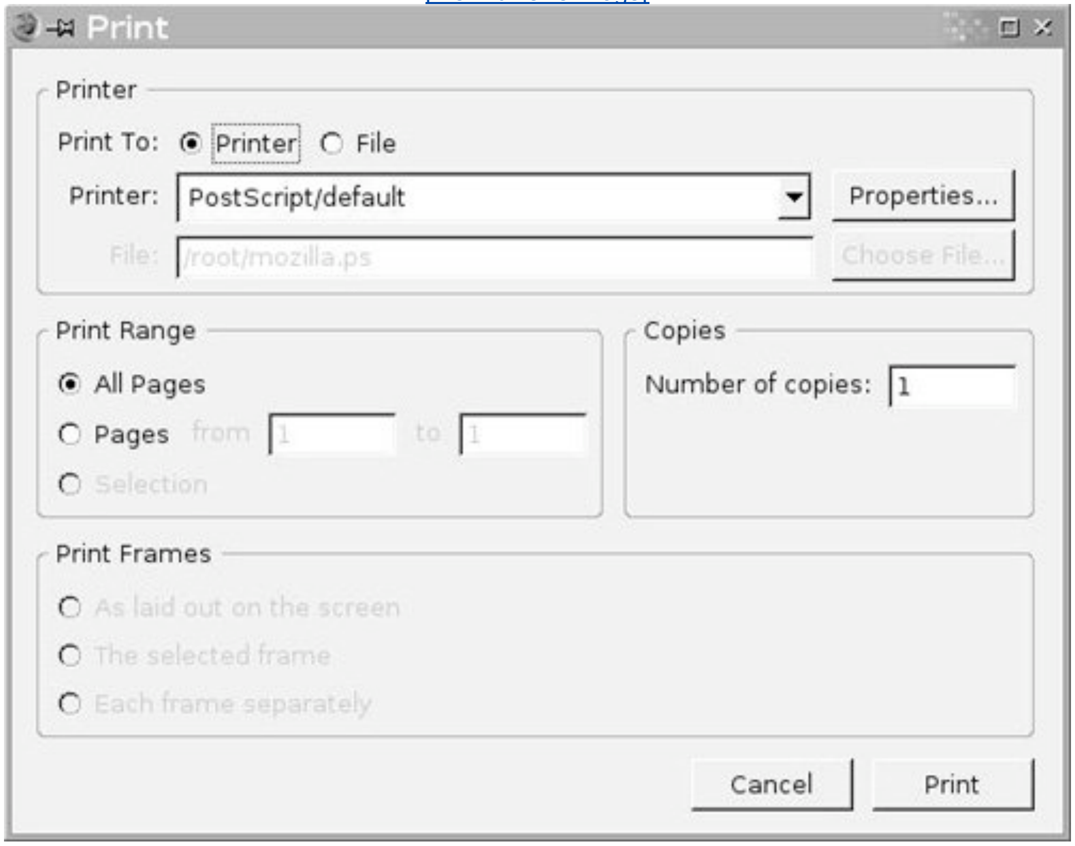
Printing from X11 Applications

Different X11 applications will have different means of printing, but most behave more or less the way you'd expect from any desktop application, as long as you've got the `lpr` subsystem working properly. In most cases, an application will simply present a "Generic Printer" option for printer output, pointing to an `lpr` command line similar to what you'd use if you were sending a file to the printer on the command line. Applications' print dialogs will vary, but because printing web pages is a fairly common task, here is an example of printing from Firefox.

To print a page you're viewing in Firefox, select File and then choose Print from the menu. The Print dialog box is shown in Figure 17.1.

Figure 17.1. The Print dialog box in Firefox. Notice that if you click the File radio button at the top, the filename will be `mozilla.ps`, indicating that the output is a PostScript file.

[View full size image]



Print

Printer

Print To: [✓ Printer] File

Printer: PostScript/default

File: /root/mozilla.ps

Print Range: [✓ All Pages] Pages from 1 to 1, Selection

Copies: Number of copies: 1

Print Frames: As laid out on the screen, The selected frame, Each frame separately

In the Print To section at the top, you can select whether you want to send the output to a printer or to a file. If you select Printer, the Printer box becomes active and you can either accept the default print spooling behavior that Firefox will use, or click Properties to modify the underlying `lpr` command to achieve alternative behaviors such as having it email you when it is done or print more than one copy. (See the section on `lpr` earlier in this chapter, as well as the `man lpr` page, for details.)

Most X11 programs can also output to a file. When they do, they will usually create a PostScript file that can then be sent to a PostScript printer directly or run through GhostScript and sent to a non-PostScript printer. This is an excellent way to create a snapshot of something you want to print, even if your computer doesn't have a printer available at the time; you can then print it later from the file when you do have a printer to use.

Note

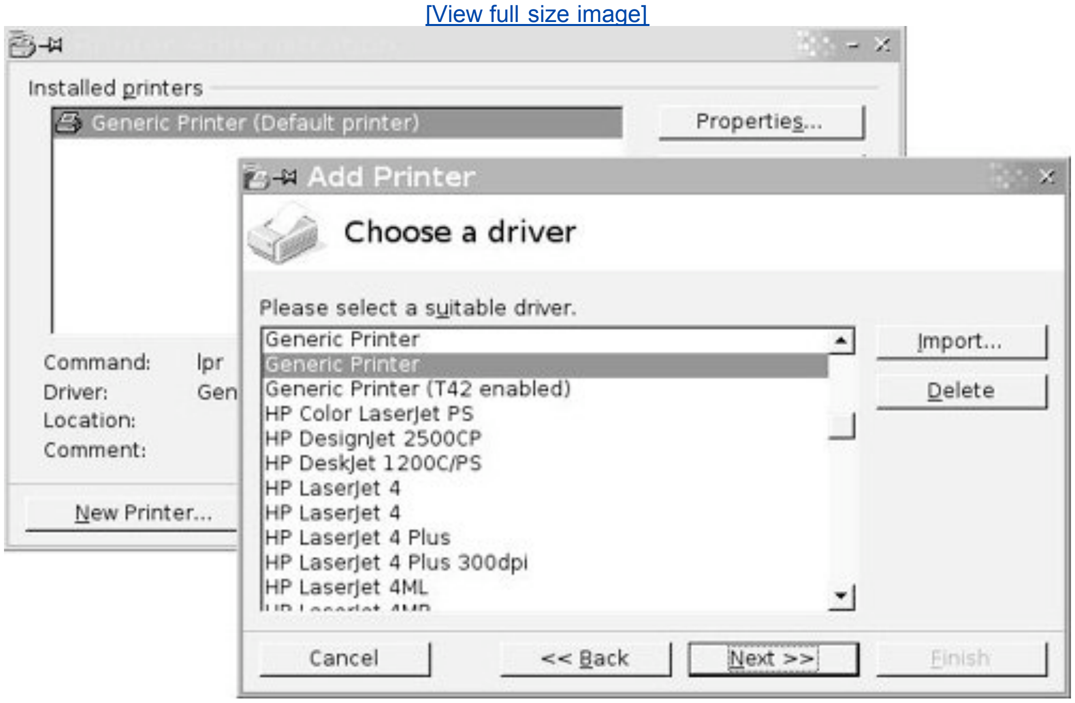
Like many other UNIX programs, Firefox has no built-in printer drivers. It simply outputs a data stream in PostScript format, feeding it either to `lpr` or to a file. This demonstrates the need for GhostScript if you are not using a printer that understands PostScript.

Printing in OpenOffice.org

If you have OpenOffice.org installed, you can configure its default printer by double-clicking the Printer Setup icon on the desktop if it exists; if it doesn't, you can launch the utility from `/usr/local/openoffice.org2.0.0/program/spadmin`. You will get a dialog box showing your default ("Generic") printer, as well as buttons you can use for adding new printers, as shown in Figure 17.2.

Figure 17.2. The Printer Configuration dialog box in OpenOffice.org. Notice that OpenOffice.org has printer drivers built-in (bottom box) for many different printer models.

[View full size image]



Because OpenOffice.org comes with a large selection of built-in drivers for various printers, it eliminates the need for using GhostScript to translate PostScript output. You can simply select your printer model from the list and follow the wizard to install it into OpenOffice.org's printer subsystem. You can then use the Properties button and other buttons in the dialog to further configure the printer, add fonts, print test pages, and more.

If you do not install a printer, OpenOffice.org uses the default Generic Printer (Default Printer), which sends PostScript output to `lpr`.

Tip

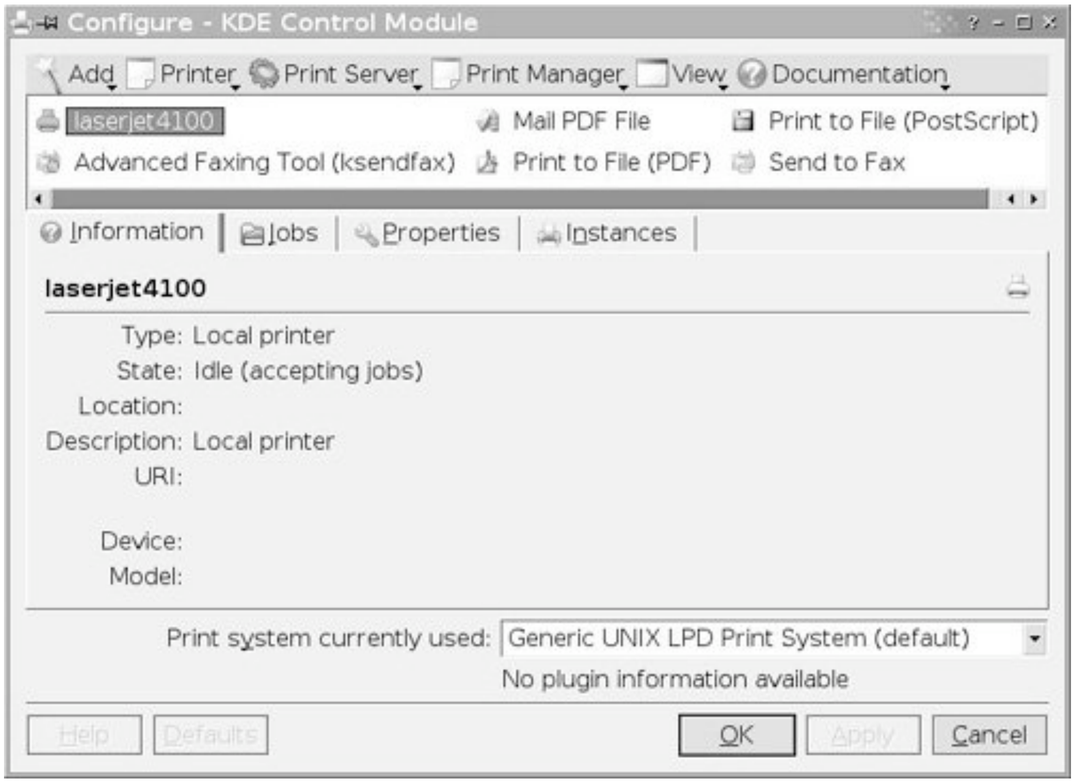
Even if you do have GhostScript installed, you will probably want to use one of the native drivers in OpenOffice.org insteadit may have better support for the various features of your printer than can be harnessed properly by the more generic GhostScript.

Printer Management in KDE

KDE has a built-in GUI-based printer queue viewer and management utility; you can reach it either by choosing Settings, Printing Manager from the K menu, or by entering the Control Center and then choosing Peripherals, Printers. This gives you a control panel similar to what's shown in Figure 17.3.

Figure 17.3. The Printing Manager control panel in KDE.

[View full size image]



laserjet4100

Type: Local printer
State: Idle (accepting jobs)
Location:
Description: Local printer
URI:
Device:
Model:

Print system currently used: Generic UNIX LPD Print System (default)

No plugin information available

You can't set up or reconfigure printers from within this utility directlyprinter configuration in FreeBSD still relies on the contents of `/etc/printcap`, which is where KDE's printer management panel gets its printer information, just like any CLI-based application. However, it does give you the ability to view the print queues of any of your existing printers (select the printer from the top panel and then click the Jobs tab) in a graphical and interactive manner akin to similar utilities in Windows and Mac OS X. You can also use the Print System Currently Used menu to tell KDE to use alternative printing mechanisms for a given printer, such as CUPS (which will be discussed later in this chapter).

Most KDE applications use a common print dialog component called KPrinter, which lets you choose from among the printers specified in the Printing Manager utility, and perform additional in-line configurations at the time you print. A full discussion of KPrinter's capabilities can be found at http://printing.kde.org/overview/kprinter.php.

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Using the `lpq` Command to Check the Status of Print Jobs

The `lpq` command can be used to check the status of jobs that are waiting in the print queue. If it is called without any arguments, `lpq` will report the status of all jobs currently in the queue for the default printer. If the `PRINTER` environment variable is set, that printer is considered to be the default printer. If the `PRINTER` environment variable is not set, the printer that is aliased to `lp` in `/etc/printcap` will be used as the default.

`lpq` can also be called with a job number to show only the status of a particular job or with a username to show only the status of jobs owned by a particular user. The output of `lpq` will look something like this:

```
# lpq -P samsunginkjet
samsunginkjet is ready and printing
Rank      Owner    Job    Files                           Total Size
active    frank    5      /home/btman/sample.txt          2000 bytes
2nd       frank    6      /home/btman/sample1.txt         2500 bytes
3rd       jack     7      /home/jack/myfile.txt           3200 bytes
4th       jack     8      ...                             5500 bytes
```

The `-P` option tells `lpq` to report on a printer other than the defaultin this case, the printer named `samsunginkjet`. All of the options to `lpq` will be explained later.

The first line in the output from `lpq` tells you what the printer is currently doing. In this case, the printer is ready and printing. If the printer is stalled, out of paper, jammed, and so on, `lpq` will report that status instead.

The example here shows four jobs in the queue; one is active, and the others are ranked as to when they will be printed. A few other things are worth pointing out. The third column, labeled `Job`, shows the ID number assigned to a particular job. If you need to cancel a print job (explained later), you will need this job ID number. Also, the fourth column lists the file or files that are being printed. Notice that the fourth job in this example is listed as just three dots. This means that the pathname of the file is too long to fit in the list, so `lpq` simply didn't list it.

The `lpq` command has a few other options, as shown in Table 17.4.

Table 17.4. Options to `lpq`

Option	Description
`-P` *`name`*	Here, *`name`* is the name of a printer. This will cause `lpq` to show information on a printer other than the default one.
`-l`	This option will cause information about each one of the files in the queue to be displayed, even if the information causes the display to break across a line. (In the previous example, this command would cause the filename to show; it currently shows up as three dots because it's too long to fit.)
`-a`	Causes `lpq` to display the status of all local queues for all printers.

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Removing Jobs from the Queue with the `lprm` Command

The `lprm` command can be used to remove print jobs that are currently in the queue and sometimes to remove print jobs that are currently printing. If `lprm` is run without any command-line arguments, it will remove whatever job is currently printing on the default printer if that job belongs to the user running `lprm`. If the currently running job does not belong to the user running `lprm`, the command will have no effect. If the root user runs `lprm` with no options, the command will remove the currently printing job from the default printer, no matter who the job belongs to.

Running `lprm` with a job number as an argument will remove the job with that ID number from the queue of the default printer, assuming that you own the job and that you are not the root user. Normal users can only remove jobs that belong to them. The root user can remove any job. Use `lpq` (as described in the previous section) to determine a job's ID, which you can then feed to `lprm`. Here is an example:

```
# lprm 5
dfA001simba.example.com dequeued
cfA001simba.example.com dequeued
```

This command "dequeues" (removes from the queue) two files associated with job ID 5: the spooled copy of the file (beginning with `dfA001`), and a control file. When both these files have been deleted, the print job stops, and any data not yet spooled to the printer is discarded.

Note

The system may take some time to respond when you run `lprm` (up to several seconds). It may seem that `lprm` has hung. Don't worry; it hasn't. Wait a few seconds, and you should get your prompt back.

If you try to delete a job that does not belong to you, and you are not the root user, `lprm` will respond with the message `Permission denied`.

The `lprm` command has a few options to modify the default behavior. These are listed in Table 17.5.

Table 17.5. Options to `lprm`

Option	Description
`-P` *`name`*	Here, *`name`* is the name of the printer that `lprm` should remove the job from. If the printer name is not specified, the default printer specified in the `PRINTER` environment variable is used. If the `PRINTER` environment variable is not set, the default printer aliased to `lp` is used.
`-`	A dash by itself will cause all jobs belonging to you to be removed from the queue. If you are the root user, all jobs in the queue will be removed.
`user`	Here, *`user`* is the username of someone on the system. This option will remove all jobs belonging to that user. This works only for the root user because normal users can only remove jobs belonging to themselves.

Caution

Removing a job that is currently printing will not cause the printer to stop immediately. Depending on the amount of RAM installed in your printer, there could be up to several pages of data already in the printer's buffer. This means that some of the document could be printed anyway (or if the document is small enough, almost the entire document could be printed), even if it has been removed from the queue.

Note

Print jobs can be removed only from the system they were sent from, even if the printer is available to more than one computer on the network.

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Controlling Printers

Printers and their associated queues are controlled with the `lpc` command. This command is used by the system administrator for printer administration. Some limited functionality is available to normal users, such as displaying the status of queues and restarting the printer daemon if it has died. Among other things, `lpc` can be used to enable and disable printers, enable and disable printer queues, change the order of jobs in the queue so that files at the bottom of the queue can be printed first, and check the status of queues.

If no command-line arguments are given to `lpc`, it will start in interactive mode with a prompt. You can also supply command-line arguments when starting `lpc`. If you do this, `lpc` will start, run the arguments specified on the command line, and then exit. You will start by looking at the interactive mode of `lpc`.

Using `lpc` in Interactive Mode

If `lpc` is started with no arguments, it will run in interactive mode. The interactive mode offers a prompt like this:

```
lpc>
```

You can type **`?`** or **`help`** and press Enter to get a list of the available commands. Typing **`help`** followed by the name of one of the commands will give you a short, one-line description of what the command does.

When you type commands, they can be abbreviated to the shortest form that is not ambiguous. For example, the `status` command can be abbreviated as `stat`. However, it could not be abbreviated as `sta` because there is also a `start` command, and `lpc` would not know which one you wanted.

If you do not provide enough of the command for `lpc` to know which one you mean, it will respond with `?Ambiguous command`. If the command you specify does not exist, it will respond with `?Invalid command`.

Checking Queue Status

To check the status of a queue, use the `status` command (which, as mentioned previously, can be abbreviated `stat`). You also need to specify an argument, which can be either `all` to display the status of all daemons and queues, or the name of a printer to show the status for only that printer. Here's an example:

```
lpc> status lp
lp:
        queuing is enabled
        printing is enabled
        2 entries in spool area
        waiting for lp to become ready (offline?)
```

This gives you the status for the system default line printer. In this case, the queue is enabled, printing is enabled, and two entries are sitting in the queue waiting to be printed. However, nothing is printing because the printer is unavailable, and `lpc` suggests that it may be offline.

The `status` command can be run by both normal users and system administrators.

Disabling, Printing, and Stopping the Daemon

The abort and stop commands can be used by the system administrator to disable printing and also terminate the daemon that handles spooling for the printer. Both commands require an argumenteither all, which will disable printing on all the queues and terminate the daemons, or the name of a printer, which will cause the command to affect only the named printer.

The abort command terminates printing immediately and stops the daemon that handles spooling for that printer. Here's an example:

```
lpc> abort lp
lp:
        printing disabled
        daemon (pid 597) killed
```

And here is the output of the status command after the preceding command:

```
lpc> status all
lp:
        queuing is enabled
        printing is disabled
        2 entries in spool area
        printer idle
```

There are two important points to note about this output:

- Two entries are still listed in the spool area. The abort command simply kills the daemon and disables the printer. It does not remove any jobs from the spool area. When the daemon is restarted and the printer is enabled again, the jobs that are in the spool area will resume printing.
- Queuing is enabled. This means you (and others) can still send jobs to the printer. They will be placed in the queue to wait until the daemon is restarted and the printer is enabled. At that point, any jobs submitted while the printer was disabled will be printed, along with any jobs that were already in the queue.

The stop command works similarly to the abort command, except it will wait until the current job has finished printing before it disables the printer and stops the spool daemon. As with abort, stop does not flush existing jobs from the queue, and the queue will still accept jobs that users submit and hold them for printing whenever the printer becomes available.

Tip

If you will be taking a printer down for an extended period of time (for maintenance, for example), consider aliasing that printer's name and its aliases to another printer in /etc/printcap. If it's the system default printer entry you're redirecting, make sure you also alias lp to a different printer. This will redirect any print jobs sent to that printer to a different printer without requiring users to make any changes to their configuration. Preferably, of course, you will want to alias the downed printer to a printer that is of a similar type and is located in the building fairly close to where the downed printer is located. In addition, you will probably want to send a systemwide email to the affected users, letting them know where they can pick up their print jobs for the time being until the printer they normally use is available again.

Disabling Print Queuing

Neither abort nor stop disables the queue. If you are taking a printer down for maintenance, for example, and you simply issue an `abort` command to kill the daemon and disable the printer, the queue will still be available. Users will be able to continue to send jobs to this printer as if nothing is wrong, and the queue will happily accept the jobs and store them to print whenever the printer becomes available. To keep your users' expectations realistic, you will probably want to disable the queue if the printer will be down for an extended period of time. There are two ways that this can be done.

The first method is with the `disable` command. It requires an argument that can either be `all` to disable all queues on the system or the name of a particular printer to disable the queue for only that printer. Here's an example:

```
lpc> disable lp
lp:
        queuing disabled
lpc> status all
lp:
        queuing is disabled
        printing is enabled
        3 entries in spool area
        waiting for lp to become ready (offline?)
```

In this case, the queue is disabled, but printing is still enabled. This means that the printer will continue to print all jobs currently in the queue (if it can), but the queue will not accept any new jobs.

If you try to send a job to a printer with a downed queue that is not accepting jobs, you will get an error similar to the following:

```
# lpr myfile.txt
lpr: Printer queue is disabled
```

The other way that a queue can be disabled is by using the `down` command. Like the `disable` command, it requires at least one argument, which can either be `all` to affect all queues on the system or the name of a printer to affect only one printer.

The `down` command actually sends a `stop` command, which disables the printer and the spool daemon after the current job has finished printing, and then sends a `disable` command to bring down the queue. The `down` command can also take an optional message as an argument. The message will be written to the status file in the printer's spool directory. This will then be displayed in the output of `lpq` to let users know why the queue is not accepting their requests. Here's an example:

```
lpc> down lp Printer is down for maintenance.
lp:
        printer and queuing disabled
```

If `lpq` is then run, it will respond with the following:

```
# lpq
Warning: lp is down: Printer is down for maintenance.
Warning: lp queue is turned off
Printer is down for maintenance.
Rank   Owner      Job  Files                               Total Size
```

To enable a downed queue, simply type **`enable all`** to enable all queues. Alternatively, you can type the name of a printer to enable only the queue on that printer. Here's an example:

```
lpc> enable lp
lp:
        queuing enabled
lpc> status lp

lp:
        queuing is enabled
        printing is disabled
        3 entries in spool area
        Printer is down for maintenance.
```

Notice that although this brought the queue back up, it did not reenable the printer. Currently, the queue will accept jobs, but they will not be printed. If you used the `down` command to bring down the queue, use the `up` command to bring it back up. This will reenable the queue, restart the spooling daemon, and enable the printer. It will not, however, clear the status message. To clear the status message, you will need to run the **`restart`** command, as discussed in the next section.

Restarting a Spooling Daemon

If you need to restart a spooling daemon, you can use the `restart` command. If there is no daemon currently running, this command will start one. If there is currently a daemon running, this command will kill it and restart it (see the following caution, however). This can be used to reset a daemon that seems to have hung, for example.

The `restart` command requires an argument that can be either `all` to restart all print daemons on the system or the name of a printer to restart only the daemon for that printer. Here's an example:

```
lpc> restart lp
lp:
        daemon (pid 2102) killed
lp:
        daemon started
```

Caution

Occasionally, the `restart` command kills a running daemon but doesn't restart it again, even though it claims it did. Because of this, it is a good idea to check the output of `lpq` for the printer in question. If `lpq` says in the status line `Warning: no daemon present`, it means that `lpc` stopped the daemon when the `restart` command was issued but then failed to restart it again. If this is the case, simply run the `restart` command again from `lpc`, and this will take care of the problem.

Cleaning the Queue Directory

The `clean` command in `lpc` causes it to clean out the queue directory. It will remove any control files and related print job fragments that cannot be printed. Like most commands in `lpc`, the `clean` command requires an argument of either `all` or the name of the printer spool directory that you want to clean.

Changing the Priority of Print Jobs

You can use the `topq` command to change the order of print jobs in the queue (that is, to move jobs at the bottom or middle of the queue up to the top so they print faster).

Only a system administrator can change the order of the print jobs. The basic syntax of `topq` is:

```
topq printername jobnum(s) ...
```

where *printername* is, of course, the name of the printer, and *jobnum(s)* is a list of job numbers you want to move to the top of the queue. You can specify multiple job numbers with the command, and it will print them in the order listed. The first job listed will be moved to the top of the queue, the second will be second in the queue, and so on. For example, suppose the queue currently looks like this:

```
Rank   Owner    Job  Files                        Total Size
1st    btman    8    myfile.txt                   151625 bytes
2nd    btman    9    cardlist.txt                 38311 bytes
3rd    btman    10   lions.txt                    1113 bytes
4th    btman    12   schedule.txt                 6599 bytes
```

To reverse the order of these jobs in `lpc`, type **`topq lp 12 10 9 8`**. The results are shown here:

```
lpc> topq lp 12 10 9 8
lp:
        moved cfA008simba.example.com
        moved cfA009simba.example.com
        moved cfA010simba.example.com
        moved cfA012simba.example.com
```

If you look at the queue again, here's what you see:

```
Rank   Owner   Job  Files                             Total Size
1st    btman   12   schedule.txt                      6599 bytes
2nd    btman   10   lions.txt                         1113 bytes
3rd    btman   9    cardlist.txt                      38311 bytes
4th    btman   8    myfile.txt                        151625 bytes
```

The `topq` command can also take a username instead of a list of jobs. When `topq` is used this way, it will move all the jobs from the named user to the top of the queue.

Note that `topq` does not preempt a job that is currently running. It moves the jobs listed to the top of the queue so that they are next in line, but whatever job was printing before `topq` was used will finish printing before the job moved to the top of the queue starts. If you want a particular job to print right away, you will first have to use `lprm` to remove the job that is currently printing.

Quitting `lpc`

To quit the `lpc` program, simply type either **`quit`** or **`exit`** at the `lpc>` prompt. This will put you back at the command line.

Using `lpc` in Noninteractive Mode

`lpc` can also be run in noninteractive mode, taking a command line which it will execute without presenting a prompt. This mode is useful for scripted applications, such as shell scripts you might write that perform printer maintenance functions. In this case, simply supply the command you want to perform, along with any parameters, after `lpc` on the command line.

When `lpc` is run in noninteractive mode, it expects the first argument to be the command and anything that follows to be arguments to the command. Here's an example:

```
# lpc restart lp
lp:
        daemon (pid 2280) killed
lp:
        daemon started
```

All the same commands available in interactive mode are also available in noninteractive mode.

Controlling Who Can Use `lpc`

Sometimes you might want to give other people the ability to control printers with `lpc` but not give them full root privileges on the system. The "operator" group allows you to do this.

Any user who is a member of the group "operator" can make full use of `lpc` without having full root access to the system. This will allow that user to change the priority of print jobs, start and stop print daemons, and bring queues up and down.

Refer to Chapter 13, "Users, Groups, and Permissions," for more information on groups and how to add users to a group.

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Basic Network Printing

In many computing environments, the computer itself doesn't have a printer directly connected over a parallel or USB port, but instead sends jobs to the printer over the network, using TCP/IP communications as with any web host or other client-server application. To configure FreeBSD to send print jobs to a remote printer over the network, you just need to add an appropriate entry to `/etc/printcap`, defining the printer's parameters so FreeBSD can find it.

```
laserjet8150|lp|local line printer (but not really):\
        :lp=::rm=nova:rp=lj8150:sd=/var/spool/lpd/laserjet8150=/var/log/lpd-errs:
```

This entry will connect to a remote printer named `lj8150` that's defined on the host named `nova`. Note that the local name (on line 1) does not have to be the same as the remote name of the printer. You can call the local name whatever you want. What printer the job is actually sent to is controlled by the `rm` and `rp` enTRies in line 2, which define the remote host and queue instead of the local device name. The local spool directory will hold the file only until the remote spool directory has room. Then, the file will be moved into the remote host's spool directory.

Note

Notice that you did not have to specify an input filter here. That is because all the filtering will be handled by the remote host.

The printer on the remote host should be configured using the instructions provided earlier in the chapter for configuring a printer, if it's a UNIX system using `lpr`. However, if it's a Windows machine that's managing your network's central printer, you might need to move to another printing system altogether in order to access the Windows-centric printing protocols that are by now becoming much more widespread. The most widely recognized successor to `lpr` in this regard is CUPS.

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Next-Generation Printing with CUPS

CUPS (Common UNIX Printing System) is an alternative to the venerable `lpr` subsystem presented earlier in this chapter, and is intended to be a cross-platform printing solution for all UNIX environments. CUPS is not a standard part of FreeBSD, nor is it included in a standard FreeBSD installation. It is, however, available in the FreeBSD ports collection, and its home page (where a great deal of useful information can be found) is at http://www.cups.org.

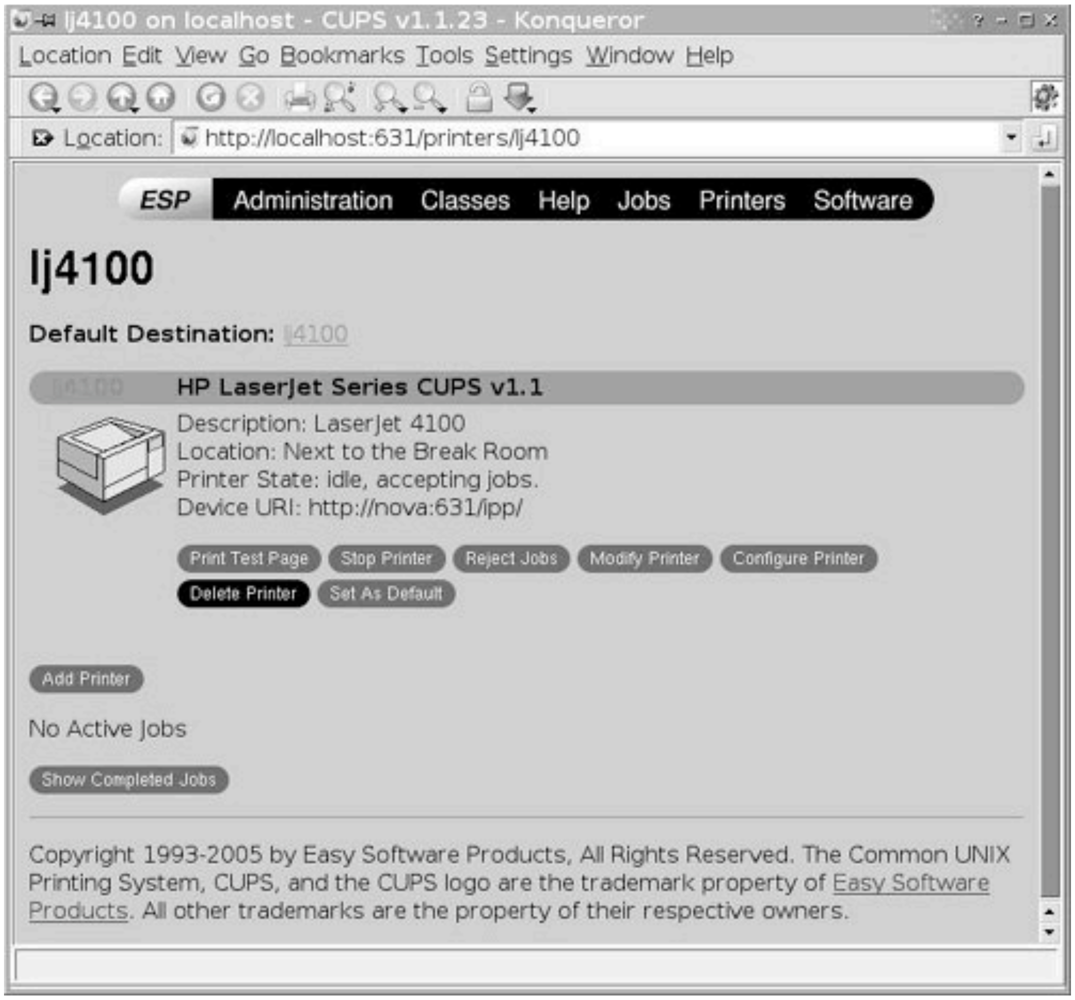
The strength of CUPS is that it's geared toward printing in the same paradigm as in the Windows world, where printers are described to the operating system using PPD (PostScript Printer Description) files that can be distributed over the network transparently to the user, and where print jobs are transmitted using the industry-standard Internet Printing Protocol (IPP). Many UNIX-style operating systems, including Mac OS X and many distributions of Linux, have already made CUPS their standard printing mechanisms.

Install CUPS from the ports or packages in the `print` category (see Chapter 16 for more information on installing ports or packages). When CUPS is installed, you need to go into `/usr/local/etc/rc.d` and rename `cups.sh.sample` to `cups.sh`, and then start the daemon using the **`./cups.sh start`** command.

There is a complete set of command-line tools for adding printers and managing queues included in CUPS; but there's also a web interface that you can use to manage your printing needs graphically, as shown in Figure 17.4.

Figure 17.4. The web interface of CUPS.

[View full size image]


lj4100 on localhost - CUPS v1.1.23 - Konqueror
Location Edit View Go Bookmarks Tools Settings Window Help
Location: http://localhost:631/printers/lj4100
ESP Administration Classes Help Jobs Printers Software

lj4100

Default Destination: lj4100

lj4100 HP LaserJet Series CUPS v1.1

Description: LaserJet 4100
Location: Next to the Break Room
Printer State: idle, accepting jobs.
Device URI: http://nova:631/ipp/

Print Test Page
Stop Printer
Reject Jobs
Modify Printer
Configure Printer
Delete Printer
Set As Default
Add Printer

No Active Jobs

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In its default configuration, the CUPS web interface can only be accessed from the local system using a browser in X11; access the URL http://localhost:631 to enter the system.

When you're prompted for user authentication information, use the system's root username and password. You can then use the buttons in the page to set up printers using sequential "wizard" screens to pick drivers and specify printer behaviors. You'll then be able to send your command-line and KDE print jobs to the much more versatile CUPS subsystem instead of `lpr`, and monitor them using the same web interface. If you need to download new drivers for your specific printer model, it's much easier to do so in CUPS than in `lpr`visit the http://www.cups.org site to look up commercially supported drivers and instructions on how to add them to the system. Because CUPS is the underlying printing technology in Mac OS X and most Linux distributions, the bulk of modern printer drivers are written for CUPS rather than `lpr`, so try CUPS if your printer isn't supported by FreeBSD's standard printing system.

Caution

It's possible to change the configuration of the CUPS web interface so that remote administration is possible. However, be aware that if you do so, you're making it possible for remote users to access a web server on your FreeBSD machine that's running with root privileges, a prospect that ought to fill you with dread. If all is working properly, and your root password is secure, there's theoretically no problem; but should a buffer overflow in the web server be discovered, it becomes a simple matter for a remote user to exploit it to attack your system. Also there is no encryption built in, so you'd be transmitting your root password in clear text every time you access the CUPS system. You shouldn't enable remote web administration for CUPS unless it's absolutely necessary.

A full discussion of CUPS and all its capabilities is beyond the scope of this book, but you can find a complete set of documentation at http://www.cups.org/doc-1.1/sam.html.

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Troubleshooting

A number of things can go wrong when you use printers. This section discusses some of the most common problems and their solutions.

Printer Does Not Receive Data; Jobs Are Sitting in Queue

Check `lpq` and make sure that the spooling daemon is running. If it says `Warning: no daemon present`, you will need to use `lpc` to restart the spooling daemon. Also check `lpc` and make sure that the printer is not disabled.

Further culprits can include a printer that's become locked up and needs to be power-cycled.

One method for narrowing down the possible causes of data that doesn't get printed is to redirect the output of CUPS to a local file, print the job, and check the file to make sure it received the data. If it didn't, the printing subsystem itself isn't sending the data. If it did, the printer is to blame.

Data Light on Printer Flashes, but Printer Will Not Print

This is often a symptom of sending non-PostScript data to a PostScript printer. Check your filter and make sure it is filtering text correctly and converting that text to PostScript.

Printing an Image File in GIMP or a Web Page Results in Hundreds of Pages of Garbage Being Printed

This can often be a symptom of feeding PostScript data to a printer that doesn't understand PostScript. The non-PostScript printer will try to print this file as plain text. Check out the GhostScript program and also see the section earlier in this chapter titled "Printing PostScript Files on Non-PostScript Printers."

Printers with a lot of onboard memory can exhibit the maddening tendency to keep printing the garbage PostScript data even after you've canceled the print job. You'll need to cancel the job and power-cycle the printer to make sure the spooled pages are flushed from the printer's memory and it stops wasting your paper.

The Printer Is Slow

Try setting the printer to polled mode (assuming this printer is on the parallel port). Use the following command:

```
# lptcontrol -p
```

Remember that you will need to add this command to a startup file if you want it to take effect at each system boot. See the section at the beginning of the chapter on `lptcontrol`.

Printed Output "Stair Steps"

The symptoms of the stair-step problem look something like this:

```
Line one of the file.
                     Line two of the file.
                                          Line three of the file.
                                                                 Line four of the
```

This pattern will continue until the text runs off the end of the page. This is a fairly common problem caused by differences in the way UNIX and DOS/Windows interpret the line-feed (LF) character. When DOS/Windows advances to a new line, it sends both a carriage-return (CR) and a line-feed. UNIX, on the other hand, sends only a line-feed character and expects a carriage-return to be implied. If your printer is expecting DOS-style carriage-return and line-feed combinations but is only receiving a line-feed, it will advance the paper but never return the print head to the beginning of the line. There are a few ways you might be able to solve this problem.

The first is to look for an option in your printer's configuration that changes the way it interprets a linefeed character. See your printer documentation to see whether there is a way you can do this.

The second way is to create a filter that converts the LF to a combination of CR and LF. If your printer understands HP's PCL language, the filter shown in Listing 17.4 is recommended by the FreeBSD Handbook for performing this task.

Listing 17.4. A PCL-based Filter That Converts UNIX-style Line-Feed Characters to a DOS-style Carriage-Return/Line-Feed Combination

```
#!/bin/sh
#
# hpif - Simple text input filter for lpd for HP-PCL based printers
# Installed in /usr/local/libexec/hpif
#
# Simply copies stdin to stdout. Ignores all filter arguments.
# Tells printer to treat LF as CR+LF. Ejects the page when done.

printf "\033&k2G" && cat && printf "\033&l0H" && exit 0
exit 2
```

See the section on text filters earlier in this chapter for more information on how to install and use this filter.

If your printer does not understand PCL, you might be able to use the `tr` command to convert the LF into a CR+LF. A filter such as the one in Listing 17.5 may do the trick.

Listing 17.5. A NonPCL-based Filter That Converts UNIX-style Line-Feed Characters to a DOS-style Carriage-Return/Line-Feed Combination

```
#!/bin/sh
# Filter that fixes the stair-stepping effect on non-PCL printers.
/bin/cat | tr '\13' '\13\10' && exit 0
exit 2
```

Once again, see the section on text filters earlier in this chapter for more information on how to install and use this filter.

All the Text Prints on One Line, Creating a Mess and Writing over the Top of Existing Text

This is essentially the opposite of the stair-stepping problem. This problem is rare, but it does happen occasionally. What's happening is that the LF is being interpreted as a CR by the printer. At the end of each line, the print head returns to the beginning of the line and continues printing, but the paper is not being advanced.

To fix this problem, you will need to make changes to your printer's configuration settings so that it interprets CR and LF characters properly. See your printer's documentation for details on how to do this.

If you find that you cannot change the hardware settings of your printer to fix this problem, you can use a filter similar to the one that fixes the stair-stepping problem; you'll just need to modify it so that CR characters (\10) are translated to CR+LF sequences (\13\10).

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Chapter 18. Kernel Configuration

IN THIS CHAPTER

This chapter covers a topic that's likely to be one of the most intimidating to a newcomer to UNIX: how to configure and rebuild your *kernel*, the innermost core of the operating system, which interacts at the most basic level with devices and coordinates processes. This is a task that simply does not happen in the desktop PC world, where the kernel is the carefully guarded domain of the software company. However, tweaking the kernel is a necessary part of life when dealing with an open-source system under constant development, in a world in which new devices constantly demand more functionality from a kernel. Kernel configuration is no simple task, but an adventurous user can master the essentials of it without much effort or risk.

Configuring the kernel is at the heart of customizing FreeBSD and other operating systems like it. A well-tuned kernel will serve 100 percent of the demands that a system and its users place on it, while eliminating all the unnecessary baggage that an unoptimized kernel might have, thus making the system operate significantly faster. This chapter provides enough insight into the kernel-configuration process to eliminate the mystery and enable you to customize your kernel to squeeze the most performance and functionality out of it that you can.

The Role of the Kernel

The kernel is the master executable of the system. It's the first thing that is executed from the boot blocks when you power on the system, and it constantly runs throughout the machine's uptime. Its job is to oversee all the processes running on the system, handle TCP/IP and other networking duties, manage access to all the devices on the system, and control memory usageto name just a few hats it wears.

Every operating system since the beginning of computing has had a kernel. Whether it's an ancient and rudimentary platform like the Apple][or a 286-based PC running MS-DOS, a desktop operating system like Mac OS X or Windows XP, or a high-end multiprocessor mainframe, there's always a kernel handling all the heavy lifting behind the scenes of your user applications. Some systems take greater pains to hide the kernel from the user than others do. In Windows, it's an executable in `C:\WINDOWS\SYSTEM`; in Mac OS X, though, it's protected by a hierarchy of hidden folders known only to experts, and in classic Mac OS it's hidden from the filesystem entirely. In many UNIX systems, the kernel's traditional place is in the root directory at the top of the filesystem. In FreeBSD, the kernel was placed in `/` prior to FreeBSD 5.0 and in `/boot` afterward. With each of these operating systems, a default (or "generic") kernel is part of every released version of the system; when a new version comes out, its changes are mostly additions to accommodate drivers for new devices that the system supports. The kernel is responsible for knowing about every kind of device that can be connected to the system.

When you install drivers for a new and previously unsupported device in Windows, you generally have to reboot. That's because the drivers, libraries, and other items used by your kernel have been modified and cannot be incorporated into the system's operation on the fly. In most cases, the system has to be restarted in order for the new resources to be used.

FreeBSD, by contrast to Linux, classic Windows and Mac OS, and some others, uses a *microkernel* architecture, which means that the kernel is fairly small and modular. Windows NT/2000/XP and Mach (the kernel upon which Mac OS X is built) are other examples of microkernels in which new devices are more frequently added through kernel modules (which can be loaded and unloaded during runtime) than by recompiling the kernel. Windows 95/98/Me (and, in past versions, Linux) are instead *monolithic* kernels, in which the kernel's code is more optimized for performance and to minimize context switching. The monolithic kernel architecture makes for kernel code that's fast in execution, but it tends to be ungainly and difficult for developers to maintain, and the administrator is required to recompile the kernel every time support for a new device is added.

It isn't terribly easy to identify a microkernel or a monolithic kernel in today's operating system landscape. Linux operates fairly heavily on kernel modules today, and FreeBSD's kernel does have to be recompiled for a number of different reasons. The difference between a microkernel and monolithic kernel architecture is largely a philosophical one and has to do with a good deal more than simply device support, andnaturallyno kernel lives up perfectly to its philosophical ideals. The biggest and most fundamental difference between the two kernel architectures is that a microkernel has a mechanism for passing certain non-core system calls to a user-level processing level, or *ring*, instead of handling them all internally and stripping down the core of the kernel to only those functions that require the highest level of supervisor-mode execution status. Keeping only essential functions in the kernel increases runtime robustness and makes the kernel processes more understandable and manageable. This arrangement also provides a measure of inherent security in the form of reduced complexity as well as easier support for modular device driver code. The bottom line is that a microkernel is like object-oriented programming: it might not run as fast as a pure procedural or monolithic program, but it sure is easy to put together quickly from basic components.

Although the ideal of total modularity is all well and good, a kernel in which every possible kind of device and option is modular and loadable during runtime is as theoretical as perpetual motion. Chances are that as you gain experience with FreeBSD, you will come to a point where you can't avoid recompiling your kernel; it's at that time that you'll undergo the rite of passage that initiates you into the circle of kernel hackers.

This chapter begins with an introduction to kernel modules and how to extend FreeBSD's microkernel on the fly; then it moves on to the far more involved tasks that are necessary for recompiling your kernel from sources to match your system's needs.

Kernel Modules

FreeBSD comes with several dozen *kernel modules* in its standard configuration, all located within the /boot/kernel directory along with the kernel file itself, and each one representing some new functionality or device support that is not necessarily present in the default (GENERIC) kernel. These kernel modules, files with extensions of .ko (for "kernel object"), can be loaded or unloaded at any time by the root user, adding features such as the ability to read a non-standard filesystem type or to use an unusual Ethernet card.

As an example, let's consider the smbfs.ko module. This module, as its name suggests, provides support for the SMB Filesystem (the filesystem type underlying Windows network file-sharing), which isn't available in the GENERIC kernel. Suppose there's a Windows machine on the network that's sharing a disk resource that you want to mount and read as a normal filesystem. To do this, you'll need to add SMBFS support to the kernel. This is done with the kldload command:

```
# kldload smbfs
```

Normally there is no output from a kldload command. However, you can use kldstat to determine whether the module was loaded correctly:

```
# kldstat
Id Refs Address     Size      Name
 1   10 0xc0400000 63070c    kernel
 2   16 0xc0a31000 568dc     acpi.ko
 3    1 0xc16ed000 15000     linux.ko
 4    1 0xc2693000 1b000     smbfs.ko
 5    2 0xc1bc6000 3000      libiconv.ko
 6    2 0xc1bdc000 3000      libmchain.ko
```

This output tells you a number of things. First it lists the modules that were present before we loaded the smbfs module: the kernel itself, followed by the ACPI driver (which supports the power management features on newer hardware), and then the linux.ko module that provides Linux binary compatibility. Then there's the smbfs.ko module that was just loaded, followed by two more modules that are necessary for the proper function of the SMBFS module and are loaded implicitly as dependencies: libiconv and libmchain.

Tip

Most kernel modules' purposes are described in man pages that you can access using the name of each module minus the .ko extension (for example, man smbfs). Others, such as the libiconv.ko library, are listed without the lib prefix (for example, man iconv).

The size of each module is given in hexadecimal format; you can decode the number next to each one to see how much memory each one is using up. Some kernel modules take up a lot of memory; others might slow down the kernel's operation. These are just a couple of the many reasons why you might want to remove a module from the kernel after you're done using its functionality; this is done using the kldunload command:

```
# kldunload smbfs
```

Loading a kernel module is usually a quick and straightforward process. Many modules are designed to be loaded automatically if their functionality is called for by a command that requires it, such as the mount_* commands that mount various filesystem types that aren't compiled into the GENERIC kernel; when you use these commands, you might not even realize that a kernel module has been loaded. However, on older hardware, or on an already heavily modified kernel, or if the module is less than stable (the smbfs.ko module is itself very shaky), the process of adding a module is anything but transparent. Sometimes it takes a long time to load the module, blocking your user input; and sometimes it conflicts with existing kernel features and can even crash your computer.

If a kernel module that you find yourself using frequently takes a long time to load on the fly, or if you just don't want to have to worry about loading it all the time, you can have FreeBSD load it automatically at boot time. To do this, add a statement for each such kernel module's name in the /boot/loader.conf file:

```
smbfs_load="YES"
msdosfs_load="YES"
```

The first part of each statement is the name of the kernel module (minus the .ko extension), and it's followed by an underscore and load="YES". This ensures that the specified modules are loaded at boot time and the commands that depend on them will always work.

Even this, though, might not suit your needs. Some modules might be too flaky to load on a regular basis; some might even cause crashes or unexpected reboots, or might disable your machine's network connectivity. To add their functionality to your kernel without having to bother with the uncertainties of kernel modules, you'll need to build a custom kernel, as detailed in the remainder of this chapter.

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Why Configure a Custom Kernel?

FreeBSD comes with the `GENERIC` kernel installed by default. This kernel is tuned to support as wide a user base as possible so that FreeBSD will work out of the box on as many different machines as there are users in the world. Given the nature of *x* 86-based hardware, this means that the FreeBSD kernel must hold a truly astounding number of built-in drivers. An operating system built for a tightly controlled set of hardware (such as SGI's IRIX or Apple's Mac OS X) can afford to get away with much less of this generic support, but FreeBSD is stuck with it. The `GENERIC` kernel also has various options for memory allocation and optimization set to lowest-common-denominator levels, and other optional elements are left out in order to keep the kernel as streamlined as possible under the circumstances. These are all aspects of the kernel that can almost certainly be configured more efficiently for your particular system.

Note

One reason for having as many devices compiled into the `GENERIC` kernel as possible is to ease installation; you don't want to boot into a stripped-down installation kernel, hoping to do a network install, only to find that your Ethernet card isn't supported in the kernel!

Streamlining the Kernel

The kernel probes at boot time for every single kind of device it knows about. This is where you see that scrolling screen full of white text while the system is coming up; the kernel is looking for dozens of different kinds of devices that are enabled in the `GENERIC` kernel. Although it doesn't hurt anything for the kernel not to find most of them, it does take time to perform each probe. You can speed up boot time significantly by removing the unnecessary devices from the kernel. This also helps reduce the size of the kernel. Modern systems with gigabytes of RAM don't need to worry about this streamlining, but it's a worthy consideration on a machine that barely meets FreeBSD's minimum requirements.

As you add devices such as USB peripherals, sound cards, SCSI controllers, and others to your system, you won't be able to use many of them unless you add support for them in the kernel. The same is true of new filesystem types (such as Linux's EXT2FS, as you saw in Chapter 12, "The FreeBSD Filesystem"). Many devices and filesystems are available today as kernel modules, but the majority still have to be compiled into the kernel, so you have little choice but to rebuild it. However, rebuilding gives you the chance to tweak other things in the system (such as the number of memory buffers, custom memory management features, and the kernel's name), so you can enhance your system's performance significantly with one rebuild.

Note

Symmetric Multi-Processing (SMP) support is not present in the `GENERIC` kernel either. If you have a system with more than one CPU or processor core, you'll need to build a custom kernel in order to take advantage of all of them.

Using `dmesg` to Get Information About the Kernel Startup

If you will be stripping unnecessary devices out of your kernel, it is imperative that you find out what devices you do have so that you don't end up accidentally removing support for your existing hardware. As mentioned earlier, the kernel probes for all its known devices at boot time, and it prints out the status of each probe, telling you which devices you must keep in the new kernel. This information isn't just printed out to the screen at boot time; it's also echoed into an internal runtime message buffer for reference at any time. The tool to use for recalling this information is `dmesg`.

The output of `dmesg` can be very long, so you'll probably want to pipe it through `less`, as shown in Listing 18.1.

Listing 18.1. Partial Output from `dmesg` Piped Through `less` for Improved Readability

[View full width]

```
# dmesg | less
Copyright (c) 1992-2005 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 1989, 1991, 1992, 1993, 1994
        The Regents of the University of California. All rights reserved.
FreeBSD 6.0-RELEASE #0: Thu Nov 3 09:36:13 UTC 2005
    root@x64.samsco.home:/usr/obj/usr/src/sys/GENERIC
ACPI APIC Table: <DELL   PE1750  >
Timecounter "i8254" frequency 1193182 Hz quality 0
CPU: Intel(R) Xeon(TM) CPU 2.40GHz (2386.76-MHz 686-class CPU)
  Origin = "GenuineIntel"  Id = 0xf29  Stepping = 9
  Features=0xbfebfbff<FPU,VME,DE,PSE,TSC,MSR,PAE,MCE,CX8,APIC,SEP,MTRR,PGE,MCA,C
MOV,PAT,PSE36,CLFLUSH,DTS,ACPI,MMX,FXSR,SSE,SSE2,SS,HTT,TM,PBE>
  Features2=0x4400<CNTX-ID,<b14>>
  Hyperthreading: 2 logical CPUs
real memory  = 2147315712 (2047 MB)
avail memory = 2096508928 (1999 MB)
config> di sn0
config> di lnc0
config> di ie0
config> di fe0
config> di ed0
config> di cs0
config> di bt0
config> di aic0
config> di aha0
config> di adv0
config> q
npx0: [FAST]
npx0: <math processor> on motherboard
npx0: INT 16 interface
cpu0 on motherboard
pcib0: <Intel 82443BX (440 BX) host to PCI bridge> pcibus 0 on motherboard
pir0: <PCI Interrupt Routing Table: 7 Entries> on motherboard
pci0: <PCI bus> on pcib0
agp0: <Intel 82443BX (440 BX) host to PCI bridge> mem 0xe0000000-0xe3ffffff at device 0.0
   on pci0
pcib1: <PCI-PCI bridge> at device 1.0 on pci0
pci1: <PCI bus> on pcib1
$PIR: ROUTE_INTERRUPT failed.
pci1: <display, VGA> at device 0.0 (no driver attached)
isab0: <PCI-ISA bridge> at device 7.0 on pci0
isa0: <ISA bus> on isab0
atapci0: <Intel PIIX4 UDMA33 controller> port 0x1f0-0x1f7,0x3f6,0x170-0x177,0x376
   ,0xf000-0xf00f at device 7.1 on pci0
ata0: <ATA channel 0> on atapci0
ata1: <ATA channel 1> on atapci0
uhci0: <Intel 82371AB/EB (PIIX4) USB controller> port 0xe000-0xe01f irq 10 at device 7.2
   on pci0
uhci0: [GIANT-LOCKED]
usb0: <Intel 82371AB/EB (PIIX4) USB controller> on uhci0
usb0: USB revision 1.0
uhub0: Intel UHCI root hub, class 9/0, rev 1.00/1.00, addr 1
uhub0: 2 ports with 2 removable, self powered
pci0: <bridge> at device 7.3 (no driver attached)
```

```
fxp0: <Intel 82557 Pro/100 Ethernet> port 0xe400-0xe41f mem 0xe9200000-0xe9200fff,
    0xe9100000-0xe91fffff irq 9 at device 11.0 on pci0
miibus0: <MII bus> on fxp0
inphy0: <i82555 10/100 media interface> on miibus0
inphy0: 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
fxp0: Ethernet address: 00:a0:c9:66:7b:32
fxp1: <Intel 82557 Pro/100 Ethernet> port 0xe800-0xe81f mem 0xe9201000-0xe9201fff,
    0xe9000000-0xe90fffff irq 5 at device 13.0 on pci0
miibus1: <MII bus> on fxp1
inphy1: <i82555 10/100 media interface> on miibus1
inphy1: 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
fxp1: Ethernet address: 00:a0:c9:8e:8e:ba
pmtimer0 on isa0
orm0: <ISA Option ROM> at iomem 0xc0000-0xc7fff on isa0
atkbdc0: <Keyboard controller (i8042)> at port 0x60,0x64 on isa0
atkbd0: <AT Keyboard> irq 1 on atkbdc0
kbd0 at atkbd0
atkbd0: [GIANT-LOCKED]
```

Tip

If your system has been online for a long time, the boot messages might have scrolled out of the `dmesg` buffer; however, you can always see the messages from the last boot in `/var/run/dmesg.boot`.

The output continues throughout all device checks, filesystem validations, and daemon startup blocks and then continues into runtime errors generated by various devices since you booted. You can ignore everything after you begin seeing date stamps and regular error messages. What you're interested in is the boot messages, such as the ones in the preceding listing.

The first part of the boot messages, after the copyright and CPU information lines, is the kernel configuration you have set in the boot configurator. Each line beginning with `config>`, if present, is a command you issued in visual config mode, most likely (as with the `di` lines) to delete unwanted devices from the probe process. These devices won't appear later in the `dmesg` output. If you haven't removed these devices in the configurator, the kernel will probe for them.

Any driver accompanied in the listing by a "not found" message is a driver you can delete from the kernel. You may want to keep two SSH terminal windows open to your FreeBSD machine: one to read the output of `dmesg` and another to configure the kernel. This will help ensure you don't delete anything that the system reports as "found."

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The Kernel Configuration Files

At the time of this writing, FreeBSD doesn't have a visual kernel configuration utility like the `make xconfig` dialog-driven process in various Linux distributions. FreeBSD's kernel is configured using text files, a method that may seem quite arcane but one that does provide some flexibility the visual methods don't.

A visual configuration tool provides interactive feedback, allowing you to enable and disable devices and options on a case-by-case basis. What it doesn't do, though, is allow you to maintain multiple configurations side by side, comparing them using tools such as `diff` and `grep`, and use the base-level `GENERIC` configuration, previous known valid configurations, and the reference `NOTES` files as guidelines. Using a text file configuration also allows you to see all your device options at a glance.

An interactive visual tool can become needlessly complex and convoluted, and in asking you to decide individually whether to include every different option, it actually can detract from useful feedback. Unless you can remember the importance and consequences of every different option available in the config file, it's hard to keep track of which options you should be selecting. With the FreeBSD method, you can tune your config file until you're happy with it, incorporating changes introduced since the release of a previous version. You can even copy a "standard" configuration from another FreeBSD system and then build the kernel from it.

Assuming you installed the FreeBSD sources on your system, go into the `/usr/src/sys/i386/conf` directory, the location for the kernel config files. There you'll see the `GENERIC` file, among other items.

Note

If you're running on Alpha hardware instead of *x*86, use `alpha` in the previous pathname instead of `i386`. The same goes for IA64, SPARC, or PowerPC hardwarego into the appropriately labeled directory in `/usr/src/sys`. A number of other details in this chapter will be slightly different as well, but the process remains the same.

The `GENERIC` Configuration File

Open up the `GENERIC` file in your favorite text editor. Scroll through the various options, but don't actually make any changes just yet (you don't want to alter the `GENERIC` file itself). You'll see that there's a lot of built-in redundancy in the file in order to make sure your system remains compatible with all kinds of machines. The block of lines near the top of the file will resemble the following, although it will vary depending on your specific version of FreeBSD:

```
machine    i386
cpu        I486_CPU
cpu        I586_CPU
cpu        I686_CPU
ident      GENERIC
```

The `machine` line, `ident` line, and *one* of the `cpu` linesthe one most appropriate to your hardwaremust be present in the file for the kernel to run. If you have a high-end Pentium, for example, you can remove the legacy `I486_CPU` and `I586_CPU` lines, and you may achieve some performance gains in the process.

Note

The cpu line is specific to your computer's architecture, and tells FreeBSD what kind of kernel to build. In the GENERIC file for IA64 hardware, the cpu value is ITANIUM; for PowerPC, it's OEA; for SPARC, it's SUN4U; and so on.

Below this block are the options linesoptional features that are built into the GENERIC kernel by default, given in Listing 18.2 (a FreeBSD 6.0 kernel is shown). Although these lines don't have to be present in order for the kernel to be valid, it just wouldn't be a very useful kernel without them. Removing certain options can improve your system's performance, but it can also break key features such as Access Control Lists, CD-ROM support (the ISO9660 filesystem), TCP/IP networking, and a raft of built-in and third-party programs that depend on SysV-style memory management and signaling, such as Oracle for Linux and PostgreSQL. Meddle with these options only if you know what you're doing!

Listing 18.2. Built-in GENERIC Kernel Options

```
#options        SCHED_ULE               # ULE scheduler
options         SCHED_4BSD              # 4BSD scheduler
options         PREEMPTION              # Enable kernel thread preemption
options         INET                    # InterNETworking
options         INET6                   # IPv6 communications protocols
options         FFS                     # Berkeley Fast Filesystem
options         SOFTUPDATES             # Enable FFS soft updates support
options         UFS_ACL                 # Support for access control lists
options         UFS_DIRHASH             # Improve performance on big directories
options         MD_ROOT                 # MD is a potential root device
options         NFSCLIENT               # Network Filesystem Client
options         NFSSERVER               # Network Filesystem Server
options         NFSCLIENT               # Network Filesystem Client
options         NFSSERVER               # Network Filesystem Server
options         NFS_ROOT                # NFS usable as /, requires NFSCLIENT
options         MSDOSFS                 # MSDOS Filesystem
options         CD9660                  # ISO 9660 Filesystem
options         PROCFS                  # Process filesystem (requires PSEUDOFS)
options         PSEUDOFS                # Pseudo-filesystem framework
options         GEOM_GPT                # GUID Partition Tables.
options         COMPAT_43               # Compatible with BSD 4.3 [KEEP THIS!]
options         COMPAT_FREEBSD4         # Compatible with FreeBSD4
options         COMPAT_FREEBSD5         # Compatible with FreeBSD5
options         SCSI_DELAY=5000         # Delay (in ms) before probing SCSI
options         KTRACE                  # ktrace(1) support
options         SYSVSHM                 # SYSV-style shared memory
options         SYSVMSG                 # SYSV-style message queues
options         SYSVSEM                 # SYSV-style semaphores
options         _KPOSIX_PRIORITY_SCHEDULING # POSIX P1003_1B real-time extensions
options         KBD_INSTALL_CDEV        # install a CDEV entry in /dev
options         AHC_REG_PRETTY_PRINT    # Print register bitfields in debug
                                        # output.  Adds ~128k to driver.
options         AHD_REG_PRETTY_PRINT    # Print register bitfields in debug
                                        # output.  Adds ~215k to driver.
options         ADAPTIVE_GIANT          # Giant mutex is adaptive.
```

The remainder of the file is taken up with device lines. These lines specify all the hardware device drivers the GENERIC kernel has built-in, and there are a lot of them. These are mostly what you will want to strip out of your custom kernel in order to optimize it (they're certainly the safest to remove). For instance, if you know your Ethernet card is an Intel EtherExpress series (handled by the fxp driver), you can disable every other PCI Ethernet driver in this block. Listing 18.3 shows a sample block of device lines, of which there are several in the file.

Listing 18.3. Some of the Device Drivers Built into the GENERIC Kernel

```
# PCI Ethernet NICs that use the common MII bus controller code.
# NOTE: Be sure to keep the 'device miibus' line in order to use these NICs!
device          miibus          # MII bus support
device          bfe             # Broadcom BCM440x 10/100 Ethernet
device          bge             # Broadcom BCM570xx Gigabit Ethernet
device          dc              # DEC/Intel 21143 and various workalikes
device          fxp             # Intel EtherExpress PRO/100B (82557, 82558)
device          lge             # Level 1 LXT1001 gigabit Ethernet
device          nge             # NatSemi DP83820 gigabit Ethernet
device          nve             # nVidia nForce MCP on-board Ethernet Networking
device          pcn             # AMD Am79C97x PCI 10/100(precedence over 'lnc')
device          re              # RealTek 8139C+/8169/8169S/8110S
device          rl              # RealTek 8129/8139
device          sf              # Adaptec AIC-6915 (``Starfire'')
device          sis             # Silicon Integrated Systems SiS 900/SiS 7016
device          sk              # SysKonnect SK-984x & SK-982x gigabit Ethernet
device          ste             # Sundance ST201 (D-Link DFE-550TX)
device          ti              # Alteon Networks Tigon I/II gigabit Ethernet
device          tl              # Texas Instruments ThunderLAN
device          tx              # SMC EtherPower II (83c170 ``EPIC'')
device          vge             # VIA VT612x gigabit Ethernet
device          vr              # VIA Rhine, Rhine II
device          wb              # Winbond W89C840F
device          xl              # 3Com 3c90x (``Boomerang'', ``Cyclone'')
```

Device Hints

FreeBSD operates using the Device Filesystem (DEVFS) and *device hints*, which provide a way of abstracting the attributes of various devices so that the system can find them without needing the attributes to be compiled statically into the kernel. These attributes used to be defined like this, in the kernel config file itself:

```
device          ata0    at isa? port IO_WD1 irq 14
device          ata1    at isa? port IO_WD2 irq 15
```

Now, however, the kernel configuration file only needs to have this line:

```
device        ata
```

This change happened because the `ata` device has its attributes stored in the `/boot/device.hints` file, which is consulted by the kernel at boot time. Here are the relevant lines of that file for this example:

```
hint.ata.0.at="isa"
hint.ata.0.port="0x1F0"
hint.ata.0.irq="14"
hint.ata.1.at="isa"
hint.ata.1.port="0x170"
hint.ata.1.irq="15"
```

With these attributes kept in a central location, the kernel knows on what bus, memory address, and IRQ (interrupt request) to find the `ata` device. Also, you can change these attributes without having to recompile the kernel. If you prefer, though, you can still compile the attributes statically into the kernel by enabling this line:

```
#To statically compile in device wiring instead of /boot/device.hints
#hints          "GENERIC.hints"         #Default places to look for devices.
```

The /etc/rc.d/devfs script is run at boot time and controls after-the-fact symlinking and permissions tweaks that normally need to be done only once in a static, non-DEVFS system (you learn about how configuration scripts like /etc/rc.d/devfs are executed in Chapter 14, "System Configuration and Startup Scripts").

DEVFS simplifies many UNIX housekeeping tasks that used to be very onerous. However, there are cases where it can lead to you having to do *more* work than would otherwise be the case. For instance, a common task in setting up a UNIX installation is to symlink /dev/mouse to /dev/psm0, or /dev/dvd to /dev/acd0c, because certain software expects to use the more generic device names; this way you don't have to configure the systemspecific devices into that software. A DVD player application will expect to find /dev/dvd, not a device label that can vary from system to system. Also, because some devices (such as DVD-R burners) must have the proper permissions so that certain userstypically those in the groups that own these devicescan write to them, the permissions on the devices must be altered with a chmod command.

Traditionally, you would issue the following commands during installation to set up /dev/dvd, after which you would never have to worry about it again:

```
# chmod 664 /dev/acd0c
# ln -sf /dev/acd0c /dev/dvd
# ln -sf /dev/acd0c /dev/rdvd
```

Nowadays, though, with DEVFS, the /dev/acd0c device is set up dynamically each time you boot, and so your previously configured symlinks would be invalid. To achieve the same effect as with earlier systems, you simply add these three lines to /etc/rc.d/devfs at the end of the file, and they will be applied after the dynamic devices are created.

The NOTES Files and LINT

Fortunately, you aren't on your own when it comes to identifying each of these uglylooking options and devices, or knowing which other ones are available. A file called NOTES, also in /usr/src/sys/i386/conf, describes all possible options and devices available in the current system. It's another file that you don't want to modify. Just open it in less and look through its contents. You'll find explanations of all the lines in the GENERIC kernel, as well as a lot more available options and devices that you can add to the kernel configuration if you so choose.

A second NOTES files, residing in /usr/src/sys/conf, is a hardware-independent version that contains all the kernel options that don't apply specifically to your system's architecture. For example, whereas in the NOTES file in the i386 subtree you'll find the documentation of lots of options for controlling specific Intel CPU features, as well as the x86-style ISA, PCI, and AGP buses and other hardware components, for general FreeBSD features such as filesystems and memory management you'll need to look in the deviceindependent NOTES file.

Everything in GENERIC has an entry in one of the NOTES files as well. You can theoretically copy any configuration line (that begins with anything other than hint) into your custom kernel config file and then run with it. This will generally be necessary only if you add some particularly unusual device or kernel option, but NOTES is the first thing you should consult in that event.

NOTES also contains device hint lines; these are the ones beginning with hint (as described previously). You can copy these lines either into /boot/device.hints or into the hints file for your kernel (for example, GENERIC.hints) if you want to compile them in statically.

Many items in both NOTES files refer to a mysterious thing called LINT. This is an old, deprecated (pre-FreeBSD 5.0) way of looking at what is now the NOTES file. LINT was named after the lint commanda C-code debugging utility that's named for the idea that it validates the code you run it on by removing excess lint and fuzz from it. One of the long-running ideals (or myths) about FreeBSD is that it offers the capability to build a kernel based on the LINT file, incorporating every possible supported option and driver. This useless feat of UNIX-geekdom is almost certainly not possible these days, because many of the kernel options are mutually exclusive or unstable, and because nobody actually tries to ensure that it can be done.

FreeBSD does, however, provide the capability to generate an old-style `LINT` file by running `make LINT` from within the directory. This strips out all comments and `hint.` lines, and creates a kernel config file that you can theoretically use to build a huge, all-encompassing kernel that probably won't have a chance of booting or even compiling.

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Creating a Custom Kernel Configuration File

Here's where you actually begin the process of creating a new kernel. Remember that you don't want to modify the GENERIC file itself; it gets updated with the system sources every time you synchronize or upgrade. Therefore, to make sure your changes don't get overwritten, make a copy of GENERIC to use as your custom kernel config. The name for the copy should be a single word in all caps, according to tradition. The custom kernel for this example is called CUSTOM:

```
# cd /usr/src/sys/i386/conf
# cp GENERIC CUSTOM
```

You can now modify the CUSTOM file all you like. The first thing you should do is go through it and change the identification of the kernel (the ident line) from GENERIC to CUSTOM (or whatever name you chose). You also should remove redundant entries for cpu and, if necessary, modify the default value of maxusers by adding a line for it (see the following note). Here is a block from a customized kernel config on a Pentium IVclass machine operating as a high-profile server:

```
machine       i386
cpu           I686_CPU
ident         CUSTOM
maxusers      64
```

Note

Don't be fooled by the maxusers setting: It doesn't actually limit the number of current users or logins the system will support. (That limit is controlled by the device pty *num* line.) What maxusers does is much more subtle: A number of internal table sizes are derived from it, such as the maximum number of processes allowed (16 times the maxusers setting, plus 20) and several others. Set maxusers to approximately what you expect the average number of users to be, but don't set it lower than 4 (if you do, you'll run out of processes quicker than you expect).

You can now start customizing the options and devices. Refer to the hardware-specific and hardware-independent NOTES files to keep yourself informed about what you're modifying, and keep your other window with the dmesg output open. Don't delete anything from the config file that dmesg says the kernel found! It's in fact a good idea not to actually delete any lines from the file. Instead, just comment them out by putting a hash mark (#) at the front of each line.

If you have any doubt about whether to disable a line that's in GENERIC, don't disable it. GENERIC definitely contains a lot of items that aren't needed on every system, but it's better to err on the side of caution when it comes to kernels, especially if you're making these changes on a production server.

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Compiling and Installing the Custom Kernel

After your config file is ready to go, building the kernel is a fairly simple process. In theory, the build requires at most three commands:

```
# cd /usr/src
# make buildkernel KERNCONF=CUSTOM
# make installkernel KERNCONF=CUSTOM
```

The `KERNCONF` argument specifies the kernel config file to use; if you omit it, the `GENERIC` config file will be assumed. The first `make` command parses the config file, sets up the build directory, builds the dependencies, and then builds the kernel itself. The second command installs it into `/boot`, moving the current kernel directory to `/boot/kernel.old`. (Prior to FreeBSD 5.0, these kernels were installed into `/`, the root.) You must then reboot (by typing **`shutdown -r now`**) to use the new kernel.

Note

The kernel has the `schg` (system-immutable) flag set on it, meaning that even root can't delete or overwrite it without first removing that flag. The `make installkernel` target attempts to remove the flag before installing the new kernel. However, if you're running with a `securelevel` setting of `1` or higher (a now-deprecated systemwide security setting that you select during installation or in `/etc/rc.conf`; see `man securelevel` for details), it won't be able to remove the flag. You'll have to reboot into single-user mode in order to complete the kernel installation; dropping to single-user mode via `shutdown` won't work.

Tip

If you're really sure of yourself, you can combine both the `make` lines into a single one, as shown here:

```
# make kernel KERNCONF=CUSTOM
```

However, this is for experts only; it's much better to be in the habit of building and installing the kernel separately, to minimize the chances of accidentally installing a flawed kernel.

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Adding Device Nodes to the `/dev` Directory

This section describes a step in the kernel building process that applies only to versions of FreeBSD prior to 5.0. If your version is 5.0 or later, you can safely skip this section because later versions use the DEVFS filesystem interface to the system's devices and build the `/dev` virtual filesystem dynamically at boot time.

Many devices will be missing an entry in `/dev` when you add them to the kernel configuration; devices in `/dev` include only those that have either been part of the base system or have been added afterward explicitly. You have to create device nodes for new devices that you add to the kernelthey're not generated automatically.

Fortunately, creating the device nodes is fairly simple. All you have to do, after you reboot with the new kernel, is go into the `/dev` director, and run the `MAKEDEV` shell script:

```
# ./MAKEDEV
```

All devices supported by the running kernel will be created as device nodes or "special files" in `/dev`. Afterward, you have a target you can use with your command-line tools to interact with each new device. A more efficient, direct solution is to make the device node only for the new device(s) you've installed (for instance, if you've enabled the `snd0` sound driver). You can enable the device by running the `MAKEDEV` command on it alone:

```
# ./MAKEDEV snd0
```

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Recovering When Something Goes Wrong

Compiler errors are not uncommon. If you're running the same source tree that you've had since you installed the system, an error in the compile process (where the compiler fails to complete, usually citing `*** Error code 1`) is probably the result of some unstable kernel option or device that you've enabled. See whether you can determine which one it is by checking the last few lines of the compiler outputthe text immediately preceding `*** Error code 1` indicates errors that terminate the compilation process. Each compiler command line is echoed to the screen, so you should be able to see what component it was trying to compile when the error occurred. If it's not obvious, you can find some guidance by visiting the FreeBSD website (http://www.freebsd.org) and searching the mailing list archives for some of the unique words in whatever compiler errors were generated.

If you've updated your sources since installing your system, it's quite likely (especially if you're tracking -CURRENT or -STABLE) that the code is in an unstable state, and whatever errors you've encountered will probably be corrected within a few days (you'll learn more about updating sources in Chapter 19, "Keeping Up to Date with FreeBSD"). You should be subscribed to the `freebsd-current` or `freebsd-stable` mailing lists if you're such a cutting-edge FreeBSD user, and you can get help there (see the FreeBSD website for details on subscribing).

However, there is always the chance your kernel will build cleanly, install cleanly, reboot cleanly, and then explode without warning when it tries to boot. It might fail to mount its filesystems, it might freeze up with a kernel trap error, or it might fail in a way you can't even imagine happening until you see it. If this happens, don't panicthere's an easy way to get out of this predicament.

Reboot the machine and press the appropriate F-key to get to the loader menu. Choose option 6 (Escape to Loader Prompt), and then enter **`boot /boot/kernel.old`** (or **`boot /kernel.old`**, prior to FreeBSD 5.0) at the prompt, and your previous working kernel will be used.

Keep in mind that if you next try to rebuild the kernel and install it, `/boot/kernel.old` will get overwritten by the previous kernel you built that was broken. To avoid this, copy `kernel.old` to some filename that won't get overwritten by any automated process (for instance, `/boot/kernel.frank`). You can use this kernel to boot from the `loader` prompt the next time if it happens again.

Another possible problem is that your system boots properly and completely comes up, but system utilities such as `ps`, `top`, and `w` no longer work (they'll report segmentation fault errors or memory size mismatches). If this happens, it's most likely because you're building your kernel from a newer source tree than your system is built from, and the `libkvm` library has become outdated by your newer kernel.

To get around this, you can rebuild your `libkvm` library, but that solution is for experts only. If you're brave, you can do this by going to the location of the `libkvm` code within `/usr/src` and attempting to make and install it by hand. (You learn about that process in Chapter 19.) A better solution, though, is to always build your kernel from the same sources that your full system is built from, and only build a kernel on updated sources if you're doing a complete `make world`, as described in the next chapter.

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Chapter 19. Keeping Up to Date with FreeBSD

IN THIS CHAPTER

Every operating system has to have a way of keeping up with the times. Administrators need to get security patches, bug fixes, and support for new technologies into their installed systems without waiting for new full releases, which can take anywhere from six months to three years or more in the operating system world. In today's "Internet time" environment, however, hackers can compromise systems within hours of a security breach announcement, so maintaining an up-to-the-minute operating system is essential.

No operating system maker neglects this need. Microsoft provides large periodic "service pack" upgrades to users of the Windows client and server families (and a good thing, too, considering that full releases are coming further and further apart these days). Between these service packs or full releases, though, rapid-response fixes for security issues found within the operating system are rolled out through the Windows Update mechanism, allowing users to download and install patches for time-critical problems. Mac OS X has a similar Software Update mechanism, and analogous patch mechanisms are in place for Linux as well, giving users the all-important ability to protect their systems with a minimum of effort or expertise required.

Maintaining a FreeBSD installation is a rather different process. Patches for security issues are made available with the same speed as with any other operating system; but because FreeBSD's operating philosophy is largely centered on its users' access to the source code (even more so than its open-source cousins), patching your system more often than not involves recompiling the software in question yourselfwhether it's a change to the kernel, to a system library, or to a third-party application. Fortunately, FreeBSD offers some well-established methods for making these periodic rebuilds a straightforward process, helping you keep your system buttoned up against even the most current conditions.

Note

Upgrading your system by downloading precompiled binary packages and installing them over the old components, in what's known as a *binary upgrade*, is possible in FreeBSDjust go into Sysinstall, specify the new release's name in the Options screen, and then choose Upgrade to perform the upgrade process, which you configure and execute in a similar manner to the initial installation covered in Chapter 2, "Installing FreeBSD." You can do a binary upgrade from a CD/DVD or from an FTP source.

This method of upgrading can be painless and quick. However, unlike with other operating systems, the binary upgrade process isn't necessarily the cleanest way of updating FreeBSD. Because the system is under constant development, with system components being moved to different locations and added or deleted on an ongoing basis; because many users have heavily customized their systems' files; and because the binary upgrade script is not always kept as current as the sources themselves, a binary upgrade is almost certain to leave some necessary tasks unfinished. You'll have to merge certain files from your old system's `/etc` directory into the new one by hand, for example. This is even more the case when you're upgrading between two widely different systems, such as going from a 4.x system to a 5.x or 6.x release, which has a radically different file structure that may not be accounted for in the binary upgrade script. Because of all these complications, tracking the sources and compiling your own operating system is not only a useful skill to have as a FreeBSD administrator, but the recommended method for upgrading your system.

Major releases of FreeBSD (such as 5.0 and 6.0) appear every one to two years, and minor releases (such as 4.2 and 5.4) generally appear every three to six months. ("Patch" releases, such as 5.2.1, are not normally scheduled, and appear on an as-needed basis.) No matter how frequently a new release that's appropriate to your needs becomes available, it's too infrequent to address the pressing day-to-day needs of a security-conscious administrator; you'll need a way to update your system in part or wholesale, at your discretion, at any time in between releases. In this chapter, you learn about CVSup, `make world`, and other real-time methods for keeping your FreeBSD system current.

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Tracking the FreeBSD Sources

The easiest and most common system upgrade path is simply to wait for each new official FreeBSD release. You get a copy of the CD or disk image file and install the new version of the operating system from it by using the methods covered in Chapter 2, or as described at the FreeBSD website.

However, new features that come with new major releases aren't the only reasons you might want to upgrade. Suppose, for example, that a major security flaw has been found in the kernel, or in a key system component such as BIND or Sendmail. This situation requires an immediate response, a real-time solution to a real-time problem. There's really only one way to achieve this end: You have to track the sources.

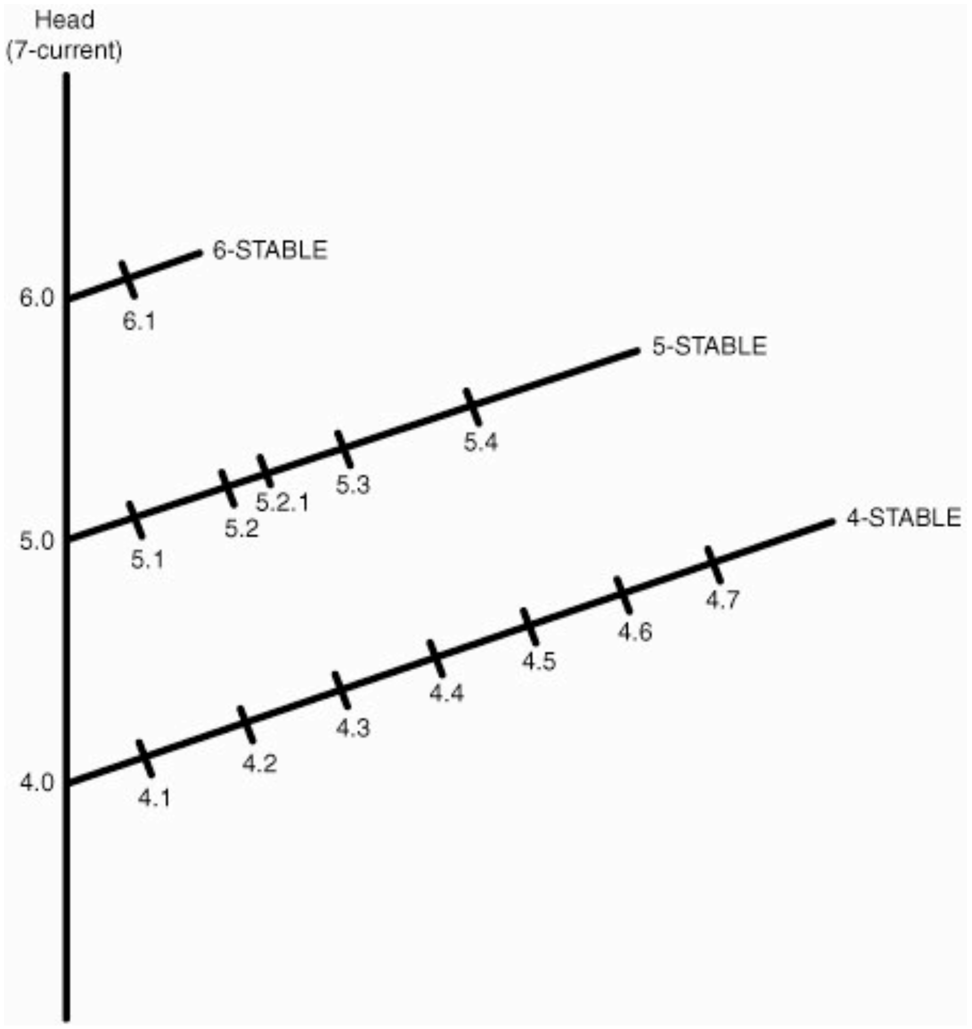
The source tree for FreeBSD is kept in a central Concurrent Versions System (CVS) repository, mirrored across a number of redundant servers, and maintained by a fairly small core of contributors and committers. FreeBSD is structured so that the entire system is available in source form at all times for anybody to use. This structure differs from the Linux model, in which the sources for the kernel are available but each individual, independent distribution of the complete operating system has its own set of executables and libraries, its own filesystem structure, and its own policies for how the source code for those resources should be made available. Whether you're a developer who intends to modify and develop the sources and check them back in to the main tree or a user who simply wants to maintain a server with a current source distribution, you use CVSand a utility called CVSupto interact with the source repository and get the up-to-date sources you need. This model gives FreeBSD developers and users the same level of access to the code.

Thus, when a security flaw has been patched or a critical bug fix has been checked into the source repository, you as a FreeBSD user have the ability to synchronize your sources with the most recent version and then build and install a new component to address your system's vulnerabilityor build an entirely new operating system from the ground up.

The STABLE and CURRENT Source Branches Explained

Between full operating system releases, the FreeBSD code is in a state of constant flux. Bugs are being fixed, utilities are being patched and extended, features are being added, and the structure of the system is being reorganized. To understand this process, think of the code repository as a tree that occasionally sprouts new branches at the top as it grows. Each time a new version of the FreeBSD code (5.*x*, 5.2.*x*, 6.*x*, and so on) is initiated, it branches off from the main development codebase (or the "trunk" of the tree). As shown in Figure 19.1, the topmost branch is called CURRENT, and the next highest is STABLE. Typically, multiple branches of the code tree are undergoing maintenance at the same time, with the two newest branches in active development and earlier branches receiving sporadic maintenance.

Figure 19.1. The FreeBSD code branches, showing the relationship of the CURRENT and STABLE branches.



This code development model is fairly common in the software world; it enables developers to freeze a certain feature set within a version and avoid the instability of ongoing minor tweaks and additions. Following this model, developers add new features in blocks, introducing each new feature set or restructuring with each new branch.

The thing to remember here is that CURRENT is *not* the branch you want to use for a production server! CURRENT refers to the very most cutting-edge branch of the codethe one where brand-new features are being tested. Consequently, it's the least stable branch of the code tree. CURRENT is intended only for developers and people who absolutely, without any possibility of alternative, must have the new features that are introduced in FreeBSD code, without waiting for them to be declared part of a STABLE version.

At some point during development on a CURRENT branchusually after the first release, for example 6.0-RELEASEthe CURRENT version feature set is deemed STABLE, and the CURRENT and STABLE designations each move up one branch on the tree. CURRENT becomes the tag for the newly created topmost branch, and the newly designated STABLE (formerly CURRENT) version feature set is now recommended for use on production servers. New releases are announced on both branches every few months, until the feature set in CURRENT has matured and the STABLE branch no longer meets the needs of the community. The tree then branches again, starting the cycle over.

Note

Of course, this model is an idealization of actual reality. FreeBSD 6.0 was released after a longer period between full releases than was characteristic of earlier version schedules, and it was a much less radical upgrade from the 5.*x* branch than FreeBSD 5.0 was from the 4.*x* branch. As of this writing, FreeBSD 6.*x* is the STABLE branch, but actively maintained STABLE branches exist for both 5.*x* and 4.*x* as well (many legacy users have still not upgraded from the 4.*x* codebase because of the major changes in the 5.*x* tree).

Selecting Your Upgrade Target

You can upgrade your system at any time, no matter how far along the development in the source tree is. You have three choices for making the upgrade:

- You can select any release in which the code is frozen and kept in a static repository.
- You can synchronize your source tree using the CVSup utility (in much the same way as we discussed synchronizing your ports in Chapter 16, "Installing Additional Software") to the "errata fix branch" for a particular release, receiving fixes for security vulnerabilities and serious bugs without requiring you to perform a major upgrade. This is the best method for most users.
- You can simply synchronize your source tree to a line of active development and build a new system from scratch any time you want to.

The remaining sections of this chapter discuss how to synchronize your source tree to a chosen release or development branch in order to update your FreeBSD system. The only difference, in practice, between the methods described here is the target branch tag you use in your CVSup configuration, the identifier that describes the FreeBSD version you want. All tags begin with `RELENG`, a prefix that stands for *release engineer*. The `RELENG` tag signifies that a branch has been officially initiated by the release engineer on the core FreeBSD team.

Note

See http://www.freebsd.org/releng/ for a current list of FreeBSD releases and their maintenance status.

Upgrading to a Release Version

To upgrade your FreeBSD system to a release version, you insert a release version tag into your CVSup configuration, which we will discuss a little later. The release version tags all have three digits, separated by underscores rather than periods, and have a suffix of `RELEASE`. Table 19.1 shows how release tags map to version numbers. This is an incomplete example; there are many more available release version numbers available, each with their corresponding tags.

Table 19.1. Mappings Between Release Tags and Version Numbers

Release Tag	Version Number
`RELENG_6_0_0_RELEASE`	FreeBSD 6.0

`RELENG_5_4_0_RELEASE`	FreeBSD 5.4
`RELENG_5_2_1_RELEASE`	FreeBSD 5.2.1
`RELENG_4_11_0_RELEASE`	FreeBSD 4.11

Upgrading to an Interim Build on an Errata Fix Branch

Interim versions for specific releases are maintained so you can apply security patches and critical code fixes to an otherwise unchanging `RELEASE` codebase. If your system is built from `5.4-RELEASE` sources and you want to track a code branch that incorporates all the most recent security fixes without having to worry about all the other new features and code (and instabilities) that go into the STABLE development branch, you can synchronize your system to the `RELENG_5_4` branch. This upgrade gives you `RELENG_5_4_0_RELEASE`, *plus* any critical patches that have been committed since then, but nothing that has gone exclusively into the 5.5 development tree.

Interim releases on a so-called "errata fix branch" (or, earlier, "security fix branch") such as `RELENG_5_4` are numbered with a `p` suffix, as in `5.4-RELEASE-p3`, which signifies a system built from the third revision that was checked into the `RELENG_5_4` branch. From this you can see that code checkins in the errata fix branches are carefully managed and only occur in response to specific issues, such as to address security flaws or bugs that cause kernel panics.

Note

Security vulnerability announcements (such as those sent to the `freebsd-securitynotifications` mailing list) usually contain two suggested paths for fixing the bug in question: the point on each errata fix branch to which you need to upgrade your sources and then rebuild a component or the entire system, or a link to a "patch" file that you can apply to your existing sources without synchronizing the entire system. The instructions for downloading and applying the patch are given in the security bulletins, as well as instructions for rebuilding and reinstalling the affected component. However, in many cases, a bug fix is in the kernel or in a very basic system component, requiring you to rebuild the kernel or the entire system as described in the rest of this chapter. Using source patches is quick and convenient if possible, but you won't always have the luxury.

Errata fixes occur usually about once a month. Each such code change is marked with a sequential `p` number and publicized in a security announcement to the appropriate mailing list (you'll see more about the key mailing lists for tracking FreeBSD sources later in this chapter). These interim releases continue as long as the release is designated as being officially supported; refer to http://www.freebsd.org/releng/ to see which branches are supported and to know when support for a particular branch is dropped.

Tip

Use the `uname -a` command to see what version you're currently running:

```
# uname -a
FreeBSD simba 5.4-RELEASE-p3 FreeBSD 5.4-RELEASE-p3 #1: Wed Jun 29 18:
06:56PDT 2005 root@simba:/usr/obj/usr/src/sys/GENERIC i386
```

To upgrade to an interim build of FreeBSD, you specify in your CVSup configuration an errata fix branch that's in development. To switch from a `RELEASE` version (such as your original installation) to its corresponding errata fix branch, create your release target by leaving off the `RELEASE` suffix and the third digit from the initial release's tag, as shown in Table 19.2.

Table 19.2. Branch Tags and Version Designations for Interim Versions

Branch Tag	Version Designation
`RELENG_6_0`	FreeBSD 6.0-RELEASE-p# errata fix branch
`RELENG_5_4`	FreeBSD 5.4-RELEASE-p# errata fix branch
`RELENG_4_11`	FreeBSD 4.11-RELEASE-p# errata fix branch

Tip

Note that Table 19.2 is current as of early 2006. Due to the dynamic nature of development branches, this information will become obsolete with time. Refer to http://www.freebsd.org/handbook/cvs-tags.html for a definitive and current table of the appropriate branch tags.

Upgrading to an Active Line of Development (CURRENT or STABLE)

Seasoned FreeBSD veterans (and *only* seasoned FreeBSD veterans) can ride the ragged edge of the system's development by synchronizing their sources with a code branch that's not a released version *or* an interim build. This is typically only necessary for FreeBSD developers and contributors with a demonstrated need for having access to the very latest code changes or experimental features, and who don't care about letting others test and endorse the code with regimented interim releases.

Tracking STABLE or CURRENT branches in this way means you specify a branch tag with only the first digit of the release branch. For instance, specifying `RELENG_6` gives you the current state of the FreeBSD 6.x source tree, including code changes checked in by independent developers hours or minutes ago; it isn't tied to the official "frozen" states of FreeBSD 6.0, 6.1, or any other designated release. And that's just for the STABLE branches. You can get even more adventuresome by specifying the `HEAD` of the code tree, which gives you the CURRENT branchas you'll recall, CURRENT is where the newest, most experimental features are being actively developed, and they may not be stable or even complete. There's no guarantee that the code will be "safe" at any particular time, as it is with the interim `p` releases on an errata fix branch. If you choose to track a CURRENT or STABLE code branch, be prepared to wrestle with a system that may be unstable or even unusable if you happen to sync your sources to it at just the wrong time!

See Table 19.3 for the branch tags you'll use to sync to a CURRENT or STABLE branch.

Table 19.3. Branch Tags for Active Development Branches

Branch Tag	Version Designation
`HEAD`	FreeBSD-CURRENT (the very most recent code, not yet designated with an official version number). In CVSup, use a period (`.`) instead of `HEAD` as the branch tag.
`RELENG_6`	FreeBSD 6-STABLE (the main line of 6.*x* development)

`RELENG_5`	FreeBSD 5-STABLE (the main line of 5.*x* development)
`RELENG_4`	FreeBSD 4-STABLE (the main line of 4.*x* development)

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Upgrading with `make world`

In the language of FreeBSD development, the *world* refers to everything within the FreeBSD system other than the kernel. Therefore, `make world` refers to the process of rebuilding your FreeBSD system from the ground up. Rebuilding your entire system is certainly a more hands-on, less "prepackaged" way of upgrading than simply dropping in a CD. However, in accordance with the FreeBSD way of doing things, building your binaries from pure source is the only way to ensure your system will truly be compatible with your hardware and your setup. The `make world` process does involve a lot of steps and a fair amount of risk, but the regimented structure of FreeBSD helps to mitigate the risk and allows you to enjoy the advantages this method provides.

The `make world` process provides safeguards that would not normally be available if you were to install precompiled binaries from a CD. If any part of the source code is broken, for example, it will fail to compile in the first place, rather than waiting until the rebuilt binaries are installed on your system before revealing themselves to be unusable. The clearest philosophical difference, though, between `make world` and other upgrade methods is that it blurs the line between released software and interim builds.

A *release* (stated somewhat glibly) is often just a snapshot of the source where it appeared particularly stable and matched a set schedule milestone. The process of synchronizing your sources to that snapshot is functionally the same as synchronizing to any other point in the brancha developer-friendly approach. There's hardly any difference in technique between updating your system to `6.0-RELEASE-p5` and to `6-STABLE`. This blurred distinction between development states encourages administrators to keep their code trees in sync, which provides the real advantage of ensuring that the most recent security patches and bug fixes are always at your fingertips.

All you typically have to do to update an individual part of your system, once you've got the appropriate sources at the development state you need, is to go to that part of the source, build it, and install it (you learn about updating individual components through this method in Chapter 30, "Network Security"). You also need to plan on rebuilding the entire systemthe entire "world"on a periodic basis.

Making the world consists of four main steps:

1. Building the world (or everything in the core system aside from the kernel).
2. Building the kernel.
3. Installing the world.
4. Installing the kernel.

Before you do any of these things, though, we need to address some essential preparations and precautions.

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Things to Consider Before Choosing a `make world` Upgrade

The risks of building your system from scratch are not insignificant. On a high-profile production server, you may deem them too great for `make world` to be a viable upgrade method. It's a simple matter to wait for each full release on CD, and you may prefer to go that route insteadeither doing a binary upgrade through Sysinstall, or (as many administrators do today) backing up the data, performing a fresh install complete with a reformat of the hard disks, and reinstalling the data. To make an informed decision, though, you need to fully understand the risks involved in building a system from interim sources.

First, and most obviously, `make world` involves at least one reboot, and it takes a long time to completeduring which time many of your system utilities might not work properly. If you're concerned about your uptime, or if your system absolutely must be online at all times (as with a high-profile network server), you would probably be best served by upgrading to each successive `RELEASE` version and applying the necessary patches in between releases.

Second, `make world` isn't a guaranteed process. The FreeBSD Group makes no claims that `make world` will not completely destroy your system (though the same is true for any upgrade path, really). The real issue is that frequently rebuilding the operating system gives it that many more chances to blow up. Using `make world` is absolutely the best way to keep on top of all the latest bug fixes, but it's also an excellent way to find yourself running a system with untested new features or code changesor even to find that your sources won't build because, by pure bad luck, you synchronized your sources just when some unstable code was being checked in.

Remember, the STABLE and CURRENT code branches are living, breathing creaturesthey're not "release" quality, nor are they intended to be. Any interim code that's not on a specific release branch should be regarded as beta quality at best. Rebuilding the entire system between releases is really something you should do only if you're using your FreeBSD machine as a workstation or a small, noncritical server, or if there is absolutely no other way for you to get a critical bug fix or new feature.

Note

In production environments, it is a common configuration to have two identical machines: the "real" server and a clone of it used for backup and testing purposes. If you have this kind of setup, you can test the results of a `make world` process on the backup system before performing the same procedure on the production server.

Because the purpose of the production environment with the mirrored test server is to provide two identical platforms where if something works on the test machine you know it will work on the live one, you need to make sure that the sources from which you build your system are identical on both systems. It's imperative that you synchronize both systems to the exact same source tree and errata fix point, and don't perform any more source sync processes between the test system's `make world` and the real one.

If you do track either STABLE or CURRENT, it's absolutely essential that you subscribe to the `freebsd-stable@freebsd.org` or `freebsd-current@freebsd.org` mailing list (as appropriate). These lists serve as forums for anyone tracking the branch to discuss problems, new bug fixes or features, and possible pitfalls for anyone choosing to synchronize sources at a particular time. A committer might post to `freebsd-stable@freebsd.org`, for instance, warning everyone not to use `make world` for at least the next couple of days until he has had a chance to test a risky new feature that has just been checked in. If you're not on the mailing list and the feature turns out to be less than rock-solid, you could end up with an unstable or insecure system, which is exactly what you're trying to avoid by tracking the sources.

Note

Both mailing lists are standard Majordomo lists. You can subscribe to either one by sending an email to `majordomo@freebsd.org`, with the message body as follows:

```
subscribe freebsd-stable
```

Do *not* send the subscription request itself to `freebsd-stable` or `freebsd-current`! This is one of the Internet's most common mistakes! These addresses are for the actual list traffic, not for control commands.

That's all there is to it. When you receive a confirmation message, reply to it as directed to be added to the mailing list. To unsubscribe, do the same thing, except replace the word `subscribe` with `unsubscribe`.

It's important to note that even though you might choose not to run the `make world` process regularly, it's still an excellent idea, in almost all circumstances, to track the sources. Tracking sources in and of itself merely synchronizes the source code tree on your system (everything within `/usr/src`) to the current state of either the STABLE or CURRENT code branch; it doesn't upgrade any binaries or affect the operation of your system at all. You can then choose to use `make world`, compiling all those sources into a completely new system, at your discretion. Alternatively, because the build process is as hierarchical as the filesystem in which it resides, you can simply go to any point within `/usr/src` and build that component individuallyfor example, go to `/usr/src/lib/libkvm` to rebuild just the `libkvm` library. This is how you typically patch your system in response to a security advisory (learn more about these in the section "FreeBSD Security Advisories," in Chapter 30).

Above all, remember that upgrading a FreeBSD system is not a reversible process. You can't deinstall a newer version and have the older version still work as it used to. The best safeguard is to take as many precautions as you can.

Bug Tracking and Problem Reports

The FreeBSD bug-tracking database is online and publicly accessible. You can view the status of all open bugs and feature requests at http://www.FreeBSD.org/cgi/query-pr-summary.cgi, or you can go to http://www.freebsd.org/support/bugreports.html to see a web interface to the GNATS bug database.

You can also submit bug reports of your own; indeed, that's how a lot of these bugs get filed. You can use a web form accessible from the preceding GNATS URL (click Submit a Problem Report); or you can use a command-line tool on your own system called `send-pr`. When you run that command, you are placed into your preferred text editor with a template file. Simply fill out the input fields with the relevant data about the bug you're submitting. When you save and exit, the problem report is sent directly into the GNATS database and reviewed by the committers.

Of course, you'll want to make sure the bug you're reporting hasn't already been submitted. Search the preceding URLs for any specific relevant text in any of the open reports. Also, don't forget to subscribe to the appropriate mailing list: `freebsd-stable` or `freebsd-current`. It's a good idea to post to the appropriate list before submitting a problem report and ask whether anyone else has seen the problem before you send it via `send-pr`. It's likely that someone has already noticed the bug and may even have a temporary workaround to suggest to you.

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Pre`make world` Tasks

So, you've chosen to rebuild your system. Whether you're going to synchronize to interim sources along one of the development branches or you want to rebuild to upgrade to the next major release, there are a number of things you need to do before embarking on the rather convoluted rebuilding process. A lot of things can go wrong, so it pays to follow the game plan:

1. *Make a backup of your system.* Nothing is more heartbreaking than performing a simple, routine upgrade, only to find that your filesystem is destroyed and all your users' data irretrievably lost. Backup solutions might include tape drives, optical disks (CD-R, DVD-RAM, DVD-R, and so on), a second hard drive that you mount only when you need to mirror your first drive's contents onto it, or a second machine that you keep synchronized via NFS or CVSup (you learn about backup methods in Chapter 21, "FreeBSD Survival Guide").

   Caution

   Having a proper backup solution is one of the most crucial, and yet most onerous, parts of system administration. Many readers will undoubtedly ignore this warning and proceed anywayit happens all the timebut if you can possibly manage the cost and hassle of setting up a backup solution, the benefits are absolutely worth the investment.

2. *Check the timing of your upgrade.* Pay attention to the mailing list for your chosen branch, if you're tracking an active development codebase. Make sure your upgrade won't occur during an announced bug fix or testing phase. If the time isn't right for your upgrade and you desperately need just a certain patch or bug fix, see if there's a way to rebuild just that one component.

3. *Synchronize your sources.* Before you can really do anything further to prepare yourself for the build, you need to synchronize your sources, as explained in the section that follows. You only need to do the setup for this once; after that, it's a process that can (and should) be automated and run regularly.

Synchronizing Your Source Tree with the STABLE or CURRENT Tree, an Errata Fix Branch, or a Release

You have a number of ways available to you to synchronize your sources. The methods suggested by the FreeBSD developers include CTM, Anonymous CVS, and CVSupand each one has its own particular advantages. You can read more about each of these at the FreeBSD website under the "Synchronizing Your Source" heading of the online handbook. This chapter covers using CVSup because it's the most advanced and efficient (not to mention coolest) option available.

Configuring and Running CVSup

We discussed how to set up CVSup in "Keeping Ports Up to Date with `CVSup`" in Chapter 16. If you haven't set up a supfile (CVSup configuration file) yet, as described in that chapter, refer to it for background information on installing CVSup and writing an appropriate supfile. If you did set up a supfile (for example, the `/etc/ports-supfile` shown in Listing 16.7), you can modify it to synchronize the entire source tree instead of just the ports by just adding a couple of lines as shown in Listing 19.1, and give it a more general name (for instance, `/etc/6stable-supfile`).

Listing 19.1. A General CVSup Config File for Synchronizing a STABLE Branch

```
*default  host=cvsup12.FreeBSD.org
*default  base=/usr
*default  prefix=/usr
*default  release=cvs
*default  tag=RELENG_6
*default  delete use-rel-suffix
src-all
*default tag=.
ports-all
doc-all
```

The file is interpreted sequentially, and later `*default` lines override previous ones, applying only to the commands that appear below them. Notice that the first set of `*default` lines, which define the settings for where CVSup should put the files it downloads and what source repository to use, set the branch tag to `RELENG_6`. As you've seen, this is the proper tag for the `6-STABLE` branch. However, these settings only apply to the `src-all` source collection, the FreeBSD system sources. After that line, another `*default` line resets the branch tag to a period (`.`), which is a synonym for the `HEAD` of the source tree. This is the appropriate tag for the ports collection (`ports-all`) and the documentation tree (`docall`), which each only have a single development branchthey aren't broken out into branches like the system sources, and the most current state of each tree is always considered the best version at any given time.

After you've set up your supfile, run a CVSup update with the following command:

```
# cvsup -L 2 /etc/6stable-supfile
Parsing supfile "/etc/6stable-supfile"
Connecting to cvsup12.FreeBSD.org
Connected to cvsup12.FreeBSD.org
Server software version: SNAP_16_1h
Negotiating file attribute support
Exchanging collection information
Establishing multiplexed-mode data connection
Running
Updating collection src-all/cvs
 Edit src/UPDATING
  Add delta 1.416.2.3.2.6 2005.12.19.10.58.56 delphij
 Edit src/sys/conf/newvers.sh
  Add delta 1.69.2.8.2.2 2005.12.19.10.58.57 delphij
 Edit src/sys/nfsclient/nfs_vnops.c
  Add delta 1.258.4.1 2005.12.19.10.58.57 delphij
```

Watch the output carefully. You should see a series of filenames whose names are relative to the base (`/usr`), each one with numbered and signed revisions being applied to itthat's CVSup synchronizing your source tree with the one on the server, downloading and applying only the portions that differ.

Tip

This CVSup command is an excellent candidate for a shell alias (as discussed in Chapter 9, "Customizing the Shell"):

```
alias sync6 cvsup -L 2 /etc/6stable-supfile
```

Each line should begin with either `Edit` or `Checkout`, or the occasional `Delete`, indicating a file that's been removed because of redundancy or moved to another location. However, if you see nothing but `Delete` lines, you should press Ctrl+C to stop the processit means you're synchronizing to a source tree that doesn't exist. Double-check your supfile to make sure your branch tag is correct and points to a valid source branch as listed at http://www.freebsd.org/doc/en_US.ISO8859-1/books/handbook/cvs-tags.html.

When you're satisfied that CVSup is synchronizing your sources properly, you probably should add a task for running the CVSup update to your daily `periodic` file, as described in "Keeping Ports Up to Date with `CVSup`," in Chapter 16. Every day afterward, you'll have sources that are always no more than a day old.

Tip

At the end of each CVSup process run from the `periodic` subsystem, a status message that contains all of the process's console output is generated and mailed to root. Pay attention to the contents of this message every time! When you're tracking STABLE or CURRENT (or an errata fix branch), these messages tell you each day what has changed. This way, you'll know exactly when a crucial bug fix has been applied to a certain component you're watching. The output of the CVSup process can be lengthy and unwieldy, but after a few days you'll get a feel for what parts of it are important and what can be ignored. Particularly in the case of an errata fix branch, you'll only see changed files when a new interim release point has been created; those are the times when you'll need to check the `UPDATING` file (discussed shortly) to see exactly what has changed and whether you need to act on it.

Using CVSup to Synchronize to an Errata Fix Branch or Release

Using CVSup is an excellent way to get the sources for a major release version or interim errata fix release as well as to synchronize to actively developed sources. To do this, you simply need to use the branch tag that specifies the release you want (as discussed earlier in the chapter).

It's tempting, especially if you're performing an upgrade from one major version series to another, to sync to a major release version (such as `6.0-RELEASE`) and build a system from that; however, you should be aware that the original `RELEASE` codebase for a particular release branch is usually insecureit's missing whatever critical fixes have been merged into it since the time the release occurred. Generally, `RELEASE` codebases are relevant only for a few weeks after the initial release on that branch appears, or until the code begins to change in response to security bulletins.

The best policy for most FreeBSD administrators is to use an errata fix branch, which gives you the key updates you need for responding to serious security issues, but doesn't make you perform large and invasive upgrades or subject you to unstable or irrelevant code changes. To specify a particular errata fix branch, edit the supfile (refer back to Listing 19.1) and change the branch tag that's relevant to the `src-all` collection. For example, the errata fix branch sources for FreeBSD 6.1 can be had with the following line:

```
*default tag=RELENG_6_1
```

If you really want to synchronize to a `RELEASE` codebase (such as the initial release of FreeBSD 6.1), knowing that it's less secure than the current state of its corresponding errata fix branch, use a line like the following:

```
*default tag=RELENG_6_1_0_RELEASE
```

Now, when you run the CVSup update from this file, you receive the "frozen" sources for the release you've chosen. Also, unlike with the constantly changing STABLE and CURRENT branches, if you update again a week later, nothing will have changed.

You can now use `make world` from these sources to build a clean system from the initial release sources; but you should then change the release tag in your supfile to indicate an appropriate errata fix branch and sync your sources again to obtain the latest security patches for your chosen release. Then, you can resume daily synchronizations so you can have all the latest source patches and updates at your disposal. This upgrade method works best if you have a critical server to keep updated.

Troubleshooting Questions

Quite a number of things can go wrong with CVSup, and because it's a type of task that has no analogue on most other operating systems, it's hard to tell when the process has gone as planned and when it has abjectly failed. Here are suggested fixes for some of the most commonly reported problems:

- *CVSup won't connect to the server I've selected (Connection refused)*.

  Try picking a different CVSup server. The servers are named `cvsup1` tHRough `cvsup18`; the higher the number (for example, `cvsup15.freebsd.org`), the less traffic it is likely to be sustaining. Also, try to run CVSup at a time of day when traffic will be minimal (the middle of the night, for example).

- *CVSup connects but nothing ever happens*.

  This might occur if you're behind a firewall or a NAT router that masks your IP address. CVSup is known to work with NAT-enabled network configurations, but a misconfigured one might cause problems. Also, make sure your firewall will allow CVSup traffic. The server port is 5999. Try using the `telnet` command to connect to the server at that port to make sure you can connect (**`telnet cvsup12.freebsd.org 5999`**); if you get no response or a "Connection refused" message, you might need to make a firewall exception for port 5999.

- *CVSup deleted my entire `/usr/src` directory!*

  This occurs if you've specified an invalid branch tag. If you give CVSup a tag that the server doesn't recognize, it responds by giving you the contents of the CVS tree at the branch you've specifiedwhich is nothing. Make sure you've got the right branch tag, and you should be all right; just run CVSup again and a fresh set of sources will be downloaded and merged with whatever's left from before the previous run.

The `UPDATING` Text File

Now that your sources are updated, you have a current `UPDATING` file in `/usr/src`. This file is a "late-breaking news" bulletin that has important information on upgrading your system, almost guaranteed to be more current than anything you read in print or online (this book is no exception). `UPDATING` contains a reverse chronological listing (each with a date stamp) of notable changes to the build process that you should know about. Read all of them between the top of the file and the date of your last `make world`.

In an errata fix branch, the entries in `UPDATING` specifically indicate the nature of each security patch or critical bug fix that was checked in, and each is labeled with the appropriate `p` number:

```
20051219:       p1      FreeBSD-EN-05:04.nfs
        Correct a locking issue in nfs_lookup() where a call to vrele()
        might be made while holding the vnode mutex, which resulted
        in kernel panics under certain load patterns.

20051101:
        FreeBSD 6.0-RELEASE
```

`UPDATING` gives you special instructions for coping with major changes in the system (moved files, added or deleted features, and so on). Something to remember is that the files in `/etc` are not altered automatically by the `make world` process. Any configuration files you have in there will not be overwritten. This ensures that your custom system setup won't be lost; it also means that whenever the default system configuration requires something new to be added to or deleted from `/etc`, you'll have to merge it in manually. The `UPDATING` file usually details cases like this. Fortunately, a neat tool called `mergemaster` allows for an easy merge of new files into `/etc`. You learn more about `mergemaster` in "Using `mergemaster` to Check for

Changed Configuration Files," later in this chapter.

Merging /etc/group and /etc/passwd

Most of the /etc files don't affect your ability to build the system. However, occasionally new services are added that have to be installed with ownership matching a certain user and group. Remember that make world is not an installer application with built-in upgrade tasks; it simply recompiles and installs a new version of the operating system on top of the old. This means that make world most likely won't create the users and groups it needs if they don't already exist. You can help avoid any collisions arising from this by merging any new entries into your /etc/group file.

The new version of /etc/group is in /usr/src/etc/group. It probably won't be any longer than 20 lines or so. Open /etc/group in another terminal window. Now, check to see if there are any entries in /usr/src/etc/group that are not in /etc/group. If you find any, simply copy them over. New entries are likely to have GIDs below 100.

One easy way to compare the two files is to use diff, as shown in Listing 19.2.

Listing 19.2. Comparing /etc/group and /usr/src/etc/group Using diff

```
# diff c /etc/group /usr/src/etc/group | less
*** /etc/group Wed May 2 09:57:10 2001
--- /usr/src/etc/group Fri Aug 27 16:23:41 1999
***************
*** 8,24 ****
  bin:*:7:
  news:*:8:
  man:*:9:
- wheel:*:10:root,frank,joe
  games:*:13:
  staff:*:20:root
  sshd:*:22:
  smmsp:*:25:
  mailnull:*:26:
  guest:*:31:root
  bind:*:53:
  uucp:*:66:
  xten:*:67:xten
  dialer:*:68:
+ network:*:69:
- mysql:*:88:
- users:*:100:
  nogroup:*:65533:
  nobody:*:65534:
```

Groups in your existing /etc/group are shown with a minus sign (-), and new groups in /usr/src/etc/group have a plus sign (+). In this example, you need to copy the network group into your /etc/group file.

It's important to preserve the GIDs suggested in the new group file. In the unlikely event that any of the GIDs don't match, you need to fix your existing /etc/group to match the new file. This fix might cause some existing files in your system (that were owned by that group) to lose their permissions. You can search the system for these files with the find command:

```
# find / -group GID -print
```

You can then fix the permissions on these files with chmod, as you saw in Chapter 13, "Users, Groups, and Permissions."

It's even less likely that any mismatches will occur in the user database. The sources don't include a `passwd` file, just a `/usr/src/etc/master.passwd` file that's even shorter than the new `group` file. Quickly scan it and your `/etc/master.passwd` file for mismatches and then use `adduser` to insert any new users you find.

Merging `/etc/make.conf`

The `make.conf` files are the global configuration files that control all `make` operations, including `make world`. You don't have an `/etc/make.conf` file in a new installation of FreeBSD. However, in the same way that `/etc/rc.conf` and `/etc/defaults/rc.conf` work, there's a file named `/etc/defaults/make.conf` that specifies all the likely default settings. You can leave things as they are, but you can speed things up a bit with the judicious use of a few options.

The FreeBSD Handbook suggests enabling the following lines by copying them out of `/usr/share/examples/etc/make.conf` and into `/etc/make.conf` and then uncommenting them:

```
CFLAGS= -O -pipe
NO_PROFILE=     true    # Avoid compiling profiled libraries
```

These modifications help to ensure that the `make world` process will be smooth, without trying to add potentially destabilizing optimizations or unnecessary compilations into the process. You can set some other options if you want to experiment, but that's beyond the scope of both this chapter and this book.

PREV NEXT

Rebuilding Your System from Sources

You're ready to go. The rebuilding process consists of a good number of steps, so take your time with it, especially if this is your first time through.

The `make world` process itself consists of four main compilation steps, listed in Table 19.4. If you're feeling exceptionally confident, you can reduce the process to two steps, but for this first time, take each of the `make world` steps individually.

Table 19.4. Steps Involved in a Complete `make world` Process

Four-step Command	Two-step Command	Meaning
`make buildworld`	`make world installworld`	Builds and installs `make` everything but the kernel
`make buildkernel`	`make kernel installkernel`	Builds and installs `make` the kernel

The `make world` and `make kernel` commands should be used *only* by seasoned veterans who really know what they're doing; everyone else needs to use the four individual `make` commands, which is a far safer way to go and barely any less convenient. You won't be using those commands in the order shown in the table, though! You actually build the world first, build and install the kernel, reboot into single user mode, and then install the rest of the world and merge your configuration files. The following sections detail the steps for this process.

Cleaning Out `/usr/obj`

This step isn't necessary if this is the first time you've done a `make world`. If it isn't, you'll probably want to clean out everything in `/usr/obj` to speed things up and prevent collisions when the system runs into files it can't overwrite.

`/usr/obj` is where the object files (compiled components) are stored after being compiled and before being installed. Deleting them, however, isn't necessarily as easy as simply doing an `rm -rf` inside that directory. Making the world creates certain files with the `schg` flag (the "system immutable" flag), which means that the files can't be deleted, even if you're root. This is a safety measure intended only to provide an extra means of protection against accidents (such as `rm -rf \.*`). To get around this and clean out the build directory properly, use the following commands:

```
# cd /usr/obj
# chflags -R noschg *
# rm -rf *
```

You won't be able to do this so easily if you're running an older FreeBSD installation and `securelevel` is set to `1` or higher (this is a systemwide security setting you select during installation or in `/etc/rc.conf`, as described in `man securelevel`). This setting prevents you from unsetting the `schg` flags. You have to reboot into single user mode to complete this step properly.

Starting an Output Log

Keep a log of the output from your `make world`. If anything goes wrong, you can review the log for clues and, if necessary, post the relevant parts of it to the appropriate mailing list. Chances are that because an error will cause the compile to fail immediately, you'll have the relevant lines in your terminal program's scrollback buffer. However, if you're doing the rebuild from the machine's local console, you won't have a scrollback buffer to copy from, and so it's a good idea to have a transcript of the entire process to peruse if you need to.

Use the `script` command to create the log. This command effectively runs a shell within a shell, capturing all output into the file you choose. You remain in the script shell until you type **`exit`** to return to your regular shell. Here's an example showing the `make buildworld` command issued after a `script` log has been started:

```
# script ~/buildworld.out
Script started, output file is ~/buildworld.out
# make buildworld

...

# exit
Script done, output file is ~/buildworld.txt
```

The argument to `script` specifies the target file that will contain all the build output. It's a good idea to name this file according to the build step you're about to capture. Each time you run `script` with the same target filename it overwrites that file rather than appending to it. Therefore, you should run `script` separatelyand have a separate target filefor each step in the `make world` process.

Caution

Don't specify a target file in `/tmp`! Files in `/tmp` are deleted on bootup, so you won't have your output files when the system comes back up.

Running and Troubleshooting `make buildworld`

Here's where the fun really begins. Go to `/usr/src`, take a final look around to make sure everything looks okay, and enter the first `make` step:

```
# make buildworld
```

Now, sit back and watch. The `buildworld` process takes an hour or two, depending on your hardware. You can speed it up by using the `-j` option to run multiple simultaneous processes, as in this example, which starts four of these parallel tasks:

```
# make -j4 buildworld
```

This is useful even on a single-CPU system, but if you have multiple processors, you can get still more performance from higher values (try as many as 10).

The build process takes a vaguely alphabetical, recursive path through `/usr/src`. You can track its progress by looking through the directories in `/usr/obj`. When you see it compiling things in `/usr/src/usr.sbin`, you know you're near the end.

As is the case with CVSup, the process of building a complete operating system is probably an unfamiliar one, and you can expect to run into some problems. Here are two of the most commonly reported problems and their solutions:

- *The compiler fails with "signal 11" errors*.

  Signal 11 refers to a segmentation fault in the compiler, which most frequently occurs due to hardware issues. Check to see whether your CPU is overclocked; this can frequently cause problems with FreeBSD when you perform processor-intensive tasks such as compiling software. If you're not overclocking, suspect your RAM or other hardware. Consider memtest86 (http://www.memtest86.com/) as a freely available method for testing your RAM.

- *The compiler fails with a lot of `*** Error code 1 ***` lines*.

  This is the generic error when the build fails at any certain point. The `buildworld` process won't proceed if any part of it fails, so the last few lines of output leading up to the failure are the most useful.

- *An error occurred that seems to be related to incorrect compiler flags, or to some mismatched configuration file in `/etc`*.

  Certain files, such as `/etc/make.conf`, affect the `buildworld` process and can make the difference between success and failure. A tool that you'll be using later, `mergemaster`, can help here: run `mergemaster -p` ("pre-buildworld mode") to compare the critical files to the ones in the new source tree, and install or merge the newer ones if necessary. See the "Running `mergemaster`" section a little later for a full discussion of how `mergemaster` works.

To avoid compiler failures resulting from incompatibilities between old object files and new sources, make sure you have completely removed the contents of `/usr/obj` before compiling. Leaving the objects from previous builds intact can save time, but it can also cause spurious failures if the compiler doesn't realize it has to rebuild some component. Clean out `/usr/obj`, as shown earlier, and try again.

If this doesn't help, search the mailing list archives at http://www.freebsd.org (in the mailing list that pertains to your code branch`stable`/`freebsd-stable` or `current`/ `freebsd-current`) on the relevant keywords from your output. If you find nothing useful, post a question to the relevant mailing list, citing the output of `uname -a`, the time of your last CVSup, and the relevant final few lines from the compiler output.

Another possible recourse would be the `#freebsd` or `#freebsdhelp` channels on various IRC servers. See Appendix D, "Sources for More Information," for fuller details on available IRC channels.

Upgrading the Kernel

Okay, your "userland" (user-accessible files, or everything but the kernel) is now built and ready to be installed. First, though, you need to get the new kernel built and installed.

Upgrading a `GENERIC` Kernel

If you're running a `GENERIC` kernel (see Chapter 18, "Kernel Configuration," for details), the process is simple:

```
# make buildkernel
# make installkernel
```

Or, even more simply (though dangerously):

```
# make kernel
```

Now, your new kernel is installed as a directory full of modules called `/boot/kernel` (a single binary called `/kernel` prior to FreeBSD 5.0), and the old one is at `/boot/kernel.old`. As discussed in Chapter 14, "System Configuration and Startup Scripts," you can boot with the old one if the new one fails.

Upgrading a Custom Kernel

The upgrading process is made a bit more complex if you're running a custom kernel. The adventurous might try building a new version of the custom kernel right away and running with that, but you can set up a safety net by building a `GENERIC` kernel first and keeping it on hand to boot with if you have to. You'll also have your old kernel (the one currently running) as a fallback if all else fails.

Still within `/usr/src`, enter the following:

```
# make buildkernel KERNCONF=GENERIC
```

This is your first backup kernel, a `GENERIC` one built from the new sources. Now, if you haven't done this already, copy `/boot/kernel` to `/boot/kernel.prev` (or some other name to indicate that this is the kernel you were already running and you know works). Next, install the newly built kernel:

```
# make installkernel KERNCONF=GENERIC
```

Then, duplicate this kernel and call the copy `kernel.GENERIC`:

```
# cp -R /boot/kernel /boot/kernel.GENERIC
```

Now, here's how to build your first-choice kernel (the custom one built from the new sources):

```
# make buildkernel KERNCONF=CUSTOM
```

Naturally, replace *`CUSTOM`* with whatever the name of your custom kernel is. Now, install the new custom kernel as `/boot/kernel`:

```
# make installkernel KERNCONF=CUSTOM
```

To recap, your lineup of kernels is shown in Table 19.5.

Table 19.5. Newly Available Kernels

Kernel	Description
`/boot/kernel`	New custom kernel
`/boot/kernel.GENERIC`	New `GENERIC` kernel
`/boot/kernel.prev`	The old tried-and-true kernel

When you reboot, if the first kernel fails, try booting with the new `GENERIC` kernel. As described in "Understanding the FreeBSD Startup Process" in Chapter 14, this is accomplished by selecting option 6 (Escape to Loader Prompt) in the loader menu, and then entering **`boot kernel.GENERIC`**. If that fails, boot with the previously working kernel, and you'll be back to where you started.

Troubleshooting the Kernel Upgrade and Installation

Building and installing the kernel is the riskiest stage yet in the `make world` process, and the safeguards in the system that protect the kernel during this process add to the arcane nature of the procedure by being quite user-unfriendly. Here are two few common failure modes and their solutions:

- *The compiler fails*.

  The kernel sources can fail to build for the same reasons that building the rest of the system can fail. If you can't resolve the failure yourself using the same methods as with the `buildworld` process, try the mailing lists.

- *The system won't let me install my new kernel!*

  If you're on an older system (before securelevels were deprecated) and have set `securelevel` to `1` or higher, `make installkernel` won't be able to remove the `schg` flag on the kernel. You will have to reboot into single user mode to complete each step of the process. Remember that when you boot into single user mode (using option 4 in the loader menu), none of the filesystems will mount automatically; you'll need to run `mount -a` before you can go into `/usr/src` and run the `make installkernel` process.

Running and Troubleshooting `make installworld`

After you've completed your kernels, it's time to reboot into single user mode, which prevents multiuser processes (either run by other users or by daemons operating automatically) from altering files that you'll be upgrading. Collisions of this type can lead to serious instability. Using single user mode is also a good idea simply because of the slight speed advantage and because it's nice to be able to bring the system back online completely upgraded and ready to go.

Reboot into single user mode by using the `reboot` command. When you reach the loader menu, select option 4 (Boot FreeBSD in Single User Mode) to bring the system up far enough for you to verify that the new kernel is working and to complete the installation.

Note

If the system fails to come up (it might crash, it might spew error messages, or there might be any number of different failure modes), first try rebooting normally to see if the behavior is different from case to case, and to try to determine what in the new kernel is causing problems. If you still have no luck, it's time to drop back to your old kernels. Reboot again, and try booting single-user with the backup kernel, as you saw a little earlier. Keep trying kernels until you reach the one you were using before you began the upgrade (which should boot without troubleso far, the kernel is the only thing you've changed in the system). You should then postpone your `make world` and try again from scratch after you've resolved the problem with your new kernel. Chances are that a kernel failure at this point is indicative of a more widespread and temporary problem that will be resolved in the source in the near future.

In single user mode, you're root by default. The first thing to do is to mount your filesystems, so you can have access to the source tree; do this with a **`mount -a`** command and then verify that it worked by using **`df`** (all your filesystems should be listed in the output). Go back into `/usr/src` now and enter the final, most important part of the `make world` process. Installing the system binaries won't take as long as building them, but there is an equal chance of errors occurringand this time, a failure will result in a partially altered system. Make sure to start your `script` output log before you begin this step. Here's the command for this step:

```
# make installworld
```

After this step completes, your binaries and kernel should be compatible; try running utilities such as `ps` and `top` to make sure they work properly. You'll get errors if the kernel and the binaries aren't built from the same source base, so if the utilities work, you can be pretty confident you successfully installed everything so far.

Anything that goes wrong during the `make installworld` step is potentially dangerousyou can end up with a partially installed system, with some of it compatible with the new kernel and some of it not. Fortunately, there are fewer things that can potentially go wrong than in the other stages. Here are the most common problems:

- *The installer fails, citing a problem with permissions or ownership*.

  This is the reason for synchronizing your `/etc/group` and `/etc/master.passwd` files before installing the world. Check again to make sure some user or group isn't missing and try again.

- *An error occurred that seems to be related to incorrect compiler flags, or to some mismatched configuration file in `/etc`*.

  Certain files, such as `/etc/make.conf`, affect the `installworld` process and can make the difference between success and failure. A tool that you'll be using later, `mergemaster`, can help here: run **`mergemaster -p`** ("pre-installworld mode") to compare the critical files to the ones in the new source tree, and install or merge the newer ones if necessary. See the "Running `mergemaster`" section a little later for a full discussion of how `mergemaster` works.

PREV NEXT

Using `mergemaster` to Check for Changed Configuration Files

There's only one step left in the `make world` process: merging your old `/etc` hierarchy (and other miscellaneous areas such as `/var/log` and `/usr/share`) with the new ones. As you learned earlier, the `make world` steps don't touch `/etc`, in order to keep from stomping on heavily customized configurations. In earlier days, the only way to merge changes into `/etc` was to do it manually, a very painful and error-prone process. The `mergemaster` utility, a standard part of FreeBSD, makes this process a great deal simpler and safer.

A lot of safeguards are built into `mergemaster`; it's a very safe tool to use. Nevertheless, there always exists the risk of damaging your configuration, so as a precaution, you should make a backup copy of `/etc`. Fortunately, this is easy:

```
# cp -Rp /etc /etc.old
```

Or:

```
# tar cvfz /etc-backup.tgz /etc
```

Running `mergemaster`

Typically, `mergemaster` doesn't really need any options; its defaults are set to sensible behaviors. This first time through, you can add the `-v` (verbose) option to see an explanation of what `mergemaster` is doing at each step. You can also use the `-c` option to use contextual `diff`s instead of unified ones. Here's the command:

```
# mergemaster cv
```

The first thing `mergemaster` does is create a temporary root directory and install everything from the relevant sources into it, including the various trees of files that need to be "installed" (processed through installer scripts) rather than simply copied over. This "staging area," by default, is in `/var/tmp/temproot`. It shows you a listing of files that only exist in `/etc` and not in the temporary root directory (generally, these are files you have added yourself, so it won't touch them). Then, `mergemaster` proceeds to compare all the files in `/etc` and certain other locations with the new ones in `/var/tmp/temproot`. Whenever it encounters files that don't match, it displays the `diff` output in whatever pager you have specified in the `PAGER` environment variable (or `more`, by default).

When you scroll to the bottom of the `diff` display (or press > to jump directly to the bottom), you are given a list of choices for what to do with the new file, similar to Listing 19.3.

Listing 19.3. Options for Merging a File in `mergemaster`

```
***************
*** 321,326 ****
--- 327,333 ----
  kern_securelevel="-1" # range: -1..3 ; '-1' is the most insecure
  update_motd="YES"     # update version info in /etc/motd (or NO)
  start_vinum=""                # set to YES to start vinum
+ unaligned_print="YES" # print unaligned access warnings on the alpha (or NO).
```

```
  ##############################################################
  ### Define source_rc_confs, the mechanism used by /etc/rc.* ##

  Use 'd' to delete the temporary ./etc/defaults/rc.conf
  Use 'i' to install the temporary ./etc/defaults/rc.conf
  Use 'm' to merge the old and new versions
  Use 'v' to view to the differences between the old and new versions again

  Default is to leave the temporary file to deal with by hand

 How should I deal with this? [Leave it for later]
```

As you can see, the default behavior is to do nothing, leaving the new file in `/var/tmp/temproot` for you to consider after you've finished running. This makes `mergemaster` a very safe utility to run.

If you select **`m`** to merge the two files, you are dropped into the `sdiff` environment. This shows you the old and new versions of the changed file, line by line, allowing you to choose between the left (old) and right (new) versions of each:

```
  *** Type h at the sdiff prompt (%) to get usage help

pccard_beep="1"         # pccard beep | pccard_beep="2"       # pccard beep
%
```

The `sdiff` command options are available by typing **`h`** at the prompt.

Tip

Each changed line is merged individually, so the `sdiff` method can become tedious if you're using it to merge very long files with lots of scattered changes. You may be better off simply making a backup copy of the existing file, replacing it completely in `mergemaster`, and then merging in the changes later with a text editor and two parallel terminal windows.

Because each changed line is shown on different halves of the same screen, sometimes the two sides look the same because the only differences might be on the right half of the line. This isn't usually a problem (the only time it tends to crop up is on FreeBSD's standardized header lines in which a modification date appears toward the end of the line). You can get around it, though, by specifying a larger screen width with the `-w` option to `mergemaster`:

```
# mergemaster -cv -w 120
```

Once you're done picking your way through the lines, you're brought back into `mergemaster`, where you are given yet another chance to review (or even remerge) your changes before moving the new file into place.

Once you're all done, `mergemaster` asks whether you want to delete what's left of `/var/tmp/temproot`. If you've left unmerged files to deal with later, select No. You then exit from `mergemaster` and have the chance to go to `/var/tmp/temproot` to merge these remaining files by hand.

Troubleshooting `mergemaster`

The things that can go wrong with `mergemaster`, fortunately, aren't destructive to the systemespecially if you have backed up your `/etc` directory. A few kinds of missteps are common, though, such as the following:

- *I accidentally overwrote a critical file in `/etc` with the generic new version!*

  Not to worry. If you kept a backup (for example, `/etc.old`), you can simply quit `mergemaster` with Ctrl+C and copy the file out of the backup directory and back into `/etc`.

- *`mergemaster` accidentally deleted the rest of the files in `/var/tmp/temproot`! I was going to get to those!*

  Just run `mergemaster` again and ignore any files you already replaced or merged. Make sure to select No at the last prompt, where it asks whether you want to delete the remainder of `/var/tmp/temproot`.

PREV NEXT

Rebooting After the Upgrade

Before you reboot, make a mental checklist:

- Have I synchronized to the latest sources?
- Have I done a `buildworld`?
- Did I compile a new kernel?
- Did the new kernel boot?
- Have I done an `installworld`?
- Do utilities such as `ps` and `top` work?
- Is `/etc` merged to my satisfaction?

If you can answer "yes" to all these questions, you're ready to reboot:

```
# reboot
```

When the system comes back up into multiuser mode, check `ps` and `top` again just to make sure everything's synchronized. Finally, run `uname -a` to see whether you agree with the kernel version:

[View full width]

```
# uname -a
FreeBSD stripes.example.com 6.0-RELEASE-p1 FreeBSD 6.0-RELEASE-p1 #1: Wed Jan 4 21:39:53
    PDT 2006 frank@example.com:/usr/src/sys/compile/CUSTOM i386
```

If it all checks out, congratulations! You've just completed a `make world`. You can now rest easyat least until the next time you decide to do it.

PREV NEXT

Chapter 20. Adding Hard Disk Storage

IN THIS CHAPTER

This chapter tries to make sense of what is surely one of the ugliest parts of dealing with a UNIX system: disks. Compared to a Windows system (where a disk is automatically assigned a drive number by the BIOS) or a Macintosh (where a new disk simply appears on the desktop), UNIX systems require a deeper knowledge of geometry, partitions, access modes, and other such esoterica. FreeBSD is, unfortunately, no exception.

As you learned in Chapter 12, "The FreeBSD Filesystem," the hierarchical filesystem structure of UNIX does provide a more flexible way of dealing with files than is possible with traditional desktop operating systems. This flexibility comes at a price, however. To add a new disk to the FreeBSD system, it must first be installed in the proper physical position and then sliced, partitioned, labeled, and finally mounted at the selected mount point. This is a far cry from the two or three steps necessary to add a new disk in most desktop systems.

Times are changing, and the progress of hardware standards has eliminated the need for some of the really nasty underlying pencil-and-paper work that used to accompany the installation of a new disk. With the right knowledge (and the help of your good friend Sysinstall), you can get the rest of the process under control.

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IDE/ATA Access Modes

The most common type of hard disk for PC hardware is the Integrated Drive Electronics (IDE) interface. The IDE interface is so named because the controller chips that manage the disk are integrated into the drive itself, rather than on a separate host adapter card (as with SCSI). The official name for this type of interface is Advanced Technology Attachment (ATA), and ATA and IDE are often used interchangeably.

Note

Serial ATA (SATA) hard drives are rapidly taking over from both IDE/ATA and SCSI drives in highperformance server installations. SATA drives are generally handled using the standard ATA kernel interface in FreeBSD, and you should be able to configure and access them using the same methods as described in this chapter for ATA drives. Bear in mind, though, that SATA is still a new and emerging technology, and support for it in FreeBSD remains spotty and poorly documented. If you have a choice, you might want to stay on ATA or SCSI drives until FreeBSD's support for SATA has developed a bit further.

This chapter discusses both IDE/ATA and SCSI disk systems. Unless you're running a highperformance server, however, you are most likely to use IDE disks. They're inexpensive and ubiquitous, but they come with their share of annoyances and quirks. SCSI disks tend to be better made and faster, but they're also more expensive and require more expensive hardware. Regardless of whether you use IDE, however, it's worthwhile to cover these issues so you can be prepared if the need arises.

IDE provides quite adequate speed, and it's the built-in standard on all *x*86-based motherboards currently on the market. If you're building a new machine from new hardware, you won't have to worry about any of the trivia in the next few sections. If, however, you're installing FreeBSD on older hardware, you will have to make a couple of purchasing decisions based on the highest access modes supported by the disk, the motherboard, and FreeBSD. An informed decision on this subject requires a bit of access-mode history.

PIO Modes

Programmed I/O (PIO) modes were the original standard for data transfer on PC hardware using the ATA interface. To this day, these modes exist as a fallback method because PIO is a built-in part of the BIOS, and it requires no additional support by the operating system. Just about every modern operating system has moved on to DMA and Ultra DMA. Unless you're using very old hardware, you needn't concern yourself with PIO modes.

PIO operated in any of five modes, with speeds ranging from 3.3MBps to 16.7MBpsunusably slow by the standards of today's demanding software.

Note

Most motherboards today use the PCI bus to talk to their hard drive chains. If, however, you've got a really old system with an ISA bus, the best it will be able to support is PIO Mode 2anything faster is beyond the throughput limit of ISA.

DMA Modes

A fundamental problem with PIO is that it requires significant resources from the CPU to direct its data flow. This problem used to be one of the biggest reasons to use SCSI rather than IDE disks because SCSI disks use an independent controller to take the load off the processor. Direct Memory Access (DMA) modes, introduced in the early 1990s, offer this same benefit to IDE disks by allowing the disk to bypass the CPU and communicate directly with the system RAM. DMA transfer modes require specialized electronics in the drive itself (particularly for first-party or "bus mastering" DMA disks) as well as operating system support, but this method is almost universal nowadays.

You may not have heard much about plain DMA during its heyday; one reason is that its transfer speeds were comparable to those of the PIO modes. Although DMA disks did benefit from lower CPU overhead, this advantage was mitigated by poor support for the modes in the operating systems of the day, such as Windows 95. PIO was built in, so there was little pressure on the industry to move away from it.

Ultra DMA (UDMA) Modes

PIO truly lost prominence with the introduction of Ultra DMA. These enhanced DMA modes are now the ubiquitous industry standard, even giving SCSI a run for its money as far as performance goes, while remaining cheaper and better supported, even on low-end hardware.

Ultra DMA gave data transfer speeds a significant and immediate boost over standard DMA by clocking its transfers on twice as many points in the interface strobe, on both the "rising" and "falling" edges of the signal waveform. This technique, known as *double transition clocking*, allowed the controller to have a "free" doubling of data transfer speed, to 33MBps, without reducing its cycle time. Subsequent incremental improvements to Ultra DMA, each one increasing the transfer speed until the culmination in Mode 6 of 133.3MBps, have raised the bar ever higher, aided by a new IDE cable standard that uses 80 pins rather than the 40 of the previous standard.

Any hardware made after about 1998 is designed to work in UDMA mode, and you won't have to worry about a thing if you have these four components:

- A hard disk that supports Ultra DMA mode
- An 80-pin IDE cable
- A motherboard (or IDE controller) that supports Ultra DMA mode
- Support in the operating system (or BIOS) for Ultra DMA mode

If you're missing any one of these items, your system will still run but in a reduced-speed mode, generally one of the PIO modes natively supported in the BIOS. Motherboards or controllers that don't support UDMA might prove troublesome. Issues with instability and lockups caused by controller issues can usually be solved either by upgrading the BIOS (to enable the controller to support UDMA) or by disabling UDMA in the disk itself through software utilities available from the manufacturer of the disk. These utilities typically run only under DOS or Windows and are either included with the disk or downloadable from the manufacturer's website.

Note

Because MS-DOS won't be available to you after installing FreeBSD, you can use FreeDOS (http://www.freedos.org), a free clone of MS-DOS, to run your DOS utilities.

FreeBSD fully supports Ultra DMA, making it perhaps the strongest link in this chain; you can see whether all the necessary components are present by watching the device-probing messages during boot (or using `dmesg` afterwards):

```
ad0: 238475MB <WDC WD2500JB-00KFA0 08.05J08> at ata0-master UDMA66
```

If the UDMA capability isn't detected and the hard disk is new but the rest of the machine's components aren't, you should find the disk manufacturer's drive management utility, boot the system from an MS-DOS floppy (or a FreeDOS boot disk), and use the utility to disable the disk's UDMA capability. This will keep you running at a lower speed than the disk can go, but it's for the best. The alternative is to run the risk of crashes and lockups. Your system will thank you for not pushing it beyond its means.

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SCSI Disks

If all this IDE nonsense is something you can afford to bypass, or if you will be attaching external disks to your system, the best-supported alternative is *SCSI* (Small Computer Systems Interface, popularly pronounced "scuzzy").

SCSI disks operate over a variety of interfaces that range in speed from the earliest and slowest (5MBps) to modern iterations such as Ultra320 SCSI that can transfer data effortlessly at 320MBps. Although the aggrandizing naming conventions for these interfaces (Fast SCSI, Wide SCSI, Fast Wide SCSI, Wide Ultra SCSI, and so on) border on self-parody, SCSI itself is relatively well behaved and predictable when it comes to its capabilities. Each successive standard is twice as fast as the previous, and although there's a truly astonishing number of different cable styles made for SCSI devices, the connector standard has remained mercifully steady over the years. This means that for the most part, any modern SCSI controller will recognizeand properly handleany SCSI device that was built to an earlier standard.

A SCSI device chain can handle up to the number of devices specified by the standard, usually 8 or 16. That's a far cry from the strictly regimented four (primary and secondary, master and slave) of the IDE/ATA structure. What's more, the order of these devices doesn't matter; there are no such things as "masters" or "slaves" in SCSI to dictate cabling order. There's only the controller, or host adapter (which takes up one of the device IDs), and the rest of the devices.

SCSI also has clear advantages if you're using external disks. IDE/ATA provides no good way to hook an external disk to the internal bus; sometimes you can get away with using the parallel (printer) port, as with Iomega Zip drives, but this is an astoundingly slow interface and is unusable for any general purpose. SCSI is the only game in town for external disks until USB 2.0 and FireWire (IEEE 1394) become more fully adopted in FreeBSD.

Note

External hard drives that connect using FireWire (IEEE 1394) or USB 2.0 are generally ATA drives operating over a FireWire or USB bus. Partitions and access modes for these drives remain the same as in ATA drives. Still, in order to address such drives, you'll need to use the `/dev/usb` or `/dev/firewire` drivers. Check your `dmesg` output to see the proper device name for an external drive hooked up over USB or FireWire.

The biggest problem with SCSI is, simply, price. SCSI disks are generally more expensive than similar-sized IDE disks by 50 to 100 percent. Beyond that, there's the cost of the host adapter card, which you have to buy separately from the motherboard. (Very few motherboards today are made with built-in SCSI cards, although the number is, in fact, rising.) These controllers aren't cheap.

If you're interested in going the SCSI route, you should know that there are more pitfalls to avoid that are beyond the scope of coverage here. These include terminators, the SCSI BIOS, setting device IDs (with jumpers), and what happens when you mix "narrow" and "wide" devices on the same chain. Further reference can be found in the many books dedicated to the subject or at the PC Guide website (http://www.pcguide.com).

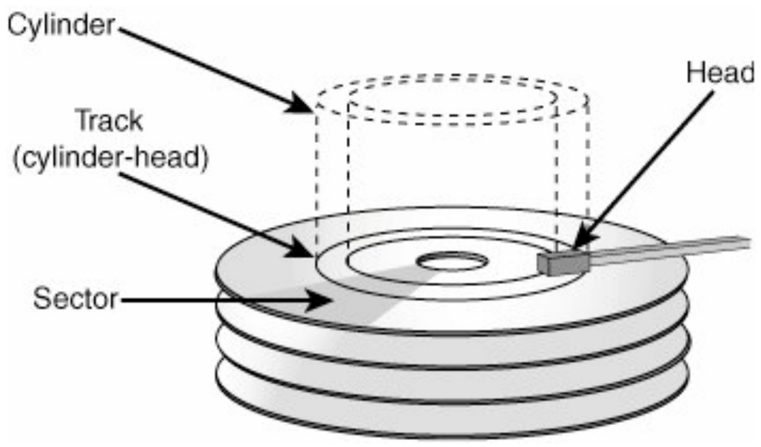
Understanding Hard Disk Geometry

You'll see a lot of references to "hard disk geometry" in the online tutorials that explain how to prepare your disks, and you'll encounter this term every time you run `fdisk` (or the friendlier interfaces to `fdisk` that you use in this chapter). Fortunately, this is something that owners of newer hardware (that is, hardware manufactured after hard disks larger than 8GB were common) or owners of SCSI disks can skip or ignore. Disk geometry data is only there for informational purposes. The functional importance of this information is now no longer the administrator's responsibilityit's the hardware's.

One of FreeBSD's strengths, though, is that it will run efficiently even on older hardware that is considered obsolete for desktop use or to run Windows. Your ancient 166MHz Pentium motherboard will support FreeBSD just fine. But there's a trap: Try to plug in a new 70GB IDE hard disk, and the system might not realize that it's any larger than 8GB. This is where the unpleasantness of disk geometry comes into play. To use the disk, you will need to use some techniques that have otherwise been made obsolete by newer BIOS technology as well as know something about the history of hard disk development.

Back in the mists of time, when data storage registers were made only as large as cost would allow, regardless of future scalability implications, IDE hard disks reported their size as a function of their physical geometry. Four dimensionsheads, cylinders, sectors, and bytesdescribed the layout of the disk and subsequently its size, or the amount of data that could be stored on it (see Figure 20.1). Hard disks still have the same internal geometry as they always did; it's just no longer as important to understand it thoroughly as it was back then.

Figure 20.1. Hard disk geometry.



A disk is made up of a number of *platters*, stacked on a central spindle, with data stored on both sides of each platter and one or more magnetic *heads* reading each side. A disk with four platters and two heads per side, for example, would have 16 heads. Each platter is divided into concentric rings, or *cylinders* (not in a spiral configuration, as with optical disks such as CDs), and the combination of a cylinder and the head that reads it is called a *track* (or cylinder-head). Tracks are then divided into *sectors* (usually 64 of them, with 63 usable), and each sector stores a certain number of bytes (generally 512).

Each disk is shipped with information, usually on the label, showing how many of each of these subdivisions exist on the disk. You can calculate the total size of the disk by multiplying all of them together. The disk used for the demonstration of `fdisk` back in Chapter 12 had the following information:

```
# fdisk /dev/ad1
******* Working on device /dev/ad1 *******
parameters extracted from in-core disklabel are:
cylinders=1247 heads=255 sectors/track=63 (16065 blks/cyl)
Media sector size is 512
```

Multiplying these figures together (ignoring the blocks-per-cylinder figure) and remembering that a cylinder-head is equivalent to a track (to keep your units straight) produces the following:

```
1247 cylinders x 255 heads x 63 sectors/track x 512 bytes/sector = 10.2GB
```

But wait a minute...255 heads? How can that many heads fit in a hard drive? Does this make sense at all? Nofirst of all we'd expect the number of heads to at least be an even number. Even if we allowed for that, we're talking about what appears to be at least 64 platters, which just isn't physically possible in a half-inch-high hard disk. What we've got here is a virtual disk geometry, made possible by two successive hacks by the hard disk industry, which get around register-size limitations imposed by the original design of the disk interface in the BIOS. These two hacks are LBA and Extended INT13 modes.

LBA and the 528MB Limit

In the days of floppy disks, nobody thought that anyone would ever use a disk as gargantuan as 528MB; this is why that number was allowed to remain as the size limitation imposed by the number of bits the original PC BIOS (combined with the ATA/IDE standard) allocated to each of the disk geometry dimensions, shown in Table 20.1.

Table 20.1. Dimensional Limits on Hard Disk Geometry

Dimension	Bit Size	Maximum Value
Cylinders	10 bits	2^10 = 1,024
Heads	8 bits	2^8 = 256
Sectors/tracks	6 bits	2^6-1 = 63

Therefore, a disk was allowed to have up to 256 heads, but no more than 1,024 cylinders. Because the number of bytes per sector and the number of sectors per track are relatively fixed numbers (dependent on physical limitations such as rotation speed and read reliability), and because you can't really put more than a few platters and heads into a drive you want people to be able to lift, this meant that the cylinder number rapidly emerged as the limiting factor in a disk's ultimate size. Disk manufacturers eventually converged on the ATA standard of 16 physical heads in a disk, so this meant a size limit of 528MB. The manufacturers could produce disks larger than that size by adding more cylinderswhich was easy because the stepper motor that moves the head's swingarm between cylinders can be controlled very preciselybut the BIOS couldn't address any of the cylinders above 1,023.

Around 1993, it became apparent that this wasn't going to fly as users' hunger for disk space continued to grow. A single video game could take up that much space! So, the BIOS manufacturers developed a scheme called Logical Block Addressing (LBA), whose purpose was to augment the BIOS disk addressing method by remapping cylinders above 1,024 to "virtual heads," thus taking advantage of all the available head numbers up to 255 that were going unused. For example, a disk with 1,852 cylinders and only 16 physical heads could actually be thought of as having 463 cylinders and 64 heads. Now the disk's calculated size was unchanged, and both the cylinder and head values were within their BIOS-imposed limits. All was well once again...for awhile.

Extended INT13 Modes and the 8.4GB Limit

The alert reader will have noticed that this scheme could only have been considered a temporary solution because eventually LBA would run out of room when both the cylinder and head numbers were completely filleda disk size that works out to about 8.4GB.

Indeed, it wasn't longanother four years or sobefore disks were jostling at the 8.4GB barrier. (It should also be noted that 8.4GB was only a theoretical limit; many buggy BIOS implementations and supporting software tools used pseudo-LBA routines that introduced barriers at lower numbers.)

The solution was a newly redesigned BIOS interface, commonly called Extended INT13, which is now in general use in modern hardware and in operating systems such as Windows (where the software still must communicate with the disk through its BIOS, something FreeBSD doesn't need to do). This new interface abstracts the disk geometry addressing through a 16-byte disk-addressing packet, effectively removing any size limitation imposed by new hardware.

If your hardware is modern enough to understand the Extended INT13 modes, you're home freedisk geometry need only interest you for curiosity's sake. If you use a tool to try to extract the geometry information from a disk larger than 8.4GB, it will report 16,383 cylinders, 16 heads, and 63 sectors per tracka "code" configuration that tells the operating system not to even try to compute the disk's size from its geometry. If you see this configuration being reported anywhere, rest assured that FreeBSD is taking care of all this "geometry" nonsense itself. That is, unless your disk is larger than 137GB, at which point even the Extended INT13 modes can't overcome the ATA standard-imposed limit of 65,536 cylinders.

48-bit LBA

Modern motherboards' BIOS chipsets support a new scheme called 48-bit LBA, the latest step in the ongoing arms race against hard drive size limitations. Prior to the introduction of 48-bit LBA, the ATA interface only had 28 bits with which to address data storage locations on a drive, which worked out to a practical maximum disk size of 137GB. With 48 bits to work with, though, the number of addressable cylinders was no longer limited to 65,536, and BIOSes could now address up to 144 petabytes of data (150,994,994 gigabytes). Hopefully that will hold us for a while....

Practical Implications of Installing FreeBSD on Older Systems

If you're installing FreeBSD on older hardware, such as a motherboard from the days of LBA, you may well run into one of these limitations. You won't lose any data, but you may notice odd problems, such as your 70GB disk only reporting 8.4GB total space. If it does, you'll know what the cause is.

Many motherboard and chipset manufacturers provide BIOS upgrades, which can help you get past these problems. Check with the maker of the motherboard or chipset (consult its website) to see whether a firmware update is available. If not, you may have no choice but to invest in a new motherboard and CPU, or else to use lots of small disks instead of one large one. FreeDOS (http://www.freedos.org) can be a lifesaver if you need to upgrade your BIOS using a DOS utility.

Of course, if you've chosen instead to use SCSI or FireWire (IEEE 1394) hard drives (and if your hardware is modern enough to support them), none of this need apply to you. These interfaces were designed with much more scalability in mind than IDE/ATA was, so their typically higher price is justified by their behavioral predictability.

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Partitioning a Hard Disk

Okaynow that all the background is out of the way, it's time to get down to the action. Adding a new disk to the system involves four steps: installing it, partitioning it, labeling it, and mounting it. Depending on whether you've gone with a SCSI or IDE disk, the installation procedure varies; use the installation instructions that come with the disk.

The following examples assume you've installed a new 80GB IDE disk as the primary slave. The device name is `/dev/ad1`. (You can learn more about FreeBSD filesystem structure, device names, and mount points in Chapter 12.) A SCSI disk in a similar configuration would be `/dev/da1`; the rest of the instructions here apply just the same.) As you learned earlier, there's a lot more to a typical disk device name; the extensions beyond the initial `ad1` specify additional partitioning and sub-partitioning information. This is how you refer to specific parts of a disk that you've separated for different useseither so you can run more than one operating system from the same disk or so you can keep different parts of your system separate so they won't steal storage space from each other.

BIOS Partitions (Slices)

Every operating system allows you to partition your disk. The thing to remember about FreeBSD, though, is that it allows not one but *two* levels of partitioning. First come the BIOS partitions, addressed directly by the system BIOS in PC hardware; you can have up to four of these, which are what other operating systems think of as "partitions." If you partition your Windows, MS-DOS, or Linux disk, each partition is one of these BIOS partitions.

FreeBSD uses the term *slices* for these BIOS partitions, and it's important that you remember this terminology. When FreeBSD refers to *partitions*, it's talking about the second level of partitioning, which occurs within the slices. This second level contains what are properly known as the *BSD partitions*.

BSD Partitions

These BSD partitions are subpartitions that separate different parts of a FreeBSD system from one another`/var`, `/usr`, `/home`, and the like. Each partition has a single letter for a name, and there are eight BSD partitions available, shown in Table 20.2. When you divide a slice into BSD partitions, the first few letters are reserved for special uses, but the remaining ones (listed as "General use") are free for you to use in the system.

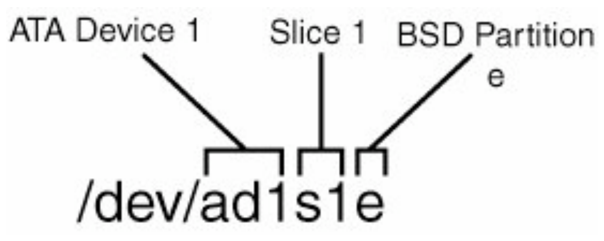
Table 20.2. BSD Partitions and Their Purposes

Partition	Purpose
`a`	Root partition (`/`)
`b`	Swap
`c`	Addresses the entire slice, or the entire disk in "dangerously dedicated" mode
`d`	General use
`e`	General use
`f`	General use
`g`	General use

`h`	General use

Figure 20.2 shows a fully specified device name. The first part (`ad1`) specifies the base device name. IDE/ATA disks can be `ad0` through `ad3` (primary master, primary slave, secondary master, and secondary slave). Next comes the slice name, whose numbers start at 1 (`s1`). Finally, comes the BSD partition name (`e`).

Figure 20.2. Understanding a disk device name.



Foreign Extended Partitions

Some other operating systems have constructs analogous to FreeBSD's partitions; for instance, Extended DOS Partitions provide a way to get subpartitions (logical partitions) into a DOS/Windows machine. Linux uses a functionally identical method. Extended DOS Partitions work by creating additional partitions in sequence beyond the first four, rather than hierarchically within the four primary ones. This method is in many ways more awkward than the FreeBSD solution. Interoperability between different operating systems can be fairly tricky because partitions within the Extended DOS Partitions scheme are treated by FreeBSD as additional slices on the same level as regular DOS partitions, but starting at slice 5 (after the four regular DOS partitions). To mount the second logical partition within an Extended DOS Partition on a disk installed as `ad3`, you would address `/dev/ad3s6` rather than trying to use BSD-style partition names within a slice.

Going the other direction is even trickier. You probably won't be able to mount a FreeBSD disk in a DOS/Windows system, but you may have to do something like that on a Linux machine. Linux treats its partitions (called *slices* in FreeBSD) the same way that FreeBSD treats them, meaning that they're labeled numerically and sequentially, rather than hierarchically. To mount a FreeBSD slice under Linux, use Table 20.3 (which describes a primary slave disk with FreeBSD in its third BIOS partition/slice) as an equivalency guide.

Table 20.3. Linux/FreeBSD Disk Label Equivalence

Linux Label	FreeBSD Label
`/dev/hdb4`	`/dev/ad1s3a`
`/dev/hdb5`	`/dev/ad1s3b`
`/dev/hdb6`	`/dev/ad1s3e`
`/dev/hdb7`	`/dev/ad1s3f`

This mapping scheme is reliable only if you don't have any more Linux partitions after the FreeBSD slice! Always be aware of the peril of expanding a hierarchical structure into a sequential one.

The Slice Editor (`fdisk`) in Sysinstall

The first step in installing a new disk is to use the Slice Editor, `fdisk`, to define the disk's slices. To use the `fdisk` program, as root, enter the Sysinstall program and select Configure. Scroll down to the Fdisk option, labeled as The Disk Slice (PC-Style Partition) Editor. Selecting this option gives you a list of all the disks the system has detected. Make sure that `ad1` (the primary slave, your new disk) is listed. If it isn't, the disk hasn't been installed properly.

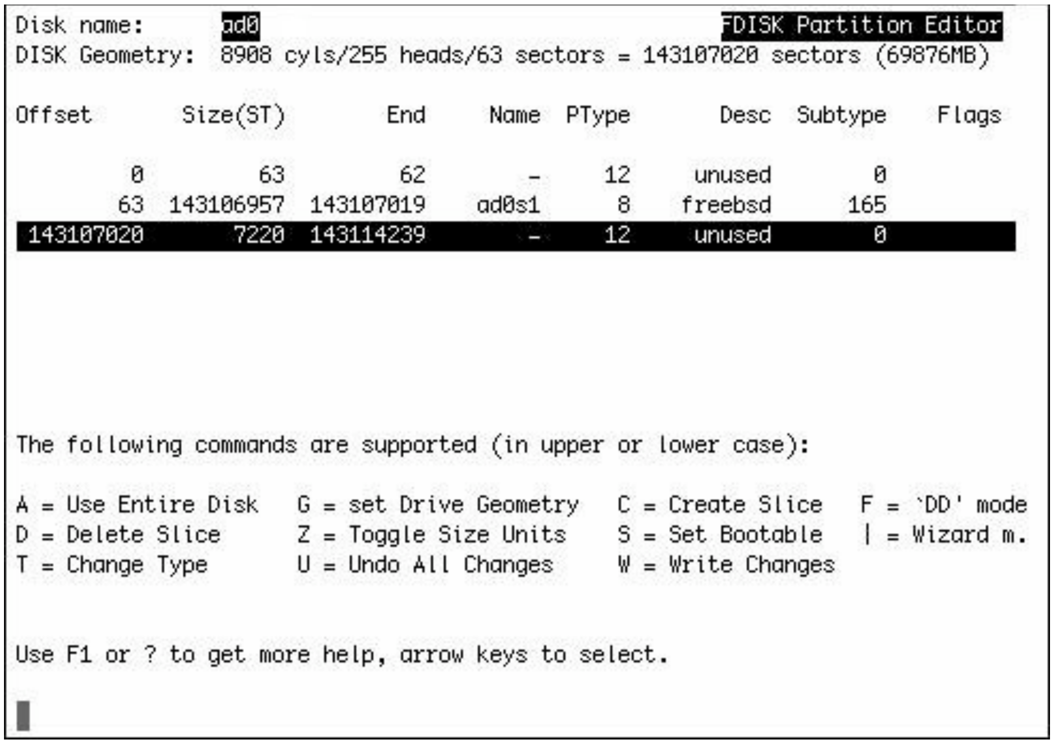
Tip

If `fdisk` doesn't detect your installed disk, check the `/var/run/dmesg.boot` file to see whether the disk was detected at all when the machine booted; if it wasn't, check your cabling and the jumpers on the disk. Remember that if you only had a single disk on the primary IDE chain before you installed the new one, its jumpers were probably set to the Single position; make sure the primary disk's jumpers are set to Master and the new disk's jumpers to Slave.

If your disk is listed, select it with the spacebar and enter the visual `fdisk` (fixed disk) editor. This utility exists in some form on every operating system because every PC hardwarebased operating system needs a way to control its BIOS partitions (slices). You can use `fdisk` directly from the command line, but its many options and potential pitfalls make it a better idea to use the more straightforward `fdisk` interface in Sysinstall. It's not especially wise to work without a net around such things as disk reformatting and repartitioning tools!

Any preexisting partitions show up in the `fdisk` menu. A new, unformatted disk displays an essentially empty list of slices. You have a lot of flexibility in how you can handle these slices. If you really want to, you can do all your slicing here in this menu, setting up BIOS partitions for other operating systems or even for FreeBSD in the Linux or DOS style. In most cases, however, this is unnecessary. In general, you should select the A option for Use Entire Disk to produce the results shown in Figure 20.3. Don't worry about any of the other optionsthey're there for flexibility and compatibility.

Figure 20.3. The Slice Editor, after you choose the Use Entire Disk option.



```
Disk name:      ad0                                  FDISK Partition Editor
DISK Geometry:  8908 cyls/255 heads/63 sectors = 143107020 sectors (69876MB)

Offset       Size(ST)        End     Name  PType       Desc  Subtype    Flags

         0         63         62        -     12     unused        0
        63  143106957  143107019    ad0s1      8    freebsd      165
 143107020       7220  143114239        -     12     unused        0




The following commands are supported (in upper or lower case):

A = Use Entire Disk    G = set Drive Geometry   C = Create Slice   F = `DD' mode
D = Delete Slice       Z = Toggle Size Units    S = Set Bootable   | = Wizard m.
T = Change Type        U = Undo All Changes     W = Write Changes


Use F1 or ? to get more help, arrow keys to select.
```

At this point in the process, you have three entries: a small "reserved" space for the boot manager to be installed later, a single large FreeBSD slice (`ad1s1`), and a third "leftover" chunk of negligible space that could not be made part of the main slice.

Nothing has yet been done to the disk. Select Q to quit the Slice Editor. You'll now be prompted for what kind of boot manager to install. If this is a secondary disk that you're adding to an already running system, select None. Install the FreeBSD Boot Manager (`BootMgr`) if you will be booting from this disk (if you're prepping this disk to be used in a new machine, for example) or to replace the existing disk in your current system. Otherwise, select Standard to do the equivalent of the DOS command `fdisk /MBR`, which removes operating systemspecific boot managers (such as Linux's LILO and FreeBSD's BootMgr) from the Master Boot Record and makes it available to other operating systems (for example, if you're reusing the disk to make a new Windows machine).

Caution

The Slice Editor has a Write Changes option: the `W` command. This should be used before quitting the Slice Editor if, and only if, you are modifying an existing disk setup. If you're installing FreeBSD for the first time, or if you're preparing a new disk for installation, just quit the Slice Editor and move on directly to the Disk Label Editor. The `W` option reiterates this warning if you use it.

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Creating the Disk Labels

The disk is now sliced and has been made FreeBSD-friendly, but it still isn't formattedyou can't use it in your system yet. You do that next, in the Disk Label Editor.

Still in Sysinstall, select Label ("The Disk Label Editor"). You'll again be asked to select from the list of installed disks; use the spacebar to select `ad1`. You're presented with the Disk Label Editor screen, a visual interface to the command-line `disklabel` command. This is where you assign the BSD partitions and format the disk.

Caution

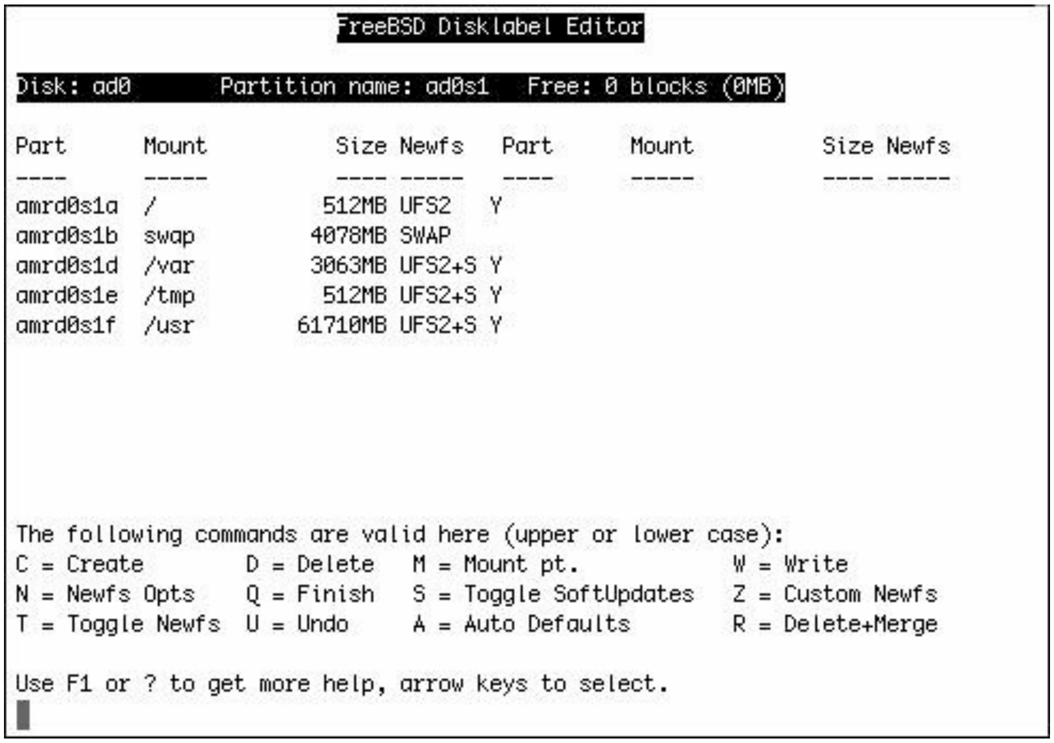
FreeBSD's Disk Label Editor doesn't allow you to resize existing BSD partitions. A partition can't be modified without reformatting it and losing its data, and FIPS (as discussed in Chapter 3, "Advanced Installation Tasks") can't operate on BSD partitions, so consider carefully what your partitions will be used for before you commit your changes!

Creating a Complete FreeBSD Partition Layout

If you're just adding a new disk to the system, skip ahead to the "Adding a New Disk" section. This section of the chapter, however, demonstrates how to use the Disk Label Editor to assign BSD partitions and mount points for a complete FreeBSD system, including a root partition, `/usr` and `/var` partitions, and a swap partition. This is useful if you're going to be installing FreeBSD onto the new disk, (for example if you're replacing your current disk with a larger one).

Press A to apply the Auto Defaults settings. This automatically allocates a set of partitions that are appropriate for most systems, choosing sizes for the various partitions that are appropriate to the size of the disk and the amount of RAM installed in your system (see Figure 20.4). You can probably go with the defaults if you plan to use your FreeBSD system as a workstation or a small server with only a few users.

Figure 20.4. The Disk Label Editor, after using the "Auto Defaults" option.



```
                          FreeBSD Disklabel Editor

Disk: ad0        Partition name: ad0s1   Free: 0 blocks (0MB)

Part      Mount          Size Newfs   Part      Mount          Size Newfs
----      -----          ---- -----   ----      -----          ---- -----
amrd0s1a  /             512MB UFS2    Y
amrd0s1b  swap         4078MB SWAP
amrd0s1d  /var         3063MB UFS2+S Y
amrd0s1e  /tmp          512MB UFS2+S Y
amrd0s1f  /usr        61710MB UFS2+S Y






The following commands are valid here (upper or lower case):
C = Create        D = Delete     M = Mount pt.           W = Write
N = Newfs Opts    Q = Finish     S = Toggle SoftUpdates  Z = Custom Newfs
T = Toggle Newfs  U = Undo       A = Auto Defaults       R = Delete+Merge

Use F1 or ? to get more help, arrow keys to select.
```

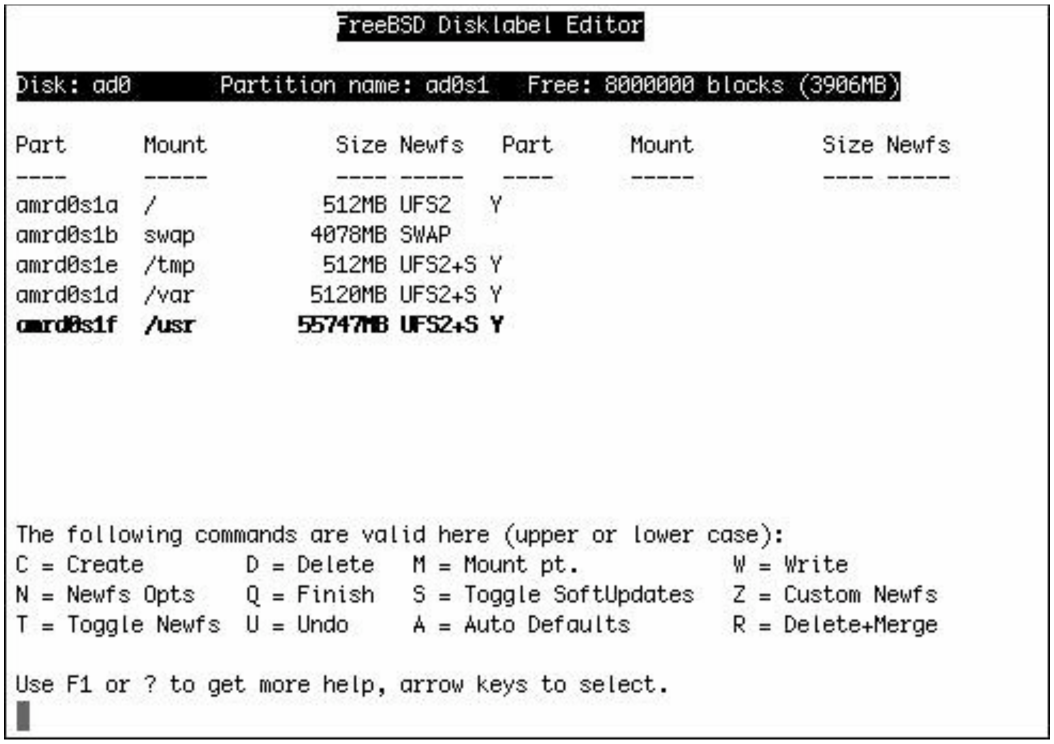
However, these defaults will often turn out to be woefully inadequate for a high-profile server. Mail and log files both live in the `/var` partition; if you have 100 users all storing their mail spools on the server, or if your web server generates hundreds of megabytes of log files every week, the default `/var` size might not be sufficient for your needs (although modern versions of FreeBSD create `/var` partitions of 1GB or more if the disk space is available). You might want to allocate some more space to `/var`; this gives you an excellent excuse to experience some of the more flexible workings of the Disk Label Editor.

First, delete both the `/var` and `/usr` partitions. (Remember, nothing is actually done to the disk itself until you press W to write changes; right now you're just setting up the configuration for it to write.) Delete these two partitions by selecting each of them and pressing D. Now, scroll back up to the top of the screen, where the `Free:` field shows all the space you've recovered by deleting these two partitions. You can now reallocate that space as you see fit.

With the selector bar on the `Partition name: ad1s1` line, press C to create a new partition. You are given a dialog asking how much space to dedicate to the new partition. Let's give `/var` 2GB; that should be enough for a medium-sized server. (Give it an even higher number if you want to be really safe.) Assign this by deleting the number displayed and entering **`5g`** or **`5120m`**. In the next dialog, select FS to create a filesystem instead of a swap partition. You're then asked for the mount point for the new partition; enter **`/var`**. The partition is created and added to the list, and the `Free:` space listed at the top is updated accordingly.

Now you can repeat the process, this time accepting the default size for the remaining partition (to use all the rest of the space on the disk) and entering **`/usr`** for the mount point. (You may need to reduce the number slightly before it will accept it.) The resulting list will be similar to Figure 20.5.

Figure 20.5. A customized partition layout.



```
                              FreeBSD Disklabel Editor

Disk: ad0         Partition name: ad0s1   Free: 8000000 blocks (3906MB)

Part        Mount            Size Newfs   Part        Mount            Size Newfs
----        -----            ---- -----   ----        -----            ---- -----
amrd0s1a    /               512MB UFS2   Y
amrd0s1b    swap           4078MB SWAP
amrd0s1e    /tmp            512MB UFS2+S Y
amrd0s1d    /var           5120MB UFS2+S Y
amrd0s1f    /usr          55747MB UFS2+S Y




The following commands are valid here (upper or lower case):
C = Create        D = Delete   M = Mount pt.            W = Write
N = Newfs Opts    Q = Finish   S = Toggle SoftUpdates   Z = Custom Newfs
T = Toggle Newfs  U = Undo     A = Auto Defaults        R = Delete+Merge

Use F1 or ? to get more help, arrow keys to select.
```

Note that in the default layout, `/var`, `/tmp`, and `/usr` have the Soft Updates data-integrity protection system turned on (learn more about Soft Updates in "Journaling Filesystems and Soft Updates," in Chapter 12). A filesystem that has Soft Updates turned on is denoted by `UFS+S`; you can toggle this setting on and off with the S key. Soft Updates are advisable for filesystems with lots of data that changes frequently; `/var` is therefore a good candidate, as is `/usr`.

Adding a New Disk

You can create up to eight BSD partitions on your new disk. Don't use the A option if you're simply creating more space to add to your current system; instead, with the `Partition name: ad1s1` line selected, press C to create a new partition. If you want to make one big BSD partition out of the disk (for example, if you want to add all 80GB to `/home`), accept the default value for the size of the partitionthe entire available capacity of the slice you're in. Alternatively, you might choose to specify a size (such as 20G) for one partition and allocate the rest to another partition. It's up to you how to carve up the space.

When prompted, select FS to create a filesystem rather than swap space and then specify a mount point. FreeBSD 5.0 and later will attempt to automount the new filesystem at the mount point you specify. This means that you should specify the mount point carefully so that the proper entry in `/etc/fstab` can be made and the disk can be mounted cleanly after the disk-labeling process is concluded.

Note

Prior to FreeBSD 5.0, what you enter as a mount point isn't really important in adding new disks to the system; you can just make something up, such as `/blah`. The mount point only specifies what will be written into `/etc/fstab` for the new filesystem that will be associated with this partition, and this does not happen in earlier versions of FreeBSD unless you're doing the initial system installation.

You can continue creating partitions this way until the available space is all consumed. Delete a partition by selecting it and pressing D. Remember, the disk itself is not touched by any of these operations; no changes are written until you press W.

Note

There is an effective limit of four working BSD partitions that you can create in the Disk Label Editor. If you create more than four partitions, the "reserved" partition names will be used, beginning with `a` and `b`; `c` will be skipped because it has a specific reserved meaning. Beyond `d`, however, a "dummy" label of `X` will be used, and you won't be able to use the partition properly.

Writing Changes and Formatting the Disk

Formatting disks in FreeBSD is done with the `newfs` command, another command-line utility that is handled automatically by the front-end in Sysinstall. Each filesystem in the list that has a `Y` in the `Newfs` column will be formatted when you commit changes. You can toggle this on and off with the T key.

Take a good look at the partition labels that the editor is assigning. These are listed under the `Part` column at the far left; you'll notice that no matter how you set up your partitions, the `a` through `d` partitions are reserved for special uses. The first partition you can create yourself is `e`. This means that your new mountable partitions, if you're adding space to the existing system, are named `ad1s1e`, `ad1s1f`, and so on. You'll need to remember these labels for when you mount the filesystems.

When you're happy with the partition layout, press W to write the changes. The disk is partitioned, and `newfs` processes are fired off to format each partition you've specified. When the partitioning is completed, press Q to exit and then quit Sysinstall.

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Making the Filesystem Available for Use

You're almost done. All that remains now is to mount the new filesystems you've created.

Tip

If Sysinstall does not automatically write an entry into `/etc/fstab` for the newly added filesystems, you might want to set up `/etc/fstab` yourself to ensure that filesystems will mount automatically on bootup (a full discussion of the `mount` command and how to use `/etc/fstab` appears in "Understanding the `/etc/fstab` File," in Chapter 12).

In this chapter, though, you're dealing with the simplest possible case: new, clean FreeBSD-formatted partitions. You can use the `mount` command in its most straightforward way.

Create a directory to act as the mount point (for example, `/mnt/newdisk`). You can do this anywhere in the filesystem. Next, issue the `mount` command:

```
# mount /dev/ad1s1e /mnt/newdisk
```

Use the `df` command to verify that the disk is mounted. You can do the same for each new partition you created, placing each one at a different point in the filesystem. Unmount it with the `umount` command:

```
# umount /mnt/newdisk
```

Congratulationsyou've tamed FreeBSD disk management!

Enhancing Disk Performance Using RAID and Vinum

Vinum is a software RAID tool built into FreeBSD, supported by a kernel module (`geom_vinum.ko`). It allows you to increase the efficiency of your ATA or SCSI disks (if you have more than one) by remapping their block device interfaces to a virtual set of "synthetic" drives (or *volumes*), which can contain *plexes* that comprise each volume's address space. A plex allows Vinum to automatically remap your data into arrangements such as RAID-1 (mirroring, which increases reliability), RAID-0 (striping, which increases performance), and RAID-5 (hybrid mirroring and striping) across the volumes constructed from your original hard disks.

Setting up Vinum is a procedure that involves a lot of manual calculations in several arcane steps, and requires a fair understanding of logical disk architectures and a willingness to dabble in areas of FreeBSD that are obscure and potentially dangerous. Advanced users who are interested in maximizing their disks' performance (especially in highavailability server applications) will want to at least consider using Vinum; but novices might want to avoid it for the time being.

Caution

Enabling Vinum also entails wiping your hard disks and reformatting them. You can't enable Vinum without erasing all your data and having to restore it from a backup. If your system doesn't have the option of being taken down to have its disk system entirely rebuilt from scratch, Vinum isn't in the cards.

To begin enabling Vinum, reboot your computer into single user mode (selecting the appropriate option at the loader menu). Mount the root partition read-write with the `mount -u /` command, and you're ready to proceed.

The first step in setting up Vinum is figuring out the exact sizes of your disks. You need to use the `fdisk` command for this (substitute `da0` for `ad0` if you're using SCSI disks):

```
# fdisk ad0
******* Working on device /dev/ad0 *******
parameters extracted from in-core disklabel are:
cylinders=8908 heads=255 sectors/track=63 (16065 blks/cyl)

Figures below won't work with BIOS for partitions not in cyl 1
parameters to be used for BIOS calculations are:
cylinders=8908 heads=255 sectors/track=63 (16065 blks/cyl)

Media sector size is 512
Warning: BIOS sector numbering starts with sector 1
Information from DOS bootblock is:
The data for partition 1 is:
sysid 165 (0xa5),(FreeBSD/NetBSD/386BSD)
    start 63, size 143106957 (69876 Meg), flag 80 (active)
        beg: cyl 0/ head 1/ sector 1;
        end: cyl 1023/ head 254/ sector 63
The data for partition 2 is:
<UNUSED>
The data for partition 3 is:
<UNUSED>
The data for partition 4 is:
<UNUSED>
```

As you can see from the middle of the `fdisk` output, the ad0 disk is 69876MB in size. This is important to remember. Repeat this command for all your disks (`ad1`, `ad3`, and so on) and write down their sizes.

Next, you need to convert your disks to the Vinum filesystem type. This involves changing their partition formats and creating new filesystems, which destroys your data. Be sure to back up your important data at this point and be sure you can restore it properly! See Chapter 21, "FreeBSD Survival Guide," for more information on backup techniques.

Use the `bsdlabel -e` command to enter an editing session (using vi, or whatever editor is specified in your shell's `EDITOR` variable) where you modify the partition layout of your disk's primary slice:

```
# bsdlabel -e ad0s1
# /dev/ad0s1:
8 partitions:
#        size   offset    fstype   [fsize bsize bps/cpg]
  a:  1048576        0    4.2BSD     2048 16384     8
  b:  8336656  1048576      swap
  c: 143106957        0    unused        0     0         # "raw" part, don't edit
  d:  6264832  9385232    4.2BSD     2048 16384 28552
  e:  2097152 15650064    4.2BSD     2048 16384 28552
  f: 125359741 17747216    4.2BSD     2048 16384 28552
```

The important thing to note is the size of the `c` partition, which is a pseudo-partition whose size is the sum of all the rest of the partitions on the disk. (Bear in mind that all the sizes you'll be working with here are in 512-byte blocks.) What you need to do is add another partition (`h`) of nearly the same size as the entire rest of the disk, but of type `vinum` instead of `4.2BSD`. This allows the two partitions to coexist and overlap. The `h` partition will need to be the size of the `c` partition minus 16 blocks, which in this case would be 143106941. Add this line to the end of the configuration:

```
  h: 143106941 16     vinum
```

Additionally, change the `b` partition as shown here, reducing the size of the swap partition by 281 sectors and changing the offset where it begins so it doesn't overlap its neighbor partitions once Vinum is in place:

```
  b: 8336375 1048857     swap
```

Finally, adjust the size of the root partition by 16 blocks:

```
  a: 1048560      16     4.2BSD     2048 16384     8
```

Save the file and exit. You now need to repeat this step for each additional drive.

Tip

For mirroring purposes, you should format additional drives with the same structure as your first one, so you might want to set up a partition structure using Sysinstall's disk label editor to match the one on your primary disk. This will allow you to use the same technique to add a `vinum` partition to the disk as you did with `ad0`.

Next, you need to set up a Vinum configuration file, which is fed into Vinum's "create" command when you set up the Vinum volumes. Listing 20.1 shows a sample configuration file. Call this file `/etc/vinum.conf`.

Listing 20.1. A Vinum Configuration Input File (`/etc/vinum.conf`)

```
drive DriveName device /dev/ad0s1h
volume root
  plex org concat
    sd len 1048560s driveoffset 0s drive DriveName
volume swap
  plex org concat
    sd len 8336675s driveoffset 265s drive DriveName
volume var
  plex org concat
    sd len 6264832s driveoffset 9385216s drive DriveName
volume tmp
  plex org concat
    sd len 2097152s driveoffset 15650048s drive DriveName
volume usr
  plex org concat
    sd len 125359741s driveoffset 17747200s drive DriveName
```

The bold parts of the listing show the areas that you will have to adjust to your own configuration. The name of the drive (*DriveName*) can be any name you choose, though it shouldn't contain any spaces or special characters, nor should it refer to any particular device namethe drive's name should be device-independent. Additionally, the `driveoffset` value for each partition needs to be reduced by 16 from the corresponding number in the `bsdlabel` configuration. (These 16 sectors are used for bootstrapping code by Vinum.)

Tip

These examples show how to set up a RAID-1 (mirrored) drive array. To create a RAID-0 (striped) array, replace `concat` in the configuration file with **`striped`**.

Add a similar `drive` directive and set of `volume` directives for each of your other disks, and save the file. Give the additional drives' volumes the same names as the ones in your first disk because you'll be adding them together, coalescing them into combined virtual filesystems spanning multiple disks.

You next need to start Vinum, using the `gvinum` command, and create the Vinum configuration:

```
# gvinum
gvinum -> create -f /etc/vinum.conf
gvinum: drive DriveName is up
gviunm: root.p0.s0 is up
gviunm: root.p0 is up
gvinum: root is up
gvinum: swap.p0.s0 is up
gvinum: swap.p0 is up
gvinum: swap is up
gvinum: var.p0.s0 is up
gvinum: var.p0 is up
gvinum: var is up
gvinum: tmp.p0.s0 is up
gvinum: tmp.p0 is up
gvinum: tmp is up
gvinum: usr.p0.s0 is up
gvinum: usr.p0 is up
gvinum: usr is up
1 drives:
D DriveName              State: up       /dev/ad0s1h     A: 0/69876 MB (0%)

5 volumes:
V root                  State: up       Plexes:       1 Size:        511 MB
V swap                  State: up       Plexes:       1 Size:       4070 MB
V var                   State: up       Plexes:       1 Size:       3059 MB
V tmp                   State: up       Plexes:       1 Size:       1024 MB
V usr                   State: up       Plexes:       1 Size:      61210 MB
```

```
5 plexes:
P root.p0             C State: up       Subdisks:     1 Size:        511 MB
P swap.p0             C State: up       Subdisks:     1 Size:       4070 MB
P var.p0              C State: up       Subdisks:     1 Size:       3059 MB
P tmp.p0              C State: up       Subdisks:     1 Size:       1024 MB
P usr.p0              C State: up       Subdisks:     1 Size:      61210 MB
P root.p1             C State: faulty   Subdisks:     1 Size:        511 MB
P swap.p1             C State: faulty   Subdisks:     1 Size:       4070 MB
P var.p1              C State: faulty   Subdisks:     1 Size:       3059 MB
P tmp.p1              C State: faulty   Subdisks:     1 Size:       1024 MB
P usr.p1              C State: faulty   Subdisks:     1 Size:      61210 MB
5 subdisks:
S root.p0.s0            State: up       D: DriveName    Size:        511 MB
S swap.p0.s0            State: up       D: DriveName    Size:       4070 MB
S var.p0.s0             State: up       D: DriveName    Size:       3059 MB
S tmp.p0.s0             State: up       D: DriveName    Size:       1024 MB
S usr .p0.s0            State: up       D: DriveName    Size:      61210 MB
S root.p1.s0            State: stale    D: Drive2       Size:        511 MB
S swap.p1.s0            State: stale    D: Drive2       Size:       4070 MB
S var.p1.s0             State: stale    D: Drive2       Size:       3059 MB
S tmp.p1.s0             State: stale    D: Drive2       Size:       1024 MB
S usr .p1.s0            State: stale    D: Drive2       Size:      61210 MB
```

In another terminal, check inside `/dev` for the existence of a `vinum` directory, and devices named `usr`, `var`, `tmp`, and so on inside them. These are your new disk devices. You can check that the virtual drives are working properly using the `fsck -n -t ufs /dev/vinum/root` command (and similar ones for your other drive devices, omitting the swap partition). You should see all your drives' names listed under the `subdisks` section, showing each disk's contribution to each volume separately. (Remember, this is a mirrored setup, so the two contributions to each volume don't add to its sizejust to its reliability.)

Tip

You should now configure `/etc/fstab` to use the new disk devices (`/dev/vinum/usr` instead of `/dev/ad0s1f`, for example).

Now you need to copy each original partition's data to the new subdisk of each volume. Within `gvinum`, issue **`start`** commands for each subdisk marked with `State: stale`.

```
gvinum -> start root.p1.s0
GEOM_VINUM: sd root.p1.s0 is initializing
GEOM_VINUM: plex root.p1 is degraded
```

Allow each `start` process to complete before moving on to the next one. When you're finished, press Ctrl+D to exit the `gvinum` shell, and reboot the system in multiuser mode.

This completes the process for setting up a mirrored (RAID-1) disk system. For more information on using Vinum to create RAID-0 or RAID-5 arrays, consult the `man vinum` page, or seek assistance from cutting-edge FreeBSD administrators on the `freebsd-questions` mailing list.

PREV NEXT

Chapter 21. FreeBSD Survival Guide

IN THIS CHAPTER

If you were to read only one chapter in this book, this should be it. This chapter is a rough guide for new users of FreeBSD: a trail map showing how to get the system up and stable as quickly as possible. It is especially targeted at administrators coming from other operating systems who might bring certain preconceptions about how FreeBSD is going to act. This chapter can help those users to see beyond their preconceptions and avoid many common mistakes born out of inexperience or unfamiliarity with FreeBSD.

The first few weeks with any new operating system are the riskiestaccidental misconfigurations can lead to security breaches, data loss, or general long-term disorganization. The key to surviving these first critical weeks is to get the platform-specific pitfalls out of the way and the necessary infrastructural safety nets in place so that you can tackle the more general administrative learning process at your leisure.

Newbies and veterans alike should be able to find useful information in this chapter. It summarizes the philosophical differences between FreeBSD and Windows as well as between FreeBSD and its much more similar cousin, Linux. It also offers suggestions for avoiding some of FreeBSD's general traps as well as some useful tips to help keep the system running smoothly. Finally, you'll learn about the inevitable specter of catastrophic system failure, the various weapons at your disposal for preparing for it, andin the absence of the ability to turn back timeways to recover from it.

Migrating to FreeBSD

At the time of this writing, and as accurately as these things can be measured (which is to say, not very), FreeBSD has approximately 10 percent of the open-source UNIX Internet server market. The rest of that market is almost all Linux, with the remainder comprised of NetBSD, OpenBSD, and a few other little-known variants. In the wider server market, Windows 2000/XP/Server 20003 claims about a 30-percent share (and remaining steady), with UNIX/Linuxboth commercial and open-sourceestimated at about 60 percent. By any measure, this means FreeBSD is not an especially large player. However, market share alone does not dictate the quality of a piece of software, as anyone reading this book likely knows.

FreeBSD usage, while perhaps not growing as rapidly as in the past, is at least holding firm. A steady stream of Linux-based and commercial UNIX-based businesses are moving to support FreeBSD for its stability and its performance, desiring an open-source solution that's free of the distribution politics of Linux (which is true because of its natureFreeBSD is a complete operating system, whereas Linux is simply a kernel). Stories also abound of high-profile, web-based services running on FreeBSD simply because it is the only solution that can handle the load (the services' parent companies' own operating systems notwithstanding). The end result is a healthy and long-lived respect for FreeBSD in the server community, and a general desire to move toward its tempting mixture of stability, standards compliance, openness, and power.

Migration away from Windows or Linux means a trade-off of two features: software availability and established practices. These two factors are the largest stumbling blocks typically faced by seasoned server veterans eyeing FreeBSD for the first timethe former applying more significantly to Windows (because more and more Linux programs are being ported to FreeBSD); the latter applying to both. The following sections look at both these migration paths in turn and address the barriers.

Migrating from Windows

If you're switching to FreeBSD from a Windows server platform, the problems you are most likely to face involve not just what software is available, but a number of fundamental differences in how the computer is used. The topological role a Windows server plays in a network is quite different from that of a FreeBSD server.

Windows is almost exclusively GUI-based, without a mature or widely used remote administration method comparable to the tried-and-true command-line shell of UNIX. Even the built-in Terminal Services in recent versions of Windows have their practical limitations and technical quirks that don't affect the minimalist command line. This means that to use a Windows server effectively, you usually need to be physically sitting at the machine. Getting used to a command-line interface to do your work can be a daunting task, but it's crucial to UNIX systems' great advantage of remote accessibility.

In this section of the chapter, you learn that setting up a FreeBSD server to provide certain common services involves much less commercial software, licensing, and client/server installation than is required to set up other servers. You learn about migrating client/server applications to the FreeBSD system, and you learn information about some of the important differences between maintaining security in FreeBSD and in Windows. An important part of ensuring a secure server is keeping your operating system up to date; later in this section, you learn how to keep your FreeBSD system current with the latest developments.

Of course, one big difference you'll notice when you migrate from Windows to FreeBSD is the change in software availability, licensing, and registration. When you move to FreeBSD, you deal with free and open-source software packages that you compile yourself, with support coming from grassroots Internet sources or third-party support services rather than from large software vendors.

Note

Built-in and third-party components of Windows are gradually increasing the remote accessibility of the platform. These days, you can manage services remotely that are controlled through the Services control panel, and various methods exist to acquire a DOS command line on the server machine. However, these are both subsets of the complete functionality of a systemthey're limited to the functionality explicitly built in to the control mechanism you're using. Complete configurability of installed server software often relies on administrative client programs, as we'll discuss next.

Client/Server Applications

Most enterprise software for Windows servers is developed on a model in which you install the server portion physically (generally from CD). In this model, you then install an administrative portiona *client*on your desktop machine as well as on the machine of anyone else who will be administering the server. Terminal services are available in modern versions of Windows, which allow you to directly control the server machine itself from a remote location; but due to the intensely graphical Windows GUI and a variety of technical quirks in the available software, these tools are not simple or elegant to use. You must accept a major philosophical shift when moving to UNIX.

There are virtually no specialized client/server applications for FreeBSD that are comparable to the groupware, calendaring, or network management utilities on Windows. Their number, however, is growingmostly due to the increase in popularity of web-based administration interfaces, such as the configuration utilities for third-party applications like the CUPS printing system and the Mailman mailing list server. These utilities are usually intended only to be run at a local console because of security concerns (configuration utilities generally have to be run as root, and you don't want any web utility running as root to be accessible from just anywhere on the network). In any case, these web-based administration systems are usually just convenient add-ons; there's always a command-line version of every administration utility, because by far the favored mechanism for administering any part of UNIX is the command line accessed from a remote terminal.

SSH (or the unencrypted Telnet, as a recourse) is the dominant all-purpose tool for doing anything in the UNIX world. Technologically, using Telnet is one of the most efficient and streamlined methods imaginable for working with the serverall you're sending and receiving is text. It's also the most versatile method, giving you much wider access to the server's operations than any graphical tool could because you're free to type any command you want at the command line, rather than being limited to the specific controls written into a GUI tool. Naturally, though, this also means you have more power to break things. It's a trade-off: the ease of use, safety, and directed functionality of Windows client/server software for the versatility, risk, and esoterica of terminal-based administration.

Security

Whole books have been written on the Windows 2000/XP/Server 2003 security model, and the topic is well beyond the scope of this chapter. However, if you're used to the Windows style of users, domains, and permissions and you're moving to FreeBSD, there are a few things you'll want to know that will help you keep your security model roughly intact.

The "root" account is the equivalent of "Administrator." That is hardly a secret. However, beyond that there are a few things you can do to keep your services running with their accustomed privileges and to give your trusted administrators exactly as much power as they needand no more. The first step is to know what some of the fundamental differences are between the Windows and FreeBSD security models:

- FreeBSD uses the "user," "group," and "other" mode bits to specify ownership and permissions, with Access Control Lists (ACLs) as an adjunct; whereas Windows uses ACLs as the primary ownership/permissions system. This scheme is discussed in Chapter 13, "Users, Groups, and Permissions."
- Windows has the concept of *trusted paths*, allowing for the implicit authentication of users coming

from specified hosts. For instance, you can tell Windows to "trust" any user connecting from a particular computer under some or all circumstances, thus eliminating the need for user authentication where it isn't necessary. FreeBSD doesn't have this capability unless you use Kerberos, as you'll see in Chapter 30, "Network Security."

- Login names in FreeBSD must be 16 characters or fewer and contain only lowercase characters or digits. No spaces or special characters are allowed. In Windows, usernames can be as many as 20 characters long, although the same kinds of special-character restrictions apply.
- Windows has as many as 27 different assignable user rights for file modification and execution with various privileges. FreeBSD distinguishes only between processes executed by root (the super-user), processes executed by individual users, and processes executed in setuid or "set user ID" mode, in which the process takes on the privileges of whoever owns the executed file. (This simpler security paradigm means that FreeBSD is less flexible than Windows, but also less prone to vulnerabilities stemming from misconfiguration.)
- FreeBSD and UNIX don't have hierarchical groups. Windows allows you to place a group of users inside another group, and so on to an arbitrary depth; this is not possible in FreeBSD. All groups exist at the same "level."
- Windows "domains" don't exist in the UNIX world. Instead, remote authentication services (as with the Domain Controller in Windows) and security domains are handled by the NIS or "yellow pages" system. Details on NIS can be found in `man nis`.
- Peer-to-peer file sharing, done by NetBIOS and SMB under Windows, is typically done over NFS between UNIX systems. You can do Windows-style NetBIOS file and printer sharing in FreeBSD by using the Samba package. NFS is covered in Chapter 33, "The Network Filesystem (NFS)," and Samba is discussed in Chapter 34, "File and Print Sharing with Microsoft Windows."
- Windows uses the Authenticode scheme for verifying code authenticity in downloaded software packages. This is a signing scheme by which downloaded software must present a digital "certificate" to the user for acceptance or rejection, adding a layer of security against potentially malicious software. UNIX has no such standardized signing mechanism; but the FreeBSD ports/packages system provides centralized auditing and a measure of authenticity assurance suitable for nearly all applications, including checksums to ensure that no malicious tampering has taken place in the portion of the distribution chain between a port's maintainer and you. (This may change in the future, however, as the ports system becomes more distributed to other platforms.) See Chapter 16, "Installing Additional Software," for more on the ports and packages.

Windows bills itself as being easier to use and to make secure than UNIX. The number of necessary security certification courses for Windows administrators and engineers suggests that this is not universally true. Windows is potentially easier to make insecure through misconfigurations that are done with the best of intentions. Although this is also possible in FreeBSD, historical data shows that it is less common. FreeBSD may suffer fewer security flaws resulting from misconfiguration because UNIX is structured to encourage tighter security by default as a result of actions a new user might take. The large amount of concise and useful information available online for securing UNIX systems certainly contributes to stronger security, as well. An excellent resource for such information is the SANS (System Administration, Networking, and Security) Institute, found at http://www.sans.org.

Software Equivalency

Table 21.1 lists some of the commonly used software on Windows servers and what the equivalents would be under FreeBSD.

Table 21.1. Windows Server Software

Service	Windows	FreeBSD	Availability
Mail (SMTP)	Microsoft Exchange	Sendmail	Core system

Mail (POP)	Microsoft Exchange	`qpopper`	Ports
MAIL (IMAP)	Microsoft Exchange	IMAP-UW	Ports
News (NNTP)	Microsoft Exchange	`inn`	Ports
System logging	Microsoft SMS	`syslogd`	Core system
Web/HTTP	Microsoft IIS	Apache	Ports
FTP	Microsoft IIS	`ftpd`	Core system
Dynamic web content	Cold Fusion, ASP	PHP, `mod_perl`, `mod_python`	Ports
DNS	Microsoft Active Directory	BIND	Core system
Remote access	Microsoft Terminal Server	SSH, Telnet VNC	Core system
			Ports
Directory Services	Microsoft Active Directory	OpenLDAP	Ports

It's worth pointing out that in the Windows world, unwanted interactions between different pieces of server software are often such a risk that enterprises typically will not run more than one critical service on the same machine. These networks have a dedicated mail server, a dedicated web server, a dedicated name serverall different machines. The open-source UNIX community doesn't subscribe as commonly to that philosophy for two reasons:

- Open-source UNIX systems are often run for their low cost, so buying multiple servers often isn't within the budget of the operator or business.
- Software under UNIX typically is much better behaved than under Windows, and detrimental interactions between services or daemons are much rarer and less potentially harmful.

You may or may not choose to follow the UNIX method, and you might not want to risk running all your network's critical services on a single machine. If you do, however, you can generally feel more at ease and operate more efficiently running multiple critical services on the same server than you could if it were a Windows machine.

Note

A practice rapidly rising in popularity is virtualization, or multiple concurrent operating system instances running on the same hardware and shielded from interfering with each other. VMWare is a popular commercial virtualization package; and Xen (http://www.xen.com) is a virtualization monitor package built into FreeBSD as of the 6.1 release.

Keeping Up to Date

Microsoft provides system updates through *service packs*. These large collections of software revisions and binary patches appear every six months or so. Quicker responses (for instance, in response to security bulletins) come in the form of binary *hotfixes*updates and patches that can be downloaded from Microsoft's website through the Windows Update mechanism.

FreeBSD's method of keeping current can be a lot more complex than Microsoft's, but once it's understood, this method also can be easier and more effective. FreeBSD places a lot of emphasis on being available in source form for you to track if you like, keeping a local copy of the entire source tree synchronized at whatever frequency you choose. The CVSup tool makes this process both automatable and easy on bandwidth resources. The recommended practice on FreeBSD is to keep a local copy of the source code for the release version of FreeBSD that you have installed, as a substrate for source patches, and to synchronize it regularly to the errata fix branch for that release, which keeps it in line with every new change checked in for a security vulnerability or a bug fix. Refer to Chapter 19, "Keeping Up to Date with FreeBSD," for more about using CVSup and how the errata fix branches are structured.

Any security bulletin that is sent out by the FreeBSD Security Officer contains a source patch or similar way to fix a particular problem. Line-by-line instructions are provided; all you really have to do is copy them verbatim to the command line, and often you don't even need to reboot after you're done.

You can, if you choose, keep your system completely cutting-edge by rebuilding the entire thing from scratch, from your synchronized sources, however often you like. This process is known as `make world` and is covered in detail in Chapter 19. This is probably not something you need to do as a newcomer to the FreeBSD world. Rebuilding the system might prove useful later, however, as you build up experience and want to work with the very latest state of the system. For now, though, use Chapter 19 as a reference for synchronizing your sources to the proper errata fix branch for your FreeBSD release so you can apply security patches and keep your system fresh.

Caution

It's always a good idea to keep a "backup" machine as a mirrored copy of your "live" machine. If you must do cutting-edge synchronization and use the newest code, do it on the backup machine first before applying the same changes to the live machine.

Migrating from Linux

FreeBSD is much more similar to Linux than to Windows, and in many ways is functionally identical, even though Linux shares no actual code with FreeBSD. FreeBSD and Linux are both derived from the same UNIX tradition, they're both open-source, and their security models follow the same rules. The same third-party software (for the most part, especially if you take into account FreeBSD's Linux binary compatibility) is available for both platforms. The same kinds of system administration problems occur on both platforms, and the same kinds of solutions tend to work as well.

Migration difficulties from Linux to FreeBSD are much more technological than philosophical, and so this section will go into more administrative detail than the section on migrating from Windows.

Functional differences between Linux and FreeBSD can be boiled down to a few basic areas:

- Where everything in the system can be found
- Partitions and filesystem types
- Ports and packages
- Keeping in sync
- Working with master password files

- Technical esoterica

Where Everything in the System Can Be Found

The most important thing to remember about FreeBSD should be a mantra by now: Everything that you install goes into the `/usr/local` subtree. FreeBSD maintains this model very carefully to prevent pollution of core system areas (`/usr/bin`, `/var/lib`, and so on). Table 21.2 lists a few common locations for the resources you'll need, but bear in mind that the Linux locations might vary from distribution to distribution.

Table 21.2. Comparison of Common Resource Locations Between Linux and FreeBSD

Resource	Linux	FreeBSD
Apache server root	`/var/lib/apache` or `/srv/www`	`/usr/local/www`
Apache configuration	`/var/lib/apache/conf`, `/etc/apache`, `/etc/httpd`	`/usr/local/etc/apache`
Apache binaries	`/var/lib/apache/sbin` or `/usr/sbin`	`/usr/local/sbin/`
Sendmail executable	`/usr/lib/sendmail`	`/usr/sbin/sendmail`
MySQL database directory	`/var/lib/mysql`	`/var/db/mysql`
System startup scripts	`/etc/rc.d`	`/etc/rc.d` (`/etc/rc.*` prior to FreeBSD 5.0)
User-installed startup scripts	`/etc/rc.d`	`/usr/local/etc/rc.d`
User-installed executables	`/usr/bin`	`/usr/local/bin`
User-installed system executables	`/usr/sbin`	`/usr/local/sbin`
User-installed libraries	`/usr/lib`	`/usr/local/lib`
User-installed shared files	`/usr/share`	`/usr/local/share`
System documentation	`/usr/doc` or `/usr/share/doc`	`/usr/share/doc`
Documentation for user-installed software	`/usr/doc` or `/usr/share/doc`	`/usr/local/share/doc`

Caution

Some ports aren't as well behaved as others. Beware of ports that install components into areas outside `/usr/local`, as some such ports do exist.

Some of these resource locations differ because of the differences between the RPM method (the widely used Linux package manager) and the FreeBSD ports/packages method of software installation. Other location differences exist because of differences in the core system layout. Linux typically has more of a "System V" structure, whereas FreeBSD is more, well, BSD-like. Refer to Chapter 16 for a fuller discussion of how ports and packages work under FreeBSD.

Partitions and Filesystem Types

The Linux bootloader architecture takes a very DOS-like approach to disk partitioning: There are four primary BIOS partitions, one of which can be made into an "extended partition" with multiple "logical" partitions inside it. These partitions all appear on the same "level" to the user, even though the structure is, in fact, hierarchical. The system can be booted only from a nonextended partition, thus leading to a lot of potential confusion.

FreeBSD's hierarchical partition structure is much more overt. BIOS partitions are called *slices*, subpartitions are called *partitions* or *BSD partitions*, and the boot process handles the different levels explicitly (each with its own boot block code) in order to remove the mystery associated with extended and primary partitions. Setting up a disk involves first slicing the disk and then partitioning each slice. This process is described in detail in Chapter 20, "Adding Hard Disk Storage."

FreeBSD's native filesystem is UFS/FFS. You can use your Linux disks under FreeBSD without modification, but FreeBSD needs to load a kernel module to support Ext2FS; if you need to use Linux disks regularly, you will want to recompile the FreeBSD kernel to add Ext2FS support and remove the need to load that kernel module dynamically every time. See Chapter 18, "Kernel Configuration," for instructions on how to enable this option and build yourself a new kernel.

Ports and Packages

Coming from a Linux background, you may be used to installing software through the RPM utility. This is not widely used or recommended in FreeBSD. In fact, you can seriously damage your system by installing incompatible libraries into places such as `/usr/lib`, although it is possible to do if you really need to. The preferred method of installing and maintaining software in FreeBSD is through the package tools (`pkg_*`) or the ports. Chapter 16 offers a full explanation of ports and packages, but some aspects of how they work in FreeBSD are especially important to users migrating from Linux. Packages and ports provide a centralized filtering mechanism to tweak the build and installation options of software written for Linux so that it will compile properly under FreeBSD and install into the prescribed locations for user-installed materials. Ports and packages travel through the FreeBSD committers and the central download sites, rather than being available directly from the software developers themselves. This helps keep a FreeBSD system neat and tidy.

Keeping in Sync

FreeBSD is more "source centric" than Linux; because there is effectively only one "distribution" of the operating system, the entire installation is directly available in source form. The Linux world doesn't do this as effectively. Each distribution has its own structure and its own software selections. The Linux kernel itself is the only source subtree that you can be sure is the same as another Linux user'sand even the kernel can be patched differently depending on the distribution. Different distributions have different philosophies toward making the rest of their source trees available for automatic download, synchronization, and building. FreeBSD provides tools and infrastructure to accomplish these tasks across the board.

This means that to keep synchronized with the latest development code, all you have to do in FreeBSD is to track the sources using CVSup, as described in Chapter 19. Security patches and hotfixes (available in Linux variously as RPMs, source patches, or binary patches) are distributed in FreeBSD both in source patch form and by checking in fixes to the central source tree. You can update your system in response to a security bulletin either by following the line-by-line patch instructions in the bulletin or by simply making sure your source tree is synchronized to your appropriate errata fix branch at a point after the fix has been made and then rebuilding that part of the system.

Caution

Patching system components without rebuilding the entire operating system is a method that usually works (especially for small, noncritical elements of the system), but not always. The more fundamental to the system's operation a component is, the more likely it is that you will need to do a complete `make world` in order to upgrade properly. Such fundamental areas of the system usually include the central libraries (items in /usr/lib) or headers (in /usr/include). Less-risky areas are the supporting binaries, in /usr/bin and /usr/sbin.

Working with Master Password Files

Linux and FreeBSD both use *shadow passwords*, a method of storing encrypted password strings in a file readable only by root (see "The /etc/passwd and /etc/master.passwd Files" in Chapter 13). However, whereas FreeBSD maintains an /etc/master.passwd file that contains all user data, with /etc/passwd being simply a subset (without the actual password strings), Linux does it a bit differently. Linux's /etc/shadow file doesn't contain any useful information other than the username and the hashed password. Both /etc/passwd and /etc/shadow are necessary to develop an entire user database on a Linux system, whereas on FreeBSD all you need is /etc/master.passwd.

With the combined /etc/passwd and /etc/shadow files from a Linux system, it's possible to put together a master.passwd that you can install into your FreeBSD machine and thus preserve all your users' login data. This can be done with a Perl script shown in Listing 21.1.

Listing 21.1. Sample Perl Script to Convert a Linux User Database for Use in FreeBSD

```
#!/usr/local/bin/perl
# Set the following to the location of bash on your FreeBSD machine (if installed),
# or to /bin/csh to switch /bin/bash users to csh
$newshell = "/bin/csh";

open (PASSWD,"/etc/passwd");
@passwd = <PASSWD>;                    # Read in the /etc/passwd file
close (PASSWD);
open (SHADOW,"/etc/shadow");
@shadow = <SHADOW>;                    # Read in the /etc/shadow file
close (SHADOW);

foreach $user (@shadow) {
  @sdata = split(/:/,$user);
  $passhash{$sdata[0]} = $sdata[1];  # Make a lookup table based on usernames
}
foreach $user (@passwd) {
  @pdata = split(/:/,$user);
  $pdata[6] = $newshell."\n" if ($pdata[6] eq "/bin/bash\n");
  $pdata[1] = $passhash{$pdata[0]};  # Replace the "x" with the password hash
  splice (@pdata,4,0,undef,"0","0"); # Splice in extra blank fields
  foreach (@pdata) {                 # Print the combined output line
    print "$_";
    print ":" unless ($_ =~ /\n/);
  }
}
```

Make sure this script is set executable; then, log in to the Linux machine, use su to gain super-user access, and run the script sending the output into a file:

```
% ./mkpasswd.pl > new.master.passwd
```

Transfer this new.master.passwd file to your FreeBSD machine and put it into /etc (pwd_mkdb doesn't like working on input files and destinations that are on different filesystems). Open up the file in a text editor and then open FreeBSD's /etc/master.passwd in another window. You will need to modify the first block of about 15 usernames (such as daemon, bin, news, and other system pseudo-users whose UIDs are different in Linux and FreeBSD). Simply copy this block of users from FreeBSD's /etc/master.passwd into the new.master.passwd file, replacing the corresponding block in the new file.

Back up your existing /etc/master.passwd by making a copy of it. Finally, run pwd_mkdb to generate the new password files and hash databases:

```
# pwd_mkdb -p /etc/new.master.passwd
```

If this command completes without errors, don't log out yetyou need to test this while you still have super-user (root) privileges so that you can fix any problems that might exist. Do this by opening another terminal window and attempting to log in as a regular user and to obtain root access using the su command. If you can't, run pwd_mkdb again on the backup file you created, and the databases will revert to their former state, so you can determine safely what went wrong.

Technical Esoterica

A lot of extra little odds and ends are different between Linux and FreeBSD. Here is a list of some of the most visible:

- Device names in FreeBSD are less generic than those in Linux, but more descriptive. In other words, all Ethernet cards in Linux are eth0, eth1, and so on, so that you can easily tell that they are Ethernet cards, but you can't immediately tell one make or model from another (although in newer Linux kernels the Ethernet interfaces are labeled with their MAC addresses). FreeBSD has specific drivers for each card manufacturer and model, with names that vaguely correspond to the manufacturer name (rl for RealTek, sf for Adaptec Starfire, and so on). Similarly, Linux hard drives are hda, hdb, and the like; FreeBSD's drives, depending on whether they are IDE/ATA or SCSI, are ad0 and ad1 or da0 and da1. These names tell you more about the specific kinds of devices you have; but they can be more confusing than in Linux, if you are simply trying to find which device corresponds to your Ethernet card or your hard drive. You can refer to FreeBSD's kernel configuration file (/usr/src/sys/i386/conf/GENERIC) to determine from the comments which device names refer to what component models.

- FreeBSD doesn't have a System.map file. Linux uses this table to look up jump vectors for commonly used kernel symbols. FreeBSD builds these symbols into the kernel, so you don't need to worry about them.

- The default shell in FreeBSD is tcsh, not bash. tcsh and csh are hard-linked to each other, so csh is the same as tcsh. If you want bash, you'll need to install it out of the ports or packages.

- The Linux binary-compatibility package (which you really should install when given the chance) creates a /compat/linux tree that contains a basic Linux executable and library structure for Linux-packaged programs that depend on them. It also creates and loads a linux.ko kernel module (you can check its status with kldstat). These structures handle Linux executables mostly transparently; some anomalies may occur, but for the most part the handling is seamless. You will certainly want to install FreeBSD-native versions of anything you can, however, from the packages or ports, if available.

- FreeBSD doesn't allow you to log in remotely as root unless you hack the /etc/ttys file (see the note in "Introduction to Users and Groups" in Chapter 13 for details). If you're at all concerned about security, you will want to leave /etc/ttys alone and use su to handle superuser duties.

- As of version 5.0, FreeBSD uses the DEVFS device filesystem rather than a standard /dev directory populated with "special" files that serve as device interfaces. The DEFVS /dev directory's contents are dynamically generated, eliminating any need for you to build devices manually if you install new hardware. See Chapter 18 for more information on how to work with DEVFS and device hints.

- Devices on the PCI bus in FreeBSD are numbered starting with zero for onboard devices and then increasing as they move away from the motherboard down the PCI chain. In Linux, the onboard device is typically the highest-numbered device, and the numbers decrease with distance for the motherboard. This means that on a machine with two Ethernet cards, the devices that were `eth0` and `etH1` under Linux might become `fxp1` and `fxp0` (respectively) under FreeBSD.

- Trading in your Tux t-shirts and bean bags for Daemon ones can be a little discouraging due to incomplete market penetration as of this writing.

Aside from adjusting to these minor differences, though, the transition from Linux to FreeBSD ought to be quite smooth.

PREV NEXT

PREV NEXT

Do's and Don'ts (Common Gotchas)

Every operating system has numerous pitfalls ready to snare the unwary. These pitfalls can be particularly dangerous when the system is newly installed or when the administrator is new to FreeBSD. This section lists some of the most commonly made errors and some of the most valuable pointers for effective FreeBSD administration.

DO:

- Do use the ports and packages to install software. It's possible to grab the source for a particular program directly from the developer and compile it using its built-in scripts, but that just risks polluting your core-system userland if the program's installer doesn't know about FreeBSD's filesystem structure. If the program isn't available as a port, post to the `freebsd-ports@freebsd.org` mailing list and ask for it, or you can even learn the porting process and become a maintainer yourself.

- Do pay attention to the nightly, weekly, and monthly `periodic` output messages. Any `setuid` executable differences are flagged in the security report. The messages also alert you to filesystem usage, rejected mail hosts, and many other forms of visibility that are an effective "closed-circuit TV" against intruders.

- Do become familiar with CVSup. CVSup is your friend. Not only can it keep your source and ports in sync at all times, it can also serve as an effective mirroring solution, as you learn in the section "Mirrors," a little later in this chapter.

- Do install `sudo` (`/usr/ports/security/sudo`) and promote its use instead of running as root directly, especially if you share administrative duties with others. The `sudo` program (invoked as a prefix before a regular command) allows you or other users to execute commands with root privileges without knowing the root password; it works by prompting the user for her own password, and then checking to make sure the user is listed in the `/usr/local/etc/sudoers` file as a valid administrator, before executing the command as root. You can also use the `sudoers` file to establish certain allowed programs or commands to be run through `sudo`. This allows you to keep the all-important root password as secret as possible, and to limit the destructive potential of an all-powerful root login, while still allowing you to share administrative duties effectively.

- Do use `ntpd` and `ntpdate` to synchronize your system's clock so that all the system logging and scheduled processes in FreeBSD that depend on the time being accurate can operate properly. You can do this by adding the following lines to `/etc/rc.conf`:

  ```
  ntpdate_enable="YES"
  ntpdate_flags="tick.usno.navy.mil"
  ntpd_enable="YES"
  ```

  ### Tip

  Other time servers you can use are listed at http://ntp.isc/org.

  You can use any NTP server you like for `ntpdate`, which runs at boot time and corrects any gross time discrepancies before other services have a chance to run. You should also create an `/etc/ntp.conf` file to control `ntpd`, which runs as a daemon and keeps your clock synchronized with the specified NTP server (or servers) on an ongoing basis. See `man ntp.conf` for details on creating that file. At a minimum, it should contain the following lines:

```
server      tick.usno.navy.mil
driftfile      /var/run/ntp.drift
```

- Do be nice to the FreeBSD committers. There are only 15 or so of them, and the responsibilities of the entire operating system rest largely on their shoulders (as opposed to the collective shoulders of thousands of independent developers and distributors of Linux, or the corporate shoulders of Microsoft). That's a lot of responsibility. Be a cooperative and supportive user.

- Do decide what kind of security model you're going to have. Do you trust all your users? If so, you can get away with leaving a lot of system-level resources viewable. This way, you won't have to worry as much when you have permission-collision problems (such as web applications that must store clear-text passwords or write to a world-writable directory). If you don't trust all your users, though, you'll have to be much more careful. However, it's always best when running a networked server to lock down as much external security as you can. Even if you trust your local users, as long as your machine is on the Internet, it will be interesting to those who would like to break into it. See Chapter 30 for a fuller discussion of security in a networked environment.

- Do subscribe to the appropriate mailing lists for your version of FreeBSD. Unquestionably, you should be on `freebsd-security@freebsd.org` if you're running a server; `freebsd-ports@freebsd.org` and `freebsd-questions@freebsd.org` are also useful. If you're tracking the STABLE or CURRENT sources, subscribe to `freebsd-stable@freebsd.org` or `freebsd-current@freebsd.org` accordingly.

- Do monitor the size of your log files. Apache's `httpd-access.log` and `httpderror.log` are notorious for eating up disk space if your web server gets any kind of significant traffic. Use Apache's built-in `rotatelogs` utility or run a `cron` job to flush the logs occasionally. If your `/var` partition fills up, your mail, databases, and runtime files will not work.

  Also, do be sure to *read* your logs! The system isn't just writing out all that data for its health. Well, it is, actually, but it only works if you pay attention to what the system has to say.

- Do fly the Daemon banner proudly!

DON'T:

- Don't use experimental features on a production server. This isn't the place to try out new ideas such as GVinum and unsupported filesystem kernel modules. Try these things out on a cheaply built "hobbyist" machine or a mirrored "backup" server; then put them into practice only once you're comfortable with their use.

  Beware, however, that if your test environment is not absolutely identical to your live machine, you run the risk of software failing in the production environment even if it worked on the test bed.

- Don't forget to add yourself to the "wheel" group at installation time! Very little is more disheartening than building a new server, driving 50 miles to the co-location facility, locking the server in a cabinet, driving home, trying to log in, and discovering you can't get root access.

- Don't get hung up on uptime. If a system has 350-day uptime, it sounds cool, but it also means the system has been sitting unused in a closet for a year or has not been conscientiously upgraded to keep up with security bulletins. Nonstop uptime doesn't make for such great bragging rights as one might think.

- When probing your server for weaknesses, be careful to avoid triggering defense mechanisms such as PortSentry which block remote access from an attacking IP addressyou might find that you've locked yourself out of your own server. If you're accessing the server from a static IP address, you might have to find an alternative location from which to access your server and reset the "blackhole" routes before you can access the server again from the original location.

  Try to be aware of any action or situation that might block remote access to your machine. If that happens, you'll require physical access to the machine in order to restore remote access.

- Don't use `shutdown` to drop to single-user mode (for high-privilege activities such as replacing the kernel) if you're using an older FreeBSD version that's running with the `securelevel` setting at `1` or higher. Using `shutdown` won't decrement the kernel security level. Instead, reboot the machine and enter **`boot -s`** at the loader prompt to boot into single-user mode. Simply exit the single-user shell to come back up the rest of the way. You must boot into and exit from single-user mode at the physical consoledon't do any of this stuff remotely!

- Don't make a habit of using filenames with spaces in them. This can be done with backslashes in front of the spaces, as with any other special character (for example, `My\ Document.txt`). There's no guarantee, however, that software will handle the filenames properly. Most of the time, it willbut all it takes is one shell script that didn't properly quote an embedded command line and you risk having your files get deleted or overwritten with files named things like `My` and `Document.txt`.

- Don't write Perl or shell scripts on a local Windows machine and then upload them in binary mode over FTP, rather than in ASCII mode. Binary mode prevents proper translation of end-of-line characters, which occurs properly in ASCII mode. Although the body of the uploaded script might look perfectly fine, the return character at the end of the very first line (`#!/usr/local/bin/perl`) will be unrecognizable to the shell and cause the script to fail.

  A much preferable method for transferring files is the secure `scp`, which avoids these pitfalls associated with FTP and is covered in Chapter 30.

- Don't use Telnet; use SSH instead, and (if at all possible) disable Telnet entirely so that your users can't expose themselves or you to the weaknesses of unencrypted terminal traffic. See Chapter 30 for more information on setting up SSH and disabling Telnet.

- Don't enable `sudo` without using a properly designed `sudoers` file that restricts administrative access to only what's necessary.

Tip

If you're having trouble with CGI programming and scripts that mysteriously fail after uploading, check the `#!/usr/local/bin/perl` script line first; then make sure you're uploading in ASCII mode. Better yet, do your programming directly on the server. Excellent text-editing tools (such as `vim`, `pico`, and `emacs`) are available for just that purpose.

PREV NEXT

Performance Tuning

In its default, out-of-the-box configuration, FreeBSD is optimized to work with low-end hardware and to be extremely safe and reliable. This means that under heavy demand load, the system in its default state will perform more poorly than similarly equipped Linux or Windows servers. FreeBSD isn't an inferior platform; quite the contrary. Rather, it simply needs to be tuned for high-performance operation. The other platforms to which it's compared tend to be optimized for high performance by default, to the exclusion of low-end hardware. Very few sites that run FreeBSD servers do so without tuning the system for higher performance.

Performance tuning involves several different areas of the system, some of which require kernel reconfiguration (as you saw in Chapter 18). The following sections look at how to tune the kernel as well as components such as the disk.

Kernel Settings

You will need to tune your kernel to support high levels of traffic if your machine will be handling extreme loads. The `GENERIC` kernel is tuned for workstation or low-load server use so that its hardware requirements can be as low as possible. High demand for kernel resources can overload a system that hasn't been optimized to support it.

To optimize the kernel for handling high levels of traffic, change the `MAXUSERS` option setting, which is set by default to `0` (which tells the kernel to auto-tune this value). Despite its name, this setting doesn't actually set a limit on the number of users who can access the system at once. Rather, it sets a figure from which other tuning values are derived; these values include the number of concurrent processes per user and the network memory buffers (or `NMBCLUSTERS`).

The maximum number of processes each user can execute at once is derived from the following formula:

```
(MAXUSERS * 16) + 20
```

If you find that you're unable to run certain programs or perform certain tasks without getting "proc table full" error messages, tune the number according to this formula. Similarly, you will want to set `MAXUSERS` to `128` or `256` (or higher) for extremely heavily loaded systems or servers that have to maintain large numbers of processes or `NMBCLUSTERS`.

Tip

The `NMBCLUSTERS` setting, derived from the formula `(MAXUSERS * 16) + 512`, controls the number of available "mbufs," which you can view with `netstat m`. Watch to see whether the mbufs are being used up. If they are, and raising `MAXUSERS` doesn't help, you can tune `NMBCLUSTERS` independently from its derivation from `MAXUSERS`. Set it in the kernel to 32768 or 65536 (or higher) for heavily loaded systems. Alternatively, you can set it as a runtime kernel variable without rebuilding the kernel. Add the line **`kern.ipc.nmbclusters="65536"`** to `/boot/loader.conf` to set it at boot time.

Soft Updates and Asynchronous Writes

One of the features that allows FreeBSD to operate so safely on low-load systems is *synchronous writes*, meaning that the system has to wait while any write operations of filesystem metadata take place. This delay minimizes the potential harm to the filesystem due to a crash or power failure. This safeguard also makes the system run noticeably slower than comparable platforms, however, and it introduces artificial performance ceilings. You can remove these performance limitations if you so desire.

"Journaling Filesystems and Soft Updates" in Chapter 12, "The FreeBSD Filesystem," discusses Soft Updates. This is a technique by which disk write operations can be done in a software-controlled, orderly manner that speeds up disk input/output (I/O) and ensures that the filesystem remains safe should the system crash. It also allows disks to be "preened" in a non-intrusive background process while the system is running (instead of as part of `fsck`), allowing you to boot the system quickly even if the system was not shut down cleanly.

The Soft Updates mechanism is built into the `GENERIC` kernel and is available for use at any time. It's the default scheme for newly created filesystems in modern versions of FreeBSD. The Sysinstall utility integrates the ability to toggle Soft Updates on and off per filesystem, in the Disk Label Editor (as covered in Chapter 20). Another, more flexible, way to enable Soft Updates on a filesystem where it is not already running is to use the `tunefs` utility. FreeBSD uses this support program for the Fast Filesystem (FFS) natively. Run the `tunefs` program in single-user mode, in order for its changes to take effect, because filesystems on which it operates (such as `/usr` and `/var`) cannot be mounted at the time you run it. Because `tunefs` is in `/sbin`, it is available in single-user mode without any additional filesystems needing to be mounted.

Reboot the system into single-user mode (enter **`boot s`** at the loader prompt). At the shell prompt, enter the following commands:

```
# tunefs -n enable /
# tunefs -n enable /usr
# tunefs -n enable /var
# tunefs -n enable /tmp
```

Repeat the command for any other regular filesystems on your disk. Note that you might have to substitute `/sbin/tunefs` for `tunefs` in these command lines.

If Soft Updates isn't an option, an alternative way to get around the problem of synchronous writes is to force the filesystems to be mounted *asynchronously*, or in such a way that write operations do not hold up system functions. This option gives you the advantage of greatly enhanced speed, but it lacks the safety of synchronous writes. If the system should suddenly shut down while a write operation is pending, the filesystem could be damaged or even rendered irreparable.

To assume the inherent risk and mount a filesystem asynchronously, use the `async` option in the appropriate `mount` command or in `/etc/fstab`. A manual asynchronous mount would look like this:

```
# mount o async /usr /dev/ad0s1f
```

To do asynchronous mounts automatically, add the `async` option to the fourth column in `/etc/fstab`:

```
/dev/ad0s1f        /usr             ufs     rw,async      2        2
```

Disk Geometry Concerns

If you're really interested in optimizing your system's disk access performance, you can squeeze some extra horsepower from FreeBSD by arranging your partitions according to their physical placement on the disk. Because data can be transferred more quickly from the edge of a spinning disk than from the center, you can gain some speed benefits by placing your more active filesystems toward the edge.

The order in which you specify partitions in the partition table (in the Disklabel Editor in Sysinstall) matters. The first entry in the table begins at the edge of the disk, and subsequent entries are placed further and further inward (the opposite of how data is arranged on a CD, which, incidentally, spins at different rates according to where the read head isconstant linear velocity, or CLV, as opposed to a hard disk's constant angular velocity, or CAV).

The root and swap partitions are accessed the most, so place them as far outward as possible. Smaller filesystems also work better toward the edge than toward the center. With this in mind, the best layout is usually to start with a fairly small root partition, followed by a swap partition about twice the size of your physical RAM. Following this are your `/var`, `/usr`, and `/home` partitions, which generally tend to increase in size respectively.

Tip

In UNIX, the algorithms that control virtual memory are optimized to work best when the swap partition is about twice the size of your onboard memory. For instance, if you have 512MB of RAM, use a 1GB swap partition. A smaller swap volume can result in speed penalties as virtual memory paging operations start to overlap each other.

A Few `sysctl` Tune-Ups

The `sysctl` program controls numerous kernel state variables, such as the `kern.ipc.nmbclusters` variable you saw earlier. The defaults for these variables are such that a low-end system can operate smoothly and safely, but not with great top-end performance. You can tune a number of these to higher-performance values by adding them to `/etc/sysctl.conf`, which is evaluated by `init` at boot time, during the ordered execution of all the scripts in `/etc/rc.d`. Edit the `/etc/sysctl.conf` file and add any or all of the variables listed in Table 21.3, according to your needs.

Table 21.3. Useful Kernel Tuning Variables

Variable	Description
`vfs.vmiodirenable=1`	Allow the system to cache large numbers of directories.
`kern.ipc.somaxconn=8192`	Maximum number of pending connections allowed.
`kern.ipc.maxsockets=16424`	Maximum number of network sockets allowed.
`kern.maxfiles=65536`	Maximum number of file descriptors (open files, sockets, fifos).
`kern.maxfilesperproc=32768`	Maximum number of file descriptors per process.
`net.inet.tcp.rfc1323=1`	Enable timestamps and window scaling per RFC 1323.
`net.inet.tcp.delayed_ack=0`	Disable TCP delayed-ACK behavior.

`kern.ipc.maxsockbuf=2097152`
`net.inet.tcp.sendspace=65535`
`net.inet.tcp.recvspace=65535`
`net.inet.udp.recvspace=65535`
	These seven lines increase the TCP and UDP send/receive window sizes. This can increase network throughput and speed.

`net.inet.udp.maxdgram=57344`	
`net.local.stream.recvspace=65535`	
`net.local.stream.sendspace=65535`	
`kern.ipc.nmbclusters="65536"`	Raise the max number of network memory buffer clusters.
`hw.ata.wc="1"`	If you have IDE disks, this turns on IDE write caching (good for data integrity, though it may negatively affect performance).

Before you reboot with the new `/etc/sysctl.conf`, you can use `sysctl` to view the default value of those of these variables which are already set in the base system (some of them are not):

```
# sysctl net.local.stream.sendspace
net.local.stream.sendspace: 8192
```

You can then manually set any value with the `w` flag:

```
# sysctl w net.local.stream.sendspace=65536
net.local.stream.sendspace: 8192 -> 65536
```

Similarly, you may want to set two or three variables in `/boot/loader.conf`, which is read by the kernel even earlier than `init` reads `/etc/sysctl.conf`. If you need your kernel tuning variables to be set as early in the boot process as possible, put them into `/boot/loader.conf` instead of `/etc/sysctl.conf`.

Helpful Manual Pages

A wealth of information is available in the `man tuning` page. This document is an essay describing some of the ideas we've covered here, such as disk geometry issues and how to optimize a filesystem according to the read and write demand on it. It also covers each of the previously discussed kernel tuning variables and how exactly each one affects the system.

Similarly, read `man tunefs` for a fuller discussion of how the `tunefs` command can be used to take advantage not only of Soft Updates but also of many other performance enhancements that are a part of FFS.

Finally, `man sysctl` offers a good description of the kernel state variable mechanism and how to use it to its full potential by tweaking the system's variables during runtime.

PREV NEXT

Preparing for the Worst: Backups and Mirrors

No matter how many precautions you take, or no matter how much of a veteran you are, your system will be hacked, your hardware will fail, or something else will happen that will make your data unusable and recovery impossible. It's all but inevitable. The only defense against this is to have the tools available for a complete rebuild from the ground up. Prepare for the worst, says one of the corollaries to Murphy's Law, and the worst will never happen. If precautions are the price we pay for safety, so be it.

Creating "Seed" Files

One way you can ensure that your custom configuration will survive a catastrophic failure is to gather together a collection of "seed" files, which you can use to customize a new system that you build from scratch. These files can be preserved offline by burning them onto a CD or, in the absence of writable optical media, a floppy disk (remember, however, that floppies can be damaged and will deteriorate with time, so you need to make multiple copies and keep them fresh):

- `/etc/rc.conf` The main system configuration file.
- `/etc/master.passwd` The master user database. All other user databases can be generated from this one.
- `/etc/mail/freebsd.mc` The Sendmail "master config" file if you have a custom Sendmail configuration. (The filename may vary according to what you have named it.)
- `/etc/fstab` Important for re-creating your disk structure.
- `/usr/local/etc/*` Individual config files for all the programs you've installed (the well-behaved ones, at any rate).
- `/etc/vinum.conf` Your Vinum setup configuration script, if you're using Vinum (discussed in Chapter 20).

Tip

If you're in a hurry, you can simply archive your `/etc` and `/usr/local/etc` directories into tarballs and back those up, rather than picking the crucial bits out of each one. However, archiving only the bare essentials can make migrating to a new machine easier if you have to restore your system on a newly installed system whose `/etc` architecture is different from the one on your existing system.

These are the most critical filesthe ones that define your system and give it its identity. All told, they won't come to more than a few hundred kilobytes; those few hundred kilobytes can save you weeks of painful tuning and trial and error when rebuilding your system.

You may even want to package these files together into a tarball and mail it to yourself (at an account *not* on your FreeBSD machine) on a daily basis. Here's a sample command to accomplish this:

[View full width]

```
# tar cvfz - /etc/rc.conf /etc/master.passwd /etc/fstab /usr/local/etc | uuencode
   seedfiles.tar.gz | mail -s "Seed Files" me@myaccount.com
```

You can put this into a shell script in `/etc/periodic/daily` or into root's `crontab` file, as you prefer.

Backups

The importance of backups can hardly be overstated. Any system administrator will tell you this. Yet, it's also no secret that doing regular backups is tedious, annoying, and expensive. Many administrators will wax lyrical about how imperative it is to have a backup scheme in place while not actually having one to wax lyrical about.

At the very least, you should become familiar with the various options for doing backups. That way, if you aren't using a backup solution, it won't be because you don't know how.

Many enterprises have a standardized backup procedure for safeguarding their data, whether it's stored on Windows, UNIX, or Linux servers. This procedure can involve a central tape carousel and controller software running on a central server as well as client endpoints to that controller running on all the other machines to be backed up. The carousel controller collects data over the network from all the subscribed servers and writes tapes. The tapes can then be stored offsite so as to protect the data in the event of a fire or other catastrophic event that would render multiple onsite backups or mirrors irrelevant.

The software for these kinds of solutions is often geared toward high-end commercial platforms, and it's a rare case when a native FreeBSD client endpoint is available. Fortunately, though, many makers of such software are writing versions of their endpoints for Linux, and because FreeBSD has Linux binary compatibility, you may be able to get away with simply using the Linux software. For instance, the Legato client for Linux runs on FreeBSD, in most cases (although not without the occasional unpredictable behavior).

Tip

Linux software is often distributed in "RPM" format, which is used by the Red Hat Package Manager. As we've discussed before, the `rpm` utility is available for FreeBSD (in `/usr/ports/archivers/rpm`), but its use has some pitfalls. For instance, you might need to use non-standard flags on the command line. The flag `-nodeps` enables `rpm` to ignore missing dependencies that it expects to have in its own package database. The flag `--prefix=/usr/local` lets `rpm` put binaries into the standard FreeBSD location instead of `/usr`. The flag `--ignoreos` lets `rpm` ignore the fact that it's not Linux you're installing on.

In the case of Legato, native versions of the endpoint software are provided by an independent software company as part of an agreement to furnish unsupported versions of the software for platforms that Legato does not explicitly support, including FreeBSD. These packages are available in the ports at `/usr/ports/sysutils/nwclient` and `/usr/ports/sysutils/nwclient602`. These might work if the Linux version fails.

More of these specialized backup solutions are available every day, and it is becoming easier to find a commercial package that will work well with FreeBSD. However, in the event that no such option is available, you can turn to the standard venerable UNIX backup/restore tools for the backup basics.

Using `dump`

The built-in UNIX utility `dump` is the good-old standby backup method. It operates based on dump levels specified in `/etc/fstab` (as you saw in "Understanding the `/etc/fstab` File," in Chapter 12). The dump levels enable a fine-grained "delta dump" system, in which you can do one complete dump at the beginning of a backup period (for instance, a week) and then subsequently dump only new or changed files each day, thus saving tape space and backup time.

Note

Be aware that FreeBSD's support for `dump` and `restore` is filesystem-specific and only guaranteed to work on native UFS filesystems; if you're using non-native filesystems such as Ext3FS or MSDOSFS, `dump` and `restore` are not likely to work properly.

You'll need a drive to use as the backup device. You can use a tape drive (`/dev/rsa0`, the default), an external hard drive, or any device that can be mounted and written to during normal operations. SCSI has always been the interface of choice for backup devices such as tape drives, because of the speed and robustness of the interface and the general quality of the components. You'll need a SCSI controller for this, which will hike up the price a bit. Alternatively, you can wait until the now-popular FireWire (IEEE 1394) devices have become fully supported by FreeBSD and then use one of those (if you're lucky, it will work already). IDE/ATAPI tape drives are also available. However, make sure FreeBSD supports the tape drive you like before you buy it! The device need not be mounted for the dump operation to workit will write directly to the device specified.

The following command executes a baseline backup, a complete dump of the `/home` filesystem:

```
# dump -0u -f /dev/nrsa0 /home
```

The **`0`** option (which is a zero, not the letter O) means to perform a level-0 dump (back up everything, regardless of whether it needs to be backed up or not), and the `u` option tells `dump` to update the `/etc/dumpdates` file, a human-readable data file that `dump` reads to figure out whether incremental dumps need to back up certain files.

Note

The `nrsa0` device is the same as `rsa0`, except it specifies a "nonrewinding" devicea confusing syntax, certainly, but it has the undeniably useful effect of telling the tape drive not to rewind when it's done. Tape drives, particularly SCSI ones, use this convention to tell `dump` how to handle the tape, as shown in Table 21.4.

Table 21.4. Device Meta-Names as Control Options

Device Meta-Name	Effect
`/dev/sa0`	The actual device name
`/dev/rsa0`	Tells `dump` to rewind the tape when it's done
`/dev/nrsa0`	Tells `dump` not to rewind the tape when it's done
`/dev/ersa0`	Tells `dump` to eject the tape when it's done

This is useful for when you're doing batch backups; specifying the nonrewinding tape device prevents it from rewinding after the first operation and overwriting the just-completed backup.

After your initial level-0 dump is done, you can do incremental dumps with the same syntax, but a higher dump level number:

```
# dump -1u -f /dev/nrsa0 /home
```

The dump levels work by dumping only the files that have changed since the last dump of any lower level. Therefore, if you do a level-3 dump and then a level-4 dump later, the level-4 dump will dump only files that have changed since the level-3 dump. If you then do a level-2 dump, everything backed up with the level-3 and level-4 dumps will be backed up again. The lower the dump level, the more backups will be "forced." Level 0 is the "ultimate" backup, dumping everything regardless of previous dump states.

The typical procedure is to do a level-0 dump at the outset and then a level-1 dump at the beginning of each week, using a different tape (or set of tapes) for each week. Each subsequent day, a higher-level dump is done, often in the staggered "Tower of Hanoi" sequence suggested in the `man dump` page.

Recovery

When it omes time to recover your backed-up data, you'll be using the `restore` utility. This can be used either in interactive or noninteractive mode. Interactive mode is helpful for specifying a particular set of files to restorefor instance, if you've accidentally deleted a file and you need it back. First, change to the directory (using `cd`) where you want to extract the file and then enter the interactive `restore` program:

```
# restore -if /dev/nrsa0
```

Within this program, you have a number of commands available to you: `cd`, `ls`, `pwd`, `add`, and `delete`, among others. These commands allow you to navigate among the files in the tape's backed-up directory structure, view them, and add them to a list (with the `add` command). You can remove files from the list (but not from the tape or disk) with the `delete` command. The `exTRact` command restores from the tape any files in the list at the time you issue it. Full syntax for each of the interactive `restore` commands can be found in the `man restore` page.

The following two commands add the directory called `frank` to the extraction list and then extract it from the tape back onto the disk:

```
restore> add frank
restore> extract
```

Alternatively, you can simply restore everything from a tape's backup session with a noninteractive command line using the following options:

```
# restore -rf /dev/nrsa0
```

A tape often will have multiple sessions of backup data on itmultiple days' worth, for example. A single tape might have a week's worth of backups, beginning with a full backup followed by six incremental backups. If you want a file from a particular day's backup, you will need to position the tape to extract from that session. The tool that does this is `mt`, the "magnetic tape" manipulation utility.

When you first insert a tape into the drive, it is generally rewound automatically to the beginning. To wind it forward to the third session, use the `fsf` (fast forward) option with `mt`:

```
# mt -f /dev/nrsa0 fsf 2
```

Here, `fsf 2` tells `mt` to fast-forward two sessions, putting it at the beginning of the third session. To move back to the second session, rewind the tape to the beginning (also using `mt`) and then fast-forward it again:

```
# mt -f /dev/nrsa0 rewind
# mt -f /dev/nrsa0 fsf 1
```

There are a great many more details to the `dump` and `restore` procedures that need not be fully covered here. Using the `-s` option with `restore` in noninteractive mode to specify a certain backup session on the tape is one such procedure. Others include advanced usage of the `mt` utility, managing multiple tapes, remote backup devices, and so on. A good tutorial on `dump` and `restore` that covers these procedures can be found at http://www.nethamilton.net/dump.html. Also, read the `man` pages on `dump`, `restore`, and `mt` for documentation of all the capabilities of these tools.

Mirrors

Backups are certainly daunting, aren't they? It's a small wonder that few people actually have the patience to do them. They do require a budgetary and time consideration appropriate to a small business at the least; a personal hobbyist system might find it difficult to justify the investment and aggravation. Fortunately, there's an alternative.

For just a little more money than it would take to set up a full-fledged tape backup system, you can instead create a mirror servera second FreeBSD machine whose only purpose is to synchronize its files with the main server on a daily basis. You can swap those files into place should anything happen to the main server, or swap the entire mirror server into the failed main server's place. And the tool you use to do the mirroring? You guessed it: CVSup.

Ideally, your secondary server should be in a physically different location from the main server, so that your data is protected even in the event of a fire, flood, or burglary. CVSup's incremental backup system makes it possible to do this even if the bandwidth available between the two systems is very limited.

Setting Up a CVSup Mirroring Solution

Let's say you want to mirror four directory structures: `/home`, `/usr/local/www`, `/var/mail`, and `/etc`. (You may well want to do more than just these in your situation, but these will suffice for this example.) The first step is to set up a base directorya staging area on the main server where the configurations of the source data trees are stored. The base directory lets `cvsupd` (which is installed in `/usr/local/sbin` as part of the `cvsup` port or package, which you should already have installed) know what collections to serve to clients, such as your mirror machine.

Enter the following commands as root:

```
# cd /usr/local/etc
# mkdir -p cvsup/sup
# cd cvsup/sup
# mkdir home www mail etc
```

Now, in each of these four new subdirectories, you need to create two files: the `.cvs` file and the `releases` file. These files describe a "collection" to the `cvsupd` server and enable it to be served. In the `home` subdirectory, create a file called `home.cvs` with the following contents:

```
upgrade home
rsymlink *
```

Next, create a file called `releases` with the following contents:

```
home list=home.cvs prefix=/
```

Do this for each of the four subdirectories, changing the name of the `.cvs` file to match the name of the directory or collection as well as altering the contents accordingly (`www.cvs`, `mail.cvs`, and so on).

Running the `cvsupd` Server

When you have set up the base directory, you can start up the `cvsupd` server. The `C` option limits the number of simultaneous clients to 1, and `l` (the lowercase letter L) specifies where to send logging information:

```
# cvsupd -b /usr/local/etc/cvsup -C 1 -l /dev/stdout &
```

Now you're done with the main server, so you can move on to the secondary server, the one that will act as a client to the CVSup server you've just set up.

Create a file in `/etc` called `mirror-supfile` (or anything you like). The contents should be as shown in Listing 21.2, in which `server1.example.com` should be replaced with the hostname of your main server, from which you will be mirroring content. You can use simple hostnames, fully qualified domain names, or IP addresses for the `host` parameter.

Listing 21.2. Example CVSup Configuration File (`mirror-supfile`)

```
*default host=server1.example.com
*default delete use-rel-suffix
*default compress
*default preserve

*default base=/usr
*default release=home
home

*default base=/usr/local
*default release=www
www

*default base=/var
*default release=mail
mail

*default base=/usr
*default release=etc
etc
```

Notice the final entry: It's not `/etc` that you're mirroring the main server's `/etc` into but rather `/usr/etc`. The reasons for this is that `/etc` is unique to each machine, where it is customized for that machine specifically; you want to mirror `/etc` into a safe and inactive location, rather than overwriting your secondary server's `/etc` with that of the main server. In any case, this is a good excuse to demonstrate the flexibility of CVSup, showing how you can "check out" a collection of files into any location on the second server.

Running the CVSup Mirroring Process

After the `mirror-supfile` is created, you're ready to do your first mirroring operation. Start up the CVSup process:

```
# cvsup -L 2 /etc/mirror-supfile
```

You'll be flooded with output, telling you exactly what is being transferred and how. You can use Ctrl+C to break out at any timeCVSup will exit cleanly and pick up where it left off the next time through. This first transfer process will take a very long timeas long as it takes to transfer all the specified data from one server to the other via any other means. It's the subsequent processes that will be fast and efficient.

After your `/usr/etc` has been transferred, you can copy the `master.passwd` file out of it and use `pwd_mkdb`, as you saw earlier in the "Migrating from Linux" section, to synchronize your users (this is relevant even if you don't use Linux). You may choose to do this as a daily automated task if you have a lot of users or add them regularly; CVSup will skip any file that it can determine has the same checksum and the same ownership information.

Note

The ownership information won't be the same if the users on one system don't match the ones on the other! If a file is owned by a user that doesn't exist on the secondary system, CVSup will "rsync" it every time the mirror process is run, which doesn't take anywhere near as long as transferring the entire file, but it takes much longer than simply skipping the file. Keeping the user database synchronized, and allowing CVSup to skip files whose information matches completely, can speed up the mirroring process from 4 or 5 hours down to about 15 minutes.

After the mirroring process is working smoothly each time you run it, you can add it to your `/etc/periodic/daily` or root's `crontab`, whichever you prefer. You'll get the verbose output mailed to you each night for your edification. Reduce the `-L` level if you want to see less output.

You can create more file collections on the server side if you want; just make more directories in `/usr/local/etc/cvsup/sup` and add them to `mirror-supfile`. You don't need to restart the `cvsupd` processit will pick up the new collections automatically each time a client process connects.

Note

Mirroring isn't a complete alternative to incremental backups. It's a solution for an administrator who doesn't need historical auditing, revision control, or offsite backup archives. Put simply, it isn't a perfect solution for a business using FreeBSD as its server platform. Mirroring provides a quick-and-easy solution to a sudden catastrophic failure. For business use, you really can't beat tape backups, tedious as they are.

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Part V: FreeBSD Networking

In This Part

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Chapter 22. Principles of TCP/IP Networking

IN THIS CHAPTER

Operating systems used to be designed either for networking or for single-user desktop settingstwo styles of computing that were worlds apart. That has all changed. In the present day, the consumer-level, single-user, nonnetworked PC platform is giving way to operating systems whose robustness and networkability put to shame many of the mainframe-class systems of the old days. Mac OS X (with its FreeBSD architecture and Mach kernel) and Windows 2000/XP are both examples of platforms that were built around networking as a fundamental tenet, and they are intended to replace older systems that had had networking tacked onto them only as an afterthought. TCP/IP (the *de facto* transport protocol suite of the Internet) is woven as tightly into the cores of these modern systems as it was in the mainframes, and as it is in FreeBSD.

FreeBSD is a system designed from the ground up to be a network-aware platform. Whether you're using it as a workstation or as a server, chances are you've chosen it at least in part for its networking strengths, and a FreeBSD machine without access to a network is frankly not a lot of use. It's certainly a great deal less fun.

In this chapter, you'll learn the basic principles of networking as it applies to FreeBSD and its role in the Internet, principles which underpin the remainder of the topics discussed in this book.

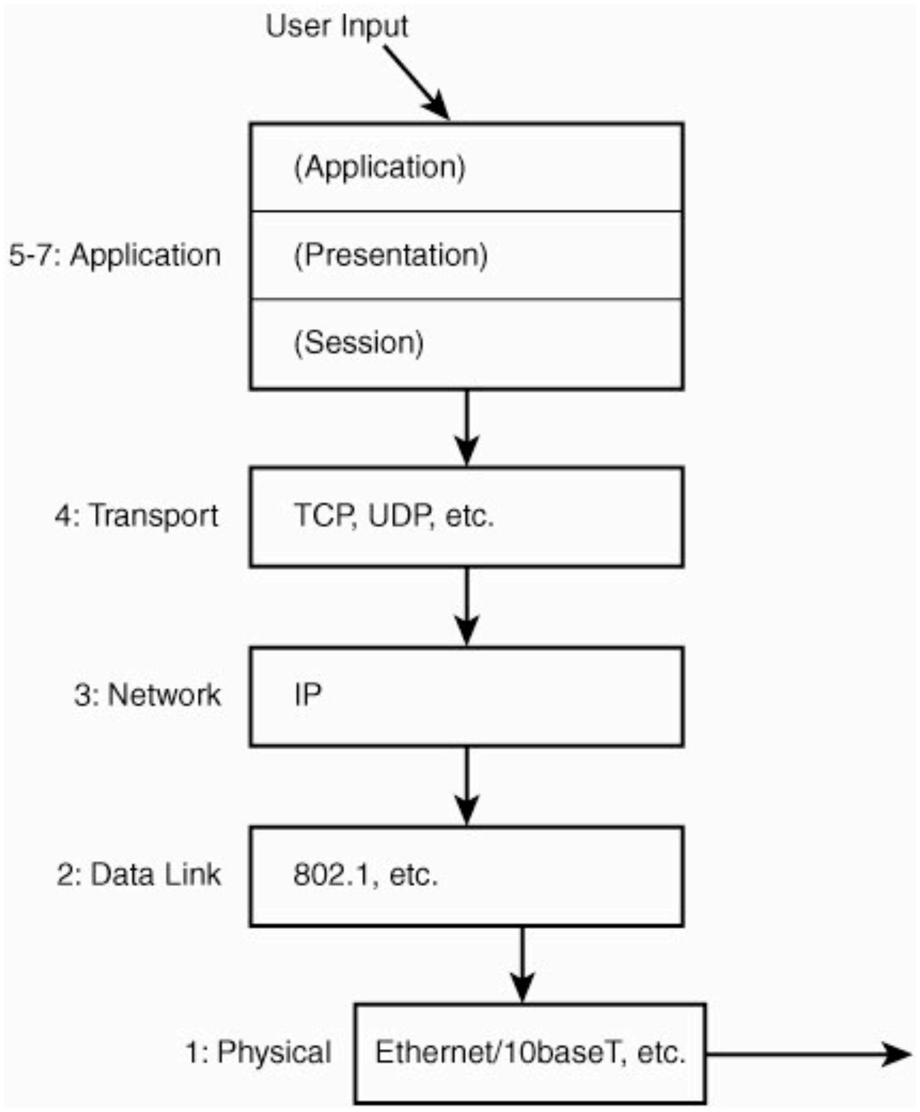
Introduction to Networking

Networking is the ability of two or more computers to be aware of each other's existence and exchange data. In the Internet age, this basic capability can mean anything from simple peripheral communication to email traveling from server to server, web browsers downloading HTML pages and large movie files from HTTP servers, and peer-to-peer MP3 sharing. A networked computer has the capability to expand its usefulness beyond what the user can buy off the shelf and install from CD, instantly and without any physical media being introduced. The advent of networking and what it means for business and recreation is what has fueled the computer revolution that is very likely behind your decision to use FreeBSD.

In the modern Internet, when people talk about networking, they generally mean *TCP/IP*: the Transmission Control Protocol/Internet Protocol, the ubiquitous architecture underlying all the applications that make the Internet what it is. With its roots in the United States Department of Defense-funded ARPAnet, TCP/IP formed the core of the UNIX systems from Bell Labs from which FreeBSD developed; this means that the code of the TCP/IP application and library suite that's in FreeBSD is based directly on the original software known as the *reference implementation*, the model that other vendors follow when designing their own TCP/IP-based systems. When you use FreeBSD, you're using one of the most mature and robust networking platforms available in the market today.

A standardized model for the networking "stack," known as Open Systems Interconnection (OSI), establishes the general structure of TCP/IP. OSI dictates as many as seven "layers" of implementation for a computer network, each of which has its own measure of specificity and its own functional applicability to the user, the software, the operating system, and the networking hardware. You'll be seeing references to the various layers of the TCP/IP stack in later chapters, as well as in the networking industry in general, so a working familiarity with the OSI model is worth having. The conceptual arrangement of the OSI model, as exemplified in the Internet's typical usage, is shown in Figure 22.1.

Figure 22.1. OSI stack layering diagram, as it is used in TCP/IP.



In an OSI stack, data travels from the highest level (the user-interface level, where it is in its most specialized form, allowing the user to interact with it using a variety of interface metaphors, such as command lines and windowing systems) progressively down to the its lowest level, where it is at its most generic and abstract forma form that can be handled by very simple hardware and software protocols. This is achieved by each layer of the stack wrapping the data in "headers," or abstraction layers that allow the data to be decoded later by another TCP/IP stack, when the data reaches that layer on the way down. At the top of the stack, user applications handle data in very sophisticated ways, but they know nothing about the nitty-gritty mechanics of data communication; by the time it reaches the very bottom of the stack, the data is not "web pages" or "email." Instead, it's just ones and zeroes that the Ethernet card knows to send to another Ethernet card (for an Ethernet card by itself knows nothing of routing, connection states, or web browsers). All the packaging tells the remote Ethernet card what to do with the datawhether it is destined for that card's machine (in which case it should pass the data further on up the stack for decoding and delivery) or for another computer elsewhere on the networkor even on another network, in which case the data is forwarded on.

The different layers of the stack define different levels of addressing and routing specificity. The IP layer, the component that corresponds to the "network" layer of the stack, knows how to send packets of data to other computers on the Internet, as defined by their IP addresses. TCP and UDP, which you will learn about later, are protocols that exist higher up the stack, in the "transport" layer. These rely on the network layer's ability to deliver packets, but they add their own specific methods of delivery and flow management. Below IP, the "data link" layer knows nothing about IP addressesall it knows about is the hardware addresses on other Ethernet cards on the network. However, because IP information is embedded in any packet that the data link layer receives to transmit, the receiver will know where on the Internet it's supposed to go.

Many other protocols exist at the various levels of the OSI stack, and they each play a part in routing traffic to its final destination or recipient user and ensuring its integrity. This chapter discusses how these protocols fit into the TCP/IP structure and how FreeBSD deals with them.

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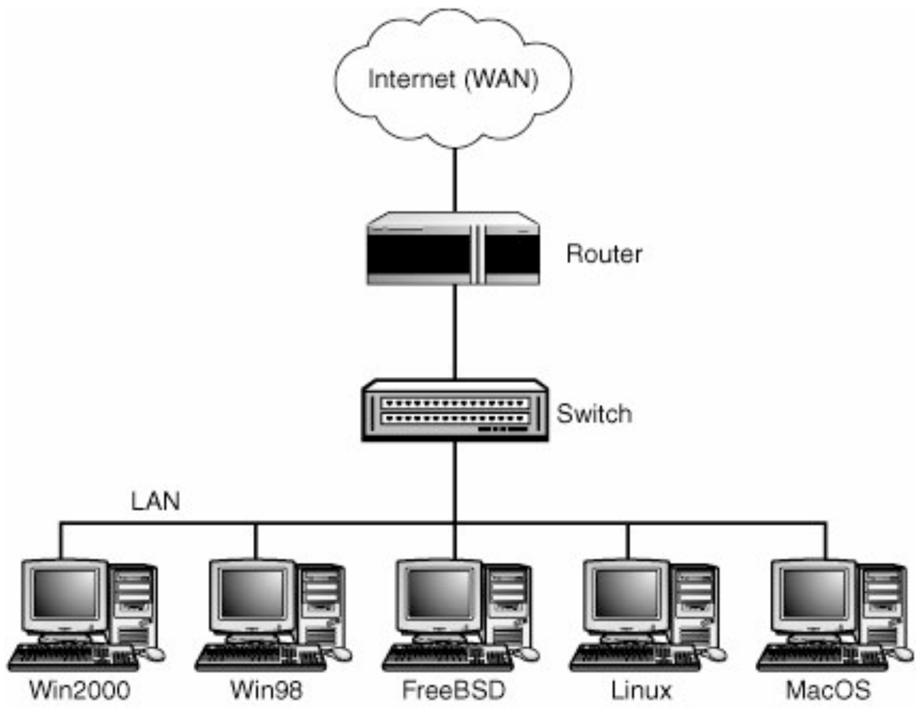
Network Topologies

Your FreeBSD machine might be installed on a university network, in a professional colocation facility, within a corporate enterprise network, or on a home dial-up network (or dialed-up directly). These are just the most common types of settings. Different network topologies, or logical layouts of devices and data link mechanisms, are as numerous as the individual networks in the worldno two are exactly the same. However, virtually all networks share a common basic topology and a few fundamental components.

In Figure 22.2, you can see the type of topology that would be found in a typical home network. The topology shown here is also serviceable as a simplified diagram of an enterprise or university network.

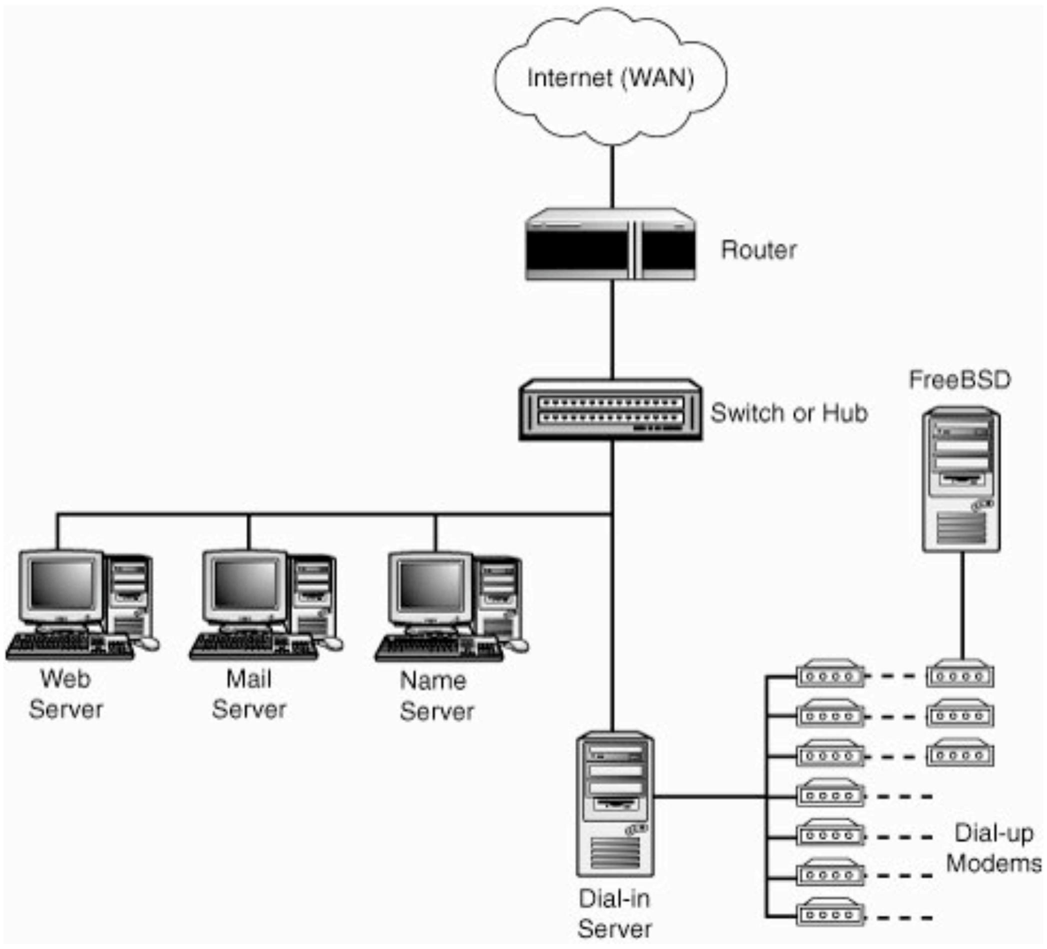
Figure 22.2. A basic network topology, showing a WAN and a LAN, separated by a router and comprising a number of different types of computers.



These WAN link types are designed to run over very long distances. Because of their serial nature, they can carry traffic over the same fiber-optic infrastructure that carries standard telephone network "trunk" traffic. In fact, data traffic over these lines is indistinguishable from digital voice traffic; it's treated exactly the same way by phone switching equipment and travels from one geographical location to another the same way a phone call would.

Another type of network topology is the, which involves a primary network like the one shown in Figure 22.2. This architecture also includes a secondary WAN that connects the network to a large number of home users dialing up via modems and phone lines. This is illustrated in Figure 22.3.

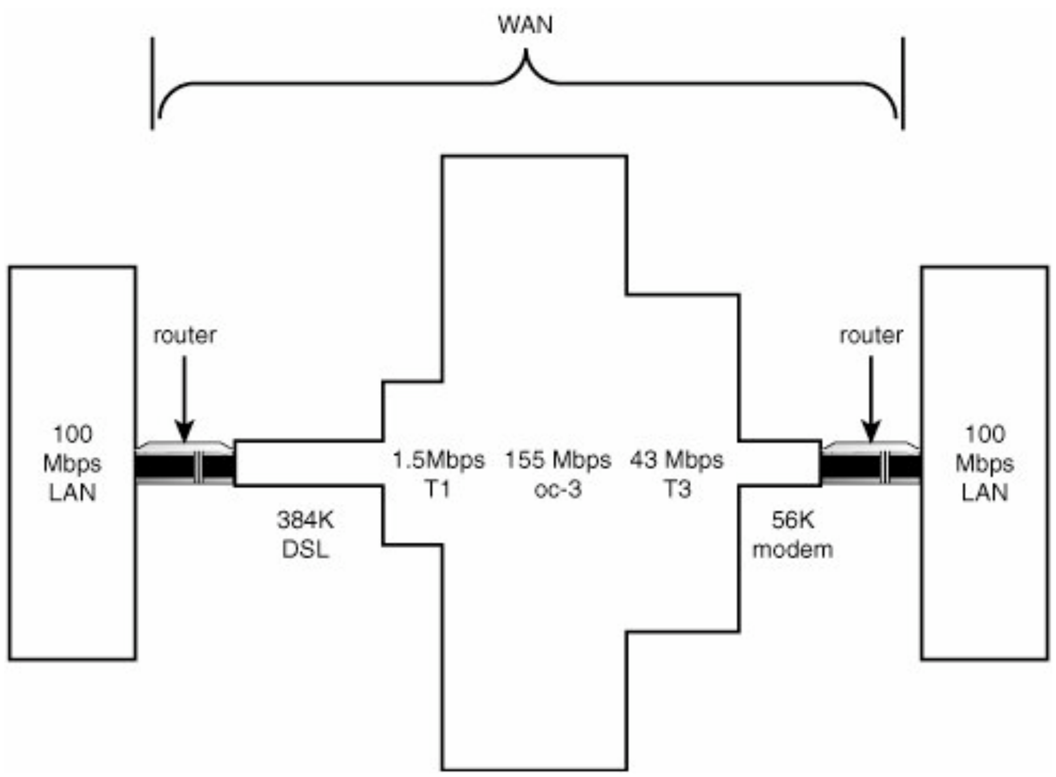
Figure 22.3. The ISP network architecture; home users dial up through the telephone WAN over modems to the ISP's LAN, which then connects to the Internet WAN.



After the WAN traffic reaches a DSU/CSU (which interfaces the phone company's transmission lines with your network's serial infrastructure) and router, however, it makes the transition to LAN transport mechanisms, such as Ethernet. These are physical link mechanisms that, unlike serial WAN traffic, can interface directly with any computer equipped with an Ethernet card.

Figure 22.4 shows a diagram of the bandwidth capacity of the entire path from one LAN to another. This is the path that Internet traffic usually takes from a server (such as a website) to a client (a user's web browser). The WAN pipe, as a rule, is narrowest right before it hits the LAN router.

Figure 22.4. A schematic diagram of bandwidth availability throughout the path from one LAN (at the server end) to another LAN (at the client end), via a WAN of varying capacity.



Notice that although traffic in the middle of the WAN travels over lines with vastly more bandwidth than even the fastest LAN wiring, this bandwidth is divided among a great many more users than a typical LAN. Thousands, even millions of users share the thickest trunk lines during peak WAN usage periods. There are seldom more than a few hundred users competing for usage of a LAN.

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Network Components

Any network is made up of the same types of component parts. These range in complexity from simple cables through complex computer-like devices such as routers. Each type of component exists at a different level of the OSI model; the brief view you have had of the TCP/IP stack and its layers will help to explain the conceptual difference between hubs, switches, bridges, and routers.

As with most computing equipment, the components you choose will vary in quality and in price. It's best to buy from vendors whose names you trustLinksys, Cisco, Intel, 3Com, and Netgear all make excellent infrastructural equipment, but they are by no means the only vendors you should consider. Bear in mind the features you need in your network. Will you have a pure 10base-T or 100base-TX network? Or will you need equipment that handles both? Will you need to support Gigabit Ethernet? Will you be using a wireless network? Also, pay attention to reviews to find out what models offer the best performance and quality for the price. Some components, however, offer opportunities to save on cost; you can make your own Ethernet cables, for example.

This section will examine the different components you will be working with in a typical networking topology, and later we will discuss how FreeBSD interacts with them.

Cables

The benefit of Ethernet and other LAN link types is that for a very low cost, traffic can be carried between machines within a network at speeds that only the most expensive WAN links can reach. Those speeds range between 10Mbps for "standard" Ethernet, 100Mbps for Fast Ethernet, 1Gbps for Gigabit Ethernet, and 10Gbps for the fastest standard in wide use today, 10 Gigabit Ethernet. These speeds can be achieved with cheap cables and components, making networking between computers via Ethernet a joy compared to a low-speed WAN. The downside is that Ethernet can't be used over long distances. Because the signals aren't serialized or transmitted by equipment designed to support long-distance transmission, signals degrade with cable length.

Twisted-Pair Cables

The most commonly used cabling these days makes use of unshielded twisted-pair (UTP) cables, due to the relative simplicity and low cost of the cables and components. UTP cables connect computers' network interface cards (NICs) directly to hubs and switches without the need for repeaters or terminators, can be coiled tightly and strung through hard-to-reach areas, can be created from inexpensive components using readily available tools, and connect easily to RJ-45 phone-style jacks.

RJ-45 jack crimpers can be bought at any electronics supply store, as well as RJ-45 connectors and UTP cable. Refer to the next section for information on pin-outs so that you can attach the connectors correctly.

Note

Twisted-pair cables do vary in quality, and some types are rated for higher speed than others (and have a commensurately higher cost). This quality rating can be expressed in a *supported speed*, a noise rating (citing such influencing factors as attenuation, NEXT distortion levels, and return loss), or a *category compliance* level. If your networking needs will require high-performance equipment (for instance, if you will be transmitting data at sustained speeds in excess of 100Mbps), you will want to pay the extra cost for quality cables, such as CAT5e or CAT6.

Straight-through and Crossover Cables

The two types of twisted-pair cables are straight-through and crossover. The difference lies in whether the positions of two pairs of wires in the cable are reversed from one end to the other. The type of the devices you are connecting determines which of these two cable types you must use.

Devices with RJ-45 connectors can be thought of as either "computer-type" or "hub-type" devices. Computers, routers, bandwidth managers, and other "endpoint" devices are considered computer-type devices, and they all share the same type of wiring. Hubs and switches are hub-type devices and also share a type of wiring. Straight-through Ethernet cables are wired to connect computer-type devices to hub-type devices, but crossover cables are wired to connect a computer to a computer or a hub to a hub. The rule to remember is this: Use straight-through cables between *unlike* devices, and use crossover cables between *like* devices.

You use straight-through cable to connect *unlike* devices, as in these examples:

- To connect a computer to a hub
- To connect a computer to a switch
- To connect a router to a hub

You use crossover cable to connect *like* devices, as in these examples:

- To connect a hub to a hub
- To connect a hub to a switch
- To connect a computer to a computer (for instance, to play in two-player deathmatch mode)

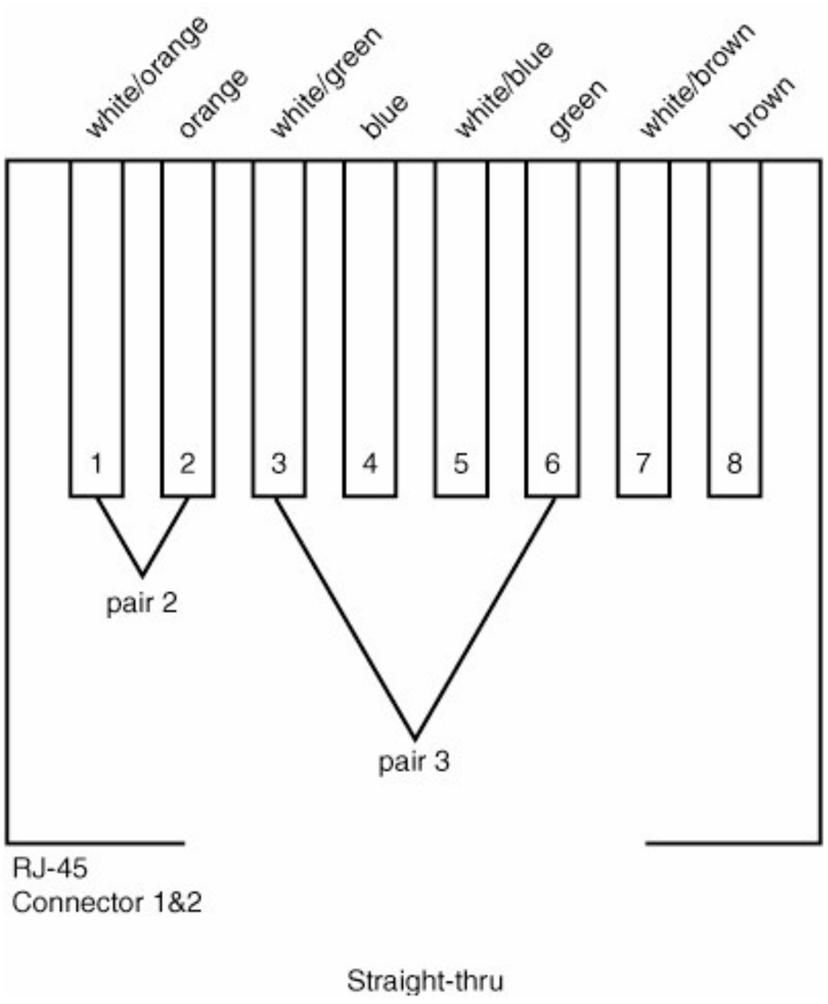
Uplink Ports

The exception to the Ethernet cabling rule is the "uplink" port on hubs. This special port is wired as if it's a computer-type device, so you can connect a hub's uplink port to a standard port on another hub with a straight-through cable. This became necessary in large networks, in which a very long straight-through cable would be connected to a large enterprisewide hub or switch (in the server room, for example) and wound through walls and conduits to emerge in another room. This cable couldn't be connected directly to a standard port on a smaller hub; it had to be fitted to an adapter and a short crossover cable before it could talk to the smaller hub. Replacing the Ethernet cable with a long crossover cable was impractical to say the least. Hence the uplink port was borna port that allows a hub to be connected directly to another hub for which swapping out the cable for a crossover is not a viable option. Remember, though, that connecting two hubs' uplink ports together requires a crossover cableand that's a configuration that rather defeats the purpose, in any case.

How do you tell whether an Ethernet cable is a straight-through or a crossover cable? It's pretty easy: Hold up the two ends of the cable next to each other. If the color sequences of the wires match, it's a straight-through cable. If some of the wires appear out of place, it's a crossover cable.

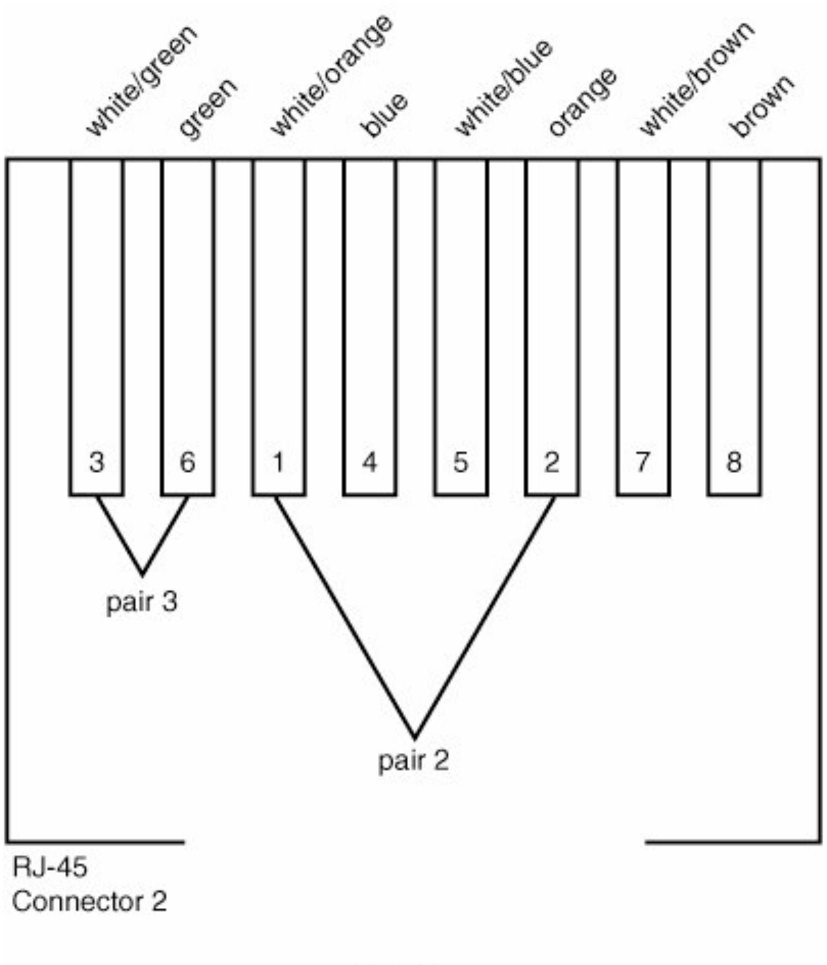
The pin-out for a straight-through cable is shown in Figure 22.5.

Figure 22.5. Straight-through cable wiring diagram.



And to make a crossover cable, reverse the positions of pair 3 (wires 1/2) and pair 2 (wires 3/6), as shown in Figure 22.6, when crimping the second end.

Figure 22.6. Crossover cable wiring diagram.



Crossover

Hubs

One end of the cable connects to your computer's Ethernet card; that much is clear. However, the other end needs to connect to something, too. Although their role has been eclipsed recently by inexpensive switches that perform similar functions, the simplest connection device for this purpose is a hub.

Hubs are devices with multiple RJ-45 ports, usually between 4 and 24, to which you can connect as many Ethernet cables as there are ports. These cables can connect to computers, other hubs, switches, or other network components as necessary. Hubs range in cost from about $20 to several hundred dollars, depending on quality, number of ports, and the capability to operate simultaneously with 10base-T and 100base-TX devices. Many hubs can only do one of the two speeds; an auto-sensing hub (often referred to as *N-Way*) can do either speed but costs significantly more.

Hubs range in size from small boxes no larger than your hand (or smaller) to full 19-inch rack-mountable units, and all require a power source. Some hubs are even "managed," meaning that you can telnet to them and configure each port's capabilities through a command-line interface. These hubs are naturally much more expensive than standalone hubs.

A hub is effectively a repeater, with all traffic appearing simultaneously on all ports, so a computer connected to one port on a hub will be able to see traffic to and from any other computer on the same hub. One port on a hub is usually reserved for uplinka link to another hub, a switch, or a router higher up in the network hierarchy, as laid out earlier in Figure 22.1. This "uplink" port is usually wired so that a crossover cable is not needed between the hub and its next upstream device. This port and one of the standard ports on the hub may also be wired so that they're mutually exclusive. A five-port hub might give you the option of hooking four computers together (ignoring the uplink port) or three computers to an upstream device (ignoring the fourth standard port). This behavior might be hard-wired, it might be controllable with a pushbutton or a DIP switch, it might autosense the polarity, or all the ports might be simultaneously usable. These are just some of the possible variations between different hubs.

Another matter that complicates the way hubs and other devices communicate with one another is the "duplex" mode in which they operate. In half-duplex mode, a host can only be "listening" or "talking" at one time. Full-duplex mode uses twice as many wires, enabling the host to "listen" and "talk" at the same time. Therefore, a 100Mbps Fast Ethernet link in full-duplex mode can transport up to 100Mbps on each direction simultaneously, whereas the same link in half-duplex mode can only do an aggregate total of 100Mbps in both directions.

Hubs can be thought of as a cheap replacement for switches, which we will discuss next. Because the cost of switches is dropping to nearly that of hubs, we may soon see the industry move entirely to switches, with hubs vanishing into obsolescence.

Note

If you have 1000base-T (Gigabit Ethernet) devices on your network, you can't use hubsGigabit Ethernet requires the use of switches, and Gigabit-capable switches are significantly more expensive than entry-level hubs. This is one reason why Gigabit Ethernet is still usually only found in business or university networks rather than the home.

Switches

A *switch* is another device that connects Ethernet devices together. A switch looks like a hub but tends to be more expensive and usually has fewer ports. It has multiple RJ-45 ports, it ranges from hand-sized to rack-sized, and the same companies that make hubs make switches, so it's easy to mistake one for the other on store shelves. They even operate somewhat similarlyyou can plug multiple devices into a switch, and a switch used in place of a hub in a network would usually give you what appears to be the same result. The difference between switches and hubs, however, is subtle yet crucial.

On a hub, all ports share the same internal wiring. All computers connected to the hub, either directly or through another hub, exist on what's known as a *collision domain*. In a collision domain, a signal sent to one computer gets sent to all computers within the domain. It's up to each computer's Ethernet card to identify signals destined for that computer's address and to discard all others.

A switch's internal wiring is much more complex than a hub's. Each port has its own unique wiring path connected to a common backplane and comprises its own collision domain, and hosts connected to one port can't see any traffic destined for hosts on any of the other ports. Switches incorporate the software necessary to read each packet's Ethernet header and destination MAC address (the unique identifier for each host's Ethernet card, as we will discuss later) and determine which port has the host that should get the packet. To make that determination, a switch stores an ARP cache, which is a lookup table of which hosts are on which ports. Managed switches, like managed hubs, have complete command-line interfaces and configurability, with the attendant high price and complexity. There are even VLAN switches, which connect multiple LANs together using many different kinds of cabling mechanisms.

Tip

You can often confuse a switch by moving a computer from one port to another, so it may be necessary to power-cycle the switch in this circumstance (which clears most switches' ARP caches).

Because each port on a switch has its own collision domain, switched network traffic is able to take fuller advantage of the available network bandwidth. To illustrate, consider a hub. An eight-port, 100base-TX hub with all ports in use has to divide the available 100Mbps among the eight ports. If all eight ports are simultaneously trying to do bandwidth-intensive tasks and their aggregate bandwidth demand is greater than 100Mbps, "collisions" become more common. In a collision, two ports try to transmit or receive traffic at the same time, resulting in retransmissions at the physical link level and performance well below each host's logical share of the available 100Mbps. Switches alleviate this problem. Whereas a 100Mbps hub has 100Mbps of internal wiring in total, an eight-port switch has 800Mpbs worth of wiringthe full bandwidth duplicated for every port. This is why switches tend to have fewer ports than hubs, and switches with many ports are quite expensive, especially for Gigabit Ethernet (whose switches often have full operating systems every bit as complex as FreeBSD itself).

Security and Switched Networks

A fully switched network gives you the added benefit that machines in one collision domain can't see any traffic in any other collision domain. As long as every host is on its own switched port, no eavesdropper on the local network can intercept any traffic not bound for his own computer.

Switches also protect your network from being overwhelmed by a single host that floods the network with an aggressive traffic flow, whether intentional or not, that uses all available bandwidth within the collision domain. Using switches rather than hubs, along with careful network planning, can greatly increase the network's reliability, security, and performance, thus making them worth the added cost.

Switches usually have no uplink ports. Occasionally, one or both ports have a pushbutton to select whether the ports need a straight-through or crossover cable. This is the case with some two-port switches, which serve purely as a filter to keep out irrelevant traffic. As a general rule, treat ports on a switch as hub-type devices and use crossover cables to connect one switch to another or a straight-through cable to connect a switch to a hub's uplink port. Most switches can auto-negotiate the speed and duplex mode of Ethernet cards, so you generally don't need to worry.

Routers

A router is the most complex (and expensive) of all networking devices. Routers have full operating systems and maintain tables that keep track of where entire IP networks can be found. Most small networks have only one router, at the "edge" of the network (the boundary between the LAN and the WAN that connects it to the Internet), specifying which network numbers indicate the LAN and which ones should be forwarded upstream into the WAN. You can have any number of routers in your network, though, each one managing a subnetwork and subservient to the topmost router.

What's more, routers throughout the Internet use a variety of protocols to communicate with one another and plot out what's the best way for a packet to get from one place to another. When you send out a packet, it travels upstream from router to router, until it reaches a router that knows where downstream to find your packet's destination network. That router sends your packet through the downstream route until it reaches the destination LAN and, ultimately, the destination host. Routing is the backbone of the Internet and possibly the most complex part of the way TCP/IP networking operates. You'll learn more about routing in Chapter 28, "Configuring an Internet Gateway."

Tip

You can see Internet routing in action by performing a `TRaceroute`; simply type **`TRaceroute`** ***`hostname`*** to get a listing of all the routers between you and your specified host as well as a reading of how quickly that router responds. This is also useful for seeing how well the routers are performing between you and your destination host. Here's an example:

[View full width]

```
# traceroute freebsd.org
traceroute to freebsd.org (216.136.204.21), 64 hops max, 40 byte packets
 1 dot7.orrc1.pf.example.com (203.152.186.253) 3.200 ms 0.632 ms 3.910 ms
 2 pos1-0-0.orrc5.pf.example.com (192.7.4.162) 1.055 ms 0.634 ms 0.572 ms
 3 gr-2-0-0-1.orpa8.pf.example.com (192.7.4.164) 1.862 ms 1.390 ms 1.426 ms
 4 so-1-0-0.orpa7.pf.example.com (192.7.4.230) 1.366 ms 1.003 ms 3.606 ms
 5 bas1-m.pao.yahoo.com (198.32.176.135) 1.211 ms 1.310 ms 1.378 ms
 6 ge-0-2-0.msr1.sc5.yahoo.com (216.115.100.233) 2.456 ms 2.413 ms ge-1-2-0.msr2.sc5.yahoo
   .com (216.115.101.230) 4.885 ms
 7 vl44.bas2-m.sc5.yahoo.com (66.163.160.222) 1.925 ms 2.295 ms 2.389 ms
 8 freefall.FreeBSD.org (216.136.204.21) 4.577 ms 2.107 ms 3.137 ms
```

Most routers have either one or two LAN-side ports, either RJ-45 jacks or AUI ports that require *transceivers*devices that translate the signal from one physical format to anotherto convert the interface to twisted pair. On the other side of the router is a serial cable that connects to the DSU/CSU or other such high-speed serial converter, beyond which you have WAN traffic. Routers vary greatly in size, complexity, number and type of ports, manageability, and price. Understanding how they work is one of the most important things you can learn in the networking world.

If you don't want to spend the money on a dedicated router, you can make one cheaply from any computer running FreeBSD, using the methods described in Chapter 28.

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Wireless Routers

Wireless routers, also known as wireless access points or base stations, are actually several networking devices at the same timethey comprise everything we've covered so far from the mechanism by which the computer is connected to the network (the wireless hub or switch) up to the routing mechanism for passing traffic up to the next router. Because they're generally inexpensive (less than $200), wireless routers don't give you the full capabilities of industrial-strength routers; rather, because most of these devices are designed to fit unobtrusively into a home or corporate network, they perform the minimum required duties of getting your computer's communications up to the next router on the way to the Internet (for example, a cable modem or a corporate LAN).

The IEEE 802.11 protocol is the wireless LAN communication standard. Two variants of this protocol are in wide use today: 802.11b (which transmits at 11Mbps) and 802.11g (which transmits at 54Mbps). 802.11g devices are favored today because of their greater speed and ability to support more simultaneous users than the older 802.11; however, all the computers on your wireless network have to support 802.11g, or else the network will revert to 802.11b as a lowest common denominator.

Note

802.11a is a variant protocol that supported 54Mbps communication at the same time that 802.11b was popular; but it did so by using a dedicated 5GHz radio frequency, rather than the 2.4GHz shared by devices such as microwaves and cordless phones. This higher frequency eliminated interference from those devices, but it also made it so that the wireless signal could be easily blocked by walls and had a much smaller overall range. 802.11g combines the speed of 802.11a with the range of 802.11b, the best of both worlds; but it means your wireless signal reception might suffer if you use a 2.4GHz cordless phone.

Because it doesn't depend on physical cables, a wireless network has an additional complicating factor beyond a wired one: security. The wireless router can be configured to require a password to allow a computer to join its network; it can also use encryption such as WEP (Wired Equivalent Privacy), or its stronger successors WPA (Wi-Fi Protected Access) or WPA2, to ensure that your wireless communications can't be decoded by an eavesdropper who might literally be hiding in your eaves with a laptop and a wireless card.

Many reputable companies make excellent wireless routers: D-Link, Netgear, Linksys, and Apple all have well-regarded and easy-to-use contenders. Some (like Apple's AirPort Express) even have additional features such as audio output, which lets them link into your stereo so you can beam music to it over the airwaves. Typical prices range from $100 to $200 or more, depending on the feature set; but if you're on a budget and adventurous, you can set up a FreeBSD machine as a wireless router, using the methods described in the "Configuring a Wireless Internet Access Point" section of Chapter 28.

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Network Protocols

I've mentioned that most Internet trafficHTTP, email, FTP, and so onuses TCP/IP as its transport protocol. *TCP/IP* itself refers to the combination of the most common "network" and "transport" protocols in use on the Internet. IP, the Internet Protocol, is the backbone of the vast majority of Internet trafficthe "network" layer of the TCP/IP stack. TCP, however, isn't the only commonly used "transport" layer protocol. There's also UDP, the User Datagram Protocol, which differs from TCP in a few key ways.

IP also isn't the only means of carrying traffic at the "network" level; it has a number of contemporaries, too, but they're mostly useful only on LANs. These include AppleTalk, IPX, NetBIOS, and so on.

Then there's ICMP, which exists partly on the "network" layer and partly on the "transport" layer; it's the mechanism by which the `ping` and `TRaceroute` utilities work. We'll talk about each of these protocols in some detail next.

The Transmission Control Protocol (TCP)

TCP is a two-way transmission protocol that's designed to be *reliable*not a subjective term, it describes a specific characteristic of its architecture. Unlike UDP, TCP has lots of built-in features to make sure the traffic it carries arrives properly at its destination. It also has features to divide large packets into appropriately sized fragments so as to transmit more efficiently.

TCP uses *retransmission* to provide reliability. Here's how a simplified version of retransmission works: When a TCP packet is sent over the network, a timeout period (three seconds at the connection's initialization) is set by the sender, which then waits for an acknowledgment (ACK) packet to come back from the other side. When it receives the ACK, the sender then proceeds to send the next packet. If the sender doesn't get the ACK within the specified timeout, it knows that either its own packet didn't make it or the acknowledgment packet got lost on the way back. The sender resends the packet and again waits for the ACK. This is a retransmission. The system keeps retransmitting until it reaches a set number of failures (usually five) and aborts the connection.

A TCP connection involves an active setup procedure in which both hosts at the endpoints of the connection exchange startup tokens; disconnection at the end of a flow involves a similar exchange. This means that, unlike UDP flows, TCP flows can be accurately tracked by the system and their state can be viewed using tools such as `netstat`. TCP has a number of other interesting features, such as bidirectional payloads (reply data carried in the ACK packets), a checksum that ensures the integrity of the data in the packet, automatic packet fragmenting and reconstruction, and out-of-order resequencing at the receiver level. These are all things that UDP doesn't door at least isn't required to do.

TCP is used in protocols in which data integrity is important and a connection can be ensured, such as web surfing, email, FTP, and the vast majority of other network applications.

The User Datagram Protocol (UDP)

UDP is a similar "transport" protocol to TCP, existing at the same layer in the OSI stack model; however, it differs from TCP in a number of key ways. The big thing to remember about UDP is that it's *unreliable*. There is no acknowledgment mechanism, no retransmission mechanism, and no true concept of a "connection." UDP packets can be broadcast to anyone on the network, if so chosen, or a selected set of recipients, regardless of whether they're expecting to hear anything. It's up to the recipients to catch the packets and do something with them.

UDP packets can get lost along the way from the sender to the receiver, and neither can have any way of knowing that it missed any packets. There are no sequence numbers in UDP as there are in TCP. A sender simply spews out the traffic, and the specified recipients can receive it or notit's up to them and the network. Any reliability in a UDP flow must be added by the application using it; an example of this is the

Network File System (NFS) protocol, which is described in detail in Chapter 33, "The Network File System (NFS)."

Note

Why would a file-management and transfer protocol such as NFS, with its obvious need for absolute data integrity, use UDP? The reason is that with NFS, many hosts on the network can be using an NFS resource, and any of them can drop off the network without warning. Rather than maintaining all the processing overhead necessary for keeping TCP connections with these ephemeral hosts, NFS chooses UDP as its transport and provides the data integrity necessary for file transfer at the application level. Information about the complete transfer is maintained in the packets' data, so NFS itself can know when it's missing any pieces, or if any are corrupt.

The biggest use for UDP these days is in streaming media. Teleconferencing, streamed video, broadcast musicthese protocols don't care if they miss a beat. They consist of long streams of datagrams (packets), usually very small ones, which are gathered in the order they're received by the application and then dumped to the screen or speakers. One lost packet probably won't even be missed. If network congestion occurs, the packets are simply lost at the router level (routers keep their own timeouts on their buffers), and the stream is resumed in real time when the host becomes available againand not where it left off. There's no reason to queue up all the missed packets and dump them through at once. They're irrelevant. That's the utility of UDP: speed and simplicity where reliability isn't important.

The Internet Control Message Protocol (ICMP)

ICMP is a small "diagnostic" protocol, mostly used in tools that gauge network health. Some consider ICMP to exist on the network layer, equivalent to IP and IPX; others treat it as a transport protocol like TCP or UDP. The truth is that it has elements of both. The messages received by ICMP are handled at the "network" layer, but these messages are built to interact with programs at the "transport" level, so it's difficult to say where it fits in the scheme of things.

The most common ways you'll use ICMP are with the `ping` and `traceroute` tools, both of which return information fundamental to the ICMP datagram structure. Mostly, they're built on ICMP's capability to query remote hosts for timestamps or echoes, which come back with specialized codes. ICMP can also be used to provide error messages to "transport" layer protocols, such as the "Port Unreachable" error returned by ICMP to a UDP sender that tries to talk to an unavailable port on the recipient's machine. ICMP has 16 of these error conditions it can report, as well as about as many additional functions. You generally won't need to know about them because they're really of interest only to the applications that can read them.

To see how TCP, UDP, ICMP, and other protocols fit into the OSI model, the best and most definitive reference is *TCP/IP Illustrated* by W. Richard Stevens (Addison-Wesley, 1994). This multivolume text is an indispensable addition to any network administrator's library; it uncovers all the relevant details of how the protocols interrelate and interoperate and presents key concepts in an understandable manner.

IP Addresses

The Internet Protocol enables computers on many disparate LANs to find their way to one another; this is accomplished through the hierarchical IP address system. If you've ever done anything on the Internet at all, you're probably familiar with IP addressesat least enough to know what they look like. An IP address is typically used as a way to refer to a specific computer on the Internet, although its meaning is actually a lot more flexible than "one IP address per machine." Most generally, it's a logical designation whose purpose is to locate a machine on the Internet so that IP routers can direct traffic between it and any other machine.

An IP address is a string of 32 bits in the IP header, which specifies either what machine a packet came from or where it is destined (both addresses are present in the header). The 32 bits can be thought of also as four 8-bit bytes, each of which is expressed as a number from 0 to 255hence, the familiar four-part dotted-decimal notation, of the form 111.112.113.114. This allows it to be treated hierarchically when dealing with Class A, B, or C subnets, as we will discuss next.

There are a few "special" IP addresses to keep in mind. First is the *network address*. This is an IP address in which one or more of its bytes are zero, such as `64.41.131.0`. If the final byte is a zero, the address is a synonym for the entire `64.41.131` network and is generally used only when configuring routers. More important is if one or more of the trailing bytes are 255 (all bits set to 1). This is the *broadcast address* for the network, an address that matches all hosts on that network as defined by the mask; for example, `64.41.131.255` matches all hosts on the `64.41.131.xxx` network, and `64.41.255.255` matches all hosts on the `64.41.xxx.xxx` network. A packet sent to the broadcast address will be received and processed by all hosts on the network, which is useful for finding out which host on the network has a certain Ethernet address. We will be discussing how these matching addresses work a little later when we discuss routing and subnets.

Subnets and the Network Mask

The *network mask* (or *netmask*), which travels hand in hand with IP addresses when you're configuring TCP/IP on a machine, is one of the most misunderstood parts of the whole structure, and yet potentially one of the most elegant when understood properly.

The purpose of the netmask is simply to tell a router or host whether a packet is supposed to go to the network it's on or go upstream to the next router. When a router receives an IP packet and it has to decide what to do with it, it checks the packet's destination IP address against its own netmask.

The netmask, a 32-bit string like an IP address, usually takes the form `255.255.255.0` (with a combination of `255` fields and `0` fields). Let's say you have a router managing the `64.41.131.xxx` network. The router receives a packet addressed for `64.41.131.45`. This address, in binary format, is matched against the netmask in an "and" fashion, where a resultant bit is set to 1 only if both addends are 1:

```
  0100 0000 0010 1001 1000 0011 0010 1101 (64.41.131.45)
+ 1111 1111 1111 1111 1111 1111 0000 0000 (255.255.255.0)
  0100 0000 0010 1001 1000 0011 0000 0000 (64.41.131.0)
```

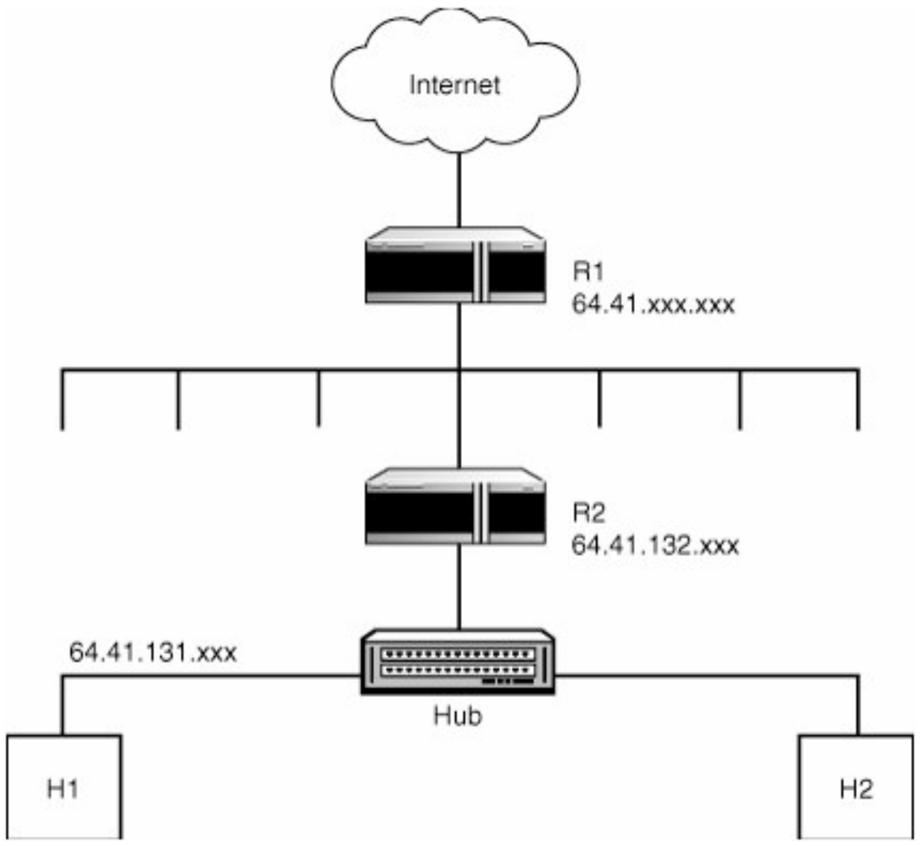
The result works out to `64.41.131.0`, the address of the network your router manages. This packet is thus a match and passed on to the network over Ethernet, destined for the target machine. Another packet now comes in, destined for `64.41.189.45:`

```
  0100 0000 0010 1001 1011 1101 0010 1101 (64.41.189.45)
+ 1111 1111 1111 1111 1111 1111 0000 0000 (255.255.255.0)
  0100 0000 0010 1001 1011 1101 0000 0000 (64.41.189.0)
```

This result does not match the router's network address, and the router passes the packet upstream to the next router.

This mechanism allows you to set up subnets within your network. Let's assume you have a Class B address range to work with (`64.41.xxx.xxx`). Your network's main router, R1, manages this entire range, but you can put a router (R2) inside this network to manage two Class C address ranges: `64.41.131.xxx` and `64.41.132.xxx`. Hosts in the `64.41.131` network can be plugged into the same hub as hosts in the `64.41.132` network, as shown in Figure 22.7, but they won't speak directly to each other if their netmasks are set to `255.255.255.0`, a Class C mask.

Figure 22.7. A network with subnets, demonstrating the packet path between two hosts whose netmasks don't permit them to communicate directly.



Destination IP addresses in sent packets won't match the senders' netmasks. However, if a sender host (H1) in `64.41.131` sets its netmask to a Class B mask (`255.255.0.0`), the addresses *will* match, and the sender would be able to send the packet directly to H2 (a host on `64.41.132`). However, note that H2 won't be able to send its replies directly back to H1 because its netmask prevents this! It has to send the reply back via R2, which has multiple network addresses and subnets bound to its internal interface. You'd need to set H2's netmask to `255.255.0.0` for it to talk directly to H1 without going through the router.

Netmasks don't need to be aligned on the byte boundary, either. For this reason, they're sometimes specified in pure hexadecimal format (for example, `0xffffff00` rather than `255.255.255.0`), as in the output of the `ifconfig` command in FreeBSD. You can specify a netmask of `0xffffffc0`, for instance, or `255.255.255.192`. This mask will match a network of 64 hoststhe ones between 1 and 64.

Another notation used in specifying networks that incorporates the netmask is Classless Inter-Domain Routing (CIDR), which takes the form of the network address, a slash, and the number of bits that make up the mask. For example, a mask of `255.255.255.0` on your `64.41.131` network would be written as `64.41.131/24` because the mask consists of three 8-bit bytes with all bits set to 1 (or 24 bits). The `255.255.255.192` example, likewise, would correspond to a notation of `64.41.131/26`. This notation is seen in routing tables and other places where succinctness is useful.

Working with IP Addresses

Typically, a single IP address is bound to a single physical port (or interface) on an Ethernet card; this is only by convention, though, and you can bind multiple IP addresses to a single card if necessary. The only constraint is that no two Ethernet interfaces on the same network can share the same IP address. Every interface needs to have at least one unique IP address to function. You might choose to install two Ethernet cards in your system in order to have access to two different networks at once, for example, or one address might be bound to an Ethernet card while another refers to your wireless 802.11 card. Many Ethernet cards have multiple ports, and each one can have one or more addresses assigned to it. What configuration you choose depends on how your network is set up.

You can find out the IP addresses of any Ethernet cards and other network interfaces in your system using the `ifconfig` utility, as shown in Listing 22.1. The `-a` option shows all devices, or you can specify a specific interface (such as `xl0`) to single out. The `inet` line shows a configured IP address; the `xl0` interface in this example shows multiple IP addresses bound to a single card.

Listing 22.1. Typical Output of `ifconfig`

[View full width]

```
# ifconfig -a
xl0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 64.41.131.102 netmask 0xffffff00 broadcast 64.41.131.255
        inet6 fe80::201:2ff:fe55:1256%xl0 prefixlen 64 scopeid 0x1
        inet 209.154.215.246 netmask 0xffffffff broadcast 209.154.215.246
        ether 00:01:02:55:12:56
        media: autoselect (100baseTX) status: active
        supported media: autoselect 100baseTX <full-duplex> 100baseTX 10baseT
   /UTP <full-duplex> 10baseT/UTP 100baseTX <hw-loopback>
lp0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
gif0: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
gif1: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
gif2: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
gif3: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet6 fe80::1%lo0 prefixlen 64 scopeid 0x7
        inet6 ::1 prefixlen 128
        inet 127.0.0.1 netmask 0xff000000
ppp0: flags=8010<POINTOPOINT,MULTICAST> mtu 1500
sl0: flags=c010<POINTOPOINT,LINK2,MULTICAST> mtu 552
faith0: flags=8000<MULTICAST> mtu 1500
```

IP Version 6 (IPV6)

Various groups, such as the KAME project (http://www.kame.net), have been working recently on incorporating support for the next generation of IP (version 6, or IPv6) into FreeBSD. IPv6 provides a 128-bit address space, with addresses effectively four times the size in IPv4 (the current version). The result is address space for 3.4x10^38 hostsa number that we're unlikely to reach anytime soon, to say the least. Also included in IPv6 are a number of other enhancements, such as built-in encryption and authentication, connection differentiation (with flow labels), complete auto-configurability of hosts, and the abandonment of several outdated parts of IPv4 that are no longer used.

IPv6 is catching on very, very slowly. Networks are expensive to build, and retrofitting them to be IPv6-compliant generally means replacing all existing equipment with newer, more expensive, less-mature hardware. Very few companies are willing to take that plunge just yet. But in the meantime, FreeBSD has full support for IPv6 and can take advantage of the various network resources currently available for IPv6.

Networking at the Ethernet Level

Every host is uniquely identified on the local network not by its IP address (which has no meaning at the Ethernet level), but by what's variously called the physical address, the hardware address, the Ethernet address, or the Media Access Controller (MAC) address. Every network interface device has a MAC address programmed into it at the factorya unique one, taking a form such as `00:01:02:55:12:56`. The MAC address is theoretically supposed to be useful as a "fingerprint" identifier for an Ethernet card (and, thereby, a computer) because no two Ethernet cards in the world ideally share one. (This doesn't work out in practice, though, because MAC addresses can be forged.) There is no routing mechanism for a MAC address as there is for an IP address. It operates entirely at the physical link level on a LAN and can't be forwarded by a router.

ARP, the Address Resolution Protocol, is what maps IP addresses to MAC addresses. If your application wants to send a packet to the IP address `10.5.6.100`, it sends the packet down the stack to the link layer. There, the stack consults the ARP cache, an OS-level table where known mappings between IP addresses and MAC addresses are stored. If the stack has never sent a packet to `10.5.6.100` before, that address won't be in the ARP table, and the TCP/IP stack must then perform an ARP query.

The ARP query is a broadcast packet, addressed to all Ethernet cards on the LAN (by setting the destination MAC address to `ff:ff:ff:ff:ff:ff`, or all bytes equal to 255, as with a broadcast IP address). The packet's payload is the IP address the stack is trying to look up: `10.5.6.100`. Every machine on the network receives this packet, but only the machine with the IP address being sought replies, telling the sender what the recipient's MAC address is. After the stack receives the reply packet, its IP address and MAC address go into the sender's ARP cache for future use. The packet is then sent by the sending machine's TCP/IP stack onto the network destined for the intended recipient's MAC address only.

Note

Earlier in the chapter, we talked a little bit about how switches keep their own internal ARP caches. Now that you know how ARP works, you can see how switches can keep track of which hosts are found on which ports through the use of ARP. A switch performs its own ARP queries to determine where to find a host to which it must send a packet it has received. After it adds that ARP information to its own cache, it can direct future traffic to that destination address more quickly.

Routing Between Networks Using ARP and MAC Addresses

ARP is very efficient for figuring out which packets should go where on a LAN; but what if the machine you're sending the packet to isn't on the same network as the sender? Well, that's where routers come into play. A router receives and replies to ARP packets like any other host. When a router looks up its IP address bindings to see whether it should reply to the ARP packet, however, it finds that its internal routes are set up to send everything except traffic destined for the LAN it manages out onto the WAN toward the next upstream router. The router's TCP/IP stack sees this as a claim that the router has all nonlocal IP addresses bound to its Ethernet card on the LAN. As far as the router is concerned, it *is* the computer you're looking for, and it replies to the ARP as though it were.

The following steps are involved in a packet's journey from one host to another across the Internet:

- A host wants to send a packet to a host with an IP address that's on a remote network, so it sends an ARP request for the machine with that IP address.
- The local gateway router, which has all nonlocal IP addresses bound to its MAC address, replies that it is the destination host.
- The sending host's Ethernet card sends the packet to the router.
- The router alters the sender MAC address in the packet's headers to match its *own* MAC address and then forwards the packet on over the WAN.
- The next router on the WAN receives the packet and performs a similar operation, setting the sending MAC address to its own and forwarding it on, until it reaches a router with a specific routing rule for the IP network that contains the destination host.
- The final router receives the packet, determines from the destination IP address and its own netmask that the packet is destined for a machine on its own network, and uses ARP to find out which machine the recipient is.
- The recipient host replies to the router with its own MAC address.
- The router alters the packet's recipient MAC address to match that of the recipient host and then sends the packet directly over the LAN.

Checking ARP Cache Contents with the `arp` Command

ARP is handled transparently by applications and the TCP/IP stack; you'll probably never have to actually initiate ARP commands by yourself. However, there are some occasions when you'll need to tweak the ARP cache. You can check the contents of the cache by using the `arp -a` command:

```
# arp -a
w001.sjc-ca.dsl.cnc.net (64.41.131.1) at 0:0:c5:7c:7:f0 [ethernet]
w013.sjc-ca.dsl.cnc.net (64.41.131.13) at 0:30:65:a4:9a:5e [ethernet]
w063.sjc-ca.dsl.cnc.net (64.41.131.63) at ff:ff:ff:ff:ff:ff permanent [ethernet]
```

Entries in the ARP cache do time out after a while, but there are times when you might need to clear the cache manually. Someone on the network might install a new Ethernet card in his machine and bind the old IP address to the new MAC address, which can make it unreachable if the old combination is still in your cache. You can delete cache entries by name, by IP address, or all at once (with `-a`):

```
# arp -d w001.sjc-ca.dsl.cnc.net
# arp -d 64.41.131.13
# arp -d a
```

Note

The `arp` command can be a useful tool for tracking down rogue DHCP servers that give out incorrect IP information to hosts on a dynamically allocated network. If your host gets a bad IP address, enter the `arp -a` command to find out the MAC address of the DHCP server. A well-managed network has all machines cataloged by their MAC addresses, so you can look up the offending machine from the output of `arp`. Even if a MAC catalog is not available, the MAC address can help you narrow down your search for an offending machineusing the first three segments of the address string, MAC addresses are keyed to particular Ethernet card manufacturers, which might lead you to a particular brand of computer.

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Routing

You've already learned a little bit about how IP routing works, but we'll now cover it in a little bit more detail. Configuring routes properly is one of the great skills one can develop in networking, and it pays to be able to do it correctlyor at least to have a working understanding of it so that you can perform administrative tasks that require interfacing with the routing table, such as `portsentry` (which we will discuss in Chapter 30, "Network Security").

A router is any device configured to act as a router, which includes actual dedicated devices sold by Cisco or its competitors, or regular computers that can do the job in a pinch. Routers work by maintaining a *routing table*a set of rules that says where packets that match certain IP address criteria should be sent. Because FreeBSD can be configured as a router, let's look at its routing tables as an example using the `netstat -rn` command (`-r` tells netstat to show the routing tables, and `n` says not to resolve IP addresses into hostnames):

```
# netstat -rn
Routing tables

Internet:
Destination        Gateway            Flags     Refs      Use     Netif Expire
default            hsrp-gw.netnation. UGSc       126  1379327      xl0
64.41.53.101/32    localhost          UGScB        0        3      lo0
net-64-40-111.netn link#1             UC           0        0      xl0 =>
ip3.example.com    0:50:ba:b3:98:13   UHLW         2   357107      xl0    735
ip4.example.com    0:50:ba:b3:95:bb   UHLW         0     2272      xl0    500
ip6.example.com    0:1:2:55:12:56     UHLW         0   118941      lo0 =>
ip6.example.com    localhost          UGScB        0        0      lo0
hsrp-gw.netnation. 0:0:c:7:ac:1e      UHLW       119     8814      xl0    405
64.77.63.139/32    localhost          UGScB        0        0      lo0
Toronto-ppp218408. localhost          UGScB        0        0      lo0
localhost          localhost          UH          45 45210727      lo0
goo.cs.und.nodak.e localhost          UGScB        0        0      lo0
```

Each line in this output is a *rule*. A routing rule specifies a particular destination and what should be done with traffic sent to that destination. The information in the routing table includes the following fields for each rule:

- *Destination* This can be an IP address, a hostname, a network address (which FreeBSD displays in CIDR format, as you can see in the preceding example), or one of several special destinations, such as the "default route." This field matches the destination address of any packet the machine doing the routing sees.
- *Gateway address* This is the "next-hop" router address where traffic to the specified destination should be sent. This can be a hostname or IP address, or for destinations on the LAN it can be a MAC address. FreeBSD also shows an entry for the `link#1` gateway, which is a route matching the network of the primary network interface, from which new routes can be cloned on use (hence the `C` flag).
- *Flags* This field specifies the type of route. Each letter represents a different flag, so this example shows routes with between two and five simultaneous flags. See `man netstat` for the meaning of each of the flags.
- *Network interface* When a packet matches a route in the table, it is passed out through this specified interface.

IP routing grew from the distributed, adaptive defense communications network envisioned by ARPA; therefore, its nature is to dynamically update these routing tables according to network conditions. The large telecommunications hubs maintain immense routing tables with many backup links from any one place to any other place. When one route is found to be unavailable, the routing table shuffles the entries around until traffic is redirected to a working route. The result is a system in which no single router has to know anything about the route to a packet's destination other than where its own nexthop router is. Any address that isn't local (in other words, any address that isn't on the network managed by that router) is passed upstream to the next-hop router, and so on, until the packet reaches a router that has an explicit entry in its routing tablewith the appropriate netmaskfor the network matching the packet's destination IP address. At that point, the packet is routed out that interface and hopefully to its destination (it might have to pass through several more routers, each with a more specific matching rule, on the way downstream to the destination host's network).

Routing Misconfiguration

IP routing is susceptible to misconfiguration. On the way upstream, the packet will keep moving upward until it finds an explicit match for its destination address. It's unlikely that a packet won't reach the backbone level without incident because someone would have to explicitly add a bogus route to the table in order to hijack the packet on its way up the chain of routers. However, after the packet starts downstream toward the destination, every router along the way must be properly configured to route to the network that the upstream routers think it's capable of routing to! A packet might start on its way downstream, only to find that the router that was supposed to have a further route for it to the destination actually *doesn't* have one. Naturally, without an explicit route for the packet, the router will pass the packet back to its upstream router, which will then send the packet back downstream again, beginning what is frequently referred to as a "router loop":

```
traceroute to example.com (209.237.26.189), 30 hops max, 40 byte packets
 1  r2-72-core-van.nx.com (10.10.4.253)  101.878 ms  135.377 ms  85.218 ms
 2  dis2-atm1.in.nx.net (206.108.110.189)  132.023 ms  80.653 ms  81.686 ms
 3  core2-1.in.nx.net (206.108.101.45)  102.365 ms  61.537 ms  68.561 ms
 4  core2.in.nx.net (206.108.102.209)  79.989 ms  109.389 ms  115.587 ms
 5  bx3-pos5-0.in.nx.net (206.108.102.202)  86.434 ms  109.678 ms  129.128 ms
 6  sea1-nx.above.net (208.184.233.73)  91.201 ms  67.287 ms  79.369 ms
 7  core2.above.net (208.185.175.178)  74.219 ms  79.480 ms  93.121 ms
 8  sjc2.sjc2.above.net (216.200.127.117)  188.692 ms  212.627 ms  181.123 ms
 9  core1.above.net (208.184.102.25)  195.260 ms  194.973 ms  272.053 ms
10  main1.sjc1.above.net (208.185.175.246)  344.104 ms  318.313 ms
11  core1.above.net (208.184.102.25)  195.260 ms  194.973 ms  272.053 ms
12  main1.sjc1.above.net (208.185.175.246)  344.104 ms  318.313 ms
13  core1.above.net (208.184.102.25)  195.260 ms  194.973 ms  272.053 ms
14  main1.sjc1.above.net (208.185.175.246)  344.104 ms  318.313 ms
15  core1.above.net (208.184.102.25)  195.260 ms  194.973 ms  272.053 ms
16  main1.sjc1.above.net (208.185.175.246)  344.104 ms  318.313 ms
17  core1.above.net (208.184.102.25)  195.260 ms  194.973 ms  272.053 ms
18  main1.sjc1.above.net (208.185.175.246)  344.104 ms  318.313 ms
```

This "bouncing" behavior will continue, preventing proper delivery of packets until the downstream router fixes its routing tables by adding the appropriate rule, allowing the packets to continue on their way downstream instead of bouncing back upstream. Fortunately, usually when this occurs it's because work is being done on the router that's at fault, and the condition is temporary, resolving itself when the backed-up routing tables are restored.

Gateways and Network Address Translation

A gateway is the router for a specific network, often used for translating addresses used by hosts on the LAN it manages to the addresses that the outside world sees. The term *gateway* is frequently used to mean *router*, and that isn't an inaccurate statement; we should clarify exactly what it means in today's parlance, though.

When you're configuring a machine's TCP/IP settings, you have to specify a gateway. This is simply the next-hop router for the machine you're configuring. H1 and H2 each have to have a gateway configured so that they can operate with hosts whose addresses don't match their netmasks. Generally, in this type of topology, the gateway would be R2. Depending on the type of router, H1 and H2 might not be able to reach

R1 directly. It's important to consider failure modes. If R2 should be shut down, it is unlikely that it would pass LAN traffic directly through; some network devices fail into a pass-through mode, but routers seldom fall into that category.

In another type of network topology, the subnets defined by R2 might be completely unlike the R1 subnet; for instance, R1 might specify the `64.41` network, but R2 would control subnets at `192.168.10` and `192.168.11`. In this case, it wouldn't do to set H1 or H2 to R1 as a gateway at all; traffic simply wouldn't reach it. The best practice is generally to set your machine's gateway to the nearest router and make sure the router is properly configured to pass traffic to the upstream router and to its managed subnets.

Note

Certain IP address ranges are "reserved" for specific private uses and cannot be assigned to hosts on public networksdata will not reach them. These ranges include `10.`*`xxx.xxx.xxx`* and `192.168.`*`xxx.xxx`*, which are commonly used in subnets and NAT topologies, and recommended for internal networks.

The traditional meaning of *gateway*, however, is the "edge device"the point at which LAN traffic passes out onto the WAN. This device, generally a router, is also where network address translation (NAT) can be done. The NAT daemon on the router specifies aliases for internal routes and their translated addresses on the outside, and vice versa. NAT can be done in a one-to-one, many-to-one, or one-to-many fashion.

To use FreeBSD as a NAT router, you will want to configure and run the `natd` daemon; we'll discuss this in more detail in Chapter 28.

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Hostnames and Domain Names

Now that you have an understanding of the way MAC addresses and IP addresses work, you can apply yet another layer of indirection to the host-finding process: hostnames and the Domain Name System (DNS). Hostnames assign human-readable names to machines that otherwise would only be identifiable by their IP addresses, and DNS is the mechanism by which those names are assigned.

Early in TCP/IP history, different networked machines were identifiable only by their IP addresses. This worked really well, until the number of online people grew so large that keeping track of all the numbers involved was tedious and error-pronenobody wanted to have to keep huge lists of IP addresses and what they all referred to. Hence the introduction of the Domain Name System, a means of assigning common names to IP addresses, resulting in the much easier-to-use system you know today.

DNS records are kept in a centralized database on multiple *root servers*the 13 "master" name servers that hold the definitive DNS information for all the Internetthat are maintained at various disparate corporate and university locations around the United States. These servers take their information from the DNS hosts they have designated as authoritative for any given domain name (for instance, `example.com`). Each domain's authoritative DNS keeps the records in a database of its own, which varies from implementation to implementation. FreeBSD, like most UNIXes, uses BIND, which keeps its records in `/var/named/etc/namedb`. We will discuss how to set up DNS on FreeBSD in Chapter 32, "The Domain Name Server."

Within a domain, every machine listed in the domain's DNS records has a hostname, or a simple machine name such as `tiger` or `pluto`. Combined with the domain, this results in a fully qualified domain name (FQDN), such as `tiger.example.com`.

Note

It is also possible for a domain name to be fully qualified without a subdomain or hostname attached. The hostname `example.com` is a fully qualified domain name, and a machine's IP address can be assigned to it.

What's important to understand for networking purposes is that the hierarchical structure of the domain name, hostname, and FQDN have no bearing on the hierarchical addressing conventions in IP addresses. The `example.com` domain can have hosts with IP addresses all over the mapthe DNS configuration just needs to point to them correctly. For instance, www.example.com can be `64.41.131.45`, and `ftp.example.com` can be `213.11.31.221`; it doesn't matter as far as TCP/IP is concerned. DNS is completely outside the TCP/IP stack.

Where DNS does come into play is at the application level, in which the hostname is used as an easier interface for the user than a bare IP address. A web browser, for example, takes a DNS name and passes it to the operating system, which translates it into an IP address transparently before it even tries to connect to the requested host. To put it into the terms we've been using throughout this chapter, the abstraction that DNS provides over IP addresses is analogous to the abstraction that IP addresses provide over MAC addresses. Just as ARP associates IP and MAC addresses for use by the data link layer, a name lookup associates hostnames and IP addresses for use by the network layer.

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The Dynamic Host Configuration Protocol (DHCP) and Automatic IP Addressing

The Dynamic Host Configuration Protocol assigns IP addresses to Ethernet interfaces on an as-needed basis. When an interface is to be configured by DHCP, it sends out a request at boot time to the designated DHCP server. This request, which is really a RARP query (analogous to ARP, but operating in reverse), carries the MAC address of the interface in question to the DHCP server, which responds with an IP address (and other network settings, such as the netmask) that it knows is available. The booting host then assigns this address to the interface, and the DHCP server sets up a "lease" period so that the host can boot with that same IP address on an ongoing basis.

We will be covering DHCP and how to configure FreeBSD for it in Chapter 35, "Dynamic Host Configuration Protocol (DHCP)."

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Chapter 23. Configuring Basic Networking Services

IN THIS CHAPTER

The last chapter offered a crash course in networking the TCP/IP way. None of it (or very little) was FreeBSD-specific or really told you how to go about setting up your system to do networking properly. The chapter did, however, lay the groundwork for the information you'll learn in this chapter. Here, you learn about the various tools you can use to configure TCP/IP.

We won't be talking about specialized network services (such as web/HTTP, mail/SMTP, FTP, and so on) in this chapter; those topics are covered individually in later chapters of the book. Right now, we'll focus on the basics: getting the machine to talk to its peers on your network.

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Configuring the Network Card

As you learned in the last chapter, a computer can have multiple Ethernet cards (interfaces), and each of these cards can have multiple IP addresses and related settings. The convention is for each machine to have one Ethernet card with one IP address, but there's no reason to limit yourself in that regard. This chapter shows you how to set up as many simultaneously installed cards as you like. You also learn how to bind as many IP addresses to each card as you see fit.

The first step is to make sure you have at least one Ethernet card that FreeBSD will work with. Table 23.1 lists all the cards (more specifically, chipsetscards from different manufacturers often use standardized chipsets that FreeBSD recognizes) that are supported in the `GENERIC` kernel. These cards comprise the vast majority of those used today, and your system should recognize any of these without any additional tweaking. The PCI cards are particularly well recognized by FreeBSD. A good many other cards are supported by FreeBSD but not included in the `GENERIC` kernel; drivers for these cards are usually available as kernel modules that are automatically loaded at boot time if necessary. For example, the `an` driver (for the Aironet Wi-Fi chipset) is available as `/boot/kernel/if_an.ko`. Refer to `/sys/conf/NOTES` (as discussed in the section "The `NOTES` Files and `LINT`," in Chapter 18, "Kernel Configuration") and recompile the kernel to include support for your card if you want to improve your system's boot time and stability by avoiding loading kernel modules.

Table 23.1. Ethernet Cards Supported in the Default (`GENERIC`) FreeBSD Kernel

Device Name	Cards Supported
PCI Cards	
`de`	DEC/Intel DC21x4x (Tulip)
`em`	Intel PRO/1000 adapter Gigabit Ethernet Card
`ixgb`	Intel PRO/10GbE Ethernet Card
`txp`	3Com 3cR990 (Typhoon)
`vx`	3Com 3c590, 3c595 (Vortex)
PCI/MII Cards	
`bfe`	Broadcom BCM440x 10/100 Ethernet
`bge`	Broadcom BCM570xx Gigabit Ethernet
`dc`	DEC/Intel 21143 and various workalikes
`fxp`	Intel EtherExpress Pro/100B (82557, 82558)
`lge`	Level 1 LXT1001 gigabit ethernet
`nge`	NatSemi DP83820 gigabit ethernet
`pcn`	AMD Am79C79x PCI 10/100 NICs
`re`	RealTek 8139C+/8169/8169S/8110S
`rl`	RealTek 8129/8139
`sf`	Adaptec AIC-6915 (Starfire)
`sis`	Silicon Integrated Systems SiS 900/SiS 7016
`sk`	SysKonnect SK-984x & SK-982x gigabit Ethernet
`ste`	Sundance ST201 (D-Link DFE-550TX)
`ti`	Alteon Networks Tigon I/II gigabit Ethernet

`tl`	Texas Instruments ThunderLAN
`tx`	SMC 9432TX (83c170 "EPIC")
`vge`	VIA VT612x gigabit ethernet
`vr`	VIA Rhine, Rhine II
`wb`	Winbond W89C840F
`xl`	3Com 3c90x (Boomerang, Cyclone)
ISA Cards	
`cs`	Crystal Semiconductor CS89x0 NIC
`ed`	Novell NE1000/NE2000, 3Com 3c503, SMC Ultra, DS8390 cards
`ex`	Intel EtherExpress Pro/10 and Pro/10+
`ep`	Etherlink III based cards
`fe`	Fujitsu MB8696x-based cards
`ie`	EtherExpress 8/16, 3C507, StarLAN 10, and so on
`lnc`	NE2100, NE32-VL Lance Ethernet cards
`sn`	SMC 9000 series
`xe`	Xircom PC-card Ethernet
Wireless (802.11) PCMCIA Cards	
`an`	Aironet 4500/4800
`awi`	BayStack 660 and others
`wi`	Lucent WaveLAN/Intersil/Symbol

Note

Be aware that the list of supported Ethernet cards changes fairly frequently. The devices are listed in the `GENERIC` kernel config file on your system, `/sys/i386/conf/GENERIC`. This will be the authoritative source for what cards are supported by your system.

Most Ethernet cards sold today for x86 hardware are PCI-based. This means that the PCI controller handles all the addressing automatically and you don't need to do any of the IRQ/DMA/memory address gyrations associated with ISA cards, the last of which was seen in the late 1990s. If you're stuck with one of these older cards, though, there are a few things you need to do, such as setting the card's memory address and IRQ through a DOS utility and modifying the device hints for the card. You learn more about these accommodations in the sidebar "Coping with ISA Ethernet Cards" later in this chapter.

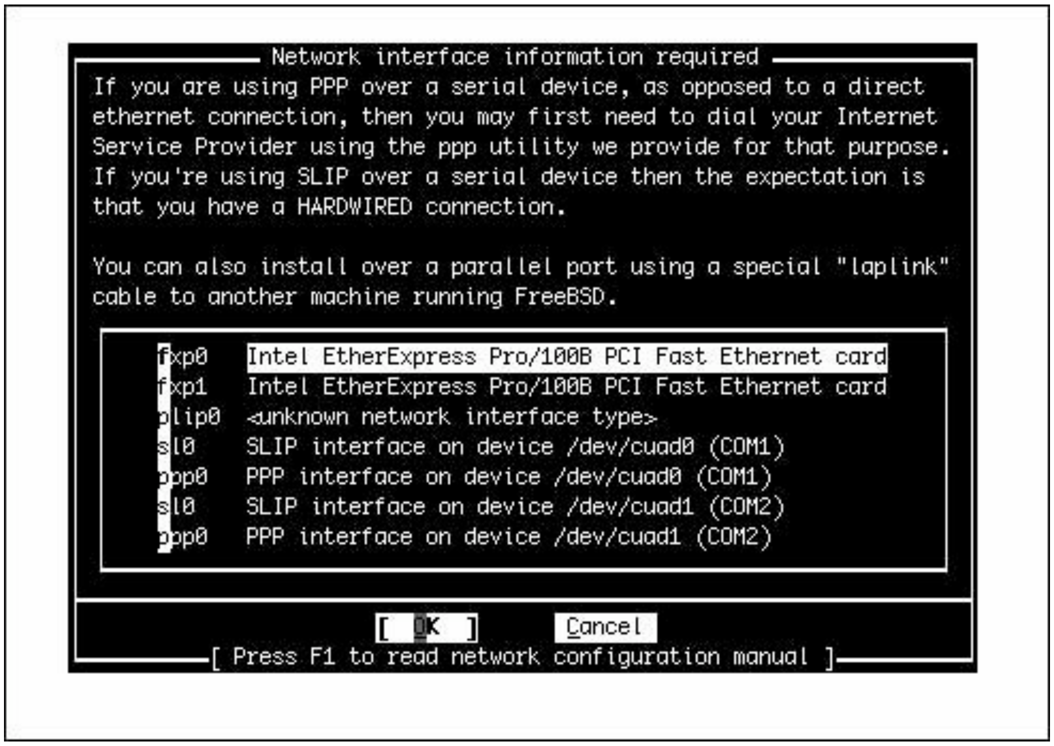
PREV NEXT

Configuring Network Settings with Sysinstall

The simplest way to configure your Ethernet card is by using Sysinstall. The Sysinstall method probably is familiar-looking to anyone who has gone through this process on a Windows or Macintosh machine. The first time you ask Sysinstall to do anything that requires a network connection (such as performing a network installation of the system, browsing packages, and various other tasks), it opens the network-configuration window, in which you can set the TCP/IP options for your Ethernet card visually.

If you're already up and running in multiuser mode and not in the initial system installation process, you can get to Sysinstall's TCP/IP configuration screen easily by running `/usr/sbin/sysinstall`, selecting Configure from the main menu, and then choosing the Media option. In this submenu, select FTP and some FTP server (it doesn't matter which; all you're doing here is triggering the network-configuration procedure, not installing any software). A dialog asks "Running Multiuser, Assume that the Network Is Already Configured?" Choose No to enter the network-configuration screens; the Network Interface Selection screen opens, as shown in Figure 23.1.

Figure 23.1. Selecting your Ethernet card in the Sysinstall program.

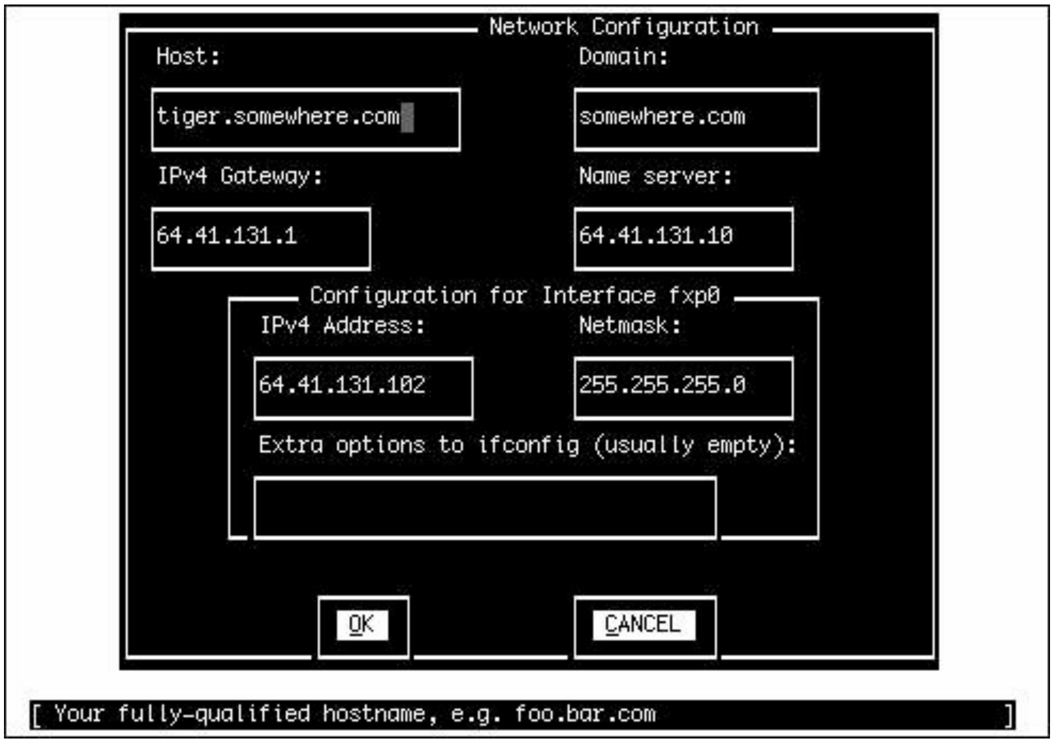


```
Network interface information required
If you are using PPP over a serial device, as opposed to a direct
ethernet connection, then you may first need to dial your Internet
Service Provider using the ppp utility we provide for that purpose.
If you're using SLIP over a serial device then the expectation is
that you have a HARDWIRED connection.

You can also install over a parallel port using a special "laplink"
cable to another machine running FreeBSD.

    fxp0   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    fxp1   Intel EtherExpress Pro/100B PCI Fast Ethernet card
    plip0  <unknown network interface type>
    sl0    SLIP interface on device /dev/cuad0 (COM1)
    ppp0   PPP interface on device /dev/cuad0 (COM1)
    sl0    SLIP interface on device /dev/cuad1 (COM2)
    ppp0   PPP interface on device /dev/cuad1 (COM2)

                 [  OK  ]        Cancel
       [ Press F1 to read network configuration manual ]
```

The Network Interface selection screen presents you with a list of the interfaces that FreeBSD has found in your system. You'll probably see a number of choices that don't make a lot of sense. In the figure, you can see choices such as `lp0` or `plip0` (the parallel port) and various PPP or SLIP options, and IPv6 devices such as `gif0` and `faith0`. You can ignore most of the options in the screen because the one you want is probably at the top. The one you're using in this example is `fxp1`, an Intel EtherExpress Pro/100B PCI card.

When you select your Ethernet card, you're given two dialogs: a choice to let the system try to configure the card automatically using IPv6 and then another choice to let it try using DHCP. Answer No to both of these. You're then presented with the visual Network Configuration screen, as shown in Figure 23.2.

Figure 23.2. The visual Network Configuration screen in the Sysinstall program.



```
Network Configuration
Host:                          Domain:
tiger.somewhere.com            somewhere.com
IPv4 Gateway:                  Name server:
64.41.131.1                    64.41.131.10
      Configuration for Interface fxp0
      IPv4 Address:            Netmask:
      64.41.131.102            255.255.255.0
      Extra options to ifconfig (usually empty):

            OK                 CANCEL
[ Your fully-qualified hostname, e.g. foo.bar.com ]
```

Tip

If your network is set up to use dynamically assigned IP addresses that are distributed using DHCP, you can choose Yes when prompted for automatic DHCP configuration and avoid a lot of the complexities of manually configuring your network. Refer to Chapter 35, "Dynamic Host Configuration Protocol (DHCP)," for more information on using DHCP both in a client and a server capacity.

Each field in this screen has a short description at the bottom of the window, but here's some further information about them:

- *Host* This is the hostname, which is just the first part of the machine's fully qualified domain name. For instance, if your machine is `simba.example.com`, the `Host:` field should be set to `simba`.
- *Domain* This is the rest of the domain name, or `example.com`. This can be a composite domain for

networks with named subnets, such as `cslab.ivyleague.edu`.

- *IPv4 Gateway* This is the IP address of your gateway router. Use the next-hop router closest to your machine, or whatever your network administrator or ISP identifies as your gateway address. If you are connected to the Internet via a DSL/cable modem or similar device, its IP address (which is assigned by the ISP) should be your gateway. This router will be responsible for transmitting any traffic between your machine and any other machines in the world. As you have learned in Chapter 22, "Principles of TCP/IP Networking," a gateway router must be on the same network as your FreeBSD machine's IP address, as defined by the netmask.

- *Name Server* The IP address of the most reliable domain name server (DNS) in your network. You should use the DNS provided by your enterprise, ISP, or university network if at all possible; remote name servers are useful as backups, but they won't necessarily be set up to service nonlocal requests reliably. Later in this chapter you will learn how to assign multiple name servers, if necessary.

- *IPv4 Address* This is the IP address you're assigning to your Ethernet card. It needs to be on the same subnet as your IPv4 gateway, as matched against your netmask. This was discussed in Chapter 22.

- *Netmask* This is used to determine whether a packet's destination is on the local network. Set the field to `255.255.255.0` for a Class C network, which is the most commonly used netmask in most home configurations. Consult your network administrator to make sure what this number should be.

- *Extra options to `ifconfig`* You most likely won't need to put anything in here unless you're a power user looking to tweak the performance of your interface card. Anything you put in here, such as specifying particular media types or duplex modes, will be added to the `ifconfig` command line that Sysinstall issues in the background. You learn more about this command in "Using `ifconfig` to Apply Network Settings," later in this chapter.

After you've set all these options, select OK. The network settings will be applied to the card on the fly. Whatever you were doing in Sysinstall continuesin this example, Sysinstall connects to your selected FTP server. If the network configuration isn't successful, there's likely a problem with the network settings you entered, and you'll have to go back in and troubleshoot your settings. If you're in an enterprise network, ask your network administrator to give you the correct settings.

This process works in much the same way if you're doing a first-time installation of FreeBSD (as you saw in Chapter 2, "Installing FreeBSD"). You are presented with this configuration screen early in the install process. If you're doing a network installation, it will use the settings to pull down the system distribution from the central server.

Coping with ISA Ethernet Cards

Most PCI Ethernet cards, which describes nearly all Ethernet cards sold today, are very troublefree. All you really need to do, especially if you have one of the commonly used cards supported in the `GENERIC` kernel, is plug it in, power up the machine, and watch the kernel identify the card in the boot process:

[View full width]

```
fxp0: <Intel PLC 10/100 Ethernet> port 0xde80-0xdebf mem
    0xff8fe000-0xff8fefff irq 11 at device 8.0 on pci1
fxp0: Ethernet address 00:d0:b7:c7:74:f1
fxp1: <Intel Pro 10/100B/100+ Ethernet> port 0xdf00-0xdf3f mem
   0xff700000-0xff7fffff,0xff8ff000-0xff8fffff irq 11 at device 9.0
    on pci1
fxp1: Ethernet address 00:d0:b7:bd:5d:13
```

However, if you're working with an old ISA card, the process can be trickier. ISA cards are set to a certain memory address and IRQ (interrupt request) number, and you have to pick values for both of them that aren't already used by some other device. Most Ethernet cards have a memory address of 0x300 or 0x280 and an IRQ of 9 or 10. Installing more than one of these cards means you have to configure the additional card to use an unused slot. Here's the really sticky part: This card configuration usually has to be done with a DOS utility that comes with the card.

First check your FreeBSD kernel for the IRQs and memory addresses already in use; use a command like `grep "irq" /var/run/dmesg.boot` to find all the kernel devices that have claims on IRQs. Pick a number between 1 and 15 that isn't already in use as the IRQ to assign your Ethernet card. Assume that the memory location `0x300` will work unless you see that string claimed anywhere in the `dmesg` output.

If you have the card's original driver disks, boot into MS-DOS (or FreeDOShttp://www.freedos.org) with a DOS "rescue" floppy disk and then run the card's diagnostic program. An Ethernet card's bundled software typically has a selection of common memory addresses and IRQs to set the card to use; enter the IRQ and memory address you settled on earlier, set the card's firmware, and boot back into FreeBSD.

You might also need to alter the "device hints" (described in Chapter 18) for your card. These hints, kept in `/boot/device.hints`, control where FreeBSD expects to find the device. You can tweak them to match your card by editing that file. You should find lines such as the following:

```
hint.ed.0.at="isa"
hint.ed.0.port="0x300"
hint.ed.0.irq="10"
```

Modify the port (memory address) and IRQ lines to match the settings of your card and then reboot to activate it.

All this said, thoughEthernet cards are very cheap nowadays, and just as with the older serial mice that FreeBSD still dutifully (but inelegantly) supports, you're probably much better off just buying a cheap PCI Ethernet card and using that instead.

Configuring Network Settings Without Sysinstall

Using Sysinstall to configure your cards makes things easy in some ways; it's nice and visual, for instance, and it does everything in one place. But configuring with Sysinstall is a less-than-versatile option for many of the networking tasks you may need to do. You can access and modify the network settings more directly from the command line. Naturally, you must be root in order to run these commands in a way that alters the system's configuration; also, you should perform these steps from the physical console, because any misconfigurations will cause you to lose connectivity to the machine.

Caution

Some of the functions we'll be discussing cannot be done in Sysinstall, such as adding IP aliases and modifying the routing tables. In fact, if you have a customized IP setup (for example, a card with many IP aliases bound to it) and then you do an additional configuration of the card using Sysinstall, you might lose your customized settings. Be aware that Sysinstall is useful for the most basic and common of configuration tasks, but it should be avoided for more complex situations, for which it is not intended.

Using `ifconfig` to Apply Network Settings

The interface configurator, `ifconfig`, is the multipurpose tool for applying network settings on the fly. Its main purpose is to assign an IP address to an Ethernet card (interface), although, as with most other UNIX tools, it can do a lot more. Here, we cover the most frequently used functions of `ifconfig`; check the `man ifconfig` page for further information.

First, let's use `ifconfig` to gather information on our network interfaces. In the previous chapter, you saw an example of `ifconfig -a`, which shows all interfaces and tells you which ones are available. Using `ifconfig -a` provides an easy way to find out whether your Ethernet driver is `ed0`, `fxp0`, `xl0`, or whatever. After you know, you can specify that device name as a parameter to `ifconfig` to just get that interface's settings:

```
# ifconfig fxp1
fxp1: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        options=8<VLAN_MTU>
        inet6 fe80::2d0:b7ff:feaa:11a9%fxp0 prefixlen 64 scopeid 0x1
        inet 64.41.131.102 netmask 0xffffff00 broadcast 64.41.131.255
        ether 00:d0:b7:aa:11:a9
        media: Ethernet autoselect (100baseTX <full-duplex>)
        status: active
```

Caution

We're about to go through a few configuration examples that will almost certainly cause your Ethernet interface to lose connectivity to any connected sessions. If you want to try out the functionality of `ifconfig` on your own machine, do it from the physical console rather than when you're connected via Telnet or SSH!

If you want to only change your IP address, use the following command:

```
# ifconfig fxp1 64.41.131.103
```

That's all there is to it. However, note that if you don't specify a netmask, it's assumed you're setting a Class A addressand the netmask and broadcast address are set accordingly, as you can see in the updated `ifconfig fxp1` output:

```
     inet 64.41.131.103 netmask 0xff000000 broadcast 64.255.255.255
```

Let's try this again, but this time let's make it a Class C addresswhich means that you'll need to set your netmask, too. You do this with the `netmask` keyword in combination with the IP address. Note that `ifconfig` accepts netmasks in hex notation, in dotteddecimal notation, or by a symbolic name defined in `/etc/networks`. Therefore, the following commands are equivalent:

```
# ifconfig fxp1 64.41.131.103 netmask 255.255.255.0

# ifconfig fxp1 64.41.131.103 netmask 0xffffff00

# ifconfig fxp1 64.41.131.103 netmask my-netmask
```

You can also specify the broadcast address, although this generally isn't useful except in really exceptional networks. Note that although the broadcast address is automatically extrapolated from the IP address and netmask if you omit it (as discussed earlier), the reverse is not true: Omitting the netmask makes `ifconfig` assume a Class A mask. If you have to set the broadcast address, make sure you set both it and the netmask at the same time:

```
# ifconfig fxp1 64.41.131.103 netmask 255.255.0.0 broadcast 64.41.255.255
```

One final trick that `ifconfig` can use involves the `media` keyword, which allows you to make the card switch between the various listed media types. This capability is very handy if you have a card with multiple interfaces and you want to switch from the BNC connector to the RJ-45 (UTP) connector or from the RJ-45 to the AUI connector. If you have a 10/100 Ethernet card and an auto-sensing hub that has auto-negotiated a speed of 100Mbps full-duplex with your card, you can force it into 10Mbps mode with the `media` and `mediaopt` keywords. Take a look at what `ifconfig fxp1` reports to be the supported media types (the following is a typical example):

```
     media: Ethernet autoselect (100baseTX <full-duplex>)
```

This example tells you that you're in auto-select mode. In that mode, the card negotiates the highest possible speed with the hub or switch to which it's connected, which in this case is 100Mbps full-duplex. Let's set it instead to 10Mbps mode (assuming, for instance, that you're connecting it to a 10base-T hub that can't auto-negotiate the speed, or that auto-negotiated it incorrectly when you connected it).

Each Ethernet driver has a `man` page. Consult this page to find out what media types and keywords are supported by the card. In this case, `man fxp` tells you the following:

```
     The fxp driver supports the following media types:

     autoselect            Enable autoselection of the media type and options
     10baseT/UTP           Set 10Mbps operation
     100baseTX             Set 100Mbps (Fast Ethernet) operation

     The fxp driver supports the following media options:
```

```
    full-duplex           Set full duplex operation
```

This tells you that the keyword for 10Mbps operation is `10baseT/UTP`, and that there's an option of `full-duplex` that you can set if you choose to (using the `mediaopt` keyword). Here's how to set this interface to each of the two available 10BaseT/UTP modes:

```
# ifconfig fxp1 media 10baseT/UTP
# ifconfig fxp1 media 10baseT/UTP mediaopt full-duplex
```

If you're doing this on a machine that's near the hub or switch where the Ethernet cable is plugged in, or if you can see the back of the computer, check the lights on the card. You should see that the "100" light has gone out, indicating that the connection has renegotiated to 10Mpbs mode. Here's how to switch back again to the previous mode:

```
# ifconfig fxp1 media autoselect
```

Recall that full-duplex mode is where the card can both read and write at the same time, so 10base-T in full-duplex mode means 10Mbps total in *each* direction. Half-duplex mode means a maximum of 10Mbps as the aggregate total of *both* directions. A hub can't do full-duplex mode. You need a switch if you want to take full advantage of full-duplex mode.

Using `route` to Set the Gateway Router

We've now covered `ifconfig` in as much detail as you're likely to need. However, we haven't yet touched on how to set the gateway router or the DNS information from the command line, both of which are functions that the network configuration screen in Sysinstall handles all at once. First, let's talk about gateway routers.

You don't set the gateway in `ifconfig` because a gateway address isn't bound to an individual Ethernet interface. Instead, FreeBSD's routing tablewhich allows the system to function as a full-fledged router in its own right (something you'll see how to do in Chapter 28, "Configuring an Internet Gateway")has a single "default" route that receives all traffic not destined for any of the LANs accessible from your Ethernet cards, regardless of how many such cards you have. This default route is what you set to specify your gateway router.

The `route` command is another large and complex beast, more so than `ifconfig`, in fact. However, because you're not actually setting up any routes right now, you need to concern yourself only with its most fundamental functions: the `add` and `delete` keywords.

Note

As long as you're on the same LAN as the FreeBSD machine, you can modify the routesincluding the default routewithout losing network connectivity. If you're going through these examples while connected via Telnet or SSH, you may have accidentally disconnected yourself with the `ifconfig` examples. This won't happen if you're just setting the router address, as long as there aren't any routers between you and the FreeBSD machine.

Advanced users might want to hedge their bets by setting up a second IP address with its own dedicated route as a "recovery" method for accessing the machine in the case of lost connectivity. For example, a web server on a DMZ might also be assigned a `192.168.`*`xxx.xxx`* address so it can be accessed from the internal LAN.

The first thing to do is to check the output of `netstat -rn`. The `netstat` tool displays the state of the routing tables and other network information; the `r` option tells it to show the currently configured routes, and `n` says to show the addresses numerically (rather than trying to resolve them into hostnames, which can be time-consuming and can confuse the tabular output). This will show what default route is currently set, if any:

```
# netstat -rn
Routing tables

Internet:
Destination        Gateway            Flags     Refs     Use     Netif Expire
default            64.41.131.1        UGSc        1        1     fxp0
...
```

It seems you already have a gateway router set. This will almost certainly be the case whether the network is running properly or not; there is little error-checking in `route`, and it's pretty easy to set up a default route that would be unreachable from any of your LANs. The system might also set up a dummy default route. In any case, setting a new router address is a two-step process: You must first delete the existing default route and then you must add the new one:

```
# route delete default
delete net default
# route add default 64.2.43.1
add net default: gateway 64.2.43.1
```

Note

It's worth pointing out that the `route` command is one of those parts of UNIX that gives people fits because it's implemented differently on almost every single UNIX variant on the planet. The differences are subtle and syntactical; although the functionality is pretty much the same whether you're on FreeBSD or Linux or Solaris or IRIX, the way you access that functionality is maddeningly varied. To get an idea of this lack of standardization, install `portsentry` (from `/usr/ports/security`), and look through `/usr/local/etc/portsentry.conf`. It lists no fewer than nine different ways (on nine different platforms) to use `route` to set up a "blackhole" route. It's a bit ridiculous, but that's part of the price we pay for the flexibility we demand from UNIX.

Using `hostname`

Setting your machine's hostname is dead simple. All it involves is the `hostname` command, with the desired hostname (as a fully qualified domain name) as its argument:

```
# hostname tiger.example.com
```

You can also print out the currently set hostname in either fully qualified or standalone format:

```
# hostname
tiger.example.com
# hostname -s
tiger
```

Network Settings in `/etc/rc.conf`

Now that you have command-line tools at your disposal for setting the IP address, netmask, hostname, and gateway router, and now that you've seen how to set them manually on a one-time basis, it's time to make sure the system takes care of all that for us. That's what `/etc/rc.conf` is for, as you'll no doubt recall from Chapter 14, "System Configuration and Startup Scripts."

Recall that the system's default settings are in `/etc/defaults/rc.conf` (which shouldn't be touched), and any overrides that supersede those defaults go into `/etc/rc.conf`. If you look in the defaults file, you'll find vague, generic, disabled settings for the various TCP/IP options. You'll be enabling your Ethernet cards permanently by putting everything relevant into `/etc/rc.conf`. If you've configured the card using Sysinstall (as we discussed earlier in the chapter), there will already be some settings in the file, such as the following (a block of "deltas" is added each time you use Sysinstall to change the configuration):

```
#-- sysinstall generated deltas -- #
ifconfig_fxp1="inet 64.41.131.102 netmask 255.255.255.0"
defaultrouter="64.41.131.1"
hostname="tiger.example.com"
```

Tip

The order in which these options are specified doesn't matter; the startup scripts read them all into variables at once. However, later repetitions of the same variable take precedence over earlier ones.

The values written into the file by Sysinstall include the following:

- `network_interfaces`, which sets an explicit list of the interfaces on your system (older versions of FreeBSD only)
- An `ifconfig_`*`xxx#`* line for each interface, which is the argument string that is passed to `ifconfig` by the configuration scripts for each card automatically detected by the kernel or specified in `network_interfaces`
- `defaultrouter`, which sets just what you think it does
- `hostname`, which is the fully qualified domain name

All these values are read into the resource configuration scripts when the system boots and are passed to the appropriate utilities (`ifconfig`, `route`, and `hostname`) automatically.

Perhaps you're wondering: What about DNS? We'll be getting to that shortly. DNS isn't really a part of the TCP/IP stack configuration; it's an application-level helper service, consulted independently by networking applications before any connections are really initiated, and you don't need it in place to get networking up and running.

Using `/etc/netstart`

A nice courtesy provided by FreeBSD is the `/etc/netstart` script. It's not a necessary part of the boot-time configuration process, and it can safely be removed from your system without hurting anything (although that would be silly, considering how useful it is). At one time, most network services were started explicitly within `/etc/netstart`. Back in the days when administrators had to edit scripts to add new services, it was a crucial part of the resource configuration process. Now, though, in keeping with FreeBSD's modern ideal of having each individual system function controlled by a separate script in `/etc/rc.d` and launched automatically at boot time, the `/etc/netstart` script is just a batch file that executes all of the appropriate network-related startup scripts at once. (You can examine the script's contents using `cat` or `more` to see which scripts it invokes.)

The various command-line tools that we've just discussed`ifconfig`, `route`, `hostname`, and the likeare all run from within `/etc/rc.d/netif`, subject to various conditionals and consistency checks, and with syntax built up from the various global config files to prevent input errors and potential illegal maneuvers. For everyday networking changes, `/etc/netstart` is the best and safest way to activate networking configuration changes, rather than running the various commands individually.

There's a caveat, however. The `/etc/netstart` script invokes `/etc/rc.d/routing` to set the default gateway using the `route` command, as you've seen; however, you can't add a new default route without deleting the old one first. The `/etc/rc.d/routing` script doesn't issue a `route delete default` commandbecause it's designed to run at boot time, it shouldn't need to. So to use `/etc/netstart`, you have to delete the default route first. This makes using `/etc/netstart` a two-step process, as shown in Listing 23.1.

Listing 23.1. Restarting the Network Using `/etc/netstart`

```
# route delete default
delete net default
# /etc/netstart
Doing stage one network startup:
Doing initial network setup:.
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet6 ::1 prefixlen 128
        inet6 fe80::1%lo0 prefixlen 64 scopeid 0x3
        inet 127.0.0.1 netmask 0xff000000
fxp0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        options=8<VLAN_MTU>
        inet6 fe80::2d0:b7ff:feaa:11a9%fxp0 prefixlen 64 scopeid 0x1
        inet 64.41.131.101 netmask 0xffffff00 broadcast 64.41.131.255
        ether 00:d0:b7:aa:11:a9
        media: Ethernet autoselect (100baseTX <full-duplex>)
        status: active
add net default: gateway 64.41.131.1
Additional routing options: tcp extensions=NO TCP keepalive=YES.
Routing daemons:.
```

This will work fine if you're on the same LAN as the FreeBSD machine or logged in at the console. You may have noticed, however, that this will contain a nasty trap if you're controlling the machine from elsewhere in the Internet. When you delete the default route, you effectively make the machine unable to communicate with you further, so you can't issue the `/etc/netstart` command (which re-enables the default route).

A trick to get around this is to put both commands on the same line, separated using a semicolon (`;`). This is risky because it still has the potential to result in a few dropped response packets. If everything is configured properly in `/etc/rc.conf`, however, your terminal connection will pick back up where it left off after just a brief hiccup:

```
# route delete default; /etc/netstart
```

PREV NEXT

Creating IP Aliases

There's nothing to stop you from assigning as many IP addresses as you want to an Ethernet card. Recalling the discussion of ARP from the previous chapter, a new TCP/IP connection looks up a LAN host by its IP address, asking for the MAC address of whatever Ethernet interface has that IP address. It doesn't do the reverse. One MAC address can answer for many different IP addresses, but one IP address can't be assigned to multiple Ethernet cards without errors and collisions resulting.

The way to assign multiple IP addresses to a single card is through *IP aliasing*. As with the `route` command, every platform does aliasing slightly differently, and the syntax varies from system to system. On FreeBSD, `alias` is used as a keyword to `ifconfig`, appended after the address and all other parameters:

```
# ifconfig fxp1 64.41.131.103 netmask 255.255.255.255 alias
```

Note that the netmask is set to `255.255.255.255`. This is required if the alias IP address is on the same subnet as the primary IP address for that interface. (If it's not, just use the regular netmask you would use for that subnet.) What does this mean from a TCP/IP standpoint? A netmask where all the bits are set to 1 ensures that the TCP/IP stack will only treat a packet where the destination address matches in all its bits as though it's on the local subnet; the netmask is creating a "subnet" of just that one address, as you can see by doing the binary math to match the address with the netmask:

```
  0100 0000 0010 1001 1000 0011 0110 0111 (64.41.131.103)
+ 1111 1111 1111 1111 1111 1111 1111 1111 (255.255.255.255)
  0100 0000 0010 1001 1000 0011 0110 0111 (64.41.131.103)
```

Thus only packets explicitly addressed to that address are accepted. All packets to and from that address are sent to the router and not to the LAN. If multiple aliases had the same netmask, their broadcast addresses would be the same, which would confuse the TCP/IP stack. Using an all-1's netmask is how you trick `ifconfig` into allowing multiple IP addresses on a single interface.

To set up IP aliases in your `/etc/rc.conf`, you would use the `ifconfig_xxx#_alias#` keyword, which works syntactically just like `ifconfig_xxx#`. Here's how a set of aliases in `/etc/rc.conf` might look:

```
ifconfig_fxp1="inet 64.41.131.131 netmask 255.255.255.0"
ifconfig_fxp1_alias0="inet 64.41.131.132 netmask 255.255.255.255"
ifconfig_fxp1_alias1="inet 64.41.131.133 netmask 255.255.255.255"

ifconfig_fxp1_alias2="inet 64.41.131.134 netmask 255.255.255.255"
ifconfig_fxp1_alias3="inet 64.41.132.161 netmask 255.255.255.0"
ifconfig_fxp1_alias4="inet 64.41.132.165 netmask 255.255.255.255"
ifconfig_fxp1_alias5="inet 64.41.132.166 netmask 255.255.255.255"
```

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Mapping Names to IP Addresses with the /etc/hosts File

You need a way for hostnames to map to IP addresses. Normally, this is done with DNS, but you don't have DNS set up yet. In the meantime, you can provide mappings for hosts you know aboutsuch as hosts on our local networkwith the `/etc/hosts` file.

`/etc/hosts` allows you to build a table in which each entry lists an IP address, its most common (or "official") hostname, and any aliases (additional names that map to the same IP address). Each of these items is separated by spaces or tabs. This table is consulted before any DNS queries are made, so `/etc/hosts` acts both as a backup to DNS (if it's not available) and an override (if it's not serving correct information). The aliases can even be used as a shorthand for favorite hosts whose names you don't want to have to remember, as with shell aliases (which we discussed in the "Shell Initialization Files" section of Chapter 9, "Customizing the Shell").

Here are a few sample lines from `/etc/hosts`:

```
64.41.131.132       ns              ns.example.com lion.example.com
64.41.131.133       www2            www2.example.com
64.41.132.165       www3            www3.example.com
114.235.123.11      www.foobar.com  fred
```

With this table in place, you can connect to the listed hosts by nameeither the "official" name in the second column or any of the aliases listed in the third columneven if no DNS servers can be reached.

Caution

You should remove host entries from your `/etc/hosts` file once they're reachable properly with DNS. The reason for this is to aid in support and troubleshooting later; if you have trouble connecting to a certain host, you might waste hours in fruitless tinkering before realizing that you had hard-coded an IP address into `/etc/hosts` rather than relying on DNS.

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Testing Network Connectivity with `ping`

After you've finished your network configurations, setting them either in Sysinstall or with `/etc/netstart`, you can use `ping` to make sure the settings are correct. The `ping` program is a simple ICMP-based tool that checks for echoes from a specified host and reports the roundtrip time it takes each packet to get to the host and back.

The use of `ping` is pretty simple. You can run it against either an IP address or a hostname (or `/etc/hosts` alias), and it will run until you interrupt it with Ctrl+C:

```
# ping fred
PING fred (114.235.123.11): 56 data bytes
64 bytes from 114.235.123.11: icmp_seq=0 ttl=243 time=485.344 ms
64 bytes from 114.235.123.11: icmp_seq=1 ttl=243 time=351.589 ms
^C
--- fred ping statistics ---
2 packets transmitted, 2 packets received, 0% packet loss
round-trip min/avg/max/stddev = 351.589/418.466/485.344/66.877 ms
```

This is a healthy TCP/IP configuration because the specified host replied to the ping. However, if the host isn't reachable, the ICMP packets will time out and report the failure to connect. If this happens, something's wrong with your configuration (alternatively, the remote host might actually be down, so make sure to try multiple target hosts). The following shows a `ping` attempt that fails to reach its target:

```
# ping 64.41.131.133
PING 64.41.131.133 (64.41.131.133): 56 data bytes
ping: sendto: Host is down
ping: sendto: Host is down
ping: sendto: Host is down
ping: sendto: Host is down
^C
--- 64.41.131.133 ping statistics ---
10 packets transmitted, 0 packets received, 100% packet loss
```

Other reasons `ping` might fail include a firewall that's configured to block ICMP (a common configuration on publicly accessible networks, due to security concerns), or a router that's overloaded (ICMP packets are discarded readily by routers under load, because they're non-essential traffic). If you can't reach a host, it's a good idea to try connecting with Telnet to a port on the host that's known to be open, such as **`telnet 64.41.131.133 25`** to reach the SMTP port.

Configuring DNS with the `/etc/resolv.conf` File

To use true DNS, you need access to at least one domain name server. It doesn't matter where this server ismost name servers are configured to allow queries from anywhere on the Internet, with no restrictions on who makes the queries. This practice is on the wane, however, and in most circumstances you will want to use only the name server addresses provided by your ISP or enterprise network administrator.

Name servers are specified in the `/etc/resolv.conf` file, an example of which follows:

```
search example.com
nameserver 64.41.131.132

nameserver 207.78.98.20
nameserver 64.40.111.102
```

The `nameserver` keyword specifies a name server's IP address; you can have as many of these as you like, and the order in which they're listed is the order in which they're consulted. If one times out, the next server is queried. Many applications have their own internal timeouts on a DNS query that gets passed to the operating system to handle, though, so servers beyond the third or fourth probably won't provide much additional benefit.

The `search` keyword specifies the search domainthe string appended to hostnames that aren't fully qualified. For instance, if you were to do an `nslookup www`, the resolver would attach the `search` domain and perform the actual query on `www.example.com`. You can list multiple search paths on the same line:

```
search example.com foobar.com cslab.ivyleague.edu
```

Technically, `/etc/resolv.conf` is just a backup and override file, like `/etc/hosts`. Ideally, or at least according to design, a system should be running its own DNS daemon, which inherits its information from a master name server upstream. DNS queries, by default, are always checked against the local system's DNS if it's running. However, in the real world, DNS is just another service to administer with more potential security risks, and thus you don't want to be running DNS unless you have to. It's necessary these days to have an accurate `resolv.conf` file containing two or three remote name servers against which to perform name lookups. If you want to run DNS on your own machine, we'll cover how to do it in Chapter 32, "The Domain Name Server."

Tip

Fortunately, `/etc/resolv.conf` can be edited and modified at any time, without any special tools to update any databases or anything. DNS lookups are only done upon request by network applications, and the `resolv.conf` table is consulted only at those times and opened from the file on disk, not held in memory and queried constantly, as with IP interface configuration. You can open `/etc/resolv.conf` in your favorite text editor, change or add `nameserver` enTRies, shuffle the order in which they're queried, and so on. The next DNS query you make through any application will query against the newly modified `/etc/resolv.conf`.

A Look at Other Network Configuration Files

You've already seen just about all the files containing network configuration information you're ever likely to need to work with. However, a few more files are still worth listing and briefly describing. This doesn't count config files for major network services, though; we'll cover those in Chapter 26, "Configuring a Web Server," and Chapter 32.

Most of these files have `man` pages; simply use `man` *`filename`*, without the path, to view them (for example, `man inetd.conf`). Here's a description of the files:

- `/etc/networks` As you've already seen, this file contains symbolic names for subnets that you might want to use in places such as the routing table.
- `/etc/hosts.allow` This is a listing of fairly complex security rules for responding to connections of various types on a per-host basis. You can use `hosts.allow` to reject connections from certain hostswhether on a particular service or on all servicesor to specify an action to take when such a connection attempt is made. This mechanism only works for services that honor the hosts.allow file; third-party software packages such as Apache tend to use their own host management rules.
- `/etc/inetd.conf` The `inetd` "super-server" is responsible for accepting connection requests for services specified in `inetd.conf` and spawning a process to handle each one. Services run from within `inetd` include Telnet, FTP, POP3, and various miscellaneous services that you may want to disable if they're not needed. More on this in Chapter 30, "Network Security."
- `/etc/services` A database of IP service types and the TCP and UDP ports each maps to. Some programs use this table to look up commonly used ports; it also provides a handy reference for what services are assigned what ports by the Internet Assigned Numbers Authority (IANA).
- `/etc/protocols` Like `/etc/services`, this is a table providing keyword mappings for various IP subprotocol numbers. It is mostly of interest as a reference.
- `/etc/rpc` Another table of mappings, even less likely to be of interest to the administrator. RPC lookups provide port-mapping services to requests such as NFS, NIS, and various status-reporting programs.
- `/etc/pam.d` Pluggable Authentication Modules (PAM) provide a way to assign cascading authenticators (S/Key, Kerberos, and the like) to various services. This will be of interest when we discuss network security in Chapter 30.
- `/etc/host.conf` If present, this file specifies the order in which name lookup sources are given priority. In the default configuration, `/etc/hosts` is consulted first, followed by the resolver in BIND (the DNS running on the local machine). This file is automatically generated and should not require any manual editing.

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Chapter 24. Networking with PPP and 802.11

IN THIS CHAPTER

Connecting your FreeBSD machine to the Internet using a dial-up modem or a wireless network is nowhere near as seamless as it is in a modern consumer operating system such as Windows or Mac OS X. Because FreeBSD is designed to be a server platform, its architecture assumes that it will be on a wired Ethernet network with a static IP address, and the vast majority of the administration tools in the system are geared toward such a configuration.

This does not mean it's impossible to make FreeBSD work with your dial-up ISP or your DHCP-based 802.11 home or corporate network, however. All it takes is proper configuration of some less well-known utilities in the system, as this chapter will discuss.

Note

Turn to Chapter 35, "Dynamic Host Configuration Protocol (DHCP)," for information on setting up FreeBSD to take advantage of dynamically assigned IP addresses in a home or corporate network.

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Dialing Up with PPP

PPP stands for *Point-to-Point Protocol*. It is the protocol used for most dial-up Internet connections, and remains in wide use in numerous homes where broadband connectivity (DSL or cable) is not available. If you are among the many users connecting to the Internet through a dial-up modem, you need to know how PPP works in FreeBSD and how you can make it work with as little hassle as possible.

Gathering Necessary Information

After you have signed up with an ISP, you will need to get several pieces of information:

- The communications port that your modem is on. If you have used your computer under Windows and know the COM port to which the modem is connected, the following FreeBSD devices correspond to the DOS COM ports: COM1: `cuad0`, COM2: `cuad1`, COM3: `cuad2`, and COM4: `cuad3`.
- The IP addresses of your ISP's DNS servers. These are used to resolve domain names to numerical IP addresses.
- Your ISP's dial-up phone number.
- Your username and password.
- The type of authentication your ISP uses. This should be either a standard shell login, Password Authentication Protocol (PAP), or Challenge Handshake Protocol (CHAP). These different authentication protocols will be discussed further later in the chapter.
- Whether you have a static IP address or a dynamic IP address. If you have a static IP address, you will need to know your assigned IP number.

All the information items except the first one can be obtained from your ISP.

User PPP and Kernel PPP

The two types of PPP available with FreeBSD are user PPP and kernel PPP. Both have their advantages and disadvantages. Kernel PPP must be set up by the root user, and support for it must be compiled into the kernel (it's built into the `GENERIC` kernel). Because it involves a daemon process that handles on-demand connections to the ISP, kernel PPP can be very efficient and seamless in operation. User PPP, however, is a scheme that exists at the user level; support for PPP need not be compiled into the kernel, so the root user does not have to be involved beyond making sure user PPP can be run in the first place. (This can be useful if you are not the administrator of the FreeBSD machine but need to use PPP anyway.) User PPP is somewhat easier to debug than kernel PPP, but because it uses a *tunnel device*a type of "virtual network interface" that encapsulates specialized traffic inside a more generic transmission protocolit can be somewhat less efficient than kernel PPP.

This book covers kernel PPP, the more common style used in FreeBSD today. If you only have user access to a FreeBSD machine and you need to dial out using PPP, you'll want to read up on user PPP in the online Handbook: http://www.freebsd.org/handbook/userppp.html.

Configuring the Kernel PPP Daemon

Kernel PPP is handled by the `pppd` daemon. The main configuration files for `pppd` will be located in `/etc/ppp`, though they're not present in the default FreeBSD installation; you'll need to create a few files there, as discussed next, and also modify the `/etc/resolv.conf` file.

Note

The `/etc/ppp/ppp.conf` file is used in user PPP, not kernel PPP; you can ignore it unless you're using user PPP.

`/etc/resolv.conf`

The `/etc/resolv.conf` file, as you learned in Chapter 23, "Configuring Basic Networking Services," is FreeBSD's Domain Name Server (DNS) configuration fileit determines how FreeBSD resolves remote hostnames to numerical IP addresses. Each line in `resolv.conf` contains the keyword `nameserver` followed by the IP address of a DNS server (or *nameserver*). Nameservers are queried in the order they are listed in the file; if the first nameserver does not respond or does not contain the requested information, the next listed server is checked. An additional useful keyword, `domain`, allows you to specify the domain name of your system or network. If the `domain` keyword is present, FreeBSD assumes that any unqualified hostnames (hostnames that do not have a domain after them) are located in the domain specified after the `domain` keyword. Here is an example of an `/etc/resolv.conf` file:

```
domain example.com
nameserver 111.111.11.1
nameserver 222.222.22.2
```

You can edit the `/etc/resolv.conf` file with any text editor. You will need to be logged in as root to do so.

`/etc/ppp/options`

The `/etc/ppp/options` file, which does not exist by default, is where most of the runtime options for the PPP daemon go. It is read before any command-line options that you specify when invoking `pppd`, so you can override options specified in the file by using the command line.

The contents of the `options` file are used to specify modem baud rates, handshaking options, routing and domain information, and connection scripts. It is possible to use kernel PPP without an `options` file because all the potential options have default values; however, you will most likely need to create this file and add a few basic configuration lines specific to your modem and ISP setup. The options that need to go in this file differ depending on the type of authentication your ISP uses. Here is a sample file for using simple shell login authentication and a dynamic IP address (the PAP and CHAP authentication methods are covered in detail in the next sections of this chapter):

```
/dev/cuad0 115200
crtscts
modem
connect "/usr/bin/chat -f /etc/ppp/chat.script"
noipdefault
silent
domain example.com
defaultroute
```

Note

Line breaks are not important in the `options` file; they're there only to aid readability. Otherwise you could put every option and argument on a single line.

Here is what each of the options listed here mean:

- `/dev/cuad0` This line sets the device that the modem is located on. In this case, this is equivalent to DOS' COM1. It also sets the port speed to 115,200 bits per second (most dial-up providers won't be able to provide more than 56Kbps, or 57,600 bps).
- `crtscts` This line sets the hardware flow control of the modem to on. Hardware flow control is required for high-speed communications. Use `nocrtscts` instead if your modem doesn't use hardware flow control.
- `modem` This tells `pppd` to use the modem control lines, wait for a carrier signal before opening the serial port, and other modem-centric behavior. It's not necessary to specify this option (it's on by default), but its opposite is the `local` option.
- `connect` This specifies the dialer program to run along with the script that should be used. The `chat` program can be used to automate the modem connection with a "connect script," specified with the `f` switch. This will be covered more in the next section.
- `noipdefault` Use this option if you have a dynamic IP address (your ISP assigns you an IP address each time you log on). This option tells `pppd` to get an IP address and gateway address from the dial-up server. If you omit this option and don't specify a static address, `pppd` TRies to figure out the local IP address from your system's hostname, which can confuse the remote server's attempts to assign a dynamic IP address.
- `silent` This tells `pppd` to wait for Link Control Protocol (LCP) packets, rather than sending out its own to initiate a connection.
- `domain` The domain name of your ISP should go here and may be used for authentication purposes. It appends the domain name onto the end of local hostnames.
- `defaultroute` This will add a routing entry to the system routing tables while `pppd` is running. When `pppd` is terminated, the route will be removed.

If you have a static IP address, remove the line that reads `noipdefault` and replace it with a line that looks like the following:

```
10.0.0.1:10.0.0.2
```

Replace the first number before the colon with the IP address your ISP has assigned you. The number after the colon is the gateway address that your ISP has given you. If your ISP has not given you a gateway address, you can leave the second number off (you should include the trailing colon, however). Leaving the gateway address blank, or using the `noipdefault` option, tells FreeBSD to use the gateway address sent by the ISP during the connection setup process.

These are just a few of the many connection options you can tune in `/etc/ppp/options`. See the `man pppd` page for an exhaustive list of these options and what they can do to help you cope with a variety of different kinds of PPP server behaviors.

Tip

If you installed FreeBSD on an ancient system (such as a 486) and you have an external modem, you may find that the preceding setup produces strange resultsconnection resets, stalled transfers, and so on. This is because older systems did not ship with high-speed UART communication chips and might not be able to handle a port speed of 115200. If you get unpredictable performance, try reducing the port speed (specified in the `/dev/cuad0` line in `/etc/ppp/options`) to 57600.

The Chat Script

The `pppd` daemon has no built-in dialing capabilities. Dialing, rather, is handled externally by the `chat` program, which allows for an automated (scripted) conversation with the modem. It uses an "expect/send" syntax; in other words, the script contains the format of the prompt to expect from the server, followed by the commands it should send in response, then the next command to expect, and so on.

Here is a sample `chat` script. You may need to modify this script slightly to work with your particular modem, but this one should get you started. As root, open a new file in any text editor (our example uses a script file saved under the name `chat.script` in the `/etc/ppp` directory) and enter the following, all on one line:

[View full width]

```
ABORT BUSY ABORT 'NO CARRIER' "" AT OK ATDT5551212 CONNECT "" TIMEOUT 10 ogin:-\\r-ogin:
    yourname TIMEOUT 5 sword: yourpassword
```

This chat script can be broken down into the following component commands:

- `ABORT BUSY ABORT 'NO CARRIER'` Tells the script to abort if the modem should respond with either `BUSY` or `NO CARRIER`.
- `AT OK ATDT5551212 CONNECT` An `ATTENTION` signal, which waits for the modem to respond with `OK`. When it does, the script uses `ATDT` (Attention Dial Tone) and dials the phone number in the script (555-1212). The script then waits for the modem to send the `CONNECT` signal.
- Timeout 10 Sets the timeout (the time it waits for the expected string from the server) to 10 seconds.
- `ogin:-\\r-ogin:` *`yourname`* `TIMEOUT 5 sword:` *`yourpassword`* Waits for the string `ogin:` (which matches either `login:` or `Login:`whichever the server happens to send, just to be safe) from the modem; this string represents the login prompt sent by the ISP. After the script has received the login prompt, it responds with *`yourname`*, which should be replaced with your ISP login name.

If the login prompt has not been received within 10 seconds, the script aborts. Assuming the script does receive the login prompt and sends the login name, the timer is then reset to five seconds, and the script waits for that length of time to receive `sword:` (another shortened string, designed to match the ISP's `password:` or `Password:` prompt). When the script receives the password, it sends *`yourpassword`*, which should be replaced with the password you use to log in to your ISP. After the password has been sent, if your ISP's server automatically changes to PPP mode, the script is done. If, instead, you are put into a login shell, find out from your ISP what shell command needs to be issued to start PPP. Then, you can simply add this command at the end of the script.

Tip

If you are unsure about what prompt syntax your ISP issues, use a terminal emulator such as `minicom` (available in the ports tree, at `/usr/ports/comms/minicom`) to dial your ISP's phone number and then perform a manual login. This will enable you to observe what prompts the ISP's server sends when requesting various items of information and update your chat script accordingly.

Caution

If you want to allow non-root users to start the `pppd` daemon, the `chat.script` file must be "world readable." A world-readable `chat.script` file can be a security hazard because anyone with a shell account on your system can get your Internet password from this file. It is much better to use CHAP or PAP authentication if you want normal users to be able to start `pppd`. The `chap-secrets` and `pap-secrets` files (discussed in a later section) need to be readable only by root, even if you are allowing normal users to start `pppd`. Also, if you do not want the rest of the world to be able to get your Internet password, don't forget to change the permissions on the `chat.script` file accordingly.

If your ISP supports your having a dial-up password that's different from your email password, you don't have to worry about the plain text `chat.script` file, because the password it contains isn't really "sensitive information."

Starting the `pppd` Daemon

After you have completed the preceding tasks, the PPP connection should be ready to go. Simply type **`pppd`** at the command prompt to bring it up. If all goes well, your modem should dial and connect. If you have problems, see the troubleshooting section at the end of this chapter.

To stop the `pppd` daemon, you can either find its PID number with `ps` and then issue a `kill` command, or you can use `killall`, like this:

```
# killall pppd
```

Caution

Be careful with the `killall` command; its behavior on other UNIX systems can be different from its FreeBSD behavior. On Solaris, for instance, it kills every running process.

PAP and CHAP Authentication

Most ISPs these days support the Password Authentication Protocol (PAP) or the Challenge-Handshake Authentication Protocol (CHAP), and somein a world where shell access is less and less commonly offeredsupport *only* PAP or CHAP. Both of these types of authentication start a PPP session immediately after login, instead of starting up a shell on the server side (as older PPP dial-up mechanisms used to do). This quick startup makes PAP and CHAP a little bit more efficient than a shell login.

PAP and CHAP also have one other advantage over the shell login. The chat script has to be world-readable if you want any users other than root to be able to start `pppd`. If you use the chat script with the shell login, your password in the chat script is visible to everyone who has access to the system. With PAP and CHAP, the files that contain the passwords do not have to be world-readable, so they are more secure for a multiuser system.

PAP/CHAP requires some extra modifications in the `options` file and the creation of one or more additional configuration files where your login information is stored. Let's start with the PPP `options` file. At least one line will need to be added to `/etc/ppp/options` to determine what profile to use for logging in (you learn more about the profile in "Running Commands on Connect and Disconnect," later in this chapter).

At the end of the `options` file, add a `user` line. This line corresponds to a profile name (the profiles will be added later in a different file). The `user` line looks like this:

```
user yourname
```

Replace *`yourname`* with the login name you use to log on to your ISP. The following is a list of other options you might need to include:

- `refuse-chap` If this statement exists in `/etc/ppp/options`, `pppd` will refuse to authenticate using CHAP, even if the remote host requests it.
- `refuse-pap` Like `refuse-chap`, except it applies to PAP instead.
- `require-chap` If this option exists in `/etc/ppp/options`, `pppd` will require the remote host to authenticate itself using CHAP. Because your ISP's server likely does not authenticate itself to you, you will probably not use this line.
- `require-pap` Like `require-chap`, except that it applies to PAP instead.

If you do not include either the `refuse-chap` or `refuse-pap` statement in your options file, `pppd` will accept whichever authentication mechanism the ISP offers first. Note also that if you reject both PAP and CHAP, the connection fails because your system does not have a way to authenticate itself to the ISP.

`pap-secrets` and `chap-secrets`

The `/etc/ppp/chap-secrets` and `/etc/ppp/pap-secrets` files contain the CHAP and PAP authentication information, respectively. The single line of each file's contents follows the basic format of *`username hostname password`* where *`username`* is your ISP login name, *`hostname`* is the name of the host that this entry will also authenticate, and *`password`* is (of course) your dial-up account password. You can replace the hostname entry with a wildcard (`*`), which tells `pppd` that this entry can authenticate to any host. Using a wildcard is a good idea for configuring your Internet account, because if you dial in to your ISP, you are already assured that the host you are contacting is who it claims to be. A sample entry for either of these files might look like this:

```
yourname * yourpassword
```

Here, *`yourname`* is the username, `*` means that this entry is good for any host, and *`yourpassword`* is the password.

You can use other options in the `chap-secrets` and `pap-secrets` files, but they are generally used only if you are providing dial-in PPP service. If you are interested, further information on how to use these files can be found in the "Authentication" section of the `man pppd` page.

Caution

The `/etc/ppp/chap-secrets` and `/etc/ppp/pap-secrets` files should be readable only by root. Change the permissions accordingly; otherwise, anyone who has shell access to your system can get your Internet password from these files.

Dial-On-Demand and Persistent Connections

As the name suggests, *dial-on-demand* means that `pppd` automatically dials out whenever it detects outgoing traffic that needs to be sent. A *persistent connection*, on the other hand, is always "up" and redials the connection immediately if `pppd` detects a disconnect. The following subsections describe how to enable both kinds of connections in kernel PPP.

Dial-On-Demand

Dial-on-demand causes `pppd` to establish a dial-up connection any time it detects outgoing network traffic when the connection is not already up. The relevant statements in `/etc/ppp/options` are as follows:

- `demand` This statement turns on dial-on-demand.
- `idle` *`n`* Here, *`n`* is a number representing seconds. This option causes `pppd` to automatically disconnect after *`n`* seconds of being *idle*, meaning that no traffic has been sent or received over the PPP link during that time.

After you have enabled dial-on-demand, you can create a startup script to automatically start the `pppd` daemon each time your system boots. There are several ways to do this; but, as you have seen in Chapter 14, "System Configuration and Startup Scripts," the best way is to create a startup script in `/usr/local/etc/rc.d` with the single line `pppd` in it. This file can be called anything you want, but it's a good idea to name it `ppp` (which succinctly suggests what it's for).

Tip

If you have dial-on-demand enabled and your modem keeps inexplicably dialing every now and then, a program is probably trying to do a DNS lookup. More often than not, Sendmail is the program causing problems. You can fix this by enabling the `SMART_HOST` relay definition or the `nodns` feature in the `freebsd.mc` configuration file, or by adding the IP address and hostname of your ISP's mail server to your `/etc/hosts` file. See Chapter 25, "Configuring Email Services," for information on how to configure Sendmail using the Master Config file.

Tip

If you have dial-on-demand enabled and you are running Fetchmail in daemon mode so that it periodically polls your mail server, this might keep the connection open all the time in addition to causing `pppd` to dial on a regular basis. See the "Email for Standalone Workstations" section in Chapter 25 for ways to stop this from happening.

Persistent Connections

You can also tell pppd to always keep the connection up. This is done by adding the persist statement to /etc/ppp/options. If this statement is present, pppd automatically tells the modem to reestablish the connection if it is lost.

Caution

Even if your ISP tells you that you have unlimited access, make sure you read the fine printthere might be a "within reason" clause or something, and it's seldom considered "within reason" to use up an ISP's modem slot at all times unless you have explicit arrangements for it. If you are using the persist option to keep your Internet connection open 24 hours a day, 365 days a year, your ISP may require you to purchase a dedicated line.

Running Commands on Connect and Disconnect

When pppd establishes a connection, it checks for the existence of a script file called ipup in /etc/ppp. Likewise, when the PPP connection goes down, pppd checks for the existence of a file called ip-down in /etc/ppp. If these files exist, whatever commands are listed in them are executed.

Running commands on connect or disconnect can be helpful if, for example, you are running FreeBSD on your laptop while traveling. You could read and respond to email while on a plane. Then when you get to your destination and dial in to your network, you could have pppd flush the mail queue (deliver all the mail you wrote on the plane), as well as running the Fetchmail program to download any new mail you had received. If you put the command to perform these options in /etc/ppp/ip-up, they will automatically be performed when you type **pppd** to start your dial-up connection. You could then have the ip-down script automatically kill Fetchmail if it is running in daemon mode so that it does not attempt to retrieve mail when the connection is not available.

A sample ip-up script could contain the following:

```
fetchmail mail.myisp.com
apachectl start
cd /etc/mail; make start
```

Similarly, ip-down could contain the following lines:

```
apachectl stop
cd /etc/mail; make stop
```

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PPP Over Ethernet (PPPoE)

Many xDSL users must set up nonpersistent PPP-based connections over an Ethernet interface; this is the case, for instance, when an ADSL modem connected to the FreeBSD machine via Ethernet does the dialing. PPPoE can be used in FreeBSD with only a few minor additions to the user PPP configuration file.

Create a new `/etc/ppp/ppp.conf` file as shown in Listing 24.1, replacing *`fxp0`* with the name of your Ethernet device connected to the xDSL modem (if necessary), *`myisp`* with a keyword identifying your ISP, *remoteaddr* with the remote dial-up server's contact IP address and *`yourname`* and *`yourpassword`* with your username and password used for logging in via PPP.

Listing 24.1. A Sample PPPoE Configuration File

```
default:
 set device PPPoE:fxp0:myisp
 set speed sync
 set mru 1492
 set mtu 1492
 set ctsrts off
 enable lqr
 add default remoteaddr
 set timeout 0
 set redial 0 0

 # Network Address Translation (NAT)
 nat enable yes
 nat log yes
 nat same_ports yes
 nat unregistered_only yes
 enable dns

myisp:
 set authname yourname
 set authkey yourpassword
```

When you want to connect to the Internet, you can run `ppp` without arguments from the command line, and then enter `dial myisp` at the interactive prompt. You should then see output indicating a successful connection, after which you should be able to access the network.

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Troubleshooting PPP

If you are having trouble getting PPP to work, here are a few suggestions for troubleshooting.

If the modem doesn't dial:

- Verify that you have selected the correct device for your modem. Remember that FreeBSD uses `/dev/cuad #` for its device names, not `/dev/cuaa #` as on some other systems.
- If you are using an older system, try reducing the speed to 57600 or 38400. Some older systems without high-speed UARTs cannot handle 115200.
- Verify your `chat` script or `set dial` line. Check your modem documentation to see whether you need to be sending it some initialization string other than the default one in the FreeBSD configuration files.

If the modem dials but fails to establish a connection:

- Verify that you are using the correct authentication type for your ISP (CHAP, PAP, or shell login).
- Verify that you are using the correct login name and password for your ISP.
- Verify your `chat` script or `set dial` line. Check your modem documentation to see whether there is an initialization string you have to send.
- If you are using user PPP, you might want to try kernel PPP instead. (I personally had a modem/ISP combination once where kernel PPP worked fine; but user PPP, for whatever reason, simply refused to work with this particular ISP.)

If a connection is made but attempts to access remote hosts by host and/or domain name fail:

- Verify that you have the correct DNS servers listed in `/etc/resolv.conf`. Also, verify the correct setup of the `/etc/host.conf` file. It should have a line that reads `hosts` followed by a line that reads `bind`.

If the preceding suggestions do not correct the problem, try turning on logging and then attempt to connect again. Logging can be enabled by adding a line to `/etc/ppp/options` that reads **`debug`** for kernel PPP and by changing the `set log` line in `/etc/ppp/ppp.conf` to read **`All`** for user PPP. Messages from kernel PPP will be logged to `/var/log/messages`, and messages from user PPP will be logged to `/var/log/ppp.log`. You can monitor the messages as they are being sent by typing **`tail -f /var/log/messages`** or **`tail -f /var/log/ppp.log`**. This will show you the last 10 lines of the file and also update the display each time the file changes.

The information logged is fairly technical. You might be able to spot the problem yourself. If you can't, the contents of the log can still be useful to your ISP if you can get them to help track down what's going wrong. If they can't figure it out either, they might be able to call their RAS vendor and let them look at your logs to diagnose the problem.

The information presented in this chapter should be enough to get most people up and running with their ISPs. However, both kernel PPP and user PPP are extremely esoteric, and this chapter cannot cover all the options available, especially considering the waning popularity of dial-up Internet access in favor of broadband solutions. If you need to do more advanced PPP configuration, both kernel PPP and user PPP have detailed `man` pages that describe all the options available. The kernel PPP `man` page can be accessed with `man pppd`, and the user PPP man page can be accessed with `man ppp`. In addition, sample configuration files are located in `/usr/share/examples/ppp`.

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Connecting to a Wireless (802.11) Network

Sales of laptop computers have exploded in recent years, and with it the demand for true mobile computing using wireless Ethernet cards and base stations and the 802.11 Ethernet standard, also known as Wi-Fi. If you have installed FreeBSD on your laptop, you will likely want to know how to connect it to your wireless network at home or at work. This can be a challenging prospectthere's more subtlety to it than you might think at first, taking into account the authentication protocols and security precautions that are in place on well-maintained wireless networks. Yet while many things in the UNIX world are difficult, very little is impossible.

Note

This section addresses configuring your FreeBSD machine as a wireless client, using the signal from an existing access point or base station. If you want to configure your own base access point using FreeBSD, turn to Chapter 28, "Configuring an Internet Gateway," and go to the section "Configuring a Wireless Internet Access Point."

Choosing a Wireless Card

The first step in making your laptop work with a wireless network is making sure the 802.11 card is supported by FreeBSD. If your wireless network uses 802.11b (the most common protocol, supporting speeds up to 11Mbps using a 2.48GHz radio signal), you're in luckalmost all common 802.11b cards are supported by FreeBSD natively.

If your wireless network uses 802.11g, the successor to 802.11b that supports speeds up to 54Mbps, the situation is not so rosy. Only a few cards are explicitly supported at the time of this writing, although this is an area where many FreeBSD developersparticularly those with laptopsare focusing their efforts. However, because of standardization in the industry (and because of a few tricks such as NDIS tools that can jury-rig a Windows driver binary into FreeBSD to support certain cards), chances are that you'll be able to get an 802.11g or even an 802.11a card to work with FreeBSD. Refer to the online Handbook (http://www.freebsd.org/handbook/network-wireless.html) for instructions on how to accomplish this.

Appendix B, "Hardware Compatibility Lists," contains a partial list of wireless Ethernet cards known to work with FreeBSD.

Basic (Unencrypted) Wireless Connectivity

Most wireless networks these days support encryption, which requires a more complicated setup procedure for your 802.11 client than is otherwise the case. To get wireless connectivity working in its most basic case, turn off encryption and authentication (if possible and advisable) in your wireless access point or base station. You can turn it back on after getting FreeBSD to connect using a standard unencrypted signal.

First, check to see whether FreeBSD has detected your wireless card, using the wi (Wireless Internet) driver:

```
# ifconfig wi0
wi0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet6 fe80::202:2ea2:dd2d:c938%wi0 prefixlen 64 scopeid 0x7
        inet 0.0.0.0 netmask 0xff000000 broadcast 255.255.255.255
        ether 00:09:2d:2d:c9:50
        media: IEEE 802.11 Wireless Ethernet autoselect (DS/2Mbps)
        status: no carrier
        ssid ""
        stationname "FreeBSD Wireless node"
        channel 10 authmode OPEN powersavemode OFF powersavesleep 100
        wepmode OFF weptxkey 1
```

The `status: no carrier` line means the card isn't connected, but the fact that you got output for the `wi0` device means it's supported by FreeBSDa good sign. The next step is to configure the card for your wireless network, which in this example has a name, or SSID, of *MyNetwork*:

```
# ifconfig wi0 inet 192.168.0.10 netmask 255.255.255.0 ssid MyNetwork
```

Use an appropriate static IP address and netmask in place of `192.168.0.10` and `255.255.255.0` in this command line. (To see how to use DHCP to obtain an IP address automatically, see Chapter 35.)

Check the output of **`ifconfig wi0`** again, and look at the `status` line. If you see `status: associated`, it means you've successfully joined the wireless network. Also check for `ssid: MyNetwork` (along with some other information), indicating that you joined the correct network by name. Then, try using the `ping` utility (as you saw in Chapter 23) to verify that you're connected successfully to the Internet.

If your wireless network normally has no encryption or authentication and this configuration works for you, you can add it permanently to your `/etc/rc.conf` file:

```
ifconfig_wi0="inet 192.168.0.10 netmask 255.255.255.0 ssid MyNetwork"
```

However, it's never advisable to run a wireless network without encryptionand most home and corporate networks do encrypt their traffic. You'll want to make sure FreeBSD works with that extra layer of security.

Encrypted Wireless Connectivity

WEP, the Wired Equivalency Protocol, is an encryption scheme for wireless networks that ensures that only authorized users can join the network or intercept its packets. It's not a particularly robust protocol, and its 40-bit cipher was cracked years ago. Most wireless Ethernet cards support the stronger 128-bit (actually 102-bit) cipher standard; use this method if at all possible. Still, though, it's important to realize that WEP is called "Wired Equivalency" for a reason: it's not designed to be perfectly secure, but rather to give you about the same amount of security that you would have from a wired connection. Just as it's possible for someone to break into your house and plug an Ethernet cable into your switch, someone can crack your WEP network and eavesdrop on your communications.

IPSec is a much more secure solution than WEP; however, not as many access points support it as support WEP. Because of its greater ubiquity, this chapter focuses on WEP. You can find out more about IPSec in Chapter 31, "Virtual Private Networks (VPNs)," or in the online Handbook (http://www.freebsd.org/handbook/ipsec.html).

First, determine what the secret key is on your wireless access point. In most cases, this will be a regular text password that you can set in the access point's configuration. For this example, assume the password is *`mypassword`*. (Note that this is not the password for administering the access point itselfthat's usually a different password entirely.) If you had previously disabled encryption for testing purposes, turn it back on now.

Next, you need to load the `wlan_wep` kernel module:

```
# kldload wlan_wep
```

If you plan to use an encrypted wireless network frequently, you should add it to your `loader.conf` file or build it into a custom kernel, as described in Chapter 18, "Kernel Configuration."

Now, use the `ifconfig` command as you did before, only with some extra commands at the end to turn on WEP and to specify the key:

[View full width]

```
# ifconfig wi0 inet 192.168.0.10 netmask 255.255.255.0 ssid MyNetwork wepmode on wepkey
    0xmypassword
```

Now, if you enter **`ifconfig wi0`**, you should see a line similar to the following:

```
authmode OPEN privacy MIXED deftxkey 1 wepkey 1:104-bit txpowmax 100
```

Tip

If you see `deftxkey UNDEF` in the output, you should add `deftxkey 1` to your `ifconfig` line.

If you're able to communicate with the Internet, congratulationsyou've got a fully functional encryption-enabled wireless network client!

Scripts for Connecting and Disconnecting

It's a good idea to write scripts to manually bring up and tear down the wireless network, just as in configuring PPP. Unlike PPP, however, these scripts are ad-hoc in nature and aren't built into any existing architecture; you're flying by the seat of your pants here. For example, Listing 24.2 shows a sample `wi-up` script that you can set executable and put into `/usr/local/bin` so that you can join the wireless network with a simple **`wi-up`** command.

Listing 24.2. A Sample `wi-up` Script for Bringing Up the Wireless Network

[View full width]

```
#!/bin/sh

kldload wlan_wep
ifconfig wi0 inet 192.168.0.10 netmask 255.255.255.0 ssid MyNetwork wepmode on wepkey
   0xmypassword deftxkey 1
echo "Wireless network status:"
ifconfig wi0
```

Similarly, a `wi-down` script (as shown in Listing 24.3) can be useful for turning off your wireless card and leaving the network, which prevents timeouts in trying to communicate over a nonexistent network and saves your laptop's battery power.

Listing 24.3. A Sample `wi-down` Script for Leaving the Wireless Network

```
#!/bin/sh
ifconfig wi0 destroy
echo "Wireless network status:"
ifconfig wi0
kldunload wlan_wep
```

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Chapter 25. Configuring Email Services

IN THIS CHAPTER

What's the Internet without email? Probably not even the Web, with its flashy graphics and its commercial opportunities, has quite the usefulness and cachet of the Internet's oldest application, electronic mail. Every UNIX server in the world has email capabilities built into itnot just the capability for users to send and receive mail, but for the system itself to act as a full-fledged mail server. FreeBSD is no exception.

The catch is that configuring Sendmail, the venerable SMTP server application that forms the email backbone of UNIX and the Internet, is perhaps the most daunting system administration task you'll face. After all, Sendmail is perhaps unique among server software in that it has a config file *for its config file*. But don't worrythis chapter outlines and gives you a solid grounding in the use of Sendmail and the basics of the skills you'll need to master as an email administrator. You learn how to configure and manage the mail server for secure and reliable performance, but you're spared the exhaustive coverage of details that could make Sendmail seem overwhelming or needlessly complex.

This chapter also covers another side of email: POP and IMAP. These are the protocols remote clients use to receive email. Fortunately, their use is nowhere near as complicated as Sendmail, even when you're configuring them for secure (encrypted) operation.

Finally, the chapter outlines some alternatives to Sendmail itself, explaining how to switch to them if you decide administering Sendmail isn't worth the headache. You'll also see how to configure your mail server to filter unsolicited junk mailunpopularly known as *spam*using third-party tools such as Procmail and SpamAssassin.

Introduction to SMTP

The Simple Mail Transfer Protocol (SMTP) is one of the oldest communication protocols on the Internetnearly as old as email itself. SMTP's purpose is to transfer plain-text messages from one host to another. This transfer often occurs between several servers in sequence, as when a dial-up client running Windows sends an email message to the ISP's mail server, which then transfers it to the recipient's mail server to be picked up by the recipient's mail program. SMTP sequences rarely get much longer than this example, though. It isn't like the Internet itself, with its hierarchical routing structure in which a packet is handed off by as many as 20 or 30 routers on its journey from one end to the other. Rather, the sender's SMTP server communicates directly with the recipient's SMTP server, and additional links in this chain are a rarity.

SMTP itself is, as its name suggests, simple. An SMTP clientsuch as a desktop email program or a relaying SMTP serverinitiates a connection to TCP port 25 on the remote SMTP server, followed by an automated greeting code, some optional authentication commands, and a couple more commands to establish what type of transaction the sender is attempting. Then, the recipient asks for the message, and the sender sends it. Finally, a termination command is sent, and the connection is closed. That's about all SMTP is ever really used for, and there really aren't many other capabilities designed into the protocol.

No specialized software is necessary for using SMTP; in fact, you can execute a completely valid SMTP transaction right from the FreeBSD command line. Listing 25.1 is an example of such a transaction. Note that the bold type indicates your input during the session.

Listing 25.1. Executing a Valid SMTP Transaction

```
# telnet destination.com 25
Trying 64.41.134.166...
Connected to destination.com.
Escape character is '^]'.
220 destination.com ESMTP Sendmail 8.13.3/8.13.3; Tue, 10 Jan 2006 16:13:30 -0800 (PST)
HELO stripes.sender.com
250 destination.com Hello w012.z064002043.sjc-ca.dsl.cnc.net [64.2.43.12], pleased to meet you
MAIL From: frank@sender.com
250 2.1.0 frank@sender.com... Sender ok
RCPT To: bob@destination.com
250 2.1.5 bob@destination.com... Recipient ok
DATA
354 Enter mail, end with "." on a line by itself
From: frank@sender.com
To: bob@destination.com
Subject: Testing, 123...
This is a test message.
.
250 2.0.0 f4H5uCu53501 Message accepted for delivery
QUIT
221 2.0.0 destination.com closing connection
Connection closed by foreign host.
```

Note

The `HELO` command, which initiates the SMTP session, is usually replaced by the `EHLO` (Extended `HELO`) command, which takes more complex arguments.

As you can see, communication between the two servers is done with four-letter command codes, by convention in caps, and with arguments that are incorporated into the message headers. The message that `bob@destination.com` receives will come up in his email program with the following headers:

```
From: frank@sender.com
To: bob@destination.com
Subject: Testing, 123...
```

The headers are separated from the body of the message by a single blank line. A single dot on a line by itself marks the end of the message body; when the receiving SMTP program sees this, it delivers the messagein the case of Sendmail, by appending it to the recipient's mailbox file (`/var/mail/bob` if it's a FreeBSD machine). And that's all there is to it.

A full-featured SMTP server such as Sendmail transmits its messages using a few extra commands to enhance performance and efficiency, but functionally it uses exactly the same method as the example you've just seen during the actual connection. Sendmail's complexity lies mostly in areas outside the actual SMTP transaction, usually having to do with ensuring that only authorized users can access the SMTP functions.

The reason the client has to communicate first with its own ISP's SMTP server, rather than connecting directly to the recipient's, is to take advantage of *queuing*. With queuing, an SMTP server can keep each message it receives from a client (on either a local or remote machine) in a "holding area" directory (commonly referred to as a *queue*), where it waits for a connection to the final recipient's SMTP server. This connection might be immediately available, in which case the message spends almost no time in the queue. If the connection isn't available, however, the message sits in the queue until a connection opens up, at which time the SMTP program sends it.

Note

Queuing is an application-level behavior of SMTP servers. The benefits of queuing for SMTP are much like those of DNS, which enhances the functionality of Internet applications while not actually being a part of the TCP/IP stack.

The benefit of queuing is that it converts email delivery from a "synchronous" to an "asynchronous" process, where both clients need not be involved at all phases of the transaction. Queuing removes from the dial-up client the burden of looking up the destination host's SMTP server, queuing the message, and retrying the connection at regular intervals. When the client dials up, it can make a single connection, upload all its pending email messages into the outgoing SMTP queue, and then disconnect. The server handles all the steps beyond that point, and the client is thus freed of the mail-sending task.

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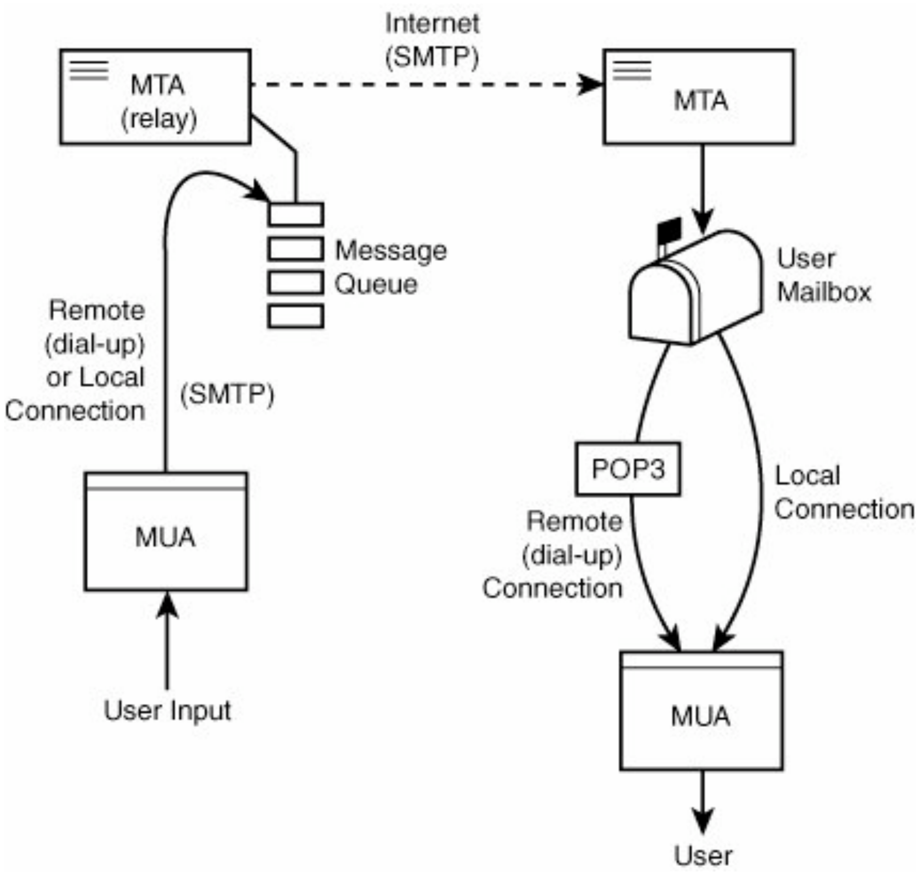
Mail Transfer Agents (MTAs) and Mail User Agents (MUAs)

The role of a Mail Transfer Agent (MTA) is to transfer mail from one mail server to another. The schematic diagram for an email message's path from one person to another is shown in Figure 25.1. Whether the user is on a dial-up connection from a remote site or sitting at the console on the mail server itself, the path the message takes is the same: From the user's input into the Mail User Agent (commonly known as an *email client program* or similar name), the message moves into the sending SMTP server's message queue, where the MTA (for example, Sendmail) pulls it out as soon as a connection to the receiving SMTP server becomes available and transmits it. (Because this process transmits a message that doesn't originate or terminate on the SMTP server machine itself, this step is known as *relaying*.) On the remote system, the MTA places the received message into the recipient's mailbox, where it can be read online with a server-side Mail User Agent (MUA) or downloaded to a client-side MUA through POP3 or IMAP.

Figure 25.1. Diagram of an email message's path from one user to another, showing the roles of MUAs and MTAs.



As a FreeBSD administrator, you'll be interested in the way Sendmail operates as an MTA, both in sender (relay) and receiver roles. This section also discusses MUA programsboth the local kind that users run on the FreeBSD machine itself and the remote kind that operate by uploading and downloading messages. You learn how these programs interact with the "holding areas" of the MTAs: the message queues and the user mailboxes.

Common MTAs

Here are a few of the Mail Transfer Agent programs routinely used on the Internet:

- *Sendmail* By far the most widely used MTA, Sendmail was developed by Eric Allman in 1983, and has developed into a cross-platform *de facto* standard with both a commercially supported and a freeware component. Sendmail, Inc. (http://www.sendmail.com) is a fully functional corporation that exists to support Sendmail for commercial UNIX and Linux resellers; the Sendmail Project (http://www.sendmail.org) is the free, volunteer-supported component, with grassroots resources positioned in the traditional open-source way for users of systems such as FreeBSD in which Sendmail is bundled.
- *Microsoft Exchange* The Windows equivalent of Sendmail, as well as of a multitude of other types of message transfer (such as POP3, NNTP, LDAP, and calendaring), Exchange is commercially developed and "closed source," in the Microsoft tradition.
- *Postfix* Written by Wietse Venema as an alternative to Sendmail, Postfix is designed to be faster, more secure, and easier to operate than Sendmail. You'll learn more about Postfix at the end of this chapter.
- *Qmail* Another response to Sendmail, Qmail was written by Dan Bernstein and is gaining rapidly in popularity due to its reputation for security and speed (although Postfix is reputedly faster). Also, unlike Postfix (which attempts to mimic Sendmail in its interactions with the system, for instance, where it keeps its spool and config files), Qmail uses its own structure and doesn't try to ease the transition for Sendmail users. Qmail is a good choice for administrators running the EZMLM mailing list manager, also by Bernstein, with which Qmail is tightly integrated.

A great many more MTAs are in general use throughout the Internet; the ones ported to FreeBSD can be found in `/usr/ports/mail`.

Common MUAs

Mail User Agents are even more numerous than MTAs. Because Windows and Macintosh email clients (such as Microsoft Outlook/Outlook Express, Eudora, Apple Mail, Mozilla Thunderbird, and so on) are so widely understood, the following list contains only the more popular MUAs available for FreeBSD:

- *Pine* Ostensibly an acronym for "Program for Internet News and Email," rumors persist that the name of this open-source product of the University of Washington is actually an acronym for "Pine Is Not Elm." In either case, Pine is quite widely used, providing an intuitive user interface, many modern message-handling features, integrated USENET newsgroup reading, and a message composer that incorporates the stalwart `pico` editor, which comes packaged with Pine.
- *Elm* The progenitor of Pine (at least, if you believe the rumors), Elm evolved from the ancient `mail` and `mailx` programs that performed email duties for the university and government networks that predated the modern commercial Internet. Primitive by today's standards, Elm still claims many loyal users.
- *Mutt* Conceived as a "mongrel" MUA and incorporating features from Elm, Pine, and a number of other programs, Mutt claims to be the most advanced of them alland it just may be. It has features the others don't, including many that require a graphical client-side MUA in other contexts as well as a great deal of customization.

- *`mail`* The ancestor of all the modern user-friendly email clients, the command-line utility `mail` is available on all UNIX platforms (including FreeBSD) and gives a user rudimentary access to email even when nothing else is available. It can also be scripted and incorporated into shell or Perl programs quite usefully.

Note that the email agents listed here are all shell oriented, meaning that they run in a Telnet or SSH session, monopolizing that session's window. This means they're (almost) exclusively text-based, and such things as inline images and HTML formatting won't work (although they can be configured to open attachments in helper applications, if you're running them on a graphical FreeBSD workstation). However, it also means that you can check your mail using these programs no matter where you're computing fromjust open up a Telnet or SSH session from wherever you are. You'll also be virtually guaranteed to be safe from the Windows/Outlook-oriented viruses that plague the Internet.

A number of full-featured, graphical email applications are available for FreeBSD, integrated into the KDE or GNOME environments. These applications turn FreeBSD into a user workstation where graphical, media-rich messages can be directly viewed, as long as you're sitting at the computer's console (it doesn't work so well if the FreeBSD machine is a remote server where the X11 environment is not available to you). For more information on these kinds of email programs, see the "Email Applications" subsection of Chapter 6, "Working with Applications."

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Configuring Basic Email Services with Sendmail

FreeBSD comes with Sendmail installed and already configured to serve basic email needs right out of the box. All you have to do to enable Sendmail (so that it starts at boot time) is add the following line to /etc/rc.conf:

```
sendmail_enable="YES"
```

You can then reboot to enable the Sendmail server, or start it by typing

```
/etc/rc.d/sendmail start.
```

When the system is up and running, you can send a message to anyone on the Internet, and they can send one to youprovided you have a few things set up properly. For the most part, these aren't configuration items for Sendmail itself, but rather for the system in generalSendmail relies on the system to have a few guarantees in place before it will operate without a hitch.

You can decide to replace Sendmail with another MTA, such as Postfix or Qmail; you learn how to do that at the end of this chapter. Meanwhile, because Sendmail's default configuration works well for the vast majority of servers, we'll talk about how to manage Sendmail itself effectively.

Sendmail File Layout

There are four places in the system that concern Sendmail:

- /etc/mail Configuration files for Sendmail
- /var/mail User mailboxes
- /var/spool/mqueue Incoming message queue files
- /var/spool/clientmqueue Outgoing message queue files

Sendmail itself is located at /usr/sbin/sendmail, and its log files are written to /var/log/maillog (which is rotated on a daily basis by the periodic job, which we discussed in Chapter 15, "Performance Monitoring, Process Control, and Job Automation").

Note

Some systems historically put the Sendmail binary in /usr/lib/sendmail. Some programs expect to find Sendmail there, including certain old web tools that were developed without FreeBSD or Linux in mind. If you run these programs, you might want to violate the FreeBSD directory structure so far as to create a symbolic link from this historical location to the current one:

```
# ln -s /usr/sbin/sendmail /usr/lib/sendmail
```

Note

`/usr/sbin/sendmail` is not actually Sendmail itselfit's in fact a link to a "wrapper," a small program that takes commands and data input and feeds them to Sendmailor to another MTA. The purpose of the wrapper is to allow you to replace Sendmail with another MTA such as Postfix; because all your programs interact with the wrapper rather than with Sendmail itself, the wrapper ensures that the transition is transparent to all your system functions.

The mailbox files (mail spools) in `/var/mail` are plain-text files, each named for the user who owns it and with permissions set to `600` (readable and writable only by the owner). New messages are appended to the end of the recipient's mail spool file. There are also temporary POP lock files that have zero length and a name of the form `.username.pop`. They receive the contents of the corresponding mail spool file while a POP3 connection is open, and any untransferred remnants are then copied back into the mailbox. We'll be talking more about how the POP3 server works later in this chapter.

Configuration Files

Here are some of the files in `/etc/mail` that you'll find important when running Sendmail.

`/etc/mail/sendmail.cf`

This is the main Sendmail config file. However, unlike just about every other config file for every other program, you're not intended to edit this file to alter Sendmail's behavior. Rather, you should make changes at a higher "macro" level in the master config (`.mc`) file, which is discussed next, and then compile a `sendmail.cf` file from that.

The `sendmail.cf` file contains options, rule sets, and featuresall in a format that can be very daunting and nearly not human readable. It's best to leave `sendmail.cf` alone.

The `sendmail.cf` file defines Sendmail's behavior for handling incoming mail addressed to local users. A corresponding config file, `submit.cf`, handles outgoing mail generated by local users and defines how it is transferred to remote SMTP servers.

See "The Message Queue" and "Email for Standalone Workstations" later in this chapter for more details on configuring the "submission" side of Sendmail.

`/etc/mail/freebsd.mc`

The `/etc/mail/freebsd.mc` file is Sendmail's "master config" file. It contains a list of features and options that override the defaults in the standard config file, much in the same fashion as `/etc/rc.conf` overrides `/etc/defaults/rc.conf`. With `freebsd.mc`, though, the format of the settings is much more bizarre. Commands are given in the `m4` macro language (which is barely used outside of Sendmail configurations). The `.mc` file is then compiled together with the default `cf.m4` file from the Sendmail source in `/usr/share/sendmail` or `/usr/src/contrib/sendmail` to create a `.cf` output file. You can then install this file as the new `sendmail.cf` file.

Sound confusing and backward? It is, yes. Sendmail's configuration methods have always been notoriously convoluted, and backward-compatibility concerns have prevented it from receiving the overhaul it so desperately needs. However, the configuration process has been made a lot more straightforward through the efforts of the FreeBSD developers, especially in more recent versions. It used to be the case that to regenerate your `sendmail.cf` file, you had to go into the source directory on your own, figure out which `.mc` file was the one that most closely matched your system, make changes according to the online documentation as best you could, and then dig out the cryptic `m4` compilation command that produced the output filewhich you then had to install by hand. The state of things today is greatly improved over that, although it's still not what anyone would call user-friendly.

Each line in the `m4` language contains the string `dnl` at some point; this stands for "delete through newline," and it marks the end of the readable line (each line must have one). To comment out a line, place the `dnl` at the beginning. Otherwise, put it at the end.

There's a makefile in `/etc/mail`, with targets defined that allow you to create a new `.cf` file from the `freebsd.mc` file simply by typing **`make cf`**. Then you install this output file (`freebsd.cf`) into `sendmail.cf` using `make install`:

[View full width]

```
# cd /etc/mail
# make cf
/usr/bin/m4 -D_CF_DIR_=/usr/share/sendmail/cf/ /usr/share/sendmail/cf/m4/cf.m4 freebsd.mc >
    freebsd.cf
# make install
install -c -m 444 freebsd.cf /etc/mail/sendmail.cf
```

The file `/etc/mail/Makefile` has a number of other uses, as you'll see in a moment.

Note

A *makefile* (conventionally named `Makefile`) is a special file that sits in the top level of any tree of source code; it contains "build targets," which allow you to compile the code in a certain predefined way. We covered the makefiles used by the ports in Chapter 16, "Installing Additional Software." In that chapter's example, you could compile the programs in a port with the `make` command, but the target `install` would specify to the `make` command that you wanted to run whatever installation procedures were prescribed in that port's makefile.

In `/etc/mail`, the makefile that FreeBSD provides allows you to compile the various databases that comprise a Sendmail configuration, and even control Sendmail itself. It's not a config file itself, per se. Rather, it's a part of the system. Therefore, you should *not* modify it unless you know what you're doing.

Just as the `/etc/mail/freebsd.mc` file is what generates the default `sendmail.cf` file for incoming mail, the `freebsd.submit.mc` file defines options for the `submit.cf` file, which controls outgoing mail.

See "The Message Queue" and "Email for Standalone Workstations" later in this chapter for more details on configuring the "submission" side of Sendmail.

`/etc/mail/aliases`

There's a mailbox in `/var/mail` for every user on the system; however, someone having an email address on your machine doesn't require that they have an account. You can always set up *aliases* to map incoming email addresses to any other address, whether it's an address somewhere else on the Internet, another account on your machine, or even a pipe to a file or program. The default `/etc/mail/aliases` contains examples of all these. An alias line contains the alias name, a colon, a space or tab (optionally), and the target address or pipe:

```
tiger: bob@stripes.com
fsmith: frank
pager: "|/usr/local/bin/pageme"
dump: ">>/home/frank/dump2me"
mylist:include:/home/frank/list.txt
```

This last example is an "include" alias, which reads in a list of addresses from a plain-text file at the specified location. This is an easy way to manage a mailing list. Just make changes to the included file, and the alias will always serve as an up-to-date shortcut to the list of specified recipients.

Traditionally, and as a matter of "netiquette," a system has a number of administration aliases for various purposes that are all aliases for root. Some of these "pseudo-accounts" include `abuse` (the address for reporting junk mail or malicious activity originating at your server), `postmaster` (the person who runs the mail server), and `webmaster` (the person in charge of the web server). Some of these are already aliased to root in the default configuration, and others you may have to enable by uncommenting them.

After you make any change to `/etc/mail/aliases`, you have to rebuild the `aliases.db` file, which is a hash table version of the `aliases` file that provides fast lookups (as with `/etc/master.passwd`, which we discussed in Chapter 13, "Users, Groups, and Permissions"). You can use the traditional `newaliases` command to do this, or for consistency's sake with the rest of the maintenance tasks, go into `/etc/mail` and use `make aliases`:

```
# make aliases
/usr/sbin/sendmail -bi
/etc/mail/aliases: 25 aliases, longest 10 bytes, 254 bytes total
chmod 0640 /etc/mail/aliases.db
```

The command shown here will not return any output if the aliases database is up to date.

Note

Using global aliases isn't the only way to redirect mail from one local address to another, or to an external address. For instance, if a user wants all his incoming mail to be forwarded automatically to some external address, you could use `/etc/mail/aliases` to do the trick, but this involves root access. There's a better way, if the user has a full account on the system.

All a user has to do to forward mail to another address is to create a `.forward` file in his home directory, containing the forwarding email address. This can be done with any text editor, or even simply with `echo`:

```
# echo "frank@somewhereelse.com" > .forward
```

Removing this file will cause mail forwarding to stop.

/etc/mail/access

The access database provides a way to apply certain rules to single hosts, subnets, or whole groups of addressesan excellent anti-spam provision. Applicable rules include `OK`, `REJECT`, `RELAY`, `DISCARD`, and `550 <message>`. The contents of the default `/etc/mail/access` file show examples of how the address/hostname field can be formatted:

```
cyberspammer.com                550 We don't accept mail from spammers
FREE.STEALTH.MAILER@            550 We don't accept mail from spammers
another.source.of.spam          REJECT
okay.cyberspammer.com           OK
128.32                          RELAY
```

The addresses on the left side can be complete hostnames or IP addresses, or else they might be only partial ones; `cyberspammer.com` will match any hostname in the `cyberspammer.com` domain, and `128.32` covers the entire `128.32.xxx.xxx` Class B network. The right side contains the rules, which can be any of the following:

- `OK` accepts messages from the specified host, regardless of whether that host might fail other checks in the system (such as the antirelaying provisions that we will discuss shortly).
- `REJECT` refuses connections initiated by the specified host.
- `DISCARD` silently drops messages after accepting them, making the sender think the message has been successfully delivered.
- `RELAY` enables relaying for the specified host, overriding other checks (as with `OK`).
- `550 "message"` specifies a "rejection" message that is displayed to a sender matching the host specification. This message will appear during the SMTP session and will be included in an error email message that is sent back to the sender.

After you've made changes to `/etc/mail/access`, the `access.db` file must be regenerated. You can do this with the `make maps` target, which regenerates any of the feature map files that have been changed since the last time `make maps` has been run. Follow this command with `make restart` to restart the Sendmail master process with the new `access.db` file:

```
# make maps
# make restart
Restarting: sendmail sendmail-clientmqueue.
```

/etc/mail/local-host-names

Formerly `sendmail.cw`, this file specifies all the hostnames that your server claims to be. This information becomes especially important if you're hosting multiple domains and doing mail service for all of them (virtual hosting). In that situation, if you don't add each relevant domain name to the `local-host-names` file, an incoming message destined for a domain you host will bounce back to the sender with the dreaded message `MX list for <domain> loops back to myself; local configuration error`.

```
# cat /etc/local-host-names
example.com
www.example.com
bobsmachine.com
```

The `local-host-names` file has a simple format: a list of hostnames, one per line. The file doesn't exist in the default installation, but you'll need to create it if you add more domain or hostname aliases to your machine via DNS. After adding names to the list, run `make restart` to restart the server:

```
# make restart
Restarting: sendmail sendmail-clientmqueue.
```

/etc/mail/virtusertable

Also on the subject of virtual hosting, `/etc/mail/virtusertable` provides a way to map addresses on one domain that you host to local accounts, other addresses, or error messages. This is somewhat like a hybrid of the access database and the `aliases` file.

Let's say you're hosting a secondary domain called mycave.org. You want webmaster@mycave.org to go to the local user "bill," info@mycave.org to go to a remote address anne@elsewhere.com, and all other addresses (@mycave.org) to be rejected. This could be done with the following tab-separated rules:

```
webmaster@mycave.org        bill
info@mycave.org             anne@elsewhere.com
@mycave.org                 error:nouser User unknown
```

Note that the order in which these rules are specified doesn't matter; when you build the `virtusertable.db` hash table, each rule has its own lookup value, and the ordering in the `virtusertable` file is irrelevant. As with the access database, you need to rebuild `virtusertable.db` and then restart the server. This is easiest to do with `make maps`, though bear in mind that this rebuilds *all* the map databases in `/etc/mail` that have been modified:

```
# make maps
/usr/sbin/makemap hash virtusertable.db < virtusertable
chmod 0640 virtusertable.db
/usr/sbin/makemap hash access.db < access
chmod 0640 access.db
# make restart
Restarting: sendmail sendmail-clientmqueue.
```

An excellent and complete discussion of virtual hosting and the use of the `virtusertable` file can be found at the Sendmail Consortium information site (http://www.sendmail.org/virtual-hosting.html).

Note

By the way, `/etc/mail/Makefile` and all these convenient targets for rebuilding the various configuration databases are additions made by the FreeBSD team and are not part of Sendmail as released by its developers. Some other operating systems don't provide these conveniences. If you're going to be maintaining a Sendmail installation on a Solaris system or some other platform, you'll want to know the underlying commands beneath each of the build targets in the makefile so that you can accomplish the same tasks. The documentation at http://www.sendmail.org is very helpful in this regard.

DNS Resolution Issues

Running a successful Sendmail server really requires that you have accurate DNS information set up for your machine. If you simply install FreeBSD, assign an available IP address to it, and attempt to send mail, it might bounce back to you complaining that the remote server "could not resolve your hostname." Many SMTP servers, including Sendmail in its default configuration, do not accept mail from senders without fully qualified domains in their addresses or resolvable DNS names.

Before you try to put Sendmail to full use on your machine, you'll need to make sure you have reverse DNS lookups correctly set up. You can check this with the `nslookup` command, giving it your machine's IP address as an argument:

```
# nslookup stripes.example.com
Server: lion.example.com
Address: 64.41.131.132

Name: stripes.example.com
Address: 64.41.131.102
```

This output shows a correctly resolving reverse DNS setup, one in which Sendmail will work just fine.

However, you may get something like the following:

```
# nslookup stripes.example.com
Server: lion.example.com
Address: 64.41.131.132

*** lion.example.com can't find stripes.example.com: Non-existent host/domain
```

This means you'll have problems sending and receiving mail until DNS is set up properly. You learn more about DNS in Chapter 32, "The Domain Name Server."

Note

You should check against a remote and independent DNS, not just one on your local network, to be absolutely sure of the DNS configuration for your machine; sometimes, a local name server plays tricks on you by reporting information only it knows aboutinformation that hasn't propagated to the rest of the Internet.

Controlling Sendmail

Sendmail operates by keeping a single "master" process running and listening on port 25 for incoming connections, with additional processes for handling queue runs on both incoming and outgoing messages, sending messages to remote recipients, and other tasks. The master process is started at boot time from `/etc/rc`. Starting and stopping the Sendmail master process is made easy by the makefile and the integrated nature of the resource configuration files in `/etc`. To start the process, simply go into `/etc/mail` and enter **`make start`**:

```
# make start
Starting: sendmail sendmail-clientmqueue.
```

This command pulls in relevant configuration details from the systemwide resource configuration files, in which flags such as `-q30m` (do a queue run every 30 minutes) and `-bd` (run as a background daemon) are centrally specified. It will even refuse to start the process if the `sendmail_enable` variable in the `rc.conf` files is set to `NO`.

Restarting or stopping the master process is equally simple:

```
# make restart
Restarting: sendmail sendmail-clientmqueue.
# make stop
Stopping: sendmail sendmail-clientmqueue.
```

You can see what state each Sendmail process is in by using `ps` in wide mode in conjunction with `grep`; each process reports its position in the queue as an argument against its name in the process table. The following example shows the master process (`419`), the "queue runner" for outgoing mail submissions (`51251`), and a process in the middle of a queue run (`17353`):

[View full width]

```
# ps -wwaux | grep sendmail
root       419  0.0  0.1  3460  1124  ??  Ss   31Dec05    2:15.28 sendmail: accepting
    connections (sendmail)
smmsp    51251  0.0  0.1  3356   712  ??  Is   31Dec05    0:00.27 sendmail: Queue
    runner@00:30:00 for /var/spool/clientmqueue (sendmail)
root     17353  0.0  0.2  3576  2028  ??  I     5:21PM    0:00.01 sendmail: server
```

```
    S0106000c6ee053fa.cg.shawcable.net [68.147.217.59
```

The Message Queue

Sendmail's operation is split into two parts: incoming messages and outgoing messages. Incoming messages waiting to be delivered to local users by Sendmail sit in `/var/spool/mqueue`. A similar directory, `/var/spool/clientmqueue`, holds messages that local command-line MUA users have submitted for Sendmail to deliver. In Sendmail's default configuration, a new `sendmail -q` process is started every 30 minutes, stepping through each queued message in both queue directories and attempting to deliver it to its destination. This continues for five days, at the end of which an "undeliverable" message is returned to the sender with the relevant error headers attached.

Note

The `/var/spool/clientmqueue` directory is actually fed by a single standalone Sendmail process that is bound only to the `localhost` interface; this is a security measure that eliminates the need for Sendmail to be setuid root in order for outgoing mail users to write their messages to the queue directory.

Messages in the incoming queue, `/var/spool/mqueue`, should never build up, technically, because once a message has reached the server there should be no reason why delivery to a local user would fail temporarily.

The outgoing "submit" Sendmail daemon is enabled by default, but you can disable it (returning to the model where a single Sendmail master process controls both incoming and outgoing mail in the same location, `/var/spool/mqueue`) by setting the following option in `/etc/rc.conf`:

```
sendmail_submit_enable=NO
```

Refer to `/etc/mail/README` for further details on other advanced configuration options concerning the split Sendmail model.

If you have some messages in your queues (which you almost certainly will if you've been using the system for any length of time), you can browse through them at will. Unlike opaque systems such as Microsoft Exchange, in which queue files are kept in a database without an easy way to tweak or even see the files waiting to be sent, Sendmail provides full access to queued messages.

Caution

Queued messages are just plain-text files, able to be read and edited by regular text editors. This gives the administrator great control over how the mail system operates; however, it also provides an opportunity for the administrator to abuse his or her power by looking through the content of pending messages, which isn't just unethical but is illegal as well. If you run a system in which you trust your users, be sure they can trust you too!

The first tool that comes with Sendmail is called `mailq`. It provides a way to list the current state of all messages waiting in the queue. Note that when called with no arguments, `mailq` reports on the contents of the incoming queue, `/var/spool/mqueue`. The `Ac` option instead tells it to look at the outgoing queue, which is likely to be much more interesting:

```
# mailq -Ac

                /var/spool/clientmqueue (2 requests)
----Q-ID---- --Size-- -----Q-Time----- ------------Sender/Recipient------------
f4H1Ahu36976     6246 Wed May 16 18:10 MAILER-DAEMON
                 (Deferred: Operation timed out with mlists.acmecity.com.)
                                       <fred@acmecity.com>
f4GKwVW16827      706 Wed May 16 13:58 www
                 (host map: lookup (hotamil.com): deferred)
                                       bob@hotamil.com
```

Using `mailq` in this way, you can keep an eye on what kind of mail transfer errors frequently occur on your system. If people often forget to specify complete email addresses or misspell common mail server hostnames, you can address that problem through education and tutorials. If you're getting a lot of hostname lookup errors, this might point to a configuration problem on your end. `mailq` is an excellent diagnostic tool.

The queue also gives you the ability to fix mistakes in messages on the way out. Let's say, for instance, you have an entry like the second one in the `mailq` output shown earlier. The erroneous recipient domain is the result of a simple typo; you can either wait five days for Sendmail to give up trying to find `hotamil.com` and send the message back to you as an error, or you can fix this problem right in the queue.

To do this, go into `/var/spool/clientmqueue` and look for the files matching the ID of the entry in the `mailq` output. These would be the files `dff4GKwVW16827` and `qff4GKwVW16827`. The first contains the message body, and the second contains the message headers in an interim format. Simply open up the file with the headers (`qff4GKwVW16827`) in a text editor, replace all occurrences of `hotamil.com` with `hotmail.com`, save the file, and wait for the next queue run. The message will go through cleanly this time.

If you can't wait that long, force a queue run by running `sendmail -q v -Ac`. (The `q` switch tells Sendmail to do a queue run, `-v` tells it to echo the results of the entire session verbosely, and `Ac` tells it to use the outgoing queue, `/var/spool/clientmqueue`.) This gives you the added bonus of a look into exactly how Sendmail does its SMTP transactions with all the remote systems. With each message Sendmail processes, it will echo to your terminal all the output from the transaction, just as in the example at the beginning of the chapter. You'll get to see all the interesting greeting messages that various administrators program into their MTAs, visible only to other MTAs, and therefore often quite creative (one memorable one said, `mail.wherever.com ready to rock!`). You can use Ctrl+C to exit at any timemessages are removed from the queue only after they've been successfully transferred.

Note

If no messages are waiting in the queue, there will be no output to the `sendmail q v Ac` command.

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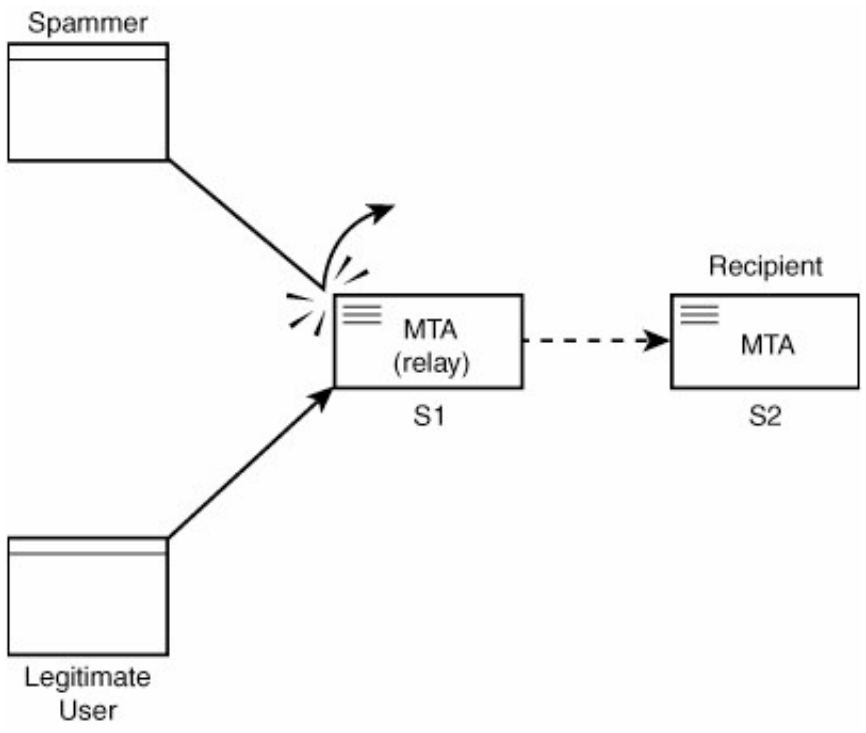
Understanding Relaying

One of the most recent additions to Sendmail is protection against spam (unsolicited email) through anti-relaying rules. These rules have been available for a long time, but only recentlyas of Sendmail version 8.9has the default configuration been to disallow relaying of messages from one server to another.

For a legitimate dial-up or remote user to use your SMTP server to send a message to another remote recipient, your server has to act as a relay, forwarding the message on to the recipient even if the message didn't originate from and wasn't addressed to anyone on its machine. Functionally, as illustrated in Figure 25.2, this is exactly how a spammer would send an unsolicited message to the same recipient through the same SMTP server: The spammer must relay.

Figure 25.2. Relaying. Spammers and legitimate users, if they're not local to S1, must use S1 as a relay to forward their messages to S2.



How Relaying Works

Relaying is usually allowed using what's known as the "MX record," a line in the SMTP server's network DNS database (either served from the same machine as the SMTP server or another server in the same network), which tells all the machines within that network that your SMTP server (S1) is a legitimate mail exchanger for them.

Sendmail, in its default configuration on FreeBSD, will accept mail from senders whose MX record points to

S1, defining it as the MTA for the network. This prevents people from outside the network from using S1 as a relay; if they try, they'll get their messages bounced back with a `Relaying denied` error.

Note

You can find out what the registered MX host is for a domain by using the `host` command:

```
# host somecompany.com
somecompany.com has address 164.199.3.78
somecompany.com mail is handled (pri=30) by mail-1.somecompany.com
```

You can then connect directly to this host on port 25 to perform raw SMTP transactions (for testing purposes, for example).

Configuring S1 to Allow Users to Relay

This configuration is great for ISPs or enterprise networks that have a fully defined network, DNS entries for all the hosts in that network, and a proper MX record pointing to the relaying SMTP server. But what about standalone Internet hosts, which might have users all over the world trying to use their Sendmail servers to transmit mail? Each of these users, when trying to send a message through S1, from wherever they happen to be, will get a `Relaying denied` error back.

To avoid this problem, you can specifically configure S1 to allow these users to relay. There are a number of ways to do this, many of which are extremely inadvisable in some situations:

- Add "trusted" sender domains to the file `/etc/mail/relay-domains`, which doesn't exist in the default installation. Any host within a listed domain will be permitted to relay through your server. You have to restart Sendmail after modifying this file. This is easy and effective, but as soon as you add a large, popular domain (such as aol.com) to this file that might contain spammers as well as legitimate senders, its benefit is lost.

  Add domains to this file one per line, as with `/etc/mail/local-host-names` (which you saw earlier in this chapter):

  ```
  # cat /etc/mail/relay-domains
  good.host.com
  23.144.12.115
  ```

  Note that local mail senders will be rejected unless the domains specified in their addresses are in `/etc/mail/local-host-names`.

- Enable SMTP authentication, which obliges remote users to provide a username and password before the SMTP server will allow them to use it. This is an advanced topic and requires you to configure authentication using SASL (the Simple Authentication and Security Layer), usually by installing a package called `cyrus-sasl` or `cyrus-sasl2` (both available in the `security` section of the ports). You should also ensure that this takes place over a connection encrypted with SSL or TLS, protecting your users' passwords. See http://www.sendmail.org/~ca/email/auth.html for more information on setting up this authentication structure and enabling SMTP authentication.

- Use the access database (`/etc/mail/access`). This feature allows you to set up an `OK` or `RELAY` rule for each known host or domain from which your users will be connecting. This works well for small impromptu networks or for a few remote hosts at easily identifiable addresses, but it doesn't scale well for lots of users on dynamic addresses. For instance, if you're running a standalone server on the Internet that hundreds of different people connect to in order to send mail, it's going to be impossible to add all their IP addresses to `/etc/mail/access`, because most dial-up users have dynamic addresses these days. Administrators running servers in this kind of situation should probably advise users to send their mail through their own ISPs' SMTP servers instead of through yours.

- Enable any of the five or six relaying exception features available in Sendmail by adding them to `/etc/mail/freebsd.mc` and regenerating the `sendmail.cf` file (as shown earlier). There's a feature that lets you allow relaying based on whether the `From:` header is set to an address at your domain (`relay_local_from`), although this is easily forged by spammers and therefore using it isn't usually advisable. There's also an optional feature to perform a check against one of the Real-time Blackhole Lists, which are centrally maintained databases of known spammers (most that exist today require paid subscription). This feature is in the default `freebsd.mc` but is commented out; to enable it, move the `dnl` to the end of the line and rebuild the config file. This may be an advisable solution for ISPs.

- As an absolute last resort, turn off relay checking altogether by enabling the `promiscuous_relay` feature. This will allow any valid user to send mail through your Sendmail server; however, it will also allow any spammer to do the same. Some independently run databases on the Internet keep records of all "open" mail servers, and some service providers use these databases as "blackhole" lists of their own. You don't want your server to end up in these databases! If it does, some legitimate mail from your users or their correspondents may be blocked due to their ISPs blocking mail to or from your server. It's an incredibly bad idea to run an open mail server.

As a general rule, the best solution to the relaying problem is simply to instruct all your users to use the SMTP servers provided by their own dial-up Internet Service Providers. These services will always have their own SMTP servers that are open to their own customers. Because the headers in a mail message (such as the `From:` address) are all derived from the message body and therefore completely under the control of the email client program, there's no reason for a remote user to want to use your SMTP server if he already has one of his own.

The Sendmail Consortium has an excellent page on relaying rules and your various available configuration options at http://www.sendmail.org/tips/relaying.html.

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PREV NEXT

Introduction to POP3

You now have a sound understanding of SMTP and Sendmail, and you have the tools you need to configure your server according to the needs of almost any typical Internet server. But SMTP is only half of the equation. For email to get completely from one user to another, there's another process that needs to take place: downloading the mail through the Post Office Protocol, known as POP.

The Post Office Protocol enables users to access their mailboxes from remote client machines and download their messages. POP became necessary once it was clear that there would ultimately be a great many more Internet users who used graphical clientside email programs on their own dial-up computers, rather than server-side shell clients such as Pine and Mutt. Shell-based clients read mail directly out of the user's mailbox file. To use an MUA such as Microsoft Outlook or Apple Mail, however, the client has to connect to the mail server in which the user's mailbox file is stored (refer to Figure 25.1), determine whether there are any new messages since the last time it checked, and if so, download them. The client program then displays these new messages and optionally deletes them from the mailbox file on the server.

Unlike SMTP, POP3 (the current and standard version of POP) requires authentication. This is sensible because although security really isn't an issue for sending mail (except as regards protecting your server from spammers), it's absolutely essential to ensure that only the intended recipient can view the mail addressed to him. After all, in real life, anybody can drop a letter in the outgoing post office mailbox, but only the legitimate receiver can open his or her mailbox and retrieve it.

Authentication makes it a little less easy to simulate a POP transaction than an SMTP one. Simulating a POP transaction is also a lot less necessary, however, largely because POP3 requires very little in the way of configuration. There's not a lot that can go wrong. However, the POP3 server, Qpopper, is not included in the core FreeBSD installation. To enable POP3 service you must install Qpopper out of the ports (`/usr/ports/mail/qpopper`). This program is derived from the original Berkeley POP server program and has been further developed semicommercially (but in a free and open-source fashion) by Qualcomm, the makers of the once-popular Eudora mail client. Qpopper is no longer officially developed or supported, but it's still available from Qualcomm, as is its complete documentation.

Note

Other POP3 server programs are beginning to take the spotlight away from Qpopper. Probably the most popular is Dovecot, available in the ports or from its site at http://dovecot.org; it's a full-featured, security-focused POP3 and IMAP server that works excellently even though it's still in alpha development at the time of this writing. Another solution is IMAP-UW, discussed later in this chapter, which also includes a POP3 server you can use instead of Qpopper.

The POP3 server runs from out of `inetd`, the "super-server." `inetd` listens for TCP and UDP connections, and upon receiving one on TCP port 110, it looks up the service name in `/etc/services`, determines how to handle requests for that service type, and fires off a Qpopper process from `/usr/local/libexec/qpopper`. (This locationin the `libexec` directory, rather than `bin` or `sbin`tells you that Qpopper is not a program intended to be run from the command line. Rather, it's only supposed to be invoked by other programs.) This process handles the transaction, authenticates the user, locks the user's mailbox, figures out which messages need to be downloaded, and serves them. This works just fine for most systems. Although Qpopper does in fact provide a rather large number of configuration options, most of them are useful only for tweaking extra performance out of the servera valuable thing to know how to do if your server is a high-profile one. For most purposes, though, all you have to do is install the port and enable the service.

Note

You may have your system configured so that `inetd` is not running (for example, for security reasons, as outlined in Chapter 30, "Network Security"). If this is the case, Qpopper can be run in standalone mode, like Sendmail. We will discuss how this is done in a moment.

It's important to note that, by default, POP3 transactions are done in clear text. This means that POP3 is a source of potential password leaks and a security risk.

In version 4.0, Qpopper enables encrypted connections through the Secure Sockets Layer (SSL) libraries, which are part of FreeBSD and also used in such protocols as SSH (Secure Shell) and secure HTTP. The following section describes how to configure Qpopper to take advantage of this security measure.

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Configuring a POP3 Server with Qpopper

You can take your POP3 server configuration to several different levels. You can simply install the server and let everyone use it; you can run it in standalone mode, which avoids having to run `inetd` if you don't want to; you can enable "server mode," which enhances performance, depending on your circumstances; and you can enable encrypted sessions through TLS/SSL. These latter options are not mutually exclusive. We'll be looking at each of them in turn.

Basic Qpopper Installation and Configuration

Getting the POP3 service up and running without concerning yourself too much about performance or security is a simple matter. Go to the `qpopper` directory in the ports collection (`/usr/ports/qpopper`) and then build and install it from there, as described in Chapter 16. Alternatively, you can install the `qpopper` package using Sysinstall or the package tools.

Next, you need to enable the POP3 service in the `inetd` super-server. You do that by adding a line to `/etc/inetd.conf`. Open up the `inetd.conf` file in a text editor and find the lines regarding POP3, as shown. Add or uncomment the `pop3` service using the following syntax:

```
# example entry for the optional pop3 server
#
#pop3   stream  tcp     nowait  root    /usr/local/libexec/popper      popper
pop3     stream   tcp      nowait   root    /usr/local/libexec/qpopper     qpopper -s
```

Note

For legacy purposes, there's also a port that's simply called `popper`. It is actually Qpopper in an earlier form, and it's generally deprecated by this point. The one you want to use is `qpopper`.

Now, restart `inetd` by using the `/etc/rc.d/inetd` script:

```
# killall -HUP inetd
```

You can check to see whether the POP3 service is available now by connecting to port 110 on your machine via Telnet (type **QUIT** to exit the session):

[View full width]

```
# telnet localhost 110
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
+OK Qpopper (version 4.0.2) at stripes.example.com starting. <4763.990313780@stripes
   .example.com>
QUIT
+OK Pop server at stripes.example.com signing off.
Connection closed by foreign host.
```

If you get this response from the server, congratulationsyou have a working POP3 server.

Enabling Standalone Mode

Certain security and configuration settings turn off the `inetd` super-server; for instance, if you chose not to enable `inetd` during your system installation, the following line would have been added to your `/etc/rc.conf`, thus preventing `inetd` from being run at all:

```
inetd_enable="NO"
```

On a security-conscious system, you don't want to have to reenable `inetd` just so you can run POP3 services. This is what Qpopper's standalone mode is for. It isn't an option available by default, but a quick tweak to the makefile makes it pretty easy.

In `/usr/ports/mail/qpopper`, edit Makefile and alter `CONFIGURE_ARGS` to add the `--enable-standalone` option:

```
CONFIGURE_ARGS= --enable-apop=${PREFIX}/etc/qpopper/pop.auth \
                --enable-nonauth-file=/etc/ftpusers \
                --with-apopuid=pop --without-gdbm \
                --enable-keep-temp-drop \
                --enable-standalone
```

Now, run **`make`** and **`make install`** to build a version of Qpopper that runs in standalone mode. It will still be installed in `/usr/local/libexec`, though. Don't move it from this location because this will make deinstallation more difficult later.

You'll need to start up the standalone Qpopper process from a script during system boot; this can be done by creating a startup script in `/usr/local/etc/rc.d` called, for example, `qpopper.sh`, as you saw in Chapter 14, "System Configuration and Startup Scripts." Make sure that Qpopper isn't enabled in `inetd` if you do this!

Enabling Server Mode

If your system *only* has users who access their mailboxes through POP3where none of the users have shell access or run shell-based, server-side mail programsyou might choose to enable server mode for Qpopper.

Server mode allows Qpopper to run in a streamlined fashion. Instead of copying the mail spool file to a temporary duplicate, locking it, making changes, keeping track of mail that arrives during the session, and merging the locked session spool back to its original location, the server can work directly from the mailbox file itself. Be aware, however, that server mode can be dangerous, particularly if you have users who access their mail spool files through other methods, such as shell-based mail clients or mail programs using IMAP. For that reason, you should use server mode *only* if your system serves mail exclusively to remote users through POP3, and if it's under enough load for you to consider this performance-boosting measure to be necessary.

You can enable server mode in a number of ways. The easiest is to use the `-S` switch on the command invocation line, whether in `inetd.conf` or on the command line if you're using standalone mode:

```
pop3 stream tcp nowait root /usr/local/libexec/qpopper qpopper -s -S
```

This will put Qpopper into server mode for all users at all times. You can do it per user, though, or per group, if you prefer. Group control is best done through a configuration file. To make Qpopper use a config file, create one in `/usr/local/etc/qpopper` (calling it, for example, `qpopper.conf`) and then indicate it on the command line in `inetd.conf` with the `-f` option:

[View full width]

```
pop3 stream tcp nowait root /usr/local/libexec/qpopper qpopper -s -S -f /usr/local/etc
   /qpopper/qpopper.conf
```

Now, in the `qpopper.conf` file, specify the name of a group to include or exclude from server mode using the `group-server-mode` or `group-no-server-mode` keywords. The following example turns server mode on for members of `group1` and `group2`, and off for members of `group3`:

```
set group-server-mode=group1
set group-server-mode=group2
set group-no-server-mode=group3
```

You can also use this technique on a per-user basis. You may choose to configure Qpopper this way if different users on your system want to interact with Qpopper differentlyif some want to use it in server mode and others don't. To do so, you need to add the `-u` switch to the command invocation line (to enable per-user configuration files). Then, each user to whom the mode should apply needs to have a file in his or her directory called `.qpopper.options`, which contains the line `set server-mode`. Alternatively, if you don't want each user to be able to modify his or her `.qpopper.options` file, use the `-U` switch instead of `-u`, and place a corresponding per-user file in `/var/mail` called `.*user*.qpopper.options` (where *`user`* is the username in question). This allows you to turn on server mode on an individual basis. Don't use the `-S` global server mode switch if you do it this way! This will only confuse the program as to whether you mean it to set server mode globally or per user.

Enabling SSL Encryption

The Secure Sockets Layer (SSL) is a set of libraries included in FreeBSD that encrypt traffic on a given service so that even if the packets carrying that service's traffic are captured by an eavesdropper, they can't be descrambled without the proper encryption keys. SSL is most frequently used on web traffic, as you'll see in Chapter 30; however, its use is not limited to HTTP and can be very beneficial on services such as POP3.

By default, Qpopper will build with implicit TLS/SSL support. However, to take advantage of it, you need to create and install security certificates using the OpenSSL library built into FreeBSD. First, create a directory for your certificates:

```
# mkdir -p -m665 /etc/mail/certs
# chown root:mail /etc/mail/certs
# chmod 660 /etc/mail/certs
```

Next, use the `openssl` command to generate a certificate request. This will require you to enter several accurate pieces of information about your organization. (In the example shown here, "`...`" represents the long interactive session that results in a certificate request file.) Afterward, make sure the permissions on the private key file (`cert.pem`) only allow root to view it:

```
# openssl req -new -nodes -out req.pem -keyout /etc/mail/certs/cert.pem
...
# chmod 600 /etc/mail/certs/cert.pem
# chown root:0 /etc/mail/certs/cert.pem
```

After this is done, you'll need to register the certificate with a Certifying Authority (CA), such as VeriSign, and submit the certificate request in `req.pem` to the CA. Then you'll get back a signed certificate. Concatenate this onto the end of `cert.pem`:

```
# cat signed_req.pem >> /etc/mail/certs/cert.pem
```

Alternatively, simply replace the old `cert.pem` with the new `signed_req.pem`.

Now, add TLS/SSL support to the config file at `/usr/local/etc/qpopper/qpopper.conf`, restart the server (if it's running in standalone mode), and SSL encryption is yours. Any client that supports SSL will now be able to negotiate a secure connection if configured to do so.

The following lines are what should be added to the `qpopper.conf` file:

```
set tls-support = stls
set tls-server-cert-file = /etc/mail/certs/cert.pem
```

Sometimes registering a certificate with a third-party authority is not feasible. If you want, you can emulate a Certifying Authority yourself to create a self-signed certificate that you can use to make sure the system works. However, SSL-enabled clients won't trust this certificate and will require the user to manually approve it before continuing.

First, create the test CA's private key (making sure to remember the passphrase you enter) and then create the CA certificate:

```
# openssl genrsa -des3 -out ca.key 1024
...
# openssl req -new -x509 -days 365 -key ca.key -out ca.crt
```

Now, you can self-sign the certificate request you created earlier (`req.pem`):

[View full width]
```
# openssl x509 -req -CA ca.crt -CAkey ca.key -days 365 -in req.pem -out signed-req.pem
   -Cacreateserial
```

This should allow you to run an SSL-enabled Qpopper server so as to test its functionality. Make sure to get the real CA-signed certificate at some point!

For More Information

Although Qpopper is no longer supported by Qualcomm, its official website is still available at http://www.eudora.com/products/unsupported/qpopper/. It has a lot of useful information, including a PDF document (in the Documentation section) that definitively describes all the possible configuration options of Qpopper. It's written from a Linux viewpoint, so many of the pathnames quoted in the documentation are slightly different from your installation.

Even more information, particularly on the use of configuration files, can be found in the `man qpopper` page.

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Configuring an IMAP Server with IMAP-UW

The Internet Message Access Protocol (IMAP) is an alternative to POP that many users prefer; in fact, in the modern era of centralized email services such as Gmail and .Mac that encourage users to archive their mail for premium-grade indexing on the server rather than deleting it all as it's read, IMAP is displacing POP as the mail-reading protocol of choice. You will probably want to support it on your mail server, along with POP and SMTP services, to make your server offerings complete.

The fundamental difference between IMAP and POP is that whereas POP downloads each message from the server and stores it in the mail program's internal database, IMAP mail is accessed and manipulated wholly on the server. IMAP clients (such as Outlook, Apple Mail, Mozilla Thunderbird, and every other client that also supports POP) cache the messages they download and keep them in a local database for quick access, but the definitive messages themselves are stored on the server and not deleted except upon explicit command. This makes it possible for an IMAP user to access her mail from any of several different computers, unlike with POP (which requires her to download all her mail to a single computer if she wants to keep it all in one place). IMAP is also used as the back-end protocol for many webmail systems, where the web-based email system acts as the MUA and synchronizes the messages from a traditional MTA.

The most popular UNIX IMAP server is IMAP-UW, by the University of Washington (the same group that produces Pine, a popular MUA that you'll learn about shortly). It's available in the ports, at `/usr/ports/mail/imap-uw`, or in the packages collection (refer to Chapter 16 for details on installing software from the ports or packages). Add `USE_SSL=YES` to both the `make` and `make install` command lines to build the port with SSL support.

The IMAP-UW package consists of a mailbox test program (`mboxtest`) and four daemon executables that go into `/usr/local/libexec`. Two of these, `ipop2d` and `ipop3d`, are POP servers (for POP2 and POP3, respectively), which you don't need to install if you're already running Qpopper. However, these POP daemons do have the capability to pipe POP commands to the IMAP server, so they can provide an upgrade path for existing POP clients to move to IMAP if you want to migrate to an exclusively IMAP environment.

Installation of IMAP-UW is fairly simple. There are no configuration files to edit for the program itself; all that is necessary is a modification to `/etc/inetd.conf` (because the IMAP server operates out of `inetd`, like Qpopper) and optionally to `/etc/pam.d/imap`.

The commented-out line in `/etc/inetd.conf` will work just fine for IMAP-UW. Just uncomment it:

```
# example entry for the optional imap4 server
#
imap4   stream  tcp     nowait  root    /usr/local/libexec/imapd imapd
```

Then, restart `inetd`:

```
# /etc/rc.d/inetd restart
```

The IMAP daemon listens on TCP port 143. You can test whether it's set up properly by connecting to port 143 via Telnet. End the session by pressing Ctrl+] and typing **`quit`**:

[View full width]

```
# telnet localhost 143
Trying 127.0.0.1...
Connected to localhost.example.com.
Escape character is '^]'.
* OK [CAPABILITY IMAP4 IMAP4REV1 LOGIN-REFERRALS AUTH=LOGIN] localhost.example.com
    IMAP4rev1 2001.303 at Sun, 10 Jun 2001 11:21:26 -0700 (PDT)
^]
telnet> quit
Connection closed.
```

Note

You might notice warnings in your `/var/log/messages` file or your IMAP client software indicating that the mailbox is "vulnerable" and urging that `/var/mail` have "1777 protection." This is a security check done by the IMAP-UW server (Pine does it, too).

FreeBSD's mail directory permissions are `775`, meaning that all programs that access or create files in `/var/mail` must be set (using `setgid`) to the mail group. However, IMAP-UW does not run `setgid`. Therefore, when creating lock files (preventing mailboxes from delivering mail while receiving new messages), it can't do so in `/var/mail`. The suggested workaround is to change the permissions on `/var/mail` to 1777, allowing non-privileged users to add and delete files. However, only the proper users can modify their own files. This isn't an ideal solution, but it will suffice in most cases.

You can use SSL/TLS encryption with IMAP, just as with POP3. When building it from the ports, use **`make USE_SSL=YES`** and **`make install USE_SSL=YES`** instead of simply using `make` and `make install`. You can then generate a certificate using **`make cert`**, or you can simply copy the certificate file you may have created for Qpopper into `/usr/local/certs` (where IMAP-UW expects to find it). For consistency's sake, you might want to alter your Qpopper configuration to point to the same certificate in `/usr/local/certs` if you will be using it for both secured services.

An alternative way to provide security for both POP3 and IMAP is to use `stunnel`, which you learn about in "Securing Email Services (POP3 and IMAP)," in Chapter 30. However, you should avoid `stunnel` if it's possible to install native SSL/TLS support in the POP3 and IMAP services themselves.

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Email for Standalone Workstations

Knowing how to run a full-fledged email server is an excellent system administration skill. But this skill won't help you much if your FreeBSD machine isn't intended to be an Internet server providing mail services for dozens of users. What if you're just running a workstation, in the same way that someone might run a Windows desktop machine, with a Gnome or KDE desktop and graphical productivity applications instead of server tools?

Fortunately, a standalone workstation's email setup is much less complex than that of a full-scale server. FreeBSD's default configuration is to start a "submission" Sendmail process (`sendmail_submit_enable="YES"` is the default setting in `/etc/defaults/rc.conf`), and you need not add any mention of Sendmail to `/etc/rc.conf` to enable your system to deliver mail from your local mail clients to remote SMTP servers.

Still, it's important that you know how to control the standalone workstation environment and customize its behavior to your needs, and there are some interesting tricks that make standalone computing with FreeBSD more convenient than would otherwise be the case.

Using Fetchmail to Retrieve Email from POP3 and IMAP Servers

Most consumer operating systems have email client programs (such as Outlook, Apple Mail, Mozilla Thunderbird, and so on) that have their own internal, built-in mechanisms for checking POP3 or IMAP servers. Each one gets your mail in its own way and then stores it in its own fashion internally. Some MUA programs of this type exist for FreeBSD, as discussed earlier (particularly in Chapter 6), and they work just as you'd expect any such program to work.

However, you might choose instead to run a shell-based MUA such as Mutt, Elm, or Pine on your local workstation, just as you would on a server. These programs operate directly on the system's central `/var/mail` directory and your mail spool file inside it, rather than keeping their own internal cache of downloaded messages. This allows you to share the mailbox between programs, search through it using command-line tools, and take advantage in many other ways of the versatility and open nature of the mail system to make it behave just the way you want, such as by writing your own scripts to parse your mail spool and process it according to your own needs.

But to get the messages from the POP3 or IMAP server where your email address stores them (for instance, all mail to a `frank@earthlink.net` address would collect on the `earthlink.net` servers) to your local FreeBSD workstation, something needs to make the POP3 or IMAP connection and deliver the new messages from the remote mailbox to your local one. That something is Fetchmail, a small but versatile utility written by Eric Raymond.

Fetchmail can be installed out of the ports (`/usr/ports/mail/fetchmail`) or packages. It runs as a user process, on demand, and takes its runtime configuration from a `.fetchmailrc` file in your home directory. This file specifies remote POP3 or IMAP servers to poll for new mail, the intervals at which to check, and numerous other options.

Fetchmail then retrieves new mail as specified and relays it to port 25 on your workstation, where Sendmail is listening for incoming SMTP connections. It then will deliver the mail to your local mailbox according to all the rules that would normally apply, such as `.forward` files and mail aliases.

After Fetchmail has been installed (it is available in the FreeBSD ports collection in the `mail` directory), you will need to configure the `.fetchmailrc` file in your home directory before you can use it. This can be done in one of two ways.

The first method involves using the `fetchmailconf` program. This is a graphical configuration program for Fetchmail that is written in Python and uses the Tk toolkit (a toolkit for building graphical user interfaces in the X11 system). Although `fetchmailconf` comes with the Fetchmail program, it requires Python and Tcl/Tk to be installed in order to work. (Python and Tcl/Tk are both popular languages available for many different platforms.)

The second method of configuring Fetchmail involves creating the `.fetchmailrc` file manually. The format of the configuration file is straightforward, and the Fetchmail `man` page is extremely good, covering in detail every option that can go in the `.fetchmailrc` file. This is the method we will cover in this chapter.

Configuring the `.fetchmailrc` File

In your home directory, open a new file called `.fetchmailrc` in your favorite text editor. The `.fetchmailrc` file you create here will contain three sections: global options, server options, and user options.

Caution

It's very important that the `.fetchmailrc` file sections appear in exactly the order shown here. Also note that no options that belong to a previous section can be used after a new section has been started. One of the most common causes of errors in `.fetchmailrc` files is having options in the wrong order or in the wrong place.

This chapter doesn't cover all the options available to `.fetchmailrc` because there are far too many. What we will do instead is to create a sample setup for retrieving mail from a POP3 server, a fairly common user situation. Use the information presented in this section as a starting point for getting Fetchmail up and running. Then, refer to the `man` page for Fetchmail for any advanced configuration you want to do.

The first section of the `.fetchmailrc` file contains the global options. These options will apply to all the mail servers and user accounts that will be listed later on in the configuration file. It is possible to override some of the global options with server- or user-specific options, but as a general rule, these lines will apply to all the servers and accounts that Fetchmail checks. Here is an example of a simple global configuration section and the options it might contain:

```
set daemon 600
set postmaster frank
set logfile ./.fetchmail.log
```

These are the most common options used in the global section. Here's an explanation of each line:

- The first line causes Fetchmail to run in daemon mode and check for new mail every 600 seconds (10 minutes). When Fetchmail is started, it will check for new mail and move itself into the background as a daemon. After that, it will check for new mail every 600 seconds. If this line is not present, when you invoke Fetchmail, it will check for new mail and then terminate immediately and not check again.
- The second line is the fallback address. Any mail that Fetchmail receives that is not addressed to a local user will be sent to this account on the local system. You should probably set this to the same user you will be running Fetchmail as.
- Finally, the third option sets a log file in which Fetchmail will log its activity. Alternatively, you can use the line `set syslog` instead, which will cause Fetchmail to use `syslogd` for logging. `syslogd` is the system-logging daemon that handles the logging of other system events. See Chapter 14 for more about `syslogd`.

The next section of the `.fetchmailrc` file is the server section, which contains information on each mail server that should be checked for mail. Here is a sample server section that is configured to check one email server:

```
poll mail.example.com
proto pop3
```

```
no dns
```

Several other server options are available. See the Fetchmail `man` page for full details. Here are the options shown in this example:

- The first line causes the server `mail.example.com` to be checked for new mail at the interval configured by the `set daemon` option in the global section, as well as each time Fetchmail is invoked manually. The alternative would be `skip mail.example.com`. In this case, this server would be skipped and not checked for new mail at the regular intervals or when Fetchmail is invoked manually. If the `skip` option is used, the server will only be checked for new mail when you specify it by name on the command line when invoking Fetchmail manually.
- The second line tells Fetchmail the protocol to use with this server. In this case, it's POP3. Other legal protocols are IMAP, APOP, and KPOP.
- The third option tells Fetchmail not to perform DNS lookups when performing "multidrop" local name resolution (deciphering local usernames from the domains in the address headers of each message). If you are running over a dial-up Internet connection, you will probably want to include this line to prevent delays in getting your mail.

The third and final section of the `.fetchmailrc` file is the user section, which contains information about the account itself. Here is a sample user section of `.fetchmailrc`:

```
user frank
pass secretword
fetchall
flush
```

Here are some points to note in this example:

- The first and second lines contain the username and password, respectively, that you use to access the mail on your ISP's mail server. (As a matter of responsible security practice, this should be different from the passwords you use for other services, such as your online banking account.)
- The third line tells Fetchmail that it should retrieve all messages from the server, including those that have already been read.
- Finally, the fourth line tells Fetchmail that it should flush the server (delete the messages it downloads off the server). This line is not strictly necessary because it's implied in the default configuration.

Several more user options are available, including options that cause Fetchmail not to delete mail off the server that it downloads, options that specify that only new messages should be downloaded, and so on. See the Fetchmail `man` page for full details.

The complete Fetchmail configuration file looks like this:

```
set daemon 600
set postmaster frank
set logfile ./.fetchmail.log

poll mail.example.com
proto pop3
no dns

user frank
pass secretword
fetchall
flush
```

From top to bottom, this file basically says the following: "Check for new mail every 600 seconds (10 minutes). Send any unaddressed mail to the user `frank`. Log the actions to `.fetchmail.log`. Perform the 10-minute-apart checks against the server `mail.example.com` using the POP3 protocol, and do not attempt to do DNS lookups on local usernames. Use the username `frank` and the password `secretword` to log in to the server, fetch all the messages, and delete the messages off the server after they are downloaded."

Caution

Because the `.fetchmailrc` file contains your username and password for the mail server, its permissions should be set so that only you, the user running Fetchmail, can read this file. The permissions should be no higher than `600`. You can set the permissions to the correct value by typing **`chmod 600 .fetchmailrc`**. This will allow only the owner of the file to read or write to it. Fetchmail will complain and refuse to run if you attempt to start it with a `.fetchmailrc` file that has permissions looser than this.

This brief introduction to Fetchmail should get you up and running with a basic configuration. For more advanced options, see the `man` page for Fetchmail. It is very detailed and fully explains all the options available for the `.fetchmailrc` file.

Sendmail Configuration for Standalone Workstations

For Fetchmail to work, Sendmail (or some equivalent) has to be running on port 25 to accept incoming messages. However, Sendmail is configured by default to handle outgoing mail, and for good reason; it's not generally a good idea to run your workstation with no MTA at all. For example, Mutt and other shell-based mail clients send messages by passing them directly to Sendmail, rather than by connecting remotely to some external SMTP host. This prevents relaying-related issues, as discussed earlier.

Still, you can do a few things to tweak Sendmail's performance and configuration so that it's optimized for use in a system that isn't connected to the Internet at all times. The first such configuration is the "smart" mail host, and the second is an automated mail spool run.

Find the following lines in `/etc/mail/freebsd.mc`:

```
dnl Dialup users should uncomment and define this appropriately
dnl define(`SMART_HOST', `your.isp.mail.server')
```

Uncomment the `define` line by removing the `dnl`, and change `your.isp.mail.server` to the appropriate mail server name. Rebuild the config file by running `make cf` and `make install` from inside `/etc/mail`.

This change allows your workstation to operate like any desktop operating system in which each mail client makes its own SMTP connection to the SMTP server provided by the dial-up ISP, which then relays the mail on to its final destination. Because you might be using shell-based MUAs such as Mutt and Pine, which send mail by passing it directly to Sendmail rather than trying to make their own in-program SMTP connections to a defined SMTP relay, you need a centralized way to make these mail clients behave like their commercial Windows counterparts. Defining `SMART_HOST` forces Sendmail to direct all outgoing mail to your dial-up SMTP server.

The reason for all this is that most SMTP servers will reject mail that comes from an unresolvable IP address, and many ISP networks don't provide DNS lookup information for their dial-up clients. If you don't define `SMART HOST`, this limitation will prevent your FreeBSD workstation from being able to send mail reliably to a good percentage of the mail hosts on the Internet. However, because you have an available SMTP server at your ISP, and because this server will relay mail from all its dial-up customers (because that's how Windows MUAs work), you can rest assured that defining `SMART_HOST` will get all your messages to their destinations.

Another configuration item you can tweak is the outgoing ("submission") message queue. By default, Sendmail does a queue run every 30 minutes (using the `-q30m` command-line option, set in `/etc/defaults/rc.conf`). If you're a dial-up user who connects for only brief periods, this interval might be too long. You can add a line to `/etc/rc.conf` overriding the default interval (changing the default `-q30m` to `-q10m`):

```
sendmail_flags="-L sm-mta -bd -q10m -ODaemonPortOptions=Addr=localhost"
```

However, an even more efficient way to handle this is to leave the default `-q30m` untouched and to simply do a queue run each time you connect to the Internet. As you'll recall, you can initiate a queue run with the `sendmail -q` command, optionally adding `-v` for entertainment or debugging purposes.

Doing this by hand is sure to become tedious, though, so you can add `sendmail -q` to your `ip-up` script, which we discussed in Chapter 24, "Networking with PPP and 802.11."

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Filtering Junk Mail with Procmail and SpamAssassin

As a FreeBSD email server administrator, it behooves you to make some attempt to hold back the tide of that nemesis of the Internet: junk mail, or spam. Most modern email client applications provide their own internal spam filtering tools, using techniques such as Bayesian pattern matching and other semantics-based and contextual artificial intelligence tricks that lets users "train" their email programs to better identify spam and shunt it away into a quarantine area. Still, though, these client-side techniques are only part of a complete solution to the spam problem, and another big piece of the puzzle can be provided by you at the server level. If you can prevent spam messages from even getting to users' mailboxes, that's so much less useless data they have to download each time they get their mail.

Most email clients can optionally identify spam based on headers set by the mail server. This means that if an email message arrives with a set of headers like the following, the mail program can immediately trust that it's spam and file it away in the Junk folder:

```
From nobody@spammer.com Wed Jan 11 12:37:35 2006
X-Spam-Flag: YES
X-Spam-Checker-Version: SpamAssassin 3.1.0 (2005-09-13) on mail.example.com
X-Spam-Level: ******
X-Spam-Status: Yes, score=6.3 required=5.0 tests=BAYES_99,DATE_IN_PAST_12_24,
        URIBL_SBL autolearn=no version=3.1.0
X-Spam-Report:
        * 1.2 DATE_IN_PAST_12_24 Date: is 12 to 24 hours before Received: date
        * 3.5 BAYES_99 BODY: Bayesian spam probability is 99 to 100%
        *      [score: 1.0000]
        * 1.6 URIBL_SBL Contains an URL listed in the SBL blocklist
        *      [URIs: premiumgoodsavailable.com]
```

These headers are set in the message by a package called SpamAssassin, whichin conjunction with a third-party local mail handler called Procmailprocesses all incoming messages, either on a per-user or global basis, and applies its own set of Bayesian filters and learned contextual rules, as well as a plethora of other tests for suspicious characteristics.

Each line below `X-Spam-Report:` in the example headers shown here represents a test that the message failed, and the "weight" assigned to that test; for example, here, the Bayesian spam probability checks reported with almost complete certainty that the message is junk, and that test is worth a score of 3.5. That in itself isn't enough to make SpamAssassin set the `X-Spam-Flag` header to `YES`, because the default threshold for that action is 5.0. However, a couple of further tests failed as well: one, worth 1.2 points, is that the sending timestamp of the message is more than half a day prior to the time the message was received, which is a suspicious indicator; another, worth 1.6 points, is that the body of the message contains a URL that's known to be a spammer site and is thus present in a list available to SpamAssassin. Taken together, these various tests add up to 6.3, which is more than the threshold value of 5.0 which is required to make the message "spam." No single test is enough to flag a message as spam; it must fail multiple tests for that to happen. This ensures that the probability of false positives is very low.

Note

Individual users can specify the threshold at which messages are flagged as spam; this is defined with the `required_score` keyword in the `user_prefs` file, which we will discuss shortly.

SpamAssassin alters the message's headers to reflect the results of its tests and then passes it back into the user's mailbox. Then, when the user's email program downloads the message and reads these headers (particularly `X-Spam-Flag`), it knows to trash the message right away so the user doesn't even see it.

Additionally, users can opt to have spam that scores particularly high (above a certain threshold, for example 7.0 or higher) be moved to a holding area or immediately deleted on the server (a task handled by Procmail, as you will see later). This clears out the messages that are obviously junk so the user doesn't even have to waste time downloading them.

You can configure FreeBSD to perform this service for your users with just a few relatively simple steps. SpamAssassin can be enabled globally for all users on your system, or for just one user at a time as requested; it's best to start out by enabling it for just one user (for instance, yourself) to make sure it's working properly, before choosing to enable it globally for all users.

Note

SpamAssassin's daemon processes can also be taxing on your system's resources, particularly CPU time. You should consider whether your hardware has the cycles to spare before enabling SpamAssassin on your MTA.

Installing SpamAssassin

Install the SpamAssassin package from the ports or packages in the `mail` category. The package name is `p5-Mail-SpamAssassin` (it's actually a set of Perl modules). See Chapter 16 for more details on installing software.

When SpamAssassin is installed, a daemon called `spamd` that's part of the package must be enabled; to do this, add the following line to `/etc/rc.d`:

```
spamd_enable="YES"
```

Next, ensure that the startup script called `sa-spamd.sh` is present in `/usr/local/etc/rc.d` and set executable. Now, the next time you reboot, SpamAssassin will be started automatically; alternatively, start it manually by typing **`/usr/local/etc/rc.d/sa-spamd start`**.

You must next prepare each user's directory for SpamAssassin by creating a `.spamassassin` subdirectory and setting its ownership to the user whose mail you're filtering:

```
# mkdir ~frank/.spamassassin
# chown frank:frank ~frank/.spamassassin
```

The `.spamassassin` directory will contain the runtime files used by SpamAssassin for a given user, such as the Bayesian tokens "learned" over time that mark a message as "spam" or "not spam" (also known as "ham"), and the automatic whitelist file that helps protect legitimate messages from being incorrectly tagged. These files are created and maintained automatically by SpamAssassin and become more accurate the longer it's used.

Finally, create a file called `user_prefs` inside the `.spamassassin` directory, and give it the same ownership as the `.spamassassin` directory itself. This file defines the behavior of SpamAssassin for each user. Listing 25.2 shows the contents of a `user_prefs` file that will suit most users' needs; each user can modify it to his own taste as necessary. See `man spamassassin` for more details on what each of these keywords means.

Listing 25.2. A Sample SpamAssassin `user_prefs` Configuration File

```
rewrite_subject 1
report_header 1
use_terse_report 1
```

```
defang_mime 0
report_safe 0
use_bayes 1
auto_learn 1
ok_locales en
```

Installing Procmail

By itself, SpamAssassin does nothing to your mailbox. Email messages must be actively directed through the `spamd` server for it to process them. The tool that accomplishes this, and the post-processing that will be applied to each message after `spamd` is done with it, is a message processing program called Procmail, also available in the `mail` category of the ports or packages.

Procmail is a highly customizable utility that any user can use to filter messages into folders, redirect them into programs, or delete them outright, depending on the contents of each message. The functions of Procmail for each user are defined by the contents of the `.procmailrc` file in the user's home directory, and by the `.forward` file, which forwards all incoming messages into Procmail. Use the following line in `.forward` to send all a user's mail through Procmail before being delivered:

```
"|IFS=' '&&exec /usr/local/bin/procmail -f-||exit 75 #frank"
```

After this forwarding command is in place, create a `.procmail` directory in the user's home directory, using a similar technique to how you created the `.spamassassin` directory:

```
# mkdir ~frank/.procmail
# chown frank:frank ~frank/.procmail
```

This directory will hold Procmail's activity log and other related files that are created through its natural operation.

Next, you must install an appropriate `.procmailrc` file for the user, defining the "recipe" for processing his incoming messages. Listing 25.3 shows a `.procmailrc` file that will accomplish our needs.

Listing 25.3. A Sample `.procmailrc` File for Harnessing SpamAssassin

```
PATH=/usr/bin:/usr/local/bin:/usr/sbin:/usr/local/sbin:/home/frank
VERBOSE=off
MAILDIR=$HOME/mail
DEFAULT=/var/mail/frank
PMDIR=$HOME/.procmail
LOGFILE=$PMDIR/log
SHELL=/bin/sh
FGREP=/usr/bin/fgrep
FORMAIL=/usr/local/bin/formail
LOGABSTRACT=all
NL="
"

SPAM=$HOME/spam-folder

#Spamassassin start
:0fw: spamassassin.lock
| /usr/local/bin/spamc
#Spamassassin end

:0:
* ^X-Spam-Level: \*\*\*\*\*\*\*
$SPAM
```

```
#/dev/null

# OK, guess we'll keep it

:0:
$DEFAULT
```

The first block of lines in this file represents environment variables that you're setting up for Procmail to have at its disposal; most aren't important for this task, but if you or your users want to customize the behavior of Procmail further to process incoming messages in still more creative ways, these variables can be very helpful. The most critical ones are the ones used later in the file, namely (in this case) the `DEFAULT` variable, which defines the default mail spool file. The `SPAM` line is also important; it defines the name of a folder (which is really just a plain text file) that will store all the messages that SpamAssassin determines is spam.

The two lines in the next block surrounded by comments are where Procmail feeds each incoming message to SpamAssassin. This is done using a command called `spamc`, which is a client that interfaces with the `spamd` daemon you enabled earlier. When Procmail encounters these lines, it forwards the message to `spamc` and waits for it to come back, tagged with headers that indicate whether or not it's spam.

Remote email client users might want to make this the end of their Procmail recipesthe `X-Spam-Flag` header is now set, and their email programs will now be able to dispose of the spam messages based on that alone. However, the next block of lines gives you still more options for how to treat spam messages.

All messages coming back from SpamAssassin will have an `X-Spam-Level` header which expresses the spam "score" as a string of asterisks (as you saw in the example headers earlier). You can use a line such as `* ^X-Spam-Level: \*\*\*\*\*\*\*` to indicate that Procmail should perform an additional step of processing on all messages that contain an asterisk string at least that long. (The backslashes are important; they indicate that the asterisks should be interpreted literally, rather than as wildcards, which would match any and all contents of all messages.) In this example, any message with a score of 7.0 or higher (expressed as a string of seven asterisks or more, which matches this regular expression no matter how many more asterisks there are) is redirected into the file called `spam-folder` in the user's home directory, rather than into his default mailbox. The user can then peruse the spam folder periodically and check for false positives if he's particularly worried. He can then delete the file when he's satisfied, or even set up a `cron` job to delete it on a regular basis, ensuring that your disk space doesn't get consumed.

Tip

If a user doesn't want to deal with checking the spam folder for misidentified messages or periodically deleting it to save space, he can instead choose to have the spam messages above a certain threshold deleted outright instead of sent into a folder. Just comment out the `$SPAM` line and uncomment the next line, `#/dev/null`. This tells Procmail to send those spam messages straight to the bit-bucket.

Finally, the last two lines (which aren't strictly necessary) tell Procmail to return the messages to the default mailbox if they didn't fall through any of the trap doors set by SpamAssassin and your Procmail rules. Legitimate mail will thus get delivered properly to the user, as will messages whose SpamAssassin scores were high but not as high as the threshold value you defined (7.0). This means that the user will still download messages whose spam scores are between 5.0 and 7.0; though their mail programs will still identify these as "spam" (because their `X-Spam-Flag` headers are still set to `YES`), the user can peruse them at leisure and check for false positivesthere will be a lot fewer of them than the obvious, high-scoring spam that's now being harmlessly filtered out.

Tip

You can, if you choose, set up every user's mail to be filtered through SpamAssassin whether they want it to be or not. To do this, use the file `/usr/local/etc/procmailrc` instead of the per-user `.procmailrc`; Procmail reads recipes in that global file and sends all users' messages to the indicated destinations. See `man spamassassin` for more information on running SpamAssassin globally.

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A Look at Some Sendmail Replacements

Although Sendmail is still widely recognized as the industry-leading MTA by a wide margin, it's not without its faultsin fact, it's generally understood to be rife with them. Sendmail is widely criticized for its barely comprehensible configuration files, the "master config" file in its otherwise almost-unknown `m4` format, the proliferation of different runtime files (such as the access database and `virtusertable` file), and its comparative bulk and sluggishness. If you're comfortable with the way Sendmail works in its default configuration (which usually doesn't take much extra effort), you may have no need to complain. However, if you find you need more speed and less resource consumption, you can choose a replacement MTA. Replacements for Sendmail abound, each with its advantages, disadvantages, and die-hard supporters.

Note

A file called `/etc/mail/mailer.conf` controls an abstraction layer that allows you to drop in a replacement for Sendmail and have the system still operate as it did beforehand. Its content is a set of aliases or pointers that define commands such as `sendmail` and `mailq` (which are really just aliases to specific Sendmail options; for instance, `sendmail bp` for `mailq`) to refer to a specific binary, which by default is `/usr/libexec/sendmail/sendmail`the actual Sendmail Consortium MTA program.

`/usr/sbin/sendmail` is really a symbolic link to `/usr/sbin/mailwrapper`, which uses the `mailer.conf` file to tell it how to redirect calls for those Sendmail-related commands. If you install a replacement program such as Postfix, its installation script will modify `mailer.conf` for you so that you can continue to type `sendmail` or `mailq`, and `mailwrapper` will redirect those commands off to the new Postfix binary instead of the default Sendmail. This technique also makes it easy to switch back to Sendmail if you change your mind later.

Postfix

Perhaps the largest and most compelling Sendmail alternative right now is Postfix, developed by Wietse Venema with the primary goals of speed and security. Also, its structure tends to be very "Sendmail-like," which makes it a good choice for an administrator of a large and entrenched Sendmail system that needs to be given a performance boost. However, its biggest advantage over Sendmail is that its configuration is vastly, *vastly* easier.

The speed of Postfix is reported to be extremely good, easily faster than Qmail, for example, although this is difficult to measure empirically. Postfix has garnered many adherents in recent years, and its feature set is now all but equivalent to Sendmail's; switching to Postfix will gain you significantly in simplicity of configuration while obliging you to endure very few sacrifices in functionality.

The Postfix home page is at http://www.postfix.org.

Qmail

Dan Bernstein wrote Qmail specifically to provide an alternative to Sendmail that was fast and secure, much the same goals as underpinned Postfix's development. Unlike Sendmail, however, the internal structure of Qmail is built up from scratch, not adapted from the Sendmail structure; this means that the configuration and the file structure for a Qmail installation don't much resemble their counterparts in Sendmail. Qmail consists of a suite of separate processes that each handle a specific part of the MTA systemdelivery, logging, queueing, and so oneach with its own permissions and execution schedule. This makes Qmail far more flexible and quick to respond, as well as easier to reconfigure on the fly, than its competitors.

Qmail is a good choice for an administrator who wants speed and security but doesn't know enough about Sendmail to be attached to it. It's also integrated tightly with the EZMLM mailing list manager, also by Bernstein, so Qmail would serve you well if you use EZMLM.

The Qmail home page is at http://www.qmail.org.

Exim

Developed at Cambridge University, Exim offers a Sendmail alternative whose chief advantage is a helpful complement of documentation, developer support, and mailing lists. It's also reputed to be very easy to configure, largely due to these sources of help, and more mature than some of the other alternative MTAs.

However, Exim has had historical problems with security, and it's one of the poorer choices of Sendmail alternatives when it comes to modularity or advanced features. Most Exim installations have been replaced with Postfix or Qmail in recent years. It's still a high-performance server, though, and can speed up SMTP services by a significant amount over Sendmail.

The Exim home page is at http://www.exim.org.

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Chapter 26. Configuring a Web Server

IN THIS CHAPTER

Whether email or the Web is the true "killer app" of the modern Internet is really a toss-up these days. Although email, the venerable workhorse of online applications, has quietly changed the way we communicate forever, there isn't anything quite like the flash of the Web and its potential as a full-fledged entertainment and commerce medium. In any case, it's probably pretty safe to assume that if you're setting up a FreeBSD server, you want it to be a web server as well as providing email and shell access. This isn't universally the case, though, so whereas FreeBSD ships with Sendmail installed to do email services with almost no additional configuration, there is no equivalent web server application installed by default. You have to get your own from the ports or packages.

For 90 percent of web server functions, Apache is the server of choice. There are a number of other servers you can use instead, such as Roxen and AOLserver, but Apache has slowly built up so much of the market share in polled Internet servers over the years that it's the leading choice by a wide margin.

The Apache Project, located at http://www.apache.org on the Web, is one of the best examples of the open-source philosophy at work, producing software that gets the job done better and in more compliance with published standards than just about all the alternatives. It's also suitable for all kinds of environmentsfrom small, low-traffic informational or hobbyist websites or personal blogs to full-scale e-commerce sites with hundreds of concurrent connectionswith the addition of plug-in modules allowing you to take advantage of such server-side technologies as database connectivity and built-in Perl scripting.

This chapter will discuss how to configure Apache for each of these types of installations. First, however, we will look at the structure of the HTTP protocol and see how a thorough understanding of it will enable you to operate an efficient Internet server.

Introduction to the HTTP Protocol

The Hypertext Transfer Protocol (HTTP) is the backbone of the World Wide Web. Developed in 1993 to support information exchange at CERN in Switzerland, HTTP is a very simple protocol, involving no authentication and only a few possible client commands. It's optimized for the lightweight serving of small (several kilobytes at most) text files, in keeping with the original intent of HTTP as a means of disseminating interlinked informational pages in the newly developed markup language understood by HTTP browsers, known as the *Hypertext Markup Language* (HTML).

Although originally not intended for this purpose, HTTP is now used for the transfer of large binary files, often including many inline images requested at once from an HTML page as it renders. This kind of data transfer was seldom done in the early days of the Web (GIF and JPEG image support in 1994 was sporadic across various platforms). In response to this change, certain augmentations have been made to the HTTP specification. The most important of these is the HTTP/1.1 standard, which provides features such as *pipelining* (combining the responses to many simultaneous requests into a single response stream), improved caching, partial requests (for resuming interrupted downloads), and compression. HTTP/1.1 is widely used on most popular browsers today, but HTTP/1.0 is a useful fallback that all browsers understand.

Unlike SMTP, FTP, and many other such popular protocols, HTTP is *stateless*, meaning that there isn't a concept of a "session" where a client connects to a server, performs several transactions, and then ends the connection. HTTP permits only a single request per connection, and therefore it's really not possible to determine how many users are connected to a web server at any given time (except for downloads that are currently in progress). This also means there aren't any of the topological issues associated with protocols such as SMTP: Relaying, MX records, queues, and so on aren't relevant to HTTP. Instead, the problems that an HTTP server administrator faces have mostly to do with bandwidth, CPU, and memory resources, and with their most efficient use as concurrent activity grows with the popularity of the website.

HTTP Request Structure

The structure of an HTTP/1.0 request is about as simple as it can get. You can simulate an HTTP transaction by connecting to port 80 of an HTTP server and issuing a `GET` request (which can contain multiple lines) in the following form:

```
# telnet www.example.com 80
Connected to www.example.com.
Escape character is '^]'.
GET / HTTP/1.0
HTTP/1.1 200 OK

Date: Thu, 12 Jan 2006 18:38:23 GMT
Server: Apache/1.3.33 (Unix) DAV/1.0.3 PHP/4.4.0
Content-Location: index.html
Vary: negotiate,accept-language,accept-charset
TCN: choice
Last-Modified: Thu, 07 Aug 2003 20:11:54 GMT
ETag: "52ab66-3c-43c6a251"
Accept-Ranges: bytes
Content-Length: 60
Connection: close
Content-Type: text/html
Content-Language: en

<HTML>
<TITLE>test page</TITLE>
<BODY>
test
</BODY>
</HTML>
```

You could instead issue a HEAD request of the same form, to retrieve the headers only, not the message body. You enter a blank line to indicate the end of the multiline request (press Enter twice).

The response from the server is divided into two sections: the header and the body. The response might contain a subset of the headers shown here, or others not shown, depending on the type of document requested and the configuration of the server. Each HTTP server has its own unique signature on the Server: line. This signature tells you the name of the server software and the platform that it was built for; bear in mind, though, that even though it says "UNIX", this doesn't actually tell you anything about the operating system that the server is running, which could be anything from Linux to Solaris or Mac OS X. The rest of the lines, especially the Content-*: lines, contain information that help the web browser lay out the page. For instance, Content-Length:, when present, allows the browser to report how much data there is left in the download, and Content-Type: tells the browser how to render the requested file (as HTML, plain text, GIF or JPEG image data, and so on).

HTTP/1.0 allows a number of extra lines to be included in the request, including lines specifying cookies, accepted encodings, preferred languages, and so on. Aside from the request line (the GET command in this case), which must appear first, the order of the rest of the lines doesn't matter. However, these additional lines are optional; only one line (the request line itself) is required. An HTTP/1.1 request is almost the same as HTTP/1.0, except that a second line is also requiredthe Host: line. This is an addition to the protocol intended to support virtual hosting, where a single web server can answer for many different hostnames. This means that the client has to specify the hostname whose web content it wants to see. Because a web browser looks up the server's IP address from the hostname the user specifies and then makes the HTTP connection based on the IP address (which is how TCP/IP applications operate, as you saw in Chapter 22, "Principles of TCP/IP Networking"), the server knows nothing about what hostname the user is trying to reach unless the client supplies the Host: header, as shown here:

```
# telnet www.example.com 80
Connected to www.example.com.
Escape character is '^]'.
GET / HTTP/1.1
Host: www.frankspage.com
```

All major browsers today, including text-only browsers such as Lynx, support HTTP/1.1-style Host: headers. (However, whether they formulate their requests to claim HTTP/1.1 support is inconsistent. Netscape Navigator, for instance, supports many HTTP/1.1 features, but it issues its requests as HTTP/1.0 anyway.) This means that virtual hosting based on the Host: header (rather than by IP address and network-level IP aliases) is now almost exclusively the method of choice, greatly simplifying matters. We'll talk more about virtual hosting later in this chapter.

Response Codes and Redirects

Although there are only a few request methods (GET, HEAD, and POST, plus several more for HTTP/1.1), the server can return a wide variety of responses. These responses are three-digit numeric codes, and they're grouped on meaning by the first digit. Table 26.1 shows the complete set of HTTP response codes and what they mean, particularly in the context of Apache and its features.

Table 26.1. HTTP Response Codes

Numeric Code	Name	Meaning
2XXSuccess		
200	OK	Standard success code.
201	Created	
202	Accepted	

203	Partial Information	
204	No Content	
3XXRedirection		
300	Multiple Choices	`MultiViews` or `CheckSpelling` found multiple matches.
301	Moved Permanently	Trailing slash was omitted.
302	Moved Temporarily	Redirect found.
304	Not Modified	Cached copy is okay to use.
4XXClient Error		
400	Bad Request	
401	Unauthorized	Must authenticate to continue.
403	Forbidden	Server permissions or configuration do not permit access.
404	Not Found	File does not exist.
5XXServer Error		
500	Internal Server Error	Server-side (CGI) program failed (generic error).
501	Not Implemented	
502	Bad Gateway	
503	Service Unavailable	Resources to process the request are not available.

You're probably quite familiar with 404 and 403 errors, and 500 errors will be familiar to you if you've ever done any CGI programming. However, one important but little-understood code is 304. This code is never seen by a user because it's intended purely for a browser's use; nonetheless, it's one of the most commonly used codes by a production server, as you would see if you were to look through the access log (`/var/log/httpd-access.log`).

When a client has to make a request for a file that it already has in its cache (such as an inline GIF image in an HTML page), it performs a `GET` request with the `If-Modified-Since` field set to the date and time the image was last downloaded. This causes the server to evaluate whether the file has been changed on the server since that time. If it has, it sends the file (with a 200 success code); if it hasn't, it returns a 304 (Not Modified) code, telling the browser that it's okay to display the copy that it has in its cache, thereby saving the trouble of serving the file all over again.

Another code frequently seen by browsers but not people is 301 (Moved Permanently). This code most often occurs when someone requests a URL of the type http://some.host.com/*Subdirectory*, where *Subdirectory* is the name of a directory on the server. The correct form of the URL that accesses the index of that directory is http://some.host.com/*Subdirectory/*, with a trailing slash. Notice, however, that if you enter the URL without the trailing slash, you'll still get the pagebut the browser attaches the slash for you. This is because it received a 301 code for the first request, redirecting it to the same URL, reconstructed from the server's hostname and the request path, with the slash appended. The URL in your browser was updated, the browser made a second request, and the correct page was served. For this to work seamlessly, the server needs to know exactly what its hostname is; this is the purpose of the `ServerName` directive in Apache, which we will discuss a little later in this chapter.

More information about HTTP, its structure, response codes, and much more can be found at the W3 Consortium website, http://www.w3.org/Protocols. The original HTTP/1.0 specification is laid out in RFC 1945, and HTTP/1.1 in RFC 2068.

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Obtaining and Installing Apache

Apache's name is derived from its original nickname "A Patchy Server," since it grew out of a series of patches applied against the industry-standard, but limited, NCSA `httpd` server in early 1995. Apache is one of the most widely ported pieces of software in the world today. It runs on dozens of different operating system platforms, from AIX to Windows to BeOS to Mac OS X, as well as, of course, FreeBSD. Probably the most complete HTTP implementation available anywhere, Apache is also seen by many as the epitome of the open-source ideal; its success demonstrates how a free, grassroots development effort can compete with large, commercially developed packages from market-leading software companies to become the *de facto* standard solution. Apache claims nearly a 70-percent market share at the time of this writinga figure that continues to grow.

Obtaining Apache is a matter of installing it from the ports (`/usr/ports/www/apache13` or `/usr/ports/www/apache2*`) or packages. At the time of this writing, Apache 1.3 is the mature code branch, with most of its bugs and security issues solved long ago; it's the codebase that has built Apache's popularity and reputation, and it will probably do everything you need it to do. However, it has a few structural quirks (such as a *forking* model, where it spawns a new Apache process to handle every single request) that you might find problematic. Apache 2.x, the modern and more actively developed code branch, is a complete rewrite that incorporates kernel threading and greater modular architecture for major performance benefits. This chapter primarily covers Apache 1.3 because of its more widespread deployment and its long history of stability, and because many popular third-party modules are only available for Apache 1.3 and not yet for 2.x; however, the chapter also includes discussions of those areas where Apache 2.x diverges in usage or behavior from Apache 1.3.

Note

The installed support files for the 1.3 and 2.x versions of Apache are kept separate in order to allow administrators to maintain parallel installations and transition gradually to the new version. If you install Apache 2.x, the configuration files will be in `/usr/local/etc/apache2x`, and the documentation and library paths will similarly end in `/apache2` instead of `/apache`. In this chapter, the examples will discuss file locations that end in `/apache`; make the necessary adjustment if you are working with Apache 2.x.

Nearly all of the operational directives are identical between Apache 1.3 and 2.x, but some filenames and paths may differ.

One interesting advantage that Apache has for FreeBSD users is that many parts of it were developed explicitly in a FreeBSD environment. These components include the URL Rewrite module (`mod_rewrite`) by Ralf Engelschall and a number of performance-tuning options discussed in the online documentation. Its development environment also means that Apache fits well into the FreeBSD directory structure, as we'll discuss in a moment.

The Apache source distribution is available from a number of worldwide mirror sites if your ports collection is unable to get it from the main, central site. These mirrors, as well as the definitive collection of Apache documentation, can be found at http://httpd.apache.org.

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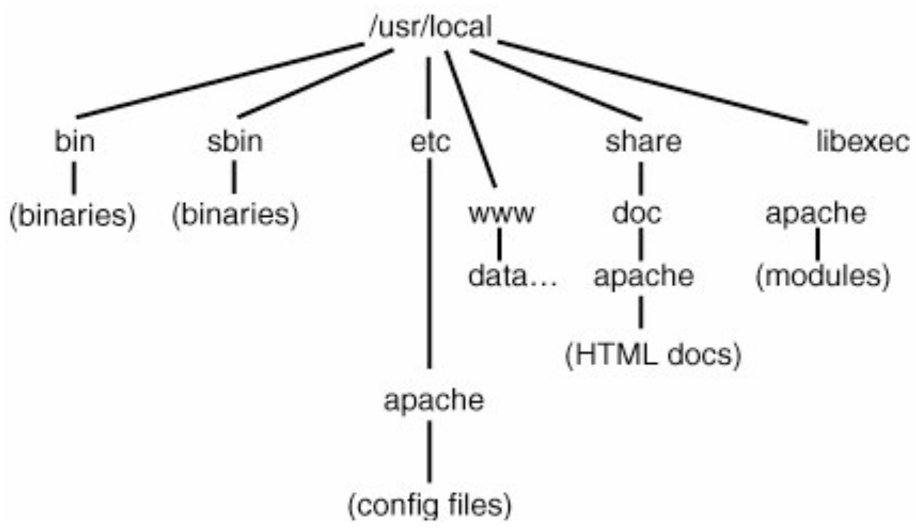
Apache File Layout

After installing Apache, you'll notice that a new directory has been created in `/usr/local` for the server's root directory. This new directory, `/usr/local/www`, contains several subdirectories for various purposes, some of which are symbolic links. The map of Apache's file layout is shown in Figure 26.1. As you would expect, everything installed as part of Apache is underneath `/usr/local`, except for log files (which go into `/var/log` with all the rest of the system's log files).

Figure 26.1. Map of the Apache file layout, showing the relationship of config files, the server document root, and support binaries.



Actually, a few of these directories are in a temporary, installation-only file structure that prevents the install script from "clobbering" existing files on a live server. For instance, `/usr/local/www/data` is the location where the default configuration expects to find the document root; however, this location is a symlink to `/usr/local/www/data-dist`, and it contains only generic HTML files in a variety of language variants that, if left unchanged, will tell a visitor to your site merely that Apache has been installed correctly. Your first step after installing Apache from the ports or packages should be to remove the symbolic link (`rm/usr/local/www/data`) and replace it with a regular directory (`mkdir /usr/local/www/data`) into which you will later put your web content. (One precaution, common to sites that use virtual hosts, is to keep your web content in a completely different location and change the `ServerRoot` directive accordingly.) Similarly, `/usr/local/www/cgi-bin` is a symlink to `/usr/local/www/cgi-bin-dist`, itself a regular directory. If you put files into `cgi-bin`, they will actually go into the `cgi-bin-dist` directory, unless you change `cgi-bin` to be its own regular directory. Making these changes ensures that even if you deinstall the Apache package, your data directory and its contents will be left untouched.

The configuration files in `/usr/local/etc/apache`, which we will discuss in a moment, also have `-dist` or `-std` variantsthere are no symbolic links here, but the `-dist` files are the only ones that are touched when you reinstall or upgrade. This gives you a "safety net" and reference file in case you change something in your live configuration files that you can't fix without hints.

As with Sendmail, Apache's file layout in FreeBSD is considerably different from the layout in an Apache installation on other platforms. Each one differs slightly, so knowing the FreeBSD layout well won't necessarily help you if you have to maintain Apache on Linux, Solaris, or Windows.

Here's one tip that may help: There's usually a "server root" directory, such as `/usr/local/www` on FreeBSD, in which everything Apache-related lives. On Linux, this is often in `/var/lib/apache`; however, in this style of installation, very nearly everything associated with Apacheincluding config files, binaries, logs, sources, and build configuration scriptslives in or under that one directory. Although this doesn't have the benefit of FreeBSD's rigid and consistent structure, at least you'll be able to find just about everything in one place in such an installation.

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Configuring Apache

Just as in /etc/mail (which you saw in Chapter 25, "Configuring Email Services"), /usr/local/etc/apache (the Apache configuration directory) contains a number of files, some of which are of interest to us and some of which are not. Let's take a look at each of them in turn:

- httpd.conf This is the main Apache configuration file. These days, everything is consolidated into this one file, rather than being grouped into as many as three more specific files, as in earlier years. However, many administrators use additional config files such as httpd-vhosts.conf to separate out configuration sections like virtual hosts.
- mime.types This file provides a lookup table between filename extensions and MIME types (Content-Type headers) in files that Apache sends. This is how browsers know how to handle files they download.
- magic An alternative method to MIME types is magic, which tries to determine a file type by looking for certain patterns within the file, making filename extensions unnecessary. This is the same method that's used by the file command. The magic file specifies the methods used for various file types.
- access.conf and srm.conf These files used to contain certain parts of what is now incorporated into httpd.conf (these files don't exist in Apache 2.0). They will still be read if you put configuration items into them, which is why they're still here (to maintain compatibility with legacy installations). However, these files have become unnecessary and can be ignored.

Note

Additionally, Apache 2.x installs a /usr/local/etc/apache2x/extra directory, which contains several additional files: httpd-ssl.conf, httpd-vhosts.conf, httpd-userdir.conf, and so on. These files allow you to configure certain specific features of Apache (such as SSL security or users' home directories) in smaller external files, to help keep them organized better and easier to maintain. If you prefer to keep all your configuration options in a single file, you can copy the contents of these extra files into httpd.conf and modify them there.

Again, note that -dist versions of all these files exist. Immediately after a clean installation, these are copies of the regular versions of each file. After you've made changes to the regular versions over the course of regular usage, though, if you install a newer version of Apache, only the -dist files will be touched by the installation scripts. This allows you to upgrade your system and merge in new configuration options at your leisure, using diff or another method of your choice.

Using httpd.conf

The httpd.conf file is long and detailed, but (unlike /etc/mail/sendmail.cf) it's entirely human-readable and very well commented. Every one of the configuration directives is set to a sensible default value; you can modify any of them that you want, and the inline documentation explains quite clearly what each one does. If you misconfigure something, Apache will tell you exactly what's wrong when you try to start it up.

Caution

Before you make any changes to httpd.conf, be sure to make a backup copy (for instance, httpd.conf.20060225) so that you can easily revert to your previous working configuration.

Immediately after installation, Apache can be started up and will serve requests properly. However, just to be safe, you should first set a couple of key configuration directives. Find each of these in the httpd.conf file and alter it accordingly:

```
#
# ServerAdmin: Your address, where problems with the server should be
# e-mailed.  This address appears on some server-generated pages, such
# as error documents.
#
ServerAdmin you@your.address

#
# ServerName allows you to set a host name which is sent back to clients for
# your server if it's different than the one the program would get (i.e., use
# "www" instead of the host's real name).
#
#ServerName www.example.com
```

The second directive, ServerName, which you must uncomment and change to match your server's hostname, is used in 301 redirections (discussed earlier in the chapter). If the trailing slash is left off of a request for a directory index or listing, Apache responds with a 301 code (Moved Permanently) and the URL to which the browser should go. Apache has to construct this redirection URL from the information it has from the client's request, which (as you've seen) contains only the portion of the URL beginning with the slash after the hostnamefor example, if the requested URL is http://some.host.com/images/foo, the request is /images/foo. If it's an HTTP/1.1 request, it contains a Host: header, which Apache can use to rebuild the full URL, but otherwise it's on its own unless you've specified the server's hostname with the ServerName directive.

HTTP/1.1 does cause a few other repercussions regarding the ServerName directive. If you're doing name-based virtual hosting, which we'll get to shortly, Apache uses ServerName to match a virtual host with a request based on its Host: header. Each virtual host must have a ServerName specified, but even if you're not doing virtual hosting, it's a good idea to define ServerName to help Apache construct its redirection URLs and match requests with the single main host configuration, effectively treating the default configuration as a virtual host that must match a Host: header.

We could go through all the available configuration directives here, but too many of them are equally important relative to each other and unimportant relative to the default configuration. Authoritative documentation can be found at the Apache Group's website at http://httpd.apache.org/docs/.

Using .htaccess Files and Overrides

Although httpd.conf provides global configuration options, many of them can be overridden on a per-directory basis without the server having to be restarted. You do this by placing a file called .htaccess, containing any directives you want to override, into the directory to which you want it to apply. On every request that comes in, the global configuration that was loaded into memory from httpd.conf is consulted, followed by every per-directory configuration file (.htaccess) sequentially down the path to where the requested file is. Each successive .htaccess file can override previously seen directives, but otherwise an .htaccess applies to its own directory and all subdirectories. This allows not just you but your regular users to alter Apache's behavior when serving files from their directories.

Whether .htaccess files can be used depends on the setting of the AllowOverride directive. As you can see by reading through httpd.conf, AllowOverride is set to None at the operating system root level and again on the /usr/local/www/data directory; therefore, .htaccess files are ignored by default. However, you can turn them on by replacing AllowOverride None (in the /usr/local/www/data block) with any of the directives in Table 26.2, or any combination thereof (for example, AllowOverride AuthConfig Limit).

Table 26.2. `AllowOverride` Configuration Options

Directive	Allows `.htaccess` Files to Override
`AllowOverride Options`	The `Options` directive
`AllowOverride FileInfo`	File-typing directives, such as `AddType` and `ErrorDocument`
`AllowOverride AuthConfig`	Authorization directives, such as `Require` and `Auth*`
`AllowOverride Limit`	Host access directives, such as `Allow`, `Deny`, and `Order`
`AllowOverride All`	All of the above

Note

The `Options` directive is one of the largest and most versatile configuration items in Apache; it controls the availability of many of Apache's most significant features, such as `ExecCGI` (the ability to execute CGI scripts), `Includes` (server-side includes), and `MultiViews` (versatile content negotiation). These features can be added to or subtracted from the current configuration at any level in the hierarchical directory structure. Refer to http://httpd.apache.org/docs/1.3/mod/core.html#options for full coverage of the `Options` directive and how to use it.

After changing `httpd.conf` accordingly, restart the server (as we will discuss in a moment). You can now put an `.htaccess` file into any web-accessible directory and place into it any configuration directives that Apache allows in `.htaccess` files (for details on which directives can be used in the `.htaccess` context, see http://httpd.apache.org/docs/).

Note

An `.htaccess` file in a commonly accessed directory can cause a performance hit because the server has to open and read it with every new HTTP request. If possible, it's better to put configuration changes into the global `httpd.conf` file so that it's only read once.

The `httpd.conf` file (or `exTRa/http-userdir.conf` file) contains a commented-out block for controlling user directories (in `/home`); if you plan to run a server where your users can have sites of their own, but you want to make sure browsers that support various data-changing HTTP/1.1 methods (such as `DELETE`, `COPY`, and `MOVE`) can't exercise them, you might want to uncomment this block:

```
#
# Control access to UserDir directories.  The following is an example
# for a site where these directories are restricted to read-only.
#
#<Directory /home/*/public_html>
#    AllowOverride FileInfo AuthConfig Limit
#    Options MultiViews Indexes SymLinksIfOwnerMatch IncludesNoExec
#    <Limit GET POST OPTIONS PROPFIND>
#        Order allow,deny
#        Allow from all

#    </Limit>
#    <LimitExcept GET POST OPTIONS PROPFIND>
#         Order deny,allow
#         Deny from all
#     </LimitExcept>
#</Directory>
```

Note that the `AllowOverride` here allows `.htaccess` files to override `FileInfo`, `AuthConfig`, and `Limit` directives, but the `Options` directives are set at the global level and not allowed to be overridden.

Note

In accordance with historical convention, per-user document directories are called `public_html`; therefore, a request for http://some.host.com/~user/ would show the documents in `/home/user/public_html`. Also traditionally, if there's an `index.html` file present, Apache will serve that file instead of the directory listing. (Microsoft servers generally use `Default.htm` for this function.) You can specify as many of these index filenames as you like using the `DirectoryIndex` directive. Apache will try each filename you specify, in the order in which you enter them.

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Starting and Stopping the HTTP Daemon

The Apache installation process in the ports collection will start the server automatically. You can verify this by looking for `httpd` processes using `ps` and `grep`:

```
# ps -waux | grep httpd
root      220  0.0  2.0  4436 2456  ??  Ss  Sat02PM  0:02.79 /usr/local/sbin/httpd
nobody    303  0.0  2.0  4496 2548  ??  I   Sat02PM  0:00.01 /usr/local/sbin/httpd
nobody    304  0.0  2.0  4460 2452  ??  I   Sat02PM  0:00.00 /usr/local/sbin/httpd
nobody    305  0.0  2.0  4460 2452  ??  I   Sat02PM  0:00.00 /usr/local/sbin/httpd
nobody    306  0.0  2.0  4460 2452  ??  I   Sat02PM  0:00.00 /usr/local/sbin/httpd
nobody    307  0.0  2.0  4460 2452  ??  I   Sat02PM  0:00.00 /usr/local/sbin/httpd
nobody  13963  0.0  2.0  4468 2468  ??  I   Sat10PM  0:00.00 /usr/local/sbin/httpd
```

Note that Apache 1.3 uses a forking model, where one "master" process (the one owned by root in the output shown here) listens on port 80 for incoming requests and then forks off a copy of itself (owned by the unprivileged pseudo-user `nobody`) as a child process to handle each request. The master process never actually serves any requests on its own.

Note

It's very dangerous to have a web server that can serve requests as root, because that means it can execute CGI programs as root tooa situation that's one small CGI script away from an exploit that can wipe your entire hard disk clean.

Under the forking model, where dozens of `httpd` processes might be running simultaneously, killing and restarting every one of these processes is impractical, to say the least. There's a better way to stop and restart the server, though. All you have to do if you want to stop the server is to kill the master process. To restart the server, send the master process a `HUP` signal (`kill -HUP 220`), upon which it will kill all its child processes, restart itself, and respawn its children.

Even this process is still fairly messy, though, and it involves using tools such as `ps`, `grep`, and `kill` in a fairly arcane manner. Fortunately, Apache provides us with a handy tool for this purpose: `apachectl`, which is installed into `/usr/local/sbin` and is therefore part of your default program path.

Note

In Apache 2.x, the `apachectl` support program is merged with the `httpd` program itself; if you call `apachectl` with any of the arguments we discuss here, it is actually passing those arguments to `httpd`, which now handles such commands internally. Therefore, the command `httpd l` (which we will discuss later in this chapter) is equivalent to `apachectl l`, and `httpd start` will have the same effect as `apachectl start`.

Apache 2.x is threaded instead of fork-based, meaning that it spawns many fewer `httpd` processes than does Apache 1.3.

Starting and stopping Apache using `apachectl` is quite easy:

```
# apachectl start
/usr/local/sbin/apachectl start: httpd started
```

```
# apachectl stop
/usr/local/sbin/apachectl stop: httpd stopped
```

After you've made any changes to any of the files in `/usr/local/etc/apache`, you must restart Apache. This is also made easy by `apachectl`:

```
# apachectl restart
/usr/local/sbin/apachectl restart: httpd restarted
```

The `apachectl restart` command does the equivalent of sending a `kill -HUP` to the master `httpd` process: All child processes will be killed, even if they're in the middle of serving files to clientsand those clients will have their connection abruptly dropped. If you want to restart Apache in a less-intrusive wayfor example, if you have a high-load server whose data integrity is criticalyou might choose instead to perform a "graceful restart," which uses a `SIGUSR1` signal instead of a `SIGHUP` signal. This less-urgent signal allows the master process to restart itself without killing its child processes, meaning that in-progress transfers will not be dropped:

```
# apachectl graceful
/usr/local/sbin/apachectl graceful: httpd gracefully restarted
```

One other common use for `apachectl` is the `configtest` command. This will cause Apache (whether it's running or not) to read in the config files from `/usr/local/etc/apache` and report any configuration errors, just as the `start` command wouldexcept that it does not actually start the server. This is an excellent diagnostic tool and an implicit part of both the `restart` and `graceful` commands. `apachectl` uses `configtest` to determine whether the configuration is valid before trying to restart the server; if the configuration isn't valid, it leaves the running processes alone. This prevents a `restart` or `graceful` command from inadvertently killing your server:

```
# apachectl graceful
/usr/local/sbin/apachectl graceful: configuration broken, ignoring restart
/usr/local/sbin/apachectl graceful: (run 'apachectl configtest' for details)
```

Tip

If Apache isn't running, `apachectl restart` or `apachectl graceful` will start it.

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Basic Access Control with Apache

Certain parts of your website will almost certainly need to be protected from being viewed by the general public; access control allows you to restrict these sections to authorized users either by hostname/IP address or by password authentication. We'll take a look at both of these methods.

Access Control by Address

Let's say you want to restrict a certain file, directory, or set of files and directories to a short list of fixed IP addresses or hostnames. You can do this at the global (`httpd.conf`) level if you have a permanent area of your site (such as a set of administration scripts) that you want to keep secure; or more efficiently for regular users or for temporary private resources, you can use an `.htaccess` file in any directory at or above the level of the items you want to protect.

Begin by making sure that `.htaccess` overrides are enabled in the part of the site that you want to protect. As you saw earlier, you can use `AllowOverride Limit`, at the `/usr/local/www/data` level or further down in the directory structure with another `<Directory>` container, to enable the use of the access-control directives `Allow`, `Deny`, and `Order`. Because Apache directives are all read in at the same time, you need to specify the order in which to read the `Allow` and `Deny` directives; otherwise, they'll override each other in ways you don't intend.

To close off a directory to everyone but certain specified addresses or hostnames, put an `.htaccess` file in that directory with the following contents:

```
Order deny,allow
Deny from all
Allow from 64.41.131.102
Allow from stripes.example.com
Allow from nowhere.com
Allow from 10.5.100
Allow from 10.67.22.211/255.255.255.0
```

As you can see, a number of different address formats are allowed; these are just matching rules, where if the connecting host matches any of these hostname or network patterns, it will be allowed access. Similarly, you can have the directory open to everybody *except* certain hosts:

```
Order allow,deny
Allow from all
Deny from l33t.hacker.com
Deny from 192.168
```

You must place these commands inside a `<Directory>` or `<Location>` block if you're doing this in `httpd.conf`; you can also use `<Files>` or `<FilesMatch>` to list certain files, wherever in the system they might be, which should be subject to the access control:

```
<Files "*.jpg">
  Order deny,allow
  Deny from all
  Allow from 64.41.131.102
</Files>
```

`FilesMatch` can be used to specify filenames matching regular expressions, as in this example, which would match all `.gif`, `.jpg`, `.jpeg`, and `.png` files:

```
<FilesMatch "\.(gif|jpe?g|png)$">
  Order deny,allow
  Deny from all
  Allow from 64.41.131.102
</FilesMatch>
```

Note, however, that `<Directory>` and `<Location>` are not available in `.htaccess` files.

The `<Limit>` block, despite its name, is not required for the preceding access controls to work. Rather, its purpose is to list certain access methods to which the access controls should apply. For instance, you might choose to limit only `GET` and `POST` but leave all other methods unrestricted. Likewise, you could use `<LimitExcept>` to specify the only methods to which the access controls should *not* apply. You saw an example of this earlier, in the commented-out block controlling user directories within `/home`.

Caution

Access restriction by address is prone to failureIP addresses can be forged by a sufficiently determined attacker. What's more, a failure to detect a forged address is transparent and all but untraceable; if you use passwords instead, there's a dialogue that can be logged with much greater detail. Opt for password-based access control rather than address-based whenever possible.

Access Control by Password

Sometimes, it's not practical or desirable to limit access by address. A privileged portion of your site might be made available to registered users who have paid a fee, for example, and these users might not come from predictable IP addresses. This is where it's much more sensible to use password authentication for access control.

Apache stores its own username and password databases, distinct from the systemwide one in `/etc/master.passwd` and its relatives. This is for security purposes, and it's an extremely bad idea to try to merge the two authentication schemes together, so don't even think about it. The FreeBSD password database is for authenticating shell users who actually have an account on the system, whereas the Apache authentication databases control access to certain parts of your website for web surfers. You might have a situation in which these two areas of functionality overlap (such as an intranet server for a company), but don't be tempted to try to serve both from the same database. If you succeed, it will be a study in insecurity and irresponsible system administration techniques. This practice is explicitly discouraged by the Apache Group and will earn you a great deal more scorn than respect from your peers. It's not worth it.

To password-protect a portion of your website, you'll need to use an `.htaccess` file (or equivalent configuration in `httpd.conf`)including the appropriate use of `<Directory>`, `<Location>`, and `<Files>` blocksjust as with per-address access control. The contents of this file or configuration block are considerably different, though, involving an entirely different module in Apache to do the access control. A simple example of such a block follows:

```
AuthType Basic
AuthName "Restricted Area"
AuthUserFile /usr/local/www/.htpasswd
Require valid-user
```

This example includes the minimum number of directives needed to make password-protection work; each of these directives, or their alternatives, is required. These directives are a little confusing, so let's look at them individually:

- `AuthType` This can be either `Basic` or `Digest`; `Basic` is the only one that really concerns us.
- `AuthName` This is just a name for the "realm" or the area you're protecting. This name pops up in the authentication window in the user's browser (for example, "Enter username for 'Restricted Area' at www.example.com"), helping to tell the user which area he is entering and which username and password are needed. This can be anything you want, except it must be enclosed in quotes if there are spaces in the name.
- `AuthUserFile`, `AuthDBUserFile`, and `AuthDBMUserFile` *One* of these directives must be present to specify the location of the file that contains the user/password database for the realm. (Each realm can have a different user database file if you like.) If it's a pure text file, use `AuthUserFile`; if it's in `db` or `dbm` format for lookup speed purposes (a good idea if there are a lot of users in it), use `AuthDBUserFile` or `AuthDBMUserFile` accordingly. We'll cover how to create plain-text or `db`/`dbm` user databases in a moment.
- `AuthGroupFile`, `AuthDBGroupFile`, and `AuthDBMGroupFile` These directives work in the same way as the `AuthUserFile` ones, except that they specify groups of users from the file indicated with `AuthUserFile`, allowing you to restrict access to a group rather than just to certain users. This directive isn't required, but if you do use it, an `AuthUserFile` directive or equivalent (and associated user database file) needs to be present for its users to be recognized as part of the listed groups.
- `Require` This tells Apache how to authenticate the user. The argument can be `valid-user` (any user present in the `AuthUserFile` file who enters the correct password), `user <username> <username>...` (a list of users), or `group <groupname> <groupname>...` (a list of groups).

Adding Users

After you have the access control block set up and `apachectl configtest` reports that the configuration is okay, it's time to add users. First, let's see how to make a plain-text user database, the kind for which you'd use an `AuthUserFile` directive. The command to use is `htpasswd`, which in FreeBSD is in `/usr/local/bin` and therefore part of your path:

```
# htpasswd -c /usr/local/www/.htpasswd frank
```

Note

The `-c` option is only necessary the first time you run `htpasswd`; this tells the program to create the file (because it doesn't exist yet), and you can omit the `-c` option every subsequent time.

You will then be prompted for the user's password, which you must enter twice (as usual). To do this in a script, you can use the `-b` option and specify the password as another argument:

```
# htpasswd -bm /usr/local/www/.htpasswd joe Pr1d3L4ndz
```

The other option used here is `-m`, which causes `htpasswd` to use an MD5-based encryption algorithm rather than the system's `crypt()` routine; this may provide you with better security. Other options can be found in the `man apachectl` page.

Caution

The user database file can be placed anywhere in the system that the web server user (`nobody`) can read, and it can be named anything you want, although having the name begin with .htpasswd (for example, .htpasswd-restrictedarea) is traditional and protects it from being viewed in directory listings, either on the shell or via the web server. However, it's a very bad idea to put the file anywhere where it can be accessed by a user with a web browser! To wit, don't put it anywhere inside /usr/local/www/data or in any user's public_html directory; instead, use web-inaccessible locations such as /usr/local/www or directly inside a user's home directory. You don't want people downloading your user database and cracking it!

Plain-text user databases work great for small lists of users; however, once you start working with dozens or hundreds of users, the time it takes to look up a user's password makes the authentication process cumbersome or even nonfunctional. The solution to this is to use a true database file, either in db or dbm form, and to use the appropriate AuthDBUserFile or AuthDBMUserFile directive in your access control block. The support program that allows you to work with the database files is /usr/local/bin/dbmmanage:

```
# dbmmanage /usr/local/www/.htpwddb adduser frank
New password:
Re-type new password:
User frank added with password encrypted to NtMDxy6jwyW7A using crypt
```

This example will create a db-style database file called /usr/local/www/.htpwddb, which you can then specify with the AuthDBUserFile directive. The dbm equivalent can also be used if necessary, but you shouldn't have to. See man dbmmanage for further details on the user management commands you can use.

Adding Groups

Listing groups in a plain-text file (AuthGroupFile) is quite easy. Each line contains the group name, a colon, and then the list of users in the group:

```
mygroup: frank joe alice
```

The group file should probably be kept in the same place as the user file, and with a similar name; however, because the group file doesn't contain any passwords, security considerations aren't quite as critical. Just make sure that only root has the ability to write to the file!

Group files can be managed with dbmmanage as well, but this practice is usually unnecessary because (as with /etc/group) there are seldom anywhere near as many groups as there are users. You can use AuthGroupFile in conjunction with AuthDBUserFile if you want to mix formats; this is probably the simplest way to maintain a large user list along with a small group list.

Access Control by Address and Password

It's possible to require that a user satisfy both host address restrictions *and* password authentication before access control allows access to a restricted area. This is done with the Satisfy directive:

```
Allow from 64.41.131.102
Require valid-user
Satisfy all
```

Satisfy all is the default setting if both Allow and Require directives are present; this behavior means that the incoming user must meet the Allow requirements *and* supply a valid username and password before access will be granted. You can also use Satisfy any to tell the server that the user must supply a valid password *or* be coming from an allowed address; this is useful if you want users at certain locations to have unconditional access to an area, but require authentication from all other users (for instance, if you're providing a service that you must administer through the same interface as every other user, but you don't want to be forever entering passwords for access).

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Virtual Hosting

Virtual hosting is the practice of keeping the website contents for multiple different domains or hostnames on the same server; a single installation of Apache serves requests for all of them. For instance, www.mystore.com and www.frankspage.com might both be configured in DNS to point to the same IP address on your FreeBSD machine, and Apache is responsible for serving both of them, as well as its own hostname (as specified in the `ServerName` directive).

As you've seen, HTTP/1.0 provided no indication of what hostname the HTTP client was trying to reach (as specified by the user), so in earlier days, virtual hosting had to be done by pointing each hostname to a separate IP address and then binding each IP address as an IP alias to the same Ethernet card. Each virtual host was then specified by IP address, so a request coming in from a web browser would always be sure to get the correct website in response. The downside was that binding these large blocks of IP addresses to the same card became unwieldynobody wants to have to make DNS changes every time he reconfigures his web serverand it caused unnecessary consumption of IP address space (which, as you saw in Chapter 22, is not infinite).

The need for this cumbersome process has been much alleviated, however, by HTTP/1.1. The mandatory `Host:` header specifies what hostname the client is trying to reach. Therefore, "name-based" virtual hosts are the norm on the modern web. Clients that don't support the `Host:` header are almost unheard-of these days, so we will be discussing only name-based virtual hosts; if you're interested in address-based virtual hosts, you can find information on them at the Apache website.

The bulk of the `httpd.conf` file specifies the "default" servera global set of definitions that apply to all requests that Apache receives. In the default server, the `ServerName` directive is used primarily for constructing 301 redirection URLs, as discussed earlier. However, you can then set up small sets of overrides to these global settings, which are used if the `Host:` header matches a certain specified hostname. These groupings of overrides make up what are known as *virtual hosts*.

Note

In Apache 2.x, the `http-vhosts.conf` file in the `exTRa` directory can be used to keep your virtual host configuration separate from the main server configuration. This is especially important if you've got dozens of virtual hosts.

Let's say your server is called `stripes.example.com`, and that's what your main `ServerName` directive specifies. To configure name-based virtual hosts, you need a `NameVirtualHost` directive with an argument of `*` (the wildcard specifies "all hostnames"), followed by as many different `<VirtualHost *>` blocks as you like:

```
NameVirtualHost *

<VirtualHost *>
  ServerName www.example.com
  DocumentRoot /usr/local/www/data
  ServerAdmin webmaster@example.com
  ErrorLog logs/www.example.com-error_log
  CustomLog logs/www.example.com-access_log common
</VirtualHost>

<VirtualHost *>
  ServerName www.frankspage.com
  ServerAlias frankspage.com
  DocumentRoot /home/frank/public_html
  ServerAdmin frank@frankspage.com
  ErrorLog logs/www.frankspage.com-error_log
  CustomLog logs/www.frankspage.com-access_log common
</VirtualHost>
```

Note

`<VirtualHost>` directives in Apache 2.x specify not just the hostname, but also the port, in the format `<VirtualHost *:80>` (TCP port 80 is the HTTP standard). However, because the `*` argument conflicts with the configuration for SSL encryption, it should be avoided in favor of explicit IP addresses.

Inside a `<VirtualHost>` container, the `ServerName` directive determines the hostname to match against the client's `Host:` header, and a match will result in the corresponding set of overrides (the appropriate `<VirtualHost>` block being applied to the configuration). `DocumentRoot` specifies where in the filesystem the files asked for in the incoming request are to be found, and the `ErrorLog` and `CustomLog` directives specify alternate log files for each virtual host. `ServerAlias` provides a way of listing multiple alternate matching hostnames for a virtual host. You can also include any other directives you like, as long as they're allowed inside a `<VirtualHost>` block`apachectl configtest` will tell you if they're not allowed there.

It's important to note, though, that in the setup shown earlier, a request for the default server (`stripes.example.com`), or for any other hostname that maps to the server's IP address but doesn't match any of the `<VirtualHost>` blocks, will not be answered by the default server; the default server never answers requests for any address that is specified for name-based virtual hosts (in the `NameVirtualHost` directive). It exists only to specify the default configuration set. Because we've used the `*` wildcard to specify name-based virtual hosts on all IP addresses, the default server will never itself service a request. In the absence of a `<VirtualHost>` matching the requested hostname, the server that responds will be the first `<VirtualHost>` that appears in the config file (www.example.com in this case).

A more correct configuration than the previous one, then, would be this:

```
NameVirtualHost *

<VirtualHost *>
  ServerName stripes.example.com
</VirtualHost>

<VirtualHost *>
  ServerName www.example.com
  ServerAlias *.example.com
  DocumentRoot /usr/local/www/data
  ServerAdmin webmaster@example.com
  ErrorLog logs/www.example.com-error_log
  CustomLog logs/www.example.com-access_log common
</VirtualHost>

<VirtualHost *>
  ServerName www.frankspage.com
  ServerAlias frankspage.com
  DocumentRoot /home/frank/public_html
  ServerAdmin frank@frankspage.com
  ErrorLog logs/www.frankspage.com-error_log
  CustomLog logs/www.frankspage.com-access_log common
</VirtualHost>
```

This setup ensures that the default server configuration for `stripes.example.com` is the one that answers a request with no explicit `Host:` header.

Virtual hosts can be done in a myriad of other ways, allowing you to specify different IP addresses and ports to match certain groups of `<VirtualHost>` blocks. Examples of the syntax for these methods can be found at http://httpd.apache.org/docs/1.3/vhosts/.

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Introduction to Apache Modules

One of Apache's greatest strengths is its modular structure. All configuration directives are part of one module or another, and while in earlier versions of Apache these modules were all painstakingly turned on or off at compile time, nowadays almost all modules are available as dynamic shared objects (DSOs) and can simply be loaded at runtime.

Built-in Modules

To see which modules are compiled statically into Apache, use `httpd -l`:

```
# httpd -l
Compiled-in modules:
  http_core.c
  mod_so.c
suexec: disabled; invalid wrapper /usr/local/sbin/suexec
```

This means that the directives in the `Core` module and the `mod_so` module are the only ones guaranteed to be available. The `Core` module provides access to the most fundamental directives without which Apache could not run at all; `mod_so` enables DSO support, which makes it possible to load all the approximately 32 further modules that ship with Apache, as well as any additional modules that you might choose to install.

Note

Ignore the note about `suexec`; this is a utility that allows Apache to run in a setuid wrapper, executing requests as a specified user (usually different for every virtual host). The `suexec` wrapper isn't installed by default; you can read more about it at http://httpd.apache.org/docs/1.3/suexec.html. Also, in Chapter 30, "Network Security," we cover CGIwrap, a more versatile alternative to `suexec`.

Note that Apache 2.x may not display the line about `suexec`, and its list of DSOs is significantly different.

Dynamically Loaded Modules

Dynamic modules are functional libraries that can be added to or removed from the Apache server at the time you run it, instead of having to be compiled into the `httpd` binary. These modules (also known as DSOs, or *Dynamic Sharable Objects*) allow you to trim down the size of your running `httpd` processes by eliminating modules you don't need. This can easily be done at runtime by commenting out the unnecessary modules from `httpd.conf`. If you decide later that you need the functionality in a certain module, just reenable it and restart Apache. A complete listing of all the Apache modules and which directives are part of each module can be found at http://httpd.apache.org/docs/1.3/mod/.

To enable a module, you need both the `LoadModule` directive (which dynamically links the module into the `httpd` process) and the `AddModule` directive (which enables the module's directives in the correct order for further use in the configuration file). If you look in `httpd.conf`, you'll find `LoadModule` and `AddModule` directives for all the bundled Apache modules, which are installed into `/usr/local/libexec/apache`. Something to note about `LoadModule` is that each `LoadModule` directive is processed inline before proceeding, so the order in which the modules are specified matters. If a module depends on another module already being linked in, the dependency must be invoked first. The default configuration has all this correctly handled for you.

Note

`AddModule` directives are not required in Apache 2.x.

Third-Party Modules

The real strength of Apache's modular structure comes with third-party modules. These modules are linked in at runtime with the rest of the available Apache modules, providing additional functionality and configuration directivesusually to give Apache the ability to process certain kinds of server-side content more efficiently. One popular module is `mod_perl`, which embeds a Perl interpreter into Apache, greatly speeding up Perl CGI scripts by obviating the need for Apache to start up a subshell process and execute the CGI program within it with every request (you learn more about `mod perl` in an upcoming subsection of this chapter). Another is `mod_php4`, a module that gives Apache the ability to parse and serve dynamic PHP pages (the UNIX analog of Microsoft's ASP technology). More than 100 third-party Apache modules are available in the ports collection in `/usr/ports/www`; they're the ones beginning with `mod_`.

Building Modules with `apxs`

Early in the development of the first third-party modules, when DSO support was experimental at best, compiling a third-party module meant having the Apache source available, tweaking the build configuration files in both the Apache source and the module's source, and cross-compiling them into a single, hybrid binary. Although this was technically a "modular" approach (which is to say that it was better than having to patch the code manually into the Apache source itself), it still wasn't what anyone would call easy to handle. It still involved building a new executable each time a new version of either Apache or the module became available, and it still involved a fair amount of code hackery to get it to work.

Enter `apxs`, the Apache Extension tool. This support program, residing in `/usr/local/sbin`, is built along with Apache to take advantage of the already compiled binary's DSO support (the statically compiled `mod_so` module) to provide a self-contained build framework that's fully aware of all the capabilities of your `httpd` binary. You no longer have to have the Apache source code around in order to build third-party modules; `apxs` compiles and converts modules in raw source form or already compiled objects into `.so` objects that can be loaded into Apache with the `LoadModule` directive, along with the rest.

You will most likely never need to use `apxs` directly; it's a compile-time tool used transparently by the build tools in the ports collection. All you have to do to build a third-party module, just as with any other port, is to go into the module's directory in `/usr/ports/www` and type **`make`**. `apxs` does the rest. If a new version of Apache is released, it can be built and installed on its own, and third-party modules will continue to work. Likewise, if a module is updated, you can simply rebuild and reinstall it. This is true modularity at its best.

More information on `apxs`, if you're interested, can be found in the `man apxs` page.

`mod_perl`

One of the most popular third-party modules is `mod_perl`. Although Perl is still the most popular choice for CGI programming (which we'll discuss shortly), executing Perl scripts means a fair amount of overhead for Apache. When an HTTP request is made for a Perl CGI program, Apache must start a shell process and run the script within it, feeding the results back to the client.

With `mod_perl`, a Perl interpreter is built directly into Apache. Specialized directives define certain file types as executable Perl scripts that Apache can execute itself; further, each Perl script that Apache executes is held in compiled form in memory for later use. This eliminates the startup overhead usually associated with

CGI execution, making the response of server-side programs a great deal faster.

More information on `mod_perl` is available at http://perl.apache.org.

`mod_python`

In keeping with the rise of Python as the likeliest inheritor of Perl's crown as the server-side programming language of choice in the future, `mod_python` provides the same kind of benefit to Apache for Python that `mod_perl` does for Perl. The Python interpreter is made directly available to the Apache executable, allowing Apache to run Python programs without any of the execution overhead of doing it through CGI.

The `mod_python` home page is at http://www.modpython.org.

`mod_php`

PHP, the wildly popular dynamic page-generation tool for UNIX, is made a part of Apache through the `mod_php4` and `mod_php5` modules. The directives enabled by this module family let Apache serve `.php` files completely natively, executing their embedded scripting functionality to generate the final form of a page before sending it to the client. When you build and install `mod_php4`, your `httpd.conf` file is automatically updated to provide support for the `.php` and `.phps` file types.

More information on PHP and `mod_php4` can be found at http://www.php.net.

`mod_ruby`

This module does for the Ruby language what `mod_perl` and `mod_python` do for Perl and Python, making the startup of Ruby CGI scripts much faster. This is especially important considering the growing popularity of web application architectures such as Ruby on Rails (http://www.rubyonrails.org), which is gaining in momentum as a competitor to other web application frameworks and technologies.

A great many more modules are available, providing Apache with enough expanded functionality to keep you busy for a long time. Apache's modularity has only fairly recently become completely entrenched, and the widespread availability of standardized third-party modules, coupled with the FreeBSD ports collection, makes for an unprecedented new era in extensible HTTP server administration.

> **Note**
>
> Some third-party modules, useful though they might be, are only available for Apache 1.3, and not for Apache 2.x. Still others come in two flavors, one for each version of Apache; these can be identified by the "2" suffix on their names and the fact that they occur in pairs (for example, `mod_log_sql` and `mod_log_sql2`). Be sure to choose the right module for your version of Apacheand the right version of Apache for the modules you want to use!

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Server-Side Includes

One popular feature of Apache is the ability to process *server-side includes*, or calls to internal Apache functions that are embedded into plain HTML files and processed by Apache before being sent to the browser. Server-side includes let you perform feats from simply echoing environment variables into a page to importing modular HTML fragments or executing server-side programs each time the page is requested.

Server-side includes are embedded into what's known as *parsed HTML*, which is effectively just regular HTML that Apache *parses* (processes for embedded command tokens) when the page is requested. Apache searches through parsed HTML for server-side includes and processes each one in turn before sending them on to the client. Each include is of the following form:

```
<!--#command attribute=value attribute=value ... -->
```

Caution

The syntax of a server-side include statement is critical; it must be of exactly the form shown here. The opening string `<!--#command` must not contain any spaces; otherwise, Apache will treat the directive as an HTML comment and ignore it.

You can use your browser's "View Source" function to see whether any malformed server-side include statements have been ignored by Apache and passed through verbatim to the browser.

In this generic example, `command` can be `include`, `exec`, `config`, `echo`, or a few other possibilities. The `attribute=value` pairs are ways of setting or reading variables, which you can define yourself using includes or read in from the available environment variables.

First, to turn on server-side includes in Apache, uncomment the following two lines in `httpd.conf` (or add them to the appropriate `.htaccess` file):

```
AddType text/html .shtml
AddHandler server-parsed .shtml
```

Note that these lines might be found in different sections of the `httpd.conf` file. Make sure they both appear in the same "container" (`<Directory>` or `<Location>`). This can be difficult to determine, because some containers have a lot of comment blocks and extra text that can make the structure confusing.

Note

In Apache 2.x, the `AddHandler` directive is separated into a number of more specifically tasked directives; the second line in this example becomes an `AddOutputFilter` directive:

```
AddOutputFilter INCLUDES .shtml
```

Tip

The `.shtml` extension is the widely accepted UNIX standard for server-parsed HTML files; however, other variants exist, such as `.shtm` and `.stm`. To enable these as well as `.shtml`, make duplicates of the directive lines shown here and alter the duplicates accordingly:

```
AddType text/html .shtml
```

```
AddHandler server-parsed .shtml
AddType text/html .stm
AddHandler server-parsed .stm
```

Next, add the `Includes` option to the `<Directory>` or `<Location>` block (or `.htaccess` file) that controls the area of the website that concerns you:

```
Options +Includes
```

The `AddType` directive maps a class of files (by their filename extensions) to a MIME type, extending the basic set that is stored in `/usr/local/etc/apache/mime.types`. The `AddHandler` directive assigns a *handler* (an internal method for Apache to process a file that is requested by the user) to a certain extensionin this case, `.shtml`, the traditional extension for HTML files that you want Apache to parse before serving. With these two directives in place, any `.shtml` file will be parsed for server-side includes on its way to the client.

Note

Aside from containing server-side includes, the only difference between `.html` and `.shtml` files is the filename extension. They're both regular HTML files. If you put a server-side include into an `.html` file, simply rename it to have an `.shtml` extension if you want it to be parsed before being sent to the browser. A server-side include in an `.html` or `.htm` file will show up unparsed in the client's HTML source for the page.

Caution

Be aware that parsing any file causes more resource drain on the CPU and memory than simply passing the file unparsed to the browser. It's best to avoid unnecessarily parsing plain HTML files; otherwise, Apache will suffer a performance hit, which might be a critical consideration for you.

A few examples of useful server-side includes follow:

- `<!--#echo var="HTTP_USER_AGENT"-->`

  Prints the user's browser identifier string into the page. A fuller discussion of the available environment variables will appear later in this chapter when we cover CGI programming.

- `<!--#set var="email" value="me@example.com"-->`

  Sets the variable called `email` to the string `me@example.com` for the remainder of the page (unless overridden later with a similar directive).

- `<!--#include virtual="/toolbar.shtml"-->`

  Embeds the contents of `/toolbar.shtml` into the page. SSIs are parsed recursively, so a file included this way can have its own includes.

- `<!--#config timefmt="%A %B %d, %Y"-->`

  Sets the time format for any server-side includes that output a date and time. The format string is the same as for the `date` command; see `man date` for more details.

- `<!--#flastmod file="index.shtml"-->`

  Displays the date and time that `index.shtml` was last modified, in the time format specified in the `config timefmt` example.

- `<!--#exec cgi="/cgi-bin/counter"-->`

  Executes a CGI script called `counter` and displays its output.

If you put directives like these into an `.shtml` file and they don't seem to be working, view the page's source. The directives should not appear in their server-side include form in the HTML code. If you see any, it means they haven't been parsed out, which means the Apache configuration hasn't been set up properly to support server-side includes.

Make sure that your `AddType` and `AddHandler` (or `AddOutputFilter`) directives are correctly specified and that they apply to the part of the site you're using.

Tip

The default page displayed in a directory when no filename is specified is `index.html`, but using the `DirectoryIndex` directive, you can change this or even specify a list of filenames to try:

```
DirectoryIndex index.php index.cgi index.html index.shtml
```

Apache looks for each of these files in turn in a bare directory request, and only if none are found (and `Options Indexes` is enabled) will it display a file listing for that directory.

If you prefer, you can simply use the following instead:

```
Options +MultiViews
DirectoryIndex index INDEX
```

`MultiViews` tells Apache to look for any file matching the requested base filename (without the extension), and `DirectoryIndex index` says that any file in the directory called `index.*` (with any extension) should be served, generally in alphabetical preference. This way, you can account for `index.htm`, `index.HTM`, and `INDEX.HTML` files, however your users happen to name their files.

`MultiViews` can cause a performance hit, however, so you should consider your server's current CPU load before enabling `MultiViews` on a commonly accessed directory.

A full tutorial on server-side includes, showing everything from conditional flow-control to external CGI execution, can be found at http://httpd.apache.org/docs/1.3/howto/ssi.html.

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Introduction to CGI

Conventional websites made up of static HTML pages are fine in their way. Server-side includes let you embed a lot of useful functionality into regular HTML pages. However, for true web applications (such as e-commerce sites, message boards, databases, and anything where the system tailors its content to the actions of the user), you need a server-side programming environment to handle the user's input and control the requested output. The standard way to do this is CGI, the *Common Gateway Interface*.

CGI exists as a "mediator" protocol, a layer of the web server that allows you to use HTML forms to take in users' data, which the server (through CGI) feeds in a common format to any program on the server, regardless of what language it's written in. A CGI program can be a Perl script, a compiled C binary, a shell script, or anything else that can be executed by the Apache user (`nobody` or `www`). The output of the program is routed back through Apache directly to the web browser. This means that, for example, you can write a CGI program that reads in variables from an HTML form, processes them, opens a pipe to Sendmail to mail the contents of the variables to you, and prints out an HTML response to the user. You'll see how to do this in a simple Perl script in just a moment.

Enabling CGI in Apache

There are two ways to use CGI programs in Apache. The first, cleanest way is with the `ScriptAlias` directive, which defines a certain directory as containing only CGI programs and maps it to a virtual path (as seen by the web browser):

```
ScriptAlias /cgi-bin/ "/usr/local/www/cgi-bin/"
```

This line, which is enabled in `httpd.conf` by default, tells Apache that the `/cgi-bin/` URL (http://stripes.example.com/cgi-bin/) is a designated CGI directory and that everything in it should be treated as a CGI program. If you put anything in this directory that isn't a CGI program, it will return a 500 Server Error code, a failure to execute it as a CGI. You can add as many additional `ScriptAlias` lines as you like. The filesystem path to the CGI directory (for example, `/usr/local/www/cgi-bin/`) need not even be in the normally webaccessible path; you can point the alias to anywhere in the system that's readable by the `nobody` (or `www`) user. This prevents people from being able to look at the contents of the directory or navigate to it from other directory listings. You generally don't want people to be able to access your CGI programs directly, anywaythey're typically called from links or as form actions, which we will discuss shortly.

Note

Note that the trailing slash on `/cgi-bin/` is specified. This is another security measure, designed to prevent unauthorized access to the directory listing. A CGI program as Apache sees it through `ScriptAlias` is the name of the program (for example, `script.cgi`) that is appended to the `ScriptAlias` virtual path (for example, `/cgi-bin/`), so the slash is required in order for the server to construct the proper path (for example, `/cgi-bin/script.cgi`). If the trailing slash were omitted, the bare directory itself would also be aliased, meaning that a client could issue a request for the `/cgi-bin` directory and get a listing; you probably don't want that. 301 redirects don't apply here.

Note

Because all files in a directory specified by `ScriptAlias` are treated as CGI scripts, you don't need to have filename extensions on each of these programs. You can have a program called

/cgi-bin/test as well as one called /cgi-bin/hello.cgi; but outside the /cgi-bin/ directory, CGI scripts must have the .cgi extension or whatever extension you have configured using AddHandler, as you will see next.

The other way to enable CGI programs is to use the Options directive to add the ExecCGI option to an area of the server specified by a <Directory> or <Location> block. This is useful for enabling CGI programs in your users' public_html directories, allowing the server to execute programs as CGI based on their filename extensions (for example, .cgi) and whether they're set executable. The following example will turn on CGI execution of all users' executable .cgi files, no matter where in their directories they are:

```
<Directory /home/*/public_html>
  Options +ExecCGI
  AddHandler cgi-script .cgi
</Directory>
```

If a CGI file (whether in a ScriptAlias directory or mapped to a handler by extension) can't be executed for any reason, the user will get a 500 Server Error message; this is a generic error condition, one that can be generated by numerous different server-side causes and can't really be used for debugging, other than to know that something *is* wrong. You can look at Apache's error log to get a more detailed diagnostic message. Here's an example of an error log from an unsuccessful request for a Perl script called blah in /usr/local/www/cgi-bin:

[View full width]

```
# tail /var/log/httpd-error.log
syntax error at /usr/local/www/cgi-bin/blah line 3, at EOF
Execution of /usr/local/www/cgi-bin/blah aborted due to compilation errors.
[Thu Jan 12 11:55:40 2006] [error] [client 64.2.43.44] Premature end of script headers:
   /usr/local/www/cgi-bin/blah
```

The first two lines of output are directly from Perl, exactly the same as if the script had been run on the command line. The third line is Apache telling us that it tried to execute the script, but it quit before printing out any HTTP headers, such as Content-type: (which is required for a valid CGI script). Our task, then, is to make sure the program is written correctly for CGI execution.

Writing CGI Programs

The format in which CGI variables are passed to a server-side program is as a URLencoded text string, with each variable separated from its value by an equals sign (=) and from other variables by ampersands (&). The script sees it as being fed in via standard input (STDIN).

Perl is the most common language for CGI programming and therefore the two terms are (incorrectly) often used synonymously. Don't confuse the two: Perl is useful for a great many things besides web programming, and CGI encompasses all conceivable languages, even ones that don't exist yet. Still, the prevalence of Perl in the CGI programming world makes it the object of our attention right now.

Accessing CGI Programs Through Forms

Perl's strengths, as you saw in Chapter 11, "Introduction to Perl Programming," are in text processing and ease of development; this makes it an ideal candidate for situations when you need to read in variables from an HTML form (such as a user's name, email address, mailing address, and comments) and process them into a form you or the system can use. A typical Perl CGI program is invoked as the action of an HTML form, like the following:

```
<FORM NAME="myform" METHOD="POST" ACTION="/cgi-bin/post2me">
```

When the user submits this form, all its variables are submitted through the CGI interface to `post2me`, the Perl program whose job it is to handle them. The first thing this script must do is read in the variables from standard input and format them into an associative array for easy access:

```
read(STDIN, $buffer, $ENV{'CONTENT_LENGTH'});
@pairs = split(/&/, $buffer);
foreach $pair (@pairs)
{
    ($name, $value) = split(/=/, $pair);
    $value =~ tr/+/ /;
    $value =~ s/%([a-fA-F0-9][a-fA-F0-9])/pack("C", hex($1))/eg;
    $value =~ s/~!/ ~!/g;
    $FORM{$name} = $value;
}
```

This code does some security parsing to prevent malicious form input from being sent to the program. Specifically, if you write a CGI program that prints a user's form input out into an HTML file, a user can embed some malicious HTML code into his input that calls a server-side include that runs some program on the server when the newly written HTML file is accessed. Because any program executed through HTTP requests is run by the unprivileged nobody (or www) user, this usually amounts only to an annoyance. Still, it's a security hole that must be addressed, and this code block disables any potentially malicious HTML tags by inserting spaces and dashes where appropriate.

Note

This method of checking for a "blacklist" of prohibited codes is not sufficient to cover all possible methods of attack. You can put Perl into "taint" mode using the `-T` flag, which prevents Perl from issuing system calls using any so-called "tainted" variables in the CGI program.

After your script has read in the form input, each form variable is available as a key in the `%FORM` array; the contents of the HTML input field called `email`, for instance, are in `$FORM{'email'}` and can be used however you like.

Next, your script must print out a valid HTML header. You have two choices here: You can print HTML code to standard output, effectively writing a new HTML page from within the script, or you can redirect the user to a different URL while the script does its work. The former is done with a `Content-type:` header, which can be any valid MIME type (it's up to the browser to know how to handle it), followed by a double newline, the standard signal for the end of the header block:

```
print "Content-type: text/html\n\n";
```

Note

If you use the `CGI.pm` module (as is very common practice), you can print out the standard HTML content type header using the `$q->header` method.

Anything printed out by your script after this header is part of the response body, rendered as HTML by the browser. You can use a type of `text/plain` to force the browser to display it as plain text, or any other type, according to your needs.

The latter method, a redirect, is done with a `Location:` header and a redirection URL:

```
print "Location: http://www.somewhereelse.com/path/to/file.html\n\n";
```

Anything printed after this header vanishes because the browser will have already moved on to this new URL.

Environment variables are also available to CGI programs, and an HTTP connection comes with a great many pieces of interesting information. Some of these include `HTTP_REFERER` (the referring URL), `HTTP_USER_AGENT` (the browser the user has), `REMOTE_HOST` (the user's hostname), and many more. You can see them all by accessing the `printenv` script, which is included as part of the default Apache installation in the `/usr/local/www/cgi-bin` directory. You can access it at the URL http://www.example.com/cgi-bin/printenv, substituting your FreeBSD machine's hostname or IP address, as appropriate. Within Perl, your environment variables are accessible as keys in the `%ENV` array, so you can access the `REMOTE_HOST` variable as `$ENV{'REMOTE_HOST'}`.

Let's look at a simple Perl CGI program, which reads in three variables`name`, `email`, and `comments`from an HTML form, mails them to you, and prints a formatted thank-you note to the user. This script is shown in Listing 26.1.

Listing 26.1. A Sample Perl CGI Program`sendcomments.cgi`

[View full width]

```
#!/usr/bin/perl -wT


read(STDIN, $buffer, $ENV{'CONTENT_LENGTH'});
@pairs = split(/&/, $buffer);
foreach $pair (@pairs)
{
    ($name, $value) = split(/=/, $pair);
    $value =~ tr/+/ /;
    $value =~ s/%([a-fA-F0-9][a-fA-F0-9])/pack("C", hex($1))/eg;
    $value =~ s/~!/ ~!/g;
    $FORM{$name} = $value;
}
print "Content-type: text/html\n\n";

open (MAIL,"| /usr/sbin/sendmail -oi -t");
print MAIL "From: $FORM{'name'} <$FORM{'email'}>\n";
print MAIL "To: you\@your.hostname.com\n";
print MAIL "Subject: Form output\n\n";
print MAIL "$FORM{'name'}, from $ENV{'REMOTE_HOST'} ($ENV{'REMOTE_ADDR'}), has sent you
    the following comment:\n\n";
print MAIL "$FORM{'comment'}\n";
close (MAIL);

print qq^<HTML>\n<HEAD>\n<TITLE>Thank you!</TITLE></HEAD>\n^;
print qq^<BODY><H3>Thank you!</H3>\nThanks for your comments!</H3>\n</BODY>\n</HTML>^;
```

You'll want to tune this script to your own needsreplace the dummy To: header with one that mails to your real email address, making sure to keep the backslash in front of the @ symbol. This sample script doesn't do very much in and of itself, but after some experimentation you'll find that the basic principles we've covered here form the heart of server-side programs you can easily create yourself, from the smallest feedback forms to the largest online databases and e-commerce systems.

Accessing CGI Programs Directly

A CGI program does not have to be called from an HTML form or with the `POST` method. You can use a direct URL to call a CGI script that doesn't need to have any variables posted directly into an associative array such as `%FORM`. Such a URL would look like this:

http://www.example.com/cgi-bin/sysinfo?frank+3

This URL calls the `sysinfo` program in the `/cgi-bin/` directory. Everything after the question mark is known as the *query string*, and its contents are available to the script as elements of the `@ARGV` array. Arguments are separated by plus signs (`+`). The `sysinfo` program would have the string `frank` available as `$ARGV[0]` and the number `3` as `$ARGV[1]`.

Tip

You can also access the entire query string as the environment variable `QUERY_STRING`, or `$ENV{'QUERY_STRING'}` in Perl.

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Chapter 27. Configuring an FTP Server

IN THIS CHAPTER

Once the foremost method of transferring files from one point in the Internet to another, the File Transfer Protocol (FTP) is now becoming eclipsed by the more glamorous and versatile HTTP.

However, although FTP is a very rudimentary protocol, and lacking in features generally considered critical in the modern era (such as SSL encryption), it is designed more specifically for large file transfers than HTTP is and therefore is able to do a number of things that HTTP cannotincluding easy uploading as well as downloading, and greater speed and efficiency. FTP's prevalence is fading, but it will always have a place in the Internet, as long as such services as authenticated downloads and two-way transfers are needed.

FreeBSD comes with an FTP server built in, and you can replace it with a different server if you desire. The built-in FTP server is quite complete and free from known exploits; it allows you to transfer files to and from your FreeBSD machine without any additional setup. This chapter discusses some of the details of the File Transfer Protocol and how it works. The default configuration of the FTP server is quite basic, but the information you learn in this chapter will help you take advantage of the more advanced features available to you.

Note

FTP is a clear-text protocol, meaning that the information packets that comprise it can be intercepted and sensitive data such as passwords extracted from them. Secure FTP, or `sftp`, is becoming more widespread and supported by most popular FTP client programs. You'll learn more about how to secure FTP (by replacing the default server with an encryption-capable one) at the end of this chapter and in Chapter 30, "Network Security."

Introduction to the File Transfer Protocol

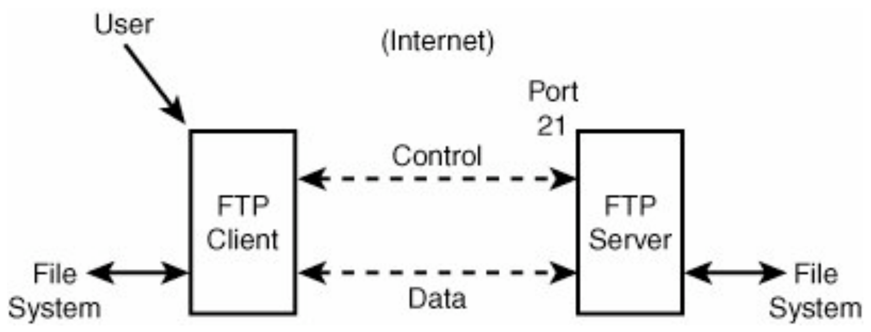
To the uninitiated, FTP and HTTP seem to be quite similar. Both allow file transfers, both support a form of user authentication, and the two protocols often appear to be used interchangeably on the Weba binary package or large multimedia file might be linked from a website via either the http:// or the ftp:// protocols, which seem to do the same thing with regard to downloading the file to your computer. However, a little further investigation shows us that the two protocols are designed for considerably different purposes and therefore support widely different feature sets. Table 27.1 shows a contrast of these crucial areas of difference.

Table 27.1. Comparison of FTP and HTTP Functionalities

Feature	FTP	HTTP
Requires user authentication	Yes	No
Primarily intended for transferring	Large binary files	Small text files
Connection model	Dual connection	Single connection
Primarily geared toward download/upload	Both	Download
Supports ASCII and binary transfer modes	Yes	No
Supports content typing (MIME headers)	No	Yes
Supports filesystem operations (`mkdir`, `rm`, `rename`, and so on)	Yes	No

The biggest difference between FTP and HTTP is that FTP is *session based*, meaning that a complete connection is initiated between the client and server, multiple commands are sent back and forth, and finally the client terminates the connection by choice. (HTTP, as you will recall, is a stateless protocola single request, followed by a single or pipelined response, comprises the whole HTTP "session.") FTP goes even beyond a single connection, as a matter of fact. A complete FTP session contains two connections: one for passing commands and status messages back and forth (control connection), and another to handle the actual file transfers (data connection). Figure 27.1 shows a diagram of a complete FTP connection.

Figure 27.1. An FTP session with both the control and data connections established.



An FTP client, such as the `ftp` command built in to FreeBSD, opens the control connection to TCP port 21 on the FTP server. This connection remains open throughout the session. When the user enters a command, such as `ls` or `get picture1.gif`, the client and server negotiate a pair of TCP ports between which they will open the data connection, which exists for as long as the response listing or file is being transferred, after which it is closed. A separate data connection is opened for each such transfer. A complete, typical FTP session is shown in Listing 27.1.

Listing 27.1. A Command-Line FTP Session

```
# ftp spots.example.com
Connected to spots.example.com.
220 spots.example.com FTP server (Version 6.00LS) ready.
Name (spots.example.com:frank):
331 Password required for frank.
Password:
230 User frank logged in.
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> cd mydir
250 CWD command successful.
ftp> ls
150 Opening ASCII mode data connection for '/bin/ls'.
total 484
-rw-r--r--  1 frank  frank   43175 Apr  8 01:14 addresses.txt
-rw-r--r--  1 frank  frank  100523 Apr  8 01:14 contents.html
-rw-r--r--  1 frank  frank   37864 Apr  8 01:14 directions
-rw-r--r--  1 frank  frank   37308 Apr  8 01:14 lk_logo.gif
-rw-r--r--  1 frank  frank   52427 Apr  8 01:12 picture1.gif
-rw-r--r--  1 frank  frank   18648 Apr 24 13:04 picture2.jpg
-rw-r--r--  1 frank  frank  175325 Apr  8 01:14 resume.html
226 Transfer complete.
ftp> get picture1.gif
local: picture1.gif remote: picture1.gif
150 Opening BINARY mode data connection for 'picture1.gif' (52427 bytes).
100% |*************************************************| 52427       00:00 ETA
226 Transfer complete.
52427 bytes received in 4.99 seconds (10.25 KB/s)
ftp> quit
221 Goodbye.
```

The first part of the connection is the username and password authentication stage, just as you would get in a Telnet or SSH connection. Similar to Telnet, FTP user authentication usually operates directly on a user's account information on the machine running the FTP server. This authentication process differs from HTTP user authentication, which is actually a function of Apache and not of HTTP itself and requires Apache's own user databases to be separately maintained.

In order to log in via FTP, the user must either have a valid user account on the server machine or must log in using "anonymous FTP," if the server allows it (a common practice that we will cover later in this chapter).

A number of user commands are available in FTP, behaving in much the same way as their familiar shell counterparts: `ls`, `cd`, `mkdir`, `pwd`, and so on. These commands help you navigate through the directory structure and modify remote files as if they were on the local (client) machine. There is also an `lcd` command that allows you to change directories on the local machine, in case you want to download a file to a different location from the one you were in when you started the FTP program. Additionally, there are the `put` (upload), `get` (download), `mput` (multiple upload), and `mget` (multiple download) commands, which control the file transfers themselves. These user commands are translated into client commands (such as `RETR`, `STOR`, `CWD`, and `LIST`) that the FTP server understands. The server responds with three-digit response codes, much as in HTTP. The meanings of the response codes aren't especially important to know, so we won't cover them here. See `man ftpd` if you're interested in seeing the complete list of FTP client commands (this manual for the server outlines the client commands the server recognizes).

Note

FTP file transfers can be done in one of two modes: ASCII or Binary. ASCII mode is used for transfers of plain text, in which all data is transferred as alphanumeric characters and end-of-line symbols are translated by the FTP application to or from whatever the client's platform uses, such as CR/LF for DOS/Windows, CR for classic Mac OS, and LF for UNIX. Binary mode is useful for transferring a stream of untranslated data. Some FTP clients, such as the one built into FreeBSD, automatically detect which type is appropriate and then switch to that mode when the transfer begins. Other clients require that you select either ASCII or Binary mode before transferring files. Use the `bin` and `asc` commands to switch modes.

It's generally safest to use binary mode at all times; however, if you find you have problems with text files such as HTML files and Perl scripts not rendering correctly after being transferred, try ASCII mode instead. This ensures that end-of-line characters are translated properly. Binary mode can cause Perl scripts to fail to run if uploaded from a non-UNIX client. Binary mode, however, is necessary for images, executables, and any other kind of binary data; binary files transferred in ASCII mode will be corrupted on the destination machine.

The default FTP server that ships with FreeBSD, which you learn about in this chapter, is the standard BSD `ftpd` daemon. It runs from within the `inetd` super-server, like `telnetd` and Qpopper, rather than as a standalone daemon. It lacks a few features supported by some of its alternatives (such as WU-FTPD and ProFTPD), but it also lacks a number of security holes that are inevitable with more complex software. You learn more about these alternative daemons at the end of this chapter; meanwhile, the following sections discuss how to make the most of the basic FreeBSD FTP server.

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File Layouts of Authenticated and Anonymous FTP

Unless you've enabled anonymous FTP logins, the file layout of the FTP server is very simple. The FTP server file layout is integrated with the system in the same way that most other core services are. There are several configuration files in `/etc`, some of which do double-duty as systemwide resource files used by other services. Individual users' home directories are considered part of the FTP server layout because each authenticated user connects directly into his home directory.

If you've enabled anonymous FTP, there's a server root area just as in Apache; this is created at the time when you elect to enable anonymous FTP, as you'll see in the later section of this chapter, "Allowing Anonymous FTP Access." The default location for the FTP server root is `/var/ftp`, and several subdirectories exist to help the server manage FTP users who don't actually have user accounts on the system.

When a user who has an account on the server logs in via FTP with her username and password, the server provides access to the user's home directory and all its files. The user can enter an `ls` command to verify that this is the area to which she has access by examining the files present there. Each regular user thus connects into a different point on the FTP server when logging in as a userher home directory.

Anonymous FTP provides a way for a user without an account to connect. An anonymous user opens the connection, enters **`anonymous`** or **`ftp`** as his username, and any text string (conventionally the user's email address, although this isn't enforced or authenticated in any way) for the password. The user is then given access to a "public" FTP area: `/var/ftp`, the home directory of the `ftp` user (which is also created when anonymous FTP is enabled).

There's a fundamental difference between regular account users and anonymous FTP users, though. Anonymous FTP is performed in a `chroot` "jail" by default, meaning that to the user, `/var/ftp` appears to be the server root (`/`). Nothing outside `/var/ftp` is accessible or even visible. A regular account user can enter a command such as `cd /usr/local` to move to any part of the system and access files with the same readability permissions as in a terminal session, but an anonymous FTP user can't get out of `/var/ftp` at all. An anonymous user who enters `cd /pub` will be taken to `/var/ftp/pub`.

You can specify additional users who must be "chrooted" in the same way as anonymous FTP logins by adding them to the `/etc/ftpchroot` file. That's just one example of the configuration files that control the FTP server.

Caution

Authenticated users have FTP access to your FreeBSD machine by default, but you have to specifically enable anonymous FTPif you want it. Allowing anonymous FTP effectively opens up your system to a form of unauthorized, untraceable access. You should only enable anonymous FTP if you have a good reason to do so!

Configuring the FTP Server

The FTP service involves a fairly large number of configuration files; some of them exist in `/etc`, and some are in `/var/ftp/etc`. The reason for this is that some of the files have to be accessible by anonymous FTP users, and, as you've seen, such users can't see any files outside of `/var/ftp`. Here are a few of the files in `/etc` that apply globally to the FTP server as a whole (not all of them exist in the default installationsome must be created manually):

- `/etc/ftpusers` A "blacklist" of users who are disallowed FTP access. Add usernames to this file to prevent them from logging in via FTP.
- `/etc/ftpchroot` Any users listed in this file will be placed in a `chroot` "jail," similar to that of anonymous FTP, limiting the user's access solely to his home directory. It's a good idea to put every user in the system into this file, unless there is a reason the user needs full system access; you might even want to modify the `adduser` script to add new users to this file.
- `/etc/ftphosts` Allows you to configure virtual hosts, much like with Apache (as you saw in Chapter 26, "Configuring a Web Server"). You'll learn more about virtual hosting later in this chapter.
- `/etc/ftpwelcome` A welcome notice. The contents of this file are displayed to everyone who connects, immediately after the connection is opened, before the login prompt.
- `/etc/ftpmotd` A second welcome notice ("message of the day"); this one appears after a regular account user has logged in. You can update this file regularly to present system news or policy changes.
- `/etc/shells` You encountered this file in Chapter 9, "Customizing the Shell." Its purpose is to ensure that anybody logging in to the system has a valid shell, thus preventing people from logging in to accounts such as `bin`, `tty`, and `nobody`, which don't have shells listed in this file.

Beyond the config files in `/etc`, a number of additional files control anonymous FTP. These aren't just config files, either. If `/var/ftp` is mapped to `/` for anonymous users, that means the tools in the system binary directories (such as `/bin`) are as inaccessible as the files in `/etc`. The FTP server relies on a few system toolsnotably `/bin/ls` and `/bin/date`to generate file listings to send to the client. These tools have to be available to anonymous users, too; that's what the `/var/ftp/bin` directory is for.

The `/var/ftp` TRee contains the following files and directories. Any anonymous user can see these files, but none of them are inherently "dangerous" for users to see (the `/var/ftp/etc` files don't contain any passwords, for example):

- `/var/ftp/bin` This directory contains `ls` and `date` executables. These are provided because they're necessary for the FTP server to be able to generate directory listings, and the system `/bin/ls` and `/bin/date` programs are not available if you've configured the server to `chroot` or have limited the anonymous FTP user's access to within `/var/ftp`. (This is the default behavior.)
- `/var/ftp/etc/passwd` and `/var/ftp/etc/group` As with the tools in `/var/ftp/bin`, these are copies of the default (skeleton) `/etc/passwd` and `/etc/group` files, whose purpose is to provide file ownership mappings during directory listings. Because anonymous FTP access is limited to what's in `/var/ftp`, these files must exist in order to show who owns the various files in `/var/ftp`. Typically, any files in the public FTP area will be owned by root or another system account because they will be put there by you, as the administrator. Other usernames, because they don't exist in `/var/ftp/etc/passwd`, will not be mapped and will appear to FTP users as raw UIDs for files owned by them.

- /var/ftp/etc/ftpmotd Operates the same way as /etc/ftpmotd, except that this one is displayed to anonymous FTP users instead of regular login users. From their perspective (with the chroot making /var/ftp appear to be / to them), this *is* /etc/ftpmotd.

- /var/ftp/pub Visible to anonymous FTP users as /pub, this is where all downloadable files should go. The hierarchy under /pub is up to you to determine, but convention says at least that /pub should contain everything that's meant to be of interest to the public.

- /var/ftp/incoming This optional directory has world-writable permissions with the "sticky bit" set (1777). This means that any anonymous user can upload files into this directory. This can be dangerous; having an open upload directory is an invitation for people to use it as a trading point for MP3 files and pirated software. Use this option only if you really need to, and if your situation is one where you can trust people not to abuse the uploading system (such as in a lab environment). Otherwise, you should remove this directory entirely just to be safe.

One final configuration file that concerns the FTP server is /etc/inetd.conf. As mentioned earlier, ftpd runs as a subsidiary to the inetd super-server, and as such it won't work if inetd isn't running. First, use ps to check to see whether the daemon is serving requests, using the w (wide format), -a (all users' processes), -u (user-oriented fields shown), and x (processes that aren't necessarily attached to terminals) options:

```
# ps -waux | grep inetd
root    1640  0.0  0.6  1048  780  ??   Ss Thu08PM  0:00.15 inetd -Ww
```

If you don't see the inetd process running, it might never have been enabled in /etc/rc.conf, such as during the initial installation of the system in Chapter 2, "Installing FreeBSD"or you might have disabled it. Check that file for the inetd_enable line and make sure it is present and set to YES. Second, open up /etc/inetd.conf and make sure the ftpd service is enabled:

```
ftp     stream  tcp     nowait   root     /usr/libexec/ftpd   ftpd -l
```

If this line is commented out, uncomment it, and then start or restart inetd (using the command **/etc/rc.d/inetd restart**). Check your configuration by trying to connect to the server (**ftp** localhost). If you are presented with a login prompt, you're in business. If not, look over the preceding steps again; check to make sure the inetd process is running after your modifications.

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Controlling FTP Access

FTP access is not something you should enable lightly. Although it's crucial for your users to have access to FTP for uploading files (such as web pages) to your server, it's also a potential source of security issuesit's a clear-text mechanism, meaning that all data (including passwords) is transmitted unencrypted and available to anybody eavesdropping with packet-sniffing software.

As you'll learn in Chapter 30, most major clear-text services can be superseded by a secure equivalent: Telnet with SSH, HTTP with Secure HTTP, and POP3 and IMAP with their own built-in encryption layers. FTP, however, is inherently insecure, and although several secure solutions have been put forth (such as the `sftp` command built into the OpenSSH package), unencrypted FTP holds out as the last widely used insecure data-transfer protocol, difficult to replace and a virtual requirement for a fully functional server. Many modern FTP client applications can support secure FTP, but it's still not built into the basic FTP mechanisms in Windows and Mac OS X, so traditional unencrypted FTP is still a widely demanded service for most users. You learn more about how to secure FTP at the end of this chapter and in Chapter 30; meanwhile, be aware that special care must be taken when enabling FTP access to your users to ensure your system's security.

With this in mind, you need a way to lock out certain users from being able to connect to the system via FTP. This can be done in a number of ways. The two most convenient involve the `/etc/ftpusers` and `/etc/shells` files. A third, `/var/run/nologin`, controls whether the server accepts connections at all.

The `/etc/ftpusers` File

The simplest way to forbid a certain individual user (or a group of users) from connecting to the FTP server is to add that user's login name to the `/etc/ftpusers` file, which exists in the default FreeBSD installation and contains the names of the various system pseudousers (such as `operator`, `bin`, `tty`, and so on). These users have null passwords, and `ftpd` will not allow anyone with a null password to connect anyway; but keeping these usernames in `/etc/ftpusers`, which rejects them explicitly by name, provides an extra layer of security.

You can add any username to the file, and because `ftpd` reads all relevant configuration files with each new connection, there's no need to restart any processes. Try connecting to the FTP server as a disallowed user, and you should get a response similar to the following:

```
# ftp localhost
Connected to localhost.example.com.
220 stripes.example.com FTP server (Version 6.00LS) ready.
Name (localhost:frank):
530 User frank access denied.
ftp: Login failed.
ftp>
```

Note

The `access denied` message appears immediately after the server receives the usernameit doesn't prompt for a password. This prevents passwords from being sent over the wire, providing an extra security precaution in the case where you've disabled a user out of concern regarding an eavesdropper sniffing for passwords.

You can also add any group name to `/etc/ftpusers`; simply precede the name with an "at" (`@`) symbol (for example, `@users`). Any user who is part of any group listed in the file will be disallowed access.

The `/etc/shells` File

After seeing whether the user is listed in `/etc/ftpusers`, `ftpd` checks the shell associated with the user and sees whether it's listed in `/etc/shells`. If it isn't, the user will get the same kind of `access denied` message as with `/etc/ftpusers`. You can leverage this functionality to prevent a user from logging in with a terminal program or with FTP by changing the user's shell to `/sbin/nologin` (which you saw in Chapter 9it simply prints out an `account not available` message and exits, and it's not listed in `/etc/shells`) or something similarly constructed.

The `/var/run/nologin` File

To turn off FTP logins completely, without modifying `/etc/inetd.conf` or any other such config files, you can simply place a file called `nologin` in `/var/run`. If `ftpd` sees this file, it will respond to all connections as follows:

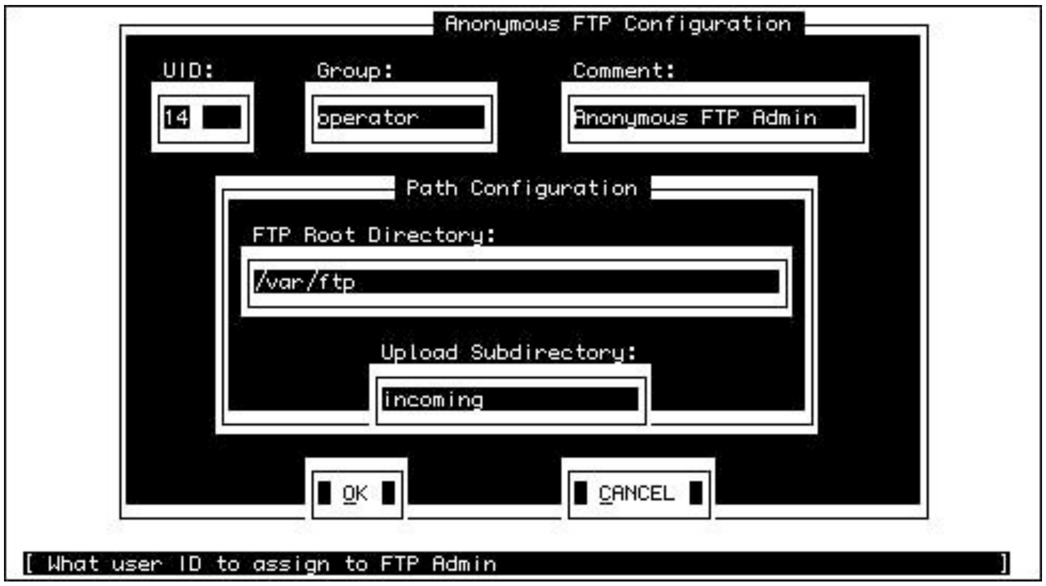
```
# ftp localhost
Connected to localhost.example.com.
530 System not available.
ftp>
```

You can enter `touch /var/run/nologin` to create the file (with zero length) and disable FTP logins. Remove the file (`rm /var/run/nologin`) to reenable the FTP server.

Allowing Anonymous FTP Access

By default, anonymous FTP is not enabled; the easiest way to enable it, if you choose to do so, is through Sysinstall. Within the Sysinstall program (`/usr/sbin/sysinstall`), enter the Configure and Networking sections. Scroll to the Anon FTP option and press the spacebar to enter the Anonymous FTP Configuration screen, shown in Figure 27.2.

Figure 27.2. Anonymous FTP configuration options.



```
Anonymous FTP Configuration
UID:        Group:        Comment:
14          operator      Anonymous FTP Admin

Path Configuration
FTP Root Directory:
/var/ftp
Upload Subdirectory:
incoming

OK    CANCEL

[ What user ID to assign to FTP Admin                ]
```

The default options are generally appropriate for a typical FreeBSD system. The UID, Group, and Comment fields control how the new `ftp` user will be created. This user's home directory is set to `/var/ftp`, which is how anonymous FTP worksthe `ftp` login is treated as a regular user that behaves as if it's listed in `/etc/ftpchroot`, so anybody logging in as `ftp` (or its alias, `anonymous`) will be put into a `chroot` jail at `/var/ftp`.

You can change any of the fields to suit your system (for instance, if you already have a user with a UID of 14, or if you want a name for the upload directory that's different from `incoming`). When you select OK at the bottom of the screen, the `ftp` user will be created, as will the `/var/ftp` TRee with its necessary subdirectories.

Note that Sysinstall doesn't provide the capability to disable anonymous FTP after it has been enabled, but you can do this in a number of ways. The following methods are ranked in descending order of preferability:

- Add the `ftp` user to `/etc/ftpusers` (probably the easiest and cleanest method). This prevents the `ftp` user, the anonymous guest user, from connecting using FTP's own mechanisms.
- Change the permissions on the `/var/ftp` tree so that its contents can't be read by regular users`chmod 0700 /var/ftp` will work.

- Remove the `/var/ftp` TRee.
- Remove the `ftp` user.

Similarly, you can disable the upload (`incoming`) directory by simply removing it, or else by changing its permissions to `755` (the default directory permissions, in which only the ownerrootcan write into it). Reenable it (or any other directory to which you want anonymous users to be able to upload files) by changing its permissions to `1777`for instance, `chmod 1777 /var/ftp/incoming`.

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Virtual Hosting

If you have multiple IP addresses bound to your machine, you can map different FTP server behaviors to each one. This virtual hosting mechanism is controlled with the `/etc/ftphosts` file, which does not exist in the default FreeBSD system (you need to create it).

Each virtual host is defined on its own line, with fields specifying alternate config files for each host separated by whitespace. Table 27.2 describes the various fields, their meanings, and the default values (the ones that the server uses without an `/etc/ftphosts` file present).

Table 27.2. Virtual Hosting Table Fields in `/etc/ftphosts`

Field	Description	Default
Hostname	The hostname or IP address of the virtual host. Note that FTP has no equivalent of the `Host:` header of HTTP/1.1, so FTP virtual hosts are defined purely on the IP address of your machine where the client is connected, so each virtual host must have its own unique IP address or alias. If you use a hostname in this field, `ftpd` uses the IP address to which it resolves. Bear this in mind when adding virtual hosts.	N/A
User	The user whose home directory is used for anonymous FTP access in this virtual host. Anonymous users are jailed (via `chroot`) into this directory, so equivalents of `/var/ftp/etc` and `/var/ftp/bin` should be present.	`ftp`
Statfile	The log file that tracks all FTP transfers for the virtual host.	`/var/log/ftpd`
Welcome	The welcome message displayed upon initial connection to the FTP server.	`/etc/ftpwelcome`
MOTD	The second welcome message, presented after a successful user login.	`/etc/ftpmotd`

A few sample virtual hosts in `/etc/ftphosts` follow. If a field is left blank or has a hyphen (`-`), the default value is used:

```
64.41.131.106    frank   /var/log/ftpd-frank    /home/frank/hi   /home/frank/hi2
ftp2.me.com      ftp2    -                      /etc/ftpd2welcome    -
64.41.131.107    ftp3    /var/log/ftpd-3        -                   -
```

Using Alternative FTP Servers

Many alternative FTP server packages exist; the three most popular are Washington University's WU-FTPD, the highly secure vsftpd, and the highly configurable ProFTPD. Both of these packages provide features that are not available in the default FTP server, including extremely flexible configurability and extra security measures.

WU-FTPD

Originally developed at Washington University to host the WUarchive (once one of the most popular file-sharing and distribution locations on the Internet), WU-FTPD has gained in popularity to become the most frequently used FTP server in the world, even though its development has stagnated in recent years and a number of serious security problems plague it. It was the default FTP daemon in Linux and many commercial UNIX brands for many years, until it was replaced with `vsftpd`.

WU-FTPD's configuration differs from FreeBSD's default `ftpd` in a few subtle ways, and it has a few features that the default `ftpd` does not, such as a configuration-checking tool, on-the-fly compression and archiving, and limitations on access and transfers by time and date. You might choose to install WU-FTPD to maintain compatibility with an existing non-FreeBSD system.

WU-FTPD is available as a package or in the ports (`/usr/ports/ftp/wu-ftpd`). After installing it, you can switch to it from the FreeBSD `ftpd` by commenting out the `ftp` line in `/etc/inetd.conf` and replacing it with one that points to the new `ftpd`:

```
ftp     stream    tcp     nowait    root     /usr/local/libexec/ftpd  ftpd -l
#ftp    stream    tcp     nowait    root     /usr/libexec/ftpd        ftpd -l
```

Tip

WU-FTPD is installed as `/usr/local/libexec/ftpd`, and its `man` page can't be accessed directly with `man ftpd`you'll get the page for the default system `ftpd`. To see the correct page, use the `-M` option to use an alternate `man` path, like so:

```
man -M /usr/local/man ftpd
```

More information on WU-FTPD is available at http://www.wu-ftpd.org.

vsftpd

A server with the stated purpose of being Very Secure (hence the name), vsftpd is the FTP server of choice for most modern Linux distributions. It's endorsed by the SANS Institute as the most secure FTP solution available, as well as being the server of choice for the FTP distribution sites of most major Linux distributions and the FreeBSD FTP server itself, ftp.freebsd.org.

Because vsftpd is very small and self-contained, it uses a single configuration file`/usr/local/etc/vsftpd.conf`and only one or two external user list files that you specify in the main configuration file. This does not, however, mean that it's lacking in features; indeed, it contains many of the advanced features that only very extensive servers such as ProFTPD offer, such as virtual hosts, virtual users, bandwidth throttling, transfer limitations, and so on. It runs as a standalone daemon rather than out of inetd.

More information on vsftpd can be found at http://vsftpd.beasts.org.

ProFTPD

ProFTPD was developed with the intention of creating an FTP server that could be managed with configuration files that resembled those of the Apache web server. ProFTPD's config file has hierarchical configuration blocks like those in `httpd.conf` (as you saw in Chapter 26) and directives that are similar in style to those of Apache. The result is a server that has very Apache-like access-limitation features as well as a high level of configurability, especially for administrators familiar at all with Apache. It's available as a package or from the ports (`/usr/ports/ftp/proftpd`).

One difference between ProFTPD and its relatives is that it can be run in standalone mode, like Apache, rather than from `inetd`. If you do run it from `inetd`, replace the default `ftp` line with one pointing to `/usr/local/libexec/proftpd`:

```
ftp     stream  tcp     nowait   root     /usr/local/libexec/proftpd      proftpd
#ftp    stream  tcp     nowait   root     /usr/libexec/ftpd       ftpd -l
```

The ProFTPD home page, http://www.proftpd.org, has much more information on ProFTPD's capabilities (such as its support for the secure FTPs protocol, which few others offer) and configuration directives.

Secure FTP (`sftp`)

The clear-text nature of FTP presents a problem. Although many users (especially those who rely on the built-in utilities in their desktop operating systems) still use traditional unencrypted FTP for transferring files, uploading web pages, and so on, this means that their critical user information (login names and passwords) are susceptible to interception by a third party with a packet sniffer.

There is, however, an encrypted alternative to FTP: `sftp`, which is part of the OpenSSH package installed by default as a part of FreeBSD. If you enabled SSH connections during the initial installation of FreeBSD, secure FTP communications are available without any further configuration on your part.

Clients can use the `sftp` command (built into FreeBSD, Linux, Mac OS X, and elsewhere) on the command line, or its graphical equivalent in any of the many GUI-based FTP client applications, to open an encrypted connection to your server. This connection invokes the `/usr/libexec/sftp-server` program on the server side, and from that point on the `sftp` session is functionally the same as a regular FTP session.

Configuring secure FTP, however, is done through the `/etc/ssh/sshd_config` file, which controls aspects of the SSH server, through which `sftp` operates. You'll use this file to present login banners and lock out users in the same manner as you would control access to the SSH daemon itself, and anonymous FTP access is not allowed over the secure channel. The activation and configuration of SSH is further described in Chapter 30.

Chapter 28. Configuring an Internet Gateway

IN THIS CHAPTER

Routing and gateways were covered briefly in Chapter 22, "Principles of TCP/IP Networking," as was the concept of NAT (Network Address Translation). Chapter 23, "Configuring Basic Networking Services," also covered routing a little bit, but mostly in the context of configuring a host to use a router. This chapter explains how to configure FreeBSD to serve as a router or a gateway as well as how to set up Network Address Translation to provide routing services to an entire subnetwork. The chapter begins with a few short definitions of each of the items we will be discussing.

The Basics of Routers and Network Address Translation (NAT)

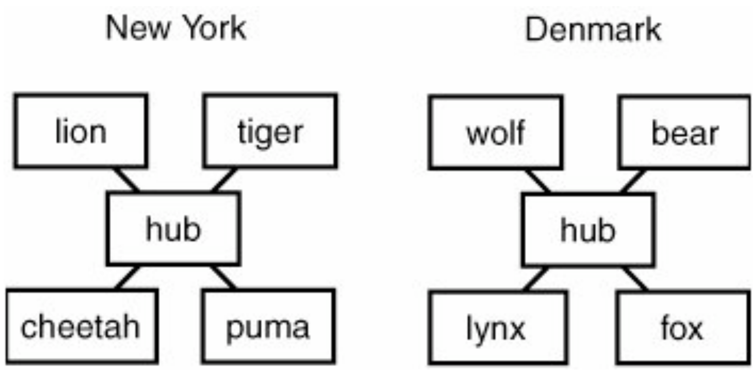
As was explained in detail in Chapter 22, a *router* is a device that connects two disparate IP networks together and determines how datagrams get from one network to another.

Note

A *datagram* is a packet of digital information. It contains addressing information as well as the data to be transmitted. Not all datagrams necessarily take the same route to get to their destinations, even if they all have the same origin.

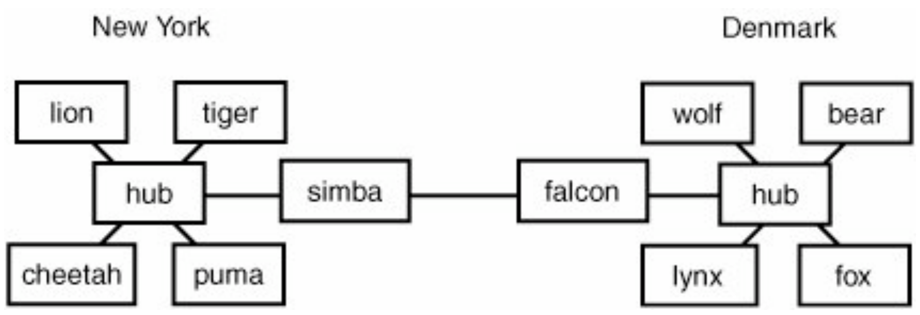
To better understand what a router does, look at the following two figures. Figure 28.1 shows two sample networks for a fictional global company that has offices in New York and Denmark.

Figure 28.1. A sample global network for a fictional company, with several hosts in its New York office and several hosts in its Denmark office.



In the network in Figure 28.1, the hosts named `lion`, `cheetah`, `tiger`, and `puma` all know about the existence of each other and can communicate with each other at the New York office. Also, the hosts named `wolf`, `bear`, `fox`, and `lynx` all know about each other and can communicate with each other at the Denmark office. The problem here is that the networks are physically isolated from each other, each one connected only to its local upstream Internet provider. None of the hosts in the New York office know anything at all about any of the hosts in the Denmark office, and vice versa. There is no way for network information to travel between the two offices. In order for data to be able to flow between these two offices, you need to install a couple of routers. Figure 28.2 shows the same network, but this time you have installed a router at each office.

Figure 28.2. The same network as shown in Figure 28.1, except that a router is installed on each end of the network.



After the router is installed, one change needs to be made to the hosts on the network: They simply need to be told about the existence of the router in the office. (See Chapter 22 for information on how to tell the hosts about the existence of the router.)

The hosts in the New York office still know nothing at all about the hosts in the Denmark office, and the reverse is also true. So what has changed about this setup? Well, the hosts in the network now know about the existence of the router in their office. If each host is configured to use this router as the default router, it will send to the router any outgoing traffic for an unknown host. The router then worries about routing the network traffic to the correct destination.

For example, suppose that the user of `cheetah` wants to establish a network connection with `lynx`. As mentioned before, `cheetah` knows nothing about the existence of `lynx`. So, when `cheetah` generates traffic to `lynx`, it will simply pass that traffic off to `simba`, which is the router in the New York office. The router `simba` does know about the existence of `lynx`, and it also knows that it can get network traffic to `lynx` by passing it to the router in Denmark (`falcon`). The router in Denmark then sends the traffic to `lynx`.

This is a very simple example. In a real scenario (especially when sending transoceanic network traffic), several routers will usually be involved, each passing the traffic to another until it gets to the proper destination. If you want an analogy, you can think of routers as being like air traffic controllers, and network traffic as being like aircraft. An aircraft en route from New York to Denmark will be handed off between several different air traffic controllerseach one aware only of the next one along the sequenceuntil it finally reaches its destination.

Okay. So why do you need a router? Why not just tell the hosts in New York about the hosts in Denmark, and vice versa, so that they can communicate with each other directly? There are two primary reasons why it is not done this way:

- *Ease of maintenance* This might not seem like a big deal with only eight systems. But now think of a network the size of the Internet. Without routers, every single system connected to the network would have to know how to contact every other system on the network. Obviously, when you are dealing with millions of systems, this would quickly become a maintenance nightmare.

- *Reduced traffic congestion* If the two offices were just connected by one big network, then all network traffic would have to be sent to all computers. If, for example, `lion` sends network traffic to `cheetah` (both in the New York Office), this traffic would also get sent through the pipe, across the Atlantic Ocean, and into the Denmark office. This would occur even though the hosts in Denmark couldn't care less about this traffic because it is not for them. Imagine the network congestion if any time any host on the Internet sent network traffic to another host, that traffic had to also go to every single other host on the Internet. And besides that, transoceanic leased lines are expensiveyou are usually charged by the amount of bandwidth you use. That means you don't want to use the line when you don't have to. The router acts as a "door" that keeps traffic intended for one of the local hosts inside the local network. Only traffic not intended for one of the local hosts will be sent outside of the local network. (This also increases securityyou don't want your internal network traffic being broadcast over the Internet where just anyone can intercept it.)

What Is a Gateway?

In general network terminology, a *gateway* is a router that allows the rest of the hosts on the internal LAN to access the outside world. Because of this, the terms *default router* and *gateway* are virtually interchangeable in most networking circles these days. In our example in the previous section, the routers `simba` and `falcon` could be called gateways.

Note

According to the technical definition, a gateway is a router that can route between two different types of networks, such as between an Ethernet LAN and a serial WAN.

One of the most common uses of a gateway is to allow multiple hosts to share a single Internet connectionfor example so that all the computers in your household can all use the same cable modem connection.

What Is NAT?

NAT, which stands for *Network Address Translation*, is a way for multiple hosts to connect to the Internet using a single IP address. For this to work, all traffic on the local network must pass through a gateway router that's set up to perform NAT. Hosts on the internal network can have IP addresses that aren't necessarily valid anywhere outside the local network. Normally this would mean that traffic from the outside can't reach them; but NAT makes this trick possible.

When the internal hosts want to send or receive Internet content, their request goes through the NAT gateway. The gateway "hides" the internal IP address and sends all requests from the hosts connected to it out on the Internet as though they had come from a single IP address (which is the IP address owned by the NAT gateway router). Responses that are sent back are sent to that single IP address, the address of the gateway router. The gateway then routes the data to the proper internal host.

There are three primary advantages of this method:

- It conserves IP addresses. The Internet's pool of valid IP addresses is a limited resource, running lower every day, and there is no reason to waste addresses where they are not needed. NAT prevents you from having to register an IP address for each one of your systems, or reserve an IP subnet carved out from your ISP's precious IP space. The only machine that needs a public and registered IP address is the NAT gateway. The rest of them can all have private, internal IP addresses.

  Note

  Because of its much vaster address space, IPv6 doesn't need to worry about conserving addresses, and NAT is considered unnecessary in the IPv6-based Internet. However, the security implications of NAT still make it an attractive proposition.

- If you are a home or small office user, it allows you to share a single Internet connection with multiple computers, and you won't have to purchase additional accounts from your ISP. You can also share a single modem and a single phone line, preventing you from having to install additional phone lines if more than one computer will use the Internet at the same time.

- NAT protects you from the vast majority of remote security exploits perpetrated by "script kiddies" who target the well-known public IP address space used by cable modem and DSL customers.

Outside hosts can't spontaneously contact any host on the inside of a NAT. FreeBSD isn't very vulnerable to most exploits in the wild, but NAT prevents them from reaching you in the first place (because the only communications between your machines and the outside world are the ones that you initiate).

Drawbacks of NAT, however, include the fact that you cannot operate an Internet server on the inside of a NAT gateway. Servers have to be publicly available for client hosts to contact them at any time; because NAT dictates that you can only initiate connections and not receive any, no outside hosts will be able to reach you. If you need to run a server, NAT is not a suitable solution. However, if you're a cable modem customer, you're likely forbidden from running servers anyway. NAT is ideal for home and business networks where the only networking that needs to occur is typical desktop surfingweb, email, chat, and the like.

To illustrate some of the ways you can configure various types of routing services on FreeBSD, this chapter presents a few sample scenarios. We begin by looking at sharing a single modem and Internet connection at home or in a small office.

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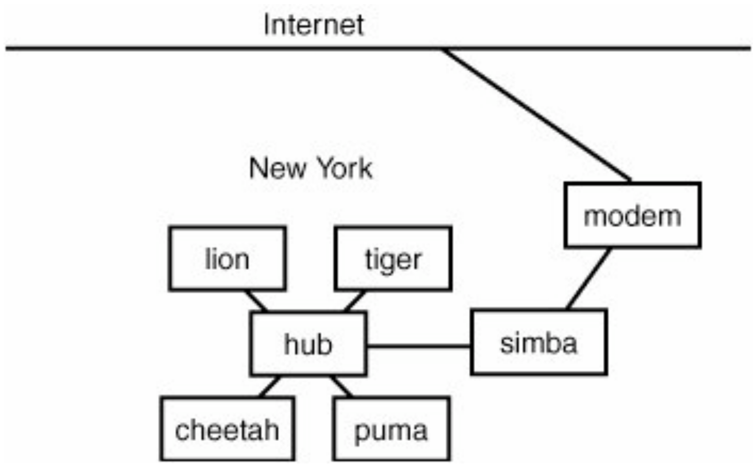
Configuring a NAT Gateway in FreeBSD

NAT gateway routers are widely available today for very little money; one of the most popular types of devices is a wireless access point, such as Apple's AirPort Extreme Base Station, which itself connects to your cable modem or DSL router and performs NAT for all the devices on your home network, whether they're connecting wirelessly or over wired Ethernet. Devices like this generally sell for $300 or less. You can, however, construct your own gateway router using any computer that is capable of routingfor example, your FreeBSD machine.

In this scenario, you will generally have a single Internet connection, which might be a cable modem, DSL, or even a phone modem. Suppose you have several computers inside the house or office that need to access the Internet. Figure 28.3 shows an example using an internal modem in the FreeBSD machine itself.

Figure 28.3. A simple gateway setup. The router `simba` has a connection to the Internet via an internal modem. The idea is to allow `lion`, `cheetah`, and `lynx` to share this modem and access the Internet through `simba`.



Note

For networks that access the Internet through a cable modem or DSL connection, your FreeBSD machine will need to have two Ethernet cards in itone to connect to the hub or switch forming the backbone of the LAN, and the other to connect to the cable modem or DSL router. This latter interface will need to be configured with the public IP address given to you by your Internet Service Provider.

In this type of setup, your system will need to have two network interfaces in it. For example, `ppp0` will be the modemthe interface to the Internet. The other interface will usually be an Ethernet card (for example, `ed0`). This will be the interface to the internal network.

Both these interfaces will be configured with different TCP/IP network settings, placing them on different logical networks; the public interface (`ppp0`) is part of the real Internet, but the private interface (`ed0`) is using a network address that's valid only inside the network, and makes sense only to the other hosts on it.

The job of the gateway is to act as a translator between these two interfaces by passing packets back and forth between them. It connects the Internet with your internal network, making the two networks visible to one another. When an internal host contacts an external one on the Internet, the NAT gateway records the connection and translates the outgoing packets so they appear to be coming from itself. When the response comes in from the Internet over the interface `ppp0`, the gateway recognizes it as being part of a valid connection and passes it to the interface `ed0` to be sent to the proper host on the network. Before this can occur, however, you need to enable packet forwarding so that network traffic can flow between the two interfaces.

Enabling Packet Forwarding

In order for your system to act as a gateway, it must be able to forward packets between network interfaces. Your system will be handling incoming and outgoing Internet traffic for other computers on your network, so when the system receives a packet that is not addressed to it, it needs to forward that packet to the correct destination. By default (and to conform with Internet standards), packet forwarding is turned off, so FreeBSD will drop any packet it receives that is not addressed to the system it is running on.

Enabling packet forwarding, though it can be accomplished through Sysinstall, is merely a matter of adding a single configuration line to the `/etc/rc.conf` file:

```
gateway_enable="YES"
```

Then, start (or restart) the routing subsystem using the following command:

```
# /etc/rc.d/routing restart
```

After you have issued this command, packet forwarding will be enabled, and the system can now forward packets between interfaces.

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Enabling NAT for Systems Without Static IP Addresses

If all the systems on your network have real static IP addresses that are valid on the Internet, you're done setting up your gateway router. You can now configure the other systems on the network to use the host `simba` as their gateway. These hosts will send to their default gateway any traffic that they do not know how to deliver. The default gateway system will then worry about handling this traffic and directing it to its proper destination on the Internet.

Note

This section and the ones that follow assume that you already have a working Internet connection on the system that you want to configure as the gateway to the Internet. If this is not the case, see Chapter 23 for setting up network access on a LAN (this chapter also applies to you if you are accessing the Internet through DSL or a cable modem). If you need to configure an Internet connection over a modem, see Chapter 24, "Networking with PPP and 802.11."

Most of the time, however, if you are configuring an Internet gateway, the other systems on the network will not have a real IP address that is valid on the wider Internet. Instead, they will just be using internal IP addresses, valid only within the local network, such as the commonly used `10.0.1.`*`xxx`*, `192.168.`*`xxx.xxx`*, or `172.`*`xxx.xxx.xxx`* addressing schemes. If this is the case, you still have a little more work to do. You will have to enable NAT on your gateway for these other systems to be able to access the Internet.

If you are using PPP over a dial-up Internet connection, the method used to enable NAT will depend on whether you are using user PPP or kernel PPP. If you have not set up an Internet connection yet, I recommend you use user PPP if you want to use NAT because it is the easier of the two to configure to work with NAT. (See Chapter 24 for more information on user PPP and kernel PPP.)

If you are using kernel PPP or you need to set up NAT for an Internet connection that is not PPP, the procedure is a bit more complex.

The NAT setup procedure has been divided into the following two sections. You only need to read the section appropriate to your situation.

Using User PPP

The user PPP program in FreeBSD has NAT capability built into it, so it is very easy to enable. You can simply use the `-nat` option to `ppp` to enable NAT. Simply add it to whatever other options you are currently using to start PPP (see Chapter 24 and the online Handbook for more details).

The only other thing you should need to do is configure your Windows, Macintosh, or other client to use the new gateway server. This will be covered later on in this chapter in the "Configuring Clients to Use the New Gateway" section.

Using Kernel PPP or a Dedicated Ethernet Connection to the Internet

If you are using kernel PPP, or you have a dedicated Internet connection (DSL, cable, T1, OC3, and so on), the configuration is a little more complicated. In this case, you will need to use the NAT daemon (`natd`), which requires a firewall in order to work. To enable the firewall, you will need to build a new kernel. This is not difficult to do, however. You can simply add the following two lines to your kernel configuration file:

```
options IPFIREWALL
options IPDIVERT
```

You can add to the kernel configuration file various other options that have to do with the firewall, such as logging. A detailed discussion of firewalls is beyond the scope of this chapter, but you may want to read the "Enabling and Configuring the Firewall" section of Chapter 30, "Network Security," before you build a new kernel with firewall support. This way, you won't have to build yet another kernel if you later decide you want another option for the firewall that you didn't include in the kernel the first time around.

Also, if you are unclear about how to build a new kernel, see Chapter 18, "Kernel Configuration," for more details.

After you have finished building a new kernel, you will need to enable `natd`.

Configuring and Enabling `natd`

The NAT daemon `natd` can be enabled either by configuring network settings in Sysinstall or by manually editing the `/etc/rc.conf` file. Once again, if you already have basic networking set up, it is easier to simply make the necessary changes manually rather than go through Sysinstall, so this is the method we are going to cover here.

Open the file `/etc/rc.conf` in your favorite text editor and add the following lines:

```
natd_enable="YES"
natd_interface="ppp0"
```

The `natd_interface` line in this example assumes that you have a modem connection to the Internet and that it is on the interface `ppp0`. If you have a dedicated connection over an Ethernet device (such as DSL, cable, T1, or OC3), you should replace `ppp0` with whatever network interface your connection to the outside world runs on.

A few other options to `natd` are available that control things such as logging. If you are interested in the other options, see the `man` page for `natd`.

Don't exit and save the modified `rc.conf` file yet because there is at least one more option you have to add. This has to do with the firewall.

Enabling and Configuring the Firewall

At a minimum, you will need to add the following line to `/etc/rc.conf` to enable the firewall:

```
firewall_enable="YES"
```

There are various ways to configure the firewall rules, and you should see Chapter 30 for full details. Here is a quick description of my preferred method.

In addition to the previous line, add the following line to `/etc/rc.conf`:

```
firewall_type="/usr/local/etc/firewall.conf"
```

Save the changes you made to `/etc/rc.conf` and exit your editor. You can then create the file `/usr/local/etc/firewall.conf`, in which you simply list the firewall rules (except for the default rule, which by default will deny anything that is not specifically allowedsee Chapter 30 for more details).

If you do not want to deny any types of network traffic and simply want to pass everything through, use the following rules in `/usr/local/etc/firewall.conf` (replacing `ed0` with your Ethernet interface):

```
add divert natd all from any to any via ed0
add allow all from any to any
```

Using this rule has the same effect as not having a firewall at all because it simply passes all traffic and doesn't deny anything.

Note

Allowing people to see the firewall rules that your system is using can be a security hazard, so you should set the permissions on the file so that only root can read it. The command `chmod 600 /usr/local/etc/firewall.conf` will do the trick.

Caution

The firewall rules described previously are very insecure because they allow all types of network traffic from any source and will happily pass that content to any one of the systems that is using this gateway. This compromises the security of your network, and is not a recommended configuration. Again, see the section "Configuring a Firewall" in Chapter 30 for information on how to configure the firewall to block potentially dangerous types of traffic.

After you have completed all the preceding steps, reboot the system for the kernel changes to take effect and for the firewall and `natd` to load, or use the `/etc/rc.d/ipfw restart` command. Your gateway should now be configured. The only thing left to do is to inform the clients of the existence of the gateway. The configuration of various clients will be covered next. For the client types that are not covered, see your system documentation.

Caution

When configuring the firewall for the first time, make sure to do it at the FreeBSD machine's local console. If you're accessing the system remotely and you accidentally misconfigure the firewall, you will lock yourself out of your own system. By default, the firewall denies all traffic, so this is relatively easy to do by accident.

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Configuring Clients to Use the New Gateway

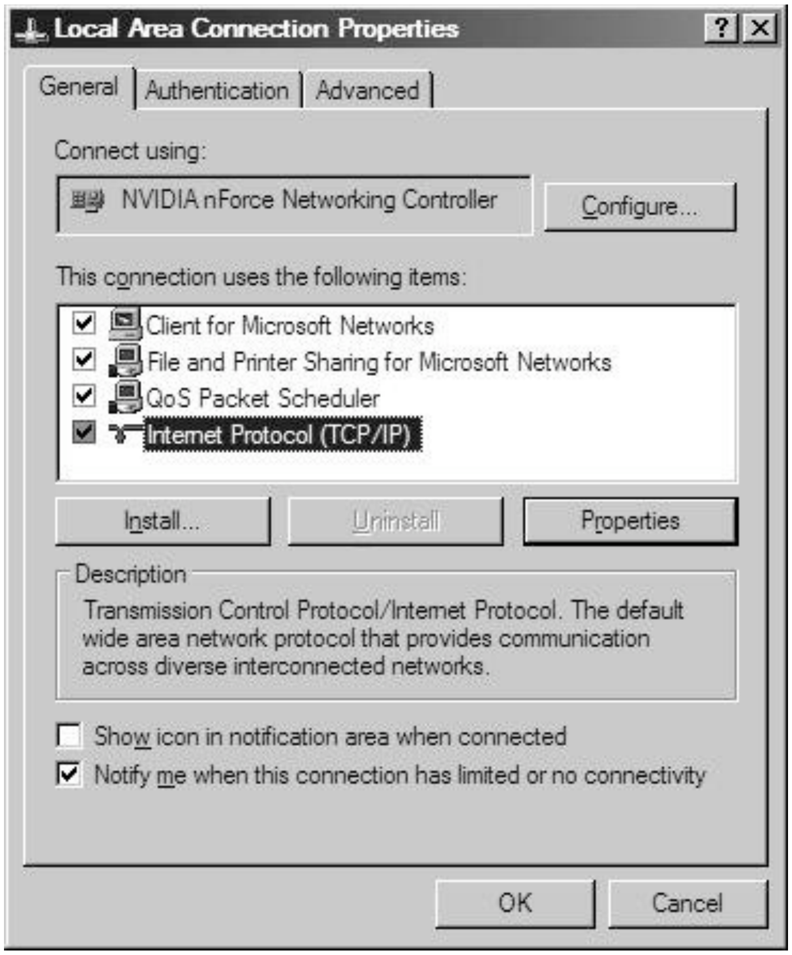
The procedures for configuring a client to use the gateway vary, depending on the type of operating system you are running. We will cover configuring Windows, Macintosh, FreeBSD, and Linux clients in this section.

Note that all the following configuration instructions assume that you already have basic networking configured and that they simply show you how to set up the system to use the gateway. If you do not have basic networking configured on the system yet, see the documentation for your system for instructions on how to do this.

Configuring Windows Clients

To configure a Windows 2000/XP client to use the gateway, go to Start, Settings, Control Panel, and then Network Connections. In the window that appears, locate the entry representing your LAN connection, and double-click it. This will open the configuration dialog box shown in Figure 28.4.

Figure 28.4. The Network dialog box in Windows XP. Windows 98 and other Windows versions may look slightly different.



Local Area Connection Properties

General | Authentication | Advanced

Connect using:

NVIDIA nForce Networking Controller

This connection uses the following items:

- [✓] Client for Microsoft Networks
- [✓] File and Printer Sharing for Microsoft Networks
- [✓] QoS Packet Scheduler
- [✓] Internet Protocol (TCP/IP)

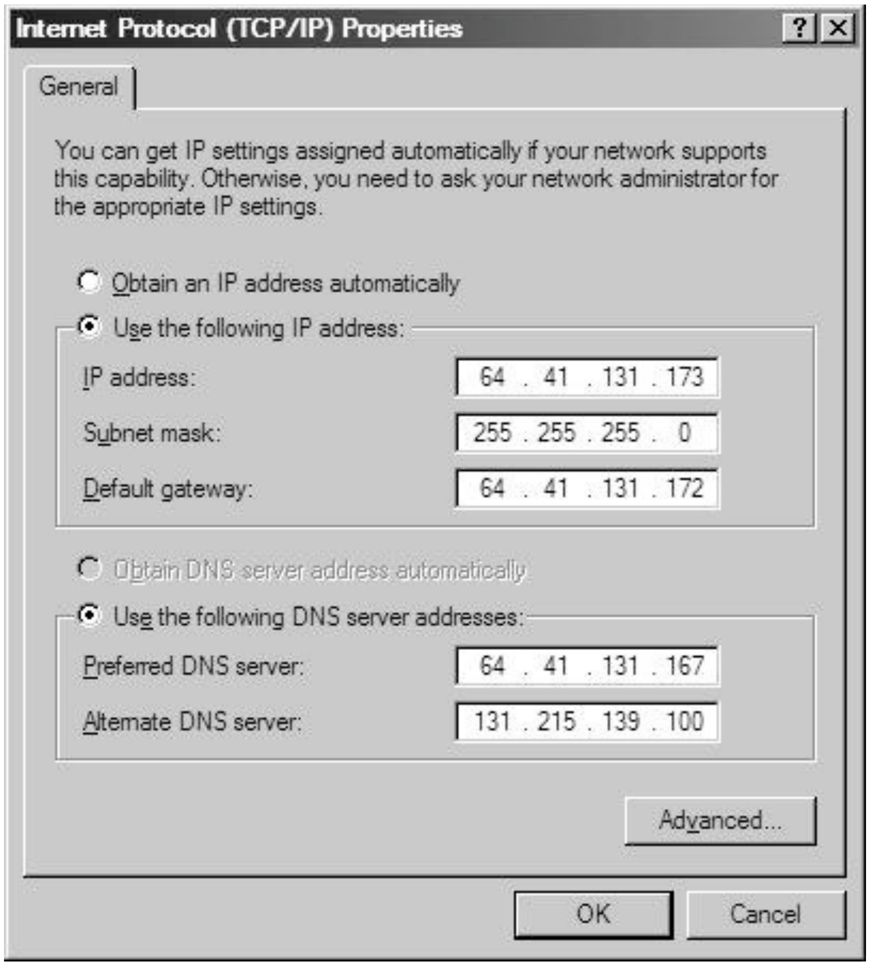
Description

Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.

- [ ] Show icon in notification area when connected
- [✓] Notify me when this connection has limited or no connectivity

From this dialog box, select Internet Protocol (TCP/IP) and then click the Properties button. This will take you to the Internet Protocol (TCP/IP) Properties dialog box, shown in Figure 28.5.

Figure 28.5. The Internet Protocol (TCP/IP) Properties dialog box in Windows XP.


Internet Protocol (TCP/IP) Properties

General

You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

Obtain an IP address automatically [✓ Use the following IP address:]

IP address:	64 . 41 . 131 . 173
Subnet mask:	255 . 255 . 255 . 0
Default gateway:	64 . 41 . 131 . 172

Obtain DNS server address automatically [✓ Use the following DNS server addresses:]

Preferred DNS server:	64 . 41 . 131 . 167
Alternate DNS server:	131 . 215 . 139 . 100

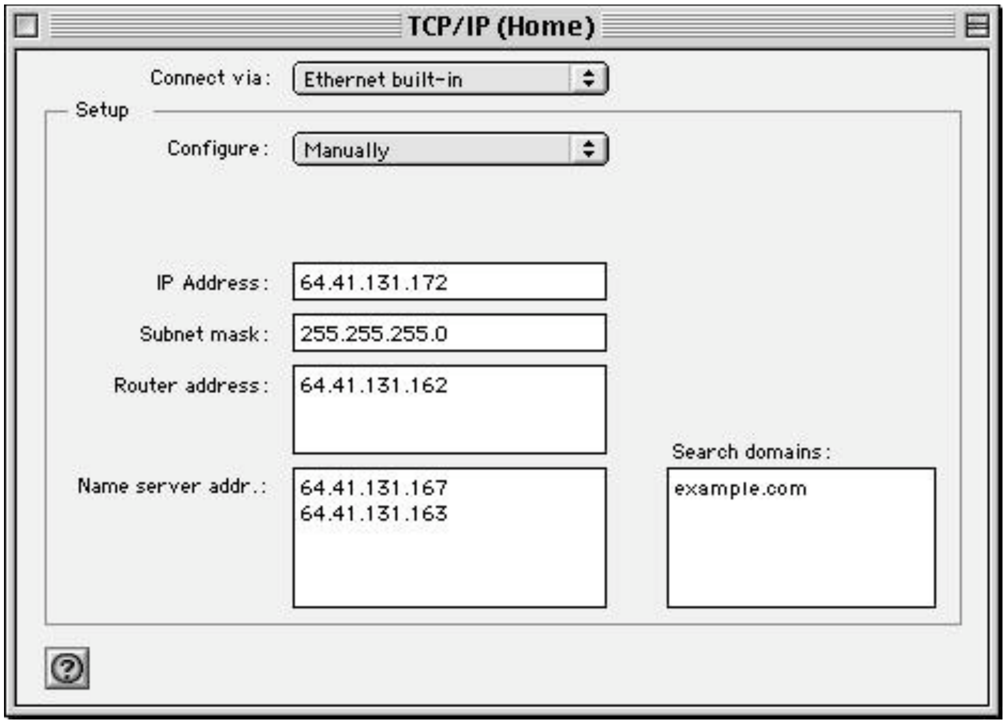
Make sure you've selected to use a specified IP address; then, along with the appropriate TCP/IP information, enter the IP address of the gateway router in the Default gateway field, as shown. Click OK to save the changes and then click OK again to leave the Network dialog box.

You should now be able to access the Internet from the Windows system.

Configuring Mac OS and Mac OS X Clients

In the classic Mac OS (version 9 or earlier), open the TCP/IP control panel, as shown in Figure 28.6, and select Manually from the Configure drop-down menu if it is not already selected. Put your gateway's IP address into the Router Address field. When you close the window, it will prompt you to save the changes. When you do so, the new settings will be immediately applied.

Figure 28.6. Configuring the TCP/IP settings under Mac OS 9.



Connect via: Ethernet built-in

Setup

Configure: Manually

IP Address: 64.41.131.172

Subnet mask: 255.255.255.0

Router address: 64.41.131.162

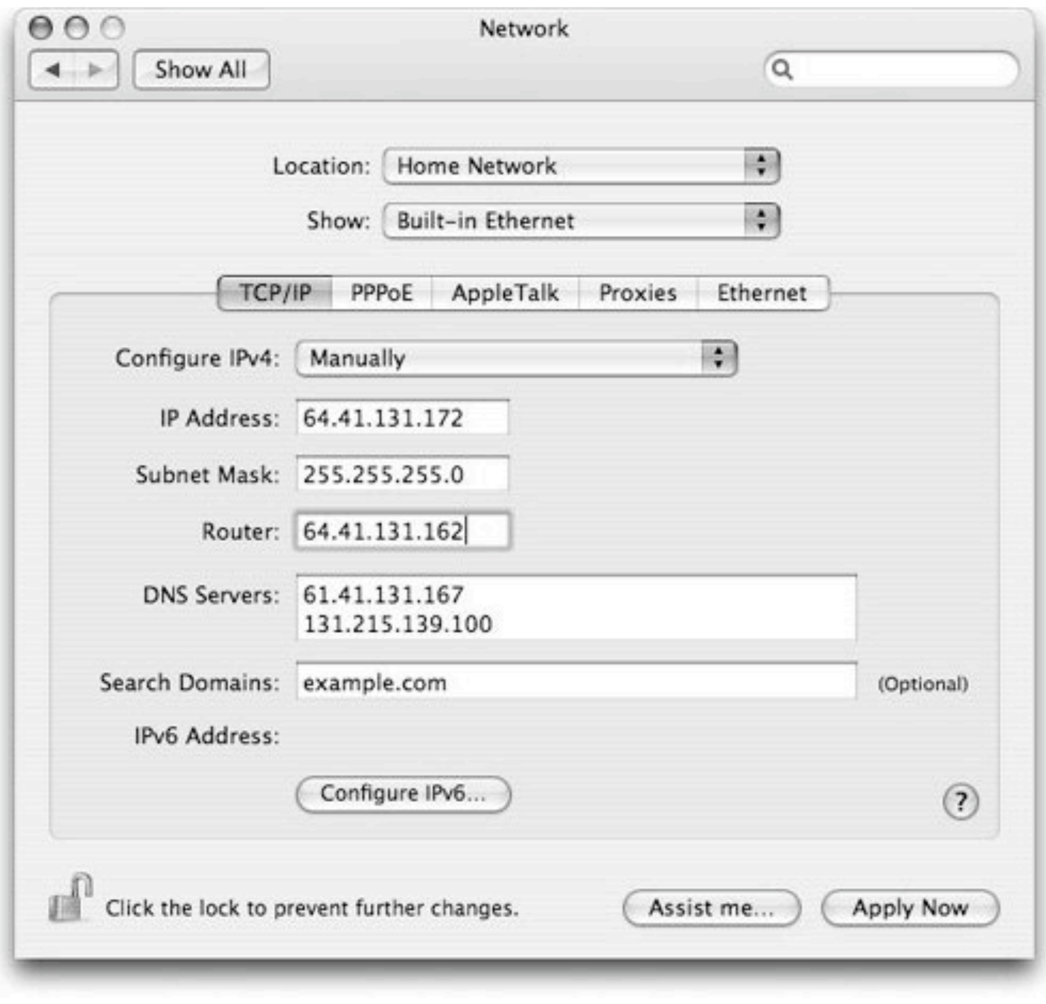
Name server addr.: 64.41.131.167
64.41.131.163

Search domains: example.com

In Mac OS X, open the System Preferences and then select the Network preference pane, shown in Figure 28.7. Choose your LAN connection from the main screen; then select Manually from the Configure IPv4 menu and fill in the gateway IP address in the Router field, along with the other appropriate TCP/IP information for your connection. Click Apply Now to commit the changes. The new network settings are immediately put into effect.

Figure 28.7. Configuring the TCP/IP settings under Mac OS X.

[View full size image]



In both these situations, you have the option to configure the built-in Ethernet card, the AirPort wireless card, or other network devices. Make sure you repeat this process for all relevant devices.

Configuring FreeBSD Clients

To configure FreeBSD for a default gateway, add the following line to the `/etc/rc.conf` file:

```
defaultrouter="64.41.131.162"
```

Of course, you will need to replace the IP address in this example with the IP address of the gateway interface on the FreeBSD system that is serving as a gateway.

The change will not take effect until you have rebooted the system. If you don't want to reboot, you can add the default route manually with the following commands issued from a root shell:

```
# route delete default
# route add default 64.41.131.162
```

Configuring Linux Clients

Because of the many styles of system configuration in Linux, how you configure your Linux system to use the FreeBSD gateway will depend on the distribution you are using. This example shows how to configure a Red Hat Linux system, and other systems' configuration details (such as which file you need to edit) might be slightly different. The documentation accompanying your distribution includes complete configuration instructions for that distribution.

Red Hat Linux network configuration is controlled by the file `/etc/sysconfig/network`. To use the new FreeBSD gateway, the following line should be present in the file:

```
GATEWAY=64.41.131.162
```

Replace the IP address in this example with the IP address of the gateway interface on your FreeBSD gateway machine. Make sure you check to see whether the line already exists before adding this line because having two `GATEWAY` lines could cause a conflict.

You will need to restart the Red Hat Linux system before the changes take effect. If you don't want to restart the system, you can add the default route manually with the following commands issued from a root shell:

```
# route del default
# route add default gw 64.41.131.162
```

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Configuring a Wireless Internet Access Point

It's become increasingly popular in recent years to create a network in your home or office completely free of wires, using any of the widely available 802.11 (Wi-Fi) wireless access systems on the market. These devices act as NAT-capable gateway routers in their own right, and they have the added bonus of broadcasting wireless signals to any authenticated computers in the vicinity. Fortunately, your FreeBSD router can perform these same functions just as well, if equipped with a supported wireless card.

Currently, FreeBSD's capabilities to act as a wireless access point require that you have a wireless card supported by the `wi` driver; these cards include any that use the Lucent Hermes, Intersil PRISM series, and Symbol Spectrum24 chipsets. Make sure (using the `ifconfig -a` command) that FreeBSD recognizes your wireless card and that it's supported by the `wi` driver (you should see a network device entry for `wi0` in the `ifconfig` output).

First, load the `bridge` module into your kernel:

```
# kldload bridge
```

Tip

You should add this module to your kernel's startup process so that the bridging module is always available; add the following line to the `/boot/loader.conf` file:

```
bridge_load="YES"
```

Alternatively, add the following line to your kernel configuration and rebuild the kernel:

```
options BRIDGE
```

Next, issue the following commands (and add them to your `/etc/sysctl.conf` file):

```
# sysctl net.link.ether.bridge.enable=1
# sysctl net.link.ether.bridge.config="wi0 ed0"
# sysctl net.inet.ip.forwarding=1
```

Be sure to replace `ed0` with the device of your WAN-side interface (`ppp0` if you're using a modem connection).

Finally, issue the following command to configure the wireless interface as an access point with a customized network name:

[View full width]

```
# ifconfig wi0 ssid MyNetwork channel 11 media DS/11Mbps mediaopt hostap up stationname
   "StationName"
```

Replace *`MyNetwork`* with the name of the wireless network you want to set up, and *`StationName`* with the name of the wireless base station. At this point you should be able to connect to the base station using any wireless client PC.

Additionally, you'll probably want to enable WEP encryption; WEP is a rudimentary privacy protocol that provides essentially no protection against determined hackers, but you'll want to enable it anyway. This is done using the following command:

[View full width]
```
# ifconfig wi0 inet up ssid MyNetwork wepmode on wepkey 0xmypassword media DS/11Mbps
   mediaopt hostap
```

Replace *mypassword* with a text pass phrase of your choice; this key will be required by any client wishing to connect to the *MyNetwork* network.

Be sure to add these configuration options to your `/etc/rc.conf` file, so that they're applied each time you boot your system. For example, the following `/etc/rc.conf` line will combine the preceding two configuration commands and apply it at each boot time:

[View full width]
```
ifconfig_wi0="inet up ssid MyNetwork channel 11 wepmode on wepkey 0xmypassword media DS/
   11Mbps mediaopt hostap stationname "StationName""
```

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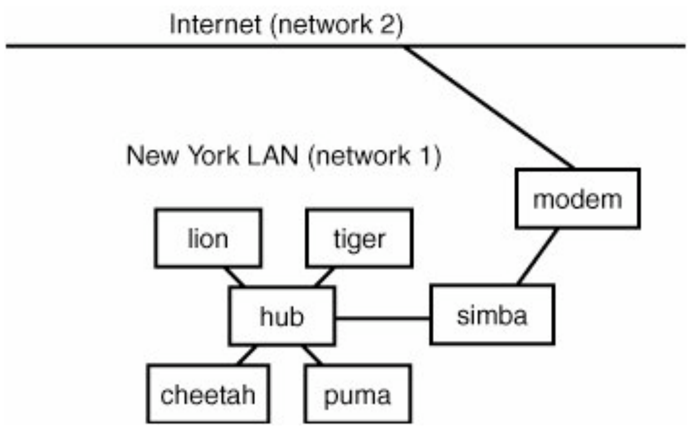
Routing Between Three or More Networks

In all the situations up to this point, the router configuration has only needed one route. For example, our `simba` gateway only has one connection to the Internet, and it only serves one network. Figure 28.8 shows how this works.

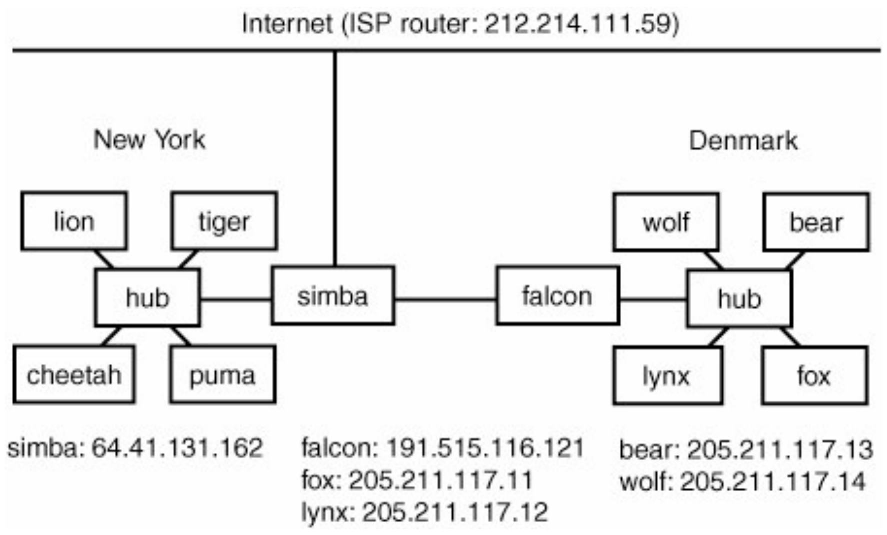
Figure 28.8. The gateway `simba` here only needs to route packets between two networks, which are the local LAN and the Internet.



In this simple example, the hosts `lion`, `cheetah`, `lynx`, and `puma` use `simba` as their default gateway to communicate with systems on the Internet. Likewise, `simba` also has a default router, and it is set to the router at the ISP. For a dial-up PPP connection, this is transparent to you because the default route will be added automatically when the PPP connection is established, and it will be deleted automatically when the PPP connection terminates. You do not need to worry about this, but you should be aware that your gateway has a default router it uses, just as your clients that use the gateway use it as a default router.

However, sometimes you might have a more complex configuration, such as that shown in Figure 28.9. In this situation, `simba` acts as the default router for its own network as well as serving as the default router for `falcon`, which is itself a default router for another network.

Figure 28.9. A more complex gateway setup. In this case, `simba` acts as a default router for its own network as well as serving as the default router for `falcon`, which is itself a default router for another network.



In this example, in addition to serving the clients on its own network, `simba` is actually serving as an Internet service provider to the network served by the router `falcon`. This means that `simba` now needs to route between three networks. For this to work, you need to add another route to `simba` so that it knows what packets should be routed to the network served by `falcon` as well as how to get them there.

The network served by `falcon` owns a Class C address block. Notice that all the addresses on the network begin with the base address of `205.211.117.` *`xxx`*. Also, notice that `falcon` has an IP address of `169.151.116.121`. To get `simba` to route packets to the network served by `falcon`, you can add the following lines to `/etc/rc.conf`:

```
defaultroute="212.214.111.59"
static_routes="falcon"
falcon="-net 205.211.117.0 169.151.116.121"
```

In this case, the IP address `212.214.111.59` is the default router for `simba`. In other words, any packets that `simba` receives that are for hosts it doesn't know about will be sent to this router. `212.214.111.59` is the router at the Internet backbone provider that serves `simba`.

You have also added what is called a *static route*. This is an entry in the routing table that is staticit does not change. In this case, you have told `simba` that any packets it receives that have a destination with a base address of `205.211.117.0` should be routed to the address `169.151.116.121`. This is the IP address of `falcon`, which itself serves as a router for another network. As you can see, all the hosts on the network served by `falcon` begin with an IP address of `205.211.117.` *`xxx`*. Therefore, any packets that `simba` receives that are intended for any of these hosts will be routed to `falcon` rather than to the default route of `212.214.111.59`. In addition, any packets received by `simba` that are intended for clients on its own network will be routed directly to those clients rather than sent to the default route.

In order for the static routes to take effect, you will need to reboot the system. It is recommended that you reboot the system, but if you do not want to, you can add the static routes manually so they will take effect immediately. In the previous example, this can be done with the following command from a root shell:

```
# route add -net 205.211.117.0 169.151.116.121
```

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Dynamic Routing

All our examples so far have used static routes, which are routes that never change. This is because in our examples up to this point, the routers have each only had one connection to the Internet. For example, in the previous section, `simba` accessed the Internet through the router at its ISP, and `falcon` accessed the Internet through `simba`. In both cases, these were the only access links that the router had to the Internet.

Sometimes, however, you may have multiple Internet connections or multiple routes to the same network. In this case, static routing does not work well. This is where dynamic routing comes in.

Dynamic routing uses a routing daemon, along with a routing protocol to discover new routes, and dynamically adds them to the routing table. In addition, dynamic routing automatically deletes routing entries from the routing table when they are no longer valid.

Several router daemons are available for FreeBSD. The one that is included with the FreeBSD base system is called `routed`. It is a fairly old program, and it uses a fairly old routing protocol known as RIP (Routing Information Protocol). RIP has some security problems, so there are better choices available for routing than `routed`. Other routing daemons available in the FreeBSD ports collection include `gated` and `zebra`, both in the "net" directory of the ports tree. For more information on installing software using the FreeBSD ports collection, see Chapter 16, "Installing Additional Software."

A discussion of how to configure the routing daemons is beyond the scope of this book. See the `man` pages and documentation for the routing daemon that you decide to use for more information.

The good news is that you probably won't need to run a routing daemon anyway. As mentioned before, the only time you will need a routing daemon is if you have multiple routes to get to the same network (for example, multiple Internet connections). If you don't have multiple routes to the same network, then using static routing entries, as discussed previously, will work fine.

Enterprise Routing and DMZ

A variation of the previous concept of routing between multiple networks is the *DMZ* (Demilitarized Zone) concept, which is fairly common in enterprise environments.

The problem here is that you may need some systems behind the gateway to have real IP addresses (such as web servers), but you want the rest of the systems to use NAT. This is usually done by having a gateway that has three network interfaces in it. One interface is the outside link to the Internet, the second is for the systems that should use NAT, and the third is for the systems that should not use NAT. The interface that serves the systems with the real IP addresses is known as the *demilitarized zone* (DMZ). More information on DMZ setups can be found in the section "Using a Firewall" in Chapter 30.

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Chapter 29. Configuring a Database Server

IN THIS CHAPTER

Sooner or later, all large and popular websites are faced with the decision of whether to provide visitors with customized, dynamic content served from a database. For commercial sites, it's almost a requirement to supplement the static web content with a database back end, populated with customer profiles, product catalogs, user preferences, and all sorts of other information that allows the administrator to present a customized interface to the user. Even noncommercial sites can benefit from using databases, though. This chapter covers the fundamentals of database back-end usage as it applies to any site administrator, whether commercial or not. Using the freely available MySQL and PostgreSQL packages, you can develop a data store to attach to your web server. This chapter will teach you what you need to know in order to efficiently administer the server, to construct the database your website needs, to optimize its performance, and to protect its security.

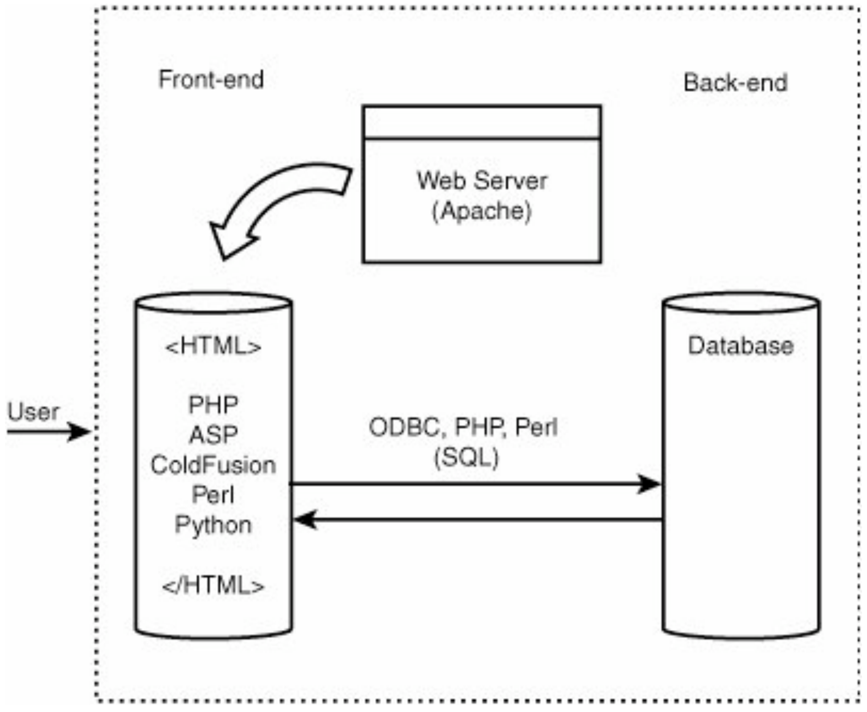
Databases aren't just for the Web, either. Long before the Web existed, databases were an integral part of commerce and engineering. But a database cannot be of any use without a good interface to the data inside it, and the Web is only the most recent such interface mechanism to achieve widespread use. Because databases can be used for a great many things other than providing dynamic web content, this chapter explains how you can use databases both in a general, standalone context and in the context of web connectivity.

Introduction to Database Design and Administration

Connecting a website to a database can be a daunting prospect. On Windows, the process is made easier by such standardized interfaces as Open Database Connectivity (ODBC), but that's not really available on FreeBSD. Nor does FreeBSD have access to native versions of the most popular high-end database packages, such as Oracle, MS-SQL, and IBM DB2, or to what have become the standard Windows-based dynamic-content pagelayout languages, ASP and ColdFusion. Creating dynamic web content in FreeBSD is accomplished largely through the use of open-source alternatives to those packages. MySQL, PostgreSQL, and other similar databases fulfill the role of the back end itself, and PHP, Perl, and Python provide tools that furnish us with the connectivity into those backend data stores.

Figure 29.1 illustrates the schematic layout of a website with dynamic content that interacts with a database back end. The user (the visitor to the site) opens the front-end content page in a browser. This content is rarely written in pure HTML. Instead, most web page content is written in a language such as PHP, ASP, ColdFusion, Perl, or a similar framework. These languages include both the HTML that lays out the page and the calls into the database that return the information the page's code uses to fill out the interesting parts of the page. For instance, a database might contain all of a bank customer's transactions in the past month. When the user accesses the page with the proper parameters to extract those transactions, the content page prints out standard HTML headers, images, and layout elements common to the site. Then, the page accesses the database and performs a *query*. The database returns the results of that query to the code in the content page, which then formats the customer's data appropriately (wrapping it in HTML, in most cases) and prints it into the page. The page then finishes the job by printing out more common HTML, such as footers and disclaimers.

Figure 29.1. A diagram of a website that uses dynamic database-driven content. The web page content and server (the front end) send queries to the database (the back end) using Structured Query Language (SQL) via a conduit layer such as ODBC, PHP, or Perl; the database returns the results of those queries through the same conduit to the front end, where it is formatted for display on the page.



The two large conceptual divisions of the website database system are in the back end (the database itself) and in the front end (the content engine and HTML output). We will turn our attention first to the back end so that you can become familiar with how database queries work because that is the foundation not only of the web applicability of databases but also of all other possible uses of databases.

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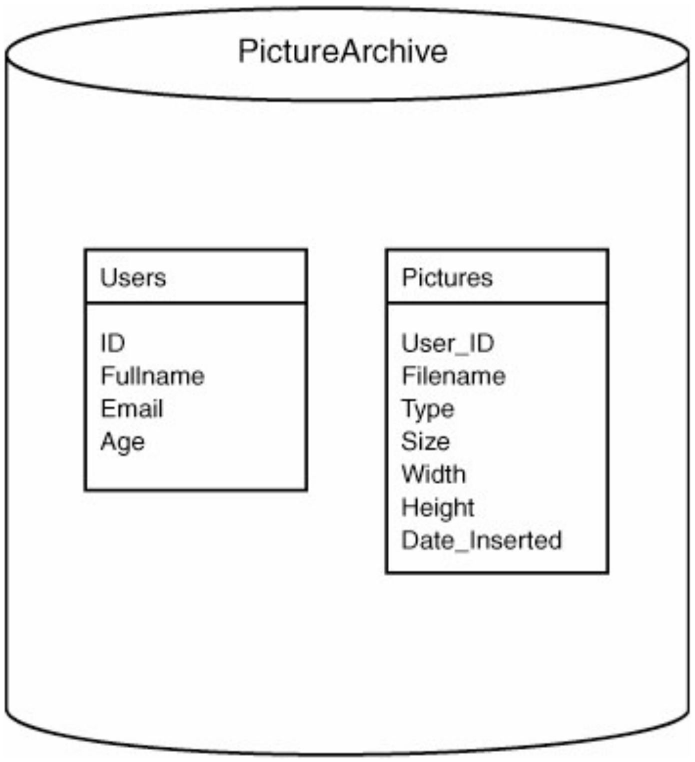
SQL: Structured Query Language

Early work on the theory of *relational databases* (that is, databases in which data is stored in multiple tables of varying sizes that can contain not just data but relations between data elements) by E.F. Codd resulted in IBM, in the late 1970s, creating a language called SEQUEL (Structured English Query Language), later shortened to SQL. This language attempted to standardize into an English-like syntax the methods by which data could be extracted from or inserted into a database. Using terms such as `SELECT` *`data`* `FROM` *`table`* and `WHERE` *`field`* `IS NOT NULL`, the syntax of SQL is easy to learnalthough the concepts behind what that syntax describes can be rather more challenging.

A database is organized as shown in the simple example in Figure 29.2. This diagram shows a database named PictureArchive that contains a number of tables (two are shown). These tables each represent a grouping of similar *rows* of dataeach row, or *record*, has a number of fields (*columns*) that contain data comprising a row. For instance, in the Users table shown, a single row would contain a user's ID, full name, email address, and age. Each of these columns is specified as a certain data typeinteger, character/string, floating-point number, Boolean, and so on. A row can have blank entries in its fields, which are usually represented by the `NULL` value.

Figure 29.2. Diagram of a simple database.



The Pictures table works the same way: It's a grouping of a different set of data, with different fields, that makes up a different part of the PictureArchive database. This table contains fields such as the filename of a picture that has been added into the system, its type, size, and so on. But what makes relational databases so useful is the ability to associate tables together via *relations* between their elements. The Users table contains related information about the system's users, and the Pictures table contains related information about pictures; but the Pictures table contains a field with the ID of the user who owns each picture. This simple linkage between the tables will allow us to access the data in all kinds of creative ways, as you will see.

Note

The conceptual structure of a database, its tables, and their columns is typically referred to as a *schema*.

Basic SQL Syntax

Beginning with the PictureArchive sample database, let's assume that its tables already contain some datathat the tables are populated and in general use.

Selecting Rows

The most common thing to do with a database is to extract data from it. You do this with the SQL command `SELECT`.

Tip

SQL query commands are not case sensitive; `SELECT`, `Select`, and `select` will all work the same. Case sensitivity does apply in some cases to the data in the fields, as you learn later in this chapter. Also, the names of databases, tables, and columns are case sensitive. However, for the purposes of these examples, we will use all caps to denote SQL keywords and mixed case (as in PictureArchive) to denote named objects such as tables and columns.

A `SELECT` command, like most SQL commands, is structured to flow like common English. First, after the verb `SELECT`, comes a nounthe name of the field (or fields) that you want to extract. Next comes `FROM`, followed by the name of the table from which you want to extract the data. Finally, at the end of the query comes a semicolon (`;`). Here's an example:

```
SELECT * FROM Users;
```

Tip

Don't forget the semicolon at the end of the SQL query! This is probably the most common mistake among SQL novices. If you leave off the semicolon before pressing Enter, the interface will allow you to keep entering text as part of the same SQL query. Queries can span multiple lines.

This command, entered either by hand into a MySQL or PostgreSQL database command line or passed invisibly to the program by a PHP or Perl interface, tells the database to return all the data in the Users tablewithout any sorting or limitations. This data will either be returned programmatically to the interface that called it or printed in tabular form to the command line.

If the response contains a lot of data but you're only interested in users who match certain criteria, you can further narrow your query in a number of ways. The first is to specify only certain fields to extract, instead of entering the asterisk (`*`), which is a shorthand for "All fields." Here's an example:

```
SELECT Fullname,Age FROM Users;
```

Fields requested in this way can be specified in any order; they can even be repeated within the same query. The response in this example will return only the full name of each user and the user's age.

Next, you can limit your search still further by using the WHERE keyword. This allows you to apply any number of criteria to your queries; WHERE can specify that a field must be equal to, less than, greater than, not equal to, or have any of a number of other relationships to a certain value. This value can be supplied explicitly in the query, or it can be the name of another field, as you'll learn in a moment. For now, limit the query to those users over the age of 18 by using the "greater than or equal to" operator. Note that when field contents are specified, they should be surrounded with quotes:

```
SELECT Fullname,Age FROM Users WHERE Age>="18";
```

Similarly, you can use the LIKE keyword and the percent (%) wildcard to specify that you want to list all users over age 18 and who have email addresses at AOL:

```
SELECT Fullname,Age FROM Users WHERE Age>="18" AND Email LIKE "%aol.com";
```

You've now addressed a fairly narrow range of users from the Users table. But maybe your database is so large that you're still getting hundreds of result rows; maybe you only want the top 20 such users, sorted in descending order of age. You can do this by adding LIMIT and ORDER BY clauses:

[View full width]

```
SELECT Fullname,Age FROM Users WHERE Age>="18" AND Email LIKE "%aol.com" ORDER BY Age DESC
    LIMIT 20;
```

If your query cannot fit on a single line, don't worrySQL queries can contain multiple lines, and they terminate only with a semicolon. This sample query could also be entered as follows:

```
SELECT Fullname,Age FROM Users
WHERE Age>="18"
AND Email LIKE "%aol.com"
ORDER BY Age DESC
LIMIT 20;
```

The additional clarity that this gives you will be invaluable when you find yourself writing really long, complex queries after you've become an SQL expert.

Note

You must enter all these clauses in a specific order. LIMIT cannot appear before ORDER BY, for instance. The prototypes for all complete SQL commands are available in the online documentation for the various database applications.

Inserting Rows

That's about it for a basic extraction of data from a single table. You use a similar process to insert data into a table, though it's a little bit more mathematical in its look and feel. You begin with the INSERT INTO statement, followed by the table in question; then, in parentheses, you enter the names of the columns into which you're adding data (you can insert into only a few fields if you want to, leaving the rest in that row as NULL). You then enter the VALUES statement, followed (in parentheses) by the values you want to insert, listed in the same order as the fields were specified:

```
INSERT INTO Users (Fullname,Email,Age) VALUES ("Sam Jones","sjones@somewhere.com","25");
```

Updating Rows

Updating data in a row (or group of rows) uses the syntax that borrows from both the `SELECT` and `INSERT` commands, as in these examples:

```
UPDATE Users SET Age="26" WHERE Fullname="Sam Jones";
UPDATE Users SET Fullname="Somebody Under 18" WHERE Age<"18";
UPDATE Users SET Age=Age+1;
```

Caution

The third example shown here has no restrictions (`WHERE` clauses); therefore, it's a global update that applies to all records. Be very careful when using commands like thisif the `WHERE` clause isn't specified properly, a single command can make blanket changes to the entire database, rendering it worthless.

Deleting Rows

Finally, to delete a row from a table, you use a syntax similar to what you've seen already:

```
DELETE FROM Users WHERE Age<"13";
DELETE FROM Users;
```

The second line in this example will delete all entries from the Users table. Use this command with the same caution with which you would use `rm -rf *`! If you ever find yourself entering a `DELETE` or `UPDATE` query that has no `WHERE` statements in it, double-and triple-check that you're doing what you want to be doing before you press Enter. You'll thank yourself for your caution.

Note

Many more complex querying techniques, such as joins and subselects, are available in SQLbut they're beyond the scope of this book. To fully realize the power of an SQL database, refer to an SQL reference book or the fully annotated online documentation for a database server such as MySQL (http://www.mysql.com).

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Using the MySQL and PostgreSQL Open-Source Databases

Now that you have a grounding in how SQL is used in all databases that support it (which is to say, almost all of them), you can turn your attention to the common open-source databases typically used under FreeBSD. These are MySQL and PostgreSQL.

In recent years, the field of open-source database software packages has narrowed to include fewer, but more useful, solutions. It used to be the case that the administrator had to choose between dozens of different solutions, all of which had some basic functionality but seemed to be missing something crucialand each one was deficient in something different. But recently the development efforts on MySQL and PostgreSQL have turned them both into packages that are every bit as full-featured as the commercial solutions they propose to replace. Even the limitations that separate these two packages from each other have grown fewer and fewer.

Today, whether you choose MySQL or PostgreSQL is largely a matter of personal taste and philosophy. MySQL is by far the more widely used and better supported open-source database system, and it's also considerably faster. That's why the examples shown in this book concentrate on MySQL syntax and usage. PostgreSQL, however, supports more advanced features than does MySQL, and it may be a better choice for high-end servers for which transactional data integrity and feature set are of critical importance. But either one will provide excellent support for all of a typical administrator's needs.

How Do MySQL and PostgreSQL Differ?

MySQL is developed by employees of MySQL AB, a commercial software company based in Sweden, whereas PostgreSQL is a more traditional open-source project. PostgreSQL has contributors from all over the globe, with varying areas of expertise. The two packages differ in many architectural details because of this. The most fundamental differences between the two databases are those of developmental philosophy; most other discrepancies can be traced to this root cause.

The primary goal of MySQL is to focus on performance and reliability, instead of implementing all the newest features, which MySQL AB considers to be the source of an unacceptable risk of instability. PostgreSQL's priorities tend to be directed more toward a complete feature set. PostgreSQL development seeks to implement as much flexibility and functionality as possible, with the goal of creating a complete replacement for any top-end commercial product. MySQL tends to be developed more slowly than PostgreSQL for this reason. MySQL's roadmap for future development includes some features currently supported by PostgreSQL, but MySQL developers consider adoption of these features to be secondary in priority to ensuring code stability and performance.

An example of this difference in philosophy is that PostgreSQL requires a periodic `VACUUM` operation in order to clean up the space that has been relinquished through `DELETE` and `UPDATE` commands. Because the `VACUUM` command tends to use non-trivial amounts of resource overhead, a PostgreSQL database may not be the best choice for a system that must have 24/7 availability. MySQL lacks some features found in PostgreSQL that may be of use to administrators with particular goals; but because MySQL's core feature set is more robustly designed, it does not have such a need for cleanup procedures and therefore is potentially more suited to mission-critical 24/7 service.

The features PostgreSQL supports but that MySQL does not support include subselects, foreign keys, views, stored procedures, and triggers, among others. Some of these features are really very cool and provide an excellent level of functionality to the administrator. If you are interested in creating a site with which you can experiment and learn what SQL can do, PostgreSQL may be a good choice for you. If, however, you are interested in running a high-performance server where availability and speed are of critical importance, MySQL may be a better choice.

Note

Both the PostgreSQL and MySQL database projects are striving toward compliance with the ANSI SQL standard, but neither supports it fully.

Finally, an operational difference between the two packages is that MySQL provides a complete command-line environment for interacting with the system directly through a terminal. The MySQL environment includes a number of commands that are not part of SQL but have special meaning within that environment, such as `SHOW PROCESSLIST` and `SET PASSWORD`. The PostgreSQL command-line interface is more austere; shell commands are given with terse backslash-prepended codes reminiscent of the command mode of the `vi` editor, and all other commands issued at the command line are interpreted as SQL queries.

Note

PostgreSQL is free under all circumstances, although commercial support is available for a fee. MySQL, however, has a licensing policy whereby if you run it in a commercial context in which you prefer not to be restricted by the terms of the GPL under which MySQL is licensed, MySQL AB requests that you pay a license fee. See the MySQL website, http://www.mysql.com, for details.

Installing MySQL

MySQL can be easily installed from the packages or ports, as discussed in Chapter 16, "Installing Additional Software." The port directory you will want, if you choose to build MySQL from the ports, is `/usr/ports/databases/mysql`*`xx`*`-server`. Go into the directory and type **`make`** and then **`make install`**.

Note

For compatibility, several major versions of MySQL are available in parallel in the ports and packages. As of this writing you can install MySQL 3.2.3, 4.0, 4.1, 5.0, or 5.1, depending on your needs and your bravery. Earlier versions are more stable and well-established, but later versions support more features. Consult the MySQL website to see what the earliest version is that has all the features you need; as with FreeBSD itself, it's a good idea to install a recent version, but not the very *most* recent one.

Caution

Before installing MySQL, make sure your `/var` partition is sufficiently large to support the size database you anticipate running. The `/var` partition must be large enough for all your data as well as for the runtime internal table structures the database may create. A partition of at least 1GB is recommended for a medium-sized database with moderate complexity, but your needs might dictate a smaller or much larger data store. Refer to Chapter 20, "Adding Hard Disk Storage," for details on partitioning your disks.

After the package has been compiled and installed and you have started the MySQL server (**`/usr/local/etc/rc.d/mysql-server start`**), you will need to set up the initial security on the root user. By default, root has full privileges in MySQL's access control system as well as a blank password. Needless to say, it's a bad idea to leave this unchanged! The first thing to do after installation completes is to issue the following commands:

```
# mysqladmin -u root password new_password
```

Replace `new_password` with the new root password for super-user access to your MySQL database.

Caution

When upgrading from an earlier version of MySQL, it is not usually necessary to back up and restore your database filesbut, as the installation script tells you, it's still a wise precaution. To begin this process, dump your databases (as explained later in the "Performing Database System Backups" section of this chapter) and shut down your MySQL server (`/usr/local/etc/rc.d/mysql-server.sh stop`). Next, perform a `make install` operation and then restart the server. If there are any problems, you can restore your databases from the dump files.

Installing PostgreSQL

PostgreSQL can be easily installed from the packages or ports, as discussed in Chapter 16. If you choose to build PostgreSQL from the ports, use the port directory `/usr/ports/databases/postgresqlxx-server`. Go into the directory and type **`make`**, make the choices you want in the full-screen option menus (or choose the defaults), and then perform a **`make install`** operation.

Note

For compatibility, several major versions of PostgreSQL are available in parallel in the ports and packages. As of this writing you can install PostgreSQL 7.0, 7.2, 7.3, 7.4, 8.0, or 8.1, depending on your needs and your bravery. Earlier versions are more stable and well-established, but later versions support more features. Consult the PostgreSQL website to see what the earliest version is that has all the features you need, and that is not exposed to security vulnerabilities; as with FreeBSD itself, it's a good idea to install a recent version, but not the very *most* recent one.

Caution

Unlike with MySQL, an upgrade from an earlier version of PostgreSQL requires that you dump your databases and restore them after the upgrade. Refer to "Performing Database System Backups," later in this chapter, for details on how this is done.

After the initial installation, a new user (`pgsql`) will have been created, as will a new startup script (`/usr/local/etc/rc.d/010.pgsql.sh`). Don't run this script to start the server yet, though; you first need to set up a few things manually. First, run the `initdb` command; this sets up the *database cluster*, which is the base directory for all the database files that will be created. The port installation procedure suggests using the default location of `/usr/local/pgsql/data` for this, and so here is the procedure to follow:

```
# su -l pgsql
$ mkdir data
$ initdb
The files belonging to this database system will be owned by user "pgsql".
This user must also own the server process.
creating directory /usr/local/pgsql/data... ok
creating directory /usr/local/pgsql/data/base... ok
creating directory /usr/local/pgsql/data/global... ok
creating directory /usr/local/pgsql/data/pg_xlog... ok
creating directory /usr/local/pgsql/data/pg_clog... ok
creating template1 database in /usr/local/pgsql/data/base/1... ok
creating configuration files... ok
initializing pg_shadow... ok
enabling unlimited row size for system tables... ok
creating system views... ok
loading pg_description... ok
vacuuming database template1... ok
copying template1 to template0... ok
Success. You can now start the database server using:
    /usr/local/bin/postmaster -D /usr/local/pgsql/data
or
    /usr/local/bin/pg_ctl -D /usr/local/pgsql/data -l logfile start
```

Tip

You may want to change PostgreSQL's database cluster directory to something like `/var/db/pgsql`, to correspond to MySQL's use of `/var/db/mysql`; after all, database content is variable and should properly be kept in `/var`. Another compelling reason you might choose to do this is if you have separate disks for the `/usr` and `/var` partitions. Having your database files and your nonvariable web content on separate drive spindles can provide a very substantial performance benefit, especially if they're also on different IDE channels.

The PostgreSQL startup script calls for `su -l`, which changes to the `pgsql` user and executes the process that starts up the PostgreSQL server. The `-l` option reads in the `.cshrc` or `.profile` shell environment file for the `pgsql` user, and each of these files sets the `PGDATA` environment variable to `/usr/local/pgsql/data`. In order to change the database cluster location to `/var/db/pgsql`, you will not only have to create that directory and run **`initdb -D /var/db/pgsql`** instead of the `initdb` command in the example shown here, you will also have to edit `~pgsql/.cshrc` and `~pgsql/.profile` and change the `PGDATA` lines (which currently specify `$HOME/data` or `${HOME}/data`) to `/var/db/pgsql`.

You can now try to start the server by ignoring the lines at the end of the `initdb` process and instead running **`/usr/local/etc/rc.d/010.pgsql.sh start`**. If it starts successfully, congratulate yourself. However, if you get a message such as `IpcSemaphoreCreate: semget(key=5432003, num=17, 03600) failed: No space left on device`, along with an explanation that you need to raise your kernel's limits on semaphore sets, you will unfortunately need to recompile your kernel (see Chapter 18, "Kernel Configuration"). Here are the kernel options you will need to add or update:

```
options         SYSVSHM
options         SHMMAXPGS=4096
options         SHMSEG=256
options         SYSVSEM
options         SEMMNI=256
options         SEMMNS=512
options         SEMMNU=256
options         SEMMAP=256
```

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Constructing a Database System

Now that your database system is installed, it's time to get started creating a working database. This is a process that involves careful planning and design; you can't just indiscriminately create tables and columns without an eye toward maximum efficiency. Likewise, you can't simply assume that you'll be able to go back and redesign the system later as you learn how it should be done. Although database schemas can be changed, it's not terribly easy to do so, and in some cases it can't be done without loss of data or without destabilizing your own web application code built on top of the existing schema.

Before you do anything else, you'll need to create your database. This amounts to little more than creating an empty directory (via the MySQL or PostgreSQL interface) that will hold your tables and indexes. Log in to the database using the `mysql` command-line interface and issue the `CREATE DATABASE` command as follows:

```
# mysql -p
Enter password:
Welcome to the MySQL monitor.  Commands end with ; or \g.
Your MySQL connection id is 8 to server version: 3.23.51

Type 'help;' or '\h' for help. Type '\c' to clear the buffer

mysql> create database PictureArchive;
Query OK, 1 row affected (0.02 sec)
```

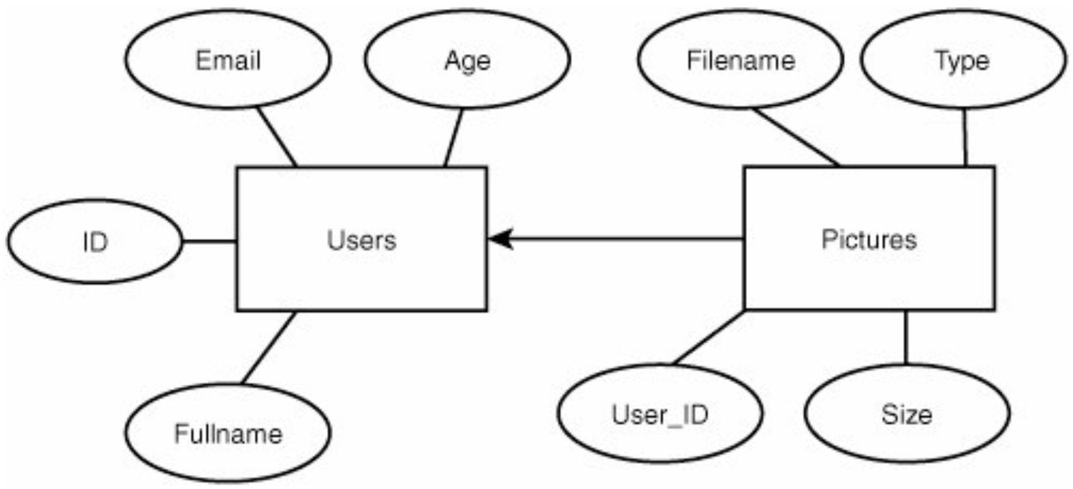
In PostgreSQL, you can use the command-line tool `createdb` (which you must run as the `pgsql` user) to open up the new database, as shown here:

```
# su -l pgsql
$ createdb PictureArchive
CREATE DATABASE
```

Designing Tables

Before you begin creating the tables for your database, it's best to come up with a conceptual diagram for how your data will be organized and how the relations will be mapped. This is typically done with an Entity-Relationship (E-R) diagram. A sample E-R diagram is shown in Figure 29.3.

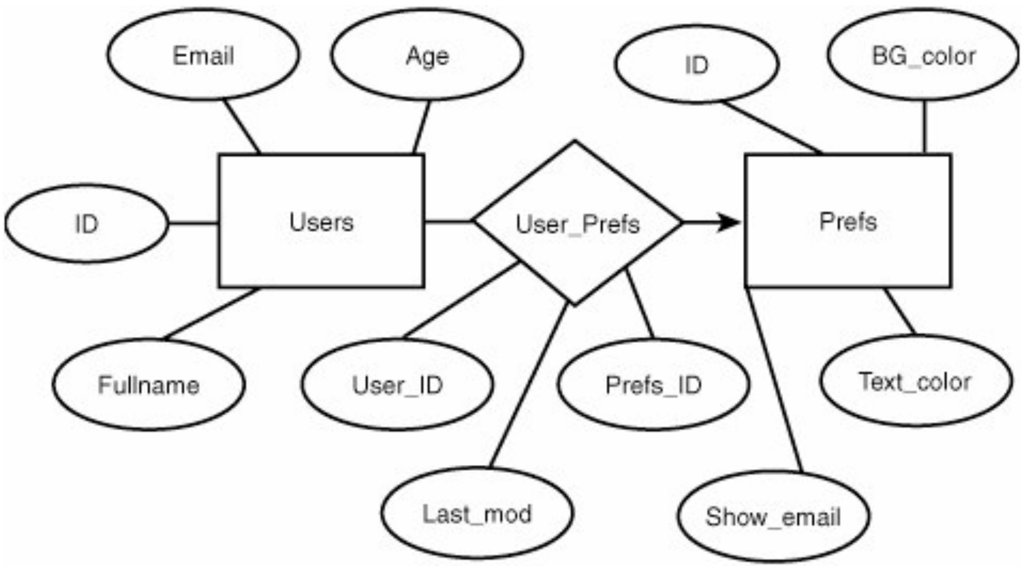
Figure 29.3. Sample E-R diagram showing a simple relationship between two tables, Users and Pictures.



In this diagram, two sample tables (Users and Pictures) are denoted by rectangles, and their component attributes (columns) are shown as ellipses. Relations between tables are shown with arrows, their shape and direction chosen by convention to indicate the type of relationship. Because the `User_ID` column in Pictures refers explicitly to the ID field in Users, you can use an arrow directly from the Pictures table to the Users table, showing that it's a "many-to-one" relationship. Arrows in E-R diagrams point toward the "one" side of such a relationship; in a "one-to-many" relationship, the arrow would point from Users to Pictures. In a "one-to-one" relationship, such as one where a second table has one entry per user, a double-headed arrow would be used.

In more complex data sets, you will want to use tables that represent relations between other tables, possibly with the addition of further data fields. Let's say you want to add a table to PictureArchive that describes a set of layout profiles for the website (so that each user can select the way the site appears for himself). This new table, called Prefs, would have fields such as `Background_color`, `Text_color`, a Boolean value describing whether or not to display the user's email address, and an integer ID. This table must be related to each user somehow, but the Prefs table doesn't have a field that refers to a specific user (like Pictures does), because each record in Prefs is just a set of attributes that should be assignable to any number of different users. You don't want to add another field to Users to specify the Prefs ID for each user. Therefore, the solution is to create a new table, called `User_Prefs`, that contains no actual data, but instead describes the "many-to-one" relationship between Users and Prefs. The E-R diagram for this is shown in Figure 29.4.

Figure 29.4. Sample E-R diagram showing data entities and relationship sets.



The `User_Prefs` table is represented with a diamond because it is just a relationship set, rather than a table of data in its own right. It contains just three columns: `User_ID`, `Prefs_ID`, and a third column called `Last_mod`, which stores the date (in UNIX time, an integer) when the user last updated his preferences. This way, each time a user updates his preferences (through some mechanism in the website that you create, as you'll learn later), the update process simply creates a new entry in the `User_Prefs` table rather than an existing entry having to be updated (and the changes could be rolled back by simply deleting the most recently added record). The insertion of the new entry could be accomplished with a query like the following, executed (for instance) by a CGI script:

```
INSERT INTO User_Prefs (User_ID,Prefs_ID,Last_mod)
VALUES ("5","3","1030745048");
```

Then, when the user views his page, your code can query the database for the most recent entry in `User_Prefs` for this user, find the `Prefs_ID`, and query for the attributes of that Prefs entry in order to generate the page according to those attributes. Here is an example of those queries:

```
SELECT Prefs_ID FROM User_Prefs
WHERE User_ID="5"
ORDER BY Last_mod DESC LIMIT 1;

... [ Extract the value of Prefs_ID into $prefs_id, as we will see later ]

SELECT Background_color,Text_color,Show_email FROM Prefs
WHERE ID="$prefs_id";
```

Alternatively, if you're even more adventurous, you can combine these into a single query with a join:

```
SELECT Background_color,Text_color,Show_email FROM User_Prefs,Prefs
WHERE User_Prefs.User_ID="5"
AND User_Prefs.Prefs_ID=Prefs.ID
ORDER BY Last_mod DESC LIMIT 1;
```

You can even do a three-way join to get all of a user's information out of the Users table as well as his latest entry in Prefs, as shown here:

```
SELECT Fullname,Email,Age,Background_color,Text_color,Show_email
FROM User_Prefs,Users,Prefs
WHERE Users.ID="5"
AND User_Prefs.User_ID=Users.ID
AND User_Prefs.Prefs_ID=Prefs.ID
ORDER BY Last_mod DESC LIMIT 1;
```

Planning out the structure of your tables in this way, before you even begin creating them, will save you a lot of heartache later on when you might otherwise have had to redesign everything from inside a running system.

Creating Tables

Now that you have a working design in mind for your database, you can begin creating tables. This is done with the `CREATE TABLE` query command. The syntax for this command in its most common form is fairly simple, but it does require the knowledge of what kinds of data types are available, whose attributes can be complicated. The most common of these are shown in Table 29.1, although more types are available as well and are fully documented at the MySQL and PostgreSQL websites.

Table 29.1. Commonly Used Column Data Types

Type Name	Description
`INT`, `INTEGER`	A "signed" integer from 2147483648 to 2147483647. This type can have the `UNSIGNED` attribute.
`FLOAT`	A floating-point number.
`CHAR(n)`	A string of n reserved bytes, up to `n=255`.
`VARCHAR(n)`	Like `CHAR`, except only as much space as is required to store the string is consumed. This type is preferable to `CHAR`. You can specify `BINARY` to make string comparisons case sensitive.
`BLOB`	A binary large object, holding text or binary data (such as images), with variable storage (like `VARCHAR`). The maximum size is 65KB. There are also `TINYBLOB` (256 bytes), `MEDIUMBLOB` (16.7MB), and `LONGBLOB` (4.3GB). The meaning of a `BLOB` is subtly different between MySQL and PostgreSQL.
`TEXT`	Same as `BLOB`, except that string comparisons are not case sensitive. There are also `TINYTEXT`, `MEDIUMTEXT`, and `LONGTEXT`.
`ENUM`	A set of permissible string values (for example, `"Red","Green","Yellow"`). These values are stored in much compressed form in the database, with small codes for each possible value, which is much more efficient than simply using a `TEXT` or `VARCHAR` field.
`BOOLEAN`	`"true"` or `"False"`. Not supported by MySQL.

Let's create the tables discussed already in the PictureArchive example. The Users table needs to have an integer ID field, text strings for the Fullname and Email fields, and another integer for Age. The following code creates that table:

```
CREATE TABLE Users (ID INT, Fullname VARCHAR(64), Email VARCHAR(32), Age INT);
```

The Prefs table will have an integer ID, six-character text fields for the two color fields (which you will populate with hex values), and an `ENUM` for `Show_email` (because MySQL doesn't have BOOLEAN). This code creates that table:

```
CREATE TABLE Prefs
(ID INT, Background_color VARCHAR(6),
Text_color VARCHAR(6), Show_email ENUM("Y","N"));
```

After entering the `CREATE TABLE` commands, issue a `DESCRIBE Users` command to view your handiwork, as shown here:

```
mysql> DESCRIBE Users;
+----------+-------------+------+-----+---------+-------+
| Field    | Type        | Null | Key | Default | Extra |
+----------+-------------+------+-----+---------+-------+
| ID       | int(11)     | YES  |     | NULL    |       |
| Fullname | varchar(64) | YES  |     | NULL    |       |
| Email    | varchar(32) | YES  |     | NULL    |       |
| Age      | int(11)     | YES  |     | NULL    |       |
+----------+-------------+------+-----+---------+-------+
4 rows in set (0.00 sec)
```

After some data has been entered into a table, the output from any queries you make at the command line will be returned in a tabular format, along with the time it took to process the query. If the columns are too wide for your screen, they will wrap rather than truncate; this can lead to a confused-looking display. Being selective in which fields you query for will help keep the output readable.

The following example shows a couple of multiline `INSERT` queries that populate the Users table, followed by the tabular output from a judiciously restricted `SELECT` query:

```
mysql> INSERT INTO Users (ID,Fullname,Email,Age)
    -> VALUES (1,"Joe Smith","jsmith@somewhere.com",22);
mysql> INSERT INTO Users (ID,Fullname,Email,Age)
    -> VALUES (2,"Alice Walker","awalker@elsewhere.com",31);
mysql> SELECT ID,Fullname,Email,Age FROM Users;
+----+--------------+-----------------------+------+
| ID | Fullname     | Email                 | Age  |
+----+--------------+-----------------------+------+
| 1  | Joe Smith    | jsmith@somewhere.com  | 22   |
| 2  | Alice Walker | awalker@elsewhere.com | 31   |
+----+--------------+-----------------------+------+
2 rows in set (0.00 sec)
```

Indexes and Keys

You now have working tables that can be used in active queries. Setting up a complete database is not quite that simple, however. One other thing to consider when designing your tables is how they will be *indexed*. Indexing determines the ordering of data within a database and is what allows databases to be as fast as they are. You saw a brief discussion of indexing using hash tables in a note in Chapter 13, "Users, Groups, and Permissions;" a fuller description is necessary here because indexes using hash tables are a big part of any database administrator's life.

Think about looking up a word in the dictionary; if you were looking for the word *sleep*, but you didn't know what "alphabetical order" was, you could literally spend weeks searching linearly through the dictionary until you found it. But because you know where the letter *S* is in the alphabet, you know how to zero in directly on the word and find it very rapidly.

Computers are the same way. If they have no indexing scheme by which to look up a piece of data, they can only search linearly through the data store for italthough they can do it faster than you can, it's still an unacceptably slow solution in most high-performance database contexts. Therefore, you have to create appropriate indexes (or *hash functions*, which for computers are similar to our concept of alphabetical order) and *keys* (such as the first letter of *sleep*) to help the database find its way through the data.

All tables of entity data (those that would be depicted with rectangles in an E-R diagram) should have a *primary key*. This is a column specifically designated to be the value upon which the data in the table should be automatically indexed. Values in this column should be specified as `NOT NULL` (in other words, they can't have a `NULL` valuea blank input value will become 0 for numeric data types and an empty string for text types). All values in the primary key column must also be unique.

This sounds like a role tailor-made for the integer ID columns in our tables. Indeed, the best practices in creating tables often call for the first column in every table to be a numeric ID that's the primary key and that also has the `AUTO_INCREMENT` attribute specified. This makes the column behave in a special way: If you insert rows into a table with an `AUTO_INCREMENT` column (which must also be a primary key), you can simply leave the value for that column blank or `NULL`, and the database will automatically fill in the next unused integer (the highest number in the column plus one) for each new row. This is perfect for the purposes of this chapter; you'll get a new unique ID number for each entry you put into your tables, and you don't even have to calculate it yourself.

Normally, you would specify these attributes at table-creation time:

```
CREATE TABLE Users (ID INT NOT NULL PRIMARY KEY AUTO_INCREMENT,
Fullname VARCHAR(64), Email VARCHAR(32), Age INT);
```

However, because in this case your tables are already created, you can use the `ALTER TABLE` command to change the ID column to your taste:

```
ALTER TABLE Users CHANGE ID ID INT NOT NULL PRIMARY KEY AUTO_INCREMENT;
```

Note

PostgreSQL does not have `AUTO_INCREMENT`; instead, it has a special data type called `SERIAL` (which is more efficient in that it's a built-in type rather than a function). The `SERIAL` data type is not subject to the same keying restrictions as `AUTO_INCREMENT`, but it acts much the same. Use `SERIAL` instead of `INT` to create an autoincrementing ID field.

Note that in PostgreSQL, if you specify `NULL` (instead of `0`) for the ID field in an `INSERT` operation, `NULL` will be entered instead of the next available integer, which you would get if you simply didn't provide a value for that field. `NULL` trumps the `SERIAL` property in PostgreSQL. MySQL's `AUTO_INCREMENT`, by contrast, is invoked on any `NULL` or `0` entry into such a field.

You can specify other keys on other columns in the table by using the `KEY` attribute after the variable name at table-creation time, or by using the `ADD INDEX` statement in the `ALTER TABLE` command. Issuing one of these commands creates an index on each key you specify. You can also create indexes based on multiple columns. This approach is useful when the unique combination of two columns taken together is what's usefully unique in a table. You can create indexes based on multiple columns like so:

```
ALTER TABLE Users ADD INDEX (Email,Fullname);
```

This code will result in a `MUL` tag (for "multiple," meaning that the table has multiple indexes) appearing in the Key column of the output of `describe Users`.

It's very important to try to anticipate which tables will be accessed a lot and which will have a large amount of data. Indexing these tables properly, with the keys being the columns on which those tables will most frequently be searched, can cause unbelievably dramatic improvements in performance. You'll see more about tuning your database for speed later in this chapter, in the "Optimizing Database Performance" section.

Maintaining Security

Accessing your databases as root isn't a particularly good idea. You will likely want to enable other usersregular usersto access their own databases on your system; this is especially true when you connect the database to the Web. Each database has access privileges that can be given to individual users at different hosts, and a properly set up database system has those privileges doled out completely but carefully.

Let's say your PictureArchive database needs to be accessible by the user `frank` on the local system. `frank` needs to have the ability to create tables, add data to them, select and delete data from them, update them, and drop them. (The ability to create and drop tables is necessary in order for him to handle temporary tables.) You can grant `frank` these privileges with the `GRANT` command in MySQL:

```
GRANT CREATE,SELECT,INSERT,UPDATE,DELETE,DROP ON PictureArchive.*
TO frank@localhost IDENTIFIED BY 'password' WITH GRANT OPTION;
```

If you want to be more lenient, you can use `GRANT ALL PRIVILEGES` instead of explicitly listing the privileges to grant. You can also grant privileges on specific tables within `PictureArchive` (by entering the name of those tables instead of the asterisk, which means "all tables"), or you can grant them on all tables on all databases by entering `*.*` in place of `PictureArchive.*`. Replace *`password`* with the password `frank` wishes to use; putting it in single quotes as an argument to `IDENTIFIED BY` will hash the password and put it into the system in an encrypted format. Finally, the optional `WITH GRANT OPTION` gives `frank` the ability to grant privileges to other users himself.

The analogous functionality in PostgreSQL is the `createuser` tool, which provides the same options in an interactive fashion at the regular system command line, as shown here:

```
# su -l pgsql
$ createuser -P
Enter name of user to add: frank
Enter password for user "frank":
Enter it again:
Shall the new user be allowed to create databases? (y/n) y
Shall the new user be allowed to create more new users? (y/n) y
CREATE USER
```

To provide user-level security on the databases, you may want to edit `/usr/local/pgsql/pg_hba.conf` and uncomment the following sample lines (and comment out the current active configuration lines):

```
# TYPE      DATABASE    IP_ADDRESS    MASK          AUTH_TYPE AUTH_ARGUMENT
local      sameuser                                 md5
local      all                                      md5 admins
```

If you want, you can create a file called `admins` in `/usr/local/pgsql/data`, with one database username per line; only those users will be allowed to work with the databases. You can do the same with each new database you createsimply add a different file for each database, with the name of the user who owns it, and the name of the file in place of `admins` in this example.

Alternatively, you can enforce a policy whereby local users can connect, without passwords, only to their own databases (those that have names that match the usernames). For instance, the user `frank` would have a database called "frank." This can be done with the following configuration line:

```
local       all                                 ident     sameuser
```

The security model for PostgreSQL is generally more advanced and robust than MySQL's, but it also requires more study in order to harness it properly. Refer to the online documentation at http://www.postgresql.org/docs for further information.

PREV NEXT

Writing Administration Scripts

You've reached the next level in our breakneck tour through the world of databases; now that the tables in the sample databases are set up, you can move on past the use of the interactive command line and learn how to automate some of the longer, more painful queries. The MySQL or PostgreSQL command line will always be useful for design and tinkering purposes. However, some tasks that must be done on a regular basis and require long, involved queries demand that you find a less frustrating way to accomplish them.

Perl and Python both provide toolkits with which you can write scripts to interface with the database. These toolkits enable you to issue queries, extract data, process it, and feed data back into the system, all within loops and conditionals and all the other programmatic benefits that those languages offer.

Database Connectivity with Perl

There are available modules for connecting your Perl scripts to either a MySQL or a PostgreSQL database. We'll look at MySQL first.

Perl and MySQL

As a courtesy, the necessary Perl modules for connectivity to MySQL are installed along with the MySQL port. These also are located in `/usr/ports/databases/p5-Mysql`; the documentation can be read with `perldoc Mysql`.

The crucial part of these modules is the setup part of any script that intends to connect to a MySQL database. This setup block includes the following lines, which should go right at the top of the script:

```
use Mysql;
$dbh = Mysql->connect(undef, "PicureArchive", "frank", "franks-password");
```

After you add these lines to the script, you have a database handle to work with: `$dbh`. A whole suite of operations can be performed on this handle; this chapter doesn't discuss all of themjust the most important operations. You will find the rest in the `perldoc Mysql` documentation.

Issue a query of any type to the database by using the `$dbh->query` method and setting it to a variable that acts as a handle to the results:

```
$queryh = $dbh->query("SELECT Filename,Type FROM Pictures WHERE User_ID='5'");
```

You can now use the `fetchrow` method to get the first row of the output. The way this works is that you can keep calling `fetchrow` over and over (in a loop) until there is no more output; this is how you can apply the same Perl code to each line of output from the database, in whatever order your SQL query specifies:

```
while (($filename,$filetype) = $queryh->fetchrow) {
  print "$filename, $filetype\n";
}
```

Here is a list of other operators that might be useful:

- `$dbh->quote` quote function>Surround a variable with this operator to quote its contents properly in a query; for example, to ensure that a full name such as "Bob O'Shea" will be properly inserted without the apostrophe causing confusion in the query string, use `$dbh->query("INSERT INTO Users (Fullname) VALUES (".$dbh->quote ($fullname).")");`.
- numrows function>`$queryh->numrows` This will return the number of rows that the query in `$queryh` will return.

- insertid function>`$queryh->insertid` If your query was an `INSERT` and the table had an `AUTO_INCREMENT` column that generated a new ID, this function will return that ID so you can use it for future queries.

Perl and PostgreSQL

To connect to PostgreSQL in Perl, you will need to install the `/usr/ports/databases/p5-Pg` port. This module provides much the same functionality as the `p5-Mysql` module does; you can set up a database connection with the following commands:

```
use Pg;
$conn = Pg::setdbLogin(undef,undef,undef,undef,"PictureArchive","frank","franks-password");
```

Next, submit a query with the $conn->exec method:

```
$result = $conn->exec("SELECT Filename,Type FROM Pictures WHERE User_ID='5'");
```

Then use `$result->fetchrow` as in the MySQL example you saw previously in this chapter. All the possibilities for the `$resulthandle` can be found in the `perldoc Pg` documentation, in the section titled "2. Result."

Note

For both these connectivity packages, the examples describe queries being executed in *autocommit mode*, meaning that each query is sent to the database as soon as it is formulated (using `$dbh->query` or `$conn->exec`), and results are immediately available to `fetchrow` commands. Each package contains analogous commands that can be used to operate in a mode where queries are not automatically committed. This approach is often very useful for operations that must be *atomic* (that is, treated as a single instruction that cannot be interrupted by other processes that can potentially change the state of the database between the start and end of the operation). Atomic operations are considered much safer than nonatomic ones, and it's good database coding practice to use them wherever possible. Refer to the `perldoc` documentation for each package for details.

Database Connectivity with Python

Python's connectivity is built upon the Python Database API Specification 2.0. Apart from the details of the setup lines and how the connection itself is set up, the command syntax for accessing MySQL and PostgreSQL databases is exactly the same. First, build and install either the `py-MySQLdb` or `py-pyPgSQL` port, both in `/usr/ports/databases`, depending on which database you are using.

To set up a connection to a MySQL database, use the following initialization lines:

```
import MySQLdb
db = MySQLdb.connect(database="PictureArchive");
```

If you're using PostgreSQL, the setup lines will look like this:

```
from pyPgSQL import PgSQL
db = PgSQL.connect(database="PictureArchive");
```

The preceding lines set up the connection to the database. Next, you can create a *cursor*, or statement handle, with the `db.cursor` operator:

```
cur = db.cursor ()
```

Now you can begin issuing queries. Python's database API defaults to non-autocommit mode, so you can issue as many queries as you like before committing them, as shown here:

```
cur.execute ("INSERT INTO Users (Fullname,Age) VALUES ('Joe Smith','22')")
cur.execute ("INSERT INTO Users (Fullname,Age) VALUES ('Alice Walker','31')")
db.commit()
```

Perhaps the easiest way to handle multirow responses from queries is to use the `fetchall` operator, which will retrieve all result rows into a multidimensional array. The following lines show how to use this command:

```
cur.execute ("SELECT * FROM Users")
r = cur.fetchall()
r
[[Joe Smith, 22], [Alice Walker, 31]]
```

As with the Perl modules for database connectivity, a great many more operations can be done through these interfaces. Refer to the Python Database API Specification 2.0 site (http://www.python.org/topics/database/DatabaseAPI-2.0.html) for full documentation of these features.

A Perl Script to Populate a Database

In this section, you will look at a simple script written in Perl. This script interfaces with a MySQL database. Its purpose is to read in a set of text files in a directory, each of which contains the information for a particular user in a system. The script will parse each file, which is of the following form:

```
User's full name
User's email address
User's age
```

It will then insert each user into the `Users` table in the database, using the `AUTO_INCREMENT` column to create unique ID numbers for each user, and finally will return the number of rows that are in the table after all the operations have completed. The script is shown in Listing 29.1.

Listing 29.1. populateUsers.pl: A Perl Script for Populating the Users Table of a Database

[View full width]

```
#!/usr/local/bin/perl

use Mysql;
$dbh = Mysql->connect(undef, "PictureArchive","frank","franks-password");

$filepath = "/usr/local/www/data/users";
opendir (DIR, "$filepath");
@userfiles = sort readdir (DIR);
closedir (DIR);

foreach $file (@userfiles) {
  open (USER,"$filepath/$file");
  @userdata = <USER>;
  chomp ($_) foreach (@userdata);
  close (USER);
  $inserth = $dbh->query("INSERT INTO Users(Fullname,Email,Age) VALUES ('$userdata[0]'
   ,'$userdata[1]','$userdata[2]')");
  $num++;
}
$counth = $dbh->query("SELECT ID FROM Users");
$count = $counth->numrows;
print "There are $count users in the table, $num of which are newly added.\n\n";
```

Note

It's generally considered poor form to directly generate content to insert on the fly; rather, your administration scripts should generate a `.sql` file (a "recipe" of SQL commands) that you then load into the database.

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Connecting a Database to the Web

Nothing we have discussed so far in this chapter is exclusively related to the web. The databases you have set up can be used by local users of the system, administered by automated scripts, and even accessed remotely by database clients on other machines if configured to do so. But most databases these days are being set up so that their content can be accessed by web browsers. Fortunately, because you have now learned all the fundamental concepts necessary for understanding web database connectivity, making that next step should be a breeze.

Using Perl and CGI to Access Database Content

As was discussed in Chapter 11, "Introduction to Perl Programming," and Chapter 26, "Configuring a Web Server," the Common Gateway Interface (CGI) is a standardized API by which data (stored in variables) is passed from web forms into back-end programs that process it and return it to the web server. Any Perl script can be made into a working CGI program simply by making sure of the following:

- Its permissions are set correctly.
- It's in a location accessible by the web server.
- It prints out the appropriate HTTP headers before it outputs content.

The same goes for programs written in Python, C, or any other language. For the purposes of the following discussion, we'll use Perl.

You have already seen how to create a Perl script that interfaces with a MySQL or PostgreSQL back end. And, you've seen (in Chapter 26) how to create a Perl script that can handle data submitted through a web form. Creating a script that does both of these things is a simple matter of merging the functionality of the two kinds of scripts. The sections that follow explain how to accomplish this merger.

Inserting Data into the Database

Let's say you have a web form that takes a user's information (the same fields that you saw earlier in the Users table) and passes this information to a CGI program that then inserts the information fields into the database. To accomplish this, you simply have to make sure the script is set up to handle form input as well as database connections. Here's how to do that:

```
#!/usr/local/bin/perl

use Mysql;
$dbh = Mysql->connect(undef, "PictureArchive","frank","franks-password");

read(STDIN, $buffer, $ENV{'CONTENT_LENGTH'});
@pairs = split(/&/, $buffer);
foreach $pair (@pairs)
{
  ($name, $value) = split(/=/, $pair);
  $value =~ tr/+/ /;
  $value =~ s/%([a-fA-F0-9][a-fA-F0-9])/pack("C", hex($1))/eg;
  $value =~ s/~!/ ~!/g;
  $FORM{$name} = $value;
}

print "Content-type: text/html\n\n";
```

Now, when someone accesses the web form page (which refers to this script in the `ACTION` field of the `<FORM>` tag, as you saw in Chapter 26), the variables from that form's fields are available to you in the `%FORM` array.

The code in this block performs several operations on the form input to prevent the user from inserting malicious HTML code instead of legitimate names and ages. However, when dealing with databases, there is an additional caveat: You must ensure that the data submitted by the user is compatible with the functions that insert it into the database as well as with the database itself. This is where the >`$dbh->quote` function comes into play.

In a loop similar to the one in Listing 29.1, you can quote the input strings in the following way:

[View full width]
```
$inserth = $dbh->query("INSERT INTO Users (Fullname,Email,Age) VALUES (".$dbh->quote(
   $FORM{'fullname'}).",".$dbh->quote($FORM{'e-mail'}).",".$dbh->quote($FORM{'age'}).")");
```

The `$dbh->quote` function will properly escape all quotation marks, apostrophes, and other special characters to ensure they don't interfere with the text, as entered by the user, being inserted into the database without being truncated or translatedor even causing the script to fail (which would have happened if someone had entered a string with double quotes in it!).

Similar failures can occur if a user attempts to input data that's incompatible with the type of column it's supposed to go into. For instance, if Age is defined as an `INT` column, and a user enters "I'm not telling!" for his age, a value of zero will be entered; similarly, if a `VARCHAR` field is only 10 characters long, and the user enters a string longer than that, the string will be truncated upon insertion into the database. Still other conditions can cause the query operation to fail completely, returning an error, and the entire script will crash.

For this reason, it's important to implement your own consistency-checking code in your script before the data gets to the database. For instance, you can ensure that data going into an `INT` column is a nonzero integer by putting it into a conditional loop, as shown here:

```
if (int($FORM{'age'}) {
  $updh = $dbh->query("UPDATE Users SET Age='$FORM{age}' where id='$userid'");
} else {
  print "Error!";
}
```

Caution

Be aware that using single quotes around field names in associative array elements, such as `$FORM{'age'}`, won't work in this kind of query (where the entire query string is double quoted and the field contents are single quoted). Perl lets you get away with leaving out the single quotes within the variable, as shown here, but this can be an invitation to trouble. It may be safer for you to reassign the contents of `$FORM{'age'}` to another variable (for instance, `$age`) before using it in the query.

Another safeguard is to use the `MAXLENGTH` attribute in your HTML form input fields. For instance, if the length of a `VARCHAR` column is 64 bytes, you can use the following HTML code for the corresponding form input field:

```
<INPUT NAME="fullname" MAXLENGTH="64">
```

This will prevent the user from entering any more than 64 characters, and you won't have to worry about the input data getting truncated when it's inserted.

Good coding practices dictate that error-trapping should be done as close as possible to the user. With web-to-database programming, you're dealing with three different layers of code separating the user from the data store: the front end (HTML and JavaScript), the CGI layer (Perl, Python, or C), and the back end (the database APIs and the built-in tableconsistency safeguards). The best-designed web applications have as much error-checking implemented in HTML and JavaScript as possible; then the CGI programming layer is used to catch more esoteric cases. Ideally, the database itself should never be exposed to input errors that fall through from those upper layers.

Creating a Search Form

Now that you know how to insert data into the database from a web form, you're ready to implement something a little more generally useful: a search form. A single HTML input field (`$FORM{'keywords'}`) can take an arbitrary set of words, separated by spaces. Then the Perl code underlying it will divide that string into its component words and search the database for matches against each one. If more than one word matches a certain entry, you want to get a better "score" for that entry and sort the results according to that score. Even better, you want to add weight to an entry that matches all the keywords in order. Here are the basic steps for creating the back-end code to handle this type of search form:

1. Check to make sure there is something in the input field (for example, "pictures of yosemite"). Then, create a *temporary table*, which is a table that exists only for the duration of this program and is dropped at the end of the `$dbh` session. (This table, called Queries, will hold all the querieswildcards and allyou plan to execute.)

2. Split the contents of the input field into the `@querywords` array: `("pictures", "of", "yosemite)`.

3. Create `$comboquery`, which is going to be a string of all the keywords separated by the `%` wildcard: `%pictures%of%yosemite%`. This will be the query term that should match entries with all the keywords, in order. If you search for this term as well as for all the keywords individually, its score should reflect all the matches of the individual words, plus that of its combined match. Therefore, it should be your topmost result. Add a final `%` to it and then push it onto the `@querywords` array.

4. Go through each keyword and create a variable with that word surrounded by `%` wildcards (such as `%yosemite%`) and quote it to protect your database. Then, insert it into the temporary Queries database.

You now have a table full of queries ready to perform.

The following examples show how these steps are executed in Perl. We begin with the form-handling preamble discussed earlier; after that, the steps you have just seen are pointed out in comments in the code.

```
#!/usr/local/bin/perl
use Mysql;
$dbh = Mysql->connect(undef, "PictureArchive","frank","franks-password");
read(STDIN, $buffer, $ENV{'CONTENT_LENGTH'});
@pairs = split(/&/, $buffer);
foreach $pair (@pairs)
{
  ($name, $value) = split(/=/, $pair);
  $value =~ tr/+/ /;
  $value =~ s/%([a-fA-F0-9][a-fA-F0-9])/pack("C", hex($1))/eg;
  $value =~ s/~!/ ~!/g;
  $FORM{$name} = $value;
}
print "Content-type: text/html\n\n";
# Here begins the handling of the form input.
if ($FORM{'keywords'}) {                          # Step 1
  $sth = $dbh->query("CREATE TEMPORARY TABLE Queries (Query VARCHAR(255))");
  @querywords = split(/\s/,$FORM{'keywords'});      # Step 2
  $comboquery = $FORM{'keywords'};                  # Step 3
  $comboquery =~ s/\s+/%/g;
  push (@querywords,$comboquery);
  foreach (@querywords) {                           # Step 4
    $_ = $dbh->quote('%'.$_.'%');
    $sth = $dbh->query("insert into Queries (Query) VALUES ($_)");
}
```

Now, you can execute the query. Here, you're searching filenames in Pictures, and a unique picture is defined by both `User_ID` and Filename, so we'll group by both of those. The `COUNT()` of the results you'll call Score, and you'll sort by that column in descending order:

[View full width]
```
 $searchh = $dbh->query("SELECT Filename,User_ID,COUNT(Filename) AS Score FROM Pictures
   WHERE Filename LIKE Query GROUP BY Filename,User_ID ORDER BY Score DESC");
```

Finally, you can assign the contents of each result row to an array and print out some appropriate HTML code, which you can season to your taste:

```
  while (@searchdata = $searchh->fetchrow) {
    print "$searchdata[0] (Score: $searchdata[2])<BR>\n"
  }
}
```

Needless to say, a more sophisticated searching algorithm can certainly be constructed, and it can be even easier to design a more efficient one. MySQL has a concept called *fulltext indexes*; you can define a `TEXT` field to have a

FULLTEXT index, and then you can perform specialized searches on that column with great speed and efficiency. Refer to the MySQL documentation (http://www.mysql.com/doc/en/Fulltext_Search.html) for details on how this is done.

Note

Note that FULLTEXT searches will not work on keywords smaller than four letters; because the indexing code is tuned to work best on very large data sets, searches on small data sets will produce very weird results.

Session Locking and Data Integrity

If your web application has a lot of users accessing it at the same time, it's important to code your application's database operations to be as atomic as possible. As we discussed earlier, an atomic operation is one in which all commands and responses are executed in a single instruction so that no competing processes can interfere and potentially cause a change in the state of the database while your operation is executing.

MySQL and PostgreSQL both support the concept of *transactions*, where instead of issuing queries in autocommit mode (where commands are sent to the database engine as soon as they're entered, and the response data is immediately returned), you can create an atomic operation by using the BEGIN and COMMIT commands as well as any number of query operations in between. The use of these commands in a transaction is shown here ($now is assumed to be a Perl variable containing the current UNIX time):

```
BEGIN;
SELECT * FROM Users;
UPDATE User_Prefs SET Last_mod='$now' WHERE Last_mod > '$now';
COMMIT;
```

The queries are not executed until the COMMIT command is given, and while the queries are operating, the tables in use are locked. When locked, the tables cannot be accessed by any other processes, which have to wait until this process is completed.

In order to use such transactions in MySQL, you must begin the session with the following command:

```
SET AUTOCOMMIT=0;
```

PostgreSQL will automatically drop out of autocommit mode at the first BEGIN statement. Also, if you use the Perl or Python modules to connect to PostgreSQL, it will be in non-autocommit mode automatically. In fact, you can choose to use the BEGIN and COMMIT methods in the query context or through the dedicated database API commands, which do the same thing. In MySQL, transactions are a much newer addition to the engine and are most easily executed directly as SQL query commands.

The ROLLBACK command can be used instead of a COMMIT to cancel any queries that have been issued since the BEGIN command. If, for instance, you're working at the database command line and you mistakenly issue a DELETE FROM User command, as long as you started with a BEGIN statement you can enter **ROLLBACK** and the deletion will be reversed. Naturally, using the BEGIN command is a desirable (if somewhat onerous) habit to develop!

Caution

If you're using transactions, don't forget to use COMMIT after you've made your (intentional) changes! It's an easy step to leave out of your code, but if you do, it won't necessarily be obvious what's going wrong when you go to debug the script.

Security Concerns

CGI programs that connect to database back ends (particularly MySQL, which is entirely password-based) have one big security weakness: The password for connecting to the database must be hard-coded into the script or read in from another file. However you choose to implement this, if the web server is running as the `www` user, it will execute the CGI program under the ownership of `www`; any file that contains the password must be readable by the `www` user.

If you put the password in a file that's readable only by root, the CGI program won't be able to get access to it. However, if you leave it hard-coded into a file that the `www` user can read, anyone on your system can write her own CGI program that can read that same file and print it out for all to seeor use it to connect to your database and issue a few `DROP DATABASE` commands. This is an inherent flaw in database security as it currently exists in the UNIX world, and there's no elegant solution to it.

The easiest workaround is to disallow regular users from running CGI scripts. You may also be able to come up with creative solutions using CGIwrap (which is covered in Chapter 30, "Network Security"). But what it ultimately comes down to is a question of what kind of security level you want to enforce. *Do you trust your local users?* If so, you can probably get away with living dangerously. But if you don't trust the users with accounts on your system not to try to hack the database access password out of your scripts, you probably shouldn't be running a database with sensitive or critical data on that same server.

However, if you're running PostgreSQL, you can implement security that does not depend on passwords. The configuration we discussed earlier using `ident` and `sameuser` will only allow a user to access his own database; it doesn't allow the user to access any other databases. This type of configuration helps to prevent local users from breaking into databases where they don't belongand you don't have to worry about your password being exposed by a malicious CGI program.

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Using PHP to Provide Database-Driven Content to Web Pages

You might be wondering whether writing your own web applications from scratch is the only way to include database-driven content in your dynamic pages, or if there's a better and cleaner way, analogous to using Microsoft's ASP or Adobe/Macromedia's ColdFusion. The answer is yes, there is. It's called PHP, which originally stood for "Personal Home Page" but now is itself the official name of an open-source HTML preprocessing framework that has become very widely used throughout the UNIX web-hosting world. PHP's official website is http://www.php.net.

PHP consists of commands that can be embedded into HTML, and they are parsed out in much the same way that server-side includes are parsed in `.shtml` files, as you saw in Chapter 26. A PHP file has the extension `.php`, `.php3`, `.php4` or `.php5`, and Apache is reconfigured at installation time to recognize those files and pass them through the PHP module before serving their content to the user.

This chapter's discussion of PHP will be brief, but it should be enough to get you started. If you've already become familiar with the more difficult concepts presented by database design, SQL, and Perl/Python connectivity, then PHP in this series of conceptual phases should be like dessert after a long meal.

Installing PHP

The PHP project is maintained and driven forward by the Apache Software Foundation, which means PHP and Apache are very closely intertwined in their operation. PHP is installed as an Apache module, `mod_php5`, which links to libraries that harness the Zend processing engine upon which PHP is based.

PHP can be installed from the ports or packages. The name of the package is `mod_php5` (earlier versions are available too), and if you choose to install it from the ports, it's located in `/usr/ports/www`. When you type **`make`**, you are presented with a list of options to compile into PHP. Select support for either MySQL, PostgreSQL, or both, depending on which database you're using. You can also choose to enable support for the GD imaging library, `mcrypt` encryption, OpenSSL, XML, and other add-ons. Unless you already know you have need for these, you can ignore these additional options.

Note

If you're running Apache 2.0, you will want to define the `WITH_APACHE2` environment variable before typing **`make`**. See Chapter 9, "Customizing the Shell," for details on setting environment variables.

At the end of the installation process, the automated installer script will modify your `httpd.conf` file to enable recognition of `.php` and other PHP-associated files and assign them to the PHP handler. You may want to examine the `httpd.conf` file after this and make sure nothing has been accidentally broken in the process.

Flow Control and Programming Techniques

The tag format for PHP commands is `<?php ... ?>`. A number of internal PHP commands can go between these two bookend tags; you can use `echo()` to print text, you can perform string operations on variables (including the HTTP connection variables, such as `HTTP_USER_AGENT`), and you can do flow control. For instance, the following `if` statement can be used to print different blocks of HTML code depending on the state of a variable:

```
<?php
```

```
if ($a > $b) {
?>
<B>A is greater than B.</B>
<?php
} else {
?>
<B>B is greater than or equal to A.</B>
<?php
}
?>
```

The syntax for naming and assigning variables is very similar to Perl. PHP includes such Perl-like control structures as `foreach`, `while`, and `do...while`, although the equivalent to Perl's `elsif` is `elseif`. There is also an array context, although the prefix for an array is `$`, as for a scalar. Also, as with Perl, PHP's variable types do not have to be declared by the programmer but are handled internally and derived from context. Lines of PHP code end with a semicolon (`;`).

Within a `<?php ... ?>` block, you can define variables and functions on as many lines as you want; you can almost pretend that it's a Perl program. Anything in a `<?php ... ?>` block will be parsed out of the HTML file it's embedded in and then replaced with the output from any functions you call. You can put PHP code blocks wherever you like throughout the file.

Interfacing with the Database

For the purposes of this chapter, what interests us is how to make PHP interact with MySQL and PostgreSQL. Fortunately, the methods for doing this are very similar to the Perl-based techniques we have already covered.

The initial MySQL database connection is set up using the `mysql_connect` and `mysql_select_db` functions, as follows:

```
$conn = mysql_connect("localhost", "frank", "franks-password");
mysql_select_db("PictureArchive");
```

For PostgreSQL, the database setup commands are as follows:

```
$conn = pg_connect("dbname=PictureArchive user=frank password=franks-password");
```

A large number of connection options can be specified in the `mysql_connect` or `pg_connect` argument string, whether in the `parameter=value` format shown in the PostgreSQL example or the ordered list of values for the MySQL example (either format will work for either database). Because PostgreSQL depends to a certain extent on environment variables, you can set the defaults for many of these options by defining them in the environment for the web server. Use Apache's `SetEnv` directive to set these in `httpd.conf` or a `.htaccess` file, as shown here:

```
SetEnv PGHOST localhost
SetEnv PGPORT 7890
SetEnv PGDATABASE PictureArchive
SetEnv PGUSER frank
SetEnv PGPASSWORD franks-password
```

For MySQL, PHP has a number of functions, such as `mysql.default_user`, `mysql.default_password`, and `mysql.connect_timeout`, that can be set within the global PHP configuration file, `/usr/local/etc/php.ini`. Note that this file must be copied or renamed from `php.ini-dist` before it will be read.

After your database connection is set up, you can then issue a query in much the same way as you have seen in earlier examples, using `mysql_query` or `pg_query` as follows (note that the two functions take the database connection identifier and the query in reverse order from each other):

```
<?php
$result = mysql_query("SELECT * FROM Users",$conn)
  or die("Invalid query");
?>

<?php
$result = pg_query($conn,"SELECT * FROM Users")
  or die("Invalid query");
?>
```

PHP operates in autocommit mode for both databases. As soon as you issue a `mysql_query` or `pg_query` command, the query is submitted, and you can then begin to work with the results in `$result`:

```
while($rowdata = mysql_fetch_row($result)) {
  print "$rowdata[0]: $rowdata[1]<BR>\n";
}
```

This syntax is very Perl-like. If you look through the PHP documentation at http://www.php.net/manual/, under the headings "MySQL Functions" and "PostgreSQL Functions," you will find a large number of well-documented functions that operate very similarly to the Perl database interfaces with which you are already familiar.

The biggest advantages of PHP over homegrown Perl or Python scripts are that because the server-processed code is all embedded into plain HTML files, you can maintain the layout of your pages with much more ease. You can edit the HTML in these same files without the danger of breaking permissions or disabling the executable code. And because the files are parsed internally by Apache, you will see a significant decrease in processing overhead, because starting up individual CGI processes for each page view is a very expensive way for a server to run.

Security Concerns

PHP potentially opens your system up to a large number of security risks. PHP is susceptible to many of the same exploits that threaten CGI programs, and it has a few new areas of susceptibility of which you should be aware.

The files that include database connection passwords, whether the HTML/PHP files themselves or include files, are subject to access by local users writing CGI programs to access the files' contents. To address this problem, you will need to take the same precautions you would take with a Perl or Python connectivity setup (as explained earlier in this chapter). Similarly, issues exist with virtual hosting and PHP files that are executed outside the main server root in the users' `public_html` directories (if you choose to allow it; a tightly secured server will run all PHP scripts from within the restricted `/cgi-bin` directory and not allow regular users to run them). Because all PHP files are parsed and executed with the same permissions and ownership, one user's actions can potentially affect other users' database code or files. Again, you will want to review your security policy: How much do you trust your local users?

Perfect security is a myth, and security and convenience are mutually exclusive. The more lenient you are in allowing users access onto your system, the less safe you are from malicious activity by your own users. Fortunately, for the purposes of database connectivity, the only sector from which to fear an attack is your local users, because most web-enabled database systems don't have their database back ends open to nonlocal connections. However, those local users can cause a great deal of trouble if you've allowed them onto the system.

Refer to the online PHP security documentation at http://www.php.net/manual/en/security.php for a thorough discussion of the ways in which a PHP server can be attacked and compromised.

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Optimizing Database Performance

No matter how well you have designed your database schema, as your site becomes more and more popular and heavily used, it is likely that certain parts of its functionality will bog down. Perhaps you've forgotten an index in a certain crucial table. Perhaps you're doing a complex join where a series of temporary tables would be computationally cheaper. Or perhaps your dynamic pages are simply far too complex, and you need to create a cache of static information that's updated on a regular basis in order to speed up on-demand queries at the expense of instantaneous accuracy.

At the top-level view, it might seem impossible to figure out what's slowing things down; all you see might be a perpetually high load average in `top`. Fortunately, there are some ways to find out just what the database is doing in those queries. The following sections discuss these techniques.

Monitoring Database Usage

MySQL has a command called `SHOW PROCESSLIST`. Entered at the MySQL command line, this command will show you all the queries currently in progress:

[View full width]
```
mysql> SHOW PROCESSLIST;
+--------+-------+-----------+----------------+---------+------+----------------+
| Id     | User  | Host      | db             | Command | Time | State
|Info                                 |
+--------+-------+-----------+----------------+---------+------+----------------+
| 625441 | root  | localhost | PictureArchive | Query   | 0    | NULL
| show processlist                    |
| 625443 | frank | localhost | PictureArchive | Query   | 0    | Copying to tmp |
select name,dirname,id,count(*) from artists,pictures where id=pictures.artistid and
    display='Y' gro |
| 625444 | frank | localhost | PictureArchive | Sleep   | 1    |
| NULL
+--------+-------+-----------+----------------+---------+------+----------------+
3 rows in set (0.01 sec)
```

If you see dozens of processes listed in this output table, with a Time value in the hundreds (of seconds), then you know you have a problemparticularly if all the queries (shown in the Info field) seem to be doing the same thing. If you can determine from the structure of the query where in your code it's being called from, you can look at the tables involved and make sure that the query is doing its joins on indexed columns and that the joins are sensibly constructed. You may also be able to redesign the code so that the query in question is called at a different time, when the CPU is not quite so busy with other queries.

The `EXPLAIN` command offers a more direct, if somewhat cryptic, way to drill down into your queries to see what's costing CPU cycles. This command, when placed in front of a `SELECT` statement, will display a table showing the tables involved in the query, the possible keys it will search on, the size of each table, and other information about how the query is being performed. You can check the table definitions to see whether all the possible keys are being indexed properly. If they aren't, you can index them using `ALTER TABLE` (as explained earlier in "Indexes and Keys").

The following examples use a more complex version of the same database you've seen in this chapter, including some tables that haven't been used before:

[View full width]
```
mysql> EXPLAIN SELECT NAME,DIRNAME,ID,COUNT(*) FROM Artists,Pictures WHERE ID=Pictures.
   Artist_ID AND Display="Y" GROUP BY Artist_ID ORDER BY Created DESC LIMIT 5;
+----------+-------+-------------------+-----------+---------+------------+------+
| table    | type  | possible_keys     | key       | key_len | ref        | rows |
Extra                                       |
+----------+-------+-------------------+-----------+---------+------------+------+
| Artists  | range | PRIMARY,Display   | Display   |       2 | NULL       | 1615 |
where used; Using temporary; Using filesort |
| Pictures | ref   | PRIMARY,Artist_ID | Artist_ID |       4 | Artists.ID |   38 |
Using index                                 |
+----------+-------+------------------+----------+---------+-----------+------+
2 rows in set (0.18 sec)
```

EXPLAIN in PostgreSQL can be tuned toward helping you root out the expensive processes that cause slowdowns in your queries through explicit "cost" analysis. The following example shows the use of EXPLAIN in PostgreSQL:

[View full width]

```
PictureArchive=# EXPLAIN SELECT Artists.Name, Pictures.name FROM Artists LEFT JOIN
   Pictures ON Artists.ID=Pictures.Artist_ID;
NOTICE:  QUERY PLAN:

Merge Join  (cost=823.39..1012.89 rows=10000 width=32)
  ->  Index Scan using Artists_pkey on Artists (cost=0.00..52.00 rows=1000
width=16)
  ->  Sort  (cost=823.39..823.39 rows=10000 width=16)
  ->  Seq Scan on Pictures  (cost=0.00..159.00 rows=10000 width=16)

EXPLAIN
```

Here, you see a join being performed between the Artists and Pictures tables, but there is no key in Pictures to help the database engine search for the elements upon which to perform the join. Costs of each operation are summed upward; as you work your way up the tree, you can see the overall cost of the query increasing. The sequential scan and sort operation at the bottom of the tree is causing a significant hit on system performance. If you had an index on the Artist_ID key in Pictures, the database wouldn't have to do a sequential scan and could instead do an index scan, which is much faster, as shown in this example:

[View full width]

```
PictureArchive=# CREATE INDEX Pictures_Artist_ID_key ON Pictures ( Artist_ID );

CREATE

PictureArchive=# EXPLAIN SELECT Artists.Name, Pictures.Name FROM Artists LEFT JOIN
   Pictures ON Artists.ID=Pictures.Artist_ID;
NOTICE:  QUERY PLAN:

Merge Join  (cost=0.00..628.56 rows=10000 width=32)
  ->  Index Scan using Artists_pkey on Artists  (cost=0.00..52.00 rows=1000
width=16)
  ->  Index Scan using Pictures_Artist_ID_key on Pictures (cost=0.00..439.06 rows=10000
    width=16)

EXPLAIN
```

Here, the overall cost range is reduced from 823.39 through 1012.89 down to 0.00 through 628.56. (These units aren't very meaningful outside of the database context but can be compared internally very effectively.) It seems this maneuver has gained some very positive results.

Creating Temporary Tables

This may not seem obvious at first blush, but sometimes it's more efficient to create a temporary table than to do a complex join. Programmatically, it may appear that the most elegant solution to a problem is to accomplish the task in as few lines of code as possibleand in fact in traditional programming languages this is mostly true. But databases don't quite work that way.

If you find yourself joining three or four tables together in a single query, and you notice that the query takes an extremely long time to execute, consider for a moment what the database is being asked to do. It must align four separate (possibly very large) disparate groupings of data together in memory, associating keys from each table with keys from another table. This process takes place in a conceptual matrix whose complexity rises by another degree with each table that's added to the mix. The multidimensional data structure that the database must hold in memory is enormous during this join, and searching through it becomes a monstrous task.

To avoid this problem, experiment with temporary tables. You can create a temporary table by simply preceding a SELECT statement with CREATE TEMPORARY TABLE *t_name*, where *t_name* is the name of the table; you can then select from this table (using the `SELECT` command) later in your session. Be sure to apply the appropriate indexes after the table is created. If you do this, a direct `SELECT` from the new tableeven including the temporary table creation and indexing queriesmight be orders of magnitude faster than a complex join that nonetheless you've managed to condense into a single query.

Note

Temporary tables only last until the end of the current database session; in the command-line context, temporary tables that you create will be there until you log out. In a web scripting context, the tables are dropped when the database handle is destroyedwhen you issue a `disconnect` command through the programmatic toolkits or when the script completes.

Temporary table names exist in private namespaces, so multiple temporary tables with the same name can exist as long as they've been created by different database sessions.

Using Cache Tables

If your queries are large and complex but they just can't be made any faster or more efficient by indexing, you may have no other option than to go to a cache table. This is a table whose contents are nothing more than values that are refreshed on occasion from the results of much more complex queries. What you're doing, in effect, is creating a layer of indirectiona table from which users can get their information very quickly, with a direct and uncomplicated query, but whose contents might not be accurate until refreshed by a periodic process that performs the complex queries and inserts their results into the cache table.

This is one area where Perl scripts that are not CGI programs will come in handy. You can run a `cron` job that executes a Perl script every 10 minutes, for instance, that connects to the database and refreshes the cache by running the complex queries. The script can operate in an atomic fashion, by issuing a `BEGIN` statement, followed by the series of queries, and finally a `COMMIT`; this way, queries that will potentially change the data involved in the complex queries are deferred until the refresh is complete.

Note

See Chapter 15, "Performance Monitoring, Process Control, and Job Automation," for more information about using `cron` to schedule processes.

The system will be a little slower to respond while the refresh process is running, but in betweenfor 10 minutes at a stretch, or an hour, or however frequently you run your cron jobeverything will be almost immeasurably faster.

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Performing Database System Backups

Finally, we must address the issue of backups. It's a fact of life that hardware suffers failures, usually when least convenient or welcome. It's also a fact that running software written with the best of intentions can result in unintended consequences. All the most seasoned database veterans have war stories of times when they froze, stared dumbfounded at the screen, and then sank their heads into their hands, sobbing at the sight of an irretrievably dropped database.

MySQL and PostgreSQL don't have the "live" backup mechanisms that high-end commercial databases such as Oracle and DB2 do. (Many third-party backup software makers have applications that interact with the database, lock it piece by piece, and save backups to tape or across the network.) What they do have, however, is the ability to be locked and "dumped," like any properly designed database. The sections that follow look at a few of the tools that are necessary for creating usable backups.

Dumping the Database

MySQL has two methods for dumping its databases to disk: `mysqldump` and `mysqlhotcopy`.

Using `mysqldump`

`mysqldump` is a command-line tool that locks the database, preventing any new connections, and then copies the structures of all tables, followed by the contents of all tables, into `STDOUT` or an output data file. This file, whose name typically ends in `.sql`, is a long list of SQL commands that, if run in sequence, will re-create the database structure and then repopulate all the data. The `mysqldump` program must be run as a user who has access to the database; it is usually safe to do this as root, but it's a good idea to specify the user who owns each database with the `-u` *`user`* or `--user=`*`user`* option. You can also specify the user's password with the `-p` *`password`* or `--password=`*`password`* option. Generally, you will want to do this as a `cron` job, with the `mysqldump` command inside the owner-readableonly `crontab` file; but if you're concerned about local security, you can create a special "backup" user who has `SELECT` and `LOCK TABLES` access to all databases, but no other privileges. That way, if the user's password is intercepted, an attacker won't be able to do anything destructive.

The `mysqldump` command is executed like this:

[View full width]
```
# mysqldump --user="frank" --password="franks-password" PictureArchive > /usr/local/www/db
   /PictureArchive.sql
```

If you're running this as a `cron` job, you might want to precede this command with something such as **`mv /usr/local/www/db/PictureArchive.sql /usr/local/www/db/PictureArchive.sql-old`** and then a semicolon. This will move the old dump file out of the way so the new dump file can be created. Then it will run the dump, all in one command.

Using `mysqlhotcopy`

If you want to quickly make a snapshot of the entire database directory without creating a dump file, you can use `mysqlhotcopy`. This is a Perl script that locks the tables and copies all their associated files into a new specified location; if your database becomes corrupted or lost, you can simply shut down MySQL, move the files into their appropriate locations under `/var/db/mysql`, and restart the server. To run `mysqlhotcopy`, do the following:

[View full width]
```
# mysqlhotcopy --user="frank" --password="franks-password" PictureArchive /usr/local/www/
   db/PictureArchive
```

Backing Up PostgreSQL Databases

As for PostgreSQL, the `pgdump` command is the equivalent of `mysqlhotcopy`. It is easiest to run `pgdump` as the `pgsql` user who owns the database:

```
# pgsql PictureArchive > /usr/local/www/db/PictureArchive.sql
```

Create `pgsql`'s `crontab` file with **`crontab -u pgsql`**, as you saw in Chapter 15.

Restoring the Database

Restoring from a `.sql` file output from `mysqldump` or `pgdump` is conceptually very simple. It's just a "replay" of SQL commands, which theoretically will re-create the entire database in every detailfirst by rebuilding the tables and all their indexes and then by reinserting all the data.

To restore a MySQL database from a `.sql` file, you must first create the database (if it has been deleted or dropped) and then use the following command:

```
# mysql -p PictureArchive < /usr/local/www/db/PictureArchive.sql
```

You will be prompted for your password. (Alternatively, you can specify the `frank` user with `-u` or `--user=`, and `frank`'s password with `-p` or `--password=`, as you saw earlier in this chapter.) After this is accepted, the `.sql` file will be read into the database, and through the use of `SHOW TABLES` and a few `DESCRIBE` *`table`* and `SELECT` queries, you should be able to verify that everything has been properly restored.

The process is almost exactly the same in PostgreSQL. First, use `su pgsql` to change to the `pgsql` user; then create the database (using `createdb`, as you saw earlier) if it doesn't already exist. Then start `psql`, reading in the `.sql` file:

```
$ psql < /usr/local/www/db/PictureArchive.sql
```

If all goes well, you should be back up and running.

Designing for Restorability

The backup/restore process isn't perfect, however. Because the tables and content are being re-created from a series of commands, and because those commands are automatically generated by the dump programs, it's conceivable that a configuration that you were able to set up manually cannot be re-created properly by the automated tools.

One potentially complicating factor, particularly in MySQL, is `AUTO_INCREMENT`. This special kind of `INT` column must be a primary key, `UNIQUE`, and `NOT NULL` by definition. Ideally you should never have to specify the values in an `AUTO_INCREMENT` column manually; you should end up with a different positive integer for every row in the table. However, you *can*if you really want togo into the database and manually specify that an entry in the table should have a value of 0. This can mess up attempts to restore the database.

When MySQL attempts to re-create this table, it will insert this row while explicitly specifying a value of 0 for the `AUTO_INCREMENT` column. However, the value of 0, as you will recall, is treated as a special case and reassigned to the maximum value of the column plus one. Therefore, if you have code in your web application that is hard-wired to treat this row a certain way because it has a unique ID of 0 (for example, if you have a table of preference settings containing a row of "defaults" that is identified by its special ID number of 0), it will not find that row there after the restore. As a result, your scripts will break; you'll have to examine the tables and reassign the value manually.

Of course, a better solution is to avoid messing with the values in an `AUTO_INCREMENT` column in the first place.

Most problems of this nature are such that you won't be able to see them coming, but the proper precautions you should have taken will seem blindingly obvious in hindsight. The best advice one can give on a subject like this is to encourage you to learn from your experience as rapidly as possiblenothing will rack up the UNIX guru points faster than an embarrassing failure.

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Chapter 30. Network Security

IN THIS CHAPTER

System security is arguably the most important part of any administrator's job, whether it applies to a Windows server, a commercial UNIX system, Linux, or FreeBSD. More books have probably been written about security issues than about any other topicand with good reason. It's an immensely complex subject, but one that's crucially important to the success of a networked system. Although this chapter can't cover every facet of system security, it offers a good, general overview of the topic and includes information on all critical aspects of the topic.

This chapter helps you develop a security policy for your FreeBSD system based on the risk factors it faces in its role as a server or workstation. This chapter will give you the tools you need to monitor your system's perimeter, keep on top of alerts that are raised in the field, patch your system in response to those alerts, and make sure the services you provide to your users are not opening your system up to attack. It also gives you some idea of what you can do to recover whennot ifyour machine is hacked.

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Choosing a Security Model Based on Your Security Risks

The Internet today is not an especially friendly place for servers, and as an administrator you must always fear and prepare for the worst. The proliferation of "rootkit" toolsprepackaged weapons that attackers can use to gain superuser access to your systemand published attack scripts provides unfortunate fodder for countless individuals with nothing better to do than pursue destructive hobbies. You must assume that your system is being probed for security weaknesses at all times and expect the situation to grow more dangerous with each new published exploit. Your only defense is to keep your system as up to date as possible, act on new security advisories as soon as they're released, run only what services are necessary, and be educated about the real dangers that threaten your system and where the greatest risks lie.

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Security Models

You can adopt one of several models of security for your system, based on your system's setup and use patterns and your philosophy toward the security needs the system presents. The security model you choose will dictate how careful you must be about certain administrative duties, such as password policies, open services, encrypted traffic, and so on. Here's a short list of some security models, each defined by a general statement that sums up the administrator's assessment of security risks:

- *I trust everybody on the Internet.* Most certainly an inadvisable model under any circumstances, this is nonetheless the philosophy that guides the lack of security safeguards surrounding many amateur servers, and the administrators of those systemswho seldom maintain them properlyultimately pay the price for it. Often found on university systems, especially those that have been around since before the Internet became so rich in hacker activity, systems administered with this philosophy have many open services, don't require encrypted logins, have loose account and password policies, and are easy targets for hack attacks.

- *I trust anybody on my system's network.* This philosophy is common in small enterprise networks where the server is protected from the general Internet by a firewall or NAT router, and the internal network is made up of employees of a single company or department at a university. In this model, malicious users on the internal network are rare, especially if the organization is small, so the system can afford to provide unencrypted services, give accounts to anybody who asks for them, and even have disabled login security and passwords.

  Unfortunately, in large organizations, it has become the case that attacks on servers maintained under this modelattacks from *within* the network, by people who are supposed to be trustworthyare more frequent than attacks from outside. If your organization is large, you must assume that you *cannot* trust everybody on your system's network, and instead choose a different security model.

- *I trust my local users.* Administrators who maintain this philosophy tend to be more paranoid than administrators of the systems described previously in this list's first two models. This security model is characterized by a tight network security policy: screening of users before new accounts are granted, encrypted network services (either required or encouraged), unnecessary services turned off, and crack-resistant passwords. However, local users are allowed to access internal services and see sensitive information (such as encrypted password strings). The idea is that once users are approved and given accounts, they can have the run of the system, and betrayal of that trust is grounds for removal from the system. This model is appropriate for hobbyist systems that serve a "low-risk" audience (for example, a fan website or community email service), or for high-profile commercial Internet servers where only a few trusted people actually have user accounts.

- *I trust only myself and other administrators.* The model favored by the most paranoid system administrators, this model not only has tight network security as in the preceding model, but tight local security as well. Regular users are denied access to system configuration files and server-side program code through carefully crafted permissions, Access Control Lists, and even Mandatory Access Control (MAC) labels (an advanced mechanism for controlling user access to files, sockets, and processes throughout the system). The administrator must watch each user carefully to make sure nothing unauthorized is being done, and special measures (such as custom shells, `chroot` jails, and the disabling of certain commands) are often taken to restrict each user's access to the system's resources. This model is useful for high-profile servers that provide email or web hosting services to hundreds or thousands of users from indeterminate or anonymous backgrounds.

After you've decided what model is appropriate for you and your system for network and user-level security, you need to decide where the risk areas are for that model and what you can do to combat the exploitability of those areas.

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The Security Risks You Face

"Perfect security" is a myth; only superhuman effort can keep a system so completely buttoned up that no attack can ever get through. The next best thing, however, is to know which areas of your system are at greatest risk and how those risks can be combated.

Security risks for a network server can be grouped into three major categories:

- *Root compromise* An attacker takes advantage of unencrypted transmissions or known programming weaknesses in server software (most commonly *buffer overflows*, or weaknesses in input boundary checking in server software) to gain super-user access to the system. He then installs tools of his own to conceal his presence from your system-monitoring tools (such as `last` and `ps`) and can steal any of your critical data or use your system as a base point for further hacking activities.
- *Privacy compromise* If network traffic to and from your system is not encrypted (scrambled), an attacker can view any of it, including passwords (potentially leading to root compromise) or any user's critical or private communications.
- *Denial of service* An attacker (or a widespread network of attackers, often comprised of unwitting "zombies") uses brute-force methods such as flooding your server with large amounts of legitimately constructed traffic, thus swamping its ability to serve traffic to normal clients and potentially crashing the system.

Within each of these categories of security risks, the most common threats result from these specific security weaknesses:

- *Insecure (weak) passwords* Passwords that can be guessed by software using common words and sequences.
- *Clear-text services* Services in which passwords and other sensitive information can be obtained just by "sniffing" the unencrypted data packets on the wire.
- *Unnecessary and exploit-prone services* If you don't need to provide a service, don't. It can only cost you in the end.
- *Open SMTP relaying* Allowing spammers to use your SMTP server as an open relay for broadcasting junk mail.
- *Unfiltered network access* Run a firewall to prevent unauthorized or undesirable traffic from getting to your machine.
- *Outdated and vulnerable software* The older a piece of software is, the greater the chances someone has found a way to break in through it.

Each of these weaknesses is a potential problem on FreeBSD in its default configuration. The sections that follow show you how to close these security gaps and find the necessary tools to maintain a system that will stand up to the inevitable hacker (or, more properly, "cracker") attacks that will be leveled against it.

Note

Marcus Ranum outlines the Six Dumbest Ideas in Computer Security at http://www.ranum.com/security/computer_security/editorials/dumb/. Consider it required reading!

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Password Policies

If your users have insecure passwords, all the other security measures you might take may well be moot. Probably the most responsible thing you can do as the administrator of a FreeBSD system is to institute a password policy, requiring (or at least encouraging) your users to use passwords that cannot be easily guessed or decoded.

Users frequently find passwords inconvenient, and strict password policies doubly so. If allowed, a user will try to use his username, his telephone number, the server's hostname, a word such as "password," or strings of convenient-to-type characters, such as repeated letters or numbers. If you choose to expire users' passwords after some period, the first thing a user will try, when prompted to choose a new password, is to reuse the password from the previous period. However, an axiom of security is that "convenience and security are mutually exclusive," meaning that to increase one, you must sacrifice the other. Increased convenience brings about decreased security. There's no easy way around that fact for you or for your users.

When a user chooses a password using the system's `passwd` program or a script that calls the same routines that `passwd` uses, a few loose checks are performed. By default, passwords must be at least six characters in length, but that's about the only built-in measure that prevents people from choosing weak passwords. You can use the following techniques to take your password policy to the next level.

Tip

An ideal password is at least eight characters long (the longer the better, actually), and contains a mixture of capital and lowercase letters, numbers, and punctuation marks or meta-characters. To keep your system security strong, you must ensure that users follow these guidelines when picking a password with the `passwd` program in FreeBSD.

Although the only password security measure currently enforced by the default `passwd` program is that passwords must be at least six characters long, the FreeBSD development community is working to incorporate further weak-password checks into the `passwd` program. You learn how to use the `login.conf` program to set a minimum password length and to require periodic password updates in "Forcing Password Expiration," later in this chapter.

Enforcing Secure Passwords with Crack

The first priority in maintaining secure user password practices is to prevent users from choosing insecure passwords in the first place. As of this writing, the best way to make sure your users aren't using easily guessable passwords is to periodically try to guess them yourself. A tool called Crack, available in the ports collection at `/usr/ports/security/crack`, helps you do just that. Although it may appear to be a "hacker" tool, Crack is primarily intended as a security-auditing tool for system administrators, allowing you to perform "dictionary" attacks (trying a plethora of English words as potential passwords) as well as a number of other commonly used "convenience" passwords: repeated strings, the user's login name, groups of numbers, and so on. Crack helps you determine which of your users are using insecure passwords. You can then contact these users directly and ask them to adhere to the password rules you set.

You can build and install the Crack port using the instructions in Chapter 16, "Installing Additional Software." The new `/usr/local/crack` directory's permissions enable only root to list its contents or run any of its programs. To check your system's user database for weak passwords, go into `/usr/local/crack` and run the Crack program like this (note the capitalization):

```
# ./Crack -fmt bsd /etc/master.passwd
```

The Crack program builds some utilities, compiles some dictionaries, and then launches its arsenal against /etc/master.passwd. Crack sends its output into runtime files that you can analyze with the Reporter program, as shown here:

```
# ./Reporter -quiet
---- passwords cracked as of Sun Jan 14 12:17:41 EST 2001 ----

979693112:Guessed frank [frank] Frank Jones [/etc/master.passwd /bin/tcsh]
979693187:Guessed joe [password] Joe User [/etc/master.passwd /usr/local/bin/bash]

---- done ----
```

Crack reports only the users whose passwords were successfully guessed. In the sample output, the cracked passwords are shown in the first set of brackets; Frank's password is `frank`, and Joe's password is `password`both very weak passwords that can be guessed by an attacker with little effort. You can then contact these users and remind them of the password policy, requiring them to change to stronger passwords.

After you're done running Crack, clean up the runtime tools and output files with the following two commands:

```
# make tidy
# rm run/F-merged
```

Note

As FreeBSD continues to develop, it's highly likely that there will be support in the `passwd` program for automatic password-strength checking such as that done manually by Crack; in fact, the libraries that Crack uses are available at `/usr/ports/security/cracklib`. On systems such as Linux, `cracklib` has been developed into a Pluggable Authentication Module (PAM), a mechanism that FreeBSD supports as well (see `man pam`), but FreeBSD doesn't have `cracklib` support fully integrated into PAM as of this writing. For now, though, if you're an adventurous sort willing to work with source code and experimental software, and you're interested in incorporating the `cracklib` routines into the `passwd` program, you can learn how at http://www.kearneys.ca/~brent/FreeBSD/passwd42.html.

Tip

A tool similar to Crack, but with more extensive checking and faster operation, is John the Ripper (`/usr/ports/security/john`). It can be very useful in conjunction with Crack or on its own.

Forcing Password Expiration

By default, passwords in FreeBSD do not expire. However, one common part of a secure password policy is to require users to change their passwords every so often, with the expiration interval chosen by you.

To do this in FreeBSD, you need to modify the /etc/login.conf file. This file controls system capabilities and behaviors, such as the number of allowed processes, the maximum allowed process size, the allowed number of simultaneous open files, and certain shell behaviors (learn more about this file in man login.conf). Each of these controls can be assigned to a "class" of users; you can assign users to classes with the chfn command (as you have seen in the "The /etc/passwd and /etc/master.passwd Files" section of Chapter 13, "Users, Groups, and Permissions"). By default, users aren't associated with any particular class, so the values in the default class apply to everybody:

[View full width]
```
default:\
        :passwd_format=md5:\
        :copyright=/etc/COPYRIGHT:\
        :welcome=/etc/motd:\
        :setenv=MAIL=/var/mail/$,BLOCKSIZE=K,FTP_PASSIVE_MODE=YES:\
        :path=/sbin /bin /usr/sbin /usr/bin /usr/games /usr/local/sbin /usr/local/bin /usr
   /X11R6/bin ~/bin:\
        :nologin=/var/run/nologin:\
        :cputime=unlimited:\
        :datasize=unlimited:\
        :stacksize=unlimited:\
        :memorylocked=unlimited:\
        :memoryuse=unlimited:\
        :filesize=unlimited:\
        :coredumpsize=unlimited:\
        :openfiles=unlimited:\
        :maxproc=unlimited:\
        :sbsize=unlimited:\
        :priority=0:\
        :ignoretime@:\
        :umask=022:
```

The backslash (\) characters "escape" the line breaks, allowing you to specify all these properties on different lines, thus keeping the file readable.

To set a password expiration date, you put an extra line into the default class, specifying the passwordtime property. The line can go into the block at any point, but the easiest place to add it is right at the top, between the class name and the first existing property line:

```
default:\
        :passwordtime=90d:\
        :passwd_format=md5:\
        :copyright=/etc/COPYRIGHT:\
        :welcome=/etc/motd:\
```

This example sets passwords to expire after 90 days. You can also use time values such as 2y (2 years), 6w (6 weeks), and 24h (24 hours). Now, because /etc/login.conf is a database that must be compiled into a hash table (as with the tables in /etc/mail, which you learned about in "Configuring Basic Email Services with Sendmail," in Chapter 25, "Configuring Email Services," and as with the /etc/master.passwd file and its corresponding hash table of user accounts), you must run the cap_mkdb program to generate the hash table and enable your changes:

```
# cap_mkdb /etc/login.conf
```

From now on, the login procedures will require users to choose a new password every 90 days. Note that when the passwordtime property is set, passwd writes the time of the last password change into the sixth field of /etc/master.passwd:

```
frank:$1$LXZkCuzD$7Oa8LyRf5jYOb.XrXiB3d.:1060:100::999066364:0:: /home/frank:/bin/tcsh
```

Tip

You can also use `login.conf` to alter the default minimum password length. This is done with the `minpasswordlen` value:

```
:minpasswordlen=8:\
```

This sets the minimum acceptable password length to eight characters.

Assigning Initial Passwords

When you're setting up a new user's account, it can be tempting to set a simple initial password, such as `Temp123` or `ChangeThis`. This seemingly innocuous practice, however, can seriously compromise your system's securityespecially if you use the same temporary password for every new user you add.

Fortunately, the `adduser` script provides you with the ability to assign randomly generated, nearly unguessable passwords to each new user you add to the system. In its default configuration, `adduser` will ask you during its questionnaire procedure what kind of password you want it to create; but you can specify that it should generate a random password for each user by adding the following line to your `/etc/adduser.conf` file:

```
passwdtype=random
```

Alternatively, invoke the `adduser` command with the `-w random` option. When you use either of these techniques, a run of the `adduser` program (as you saw in Chapter 13) ends with output similar to the following:

```
adduser: INFO: Successfully added (joe) to the user database.
adduser: INFO: Password for (joe) is: cwwqAuSpwd0rYG
Add another user? (yes/no): no
Goodbye!
```

There's little to no chance that a casual password-cracking program will guess the password `cwwqAuSpwd0rYG`. Now, however, your task is to make sure that Joe doesn't turn right around and set his password to "joe" or something equally trivial. One way to enforce this policy is to require onetime passwords that are good only for a single login session.

Tip

A tool for generating random passwords on demand is `pwgen2`, available in the ports in the `sysutils` category. It allows you to change users' passwords at any time, rather than just at user creation time, and gives you many flexible options for how the passwords should be created.

Onetime Passwords with S/Key

If you're really serious about password security, you can do what they do at government offices and super-secure businesses: You can assign onetime passwords to your users, shifting part of the security burden from your own shoulders onto those of your users. The idea is that each user gets a set of passwords (or a means to generate one on-demand), each of which are only good for a single login attempt. Onetime passwords are generated by the `key` program, which has variants on all major platforms, and there's even a platform-agnostic Java key calculator at http://www.cs.umd.edu/~harry/jotp/src.html. (FreeBSD uses MD4 for its calculations.)

When the user attempts to log in, the server presents him with a "challenge" phrase and a number. The user then uses the `key` program and those input values to generate a password for that one login attempt and enters that password. This password is then never used again; at the next login attempt, he must generate a new password using the new number presented in the server's challenge.

Onetime passwords are good candidates for use on systems in which you don't obligate your users to use SSH instead of Telnet (as we will discuss shortly). Because a new password has to be generated by the user with the `key` program on a local system, with the user feeding into it the server's challenge phrase and the user's own secret password, which is never transmitted over the wire (except during initial key setup), an eavesdropper can never get any useful data by sniffing the connection. Once the password is used once, it can't be used again. The user can transmit his onetime password in clear text without fear.

Note

S/Key is as much a tool for a security-conscious user as it is a way for the administrator to enforce good security practices. Many parts of S/Key setup (for example, the `keyinit` program) are the user's responsibility to maintain. If a user feels strongly about keeping her passwords private, she might choose to use onetime passwords, even if she has the option to do otherwise. However, this also means that a user is free to choose not to use onetime passwords if she doesn't have to.

Let's say you want to make it so that the user Frank cannot log in with his usual UNIX password from a remote host but instead must use S/Key onetime passwords. While logged in to the server (preferably securely, as with SSH), he must use the `keyinit` program to set up S/Key authentication:

```
# keyinit
Adding frank:
Reminder - Only use this method if you are directly connected.
If you are using telnet or rlogin exit with no password and use keyinit -s.
Enter secret password:
Again secret password:

ID frank s/key is 99 st28077
COL APT HELM TAB DRY TRIM
```

Note

If Frank is not securely connected to the server (as with a clear-text Telnet connection), he ought to use `keyinit -s`, which increases security by separating the `keyinit` and `key` steps. Without the `-s`, `keyinit` incorporates the `key` program into its own operation. Frank enters his secret key-generating password (which is used only for calculating S/Key onetime passwords and shouldn't be the same as his UNIX password) and transmits it over the network to the server. If the connection isn't secure, the secret password is susceptible to interception, making any further attempts at security moot.

If Frank uses the `-s` option, he must first use the `key` program locallyon his own Windows, Macintosh, or UNIX machineto generate a password without exposing his secret keygenerating password to the network. He then enters this password into `keyinit` at the `s/key access password:` prompt (which only appears if the `-s` option is used).

After Frank has used `keyinit` to set up his S/Key mechanism and has added an entry for his login to `/etc/skeykeys`, you must create the file `/etc/skey.access` (if it doesn't already exist) and add the following line:

```
deny user frank
```

The `/etc/skey.access` file tells FreeBSD under what conditions a remote user is permitted to use his regular UNIX password, and under what conditions he must use an S/Key onetime password. A line in `skey.access` specifies a rule beginning with `permit` (allowing either an S/Key or UNIX password) or `deny` (requiring an S/Key password), followed by as many conditions as you like. These conditions can specify certain users, groups, remote hostnames or networks, or login terminals (you can read a full description of the conditions in `man skey.access`). The sample line you just saw requires that when Frank tries to log in, only an S/Key password is permittednot his UNIX password.

The next time Frank uses Telnet to connect to your system, his login prompt will look like this:

```
# telnet stripes.example.com
Trying 64.41.131.102...
Connected to stripes.example.com.
Escape character is '^]'.

FreeBSD/i386 (stripes.example.com) (ttyp2)

login: frank
s/key 99 st28077
Password:
```

Note

As mentioned earlier, S/Key provides a way to make even clear-text Telnet logins secure. However, if you have a tight security policy, you should require your users to use SSH and disable Telnet logins altogether. If Frank were to use SSH to connect, the S/Key behavior would be the same as in the example, although the output lines would look somewhat different.

Frank must now use the `key` program (or its equivalent) on his own machine to figure out what password to enter. He has to feed into it the challenge information presented by the server: the iteration count (99 in this case, meaning that there are 99 logins left before Frank must run `keyinit` again), followed by the "seed" string (`st28077` here, the same as you saw in the `keyinit` example). These numbers, combined with Frank's secret password, generate an S/Key password made up of six short, uppercase English words:

```
# key 99 st28077
Reminder - Do not use this program while logged in via telnet or rlogin.
Enter secret password:
COL APT HELM TAB DRY TRIM
```

Frank now enters this string of words as his password and is granted access. An attacker, if he intercepted the words, would be out of luckthey only went across the wire once (on the way to the login prompt). The next time the system asks for Frank's S/Key password, the iteration number will be 98, and the password will be different. The iteration keeps counting down until it hits zero, at which time Frank must run `keyinit` again to set the counter back to 99; otherwise, he will be denied access and you'll have to get involved (by changing his rule in `/etc/skey.access` from `deny` to `permit` until he's reinitialized S/Key).

Tip

If he wants, Frank can generate multiple keys at once by using `key` with the `-n` option. He can then print out these keys and take them with him if that's more convenient or secure for him:

```
# key -n 5 50 st28077
Reminder - Do not use this program while logged in via telnet or rlogin.
Enter secret password:
41: SHOT YOU BIEN GIN JUDD AS
42: CHOW AVIS DOES EMIT FLAM WORK
43: DOCK ATE ANN WAS JOCK OAT
44: WALE AWL ELK LETS AWK WALE
45: GIFT BERT ROD GRIN YANG EAST
```

This practice is often observed by high-sensitivity employers such as defense contractors, where computers are isolated behind "air gaps" and their capabilities are highly restricted.

The S/Key password challenge is also issued as part of the `su` command, helping to prevent the actual root password from being transmitted over the network at any time.

To turn off S/Key for a user, remove that user's entry from `/etc/skeykeys` and any mention of him from `/etc/skey.access`.

Kerberos

One last authentication method that deserves mention is Kerberos. Developed as a centralized login-management system at the Athena cluster at MIT, Kerberos provides a way for users to authenticate with a central server on a network and be issued "tickets" for performing tasks such as Telnet, FTP, POP3, and NFS, without having to log in each time. As long as the hosts on your network between which you're running traffic support Kerberos and subscribe to the master server, the Kerberos subsystem takes care of all the authentication chores for you. FreeBSD allows you to set up a Kerberos master server to which other hosts in the network subscribe, or to simply support Kerberos in a network where it's already running.

Until fairly recently, Kerberos has been a scheme that was really useful only in legacy situations or at MIT. Its usefulness is in streamlining often-used tasks in large LANs, such as those found at universities or hierarchical enterprise networks, and there aren't many situations left where Kerberos is especially important in today's networking atmosphere. It's less a security measure than a way of eliminating unnecessary work in pure UNIX environments. However, because many enterprise networks use Kerberos to provide centralized, encrypted login services, and because Windows 2000/XP/2003's security model is largely tied together with Kerberos (albeit a somewhat modified version), it's once again becoming increasingly important and ubiquitous. You may need to set up your FreeBSD machine to integrate with it.

If you want to enable Kerberos in FreeBSD, you can do so. `kerberos_server_enable="YES"` in `/etc/rc.conf` will start up the services that manage a master Kerberos server; if you're working with an existing master server, you can uncomment the appropriate lines in `/etc/pam.conf` to enable centralized authentication for the services that support it. Here's an example:

```
login   auth    sufficient      pam_kerberosIV.so           try_first_pass
```

You can read more about Kerberos in the `man kerberos` page and in the online FreeBSD Handbook (http://www.freebsd.org/handbook).

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Avoiding Problems with Clear-Text Services

Transmissions between your client machine and the server (in applications such as Telnet, email, and HTTP) might seem secure to you; after all, your passwords are hidden, and everything travels in tiny packets of data that flow out onto the network along with many millions of other tiny packets. Who could have the patience to apply the networking equivalent of a wiretap and piece together the fragments of an interesting transaction?

They'd have to be on the same network segment as your LAN or the LAN at the opposite endor at some trunk service provider along the wayand they'd have to possess stealth and equipment befitting James Bond. And even if they did, they'd have to eavesdrop on many different such sessions in order to unearth anything they could use. Who could have that kind of spare time?

Anybody, that's who. Security in clear-text services (applications that don't encrypt, or scramble, their transactions) is a myth. Even more importantly, *security through obscurity*the notion that your communications or services are secure because you think nobody pays attention to themdoesn't work, as this myth has been proven wrong repeatedly over the years. Don't fall prey to the false notion that hackers aren't interested in cracking your system. You should always assume that your traffic is constantly being watched by a hacker with malicious intent.

Using `tcpdump` to Monitor Traffic

You can illustrate the risks inherent in your network's clear-text services by using a *packet sniffer*, a software tool that watches all packets on your network segment and displays the ones that interest you. A sniffer operates by putting your Ethernet card into "promiscuous mode," where it accepts all packets that it sees on the network, rather than discarding packets not addressed to it (for information on packets, see Chapter 22, "Principles of TCP/IP Networking"). The sniffer then applies all kinds of highly configurable filters to the traffic it sees. This is how an eavesdropper can extract the relevant packets from the storm of traffic to capture a transaction with ominous ease.

FreeBSD's built-in packet sniffer is `tcpdump`, available in `/usr/sbin`. Its use is barred to regular users, who get a `Permission denied` error on the `/dev/bpf0` (Berkeley Packet Filter) device; only the administrator (root) can use the program. The purpose of `tcpdump` is not to log the actual data of the TCP/IP packets it sees (you might want to look into `tcpflow`, available in the ports at `/usr/ports/net/tcpflow`, or the GUI-based Ethereal, available at `/usr/ports/net/ethereal`, for that functionality). Instead, `tcpdump` is much like Crack in that it's intended as an administrative security-auditing tool that allows you to see how much unencrypted traffic is being sent to and from your system, and to watch for suspicious network activity that might indicate illicit pursuits on the part of your users.

Note

It's possible to use `tcpdump` to spy on the activities of your users, regardless of whether they're doing anything wrong. A warning in the `GENERIC` kernel configuration file reminds you to consider the ethical issues involved with using a packet sniffer. It all depends on what kind of system you're running, naturally, but packet sniffers are the equivalent of telephone wiretaps or hidden security cameras, and you should use `tcpdump` only under circumstances in which you would be comfortable using wiretaps and hidden cameras to gather information.

The configuration of `tcpdump` is quite complex, and it allows you to do a lot of very useful and versatile things. All we're interested in right now, though, is demonstrating the dangers of clear-text TCP/IP traffic. Let's set up a simple monitoring filter on the Telnet port (TCP port 23):

[View full width]

```
# tcpdump -x port 23
tcpdump: listening on fxp0
20:14:19.076941 w044.z064002043.sjc-ca.dsl.cnc.net.54109 > w012.z064002043.sjc-ca.dsl.cnc.
   net.telnet: S 1972342903:1972342903(0) win 32768 <mss 1460,nop,wscale 0,nop,nop,timestamp
   465710 0> (DF) [tos 0x10]
                         4510 003c e44b 4000 4006 8024 4002 2b2c
                         4002 2b0c d35d 0017 758f 9077 0000 0000
                         a002 8000 001b 0000 0204 05b4 0103 0300
                         0101 080a 0007 1b2e 0000 0000
20:14:19.077050 w012.z064002043.sjc-ca.dsl.cnc.net.telnet > w044.z064002043.sjc-ca.dsl.cnc
   .net.54109: S 1734674412:1734674412(0) ack 1972342904 win 17520 <mss 1460> (DF)
                         4500 002c c9c2 4000 4006 9acd 4002 2b0c
                         4002 2b2c 0017 d35d 6765 07ec 758f 9078
                         6012 4470 349c 0000 0204 05b4
...
20:14:19.677472 w044.z064002043.sjc-ca.dsl.cnc.net.54109 > w012.z064002043.sjc-ca.dsl.cnc.
   net.telnet: . ack 195 win 33580 (DF) [tos 0x10]
                         4510 0028 e458 4000 4006 802b 4002 2b2c
                         4002 2b0c d35d 0017 758f 910a 6765 08af
                         5010 832c 0c49 0000 5555 5555 5555
^C
134 packets received by filter
0 packets dropped by kernel
```

The `x` option tells `tcpdump` to output the first part of each packet's payload in hexadecimal; if this option is omitted, `tcpdump` only outputs the link-level headers. You may want to use `w` *"filename"* to send `tcpdump` output into a file so that you can peruse it more easily.

Because `tcpdump` is not designed as "spyware," it does not decode the hexadecimal output for you. You can, if you wish, convert it to plain human-readable text with a hex editor such as `/usr/ports/editors/hexedit`. However, if you're interested in the contents of the packets, you will want to use a different program (such as `tcpflow` or Ethereal).

Adding Extra Security with Encrypted Protocols

The `tcpdump` data isn't encrypted at all. It only takes a little bit of effort to be able to see the complete contents of every packet sent via Telnet. It's even easier with tools that do the packet decoding for you, such as `tcpflow`, `tcpshow`, and Ethereal. If these packets contain a user's login session, an attacker using any of these programs would know the user's login password and could use it to log in to your system. This security gap endangers POP3, IMAP, FTP, and HTTP traffic, too, as well as just about every small and nonessential service, such as Finger and Syslog. Safeguarding against the use of these sniffer programs is especially important in systems where passwords or any other sensitive data is transferred. Protecting communications is as much a privacy issue as it is a security concern.

Fortunately, there's a way to combat the problems of sniffer programs. You can use an encrypted alternative to any of the major data-transfer protocols, many of which are part of the default FreeBSD installation. For instance, SSH (Secure Shell) is a secure alternative to Telnet, and SSL (Secure Sockets Layer) is a method for encrypting web traffic, email, and other services. Sealing the security holes inherent in clear-text services is only a matter of knowing the encrypted versions exist, implementing them, and convincing your users to adopt them.

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Securing Terminal Traffic (SSH)

Terminal traffic, which is typically from the Telnet or `rlogin` application, is a result of remote users interacting with UNIX systems; you are probably accustomed to connecting to your FreeBSD machine remotely both to use it and to perform your administration duties. However, terminal use is probably the riskiest type of clear-text trafficand it's the easiest to fix. FreeBSD comes with a complete SSH (Secure Shell) package designed to supplant Telnet and `rlogin`. The SSH package is called OpenSSH, and it was developed originally for OpenBSD. OpenSSH allows users to establish a completely encrypted tunnel to your server, protecting their login passwords and any command-line activity from snooping intruders.

The SSH server, `sshd`, runs on port 22 as a standalone daemon that, like Apache, spawns off new `sshd` processes when new connections come in. To enable the SSH server, add the following line to `/etc/rc.conf` (if it's not already there) and then reboot (or simply type **`/etc/rc.d/sshd start`**):

```
sshd_enable="YES"
```

The SSH client is a replacement for Telnet. To use it instead of the command-line `telnet` program, issue the `ssh` command instead of the `telnet` command:

```
# ssh stripes.example.com
```

Instead of letting the server issue its own `Login:` and `Password:` prompts, the SSH client itself prompts for your password, assuming the remote username is the same as the local one. You can specify an alternate username with either of a couple of different methods:

```
# ssh stripes.example.com -l frank
# ssh frank@stripes.example.com
```

The `ssh` program establishes the encrypted connection and passes the login data to the server in a secure fashion. From that point on, it acts just like a regular Telnet connectionthere's no difference as far as the user is concerned. A user on a FreeBSD, Linux, UNIX, or Mac OS X system can use this process to connect to your machine.

Users on desktop client systems such as Windows or classic Mac OS have a little bit more work to do. These platforms have no command-line SSH client programs, but there are some excellent graphical terminal programs that incorporate both Telnet and SSH functionality: Windows users have the commercial SecureCRT (from Van Dyke, http://www.vandyke.com) or the freeware PuTTY (by Simon Tatham, http://www.putty.nl), and Mac OS 9 users can use NiftyTelnet/SSH or MacSSH.

Your task lies in convincing your users to switch to SSH rather than using Telnet. Let them all know via your published server policy that they are advised to use SSH to protect themselves at their option; however, this doesn't guarantee they will use it, and you as the administrator are still faced with the threat of an attacker who sniffs the connection of someone who has chosen not to use SSH. A more heavy-handed but complete approach is to disable Telnet entirely and require your users to use SSH instead. To disable Telnet, comment out the `telnetd` line from `/etc/inetd.conf`:

```
#telnet   stream   tcp     nowait   root    /usr/libexec/telnetd    telnetd
```

Then, restart the `inetd` process:

```
# /etc/rc.d/inetd restart
```

Note

SSH has two popular protocol flavors: SSH1 and SSH2. FreeBSD supports both, but SSH1 is less well designed and potentially more likely to exhibit security vulnerabilities than SSH2. You can disable SSH1 by adding the following line to `/etc/ssh/ssh_config`:

```
Protocol 2
```

However, note that not all consumer SSH clients have full support for SSH2. Don't worry about disabling SSH1 unless you have to.

Tip

Even if you disable the Telnet service in inetd, regular users can still launch the `telnetd` program themselves; because of this, you might want to remove `telnetd` from the system completely if you have a strict security model.

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Securing Email Services (POP3 and IMAP)

POP3 and IMAP are arguably even more vulnerable to clear-text security risks than Telnet. If your users have set their email clients to connect to the server every five minutes or so to check for new messages, a plainly visible login and password transaction occurs with each one of these connections, resulting in an even higher likelihood of password compromisesespecially because these services send their sensitive data at predictable, regular intervals. If you're enforcing SSH rather than Telnet on your server, it's in your interest to do the same for your email services.

You learned in Chapter 25 how to secure the Qpopper program to use the built-in SSL tools in FreeBSD to encrypt POP3 connections. You can use the same method to secure IMAP, employing the IMAP-UW software package. You can enable SSL support in IMAPUW by generating a certificate with a Certifying Authority (as you learned in "Enabling SSL Encryption," in Chapter 25). If you have a certificate generated for a different service (Qpopper, for example) on your site, you can use the same certificate for IMAP-UW. Refer to the IMAP-UW documentation at http://www.washington.edu/imap/ for more details.

The `stunnel` program provides an alternative way to encrypt both POP3 and IMAP. `stunnel` manages your SSL certificates centrally and doesn't use each service's built-in SSL support. Also available in the ports (`/usr/ports/security/stunnel`), `stunnel` allows you to set up a universal SSL tunnel for any service on the system that you choose. If you install `stunnel` from the ports, its default startup script (`/usr/local/etc/rc.d/stunnel.sh.sample`) starts a listener process on port 993 (for IMAP) and 995 (for POP3), which are the generally accepted ports for the secure versions of these protocols, as you can see in `/etc/services`.

Note

Remember to rename `stunnel.sh.sample` to `stunnel.sh`, as you learned in the section titled "Resource Configuration Scripts," in Chapter 14, "System Configuration and Startup Scripts." The `.sample` suffix is there to make sure you look at the script's contents to ensure the paths to the `.pem` certificate files are correct.

If you choose to use `stunnel`, you'll still have to generate a certificate, just as you do with Qpopper and IMAP-UW. The `stunnel` certificate should be placed at `/usr/local/etc/stunnel.pem`. When it's in place, your POP3 and IMAP clients should be able to connect to the appropriate ports to establish a secure connection (993 instead of 143 for IMAP, and 995 instead of 110 for POP3).

Caution

Many of the popular email client programs, such as Microsoft Outlook and Apple Mail, support SSL encryption for POP3 and IMAP, but others have support for only one of the two, or neither. In other email client programs, such support is incomplete or optional. Requiring users to use SSL might mean requiring them to switch email programs, something not many people like to do.

Also, note that `stunnel` is not a replacement for POP3 or IMAP. Rather, it's an augmentationthe generalized addition of SSL capability to any specified service. This means that the regular POP3 and IMAP services must still be enabled; you can't remove these services from `/etc/inetd.conf`. You'll need to use IPFW (as you will see later in this chapter) to disallow connections to these ports from any host other than `localhost` if you want to enforce a "secure connections only" policy.

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Securing FTP

FTP, as you learned in Chapter 27, "Configuring an FTP Server," is another clear-text service that has inherent password authentication and therefore has the potential to be compromised by an attacker watching the wires. FTP is used frequently by users to do things such as uploading web pages, but it isn't used at predictable, regular intervals like POP3 or IMAP. This makes FTP a bit less risky to your system than Telnet, but still worth securing.

Fortunately, secure FTP is just as easy to implement as SSH. If you've enabled SSH (as you learned to do in "Securing Terminal Traffic (SSH)," earlier in this chapter), secure FTP is available to your system. Encrypted FTP sessions actually operate over the SSH channel, with the SSH client establishing a terminal connection, starting the `/usr/libexec/sftp-server` program on the server end, and opening the necessary connections back to the client over encrypted channels. The secure FTP client then operates transparently to the user, just like a regular FTP program.

On FreeBSD, the built-in `sftp` program that's a part of OpenSSH serves the purpose of handling the client end of a secure FTP session. On Windows, the SSH Communications Security package provides a secure FTP client that works with FreeBSD. The previously mentioned Mac OS clients (NiftyTelnet and MacSSH) also have secure FTP capabilities, and Mac OS X has the command-line `sftp`.

Secure FTP isn't as configurable as regular FTP, and it doesn't use any of the standard configuration files that the built-in FTP server uses. Instead, you need to use the same configuration file for secure FTP as you would use for SSH: `/etc/ssh/sshd_config` (see `man sshd_config` for details). If, for example, you want to deny certain users access to FTP, you need to use the `DenyUsers` statement, which blocks specified users from accessing the system through secure FTP *or* SSH:

```
DenyUsers frank joe
```

Note

Anonymous FTP is also not supported in the secure FTP model. However, because the major reason for encryption is to prevent the passwords of your system's login users from being exposed in clear-text, there really isn't much point to encrypting anonymous FTP, which has no passwords or linkage to your local users.

Note

Secure FTP (SFTP) is subtly different from FTPS, a similar solution for securing FTP traffic. Refer to http://www.ford-hutchinson.com/~fh-1-pfh/ftps-ext.html for details on the differences.

An alternative way to perform file transfer over a secure channel is to use `scp`. This enables you to copy files to and from a remote server using login authentication, much in the same way that `rcp` works (see `man rcp` and `man scp` for details), except that `scp` operates via the encrypted SSH tunnel.

To use `scp` to transfer a file from your local machine to a remote SSH server, use a command like the following:

```
# scp file.txt stripes:
frank@stripes's password:
```

```
file.txt              100% |******************************|  511       00:00
```

The remote hostname is specified with a trailing colon (`:`) and can be either the source or destination argument. Either of these arguments can also contain full pathnames to the file's location (for example, **`scp file.txt stripes:public_html/textfiles`**). Using `scp` is a quick way to transfer files securely if you don't need all the features of full-fledged FTP. You can even perform recursive fetches, making `scp` a handy tool for transferring whole directory structures.

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Securing Apache

HTTP, the protocol over which the Web travels, is probably the most visible service on the Internet today, and more and more sensitive information is being sent over the Web with each passing day. Secure HTTP is vitally important to e-commerce, because it protects clients' credit card numbers and billing informationconsiderably more critical, especially to home Internet users, than protecting login names and passwords. Secure HTTP is especially important if your business depends on your clients' confidence in the privacy with which you handle their information. FreeBSD's flagship HTTP server, Apache, must be secured if you intend to use it for any kind of commercial or privacy-sensitive purpose.

Securing HTTP was one of the earliest widespread uses for SSL. Until recently, integrating Apache with SSL was a matter for commercial software vendors who developed products based on Apache, and there were comparable but competing versions of SSL-enabled Apache available for free. However, since the release of Apache 2.0, SSL is integrated into the software in the default installation, and enabling it is a much simpler matter. However, for the benefit of users who might still be using Apache 1.3 or earlier, we will cover the SSL implementations designed for that version.

Note

Secure and clear-text HTTP are intended to operate side by side. It's not a good idea to serve all HTTP requests through SSL, and rarely is it done. High-traffic websites would suffer a speed impact from the processing overhead of encrypting every page and image regardless of whether it contains sensitive information, and convenience and convention discourage the practice. Most public web data has no need for encryptionafter all, it's public. But switching to secure mode when a customer enters an online purchasing page or information-gathering form helps to provide your web users with assurance that they're now in a more heavily protected area. Remember, you're serving the user's expectations and confidence as much as the user's data.

Apache-SSL

Apache-SSL is the "official" secure implementation of Apache prior to version 2.0. Apache-SSL has a more limited feature set than `mod_ssl`, being primarily concerned with stability and performance rather than with advanced features. Development on Apache-SSL is not very active these days, largely because of the tightly controlled feature set and the lack of known bugs.

The Apache-SSL binary is called `httpsd` rather than `httpd`; the idea is that you would run a regular `httpd` to serve regular HTTP requests on port 80, and `httpsd` to handle encrypted requests on port 443. Of course, this means you would have to have a version of Apache without SSL installed as well to accomplish this.

You can install Apache-SSL from the ports at `/usr/ports/www/apache13-ssl`, and the official website is http://www.apache-ssl.org.

Apache with `mod_ssl`

`mod_ssl` is a more complete and active implementation of SSL on HTTP than Apache-SSL. `mod_ssl` is a standard Apache module that links OpenSSL into Apache, taking advantage of the modern modular architecture of the software. It's more streamlined than Apache-SSL, and it incorporates many more features and a more versatile configuration model. The `apache13-modssl` port installs a single `httpd` executable, for example, just like the regular `apache13` port, except that the configuration files have special tuning to enable SSL connections when requested:

```
<IfDefine SSL>
Listen 80
Listen 443
</IfDefine>
```

You can add further modules to Apache with mod_ssl; these include mod_perl, mod_php, and all the rest in /usr/ports/www. The focus of mod_ssl is a rich and complete feature set and easy configurability; it's not necessarily as fast or robust as Apache-SSL, but statistics on this are scarce.

In Apache 2.0, mod_ssl is compiled into the httpd binary by default, and the configuration options for it are given in the basic configuration file /usr/local/etc/apache2/ssl.conf, which you can incorporate into your httpd.conf as necessary.

Apache with mod_ssl can be installed from /usr/ports/www/apache13-modssl; the official website is http://www.modssl.org.

Running a Secure Web Server

Installing either Apache-SSL or Apache with mod_ssl makes maintaining your web server a little more complex. As mentioned earlier, Apache-SSL operates under the assumption that you will run a regular httpd to handle regular clear-text HTTP connections, and httpsd for encrypted requests on port 443. This means that a separate httpsdctl program controls Apache-SSL, operating the same way as apachectl with the regular Apache. Furthermore, an httpsd.conf program is added to /usr/local/etc/apache in parallel with httpd.conf. These separate programs aren't present if you install Apache with mod_sslthe functionality is rolled into a single set of files (you saw these files in Chapter 26, "Configuring a Web Server").

The ports (both apache13-ssl and apache13-modssl) install complete Apache directory treesincluding icons, sample HTML pages, dynamic modules, and configuration files. For this reason, you must take care when updating the parallel installations of Apache-SSL and regular Apache. The mod_ssl version only has a single installation, replacing the standard Apache installation, so the maintenance is potentially much simpler.

Managing Your OpenSSL Certificates

Create your OpenSSL certificates, again using the method you learned in "Enabling SSL Encryption" in Chapter 25. Note that mod_ssl expects to find its certificate in /usr/local/etc/apache2/ssl.crt/server.crt and its private key in /usr/local/etc/apache2/ssl.key/server.key. You can adjust the directives in your Apache configuration file, which specify those files to point to the location of your existing systemwide security certificates. Alternatively, be sure to place copies of those cert files into the locations that Apache expects.

Your OpenSSL certificates are read much more interactively by a web browser than by other secure services, so you must take special care to be sure that the certificates match reality. If the hostname in the certificate doesn't match the server's hostname or if the certificate isn't signed by a recognized Certifying Authority (in other words, if it's selfsigned), the user gets a dialog showing all the information about your certificate and asking for confirmation on whether the browser should accept it. This dialog can bewilder your users and undermine their confidence in your site's security.

Even if your certificate matches your site's information properly, the user can view the certificate's contents through a web browser's Security Information feature, so all the fields you specify when generating the certificate request will be visible to any interested party. Bear this in mindit's fairly difficult to change the information on a certificate once it has been signed.

Poorly Written CGI Scripts

Clear-text traffic isn't the only potential security hole in an Apache installation. If your security model is one where you don't necessarily trust your local users, you should be equally concerned with the possibility of users' CGI scripts running amok on the system (whether intentionally or accidentally) and destroying files.

Many files in Apache's document root are owned by the `www` or `nobody` user (especially files created dynamically by your own server-side programs); the same `www` user executes every user's CGI programs as well. Given those facts, it's a simple matter for a user CGI program to be able to delete or modify anything else on the server owned by `www`.

It's easier than you might think for this to happen. All it takes is for a user to design a CGI program to remove her own unneeded files, but to mistakenly code the program to prepend the wrong path to the filenames. The same might happen in a program that prints data out into a file, potentially corrupting other users' data. Even the most seasoned CGI veterans have fallen prey to this trap. The danger is naturally much higher if you have a malicious user on your system who decides intentionally to write a destructive script to be executed by Apache as `www`.

The solution to this problem is to run Apache within a "wrapper" program that intercepts user CGI programs, performs security checks on them (making sure the permissions are appropriate), and executes them as the users who own them rather than as `www`. This has traditionally been done with the `suexec` wrapper that comes with Apache, but an easierto-use and more flexible solution is CGIWrap, by Nathan Neulinger.

Making CGI Scripts Safer with CGIwrap

CGIWrap, available in the ports at `/usr/ports/www/cgiwrap`, provides two security advantages: It protects users and the server root from attack by poorly written CGI scripts, and it also enables users' CGI programs to write files that the users themselves can modify or delete in the shell.

In an ideal world, where programs are always written perfectly and nobody tries to sabotage others' files, a user CGI program would be executed by the user who owns it, rather than by the unprivileged `www` user. However, it's not an ideal worldpeople write buggy CGI scripts, and hackers abound. It's a fairly simple matter for a user to create a CGI program owned by root, put it in his directory, and wait for it to be executed as the owner (the super-user), unleashing its destructive payload against any files in your system.

CGIWrap protects your system against such problems. It's not a complete or ideal solution, but it reduces the security risks associated with user CGI scripts so that you can put your administrative efforts elsewhere. By running security checks against all user CGI programs before executing them, and by running each program as its owner, CGIWrap shifts the risks inherent in a badly written CGI from you onto the script's owner.

When you install CGIWrap from its port directory, the `cgiwrap` program (a precompiled binary) goes into your top-level `cgi-bin` directory, `/usr/local/www/cgi-bin`. Rather than operating as a wrapper around Apache itself as `suexec` does, CGIWrap has to be called explicitly by your users, with a URL of the following form:

```
http://www.example.com/cgi-bin/cgiwrap/frank/myscript.cgi
```

Or as a server-side include:

```
<!--#include virtual="/cgi-bin/cgiwrap/frank/myscript.cgi"-->
```

This executes the `myscript.cgi` program in `/home/frank/public_html/cgi-bin`. All of a user's CGI programs must go inside his or her `public_html/cgi-bin` directory, which the user needs to create if it doesn't exist already.

Tip

CGI programs outside the user's `public_html/cgi-bin` directory will not be run through CGIWrap, so it's important that you disable CGI execution outside the server `DocumentRoot`. To do so, make sure you don't have an `Options +ExecCGI` directive in a block that defines your users' directories, and make sure users can't override that setting with `.htaccess` files (make sure `AllowOverride Options` is not set for `/home`).

The official CGIWrap home page is at http://cgiwrap.UNIXtools.org/, for further reference.

Preventing SMTP Relaying

It can be construed as a security weakness for your Sendmail server to be open for anybody to send mail through it. These days, an open mail relay is almost synonymous with a mail server that's being used by spammers to broadcast junk mail, and that constitutes a theft of your services. Furthermore, you're subject to a form of denial of service if other mail service providers add your host to a "blackhole" lista list of banned remote addresses with which they refuse to exchange any mailas a result of your server being an open and unprotected mail relay.

It is critical to configure Sendmail so that your own legitimate users and their correspondents can continue to use your SMTP server, but unauthorized spammerswho want to send mail that neither originates on nor is destined for your servercannot. You can find a full description of how this can be achieved in the "Understanding Relaying" section of Chapter 25.

PREV NEXT

PREV NEXT

System Security Profiles and Kernel Security (Securelevels)

Prior to FreeBSD 5.0, FreeBSD was configured to provide a layer of security over its kernel and user process with a mechanism called Securelevels. You chose a `securelevel` setting at the time you installed FreeBSD, and it enforced protections such as setting the "immutable" flag on the kernel such that even root couldn't delete or overwrite it.

Securelevels have, unfortunately, been proven to be ineffectual (details are at http://www.securiteam.com/unixfocus/5NP0G0AHFC.html), and the `securelevel` setting has been removed from the standard installation and system configuration procedures in modern versions of FreeBSD. However, the functionality of Securelevels is still present in FreeBSD, and you can still enable it if you want; you might also be responsible for maintaining a legacy FreeBSD system that was configured with what protection Securelevels does provide, which means you need to understand how the feature interacts with your system's operation. This section explains the concepts behind Securelevels for the benefit of such users.

The Mandatory Access Control (MAC) Framework

The phasing out of Securelevels should not be construed to mean that FreeBSD has been made less secure. Rather, users are encouraged to use Mandatory Access Control (MAC) labels, a much more fine-grained and flexible security scheme that allows the administrator to assert a high level of control over users' access to system resources such as files, sockets, and processes.

The configuration of MAC labels, however, is extremely complex and requires a great deal of disciplined study; it's beyond the reach of a book where security is tackled only as a single chapter. If your security needs demand that you work with the MAC framework, a full course in its use can be found in the FreeBSD Handbook, at http://www.freebsd.org/handbook/mac.html.

The FreeBSD kernel runs with five different levels of security, controlled by the `kern_securelevel` option in `/etc/rc.conf`levels 1 through 3. Each of these settings corresponds to a profile that controls such things as whether the kernel can be replaced on the disk, whether kernel modules can be loaded or unloaded, whether certain file permissions and flags can be set or altered, and whether filesystems can be mounted on demand. The profile also controls whether utilities such as the IPFW built-in firewall can be disabled or modified (you learn more about IPFW later in this chapter). As you learned in Chapter 18, "Kernel Configuration," you can raise the `securelevel` setting only during runtimeyou can never lower it, except by rebooting. More information on kernel security can be found in `man securelevel`.

During installation, you saw a second multilevel network security profile set in FreeBSD. You can see it again in Sysinstall, under Configure, followed by Security. This menu allows you to choose one of two different systemwide security profiles: Medium or Extreme. These profiles control whether services such as Sendmail, `sshd`, and `inetd` should be run, and they also have a very rough correspondence to the kernel security levels. Table 30.1 shows a breakdown of each of these security profiles and what options each sets in `/etc/rc.conf`. The table also includes the Low and High security profiles, which existed until FreeBSD 4.6; if your system was originally installed with an earlier version, you will probably see all four profiles.

Table 30.1. Systemwide Security Profiles

Profile Name	`/etc/rc.conf` Settings

Low	`sendmail_enable="YES"`
	
	`sshd_enable="YES"`

	`portmap_enable="YES"`
	`inetd_enable="YES"`

Medium	`sendmail_enable="YES"`
	`sshd_enable="YES"`
	`inetd_enable="YES"`

High	`kern_securelevel="1"`
	`kern_securelevel_enable="YES"`
	`sendmail_enable="YES"`
	`sshd_enable="YES"`
	`portmap_enable="NO"`
	`nfs_server_enable="NO"`
	`inetd_enable="NO"`

Extreme	`kern_securelevel="2"`
	`kern_securelevel_enable="YES"`
	`sendmail_enable="NO"`
	`sshd_enable="NO"`
	`portmap_enable="NO"`
	`nfs_server_enable="NO"`
	`inetd_enable="NO"`

As you might expect, the Extreme profile is restrictivealmost to the point of making the system unusable. The kernel `securelevel` is set to `2`, meaning that the kernel can't be modified (with kernel modules) or replaced without rebooting into single-user mode; the only way to mount or unmount filesystems is explicitly with the `mount` and `umount` commands (implicit, on-demand mounting, as with `amd`, is not allowed). Additionally, `inetd`, Sendmail, `sshd`, the NFS server, and other services are not enabled.

The High profile is a little less restrictive, with a `securelevel` of `1`, meaning that filesystems are more easily mountable but the kernel still cannot be modified. Sendmail and `sshd` are enabled, but the rest of the services from the Extreme profile are not.

Of course, because the security profiles work purely by setting options in `/etc/rc.conf`, you can mix the settings from Table 30.1 to your taste, creating a security profile that fits the model by which you're running your system.

Caution

Generally, you should never enable a service that you don't think you'll need. If it doesn't serve a useful purpose for you, it is at best useless; at worst, it offers a security vulnerability that opens your system up to security breaches. Therefore, you should play it safe wherever possible.

Using a Firewall

It's undeniable that *firewalls* (machines that operate as routers with filters) are almost indispensable to Internet server maintenance. Bored "script kiddies" with nothing better to do than to try to break into systems with easily accessible hacking tools make it imperative that you protect your system. Most administrators need protection that goes beyond simply electing not to run certain services and keeping on top of security bulletins. You need a generalized shield at the kernel level that prevents your system from being accessed at all on certain ports, from certain hosts, or over certain protocols. Firewalls, particularly the IPFW firewall that comes with FreeBSD, provide an answer to this need.

A firewall can prevent the vast majority of casual attacks by only allowing traffic that you designate as valid to enter your system. Even the most expensive and robust firewall, however, can be made useless through a simple misconfiguration. Most ineffective firewalls are made that way through misconfigurations rather than poor quality or design.

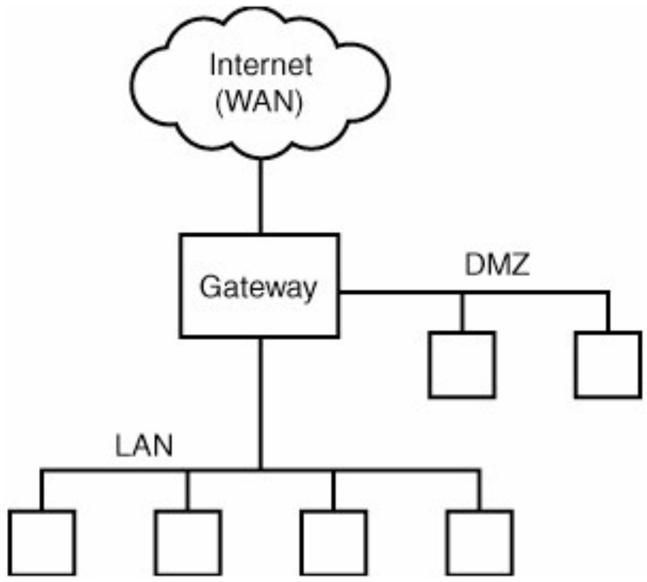
Caution

There is no substitute for a properly designed and well-maintained security policy used in conjunction with a competent firewall; don't be fooled into thinking that if you just buy a more expensive firewall, your network security problems are solved. That's the type of thinking that leads to a great many security breaches on the Internet today.

A firewall enables you to configure your system to filter packets based on the criteria you specify, discarding unwanted traffic at the kernel level (before it reaches any critical system services). Firewalls also help you with administrative accounting, keeping statistics on the usage of your system and seeing how much traffic comes from where.

IPFW does both of these things; you can run it directly on your FreeBSD machine, or you can use it on a system acting as a gateway router protecting multiple hosts on the inside LAN. Figure 30.1 shows this latter case, with a FreeBSD machine with three Ethernet cards acting as a gateway router (as you saw in Chapter 28, "Configuring an Internet Gateway"), passing packets between the inside (LAN), "demilitarized zone" (DMZ), and outside (WAN) networks (you learned about gateway routers in Chapter 28).

Figure 30.1. A diagram of a gateway router providing firewall services, showing the LAN, DMZ, and WAN interfaces.



Note

The "demilitarized zone," or DMZ, is a network that is exposed to the WAN traffic directly, rather than being on the LAN. A DMZ is particularly useful in cases where the IP addresses on the LAN are translated (as you learned in "IP Addresses," in Chapter 22). A DMZ provides an enterprise or ISP with a network on which to place untranslated "edge" machines such as web servers, mail gateways, and other hosts that need to be accessible from the general Internet.

A DMZ may or may not be configured to be protected by the firewall rules in the gateway router. Usually this is desirable, but some specialized cases require that the DMZ be exempt from the LAN's firewall rules. Your network situation will dictate your needs.

Enabling the Firewall

IPFW is not supported in the `GENERIC` kernel. You can compile certain options into a custom kernel to enable IPFW, including `IPFIREWALL`, `IPFIREWALL_VERBOSE`, and `IPFIREWALL_VERBOSE_LIMIT=10`. You don't need to build a new kernel, however, in order to use IPFW; it's available as a kernel module, which is loaded automatically by the `/etc/rc.network` script. To enable the firewall without rebuilding the kernel, add the following lines to `/etc/rc.conf`:

```
firewall_enable="YES"
firewall_type="open"
```

The second line is optional, and not recommended for highly secure networks. If you don't specify that the firewall type should be `open`, the only rule that IPFW will start with is the default one, with an index of 65535 (the maximum), specifying `deny ip from any to any`. In other words, if you reboot with IPFW in its default configuration, your machine will be completely blocked off from the network, and you'll have to have physical console access to it in order to get it back. For maximum security, it's best to leave the firewall in this configuration, and then add specific rules to allow traffic from certain hosts and on certain ports.

Caution

It's dangerous to experiment with IPFW if you don't have console access, because it's very easy to put your machine into an unreachable state. Until you are comfortable enough with IPFW to know exactly what you're doing, always make sure you can access the machine via the console in case something goes wrong.

If you do end up blocking your machine from the network through experimentation with IPFW, the only way to recover is to go to where the machine is physically located and log in from the console. From there, you can disable IPFW by removing the lines in `/etc/rc.conf`, or you can configure it properly and reboot.

One trick to prevent falling into this trap is to set up a `cron` job to turn off the firewall every five minutes (**`/etc/rc.d/ipfw stop`**); enable this automated command as a "safety net" whenever you experiment with the firewall. That way, if you end up locking yourself out, you just need to wait five minutes and the system should become available again.

The `open` setting changes the default rules so that IP traffic is passed (allowed) by default, rather than blocked. Blocking traffic by default creates a truly secure system, but it can be excessively restrictive for systems that exist within a secure environment. At the same time, allowing traffic by default (blocking only specified IP traffic) eliminates the possibility of having complete system security. Use the `open` setting if your system is in a network that's already behind a firewall; you probably don't need to apply the same kind of protection twice.

After your `/etc/rc.conf` is set up properly, reboot. Alternatively, you can issue the **`/etc/rc.d/ipfw start`** command from the physical console (not from a remote terminal, which is *very* dangerous because it can cause your machine to lose network connectivity and become inaccessible). You will know the firewall has been enabled properly if you see the following lines:

```
Kernel firewall module loaded
Flushed all rules.
00100 allow ip from any to any via lo0
00200 deny ip from any to 127.0.0.0/8
00300 deny ip from 127.0.0.0/8 to any
65000 allow ip from any to any
Firewall rules loaded, starting divert daemons:.
```

You can also use `kldstat` to check whether the IPFW module has been loaded automatically:

```
# kldstat
Id Refs Address    Size    Name
 1    3 0xc0100000 355be4 kernel
 2    1 0xc0eee000 6000    ipfw.ko
 3    1 0xc0f19000 12000   linux.ko
```

You now have full access to the `ipfw` command, which lets you set rules on what kinds of traffic to allow and view the accounting information accumulated by IPFW.

Designing IPFW Rules

The `ipfw` command is used to either add or delete rules from the kernel filter and accounting system. The rules are constructed in a syntax that flows somewhat like natural English; it's made up of an action (such as `deny`), a protocol to which the action applies (such as `tcp`), and an address specification involving a `from` clause and a `to` clause. A rule such as `deny tcp from badhost.com to any`, for example, blocks TCP traffic from a host called `badhost.com`. You would add this rule to the kernel firewall like this:

```
# ipfw add deny tcp from badhost.com to any
```

A number of variations on this theme are possible. You can specify an address based on a network mask either with a mask pattern (for example, `255.255.255.0`) or with a CIDR bit-mask (for example, `/24`). You can also block individual ports rather than an entire system; this technique prevents hosts within a large ISP with unpredictable IP addresses from targeting a single service on your machine. Such a rule might look like this:

```
# ipfw add deny all from evil.isp.com/16 to www.example.com 80
```

Similarly, you can exempt hosts from earlier rules by adding `allow` rules as exceptions, like so:

```
# ipfw add allow all from goodhost.evil.isp.com to www.example.com 80
```

More usefully, you can block or allow traffic from any external host based on the TCP or UDP port it uses. For example, you might choose to allow only web and email traffic to reach the server, using TCP ports 80 and 25 respectively:

```
# ipfw add deny tcp from any to www.example.com

# ipfw add allow tcp from any to www.example.com 80

# ipfw add allow tcp from any to www.example.com 25
```

Note that IPFW rules are entered in a "chain," in which each rule is evaluated in the order it was specified. Each rule has an index number, normally spaced by 100 from its neighbors, which you can control by specifying the index number after the `add` or `deny` keyword in an `ipfw` command; this is how you can indicate the execution order of your rules. View the existing rule set with `ipfw -a list`:

```
# ipfw -a list
00100    0      0 allow ip from any to any via lo0
00200    0      0 deny ip from any to 127.0.0.0/8
00300    0      0 deny ip from 127.0.0.0/8 to any
00400    0      0 deny tcp from badhost.com to any
00500    0      0 ipfw add deny all from evil.isp.com/16 to www.example.com 80
00600    0      0 ipfw add allow all from goodhost.evil.isp.com to www.example.com 80
65000 1214  79688 allow ip from any to any
65535    1     40 deny ip from any to any
```

The index number is shown in the first column; the number 65535 rule, as you saw earlier, is the default `deny` rule that rejects anything that falls through from above. The `open` setting puts an `allow` bucket above the `deny` rule; however, the `allow` rule has a high index number to help ensure that it comes after any other rules that you might add through regular usage.

The second and third columns show usage statistics, displaying the total number of packets and bytes that have matched each rule, respectively. This is how you can tell whether your rules are being effective.

Troubleshooting IPFW

You might find that what you think is a very straightforward configuration results in completely unpredictable results. For instance, you might have added a `deny` rule for all hosts and an `allow` rule for your own remote machine's IP address, but you find you still can't access the FreeBSD machine.

Always remember that IPFW rules are specified and applied in subsequent order. A rule that comes later in the list supersedes a rule specified earlier in the list; a packet is compared against each rule in the order specified by the index number. In most cases (although it depends to a certain extent on the action taken and the system settings), the packet continues to be checked against further rules that might match in a more specific manner; this is how "exception" rules work. However, the "default" rule, with index 65536, only matches packets that match no other rules.

Make sure your index numbers apply the rules in increasing order of specificity. To make configuration easier, consider using a firewall configuration file, as we'll discuss shortly.

You can specify a number of different firewall types in `/etc/rc.conf`. Each keyword has a different meaning, as shown in Table 30.2. The exact definitions of these profiles can be deciphered from the shell script code in `/etc/rc.firewall`.

Table 30.2. Available Firewall Types

Keyword	Meaning
`open`	Allows access to all, from all
`closed`	Disables all IPs except on the loopback (`lo0`) interface
`client`	Sets up rules designed to protect just this machine
`simple`	Sets up rules designed to protect the whole network
`UNKNOWN`	The default; loads no rules except for the default `deny` rule at index 65535
`filename`	Loads rules from *`filename`*

For your purpose, if your setup is uncomplicated, a "canned" IPFW profile such as `client` or `simple` might be appropriate. However, you're likely to need a specialized configuration as your system continues to evolve.

Using a Firewall Configuration File

Because firewall rules are not persistent (they are flushed with each reboot), you will want to maintain your firewall with a configuration file if you have customized firewall settings. This also has the benefit of being easier to maintain and faster to troubleshoot than working with IPFW from the command line.

Put your specialized rule set into a file of your choice; for this example, call it `/etc/firewall.conf`. List your desired rules in that file, omitting the `ipfw` command itself:

```
add deny tcp from badhost.com to any
add deny all from evil.isp.com/16 to www.example.com 80
add allow all from goodhost.evil.isp.com to www.example.com 80
add 65000 allow all from any to any
```

Now, change the `firewall_type` in your `/etc/rc.conf` file:

```
firewall_type="/etc/firewall.conf"
```

The next time you reboot or run `/etc/netstart` or `/etc/rc.d/ipfw start`, the rules from `/etc/firewall.conf` will be loaded with indexes of 100, 200, 300, and so on. An `allow all` rule at index 65000 provides a default behavior of passing traffic rather than denying it, which is desirable in most cases (unless you only want specified hosts to be able to access your machine).

For further reading on IPFW, see the `man ipfw` page and the online *FreeBSD Handbook* at http://www.freebsd.org/handbook.

PREV NEXT

Preventing Intrusions and Compromises

Firewalls, password policies, and encryption go a long way toward protecting your system from malicious access. They still aren't enough, though, to defend against a really determined hacker who has a "rootkit" or other tool designed to take advantage of some known weakness in one of your system's services.

You can use a variety of third-party tools in FreeBSD that go beyond the functionality of a simple firewall to dynamically block suspicious hosts, monitor for intrusions, and control access to individual services on a host-by-host basis. The following sections describe a few of these tools.

Using PortSentry

PortSentry, from Psionic Software, is a daemon that monitors all incoming network traffic to detect port scanspreliminary attacks in which a hacker probes your system for open services that can be exploited. PortSentry listens in on a list of ports you specify. When PortSentry detects traffic that might indicate a port scan, it blocks that host from accessing your system by wrapping it in a blackhole route (a route that silently discards packets from a given IP address or range) or IPFW rule. All future connection attempts from the offending host are discarded.

PortSentry monitors both TCP and UDP traffic, dynamically building a "killfile" table of sortsa list of banned addressesthat acts like an antibody against a virus. PortSentry reacts to suspicious activity by blocking it before it has a chance to cause any damage.

PortSentry is an open-source tool and can be installed out of the ports (`/usr/ports/security/portsentry`). The `portsentry` binary is installed into `/usr/local/bin`, and the configuration file is `/usr/local/etc/portsentry.conf`. Open this file in your favorite text editor; it needs to be edited in order for PortSentry to work properly.

You must decide which set of ports you want PortSentry to monitor. There are three available sets, in pairs beginning with `TCP_PORTS` and `UDP_PORTS`:

```
# Un-comment these if you are really anal:
#TCP_PORTS="1,7,9,11,15,70,79,80,109,110,111,119,138,139,143,512,513,514...
#UDP_PORTS="1,7,9,66,67,68,69,111,137,138,161,162,474,513,517,518,635,640...
#
# Use these if you just want to be aware:
TCP_PORTS="1,11,15,111,119,540,635,1524,2000,5742,12345,12346,20034,31337...
UDP_PORTS="1,7,9,69,161,162,513,635,640,641,700,32770,32771,32772,32773...
#
# Use these for just bare-bones
#TCP_PORTS="1,11,15,110,111,143,540,635,1080,524,2000,12345,12346,20034...
#UDP_PORTS="1,7,9,69,161,162,513,640,700,32770,32771,32772,32773,32774...
```

The first set is quite large; it is intended for a very strict security policy in which any remotely suspicious port will trigger a blocking rule. The second set is more moderate, and the third is minimal, watching only the ports that a remote user can't possibly be contacting unless he's performing a port scan or trying to run an exploit.

The middle set, the "if you want to be aware" grouping, is enabled by default. To switch to one of the other two, comment out the middle set and uncomment the one you want. If you like, you can create your own set. Make sure that none of the ports used by your core services are included in this list! For example, port 143 is listed in all three sample sets, but 143 is the IMAP port. If you're running IMAP services, make sure to remove port 143 from the list. If you're not, however, leave it init will trap attackers who try to exploit IMAP-related security flaws.

After choosing the ports to be monitored, you must choose a method by which to block suspicious hosts. You can do this through IPFW (if you're running it, as discussed earlier in the chapter) or through blackhole routes (if you're not running IPFW). Choosing a method involves uncommenting a single line beginning with `KILL_ROUTE`, which specifies the system command that PortSentry should use to block an offending host.

For a system running IPFW, uncomment the line in `portsentry.conf` containing `/sbin/ipfw`, like so:

```
# For those of you running FreeBSD (and compatible) you can
# use their built in firewalling as well.
#
KILL_ROUTE="/sbin/ipfw add 1 deny all from $TARGET$:255.255.255.255 to any"
```

If you're not using IPFW, use the blackhole route method, which, despite the comments, works just as well as IPFW:

```
# FreeBSD (Not well tested.)
KILL_ROUTE="route add -net $TARGET$ -netmask 255.255.255.255 127.0.0.1 -blackhole"
```

After you've enabled a blocking method, PortSentry is ready to run. However, as of this writing, the PortSentry port doesn't come with an automated startup script. You can use the script shown in Listing 30.1 set it to be executable, and copy it into your `/usr/local/etc/rc.d` directory to start up PortSentry each time your system boots.

Listing 30.1. Sample PortSentry Startup Script`portsentry.sh`

```
#!/bin/sh

PORTSENTRY="/usr/local/bin/portsentry"

case "$1" in
    start)
        ${PORTSENTRY} -tcp && echo " Starting PortSentry TCP mode..."
        ${PORTSENTRY} -udp && echo " Starting PortSentry UDP mode..."
        ;;

    stop)
        killall `basename ${PORTSENTRY}`
        ;;
    *)
        echo ""
        echo "Usage: `basename $0` { start | stop }"
        echo ""
        ;;
esac
```

Tip

While PortSentry is running, you can see which ports it's listening on by using the `sockstat` command:

```
# sockstat
USER     COMMAND    PID   FD PROTO  LOCAL ADDRESS         FOREIGN ADDRESS
root     portsent  2432    0 udp4   *:1                    *:*
root     portsent  2432    1 udp4   *:7                    *:*
root     portsent  2432    2 udp4   *:9                    *:*
root     portsent  2432    3 udp4   *:69                   *:*
root     portsent  2432    4 udp4   *:161                  *:*
root     portsent  2432    5 udp4   *:162                  *:*
...
```

Each time PortSentry detects an attack attempt, it lists the host and ports that triggered the detection in `/usr/local/etc/portsentry.blocked.tcp` for TCP attacks and `/usr/local/etc/portsentry.blocked.udp` for UDP attacks. PortSentry uses these lists to keep track of which hosts it has already blocked so that it doesn't try to block them again later. You can also use these files to see what hosts have been caught by your attackdetection system. These files are cleared out automatically each time PortSentry starts up. When you reboot, both IPFW and the routing table are cleared of any entries that were added during runtime, so a host that was blocked once will have access to you again if you rebootat least until it tries to probe your ports again.

Tip

If you're using the IPFW `KILL_ROUTE` method, view the current blocking rules with `ipfw -a list`:

```
# ipfw -a list
00001     1       44 deny ip from 209.237.26.165 to any
If you're using blackhole routes, use netstat -rn:
# netstat -rn
Routing tables

Internet:
Destination        Gateway          Flags     Refs     Use     Netif Expire
...
209.237.26.165/32  127.0.0.1        UGScB       0        0       lo0
```

The `B` flag indicates a "blackhole" route, in which packets are simply discarded.

Tip

Each time an attack is detected, `/var/log/messages` receives lines indicating what PortSentry is doing about it:

[View full width]

```
Jun 2 23:50:56 stripes portsentry[2430]: attackalert: Connect from host: 209.237.26.165
   /209.237.26.165 to TCP port: 1
Jun 2 23:50:56 stripes portsentry[2430]: attackalert: Host 209.237.26.165 has been blocked
    via wrappers with string: "ALL: 209.237.26.165"
Jun 2 23:50:56 stripes portsentry[2430]: attackalert: Host 209.237.26.165 has been blocked
    via dropped route using command: "/sbin/ipfw add 1 deny all from 209.237.26.165:255.255
   .255.255 to any"
```

Another tool from the makers of PortSentry is Logcheck (available in `/usr/ports/security/logcheck`); it analyzes this and other log files and sends you a daily report on any unusual activity or detected attacks.

Caution

As with IPFW, be careful when testing PortSentry. It's very easy to trigger an attack detection; if you do, the system from which you're administering your FreeBSD machine becomes blocked. That can happen, for instance, if you telnet to port 1 "just to see what happens." What will happen is that your host will be blocked, and further connection attempts will simply time out. You will have to connect from a different host or the physical console to remove the mistakenly applied rule, either through an **`ipfw delete 1`** or `route` **`delete IP-address/32`** command.

As with IPFW, you can set up a `cron` job to issue these commands every five minutes to protect against locking yourself out.

If you want to protect certain hosts (such as your own machines) from ever being blocked by PortSentry, add their IP addresses to the `/usr/local/etc/portsentry.ignore` file.

Using `/etc/hosts.allow`

The /etc/hosts.allow file lets you block certain hosts from accessing certain services on your system. This file is like a manual version of PortSentry. You can specify a block of rules for a given service and apply each rule to a certain IP address or set of addresses; each rule either allows or denies matching hosts access to the service. Here's a sample block of rules from the default `/etc/hosts.allow` file, with a few extra lines added to show sample syntaxes:

```
sendmail : localhost : allow
sendmail : .nice.guy.example.com : allow
sendmail : .evil.cracker.example.com : deny
sendmail : 231.21.15.0/255.255.255.0 : deny
sendmail : 12.124.231. : deny
sendmail : ALL : allow
```

Because you've seen how IPFW works, the format of these rules is pretty easy to figure out. A rule has at least three fields:

- The service (specified by process name)
- The matching hostnames or IP addresses
- The action to take (or multiple actions, if there are four or more fields)

The first two columns can be lists (multiple entries separated by spaces), and the host column can match a variety of different ways: a leading dot to specify an entire DNS subnet or a trailing dot to do the same for an IP address. Separate an IP address and a netmask with a slash to specify a network. The block should end with a "default" rule, specifying whether to allow or deny access to the service by default. Generally, if you're running the service, there's a good reason for it; you'll probably want your default rule to be "allow" so that clients other than ones you've explicitly allowed can access that service.

You can use `/etc/hosts.allow` to specify actions other than simply "allow" and "deny." You can use it to make unauthorized access to a service, trigger an email to you, or execute a program that does some kind of reverse probing against the remote host (although this is probably not a good ideait can be fun to "fight fire with fire," but it's bad form, and dangerous, to stoop to the level of the hacker who attacked you). This file can execute any shell command in response to a match for a given rule. The default rule for the `fingerd` service shows an example of this type of configuration:

```
fingerd : ALL \
        : spawn (echo Finger. | \
         /usr/bin/mail -s "tcpd\: %u@%h[%a] fingered me!" root) & \
        : deny
```

The `%u`, `%h`, and `%a` codes and additional configuration options are described in `man 5 hosts_access` and `man hosts_options`.

Using Tripwire

You can use intrusion detection to provide security that goes beyond outright blocking of suspicious hosts. A sufficiently wily hacker will be able to get past your security checks, no matter how carefully you set them up. If that happens, you need to be able to see whether he got into the system and caused any damage. If your system has been "owned," you want to know about it as soon as it happens, and the exact extent of the damage.

Tripwire, available at `/usr/ports/security/tripwire`, is a widely used intrusion-detection tool. Tripwire keeps an authenticity record of every program on the system. It compiles an "authoritative" record on your programs when you first run it during installation, and it adds records of new programs when you install them. On a daily basis, Tripwire compares a new record of every program on the system to the authoritative record. If Tripwire detects any differences in the programs (for example, if the `sshd` executable has suddenly changed size or had its contents or meta-data altered in any way), it notifies you via email. That email gives you an immediate notification that your system has been compromised.

When you first install Tripwire, it builds its initial database of program "fingerprints" during the `make install` phase, and it writes this out into a file in the `/var/db/tripwire` directory. This file is signed with local and site passphrases that you specify at installation time; therefore, you don't have to worry about the database file being tampered with. If it's modified without your knowledge, Tripwire will warn you that a security breach has occurred at the next time you use it.

You must first create a configuration file for Tripwire. This is done with the `twadmin` utility; in this case, you'll use the `m F` mode (Create Configuration File), specifying the site keyfile with `S` and the input configuration file at the end:

```
# twadmin m F S /usr/local/etc/tripwire/site.key /usr/local/etc/tripwire/twcfg.txt
Please enter your passphrase:
Wrote configuration file: /usr/local/etc/tripwire/tw.cfg
```

From now on, you can have the system run `TRipwire` every night in the `periodic` tasks (you learned about these tasks in Chapter 15, "Performance Monitoring, Process Control, and Job Automation"). When `TRipwire` is run with the `--check` argument, it operates in integrity-check mode, scanning all the files specified in `/usr/local/etc/tripwire/twpol.txt` for mismatches against the database of file fingerprints. If any inconsistencies are found, it reports them, as with this example, in which the file modification time of `/usr/sbin/sshd` has been changed:

```
# tripwire --check
...
===============================================================================
Rule Summary:
===============================================================================

-------------------------------------------------------------------------------
Section: UNIX File System
-------------------------------------------------------------------------------

  Rule Name                       Severity Level    Added    Removed  Modified
  ---------                       --------------    -----    -------  --------
  Invariant Directories           66                0        0         0
  Sources                         100               0        0         0
  Temporary directories           33                0        0         0
  Tripwire Data Files             100               0        0         0
  Local files                     100               0        8         0
  Tripwire Binaries               100               0        0         0
  Libraries, include files, and other system files
                                  100               0        0         0
* System Administration Programs  66                0        0         1
  User Utilities                  100               0        0         0
  X11R6                           100               0        0         0
  NIS                             100               0        0         0
  (/var/yp)
  /etc                            100               0        0         0
  Security Control                100               0        0         0
  Root's home                     100               0        0         0
  FreeBSD Kernel                  100               0        0         0
  FreeBSD Modules                 100               0        0         0
  /dev                            100               0        0         0
  Linux Compatibility             100               0        0         0
  (/compat)

Total objects scanned:  466299
Total violations found:  1
```

It may well be that you expect this file to be different from what Tripwire expects; you may have installed an updated version of `sshd`, for example. Whenever you update files that Tripwire is monitoring, you should update the Tripwire database to reflect the new information. You can update it with the `--update` option:

```
# tripwire --update
```

This command reruns the entire Tripwire database-generation process, which scans the entire filesystem and writes out an updated database file signed with your site and local passphrases (for which you are prompted when you run the program).

Caution

Be sure to update your Tripwire database *only* if you know the system is uncompromised! You don't want to pollute the database with information that says your already-compromised files are the gold standard against which future versions are compared. The best policy is to remove the system from the network, reboot, run a Tripwire scan to verify that your system is clean based on its known information, and *then* update the Tripwire database.

If you *really* want to make sure your Tripwire database is secure, and you don't even trust the built-in signing mechanism that protects it, you can create a Tripwire floppy diskplacing the database in a separate location from the computer is the most secure method of all to ensure data integrity.

Unfortunately, a Tripwire database is too big to fit on a floppy; however, you can remove items from the Tripwire "policy" to make the database file smaller. Do this by editing `/usr/local/etc/tripwire/twpol.txt`, removing or commenting-out the lines specifying file locations you don't want, and then creating the actual (non-human-readable) policy file by issuing the `twadmin` command with the `m P` (or `--create-polfile`) argument:

```
# twadmin m P S /usr/local/etc/tripwire/site.key /usr/local/etc/tripwire/twpol.txt
```

Then, when the database file that results from another `tripwire --update` run is less than 1.44MB in size, you can go to `/usr/ports/security/tripwire` and use the `make floppy` command to automatically create a floppy disk with the Tripwire database file and the associated tools copied to it. You should note, however, that going to the length of creating a Tripwire floppy disk is considered completely unnecessary today, now that the local database files are themselves protected, and the `make floppy` command is being deprecated and might not be available on your system.

Another option, naturally, is to use a writable CD or DVD for your offline Tripwire database. You'll have to create this disc manually, though, without the aid of Tripwire's tools.

Air Gaps

When you keep your Tripwire database on a floppy disk or other removable media, you're using an *air gap*a security condition where no automated process can possibly get data from one side of the "gap" to the other. Any system in which data can move via software from point A to point B is potentially susceptible to penetration by a sufficiently ingenious hacker. Given enough time and effort, someone intent on infiltrating your data will be able to access your archiveseven if you go to such lengths as having a second "hidden" hard drive that mounts itself automatically during the night to perform a backup operation. That's still an automated procedure and therefore vulnerable to anyone willing to try to break its security.

Properly designed hospital and government networks maintain critical databases on machines that have no connection to any machines on the network; they're separated by an air gap and are therefore secure...at least as far as the administrators physically in charge of the systems can be trusted. An air gap is a "last-resort" security measure, the ultimate in decreased convenience for the sake of guaranteed security. If you keep your data in a physically separate location from any machine connected to the network, no hacker can break into it.

When you keep your crucial data on a floppy disk, CD-R, or other removable media, you are employing an air gap that protects your data from being compromised, even if the entire networked system is infiltrated. That is, of course, unless you leave that removable disk in the drive...

If You Think You've Been Hacked...

As you learned earlier, you should assume that your systemno matter how securewill be hacked at some point. Although Tripwire and PortSentry can take a great deal of the drudgery of intrusion prevention and detection off your shoulders, you should still be on the alert for subtle and subjective changes in how the system behaves. Here are some simple ways you can monitor your system's security:

- Keep an eye on `top`, as described in Chapter 15; monitor what your system's load is over long periods, and see whether it gradually gets higher; if it does, investigate to see what might be causing this.
- Don't ignore mysterious behavior changes such as login prompts that seem to be formatted wrong or command-line output that doesn't look right.
- Look through `/tmp` and `/var/tmp` periodically, watching for anything executable or `setuid` or very large. Also, clear out those directories regularly. Perform web searches on the names of any mysterious files you find in there, as they might be the detritus left by a well-known rootkit.
- Watch your system's log files in `/var/log`; be on the lookout for messages that seem suspicious, such as anything with long strings of garbage characters. These are almost certainly hack attempts probing for buffer overflows.

In short, be constantly on the lookout for anything out of the ordinary. Such ad-hoc watchfulness is sometimes the only way to notice that your system isn't behaving the way it should.

Note

A favorite place to find evidence of hacker activity is in `/dev`. That's where packet-sniffing tools are often placed by intruders running prepackaged "rootkits" or scripts. However, because FreeBSD now uses a dynamically generated `DEVFS` device filesystem, this is less of a worrybut it still doesn't hurt to keep an eye out.

If you do suspect that you've been hacked (and especially if you find any evidence of it), you must assume that the damage is greater than it appears. The most common mistake for an administrator to make who has discovered evidence of a security breach is to simply disable a few services and assume that the attacker has gone away. Often, this may be the case; however, treating all such incidents in this manner is an invitation to disaster. All it takes is for the attacker to have installed a "backdoor" of some kind that lets him return and cause much more destructive damage than before.

If you suspect you have been hacked, or "owned," here are some steps you must take:

1. Disconnect the system from the network immediately. No matter what backdoors the attacker has installed in your system, he can't do anything if the system isn't on the network (in other words, it's behind an air gap). This prevents a hacker who realizes that he has been discovered from covering his tracks by wiping your hard disk clean.
2. Check `/var/cron/tabs` and `/etc/crontab` for new entries; also check `atq` for jobs the attacker has left to be run in his absence. The system might be off the network, but `cron` jobs will still run, and the hacker can still trash your system in this way unless you clear out any suspicious pending jobs.
3. Don't try to contact the attacker or let him know that you're on to him. Even after you've removed your system from harm's way, the attacker will vanish if he realizes you're trying to track him down, and law enforcement will have a much harder job finding him. Let him think you've simply taken the machine offline to recover from the damage.

4. Evaluate the extent of the compromise, and determine whether you will want to proceed with a prosecution against the attacker. If you do, proceed to step 5; otherwise, go to step 6.

5. Go to the National Infrastructure Protection Center (NIPC) website, http://www.nipc.gov (or the equivalent for your country's cybercrime investigation agency, if you're not in the United States), and fill out an incident report. This arm of the FBI is in charge of investigating cybercrime and hacker activity, and provided they have enough concrete information from your affected data, they can swiftly track down the perpetrator. Most hacker activity is committed by "script kiddies"casual vandals who use tools prepackaged by others to exploit certain known vulnerabilities. These types of hackers usually can be found and prosecuted quite successfully. However, because the FBI and similar bodies require that their information-gathering efforts be performed under their own auspices and under their own standards of due diligence, you will have to allow it to investigate the information on your system rather than providing your own filtered log files and surveillance data. You might think it would help, but the FBI won't act on the basis of data whose integrity it can't guarantee.

6. Back up your important dataweb documents, configuration files, home directories, and everything in `/usr/local`and reinstall the operating system. To be really thorough, wipe the hard disk clean, reinstall FreeBSD from scratch, and restore the local data. Use the daily output of Tripwire to tell you to what extent you need to "nuke and pave" the machine; beware of backdoors that may have been installed among your own installed programs in `/usr/local`, or even among your web documents or configuration files.

7. Update all your services to the most recent versions, referring to all relevant security bulletins, before putting the system back online. Be especially vigilant for the first few days after bringing the system back up; the hacker may continue to try to break in. Pay especially close attention to your log files during this period; the more evidence you can gather, the easier it will be for the NIPC and FBI to do their job.

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Denial of Service (DOS) Attacks

In modern parlance, "security" in networking refers to three factors: Confidentiality, Integrity, and Availability (or C.I.A.). Thus, even though Denial of Service (DOS) attacks don't directly involve the security of a system or the integrity of its components, defending against them is still central to the subject of network security.

DOS attacks don't involve any compromise of a system's security or privacy. Rather, they are simply brute-force floods, sending so much traffic over a network that legitimate traffic is lost in the shuffle. The goal is often to crash the server through sheer overwhelming volume of data and number of requests. These kinds of attacks are much harder to defend against than directed hack attacks, which can be foiled through the use of IPFW, PortSentry, and the other tools we have already discussed. The impact of a DOS attack cannot be eliminated; it can only be mitigated because DOS attacks are made up completely of legitimate traffic, indistinguishable from your actual mission-critical data flow. The problem is just that there's too much of it.

Sometimes, a DOS attack can be identified as coming from a certain source, and you can block it by adding a firewall rule to deny traffic from or to that source. However, many recent attacks hide the actual sourceping (ICMP) broadcast attacks look as if they're coming from a certain source address, which is actually the victim address that receives the brunt of the attack. Distributed DOS, or DDOS, attacks work even more insidiously, with hundreds or even thousands of compromised desktop machines (or "zombies") unwittingly taking part in the attack, so tracking down the actual culprit is pretty much impossible.

Certain configuration options in various servers and in the kernel can help to prevent your system from completely submerging during a DOS attack. The following sections look at a few of these measures; however, bear in mind that they can only serve to increase your system's chances of surviving a DOS attackthey can't neutralize the attack itself, nor can they guarantee that the attacker won't simply try harder until your system does succumb.

Limiting Server Forks

Many DOS attacks are targeted against services such as Apache, Sendmail, or others that operate by *forking* a new process to handle each incoming request. If an attacker sends an overwhelming number of requests to the service, it will fork off so many processes that the CPU and memory will eventually become exhausted, possibly destabilizing your system.

You can mitigate the risk of a server fork attack by making sure that all your forking services have built-in limits to the number of simultaneous child processes they can have. These limitations can impact the services' ability to fulfill legitimate requests during normal operation, but that trade-off may be what saves you during a DOS attack.

Apache has a `MaxClients` directive (by default set to 150) that keeps more than that number of requests from being serviced at once. A wily attacker, however, can repeatedly request a processor-intensive CGI script until Apache is creating executable processes faster than they can complete. Requests for executable processes are much more likely to trigger a runaway server than are requests for static HTML pages. If you can get the system to accept a Telnet or SSH login, shut down Apache (**`apachectl stop`**) until the attack is over. That may be the only way to recover from such an attack.

If you're lucky, an HTTP DOS attack will be traceable to a single client IP address, which you can block with IPFW rules or with a `deny from` directive in Apache itself.

If this doesn't work, though, you can always decrease `MaxClients` to the point where even if the server is maxed out, the clients can't swamp it.

Note

Most HTTP-based DOS attacks today, unfortunately, are distributedand as such their points of origin cannot be determined. The best defense against such attacks is to locate your server behind a network device that can detect and respond heuristically to massive activity, differentiating between IP addresses that can be blocked and ones that should be left open, or creating a "tar pit" that absorbs the attacking traffic harmlessly.

There's a similar feature in Sendmail: `MaxDaemonChildren`, disabled by default, which you can enable by uncommenting it in `/etc/mail/sendmail.cf` directly and restarting the server (`make restart`). Apart from this, Sendmail has a built-in brake that prevents it from starting new processes if the system load is over 12; however, this mechanism has too much lag during a fast-moving attack for the server to respond well, so it might be necessary to explicitly limit the number of children Sendmail can have at a time.

Tip

Other directives in Sendmail that you can use to help foil attackers (or anybody using your server too aggressively) are `QueueLA`, `RefuseLA`, `DelayLA`, and `ConnectionRateThrottle`. These directives are documented with comment lines in `sendmail.cf` itself and should be fairly self-explanatory. For instance, `QueueLA` (which in its default state is set to 8, but disabled) can be uncommented to make Sendmail queue messages automatically rather than attempting to deliver them, if the load average is higher than 8.

A potential general solution to fork attacks, even defending against those that might originate from your own system (a renegade or clumsy user, for example), is to modify `/etc/login.conf` to put limits on the CPU, RAM, and open file usage that a user can have. Create a class for the user that runs the service in question`nobody` in the case of Apache, or an individual local user whose resources you want to limitand use `chfn` to put the user into the class. An example `login.conf` class might look like this:

```
baduser:\
        :cputime=30m:\
        :openfiles=24:\
        :maxproc=32:\
        :memoryuse=16m:\
        :tc=default:
```

Then, use **`cap_mkdb /etc/login.conf`** to enable this new class and enforce these limits on any user in it.

Defending Against Springboard Attacks

A *springboard attack* leverages the resources of your own network to achieve its ends. Whereas brute-force and forking attacks require a high-powered attacker doing a lot of work, an attacker can launch a springboard attack simply by injecting a carefully constructed set of requests into the network. Those requests make the network's own infrastructure its own worst enemy.

An attacker can launch a broadcast ping (or *Smurf*) attack, for example, by sending normal ping requests to your network's broadcast address (which multiplexes the requests out to all hosts on the network). The hacker spoofs the requests' source address so it appears to be a different host. Typically, that host is a hapless victim who suffers a lot more than you do in this type of attack, because every host in your network turns around and floods the victim with ping responses. The multiplication effect of this kind of attack can be disastrous for the victim, and the source is very difficult (if not impossible) to trace.

Note

Another kind of springboard attack injects a UDP packet between two servers' `echo` service ports. This packet causes the servers to enter into an "echo war" that can be stopped only by shutting off the echo port (FreeBSD shuts off the echo port by default).

Springboard attacks are best prevented at the network's edge router; Smurf attacks can be prevented by configuring your router not to respond to broadcast ping requests. If your router is a FreeBSD machine (see Chapter 28 for information on using FreeBSD as a router), the `icmp_bmcastecho="NO"` setting in `/etc/defaults/rc.conf` prevents it from responding to these kinds of requests, which are almost never used for any good purpose.

ICMP error messages are another common source of springboard attacks. The `ICMP_BANDLIM` tool (compiled into the `GENERIC` kernel by default) limits the rate at which responses to ICMP error messages are sent, limiting such an attack's effectiveness. In FreeBSD 5.0 and later, `ICMP_BANDLIM` is no longer even an optionit can't be disabled. You can, however, tune the number of ICMP responses your machine will handle per second with the `sysctl` command:

```
# sysctl net.inet.icmp.icmplim=100
net.inet.icmp.icmplim: 200 -> 100
```

Use `sysctl a` to determine what the currently set value for the variable is, as shown here:

```
# sysctl -a net.inet.icmp.icmplim
net.inet.icmp.icmplim: 100
```

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Physical Security

The most secure system in the world can always be compromised if there's a possibility that an unauthorized person can gain physical access to the server machine itself, because no amount of software security can defend against a guy with a screwdriver.

Secure co-location facilities are vital for a commercial or otherwise high-profile Internet server. Such a facility provides locked server cabinets in locked machine rooms, and only employees of the facility are generally allowed to open the cabinets and physically access the machines. Your system might itself be in a rack-mounted case with a locked front panel and BIOS security measures that warn you if the panel has been removed. In the best case scenario, the co-location facility is specifically dedicated to physical security, as are companies such as InfoBunker (http://www.infobunker.com). Naturally, though, such services come at a price.

Anybody with physical access to the machine can reboot it into single-user mode, which doesn't prompt for the root password in the default configuration. You can change this so that it does prompt for a password by telling `/etc/ttys` that the console is "insecure," meaning that you can't guarantee that anybody accessing it is authorized:

```
console none                                unknown off insecure
```

However, this doesn't stop an intruder from being able to boot from a floppy disk or CD to compromise your system. Other devices attached to the machine can also be used to gain unauthorized access: modems, for example, or wireless networks, which should not be a part of any machine from which you're trying to restrict physical access. You can configure your machine's BIOS not to allow the machine to boot from any device other than the primary hard disk, and then lock the BIOS with a password, but these measures are just part of an arms race that a determined attacker with physical access is bound to win. The bottom line is that you cannot totally secure your system unless you control all physical access to it.

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Other Security Resources

This chapter has covered a few general security topics as they apply specifically to FreeBSD. However, the subject of network security is vast, and it grows each day as more and more malicious users try to find ways to bring down the Internet's core services.

A number of excellent resources are available on security, both FreeBSD-specific and general, that you would do well to check out.

The `man security` Page

Compiled by Matthew Dillon, the `man security` page contains a long discussion of general security topics and good administrative habits. It also provides miscellaneous tips for preventing break-ins and DOS attacks. This page is the basis for a number of online resources, including part of the FreeBSD Handbook.

Mailing Lists

Join the `freebsd-security@freebsd.org` mailing list. Do this by sending a message to `majordomo@freebsd.org`, with `subscribe freebsd-security` in the message body. This list is where the most up-to-date discussion of security issues takes place. As an administrator, you will need to keep abreast of the most recent developments so you can defend against each new vulnerability as it becomes known.

Another useful security list, geared toward UNIX security issues in general, is Bugtraq. This list receives advisories of all major issues that arise in Internet security, sometimes before their full impact on FreeBSD is known. Bugtraq is hosted at http://www.securityfocus.com, where you can subscribe to the list or search its archives.

CERT (http://www.cert.org) and SANS (http://www.sans.org) are indispensable securityfocused resources that will keep you abreast of developments in the world of security and new vulnerabilities across the spectrum of operating systems.

Finally, the `comp.risks` newsgroup is available in digest form at http://catless.ncl.ac.uk/Risks; this list is a forum for security professionals who discuss the technical and philosophical ramifications of security-related issues in everything from server platforms to credit card checksums and RFID tags.

FreeBSD Security Advisories

Security advisories are sent out by the FreeBSD Security Officer onto the `freebsdannounce@freebsd.org` and `freebsd-security@freebsd.org` lists to warn of newly discovered vulnerabilities. Each advisory is also archived at http://www.freebsd.org/security/.

An advisory contains a complete discussion of the nature and impact of a vulnerability, whether it exists in part of the core FreeBSD system or in a program in the ports collection, whether it's FreeBSD-specific or not, and how to work around or solve the problem. Because it would be inviting hackers to a free lunch to disclose the exact nature of a vulnerability before a fix is available, advisories are released only after a solution has been found. This is one good reason to subscribe to `freebsd-security@freebsd.org`; there will be discussion of a vulnerability there even before the advisory is released.

Fixes to vulnerabilities in ports or packages usually mean simply synchronizing your ports tree and rebuilding the port in question (see Chapter 16). A fix to the core FreeBSD system, though, is usually checked into the appropriate errata fix branch of the FreeBSD version you're running; to take advantage of it, you will need to rebuild that part of your system after synchronizing your sources. If the fix is in a sufficiently fundamental part of the system code, you might need to do a complete `make world` to make your system secure. Instructions on how to do this are in Chapter 19, "Keeping Up to Date with FreeBSD."

Web Resources

The FreeBSD Security Information page, http://www.freebsd.org/security/, contains resources and links geared toward the FreeBSD administrator or developer. Security advisories are archived here, as are various tips and tricks for reducing your risk factors.

CERT (http://www.cert.org), the Internet's foremost security advisory site, maintains resources on security vulnerabilities in all different operating systems and is widely regarded as the authoritative source of alerts and recovery information. CERT also handles incident reports; you can report a break-in there, and it will work with the proper authorities to catch the perpetrator.

SecurityFocus, the site that hosts Bugtraq, is a security news site covering topics from intrusion-detection systems to virus protection. It also has numerous articles on good security practices and how to run a system responsibly. It doesn't have much in the way of FreeBSD-specific material, but much of its information can be applied to any platform. The URL is http://www.securityfocus.com.

SANS (http://www.sans.org) is a security resource that provides training courses and certifications to security professionals, as well as an ongoing series of newsletters about the state of Internet security, and an "Internet Threat Level" that tracks the progress of active exploits making the rounds at any given time.

Books

Two books suggested in `/etc/rc.firewall` are *Firewalls & Internet Security*, by William R. Cheswick and Steven M. Bellowin, for general network security topics, and *Building Internet Firewalls, 2nd Edition*, by Brent Chapman and Elizabeth Zwicky, for fuller coverage of firewall theory and practice.

Further books and papers on security are listed and scored for usefulness at the SecurityFocus site, under the "Library" link.

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Chapter 31. Virtual Private Networks (VPNs)

IN THIS CHAPTER

If you have reached this stage in this book and have paid careful attention to the preceding chapters on security and server management, it's clear you have an active interest in being a security-conscious network citizen. Even if you're not a network administrator, you have learned the importance of keeping the transactions associated with your everyday computing as secure as possible. You use SSH for your remote terminal operations, you encrypt your POP3 and IMAP email traffic, and you implement a secure password policy. Your online life is about as secure as it can be.

However, that all changes as soon as you start talking about networking protocols beyond basic email and terminal traffic. Network security can become particularly complex when it incorporates aspects such as Network Address Translation (NAT), firewalls, and corporate LANs that are not accessible from anywhere on the public Internet. How are you supposed to do Windows file sharing with your company's corporate LAN servers if you're at home or on the road? How can you be sure your communications with the office are encrypted no matter what protocol you're using?

This is the role of the Virtual Private Network (VPN) model. This chapter introduces the underlying concepts of VPNs, describes some of the various types of VPN implementations and topologies, and guides you through configuring your FreeBSD machine to support a VPN, whether as a client (dialing in to a remote private network) or as a server (allowing other clients to access the network your FreeBSD machine is protecting).

What Is a VPN?

Corporate networks are protected from prying public eyes through various methods, many of which you have already seen in this book. Arguably the most common situation is for a company's network to be situated behind a firewall device that performs Network Address Translation (NAT) of IP addresses within the company to a single "masked" address visible from the outside. The idea behind this configuration is that machines within the network can access resources out on the Internet, but machines on the Internet cannot contact the "masked" corporate machines directly.

Tip

Network Address Translation is an Internet connection technique that enables multiple hosts to connect to the Internet using a single IP address. NAT is fully described in Chapter 28, "Configuring an Internet Gateway," in the "What Is NAT?" section. It is possible to perform NAT operation as well as VPN services on the same FreeBSD machine, as you will see in this chapter.

Protected in this way, servers within the corporate network are free to implement lax security policies (allowing employees to share resources among corporate servers without encryption or even authentication) and LAN-level network services (such as Windows file sharing and videoconferencing). The employees don't need to worry about security for these services because nobody outside the corporate LAN is capable of accessing anything inside it. This is an ideal configuration...as long as all the company's employees are within the corporate network at all times.

But what happens when employees want to work from home? What if members of the sales team want to check their intranet-based email and calendar sites and access marketing documents from internal corporate servers while they're in a hotel halfway around the world? Because of the firewall and NAT, they have no way of contacting the internal servers directly; if they try to look up the servers' hostnames, their external DNS servers will be unable to map the names to meaningful IP addresses.

If they try to connect directly to the servers' internal IP addresses, the Internet routers will be unable to find a way to the network containing the translated IP numbers (usually reserved ranges such as `10.x.x.x` and `192.168.x.x`). The employees have no way to get into the network; they're locked out by virtue of being topologically located outside the company's private LAN.

This is where a Virtual Private Network comes in. Conceptually, a VPN allows a client machine on the *outside* of the private network to join itself to the translated IP address pool used *inside* the network. The packets that carry data from the machine to the corporate servers travel over public Internet routers, but they're encrypted so as to protect them from the watchful eyes that drove the company behind a NAT firewall in the first place. Such encryption creates a *tunnel*, which is the term for the extra layer of encoding and packet headers that allows normal IP packets to be routed between machines whose configurations would not otherwise allow them to communicate. In a VPN tunnel, the public Internet's routers get your data packets to the VPN server, and then it does the rest. The conceptual layout of a VPN is shown in Figures 31.1 and 31.2.

Figure 31.1. Without a VPN, a packet either has no route to the translated corporate IP network or is rejected by the firewall as coming from an illegal source.

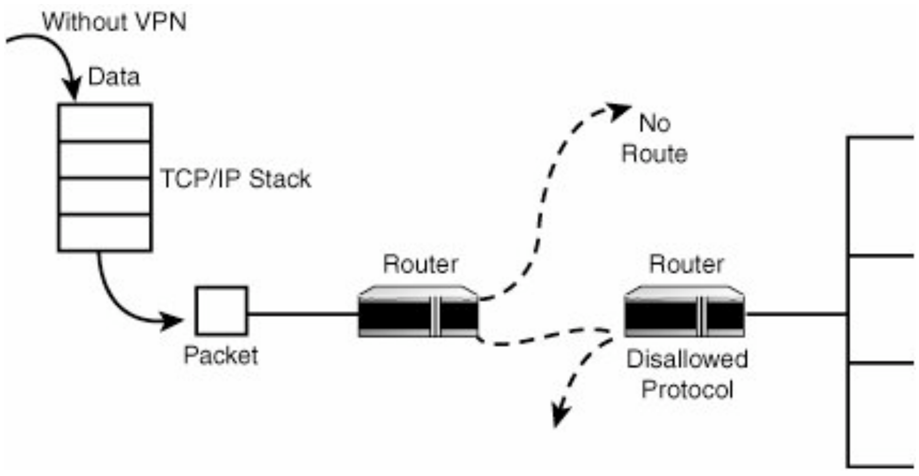
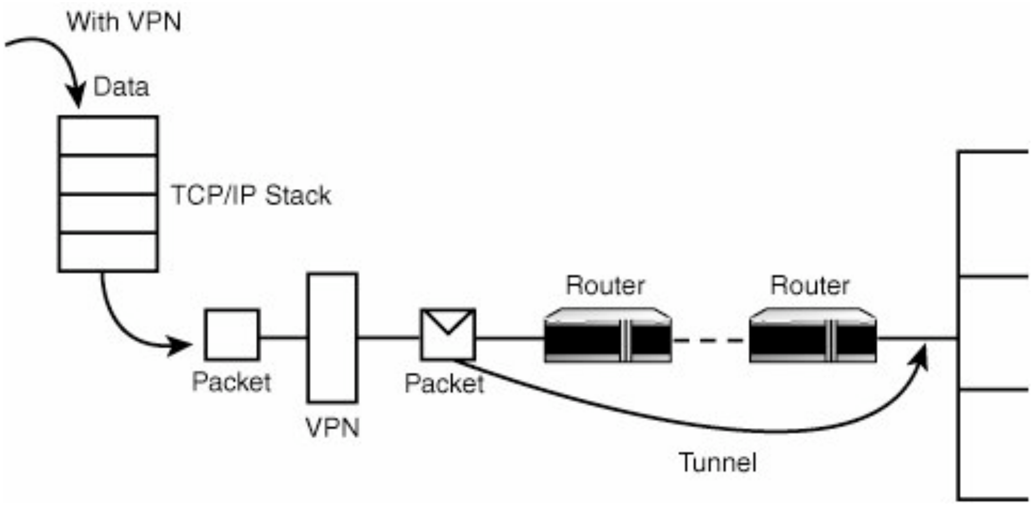


Figure 31.2. When a VPN is added to the client's packet path, each packet is encrypted and given a new IP destination, which sends it through the tunnel to a VPN server at the corporate network that decodes it.



A VPN is created through an authentication sequence in which the client machine exchanges keys with the VPN server to establish that it is a legitimate member of the corporate network. (Typically, a VPN would be used by an employee, and his username and password for the corporate network would be suitable to gain VPN access. This method is secure because the VPN authentication scheme is itself encrypted.)

Subsequently, the client machine is given a new virtual interface with an IP address that is compatible with the addresses of machines within the private network. With a VPN in place, DNS lookups of corporate servers work; LAN-level services such as Windows file sharing also function normally (even though the packets are encrypted and actually travel across the Internet instead of just the LAN). Best of all, the whole process is encrypted so that sensitive corporate data is not exposed to anybody who might want to sniff the public network for such treasures.

Note

Security-conscious administrators will recognize that if remote users use Windows file sharing and other such services while attached to unfamiliar networks, regardless of whether the actual sharing occurs over a VPN, the users have already exposed their laptops to a potential route of attack from other machines on their hotel or airport LANs merely by having file sharing active. These laptops, when brought back into the company's network, can proceed to infect its peers with any viruses or Trojans they brought with them from outside. For this reason, roaming employees should always be counseled that VPNs alone will not protect them or the company's security, and they should avoid using Windows file sharing unless absolutely necessary.

Each operating system handles VPN functionality in its own way. FreeBSD's implementation involves more work than you might be accustomed to using in a fully developed desktop operating system, but it has a number of features that help. This automation is largely due to the optional support for IPSec (Secure IP) in the kernel, rather than a reliance on third-party tools (you learn more about IPSec in "VPN Services in FreeBSD: IPSec," later in this chapter).

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VPN Topologies

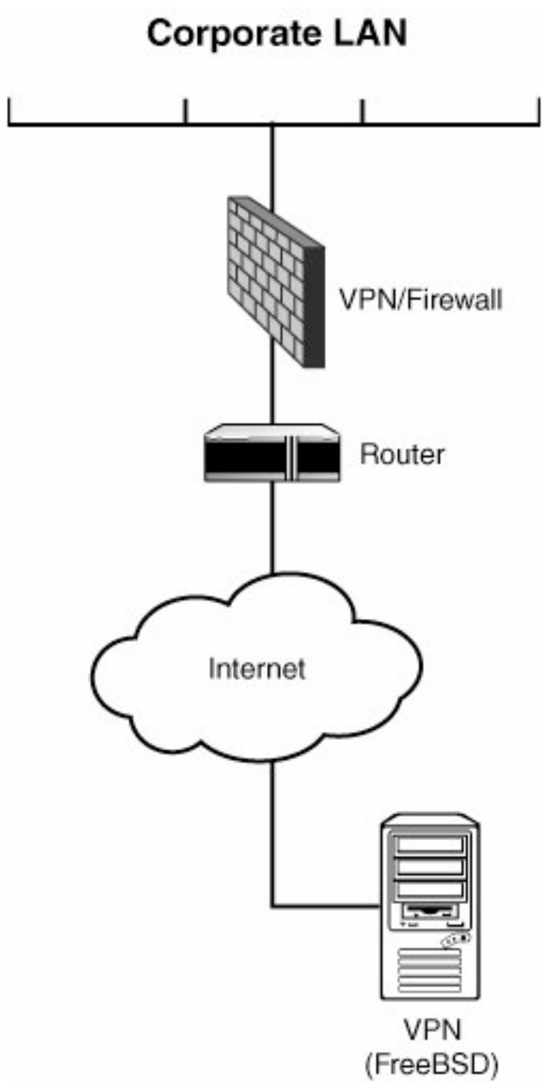
All VPNs have a few basic components in common:

- *A private network* The network is often a Class C subnet managed by a router, or it's a block of IP addresses translated by a NAT firewall into as large an internal virtual network as is necessary.
- *A VPN server* The server sits just inside the router or is incorporated as part of the router itself, as in the case of many modern routers from Cisco and other manufacturers, or a FreeBSD machine acting as a router.
- *A client* The client is somewhere out on the Internet.

The details of these configurations, however, can vary quite a lot.

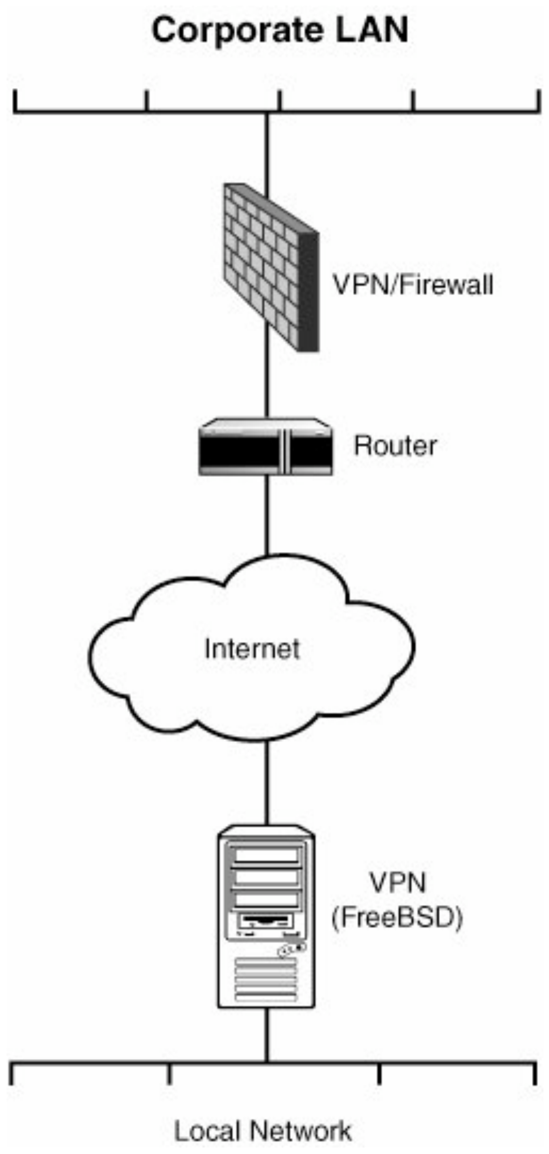
Figure 31.3 shows the kind of topology likely to be used by employees on the road. A single machine uses a standard dial-up ISP (such as found in a hotel or an airport) to connect to the Internet. This machine then contacts the corporate VPN server, which has an IP address that's not translated and is therefore accessible directly from the Internet. This VPN server performs the necessary authentication and serves up the client's tunnel IP address, allowing it to communicate with the machines inside the NAT network.

Figure 31.3. A single client machine connects to the Internet and communicates directly with the corporate VPN server to set up a tunnel.



A more ambitious layout is shown in Figure 31.4. Here, the VPN client is actually a FreeBSD machine serving as a NAT gateway and firewall for a home (local) network, the kind likely to be used by an employee who frequently works from home. The FreeBSD machine creates a permanent tunnel to the private network over the Internet but is itself operating as a router managing a network of machines of various types. Each of these machines has the VPN client machine set as its gateway router; if one of the machines tries to open up a connection to the private network, the FreeBSD machine will have a permanent route (the VPN tunnel) into which to send the connection. Normal requests to the Internet will be passed upstream to the regular ISP's router, unaltered. The machines on the local network do not need to undergo any special configuration in order to interoperate seamlessly with the machines at the corporate site. This topology enables large companies to maintain multiple branch offices in widely separate locations around the country or the world, while at the same time allowing employees at any location to access the resources at any other location as though they are all plugged into the same switch at the central office.

Figure 31.4. Two networks are connected by a permanent VPN tunnel; the machines on either network can now all freely communicate with each other with no additional configuration on the individual machines.



The same principles underlie both the simple and the more complex topologies just described. Next in this chapter, you learn the techniques for putting these principles into action. First, we look at how to configure FreeBSD as a VPN client to connect to a remote VPN server, regardless of whether your topology involves a local network. Afterward, you learn how to create a VPN server so other machines can tunnel into your own private network.

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VPN Services in FreeBSD: IPSec

VPN services in FreeBSD are conducted using *IPSec*, or *IP Security*. The IPSec protocol is routed like IP, but it contains a payload that's encrypted and authenticated. This payload needs to be decrypted by the machine at the other end using the key exchanged during the tunnel-setup procedure. IPSec is an industry-standard protocol that has been supported in FreeBSD for some time as the result of the work of the KAME project (www.kame.net). It is not built into the default FreeBSD kernel; however, you can enable it easily by building a new kernel.

Tip

The techniques in this chapter describe setting up a VPN using the built-in IPSec functionality in FreeBSD. An alternative VPN infrastructure, using SSL instead of IPSec and boasting a more straightforward configuration, is OpenVPN, available in the ports or packages (in the `security` category), and with a website at http://openvpn.net/. Try OpenVPN if your company's VPN architecture supports SSL, or if you will be in control of both ends of the tunnel and can specify that the VPN should use SSL instead of IPSec or PPTP. Note, though, that OpenVPN cannot interoperate with an IPSec or PPTP tunnel.

There are third-party tools available to allow FreeBSD to work with a PPTP tunnel if that's what your company uses. Try `pptpclient`, in the `net` category of the ports or packages, and refer to http://www.freebsddiary.org/pptp.php for a how-to guide.

A popular VPN solution used by many companies is the Cisco 3000 Series Concentrator, which uses a proprietary protocol and a software client that isn't available for FreeBSD. Instead, use `vpnc`, a Cisco-compatible VPN client available in the `security` category of the ports or packages.

Preparing Your System

To add IPSec support to your FreeBSD kernel, you'll need to add the following three `options` lines to your kernel configuration file (consult Chapter 18, "Kernel Configuration," for details on modifying your kernel if you're unfamiliar with the process):

```
options IPSEC           #IP security
options IPSEC_ESP       #IP security (crypto; define w/ IPSEC)
options IPSEC_DEBUG     #debug for IP security
```

Recompile your kernel and restart your system.

With these kernel options added, your machine will have two internal databases you will have to know about when configuring IPSec:

- *The Security Policy Database (SPD)* Used for determining your tunnel's *policy*, or which packets it should be encrypting
- *The Security Association Database (SAD)* Maintains the encryption keys used to decipher the encrypted packets received via the tunnel

These two databases can be manipulated using the `setkey` command, which is part of the FreeBSD system.

You will next need to install racoon (note the spelling), which is a tool developed by KAME to facilitate the exchange of keys during the creation of an IPSec tunnel. The racoon program, which is a component of a project known as IPSec-tools, can be installed from the ports at /usr/ports/security/ipsec-tools. (Refer to Chapter 16, "Installing Additional Software," for more information on using the FreeBSD ports collection.) The purpose of racoon, as far as basic VPN setup is concerned, is to automatically manipulate the SAD and create a VPN tunnel upon startup of the computer.

In order to set up your tunnel, you will need the following few pieces of information:

- Your own machine's IP address
- The VPN server's IP address
- The remote private network address and netmask
- The "shared key," which is a passphrase that will need to be stored in a privileged-access file on both sides of the tunnel

The most important piece to remember is the shared key; this will have to be agreed upon in advance by you and the administrator of the remote VPN server. The shared key is stored in the file /usr/local/etc/racoon/psk.txt, which does not exist in the default racoon installation. This file contains line-by-line pairs of peer IP addresses and their respective shared keys; a file located at /usr/local/share/examples/ipsec-tools/psk.txt contains sample lines to show you the required format. Create the directory /usr/local/etc/racoon, and then create your own psk.txt file in that directory and add to it the following line, where IP-address is the address of the remote VPN server and shared-key is the shared key agreed upon by you and the administrator of the server:

```
IP-address      shared-key
```

In other words, if the server's IP address is 221.222.223.224 and the shared key is "somesecurestring," you would add the following line:

```
221.222.223.224   somesecurestring
```

Note

The two fields in the shared key line you add to your psk.txt file can be separated by either tabs or spaces, as is the case with most configuration files.

Next, make the psk.txt file secure by giving it a permissions mode of 600 (readable only by the owner) and ensuring that it's owned by root; otherwise, racoon will refuse to read the file:

```
# chmod 600 /usr/local/etc/racoon/psk.txt
# chown root /usr/local/etc/racoon/psk.txt
```

Finally, create racoon's configuration file by copying /usr/local/share/examples/ipsec-tools/racoon.conf to /usr/local/etc/racoon/racoon.conf; then make a couple of modifications to ensure smooth operation over the Internet WAN. Change the lifetime time and lifetime byte fields, specified in the sainfo anonymous block, to 36000 secs and 50000 KB, respectively. (Add the lines if they are not present in the default configuration.)

Note

There are several sample variants of the racoon.conf file inside /usr/local/share/examples/ipsec-tools; these include sample configurations for GSSAPI (Kerberos) authentication, NAT Traversal topologies, and PlainRSA keys (as used in SWAN networks). There is also a roadwarrior subdirectory that contains sample configurations for a static server and a roaming client (for example, a laptop using unpredictable dynamic IP addresses).

When you are done, the block should look like this:

```
sainfo anonymous
{
        pfs_group 2;
        lifetime time 36000 sec;
        lifetime byte 50000 KB;
        encryption_algorithm 3des;
        authentication_algorithm hmac_sha1;
        compression_algorithm deflate ;
}
```

Also, add the lifetime 50000 KB line to the corresponding point in the remote anonymous block:

```
remote anonymous
{
        ...
        nonce_size 16;
        lifetime time 1 min;
        lifetime byte 50000 KB;
        initial_contact on;
        support_mip6 on;
        ...
}
```

Connecting to a FreeBSD VPN Server

It may be that you are fortunate enough to have another FreeBSD machine as the server for your VPN connection. If this is the case, you can set up both machines in the same way, with their racoon configurations mirroring each other.

However, racoon only works if you have set up the SPD and SAD using the /etc/ipsec.conf file, which does not exist by default. First, enable the reading of that file at startup time by adding an override line to /etc/rc.conf:

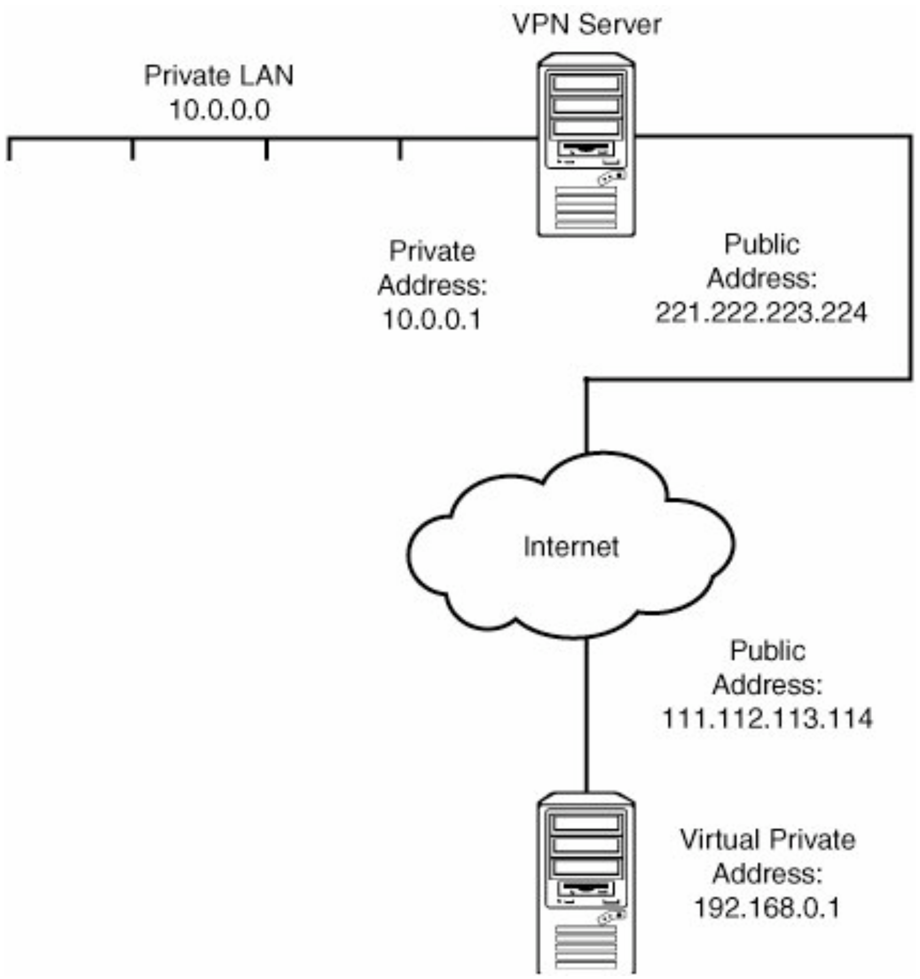
```
ipsec_enable="YES"
```

Also, you will need to add the gif0 virtual interface to your available network interfaces and configure it according to the local and remote IP addresses so that the kernel can route tunneled traffic to the proper destination. Add a gif_interfaces line in /etc/rc.conf like this:

```
gif_interfaces="gif0"
```

IPSec in FreeBSD works as shown in Figure 31.5. Each VPN peer machine has two network interfaces. On the server side, one of the interfaces is "private" and on the same LAN as the address-translated private network to which you want to connect, and the other is the "public" IP address in the untranslated address space. On your local machine, which only has one physical Ethernet card, your private IP address is really just an internal "dummy" address because your machine isn't routing any traffic except to itself. However, the `gif0` device needs the private address in order to route properly. You will need to bind both your public and private addresses to your single Ethernet card.

Figure 31.5. Each of the peer machines in the VPN connection has a "public" and a "private" IP address. The private address on the local machine is a dummy address bound to the same card as the public address.



Suppose that your machine's IP address in the public space is 111.112.113.114 and that this address is already bound to your `fxp0` card. You can create a virtual address of 192.168.0.1 for use with the IPSec tunnel. Add the following line to `/etc/rc.conf` immediately after the line that configures the card:

```
ifconfig_fxp0_alias0="inet 192.168.0.1 netmask 255.255.0.0"
```

Furthermore, suppose that the remote VPN server's public IP address is 221.222.223.224 and that this server manages the internal, private Class A network 10.0.0.0, on which its own private IP address is 10.0.0.1. You now can configure the local machine's `gif0` device by adding the following lines to `/etc/rc.conf`:

```
ifconfig_gif0="inet 192.168.0.1 10.0.0.1 netmask 255.0.0.0"
```

This line tells FreeBSD to assign the virtual private address `192.168.0.1` to the `gif0` interface and connect it to the remote private address `10.0.0.1` at the other end.

```
gifconfig_gif0="111.112.113.114 221.222.223.224"
```

This line creates the "public" side of the connection, directing traffic from your public address `111.112.113.144` to the public address of the VPN server, `221.222.223.224`.

Finally, create `/etc/ipsec.conf` and add the following lines to it:

```
flush;
spdflush;
spdadd 192.168.0.1/32 10.0.0.0/8 any -P out ipsec
  esp/tunnel/111.112.113.114-221.222.223.224/require;
spdadd 10.0.0.0/8 192.168.0.1/32 any -P in ipsec
  esp/tunnel/221.222.223.224-111.112.113.114/require;
```

The `spdadd` lines are what control the SPD and assign the rules for what traffic FreeBSD should encrypt. Note that there are two such rule lines, and they're mirror images of each other; this is because you're creating a virtual routing mechanism, and routers must be bidirectional.

The first `spdadd` line applies to all traffic originating from your machine's private network (`192.168.0.1`, with a CIDR mask of `/32`, making the network synonymous with your single IP address) and destined for the remote private LAN (`10.0.0.0`, a Class A network). It specifies that all traffic matching that pattern should be routed across the tunnel between the two public addresses, `111.112.113.114` and `221.222.223.224`.

Tip

Classless Inter-Domain Routing (CIDR) is a network mask notation. A CIDR mask of `/32` describes a network that matches all 32 bits of the given IP address (a netmask of `255.255.255.255`), or in other words, that given machine only. A CIDR mask of `/8` means the mask is only 8 bits long, or `255.0.0.0`, which describes a Class A network.

Replace these numbers with the addresses that are correct for your configuration; make sure to set up the second line as a mirror image, as shown here.

Restart the machine to ensure that all the configuration items are read properly and cleanly.

Note

A remote FreeBSD VPN server will likely be configured similarly to your own machine, using `/etc/ipsec.conf` and `racoon`. However, it is critical that it have its own configuration rules that mirror those on your own machine. The remote FreeBSD VPN server must be configured to send encrypted traffic to your machine through its own `gif0` interface. Add (or have the remote machine's administrator add) the appropriate `spdadd` lines, which would be the same as the ones shown here. The lines are symmetrical, so if you reverse the numbers, they turn out to be the same set of lines as on your local machine, except for the `in` and `out` tags:

```
spdadd 10.0.0.0/8 192.168.0.1/32 any -P out ipsec
  esp/tunnel/221.222.223.224-111.112.113.114/require;
spdadd 192.168.0.1/32 10.0.0.0/8 any -P in ipsec
  esp/tunnel/111.112.113.114-221.222.223.224/require;
```

Now that the kernel is set up to use the `gif0` virtual interface, there's only one thing left to do: You must run `racoon`, which monitors outgoing flows and sets up the appropriate key exchange. This process happens transparently and may cause a slight delay in the first few packets you send.

When you installed `racoon`, it created a startup script in `/usr/local/etc/rc.d`. This script automatically starts `racoon` at boot time. However, if you need to start `racoon` while the machine is already running, you can do so by invoking the script with the `start` parameter:

```
# /usr/local/etc/rc.d/racoon.sh start
```

Try sending a ping to a machine on the remote private network (for example, `ping 10.1.1.10`). If you get a reply, your VPN tunnel is up and running!

Connecting to a Windows 2000 VPN Server

Most of the time the remote VPN server will not be a FreeBSD machine. It's far more likely these days to be a Windows 2000/2003 server. However, this should not present a problem; with a few tweaks to `racoon.conf` on your end, you should be able to connect to a corporate Windows server seamlessly.

The first thing to note is that a Windows server assigns identifier addresses dynamically; therefore, in the `remote anonymous` block, comment out the whole set of lines beginning with `my_identifier`:

```
#my_identifier address;
#my_identifier user_fqdn "sakane@kame.net";
#peers_identifier user_fqdn "sakane@kame.net";
#certificate_type x509 "mycert" "mypriv";
```

Next, change the `proposal` sub-block to list the encryption and checksum methods preferred by Windows 2000:

```
proposal {
        encryption_algorithm 3des;
        hash_algorithm md5;
        authentication_method pre_shared_key ;
        dh_group 2 ;
}
```

Finally, go down into the `sainfo anonymous` block and alter it to match the following:

```
sainfo anonymous
{
        pfs_group 2;
        lifetime time 36000 sec;
        lifetime byte 50000 KB;
        encryption_algorithm 3des,des,cast128,blowfish ;
        authentication_algorithm hmac_sha1,hmac_md5;
        compression_algorithm deflate;
}
```

Now, you must do some configuration on the Windows end. The following instructions are for a Windows 2000 server; Windows Server 2003 configuration might be slightly different.

1. Run the `mmc` program from within a Command Prompt window.

2. Go to the Add/Remove Snap-In option in the Console menu.

3. Add the IP Security Policy Management snap-in by clicking the Add button, and then selecting the snap-in from the pop-up window. Select to install it for the local computer (the default option).

4. Close the Add/Remove Snap-In window to finish the process.

5. Click IP Security Policies in the tree listing and then select Create IP Security Policy from the Action menu. This starts a wizard. Don't activate the default response rule (uncheck the check box it offers you); instead, edit the properties when given the option to do so. In the Properties dialog, click the Add button to add a new rule. Make sure the rule has the following properties:

    - The rule does not specify a tunnel.
    - The rule applies to the LAN.
    - To protect the key exchange, use a stringthe same "shared key" string as you put into `psk.txt` (somesecurestring) in the earlier example.

6. In the next screen, create a new IP filter so that only traffic from a source address of your Windows machine's subnet (or any IP address) to a destination of your FreeBSD machine's specific IP address is subject to the security policy. Select this new filter.

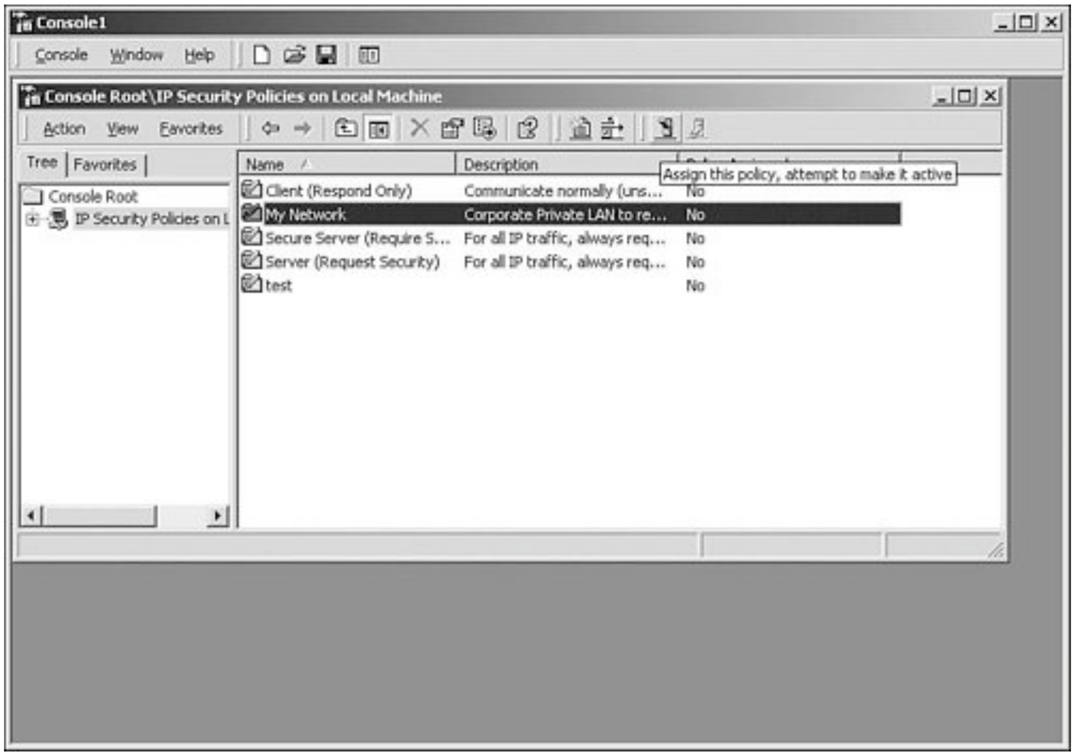
7. Select the filter action Require Security and click Edit to modify the rule so that the topmost line has the following properties (use the Move Up and Move Down buttons):

    - AH is disabled.
    - ESP Confidentiality is 3DES.
    - ESP integrity is MD5.

8. Finish the wizard and examine your list of rules. It should look like Figure 31.6.

Figure 31.6. The IP Security Rules dialog showing the new filter you have created; click the check box preceding the filter's listing to toggle on the filter.

[View full size image]


Console1

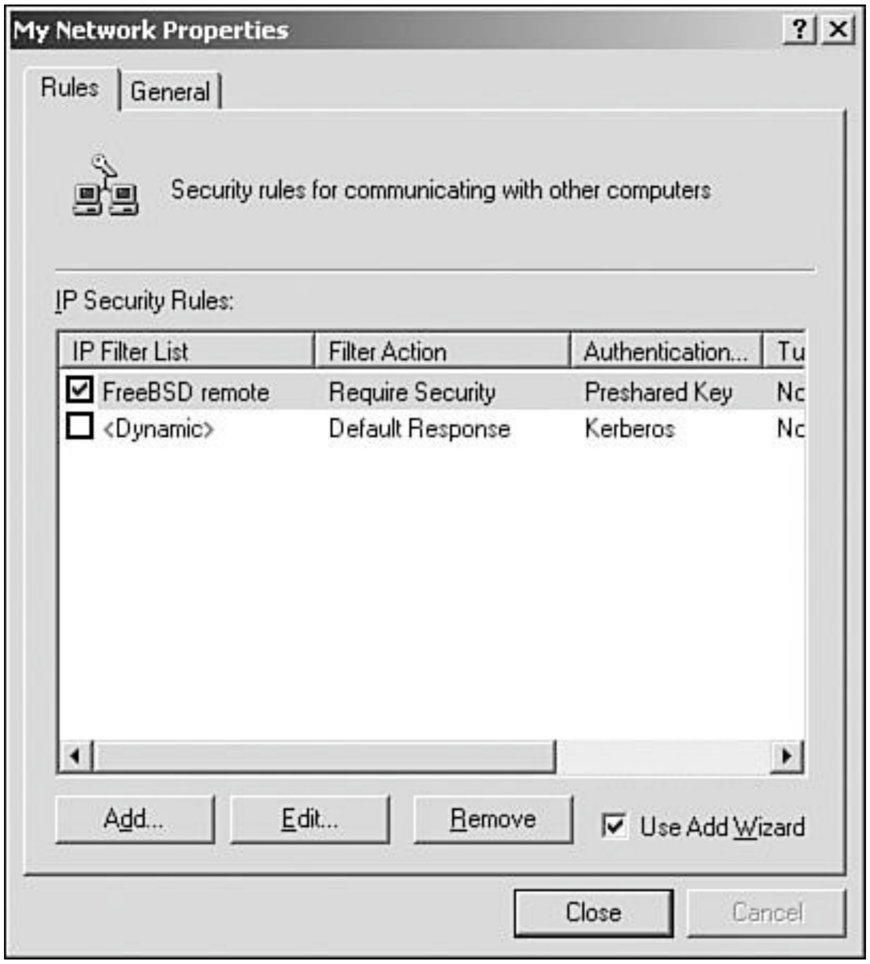
Console Root\IP Security Policies on Local Machine

Name	Description	Policy Assigned
Client (Respond Only)	Communicate normally (uns...	No
My Network	Corporate Private LAN to re...	No
Secure Server (Require S...	For all IP traffic, always req...	No
Server (Request Security)	For all IP traffic, always req...	No
test		No

Assign this policy, attempt to make it active

9. Using the Component Services management program (one of the Administrative Tools in the Control Panel), restart the IPSec Policy Agent, as shown in Figure 31.7. You should restart the agent after each change you make during debugging because this ensures the changes you make are always currently in use.

Figure 31.7. Enabling the new security policy using the toggle switch in the `mmc` program.



My Network Properties

Rules | General

Security rules for communicating with other computers

IP Security Rules:

IP Filter List	Filter Action	Authentication...	Tu
☑ FreeBSD remote	Require Security	Preshared Key	Nc
☐ <Dynamic>	Default Response	Kerberos	Nc

10. Activate the new policy by clicking the check box that precedes the filter listing in the My Network Properties dialog shown in Figure 31.6 (clicking the check box toggles on the filter). Now, in another Command Prompt window, run the `ipsecmon` program to monitor the tunnel rules in action. In a third window, try to ping your FreeBSD machine. The first ping will emit a "Negotiating IP Security" message, but subsequent pings should go through successfully. If this occurs, your IPSec tunnel is functional.

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FreeBSD as a VPN Server

It won't always be the case that you only have one FreeBSD machine to connect to a remote Virtual Private Network. You might have to set up a routed, translated subnetwork of your own, for example, and create a permanent VPN tunnel to the remote network for the use of multiple machines on your own subnet. Fortunately, because you have set up the `gif0` interface to use a virtual private IP address on your own local machine, making the jump to a fully routed VPN link should be child's play.

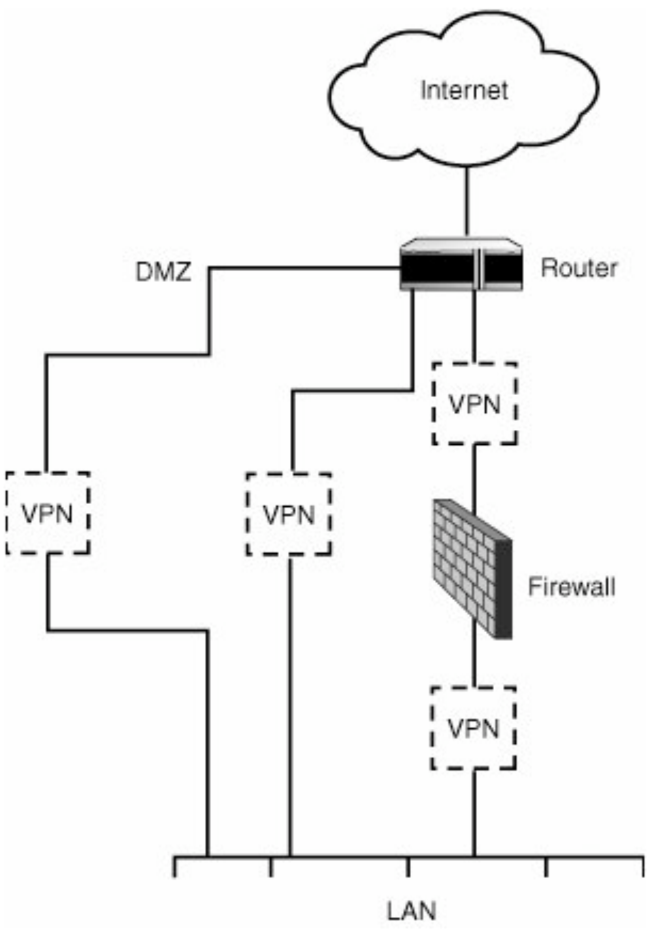
All that's required is a second Ethernet card on your machine that's plugged into the local private network. Follow the same instructions listed in the previous section, except for the part where you alias the private address (192.168.0.1) to the public Ethernet card. Instead, assign that address to the second Ethernet card. Then, set up the `spdadd` lines to reflect the network address of the whole network you're managing instead of just your own single machine. For instance, the following lines in `/etc/ipsec.conf` would allow you to tunnel the entire private 192.168.0.0 network (Class B, with a mask of 16 bits) to the remote VPN server, enabling the machines on your network to communicate with the machines in the remote 10.0.0.0 network, and vice versa:

```
spdadd 192.168.0.0/16 10.0.0.0/8 any -P out ipsec
  esp/tunnel/111.112.113.114-221.222.223.224/require;
spdadd 10.0.0.0/8 192.168.0.0/16 any -P in ipsec
  esp/tunnel/221.222.223.224-111.112.113.114/require;
```

One final point to note is that to run a proper subnetwork, your FreeBSD machine will have to be doing all the routing and NAT/firewall work for that network; otherwise, you will have to have dedicated equipment on your end to handle those tasks, the same as on the remote end.

Figure 31.8 shows a topological layout of the network, including several potential, correct locations for the VPN device or functionality (indicated by "VPN" in a dashed box). VPN can be handled by a dedicated machine, or it might be consolidated into the same machine as the firewall or router. If your FreeBSD machine is doing all these tasks itself, you probably won't have to worry; if it's not, however, you must ensure that each piece of functionality is positioned properly in the network so that the right addresses are visible to the devices that need them. Particularly bear in mind that if you have VPN functionality in the network at any point, your firewall will almost certainly have to be set up to allow its traffic through with specialized rules. Moreover, your router will have to be able to route the tunnel traffic to and from the VPN device. Most VPN misconfigurations stem from incorrect firewall or router rules that don't take into account the specialized addressing needs of the VPN tunnel.

Figure 31.8. A topological diagram of a subnetwork, including the LAN, firewall, NAT, router, and WAN, as well as four potential locations for the VPN device.



Note

Refer to Chapter 28, for details on routing a subnetwork using FreeBSD as well as NAT configuration. See Chapter 30, "Network Security," for more on firewalls.

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Chapter 32. The Domain Name Server

IN THIS CHAPTER

In Chapter 22, "Principles of TCP/IP Networking," and Chapter 23, "Configuring Basic Networking Services," you learned how DNS (the Domain Name System) provides a common naming scheme for finding hosts on the Internet, eliminating the need for users to memorize IP addresses. You also learned about the process of setting up a FreeBSD machine to gather domain name information from a designated server. However, you now come to the topic of configuring the FreeBSD machine to act, itself, as a domain name server, providing lookup information to itself and to any client machines that wish to use it.

Domain name service is one of the most complex single subjects in network administration. Although it's fairly easy to set up a web server on each of as many different servers as you might install in a network and on as many occasions as might come up in your network's lifetime, the installation of a name server is something that typically is done just once. In many cases, the installation is handled by a "guru" whose efforts quickly become folklore to the rest of the network staff, resulting in a DNS setup that is hard to maintain or even understand. Administrators who know DNS inside and out are far less numerous than those who don't. This chapter cannot attempt to describe DNS exhaustively. For that purpose, there are lengthy books devoted to the subject. This chapter's purpose is to enable you to set up your FreeBSD machine as a basic name server in any of several common configurations.

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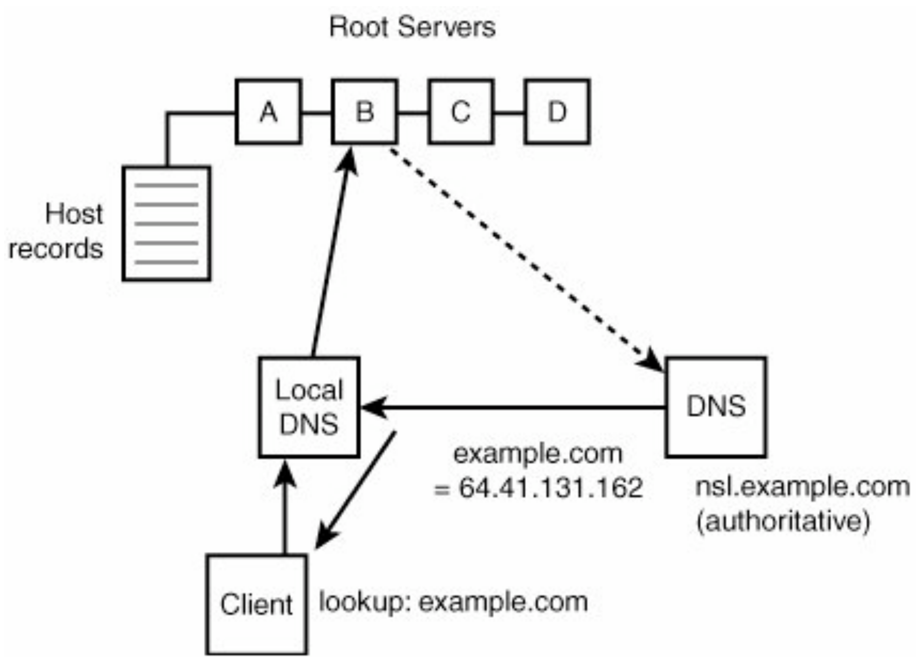
Introduction to DNS Structure, Functions, and Software

DNS is a hierarchical protocol, operating across the Internet in a fashion similar to how routing works. A number of "root servers" are maintained by various university and government entities, distributed geographically around the Internet for redundancy reasons. The list of root servers is maintained by the Internet Corporation for Assigned Names and Numbers (ICANN), and their locations are listed at http://www.root-servers.org. Each domain name (for instance, `example.com`) is defined in backward order from the root zone, with the domain suffix`com`, `org`, `net`, and so onbeing the topmost layer of the hierarchy directly under the `.` (a single dot), which refers to the root zone. Below each of the suffixes (commonly known as *top-level domains*, or *TLDs*) are the regular domain names, each typically defined not by the root servers but by individual DNS hosts on the Internet. The `example.com` domain, for example, would have its DNS administered by a server on its own network, such as `ns1.example.com`. This server is the "authoritative" DNS host for that domain. A central registryalso maintained by ICANNkeeps records of these individual domains so that the root servers can provide authoritative lookup information on them. You define these "host records" when setting up a new name server by submitting a form to a domain registrar such as Network Solutions or any of the hundreds of other accredited registrars that are recognized by ICANN.

When a client makes a DNS request, it queries the name server configured in its TCP/IP settingsusually a server on its own network, as shown in Figure 32.1. If that server cannot answer the request, it passes the request on to its upstream DNS forwarder if one is available. If not, the request goes directly to the root servers.

Figure 32.1. A diagram of a DNS lookup, showing the path from a client to the local DNS, the root servers, and the authoritative name server.



The root servers don't maintain any authoritative DNS data of their own. All they have are host records, which you will come to know as *NS records*, which point to the authoritative name servers for each domain.

The root servers send back a DNS response that refers the requester to the authoritative name server for the domain the client wants to find out about. This server sends back the requested DNS data to the local DNS machine, which passes it back through to the client.

The local DNS might keep lookup information around in its cache for a period of time specified by the authoritative name server. This speeds up the query process, allowing local clients to get immediate responses to their DNS queries from the local server without the queries having to travel out over the Internet. However, this means that changes to DNS records at the authoritative DNS will not be available to the client until the expiration period has passed. Until that time, the DNS information the client sees is "stale" and potentially inaccurate. The time period between DNS cache updates can be controlled for each domain using the Time-To-Live (TTL) value, which you will learn more about later in this chapter.

DNS Software: BIND

DNS software is ubiquitous. For UNIX systems, which account for the vast majority of name servers on the Internet, the software of choice is BIND, by the Internet Software Consortium (ISC). BIND, short for *Berkeley Internet Name Domain*, consists of one major daemon program (`named`), a set of resolver libraries that provides the ability to perform name lookups, and various administrative tools. BIND is built into FreeBSD, although it is not enabled by default.

Zones

BIND allows you to define *zones*, which are logical groupings of IP addresses and hostnames that exist at a certain level in the DNS naming hierarchy. For example, `com.` is a zone under the root (`.`) zone, and `example.com.` is a zone that exists underneath the `com.` zone. Note that zone names always end in a dot, referring to the root zonethis will be important when you create your zone files! *Subdomains* are zones managed by the individual domain name servers; `cluster.example.com.` is a zone that can have multiple machines inside itindeed, it can have as many further subdivisions within it as you are willing to configure. These zones provide *forward DNS lookups*, or mappings from names to IP addresses.

Similarly, *reverse DNS lookups*or mappings from IP addresses to hostnamesare managed in zones. Because DNS and IP addresses have their roots in the ARPAnet (see Chapter 22 for details) and have not changed fundamentally in structure since that time, a reverse DNS zone name is of the form `CCC.BBB.AAA.in-addr.arpa`. This is a name constructed of the IP address space in reverse order, with `.in-addr.arpa` appended to it. For example, the `64.41.131.*` network would be defined by the zone `131.41.64.in-addr.arpa`.

Each zone that your name server will manage must be defined in a *zone file*a formatted text database of definitions that map hostnames to IP addresses (or vice versa) within the zone. A zone file also contains parameters for the behavior of the zone, such as the caching expiration period. The zone files are the most critical part of proper DNS configuration; we will be discussing them in detail later in this chapter.

BIND Files and Programs

Because BIND is a built-in part of FreeBSD, you don't need to worry about installing it or making sure the proper files are in the proper places. It is worthwhile, though, to know what programs are involved in name server operations and where you will be making your configuration changes:

- `/usr/sbin/named` The name server daemon itself. It listens on port 53 for DNS lookup requests, using both TCP and UDP. UDP is used for normal name lookups by host machines; TCP is used for more complex DNS infrastructure such as zone transfers between name servers.

- `/usr/sbin/ndc` The name daemon controller program. This is a tool you can use to start, stop, reload, and monitor the `named` server. However, the preferred method for controlling the daemon in FreeBSD is the `/etc/rc.d/named` script, which works as you saw in Chapter 14, "System Configuration and Startup Scripts."

- `/etc/namedb` All your BIND configuration and runtime status files, including zone definition files, are in this directory (or any subdirectories of it that you create). Actually this is a symbolic link to `/var/named/etc/namedb`, as you'll see in the next section.

- `/etc/namedb/named.conf` The master BIND configuration file. This file tells BIND which domains you are to manage as well as how to handle each one.

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Enabling the Name Server Daemon

Enabling BIND in FreeBSD is the simplest part of configuring it. All you have to do, just as with other built-in FreeBSD services we have discussed, is add the following line to `/etc/rc.conf`:

```
named_enable="YES"
```

With this option set, `named` will run automatically at boot time. To start it without rebooting, use the appropriate `rc` script:

```
# /etc/rc.d/named start
Starting named.
```

The server should now be running. However, this is only scratching the surface of a complete BIND configuration.

Note

If you're enabling BIND on your FreeBSD machine, put a `nameserver` line into your `/etc/resolv.conf` file, referring to the loopback address (`127.0.0.1`) as your primary name server. This way, you will be able to perform DNS lookups the quickest way of all: from your own machine. Make sure this line appears before any additional servers:

```
search example.com

nameserver 127.0.0.1

nameserver 64.41.131.167
```

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Running BIND in a Sandbox

As you saw in Chapter 27, "Configuring an FTP Server," it's often advisable (for security purposes) to run certain services within what's known as a *sandbox*, or a directory structure that's been pruned off so as to appear that it's all that exists in the filesystem. In FTP, this is known as a `chroot` jail; the effective "root" of the filesystem is changed so that the server and the processes it creates cannot see outside their own directory structure above a certain point. BIND provides the same kind of capability, although most of the documentation refers to it as a "sandbox" rather than as a "`chroot` jail." The concept is the same, however.

FreeBSD runs `named` in a sandbox by default. (This is a precaution that was taken in response to a number of security flaws found in `named` in recent years.) The sandbox root is the `/var/named` directory; if you look inside this directory you'll find subdirectories named `dev`, `etc`, and `var`, all of which are necessary to the internal operation of `named` (which cannot see into the real `/dev`, `/etc`, and `/var` directories when it's running in `chroot` mode). Indeed, a second device filesystem (`devfs`) is mounted at `/var/named/dev` if you enable `named`. This may look surprising when you see it in the output of `df`, but rest assured that it's necessary for `named` to operate properly in the sandbox.

A set of symbolic links is in place to ensure that you don't have to deal with the esoteric `/var/named` directory tree. `/etc/namedb`, TRaditionally the configuration directory for `named`, is a symlink in FreeBSD that points to `/var/named/etc/namedb`; thus, you can put your zone files inside `/etc/namedb/master`, and they'll actually be going into `/var/named/edc/namedb/master`, the correct location within the `chroot` sandbox.

Tip

The default configuration of running `named` in a sandbox was instituted in the middle of the FreeBSD 5.x series. Prior to that, zone files were kept directly in `/etc/namedb`, which at the time was a regular directory. If you're maintaining a legacy installation of FreeBSD, you should migrate your zone files to the new layout by copying them into `/var/named/etc/namedb/master` (or `slave`), and then removing the `/etc/namedb` directory and replacing it with a symlink to `/var/named/etc/namedb`. This will allow the `/etc/rc/named` script to launch `named` properly with its `chroot` protections.

It's inadvisable to try to turn off or defeat the sandbox behavior of `named`, but sometimes it's what the situation demands. If you absolutely have to run `named` outside its sandbox, you can do so by adding the following line to `/etc/rc.conf`:

```
named_chrootdir=""
```

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Working with the BIND Configuration File (named.conf)

To make your name server do anything useful, you need to make sure that it is topologically in the right place with respect to its clients and the rest of the network and that it is configured to interoperate properly with other name servers. A misconfigured name server can result in deluges of DNS traffic between your server and the root servers as it tries futilely to synchronize its data. Your `/etc/namedb/named.conf` file must be constructed properly, so it needs to be understood properly.

Caution

As should be a habit by now, be sure to make a backup copy of your `named.conf` file (such as `named.conf.20060315`) before you make any changes to it. Always leave yourself the option to revert to your previous working configuration!

Fortunately, BIND 9 (the version included in FreeBSD at the time of this writing) greatly simplifies many of the esoteric details of name server configuration that were the norm in BIND version 4 and earlier. BIND 8, which immediately replaced BIND 4, introduced a lot more configurability and at the same time eliminated many elements that were obsolete or poorly designed, and BIND 9 continues this simplification. Listing 32.1 shows a sample `named.conf` file, giving you an idea of its syntax and structure.

Listing 32.1. Sample `/etc/namedb/named.conf` File

```
/*
 * A simple BIND 8/9 configuration
 */

logging {
    category lame-servers { null; };
    category cname { null; };
};

options {
    directory "/etc/namedb";
};

zone "example.com" {
    type master;
    file "master/example.com";
};

zone "131.41.64.in-addr.arpa" {
    type master;
    file "master/131.41.64.in-addr.arpa";
};

zone "elsewhere.com" {
    type slave;
    file "slave/elsewhere.com";
    masters { 113.125.2.145; };
};

zone "." {
    type hint;
    file "named.root";
};
```

```
zone "0.0.127.in-addr.arpa" {
    type master;
    file "master/localhost.rev";
};

zone "0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.IP6.INT" {
        type master;
        file "master/localhost.rev";
};
```

As shown in the listing, a configuration file consists of a number of blocks (or *statements*) in C-style syntax, with substatements allowed within curly brackets (`{}`). All possible statements are listed and described in the `man named.conf` page. Some of the most useful ones are `options`, `controls`, `logging`, and `zone`.

Comments in `named.conf` are also C style; single-line comments are done with double slashes (`//`), and block comments are done with the `/* comment */` syntax. Shell-style comments (`#`) are also supported.

The `named.conf` file that exists in the default installation of FreeBSD has a few of the statements shown in Listing 32.1 and a few that are not. It also has a lot of inline documentation that describes how to use each of them.

Whenever you make a change to `named.conf` or to any of the zone files (which we will discuss later in this chapter), restart `named` using the `ndc` program:

```
# ndc reload
Reload initiated.
```

Using a Forwarder

Recalling the topology shown in Figure 32.1, a *forwarder* is a name server at an "upstream" networka larger network "closer" to the root serversthat allows you to request DNS information from it. (Note that access to a name server can be restricted, as you will see.) A good candidate for a forwarder is your uplink ISP's name server, if your FreeBSD machine is acting as a name server for a home network. Normally, if your machine can't answer a DNS request on its own, it must query the root servers (found in `/etc/namedb/named.root`) for the authoritative reply. These extra steps take time and add to the packet traffic on the network.

It really isn't necessary for everyone to get authoritative answers all the time. It's perfectly acceptable in most cases to work from nonauthoritative DNS information, such as that from a caching name server:

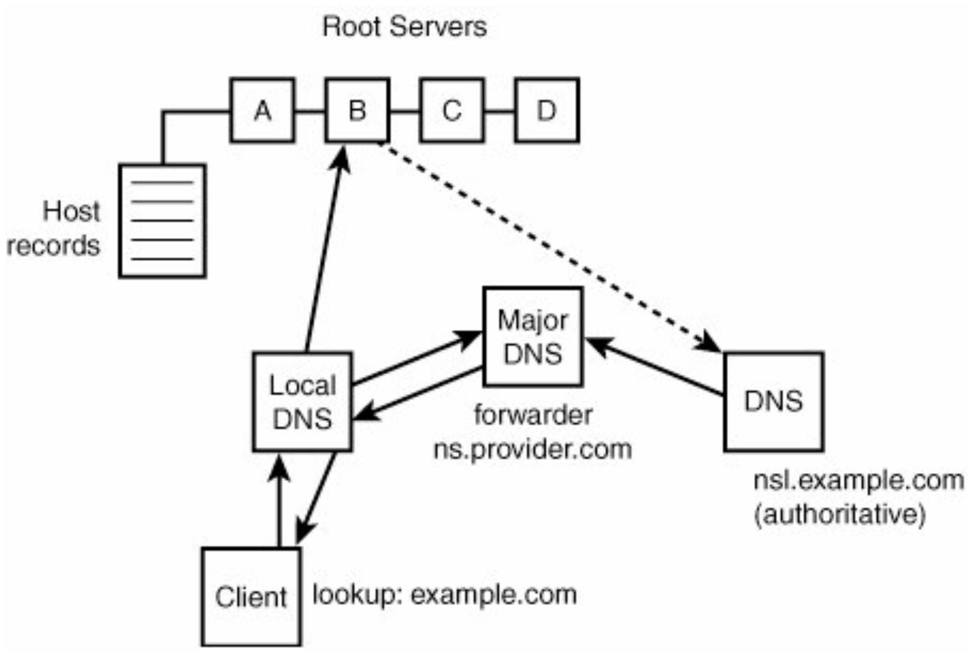
```
# nslookup www.freebsd.org ns.example.com
Server:  ns.example.com
Address:  64.41.131.172

Non-authoritative answer:
Name:    freefall.freebsd.org
Address:  216.136.204.21
Aliases:  www.freebsd.org
```

Note

Although the examples in this chapter use the rudimentary `nslookup` program (because of the clarity of its output), `nslookup` has been superseded for most administrators by the more versatile and verbose `dig`.

Configuring your FreeBSD system to query one or more forwarders allows it to benefit from the cache of the upstream name server, rather than to fetch authoritative data on every query. The downside (as we discussed earlier) is that the cached data can become "stale" by as much time as the authoritative server's zone file specifies it should (a period frequently measured in daysthough most forwarders do use reasonably short TTL values, which mitigates this drawback). Figure 32.2 shows a DNS query path in which a forwarder is involved. The forwarder does most of the work, building up its cache through queries of its own and in service to its own clients. The downstream DNS that points to it needs only to query the forwarder, thus preventing unnecessary lag and query traffic.

Figure 32.2. A diagram of a DNS lookup involving a forwarder providing cached DNS information in a nonauthoritative capacity to the local DNS and the client.



Tip

The deluges of DNS traffic mentioned earlier are often caused by name servers that are improperly configured, never to take advantage of caching name servers. These forwarders are what prevent too much unnecessary traffic from swamping low-bandwidth linksfor instance, in cases where a DNS host serving as the authoritative name server for a domain is on a small DSL or dial-up link. Without caching name servers, every host on the Internet would have to send DNS queries to that overloaded name server directly. With forwarders, the load on the target host's link is greatly reduced. Using a forwarder is a way to act as a good network citizen and make your own queries faster and more efficient.

To enable a forwarder, replace `127.0.0.1` in the `forwarders` block of the `options` statement with the upstream name server's IP address (127.0.0.1, the localhost address, will not work here) and uncomment the block by removing the /* and */ comment tags:

```
/*
        forwarders {
                127.0.0.1;
                66.114.72.112;
        };
*/
```

You can specify as many forwarders as you like, and named will consult each one before giving up and querying the root servers. You can additionally uncomment the forward only; statement in the options block to force named to consult only the forwarders on all queries. Normally, your machine will consult the forwarders for DNS data unless it appears that the forwarders are unreachable or broken, in which case it makes full queries to the root servers. Setting the forward only; option prevents it from making root server queries on any occasion.

Master and Slave Configurations

Each zone block defines a domain or subdomain that your FreeBSD machine will administer. Most commonly, a zone block defines a domain of the form example.com:

```
zone "example.com" {
    type master;
    file "master/example.com";
};
```

All that's absolutely necessary in this block is the name of the domain or subdomain (without the trailing dot that will usually be associated with a zone name), the type statement that defines whether it's a master or slave configuration for that domain, and the name of the file that contains the zone information (relative to the /etc/namedb root, which is actually /var/named/etc/namedb). Let's examine what it means for a name server to act as a master or a slave for a particular zone.

The type substatement can be master, slave, stub, forward, or hint. The most commonly used of these are master and slave; the rest are used in special circumstances only, which we will look at shortly.

A *master* zone indicates that the server is authoritative for the zone; it means the server has a master copy of the zone file, defining name-to-address mappings that are to propagate throughout the Internet, and any changes to it must be made manuallybut those changes override the information in every other name server's DNS cache when the existing information expires.

A *slave* zone is a replica of a master zone obtained from another server, with a zone file derived from the one that the master has. Slave servers can provide authoritative answers to DNS queries. A slave zone block looks like this:

```
zone "elsewhere.com" {
    type slave;
    file "slave/elsewhere.com";
    masters { 113.125.2.145; };
};
```

The masters statement contains a semicolon-delimited list of master servers from which to transfer zone information. These masters can be actual authoritative master zone servers or they can be other slaves, but if a specified master has an allow-transfer statement in its global configuration, the slave's IP address must be listed in that statement. (Access restrictions are discussed later in this chapter.)

The file statement in a slave zone refers to the name of the autogenerated zone file that named will create when it transfers it from the master. In this example, the elsewhere.com file is automatically generated within the /etc/namedb/slave subdirectory. Master zone files, which you create manually, are kept instead in the `master` subdirectory.

Tip

When you set up a slave zone on your server, run **`ndc reload`** to cause BIND to perform a zone transfer and create the new zone file at the location you specify in the `file` statement.

When changes are made to the master zone file on the master name server, your slave server inherits the changes only after the caching period specified in the file has expired. You can force the file to be updated more immediately by simply deleting the zone file in the `slave` directory and issuing the `ndc reload` command to re-create it.

Make sure that the `/etc/namedb/slave` directory exists before you issue the `ndc reload` command; otherwise, the command will fail.

Other Zone Types

As described in `man named.conf`, you can have three other types of `zone` blocks. These types are as follows:

- `stub` A `stub` zone works in the same way as a slave zone, except that it transfers only the NS recordsthe records specifying where clients can find valid DNS information for the specified domain.
- `forward` You can use a `forward` zone type to forward all requests for the zone to another server or set of servers. A `forwarders` block can be specified in this type of `zone` statement, operating like the global one in the `options` block; this enables you to override the global `forwarders` list.
- `hint` A `hint` zone is only really used in connection with the initial list of potential root servers, found in `/etc/namedb/named.root`. This initial list is not actually the authoritative list of root servers; it's a list of "hints" for BIND, specifying servers that will have the current true list of root servers. The contents of the true list has a habit of changing as network conditions vary.

Restricting DNS Access

Of interest to administrators with complex DNS configurations is that BIND has the capability to restrict access based on Access Control Lists (ACLs). ACLs are not a requirement, but they can make configuring your server much simpler, allowing you to use shorthand names for lists of addresses that you tend to reuse. An ACL is specified in an `acl` statement, which defines a name for the list and contains the criteria for which hosts are included in the list. These criteria can take a number of forms, and they can be recursive; in other words, an ACL can contain other ACLs. The following ACLs are predefined for you:

- `any` Allows all hosts
- `none` Denies all hosts
- `localhost` Allows the IP addresses of all interfaces on the system
- `localnets` Allows any host on a network for which the system has an interface

Other types of list elements that are allowed can be IP addresses (for instance, `111.112.113.114`), networks in CIDR format (for instance, `111.112.113/24`), a "negated" version of either of these (`!111.112.113.114`, which means "any host but `111.112.113.114`"), or a `key` statement (used in secure DNS transactions, which are beyond the scope of this chapter). When you're compiling a list of ACL elements, it's best to put the more specific elements before the broader ones because the list is evaluated in the order in which it's specified. If a host matches any element, it will be allowed, regardless of whether a later "negation" element would have matched it. Put all such exceptions toward the beginning of the list.

Because the contents of `named.conf` are read sequentially, an ACL must be specified in the file before it can be referred to later in other statements. For best results, put all `acl` statements toward the top of your `named.conf` file, above the `options` block. A sample ACL would be the following:

```
acl "my_list" {
  localhost;
  localnets;
  another_list;
  !132.112.14.124;
  132.112.14/24;
};
```

This list first contains the built-in `localhost` and `localnets` ACLs and then includes another ACL called `another list`, which would be defined elsewhere in the file. Then a negated "exception" host appears (`132.112.14.124`), with the "`!`" prefix exempting it from the `132.112.14/24` subnet that comes next. Thus, this ACL contains everything in that subnet except for the single host `132.112.14.124`.

After you have a list specified, you can use it along with other address list elements later in a `zone` statement (to control access to requests for just that zone) or in the global `options` statement. Here's a list of the available access-control statements:

- `allow-query {` ***`address_list_elements`***`; ... };`

  Specifies which hosts are allowed to perform ordinary DNS queries. `allow-query` may also be specified in a zone statement, in which case it overrides the `options allow-query` statement. If not specified, the default is to allow queries from all hosts.

- `allow-transfer {` ***`address_list_elements`***`; ... };`

  Specifies which slave servers are allowed to receive zone transfers from this server. `allow-transfer` may also be specified in the `zone` statement, in which case it overrides the `options allow-transfer` statement. If not specified, the default is to allow transfers from all hosts.

- `allow-recursion {` ***`address_list_elements`***`; ... };`

  Specifies which hosts are allowed to make recursive queries through this server. If not specified, the default is to allow recursive queries from all hosts.

- `blackhole {` ***`address_list_elements`***`; ... };`

  Specifies a list of addresses that the server will not accept queries from or use to resolve a query. Queries from these addresses will not be answered.

For example, you could restrict queries globally to members of the `my_list` ACL that you specified earlier. You also could restrict queries for the example.com domain to the members of `my_list`, as well as to an additional network, and restrict zone transfers only to two specified slave servers with the following partial configuration:

```
options {
    directory "/etc/namedb";
        allow-query { my_list; };
};

zone "example.com" {
    type master;
    file "example.com";
        allow-query { my_list; 64.2.43/24; };
        allow-transfer { 64.2.43.167; 123.15.221.3; };
};
```

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Creating a Zone File

The zone file is where the mappings for hostnames to IP addresses within a domain or zone are defined; it's also where the most mistakes are commonly made in a BIND configuration, so we will cover it in detail.

The format of a zone file (often referred to as a *master zone file* or simply *master file*) is quite complex and regimented, although there are certain things you can get away with. A "living" zone file in an existing BIND setup can be all but incomprehensible. It helps to understand what kinds of primitives (directives) are allowed and how each one is specified, as well as the shortcuts that are allowed and commonly used.

First, consider the sample zone file, and its components, shown in Listing 32.2. Note that semicolons (;) are the comment characters in zone files.

Listing 32.2. A Sample Zone File for the example.com Domain

```
$TTL 3600

    example.com. IN SOA stripes.example.com. root.example.com. (
                            20050610        ; Serial
                            10800           ; Refresh
                            3600            ; Retry
                            604800          ; Expire
                            86400 )         ; Minimum TTL
    ; DNS Servers
    @       IN NS           stripes.example.com.
    @       IN NS           spots.example.com.

    ; Machine Names
    localhost       IN A    127.0.0.1
    ns1             IN A    64.41.131.162
    ns2             IN A    64.41.131.163
    mail            IN A    64.41.131.167
    @               IN A    64.41.131.162

    ; Aliases
    www             IN CNAME        @
    ftp             IN CNAME        www.example.com.

    ; MX Record
    @               IN MX   10      mail.example.com.
```

Although it may look as though this is an unformatted mess, there is in fact a distinct structure to it. Listing 32.2 consists of six basic elements:

- A $TTL directive
- The SOA (Start of Authority) record
- A block of NS (Name Server) records
- A block of A (Address) records
- A block of CNAME (Canonical Name) records, which define aliases

- An MX (Mail Exchanger) record

Aside from the directives, each element of the file is a *resource record* (RR), defining the properties of a name within the zone relative to a certain "origin." The following sections look at each of these elements in turn.

Start of Authority (SOA) Records

Following the basic directives that might appear at the top of the file (such as `$TTL`, which specifies a default time-to-live value), we come to the first resource record in a zone file: the Start of Authority (SOA) record. This is the most important part of a zone file, and the most commonly botched. Many mistakes are the result of the counterintuitive style of the SOA record's format. To understand this record, you need to look at it piece by piece.

Here's the sample SOA record from Listing 32.2:

```
example.com. IN SOA stripes.example.com. root.example.com. (
                        2001061000      ; Serial
                        10800           ; Refresh
                        3600            ; Retry
                        604800          ; Expire
                        86400 )         ; Minimum TTL
```

The SOA, like all records, has the following basic form:

```
name [ttl] [class] type value
```

If *`name`* is not absolute, the current contents of the `$ORIGIN` directive (which starts out with the same value as the corresponding `zone` statement in the `named.conf` file) are appended. In this case, the name is absolute (it ends with a dot).

The *`ttl`* field is omitted because the sample file has a global `$TTL` directive specifying it. `IN` (for "Internet") is the class; BIND supports other kinds of classes, but we're not interested in them here. If `in` was specified in the `zone` statement in `named.conf`, this field is redundant and can be omitted.

The *`value`* field for most records is quite simple: an IP address, a hostname, or some symbolic name. For the SOA record, though, it's much more complex. It begins, first of all, with the name of the authoritative name server for the zone (`stripes.example.com`). The next piece of information is the email address of the administrator of the domain, with the `@` sign replaced by a dot. It also has a trailing dot at the end. In our example, the administrator (`root@example.com`) is specified as `root.example.com.`, which will be used by BIND to mail status notifications to the responsible party.

Note

The reason for the `@` sign in the administrator email address being replaced with a dot is that the `@` symbol, in a zone file, has a special meaning. It's shorthand for the current value of the `$ORIGIN` directive and will be expanded by BIND into a fully qualified domain name.

Note that the `@` symbol must be the complete key if you use it; it can't be expanded implicitly, as in `www.@` or some similar construct.

Following the administrator address is a parenthesized block of settings; the parentheses specify a block in which line breaks are ignored, so you can format the values for better clarity. These are the numbers that define how the zone data will behave on the Internet:

- *Serial Number* The serial number is the way BIND keeps track of how recent a zone file is. Each time you update the zone file, you must increment the number so that BIND knows to refresh its information from the file. Standard practice is to use the format `YYYYMMDDNN` for this number; the final two digits are for revisions within a day. Update the number to reflect the current day when you make a change.

  Note

  When you use `ndc reload` to refresh a master zone file's information, BIND will automatically determine that the data needs to be refreshed, regardless of the serial number. However, keeping the serial number accurate is a good habit to be in; it will ensure proper operation in cases such as manually refreshing slave zone data.

- *Refresh* This number, in seconds, specifies how frequently slave servers should check the master for updated zone data. If the master's serial number has changed since the last zone transfer, a new zone transfer will be performed.
- *Retry* If the master server cannot be contacted, the slaves will retry at intervals specified by this number (in seconds).
- *Expire* If the master server cannot be contacted within this time (in seconds), the slave servers discard all their data for the zone.
- *Minimum TTL* This number (in seconds) specifies how long "negative cache" responses (which indicate the absence of a piece of data) should be kept.

Name Server (NS) Records

Listing 32.2 showed the following sample Name Server (NS) records:

```
; DNS Servers
@       IN NS           stripes.example.com.
@       IN NS           spots.example.com.
```

These records specify the DNS servers that are allowed to give authoritative answers to queries about the zone. Note that the `@` symbol refers to the current `$ORIGIN` (which, in this case, is `example.com.`) and that both server names have trailing dots (indicating that they are absolute).

You can create NS records for subdomains, or zones within the current zone. For instance, suppose you have a cluster of machines within a zone called `cluster.example.com.`, with their DNS information handled by their own name server (`ns.cluster.example.com`). A valid NS record for that server, allowing external hosts to query it for the cluster's IP addresses, would be

```
cluster IN NS          ns.cluster.example.com.
```

Recall that by leaving the trailing dot off of `cluster`, the current `$ORIGIN` (`example.com.`) is appended to it by BIND.

Address (A) Records

The Address (A) record is what you use to associate a hostname with an IP address. Our example had the following records:

```
; Machine Names
localhost       IN A    127.0.0.1
stripes         IN A    64.41.131.162
spots           IN A    64.41.131.163
mail            IN A    64.41.131.167
@               IN A    64.41.131.162
```

The meaning of these records is fairly straightforward. The unqualified names on the left-hand side are expanded with the current `$ORIGIN`. Therefore, `mail.example.com` would resolve to `64.41.131.167`. Similarly, the `@` symbol expands so that a query for `example.com` would return `64.41.131.162`.

Names that are defined in A records are known as *canonical names*, as opposed to *aliases* (which are defined by CNAME records).

Canonical Name (CNAME) Records

Canonical Name (CNAME) records are used to create aliases. The terminology is such that in our example from Listing 32.2, the alias name `www` (which expands with `$ORIGIN` to www.example.com.) points to the canonical name `@`, or `example.com.` (whose IP address is defined in the A block):

```
; Aliases
www             IN CNAME       @
ftp             IN CNAME       www.example.com.
```

Note

It's critical to remember that the trailing dot at the end of a hostname indicates that the name is absolute (fully qualified). If the dot is omitted, the value of `$ORIGIN` is appended automatically. If you find your programs looking for hosts with names like www.example.com.example.com, you know that a potential culprit is a DNS configuration where a hostname has been left unqualified and needs to have a dot added.

CNAME records are often useful in that they are not immediately bound to an IP address. You can use CNAME records to point to names in another zone, for example, which can then be controlled by the owner of that zone. Also, CNAME records are helpful in reducing the number of changes that must be made in a zone file if an IP address changes.

Mail Exchanger (MX) Records

Mail Exchanger (MX) records define which hosts are to be used for mail delivery to addresses in the zone. Sendmail (and other MTAs) look up the most preferred MX record within a zone and open a connection to it; you can find out the MX hosts for a domain with the `host` command:

```
# host somecompany.com
somecompany.com has address 207.114.98.18
somecompany.com mail is handled (pri=100) by mail.uu.net
somecompany.com mail is handled (pri=5) by mx-1.somecompany.com
```

Each MX record has a "priority" number associated with it, and mail servers for a domain are tried from lowest to highest numerical value until a successful SMTP connection can be made. The priority is specified as part of the value field in the record, as in this example, which sets the priority to 10:

```
; MX Record
@               IN MX    10 mail.example.com.
```

Caution

An MX record cannot point to an IP addressyou must supply a name. Also, many MTAs and mail clients will complain if they detect an MX record that points to a CNAME. Make sure your MX records point to defined names specified elsewhere with A records!

Pointer (PTR) Records

Pointer (PTR) records are the reverse of A or CNAME records and are used in reverse DNS zone files (for example, `131.41.64.in-addr.arpa`) to map IP addresses to domain names. (An example of a reverse DNS zone file is shown in Listing 32.3.)

It's possible to specify more than one PTR record for a given IP address, a configuration practice that's increasingly in use for purposes such as spam control. However, because a reverse DNS lookup only returns a single name, many administrators only attach a single PTR record to a given IP address even if many hostnames resolve to that address; this means that reverse files are often shorter than their forward counterparts.

Reverse DNS Zone Files

A reverse DNS zone file, defining a zone of the form `131.41.64.in-addr.arpa`, is used to map IP addresses to names. Files of this sort are referenced in `named.conf` and propagated to slave servers just like forward DNS zone files. Listing 32.3 shows a sample reverse DNS zone file.

Listing 32.3. A Sample Reverse DNS Zone File for the `131.41.64.in-addr.arpa` Zone

```
$TTL 3600

131.41.64.in-addr.arpa. IN SOA stripes.example.com. root.example.com. (
                         2005061000      ; Serial
                         10800           ; Refresh
                         3600            ; Retry
                         604800          ; Expire
                         86400 )         ; Minimum TTL

@      IN NS     stripes.example.com.
@      IN NS     spots.example.com.

162    IN PTR    stripes.example.com.
163    IN PTR    spots.example.com.
167    IN PTR    mail.example.com.
```

Note the use of PTR records instead of A or CNAME records. The name that each PTR points to is the true canonical name for that IP address. There is also no need for an MX record in a reverse file because MX records cannot be associated with IP addresses in the first place.

Making a `localhost` Zone File

A special zone file must exist for the `localhost` zone (`0.0.127.in-addr.arpa`) to work properly. There's a shell script in `/etc/namedb` to help you create one. The script is called `make-localhost`, and it reads in a template (`PROTO.localhost.rev`) and fills in information that it derives from your input. Because it isn't set executable, you must run it with the `sh` command:

```
# sh make-localhost
Enter your domain name: example.com
```

The resulting file, `/etc/namedb/master/localhost.rev`, should look something like Listing 32.4.

Listing 32.4. Autogenerated `localhost.rev` Zone File

```
;       From: @(#)localhost.rev 5.1 (Berkeley) 6/30/90
; $FreeBSD: src/etc/namedb/PROTO.localhost.rev,v 1.6 2000/01/10 15:31:40 peter Exp $
;
; This file is automatically edited by the `make-localhost' script in
; the /etc/namedb directory.
;

$TTL    3600

@       IN      SOA     stripes.example.com. root.stripes.example.com. (
                                20050612        ; Serial
                                3600    ; Refresh
                                900     ; Retry
                                3600000 ; Expire
                                3600 )  ; Minimum
        IN      NS      stripes.example.com.
1       IN      PTR     localhost.example.com.
```

Make sure to create this file before fully deploying your DNS service!

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Configuring a Caching Name Server

It's entirely possible to run a name server that is not authoritative for any zones. This is what's known as a *caching name server*, and its job consists solely of making DNS queries when prompted by clients and storing the results for later use. This is the opposite effect of the `forward only` option we discussed earlier in this chapter. Whereas a `forward only` name server would pass off all requests to its forwarder to handle, a caching name server performs all requests that are asked of it by itself and caches the results. Other name servers can use this server as a forwarder, leveraging the work that it has already done.

To configure a caching name server, simply omit any `zone` statements from your `named.conf` file other than the ones necessary for its own operation. Listing 32.5 shows such a configuration.

Listing 32.5. A Sample `/etc/namedb/named.conf` File

```
/*
 * A simple BIND 8 configuration
 */

logging {
    category lame-servers { null; };
    category cname { null; };
};

options {
    directory "/etc/namedb";
};

zone "." {
    type hint;
    file "named.boot";
};

zone "0.0.127.in-addr.arpa" in {
    type master;
    file "master/localhost.rev";
};
zone "0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.IP6.INT" {
        type master;
        file "master/localhost.rev";
};
```

Because a caching name server is simply a "degenerate case" of a fully configured name server, you can easily expand your server's functionality by adding additional zones as time goes on. There is no real fundamental difference between the two "modes."

Your DNS configuration will change with time as your network evolves. Each time a new host is added to your network or changes its name, and each time you take on or remove the name service authority for a zone, you will need to make changes to the configuration. It's a good idea to keep in practice with DNS administration so that these tasks become more natural with time.

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Chapter 33. The Network Filesystem (NFS)

IN THIS CHAPTER

NFS, the *Network Filesystem*, is the UNIX way of performing file sharing. Windows and the Mac OS both have their own file-sharing mechanisms, enabling networked computers to access files on remote machines on a LAN as if they were local. NFS provides the same benefits to UNIX machines, with a few extra features that other sharing protocols don't have, although not without its limitations as well.

This chapter will describe how to configure your FreeBSD machine to operate as an NFS client and/or server, sharing files with other UNIX machines on your LAN or across the Internet.

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Introduction to NFS

Windows uses NetBIOS/SMB/CIFS for its file sharing, and Macintoshes use AppleTalk or AppleShare/IP. These are all peer-to-peer protocols, with each system broadcasting its presence onto the LAN, and all machines being able to mount each other's shared folders dynamically. NFS is a bit different in that it's a client/server protocol, with designated servers sharing items that can be mounted remotely by specified NFS clients. This model is designed for centralized file servers, as is common in enterprise or university networks, rather than for peer-to-peer file transfers. However, with the proper configuration, NFS can do almost everything that the other protocols can do, and more, with the exception of server discovery.

Under both Windows and the Mac OS, the built-in filesharing protocol on a computer broadcasts information about its own shared folders (or *shares*) and asks for responses about other available shares on the network. These "discovery" queries and responses are sent out by each machine on the network and trigger frequent responses from all other machinesresulting in a very "chatty" network environment. NFS doesn't have a corresponding discovery mechanism. As you will see, each NFS client has to know where to find each server and mount it manually. However, this does mean that the network is much quieter due to a lack of discovery traffic.

Tip

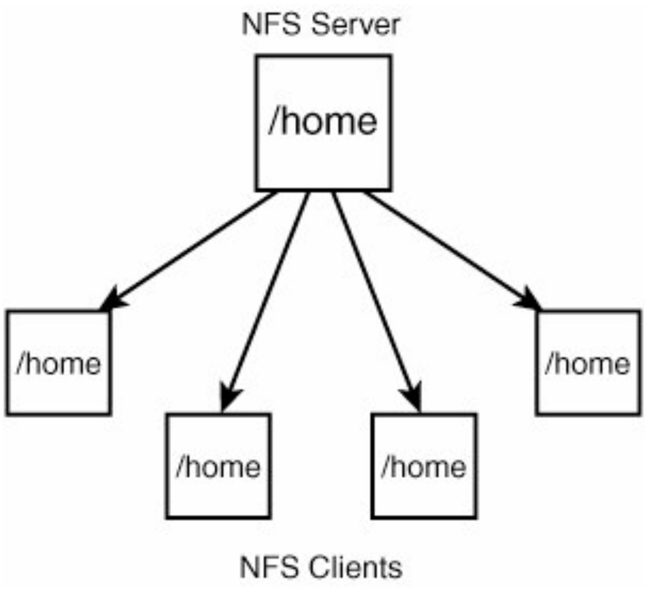
The *Service Location Protocol (SLP)* is a separate technology that allows for the automatic discovery and browsing of network resources such as NFS shares. You can install the OpenSLP package (in the `net` category of the ports or packages) to give your FreeBSD machine the capability to discover NFS shares on the network; modern versions of Windows and Mac OS X have SLP functionality built into their filesystem browsers. Without SLP, though, you have to know the name and location (and authentication requirements) of any NFS share you try to mount.

This less-convenient structure of NFS does have its benefits. The centralized model provides better security; a server can control exactly which clients are able to connect to itfor example, by hostname or IP address, or by centralized login, as with NIS or Kerberos. Another feature of NFS is that because it does not depend on LAN broadcasts for server discovery, it can be used across the Internet just as easily as across the LAN. A client in Boston can mount a share from a server in San Francisco, if necessary. By contrast, NetBIOS/SMB/CIFS and AppleTalk only can operate within "domains" or "zones" on the local network, or over a VPN tunnel where all hosts are topologically on the same LAN (although AppleShare/IP can cross the Internet freely).

As far as FreeBSD is concerned, NFS is a filesystem just like any other. You can mount an NFS share over the network just as if you were mounting a floppy disk or a new hard drive partition, as you saw in Chapter 12, "The FreeBSD Filesystem." Shares can even be mounted automatically if their resources are requested. We will go over the procedure of mounting an NFS share manually and automatically later in this chapter.

The client/server structure of NFS is designed so that you can centralize the resources in your network. For example, an enterprise might give all its employees home directories on a central UNIX machine, and every other system in the network that supports NFS will be able to mount those home directories and access them remotely, rather than requiring each machine to have its own copy of every home directory. Figure 33.1 shows this kind of network topology in action. The same can be done for build directories (in a software development environment) or shared applications that are centrally installed (as in a university workstation cluster). NFS mounts can be used in conjunction with NIS (centralized login management) to provide the entire network with user authentication; then, file ownership and permissions on every file in a mounted share will work just as on the NFS server machine itself. You can even install FreeBSD over NFS if you mount the installation DVD on the NFS server and point Sysinstall toward it.

Figure 33.1. An enterprise network with central NFS-mounted home directories.



An interesting aspect of NFS is that it's primarily based on UDP rather than TCP. As you learned in Chapter 22, "Principles of TCP/IP Networking," UDP has none of the reliability or connection-centric structure of TCP and is inherently unreliable. Although it seems odd that a data-conscious network protocol would use UDP as its transport mechanism, spewing datagrams from server to client without any guarantee of their integrity, NFS is actually one of the best examples of UDP used properly. Full TCP connections aren't really needed, especially on a LAN. NFS clients come and go as machines on a network come up and shut down, and TCP connections would just get in the way of data streams sending files and directory information back and forth between the endpoints on request. An NFS mount can stay dormant for days and then suddenly be called into use again. UDP allows the shared resources to be immediately available without connection startup overhead or lag time, and if a host drops off the network, it's no big deal to the server.

Data integrity is maintained by the NFS software itself, higher up the OSI stack in the application layer, keeping checksum and sequencing information in the packets' payload and doing all the work that TCP would otherwise have done. However, NFS clients that operate over TCP do exist, and the NFS server supports them, too. NFS over TCP is primarily intended for mounts that take place over a WAN, in which dropped packets are much more likely, and the benefits of full TCP connections mitigate the benefits that UDP offers on LAN connections. TCP-based NFS can also be useful for firewall administrators who need to know a predictable TCP port on which to allow NFS traffic (UDP-based traffic tends to use large and unpredictable port ranges that confound firewall configurations).

Note

One downside to using UDP, though, is that if a client tries to contact an NFS server that isn't there, it can take forever to time out. The lack of a full TCP connection means that more primitive methods are necessary to determine whether a server is not responding. We will talk about some of the ways to avoid running into the lengthy NFS timeout later in this chapter.

Caution

NFS doesn't have any built-in encryption, so it should be used over the Internet only if you're working with files that can be safely exposed to the public. Mission-critical or sensitive data should never be sent over wide-area NFS, except through an encrypted VPN tunnel.

A FreeBSD machine can be configured to be an NFS server, an NFS client, or both. Depending on how you configure it, the system will run a few different processes that manage the end of the NFS connections it will handle. We'll talk first about setting up a FreeBSD machine as an NFS server and then about configuring it as a client.

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Configuring an NFS Server

Setting up your FreeBSD machine to be an NFS server involves a one-line addition to /etc/rc.conf:

```
nfs_server_enable="YES"
```

Also, make sure that rpcbind_enable (portmap_enable prior to FreeBSD 5.0) is set to "YES" because it is disabled by default unless you override it. The rpcbind (or portmap) daemon needs to be running in order for NFS to work because the NFS server needs a mechanism by which to tell its clients which port to connect to. UDP services operate with only one "connection" per port, so while initial connections to the NFS server take place on the server port 2049, these connections are mapped by remote procedure call (RPC) services, provided by rpcbind, to a new and unused server port. Note that rpcbind services are fairly insecure and subject to a number of recurring security issues; for this reason, it's not a good idea to have an NFS server exposed to the Internet without a firewall protecting it. See Chapter 30, "Network Security," for more on firewalls.

When you set the nfs_server_enable option and reboot (or run **/etc/rc.d/nfsserver start**), FreeBSD starts two kinds of daemon processesthree if you count rpcbindafter reading the contents of the /etc/exports file to determine what parts of the filesystem to share over NFS. The following sections look at each of these components to explain what they do and how to control them.

NFS Daemon (nfsd)

The NFS server daemon, the equivalent of sshd or httpd, is nfsd. A certain number of nfsd processes are started when the network is initialized (the default is four); these processes are assigned to service NFS clients when they connect, one process per client. In the default configuration, a maximum of four clients can connect to your NFS server at the same time. You can tune this with the nfs_server_flags setting in /etc/rc.conf, of which the following is the default:

```
nfs_server_flags="-u -t -n 4"
```

The -n flag can be set to any number you like; set it to the highest number of concurrent NFS clients you expect to be connected to your server at any one time. The -t and -u flags tell the nfsd processes to serve both TCP and UDP clients. Other flags are available for you to tweak, if you like. For instance, if your machine has multiple network interfaces, you can specify **-h 64.41.131.102** among the other flags to bind the NFS servers to the interface with the address 64.41.131.102. (You can also use a hostname instead of an IP address.) This can be necessary because the UDP mechanism is such that if you don't tell nfsd for which specific IP addresses it should serve requests, its responses are not guaranteed to emanate from the address that the client contacted. You can list as many addresses as you need with multiple -h flags. For example, let's say you have a server acting as a gateway with two network cardsone on the "inside" and one on the "outside" of the network. Your "inside" card has two IP addresses bound to it, and you want to serve NFS shares only to clients on the inside. You can set up NFS like this:

```
nfs_server_flags="-u -t -n 4 -h 64.41.131.102 -h 64.41.131.116"
```

Then, you can block access to the NFS service on the outside interface with an IPFW rule, like so:

```
ipfw add deny udp from any to 64.41.131.10 nfsd
```

Refer to "Using a Firewall," in Chapter 30, for more information on how to configure firewall rules using

IPFW.

NFS Mount Daemon (`mountd`)

Whereas `nfsd` is the program that provides the connection end of each individual NFS mount, a second program is in charge of listening for new NFS client requests (on TCP port 2049). This program is `mountd`, the mount daemon. It is executed automatically along with the `nfsd` processes during the network setup procedure at boot time if `nfs_server_enable` is set to `"YES"`.

`mountd` takes incoming NFS connections and passes them to `nfsd` processes. It's also in charge of keeping track of the NFS shares you have specified in `/etc/exports`. To restart NFS services after making changes to `/etc/exports`, you need to send an `HUP` signal to `mountd`, as you will see shortly.

There aren't too many useful options for `mountd`. The default settings in `/etc/defaults/rc.conf`, which you can override in `/etc/rc.conf`, are as follows:

```
mountd_flags="-r"
```

The `-r` flag allows `mountd` to serve regular files rather than only directories, to maintain compatibility with certain diskless workstations that boot via NFS. The `-l` flag allows you to log all NFS mount requests, and the `-n` flag allows NFS shares to be mounted to remote systems such as Windows PCs that don't share the same ownership and permissions model as UNIX.

Determining What to Share with the `/etc/exports` File

The `/etc/exports` file lists what directory trees should be shared via NFS as well as who should be allowed to share them. If `/etc/exports` does not exist or is not readable at the time the network interfaces are brought up at boot time, the `nfsd` and `mountd` processes are not started.

The full format of `/etc/exports` is defined in `man exports`. A basic export line specifies one or more directories that should be exported (shared), any of several options, and then an optional list of hosts (by IP address, network, netgroup, or hostname) allowed to share the specified directories. For example, the following line shares the `/home` directory and all its subdirectories to anybody who connects:

```
/home -alldirs
```

Note that the `-alldirs` option can only be specified if the share is the mount point of a filesystem (for example, `/usr` or `/var`). If it isn'tfor example, if `/home` is not a separate filesystem but a directory within anotherthe share will not be made available.

A share that can be accessed only by three specified hosts and is read-only would look like this:

```
/usr2 -ro -alldirs stripes.example.com spots.example.com 64.41.131.165
```

Tip

You can create groups of hosts by specifying them in the file `/etc/netgroup`, which does not exist in the default installation. A group can be specified in the following form:

```
groupname (host, user, domain) (host, user, domain) ...
```

For instance, to create a group called `desktops` that contains three particular hosts (named `sol`, luna, and terra), the line would look like this:

```
desktops (sol,,) (luna,,) (terra,,)
```

A netgroup defined on usernames would look like this:

```
developers (,frank,) (,bob,) (,alice,)
```

You can then use any of these netgroup names instead of hostnames in `/etc/exports` to confine an NFS share to members of that group.

File ownership in an NFS share is mapped based on the UIDs of each file and directory. If the usernames and UIDs on the server and client machines are the same (for instance, if the machines' logins are synchronized via NIS or Kerberos), the permissions will match. However, if UID 1045 maps on the server to the username `bill`, but UID 1045 on the client is `john`, John will own the files in the share that the server thinks Bill owns. When exporting a share containing files owned by many different users, make sure the infrastructure is in place to provide consistent mappings between UIDs and usernames on all the machines on your network.

You can use the `-maproot=`*`username`* or `-maproot=`*`UID`* option to map ownership so that the username matching *`username`* or the user ID matching *`UID`* on the client machine will have full root permissions in the share. For example, here's how to share the entire filesystem of the NFS server with anybody in the `64.41.131` network, with the client user `frank` having full read/write access to all the files:

```
/ -maproot=frank -network 64.41.131 -mask 255.255.255.0
```

After making any changes to `/etc/exports`, you need to restart the `mountd` process (assuming it's already running). Do this by running **`/etc/rc.d/mountd restart`**, or by accessing the runtime PID file directly:

```
# kill -HUP `cat /var/run/mountd.pid`
```

Note

You can't have multiple export lines for mount points within the same partition or filesystem. This is to prevent problems in cases where the export permissions for different shares in the same filesystem would conflict. An NFS client cannot access one filesystem from within another that it has mounted, and the same access permissions must apply for all shares within a filesystem. The following setup is illegal:

```
/home/frank 64.41.131.102
/home/joe 64.41.131.102
```

However, this one is correct:

```
/home/frank /home/joe 64.41.131.102
```

You can use the showmount program (with the e, or "show exports list" option) to display the valid shares and their permissions. This is how you can tell whether your /etc/exports setup is valid:

```
# showmount -e
Exports list on localhost:
/usr                             Everyone
/home/frank                      64.41.131.102
/home/joe                        64.41.131.102
/                                64.41.131.0
```

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Configuring an NFS Client

If your FreeBSD machine will be mounting NFS shares from other servers, you will need to configure it as a client. Technically this isn't really necessaryyou can mount an NFS share in a rudimentary fashion right out of the box. However, configuring the system as an NFS client gives you a few features that ensure speedy and reliable performance, such as the `nfsiod` dispatcher.

To set up an NFS client machine, simply enable the following line in `/etc/rc.conf`:

```
nfs_client_enable="YES"
```

This setting enables the NFS Input/Output Daemon, `nfsiod`, which helps to streamline NFS client requests and tunes a few kernel settings to improve access time. This is all handled automatically in the `/etc/rc.network` script at boot time, along with the NFS server settings (which you saw earlier).

NFS Input/Output Daemon (`nfsiod`)

The `nfsiod` daemon isn't required for proper NFS client operation, but it helps to speed things up. The `nfsiod` daemon operates by allowing NFS read and write operations to be done in an asynchronous manner, with "read-ahead" and "write-behind" operations occurring in the background, rather than having to wait for each sequential step in the process to complete. Just as with `nfsd`, there should be as many `nfsiod` processes running as there are mounted NFS shares on the client machine. You can tune the number of processes with the `nfs_client_flags` setting in `/etc/rc.conf`, which uses the `n` option to create four processes by default:

```
nfs_client_flags="-n 4"
```

There aren't any other settable options for `nfsiod`. To start it without rebooting the machine, simply run the appropriate `rc` script:

```
# /etc/rc.d/nfsclient start
```

Mounting Remote Filesystems

Mounting an NFS share is done with the `mount_nfs` command, which is a shorthand command for `mount -t nfs` (as you learned in Chapter 12). In its most common form, you would pass to it two arguments: the host and share names in a combined string, and the local mount point:

```
# mount_nfs spots:/home /home2
```

A successful mount will result in no output. You can check whether the mount was successful with the `df` command:

```
# df
Filesystem           1K-blocks     Used    Avail Capacity  Mounted on
/dev/ad0s1a             992239    54353   858507     6%    /
/dev/ad0s1f           26704179  4872963 19694882    20%    /home
/dev/ad0s1e            9924475  1642343  7488174    18%    /usr
procfs                       4        4        0   100%    /proc
```

```
spots:/home            9924475  1642343  7488174    18%    /home2
```

If you go into the `/home2` directory, you'll see all the directories within `/home` on the NFS server, with each file's ownership mapped based on UID, as discussed earlier. The filesystem will remain mounted until you explicitly unmount it with the `umount` command:

```
# umount /home2
```

Caution

Remember to leave any NFS-mounted directory before you try to unmount it with `umount`! You will get a "device busy" error if you try to unmount a filesystem while you're still inside it.

NFS shares can be mounted in a great variety of ways, and the options are laid out in the `man mount_nfs` page. Some of the more useful ones are the `-T` option, which forces TCP transport rather than UDP (useful for mounts done over WAN links), and the `-s` and `-x` *`seconds`* flags, which allow the mount to time out and disappear after a specified period and then fail (a "soft" mount). Here's an example:

```
# mount_nfs -s -x 60 spots:/home /home2
```

Tip

Another useful option is `-i`, which enables interruptibility. Normally, if you have mounted an NFS share and the server becomes unresponsive or unreachable, any filesystem calls you make (commands that deal with the shared files, such as `ls`) can hang in such a way that even pressing Ctrl+C (the termination signal) won't stop them. The `-i` option makes it so that Ctrl+C will force the command to fail, returning control to you.

As with other filesystem types, you can add NFS mounts to `/etc/fstab` to set up predefined mount points, thus simplifying the mount process. Place any options you would otherwise pass to `mount_nfs` in the `Options` column, separated by commas, as shown here:

```
# Device                Mountpoint      FStype  Options         Dump    Pass#
spots:/home                 /home2          nfs     rw,-T,-i,noauto 0       0
```

With a table entry like this, you can mount an NFS filesystem with a much simplified `mount` command:

```
# mount /home2
```

Mounting Remote Filesystems Automatically at System Boot

All filesystems in `/etc/fstab` are automatically mounted at boot time, unless the `noauto` option is present. You can specify that remote NFS shares should be mounted at startup by simply adding them to `/etc/fstab`, as you just saw. However, there are a few things to watch out for.

Most notably, NFS has an extremely long default timeout period, and the phase during startup when filesystems are mounted is a synchronous, blocking process. If your NFS server or servers cannot be foundfor instance, if the server machine isn't running, or if your own machine's network connection is not configured properlythe boot process can hang for an intolerably long period before NFS gives up and allows the system to finish the boot procedure.

You can solve this problem by placing the `noauto` option in `/etc/fstab`, as you saw in the earlier example. However, this means that you have to mount each NFS share manually after the system is fully booted. There's a better way to handle thisthe `-b` option. Here's an example:

```
# Device                 Mountpoint       FStype  Options          Dump     Pass#
spots:/home              /home2           nfs     rw,-b              0        0
```

The `-b` option tells `mount` to make a quick attempt to contact the server, and if it can't, to fork off a child process to continue trying to connect while the boot process continues on. Similarly, if you mount a share from the command line using `-b`, the process forks into the background and returns you to the command prompt. The following is the output you would get when trying to mount the share specified in the preceding sample `/etc/fstab` line, after trying for 60 seconds:

```
# mount /home2
spots:/home: nfsd: RPCPROG_NFS: RPC: Port mapper failure - RPC: Timed out
nfs: Cannot immediately mount spots:/home, backgrounding
```

The background `mount_nfs` process will keep trying to mount the share until it's successful. This method is particularly useful in computing clusters or labs in which NFS-mounted resources are nice to have but not required for correct operationfor example, a cluster in which an NFS mount contains popular user programs or games, but all critical system functions are available on disks on the local system.

Auto-Mount Daemon (amd)

The auto-mount daemon, amd, makes NFS mounts even more convenient. This daemon allows you to mount NFS shares (and other filesystem types, as a matter of fact) dynamically, simply by working in the directory in which the share would be mounted, without ever having to bother with mount commands.

FreeBSD provides a basic way to set up amd. Simply add the following line to /etc/rc.conf:

```
amd_enable="YES"
```

When the system is booted with this option, amd runs with the options specified in the amd_flags setting, which are such that anything in the /host or /net directoriesboth of which are created automatically by amdwill auto-mount by name. You can also start it in the same way as it would be at boot time by issuing the **/etc/rc.d/amd start** command.

With amd running, use the cd command to move into the /host directory. Look around, and you'll notice the directory is empty:

```
# cd /host
# ls
#
```

However, try listing by name as if there were a directory there with the same name as a known NFS server on the network:

```
# ls stripes
home
```

So, it seems that there's indeed a directory called stripes in the /host directory, and inside it is a home directorywhich contains everything that the stripes:/home share has. You've just auto-mounted that share into the /host directory, simply by listing it as a directory name. /host/stripes/home is functionally the same thing as the /home2 mount point you manually created in the earlier example. The df command will verify it:

```
# df
Filesystem    1K-blocks     Used    Avail Capacity  Mounted on
stripes:/home   9924475  1642345  7488172   18%     /.amd_mnt/stripes/host/home
```

Note

Notice that NFS shares mounted in this manner actually appear to be mounted inside a directory called .amd_mnt in the root directory. This directory doesn't actually exist; it's just a type of shorthand used by the amd daemon for bookkeeping purposes.

To specify a permanent location for a mountable NFS resource, simply make a symbolic link to the appropriate path within /host or /net:

```
# ln -s /home2 /host/stripes/home
```

From now on, whenever you go into the `/home2` directory, the `stripes:/home` share will automatically mount and give you access to its files. When the share is no longer in use, it will automatically unmount.

Tip

You can specify much more complex `amd` mount maps, which are more direct methods of mounting filesystems at particular points, with the `/etc/amd.conf` file. This file doesn't exist in the default FreeBSD installation; see `man amd.conf` for details on its format and capabilities.

PREV NEXT

Chapter 34. File and Print Sharing with Microsoft Windows

IN THIS CHAPTER

NFS is an excellent solution for file sharing between FreeBSD, Linux, and similar systems, where UNIX permissions and file metadata (such as modification times) must be preserved from machine to machine. However, NFS isn't widely supported on many consumer operating systems. Windows and classic Mac OS support it only through third-party applications, andmore importantly in an enterprise environmentthere isn't any "discovery" mechanism built into NFS to allow clients to browse lists of available servers.

When you put a FreeBSD machine into an existing network, chances are that most of the computers already there will be running Windows. True interoperation with these clients and with existing Windows file servers requires that FreeBSD share files the same way Windows does. This method involves SMB, the *Server Message Block* protocol, and the *Common Internet File System* (CIFS), which replaced it and is itself now slated to be phased out in upcoming versions of Windows.

File sharing over SMB/CIFS is not a built-in part of FreeBSD. However, an add-on package called *Samba* gives a FreeBSD machine the capability to act as a Windows file server and participate in all the same file-sharing activities as true Windows clients.

Samba is an open-source, volunteer project originally begun by Andrew Tridgell and now developed collaboratively by the general UNIX community. It provides a UNIX system (such as FreeBSD) with the capability to do everything that Windows file sharing can do, including appearing in network browsing lists, securing connections based on NT domain and username logons, and providing network print services. Samba also includes tools that provide many of the administrative functions of a Windows server. With the addition of the `smbfs` kernel module to allow FreeBSD to operate as a Windows file-sharing client (you learn more about `smbfs` later in this chapter), you can use a FreeBSD machine in a Windows network environment with just as much functionality as a native Windows machine would have.

This chapter will guide you through configuring Samba. Here, you'll learn how to add Windows-like file-sharing and printer-management capabilities to your FreeBSD system, including integration into Windows workgroups and domains so that your system is indistinguishable on the network from native Windows PCs.

Note

The official website for Samba is www.samba.org, from which you can select any of a number of different geographical mirror sites.

SMB/CIFS and Samba

SMB, dating back to documents published in 1985 by IBM and later further expanded by Microsoft and Intel, is a generalized system for sharing all kinds of system resources over a local network. Such resources include files, printers, serial ports, and software abstractions such as named pipes. It's a protocol that operates in a client/server fashion, even if Windows file sharing on the surface appears to be a peer-to-peer structure. SMB is a fundamental part of many operating systems, including MS-DOS, Windows, OS/2, and Linuxalthough the primary uses for SMB today are in Windows and promulgated by Microsoft.

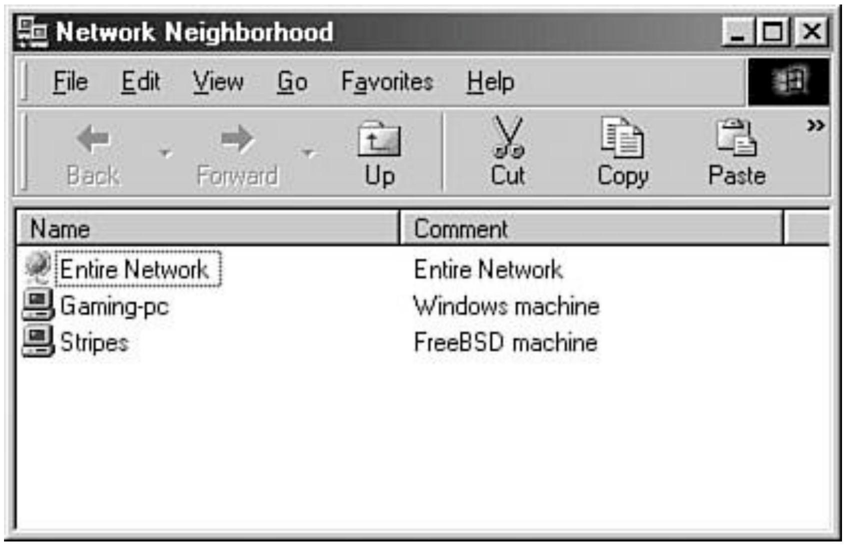
SMB and CIFS commands can be sent over network protocols such as IPX, NetBEUI, Banyan VINES, and DECnet. These protocols operate at the "network" level of the stack, the same level as IP (as you saw in Chapter 22, "Principles of TCP/IP Networking"), and SMB is therefore not limited to TCP/IP transport. However, the most commonly used transport for SMB is NetBIOS (Network Basic Input/Output System, described in RFCs 1001 and 1002) traveling over IP, operating with both TCP and UDP components. This is the protocol used in Windows file sharing.

Browsing

An advantage that SMB has over protocols such as NFS is that it supports automatic server discovery, or *browsing*. In Windows, if you open the Network Neighborhood or My Network Places window, it will display the names of all the available SMB servers on the local network. This list is built up dynamically, with each machine sending out periodic broadcast packets looking for the "master browser" of the network (a computer with a definitive list of local and remote SMB hosts) and announcing its own presence. Every other machine on the network builds its "browse list" from those broadcasts.

The name of each machine, as it appears in the network browser window (as shown in Figure 34.1), is its *NetBIOS name*, a designation that Windows allows to be up to 15 characters long. Although Windows makes you input a NetBIOS name in uppercase, it shows up in the network browser window with only the first letter capitalized. Under other operating systems (such as FreeBSD), the NetBIOS name is the same as the machine's hostname, truncated to 15 characters if necessary.

Figure 34.1. The Windows network browser window, showing a FreeBSD machine running Samba.


Network Neighborhood
File Edit View Go Favorites Help
Back Forward Up Cut Copy Paste

Name	Comment
Entire Network	Entire Network
Gaming-pc	Windows machine
Stripes	FreeBSD machine

NetBIOS names are handled by a form of name service, somewhat like DNS names, but mapping the displayed NetBIOS machine names to particular machines based on other criteria as well as the IP address (because NetBIOS isn't restricted to IP). Samba's name server component is separate from the actual SMB data server.

One drawback to NetBIOS is that it operates only on a LAN; NetBIOS packets are broadcast-based and therefore aren't forwarded by routers. The Windows Internet Name Service (WINS) protocol exists to link Windows sharing zones on different networks, thus mitigating this issue somewhat. A VPN can also allow you to access Windows shares over the Internet, though high-latency WAN links can make this kind of traffic all but unusable without acceleration technologies deployed at the network level.

Security, Workgroups, and Domains

Access to SMB shares is controlled at various levels. The topmost level restricts access based on host IP address or by password authentication from viewing any of the file server's contents. Beneath that, each individual share (a directory, printer, or other resource) has its own access permissions and optional host/password restrictions as well. Finally, within a share, individual files are subject to access permissions based on the authenticated user or host that has gained access to the share.

User authentication with passwords can be handled in a distributed way (by each individual sharing host) or in a centralized way (by a central network logon server). This is the difference between "workgroups" and "domains" in Windows. A *workgroup* is a collection of machines that agree to appear in one another's network browser windows, and each individually handles its own authentication and security. A *domain* is a group of machines whose security duties are handled by a central server to which all member machines must be subscribed.

Samba provides the ability to restrict access on all these levels, as well as to act itself as a "master browser" (in workgroup context) or as a domain controller (the central logon authority in a domain environment). You will see how this is done shortly. Furthermore, newer versions of Samba are designed to act as complete replacements for Microsoft's Active Directory; instructions for how this is accomplished can be found at the Samba website, though that level of detail is beyond the scope of this chapter.

File and Print Sharing with Macintosh Clients Using Appletalk

Macintosh client systems present a different kind of challenge to the file server administrator.

Modern Mac OS X systems can access NFS, SMB/CIFS, AppleShare/IP, or AppleTalk shares, but legacy Mac OS machines are restricted only to AppleTalk. Even the most modern Macs, understandably, are happiest using their own native protocols; a Mac using Windows-style file sharing can result in "meta-files" being left all over the server wherever the Mac has browsed. For this reason, you might consider adding support for AppleTalk shares to your FreeBSD machine.

The software package that provides AppleTalk functionality to UNIX platforms, called *netatalk*, is available in the ports or packages. To install AppleTalk support, build netatalk from the ports at `/usr/ports/net/netatalk`. You'll also have to enable the `NETATALK` option in your kernel configuration. See Chapter 18, "Kernel Configuration," for information on building a custom kernel.

The netatalk port installs a number of configuration filesone for each necessary daemonalong with `.dist` (or distribution) reference copies. Its daemons run in the default installed configuration; you can change some of the config files to tweak their behavior. Every Macintosh on the network will see the machine in its AppleShare zone in the Chooser (or in the Network volume in the Mac OS X Finder).

See the official netatalk website at http://netatalk.sourceforge.net/ for fuller descriptions of the various tools in the netatalk package and links to other documentation.

Installing and Configuring Samba

Samba is available in the ports at `/usr/ports/net/samba3` (or `samba` for the unsupported legacy version that lacks some of the newer Windows interoperability features) or in the packages. Refer to Chapter 16, "Installing Additional Software," for details on how to install a package or port.

After you have installed the Samba package, a variety of new items will be installed, including daemon executables (in `/usr/local/sbin`), administrative tools (in `/usr/local/bin`), documentation and examples (in `/usr/local/share`), and configuration files that go into `/usr/local/etc`. Some of the possible config files don't exist in the default installation; you have to create them from scratch if you want to take advantage of their functionality. There are also code pages (in `/usr/local/etc/codepages`) that map Windows character sets to UNIX ones.

The only configuration file that exists in the package is `smb.conf.default`, which you must rename to `smb.conf` for it to work. Similarly, the `/usr/local/etc/rc.d/samba.sh.sample` startup script must be renamed to `samba.sh`. For the very easiest way to get Samba running, you only need to edit `smb.conf` and modify the `workgroup` line to reflect the workgroup or domain of which your machine is a part:

```
# workgroup = NT-Domain-Name or Workgroup-Name, eg: REDHAT4
   workgroup = MYGROUP
```

Samba will now start automatically when the system boots. To start it manually, run the `samba.sh` script with the `start` parameter:

```
# /usr/local/etc/rc.d/samba.sh start
 Samba#
```

Note

There is no line break in the script output after the service name `Samba`. This cosmetic flaw exists because during startup, each service in `/usr/local/etc/rc.d` is started sequentially, and the echoed output of each startup script goes onto the same line.

The `smbd` and `nmbd` Daemons

If the `samba.sh` script runs successfully, you will notice two new processes running`smbd` and `nmbd`as shown here:

```
# ps -wwaux | grep mbd
root  3855  0.0  1.5  2368 1816  ??  Is  2:43PM  0:00.00 /usr/local/sbin/smbd -D
root  3857  0.0  1.2  1940 1496  ??  Ss  2:43PM  0:00.02 /usr/local/sbin/nmbd -D
```

The `smbd` daemon is the actual data server, the process that handles SMB/CIFS requests from connected Windows clientsfile transfers, print jobs, listings, and so on. Unlike NFS, SMB doesn't require a separate process to be running for each simultaneous connection; the master `smbd` process forks off a new copy of itself for each new client session and handles all that client's requests for the duration of the session. The `-D` option specifies that `smbd` should operate as a standalone daemon, listening for requests on TCP port 139.

Operating in parallel with `smbd` is `nmbd`, the NetBIOS name server. It's the process that allows Windows clients to see the FreeBSD machine in the network browser view, as you saw in Figure 34.1. It also has the job of responding to client requests for a particular NetBIOS host if it's specified by name; if a Windows client uses the `\\name` syntax to connect to a particular server by name, the client sends out a broadcast name request asking for the IP address of the server with that NetBIOS name. It's the job of `nmbd` to send back a response with the requested host's IP address so that the client can open an SMB session directly to the server. It's somewhat like DNS (in that it maps a common name to a direct address), and it also has a lot in common with ARP (in that it operates on a LAN through broadcast name requests, rather than to a designated central name server).

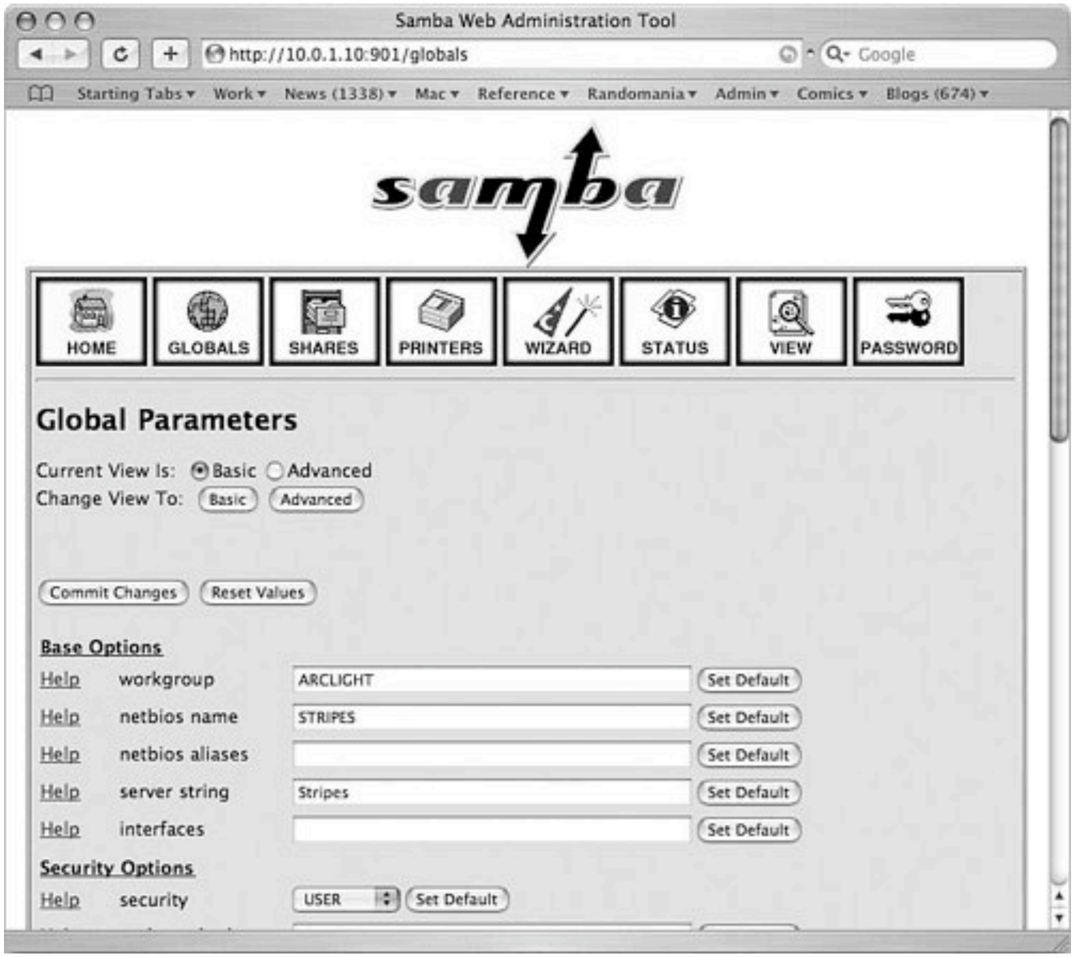
`smb.conf` and SWAT

The main configuration file for Samba is `/usr/local/etc/smb.conf`, in which you can set any of dozens of different options and create shares with customized settings. In this file, lines beginning with `#` or `;` characters are comments; the usage in `smb.conf.default` (the sample config file) is to use the `#` characters as comments and the `;` characters to enable and disable configuration lines.

Each option is pretty well documented in comments in `smb.conf.default`. However, it can become very daunting to try to keep track of everything in that file because there are so many possible options (listed in `man smb.conf`) that you can set, with so many subtle differences between them. There's an alternative method to administering `smb.conf`, however, if your network circumstances permit it. This method involves SWAT, the *Samba Web Administration Tool*, which is shown in Figure 34.2.

Figure 34.2. SWAT, the Samba Web Administration Tool.

[View full size image]



Global Parameters

Current View Is: [✓ Basic] Advanced

Change View To: Basic Advanced

Base Options

Help	workgroup	ARCLIGHT	Set Default
Help	netbios name	STRIPES	Set Default
Help	netbios aliases		Set Default
Help	server string	Stripes	Set Default
Help	interfaces		Set Default

Security Options

Help	security	USER	Set Default

SWAT comes with the Samba port and allows you to configure Samba graphically through a web browser interface. This graphical configuration capability simplifies the process of managing the `smb.conf` file and reduces the risk of errors. As a web application, however, the security risks associated with SWAT are significant. SWAT authenticates users against the system user database in `/etc/master.passwd`; authentication passwords are sent in clear text over the network from your client machine to the Samba server you want to configure. Unless you're configuring Samba from the local machine (`localhost`, using an X11-based web browser), this presents a major security risk. The risk can be managed a number of ways, but it's still not foolproof. You must take one of the following routes when deciding to run SWAT:

- Access SWAT only from `localhost`. This prevents any traffic from being sent over the wire at all.
- Operate entirely behind a firewall that allows no traffic from the outside. The `smb.conf` file is owned by root, by default, so your browser must log in to SWAT using the root password, sent over the network in clear text, with each HTTP request you make to the SWAT program. This should never be done on a network in which the password could be exposed to a malicious eavesdropper.
- Create a "dummy" user (for example, `samba`), and change `smb.conf` to be owned by that user (using `chown`). When running SWAT, log in as that user, not as root. Don't use the dummy username for any other tasks on the server; also, don't give the user any privileges, a shell, or a home directory. Be aware that if the password for this user is sniffed, an intruder can easily alter your Samba configuration. However, he won't be able to do anything else.

If the security risks are acceptable to you, and you can adhere to one of these methods of accessing SWAT, you can enable it by uncommenting the following line in /etc/inetd.conf:

```
swat    stream    tcp     nowait/400     root     /usr/local/sbin/swat     swat
```

Note

The /etc/services file is what maps TCP and UDP port numbers to well-known service names. Make sure that the swat service is listed in that file and assigned to TCP port 901; if it isn't in there, add it.

Then restart inetd:

```
# /etc/rc.d/inetd restart
```

You can now access SWAT by the URL http://stripes.example.com:901, substituting your Samba server's hostname or localhost, as appropriate. You will be prompted for a username and password. Use the system username you have decided to use for SWAT access: root, if your security situation allows it, or the dummy user otherwise.

SWAT allows you to access and modify your shares and printers as well as global settings; you can also view the current status of the server and do Samba user management. If SWAT recognizes that the username under which you are logged in has full access to the smb.conf file, you will see all eight action buttons shown in Figure 34.2. Otherwise, you will see only four, allowing you to view Samba information and status, but not make any configuration changes.

Because SWAT operates as a front end to smb.conf, and because SWAT is not necessarily a viable administrative option, the rest of this chapter will concentrate on configuring Samba through smb.conf directlynot on SWAT's equivalent actions.

Sharing Directories

Many examples for how to configure a shared directory can be found in smb.conf.default. To enable any of them, make the appropriate change in smb.conf; then restart Samba:

```
# /usr/local/etc/rc.d/samba.sh restart
```

Share examples are displayed below the ===== Share Definitions ===== line in smb.conf. Each share's name is listed in brackets, and the configuration lines following it apply until the next bracketed block. The smb.conf file begins with a [global] block, allowing you to set global parameters; the rest of the blocks each define a share whose settings override the previously defined global settings, much in the same way httpd.conf works for Apache (as you saw in Chapter 26, "Configuring a Web Server").

Tip

The man smb.conf page lists all available configuration parameters and describes in detail what each does. However, you may find it easier to view the page in HTML format, in which headings and examples are set apart with text formatting and made easier to read, as well as being contextually hyperlinked. Refer to the online documentation at http://www.samba.org/samba/docs/man/manpages-3/smb.conf.5.html for the formatted version.

To share a regular public directory, define a share block like this:

```
[my-public]
   comment = Public Stuff
   path = /usr/local/share/samba-stuff
   public = yes
   writeable = yes
   printable = no
   write list = @staff
```

With this share enabled, a client will see a share called `my-public` at the top level of the server's share listing. However, unless the user is authenticated and is a member of the UNIX group `staff`, the files in the share will be read-only. Remove the `write list` line to make the share writable by all users. Note that `writeable = yes` is equivalent to saying `read only = no`.

By default, a `[homes]` share is defined and enabled. This special share is built-in, allowing access to each user's home directory on the Samba server if the Windows client connects to it with the proper credentials (you learn about user-level and share-level security a little later):

```
[homes]
   comment = Home Directories
   browseable = no
   writeable = yes
```

Because this share is set as not browsable, home directories that are not owned by the client user are not displayed; if a client connects as a valid user with a home directory on the Samba server, her home directory (labeled with her username because that's the name of the directory in UNIX) appears as one of the available shares. No other users' home directories appear.

Sharing Printers

Like `[homes]`, `[printers]` is a special share that behaves a little differently from regular shares. Under FreeBSD, all attached printers that are defined in `/etc/printcap` are available to Samba users. Chapter 17, "Printing," explains how to set up your FreeBSD machine to support local printers in `/etc/printcap`.

By default, the `[printers]` share is set up like this:

```
[printers]
   comment = All Printers
   path = /var/spool/samba
   browseable = no
# Set public = yes to allow user 'guest account' to print
   guest ok = no
   writeable = no
   printable = yes
```

As stated in the embedded comment, you can make your printers public so that anyone on the network can use them. This involves the use of a *guest user*, which you learn about in an upcoming section of this chapter. Note that `public` is a synonym for `guest ok`, so you would change the `guest ok` line to `yes` instead of adding a `public = yes` line to allow the guest user to print.

In Samba 2.2.0 and later, Windows 2000-style printing RPCs are supported, meaning that you can push the appropriate printer drivers to a client that lacks them. For documentation on this feature, see the Samba website.

Access Control

Samba access control involves a number of abstract concepts that can be very difficult to reconcile. Windows user authentication schemes include LAN Manager (LANMAN), Windows NT/2000/XP, Windows 95/98/Me, and Windows for Workgroupsall subtly different in how they handle encryption, login names, and challenge/response procedures.

In Samba, there are two widely used ways to perform access control: user-level and share level. The default setting is user level, defined by the `security` option:

```
# Security mode. Most people will want user level security. See
# security_level.txt for details.
   security = user
```

User-Level Access Control

In *user-level* security, the client presents a username/password pair to the server upon the initial setup of the connection. The server determines whether to accept the client based on the username/password pair and the identity of the client machine itself. If it accepts the client, all shares are accessible.

It can be tricky to set up user-level security properly. The Windows username, which is defined either when logging in to a local profile or to a domain controller in a Windows session, must exist on the Samba server as a regular UNIX user (or mapped to a UNIX user). For instance, if the Windows user Harris logs on to his Windows machine, opens up the My Network Places window, and tries to connect to your Samba server, he will be denied access (and given a password prompt for a share called `\\STRIPES\IPC$`) unless the user `harris` exists on the UNIX machine.

Tip

Instead of authenticating users directly on your FreeBSD machine, you can specify `security = server`, instead of `security = user`, and then use the `password server = *Windows-Server-Name*` line to specify the machine name of the server you want to do the authenticating. That server must be running in user-level mode, whether it's a real Windows machine or another Samba server. Samba will pass off the task to this second server and authenticate the user based on what the other machine says.

Note

In Windows 2000/XP, the password prompt allows you to enter a username as well as a password. However, in Windows 95/98/Me, all you get is a password prompt, and the username is derived from the login name.

Samba users must exist in a password database at `/usr/local/private/smbpasswd`, similar to `/etc/master.passwd` in that encrypted passwords are stored in it for each local UNIX user. When Samba is installed, users from `/etc/master.passwd` are converted into Samba format and placed into `/usr/local/private/smbpasswd`, with both the LANMAN password and the Windows NT/2000/XP password (both are present for compatibility) set to strings of 16 `X` charactersindicating that the user cannot log in:

```
harris:1001:XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX:
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX:
```

```
[U          ]:LCT-00000000:Pauline Harris
```

To enable a user, you must set the password to something valid; you can do so with the `smbpasswd` program. It works similarly to `passwd`, prompting you for your old Samba password and then requiring you to enter a new one twice, unless you're rootin which case, you need not supply the old password, and you can change any user's password as well as your own:

```
# smbpasswd harris
New SMB password:
Retype new SMB password:
Password changed for user harris.
```

The new password for the user `harris` is now stored in an encrypted string in the smbpasswd file:

```
harris:1001:2E89BF7B23B65C7EB79AE2610DD89D4C:
DADDCE7852B574A9EAE9F164F876D025:
[U          ]:LCT-4421CC23:Pauline Harris
```

Caution

Passwords negotiated between Windows clients and a Samba server are encrypted by default before being transmitted (although encryption can be turned off for compatibility with very early Windows clients). Encrypted passwordsalthough they seem like a sensible security measuredon't actually increase security on the server endquite the contrary. The encrypted Samba passwords that are stored in the `/usr/local/private/smbpasswd` file are the same as the passwords that are sent over the wire. Encrypted Samba passwords, therefore, are equivalent in security to passwords stored in clear text. An intruder who gains access to the `smbpasswd` file could immediately log in as any user (including root) through Samba, whereas the encrypted passwords in `/etc/master.passwd` must be cracked through some brute-force method. (By contrast, a UNIX password is transmitted in clear text and *then* encrypted on the server and compared to what's in the password file; this arrangement renders a compromise of the server's password file itself harmless.) Guard the `smbpasswd` file just as carefully as you would `master.passwd`, if not more so!

Tip

You can map Windows users on a many-to-one basis to UNIX users, allowing you to give groups of Windows users the same privileges as a single UNIX user. To do this, create a file containing the mappingsfor example, `/usr/local/etc/smbusers.map`. The format of this file is with one mapping per line, as follows:

```
UNIX-user = win-user-1 [win-user-2 ...]
```

For example, to map three different Windows users to the UNIX username webadmin, use the following statement:

```
webadmin = harris erodriguez mfoster
```

Next, enable the username mapping file by adding the following anywhere in the `[global]` section of `smb.conf`:

```
username map = /usr/local/etc/smbusers.map
```

Each aliased Windows user must log in with the correct password for the UNIX user to which she maps.

Share-Level Access Control

In *share-level* access control, a client can connect to the Samba server without any username/password authentication and receive the list of shares; the client will be refused access only if denied by IP address in the `smb.conf` file (the `hosts allow` line). However, each share has its own user authentication, using the same password scheme as you already saw in the discussion on user-level access control. A public share, in which access is open to all, can be entered without any barriers. A share that is restricted to a particular user (such as a home directory from the `[homes]` block), however, presents the same username/password challenge as user-level security presented at the initial connection.

More details on the workings of user-level and share-level security can be found at http://www.samba.org/samba/docs/man/Samba-HOWTO-Collection/ServerType.html#id2526819.

Guest User

For some Samba services, notably printing, you will want any user on the network to be able to have access regardless of authentication. You accomplish this with a guest account. A guest account is an unprivileged user account that has access as a UNIX user only to the service you want to provide. Note that guest users are primarily intended for Samba servers running in share-level security mode because guest user access is allowed or disallowed on a share-by-share basis.

To enable a guest user, uncomment the `guest account` line in `smb.conf`:

```
# Uncomment this if you want a guest account, you must add this to /etc/passwd
# otherwise the user "nobody" is used
  guest account = pcguest
```

You must then add the `pcguest` account (or any other name you choose) to the system using `adduser`. Use `chfn` to tune the user's capabilities; the `ftp` user is a good model for the Samba guest account. (The `ftp` user is created by Sysinstall if your system allows anonymous FTPsee Chapter 27, "Configuring an FTP Server," for details on FTP server setup.)

With this account enabled, any Windows user connecting to the Samba server will have full access to any share where the `guest ok` or `public` parameter is set to `yes`. No authentication challenge will be presented for that share. Be sure to use a `read only` statement on shares that you don't want getting messed around with by every Tom, Dick, and Harris on your network!

Tip

The `guest only = yes` parameter can be specified to indicate that only guest connections are permitted for a service.

Samba Log Files

In `/var/log`, there are various log files for Samba, one for each type of service and for each client that has connected. These files' names are of the form `log.`*`service`*:

```
# ls -l /var/log/log.*
-rw-r--r--  1 root  wheel   468 Jun  9 12:42 /var/log/log.gaming-pc
-rw-r--r--  1 root  wheel  2343 Jun  9 14:49 /var/log/log.nmb
-rw-r--r--  1 root  wheel  1606 Jun  9 14:44 /var/log/log.smb
```

The `log.nmb` and `log.smb` files report status and error conditions for the `nmbd` and `smbd` servers, respectively. Additionally, whenever any errors are reported for any connecting client host (such as authentication failures), these messages are printed into a `log.`*`name`* file for that client. Note that this can result in a lot of files cluttering up your `/var/log` directory, on a network with lots of client PCs. You can switch to a combined log format by commenting out the `log file` line in `smb.conf`:

```
# this tells Samba to use a separate log file for each machine
# that connects
;   log file = /var/log/log.%m
```

SMB errors for individual hosts will go into `log.smb` with this line commented out.

Another useful line to modify is the `max log size` line, which is set to 50KB by default. This control allows you to set the "rollover" size for any of the log files. When any Samba log file reaches the size you've designated, the file is renamed by appending `.old` to the filename, and new log entries are added to a new file. The `.old` file is overwritten at the next rollover.

```
# Put a capping on the size of the log files (in Kb).
   max log size = 50
```

Samba Variables

Configuration parameters in `smb.conf` don't have to be hard-wired. You have a number of variable substitutions at your disposal, so you can set certain options to be dynamically determined, depending on the conditions of the connection. For example, you can set an option to reflect the client's username with the `%u` variable, allowing you to set a parameter such as `path = /usr/local/share/user-files/%u`. The user `harris` would thus receive the path `/usr/local/share/user-files/harris`.

Here are a few of the most useful variables:

- `%u` The client's username.
- `%g` The primary group name of `%u`.
- `%S` The name of the current service, if any.
- `%H` The home directory of the user given by `%u`.
- `%h` The Internet hostname of the Samba server.
- `%M` The Internet hostname of the client machine.
- `%L` The NetBIOS name of the Samba server. This allows you to change your config based on what

the client calls you; your server can have a "dual personality."

- `%m` The NetBIOS name of the client machine.
- `%I` The IP address of the client machine.
- `%T` The current date and time.
- `%$(envvar)` The value of the environment variable `envvar`.

The complete list of variable substitutions is available in `man smb.conf`.

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Other Samba Components

The Samba package includes a number of additional tools:

- `smbclient` A simple FTP-like client that allows you to connect to remote SMB shares and print to remote Windows printers.
- `testparm` A configuration file syntax checker that tests your `smb.conf` for correctness; similar to `apachectl configtest` for Apache.
- `smbcontrol` A tool that allows you to send messages to running `smbd` processes, such as a command to kick a user off the system.
- `smbstatus` Displays current connections to the Samba server. SWAT, as you saw earlier, has a page that shows the formatted output of this command in a web browser.
- `nmblookup` Allows you to make NetBIOS name queries like those made by Windows hosts connecting directly to SMB shares by name.

These tools and a number of others that come with the Samba package also are described in `man samba`; each one has its own `man` page for further details. Finally, these tools are in addition to the `smbd`, `nmbd`, and `smbpasswd` utilities discussed previously in this chapter. Each of those has its own `man` page as well.

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Accessing Shared Files on a Windows System (the `smbfs` Filesystem)

SMB file sharing can work both ways. Samba allows you to set up your FreeBSD machine as an SMB server only, but there is a way to set it up as a client and mount a remote SMB share like any other volume FreeBSD can read. This involves the use of the SMBFS filesystem, which is not built into the kernel by default, but can be added through a kernel module or compiled into a custom kernel.

The SMBFS implementation in FreeBSD includes an `smbfs.ko` kernel module in `/modules` and a `mount_smbfs` tool in `/sbin` that works like all the other `mount_*` tools you saw in Chapter 12, "The FreeBSD Filesystem." The best documentation for SMBFS is found in the `man mount_smbfs` page.

To mount an SMB filesystem using `smbfs`, use `mount_smbfs` with a few basic options. The `-I` flag specifies the hostname or IP address of the server, and the two remaining arguments are the remote share name (of the form *`//user@NetBIOS-hostname/share-name`*) and the local mount point. To mount the share called `public` from a Windows machine called `gaming-pc` onto the local `/smb/public` directory, use the following syntax:

```
# mount_smbfs -I 64.41.131.139 //guest@gaming-pc/public /smb/public
```

You will be prompted for a password. Use a blank password if the share is set to allow full access; use the appropriate password if the share is set to read-only or password-protected mode.

Note

The `smbfs.ko` kernel module is loaded automatically when needed by `mount_smbfs`. If you want to, you can load it at boot time by adding the following line to `/boot/loader.conf`:

```
smbfs_load="YES"
```

However, this is probably not necessary unless you regularly mount SMB shares. If you do use SMB shares a lot, you might consider simply building SMBFS support into the kernel, with the following option:

```
options         SMBFS
```

To add an SMB share to `/etc/fstab`, use the following syntax:

```
//guest@gaming-pc/public   /smb/public    smbfs rw,noauto 0   0
```

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Chapter 35. Dynamic Host Configuration Protocol (DHCP)

IN THIS CHAPTER

DHCP, which stands for *Dynamic Host Configuration Protocol*, is a network protocol that allows a client to obtain its IP address, name server information, gateway server information, and several other network-configuration options from a server that is running a DHCP server.

This chapter will show you how to configure a DHCP client on your FreeBSD system (so that it can obtain an IP address from a DHCP server). It will also show you how to configure your FreeBSD machine as a DHCP server for other client machines on your network to use.

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How DHCP Works

DHCP eliminates the need for you to manually configure your system's TCP/IP information, and instead fetches that information from a central server. A program called `dhclient` allows FreeBSD to act as a DHCP client. When a system configured to use DHCP boots and `dhclient` starts, it sends out broadcast requests on UDP port 68, looking for any server on the LAN that will respond with DHCP information. Because these datagrams are sent to the broadcast address (255.255.255.255), it doesn't matter that the client machine doesn't have any TCP/IP information configured yet.

If there is a DHCP server on the network, it listens on port 68 for these requests. When it receives a request for configuration information, it checks its database for a free IP address that can be assigned to the client. It then sends back (again to the broadcast address, because the client doesn't have an IP address yet) an "offer" containing the selected IP address. After some negotiation, all of which takes place on the broadcast address and thus is visible to all computers on the network, the DHCP server sends the client (on UDP port 67) all the TCP/IP configuration information that you would otherwise have had to set manually. The IP address that is assigned to the client is removed from the pool of available addresses so that it is not assigned to another client that requests DHCP configuration information.

The host that is running `dhclient` applies the agreed-upon TCP/IP configuration, and from then on can use the routed IP network using the assigned IP address and other settings.

IP Address Leases

When the DHCP server assigns an IP address to a client, the client does not "own" the address on any permanent basis. Rather, the address is *leased*, for a term that is configured on the DHCP server. The information about how long the lease is good for is sent to the client along with the configuration information.

The leasing of IP addresses serves two purposes:

- If the DHCP server cannot be contacted, the client checks its database to look for a lease that is still valid. Assuming it has a valid lease, the client can continue to function normally, even if the DHCP server is currently down, though its configuration will eventually time out and become invalid.
- It automatically places IP addresses that are not in use back in the pool after the lease expires. This helps conserve IP addresses. For example, when a guest from a branch office visits, he can plug his laptop into your network and be assigned an IP address so that he can use your network. When he leaves, that IP address will eventually expire and be placed back into the pool for others to use. This way, IP addresses are not being wasted on systems that do not exist anymore.

Advantages of DHCP over Static IP Addresses

Depending on your situation, DHCP may have several advantages over simply assigning each system its own static IP addresses. These advantages include the following:

- *Ease of maintenance.* DHCP automatically keeps track of which IP addresses are in use and which ones are free. This prevents the system administrator from having to manually update a list of which IP addresses can be assigned to new clients, as well as having to remember to reclaim old IP addresses when clients are permanently removed from the network. All this is handled automatically with DHCP.
- *Ease of installing new clients.* When new clients are installed, you (or the user) do not have to worry about setting up the network information. You can simply ask the new client to obtain its information

via DHCP, and all the networking information will be configured automatically.

- *Ease of use for travelers.* If your users travel to branch offices, DHCP makes their life a lot easier. With DHCP, they can simply plug their laptops into the network at the branch office and have all the network information configured for them automatically. At the next branch office they go to, they can do the same thing and get a new set of valid information. This way, your users do not have to reconfigure their network settings at each office they visit.

- *It conserves IP addresses.* This is especially true if you have traveling users who go to branch offices occasionally and plug their laptops into the network. DHCP allows these IP addresses to be automatically reclaimed after the traveling user leaves. This way, you don't have IP addresses wasted on systems that are rarely plugged into the network anyway.

- *It eliminates problems caused by IP address conflicts.* It only takes one user to make one typing mistake when setting up a system to cause all kinds of problems on a network. The user might enter an IP address that conflicts with another system on the network, for example, or an address that conflicts with the IP address assigned to a server. DHCP eliminates these problems by assigning IP addresses automatically and keeping track of ones that are in use so that they do not get assigned to multiple systems.

DHCP has become an integral part of any well-maintained corporate network and critical to the accepted best practices of network management. Even home network users will find DHCP to be indispensable, even if they don't know it existsit means they no longer have to worry about typing in esoteric TCP/IP information themselves, whether they're dialing up directly to an ISP or attaching themselves to a wireless home network. Indeed, DHCP has been one of the cornerstones of the proliferation of home broadband Internet in recent years, and without it millions of people would find the experience more technical than they were comfortable with.

The only time when it is not appropriate to use DHCP is when you're running a server. Machines with assigned DNS names, and machines that provide services such as NFS shares and web and email, have to have static IP addresses so that client machines can reliably contact them. For this reason, a common corporate network topology is one where the internal network is based on DHCP, so that the hundreds or even thousands of employees, whose IP addresses aren't important, can all receive dynamic TCP/IP information within the corporate network; but the company's official web server is located on the DMZ network with a static IP address and a public DNS name so that it can be reached from anywhere on the planet at any time.

Note

The reason why many broadband service providers don't allow customers to run servers has not only to do with the limited upload speed of the cable or ADSL connection, but with the fact that assigning customers dynamic IP addresses through DHCP is far more economical than reserving static IP addresses for the thousands or tens of thousands of customers on the network.

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Enabling DHCP

In order to configure FreeBSD as a client on a DHCP network, it needs to be able to put its network interface in "promiscuous mode," which means it can see and respond to packets that are not explicitly destined for its IP address. This functionality comes from the Berkeley Packet Filter device compiled into the kernel. This device is installed by default in the `GENERIC` kernel, so unless you built a custom kernel and removed it, you shouldn't have to do anything.

To verify that the Berkeley Packet Filter device is installed in the kernel, look for the following line in your kernel configuration file:

```
device     bpf
```

If this line is present, there is nothing you need to do here. If the line is not there, you will need to add it and then rebuild your kernel. Complete instructions on kernel building can be found in Chapter 18, "Kernel Configuration."

After you have made sure the kernel is equipped for promiscuous-mode communication, you can enable DHCP by editing the `/etc/rc.conf` file. If there is already an `ifconfig` line in the file specifying the configuration information for your network interface (for example, `ifconfig_fxp0`), change it as follows:

```
ifconfig_ed0="DHCP"
```

If such a line is not present, add it. Then either reboot the system or run the `/etc/netstart` script to activate the new configuration.

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The `dhclient` Program

The `dhclient` program is the client portion of DHCP. It is run automatically at each system boot if you have any network interfaces that are configured to use DHCP.

Command-Line Options for `dhclient`

If you need to modify the default behavior of `dhclient`, you can do so by supplying flags to it with an option in `/etc/rc.conf`. This option should appear below the `ifconfig` line where the DHCP interface is configured:

```
dhcp_flags="flags"
```

Here, *`flags`* is a list of options for `dhclient`, which are passed to the program as though it were being invoked at the command line. Table 35.1 shows the valid options that can be used.

Table 35.1. Valid Options for `dhclient`

Option	Action
`-d`	This option will force `dhclient` to stay in the foreground rather than move to the background after it gets its configuration information. This should be used only for debugging purposes and should probably never be used in `/etc/rc.conf`.
`-q`	This option tells `dhclient` to be quiet when it runs (in other words, it won't print messages except in error conditions).
`-1`	This option causes `dhclient` to try only once to get a lease on an IP address. If this fails, `dhclient` will exist with a status of 2. Note that this is the numeral 1 and not a lowercase letter l.

The `dhclient.conf` File

`/etc/dhclient.conf` is the configuration file for `dhclient` in which you can specify various options beyond the simple behavior switches available at the command line or in `rc.conf`. The file must exist for `dhclient` to run, although by default, the file contains nothing but comments. `dhclient` has reasonable default values that will work fine in most typical circumstances, so most users will not have to worry about this file.

However, you should be aware of some of the options that can be controlled in this file. Table 35.2 lists some of them.

Table 35.2. Some `dhclient.conf` Options

Option	Action
`timeout` *`n`*	Here, *`n`* is the number of seconds `dhclient` should wait for a response when trying to contact a DHCP server before giving up and deciding the

	server is unavailable. By default, this is 60 seconds.
`retry` *`n`*	Here, *`n`* is the number of seconds `dhclient` should wait before trying to contact the DHCP server again if the first request timed out. By default, it will wait five minutes.
`select-timeout` *`n`*	Some networks may have more than one DHCP server on them. In this case, the client may receive multiple offers of configuration information. The first offer received is not always the best offer (for example, if the second offer received contains the same IP address the client was using in a previous session, it is preferable to an offer where the IP address is different). Here, *`n`* is the number of seconds `dhclient` should wait after receiving a first offer to see whether any other servers respond with offers.
`reboot` *`n`*	When `dhclient` starts, it will try to obtain the same IP address it had the last time. If it cannot get the same address, it will then accept a different one. Here, *`n`* is the number of seconds `dhclient` will wait before giving up and deciding it can't get the same IP address it had last time. The default is 10 seconds.
`request` *`option`*	The client will request information for the specified options from the DHCP server. See the `man dhcp-options` page for information on the available options.
`require` *`option`*	The client will require information for the specified options from the DHCP server. If the required information is not provided, the client will reject the offer. See the `man dhcp-options` page for information on the available options.
`default` *`option value`*	If the DHCP server does not provide information for the specified option, then *`value`* will be used for that option. See the `man dhcp-options` for information on the available options.
`supersede` *`option value`*	The specified option will always use *`value`*, even if the DHCP server sends a different value for that option. See the `man dhcp-options` page for information on the available options.
`reject` *`address`*	Any offers sent from the DHCP server with the IP address of *`address`* will be rejected.

Many more options can be used in the `/etc/dhclient.conf` configuration file. See the `man dhclient.conf` page for more information on options available in this file. Also, see the `man dhcp-options` page for more information about the DHCP options that can be requested or required from the DHCP server.

As mentioned previously, most users will not need to make any changes to `/etc/dhclient.conf` because the default `dhclient` values will usually work fine except in highly customized DHCP environments.

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Running a DHCP Server

The software required for running a DHCP server is not built into FreeBSD. Third-party packages for performing this duty are, however, available in the ports or packages; probably the most popular and full-featured is the ISC DHCP server package, a "reference implementation" suite of tools written by the same folks who brought us BIND. The port, called `isc-dhcp3-server`, is available in the `net` directory of the ports tree. See Chapter 16, "Installing Additional Software," for information on how to install ports.

When `isc-dhcp3` is installed, it creates a startup file in `/usr/local/etc/rc.d` called `isc-dhcpd.sh`. The next time you restart your system, this file will cause the DHCP server to start automatically on system boot. Before you do so, however, you need to set up your `dhcpd.conf` file to suit the needs of your system.

It's probably not a good idea to simply rename the default `/usr/local/etc/dhcpd.conf.sample` to `dhcpd.conf` and hope for the best. The sample file contains a large number of example configurations intended to demonstrate the proper syntax for each of several possible network environments. If you just enable the file as-is, you'll be setting up a configuration that has no bearing on reality.

Instead, create a brand-new `dhcpd.conf` file and use `dhcpd.conf.sample` as a guide to tell you how to set up your DHCP network according to your specific needs. For example, first you should decide whether you want to restrict DHCP service only to certain subnets, how you want to define the pool of available IP addresses, and so on. Then look in the sample configuration file for example settings that meet your needs.

The contents of `dhcpd.conf` consist of `option` statements that can be placed inside a configuration block that applies to a certain group of clients (such as a `subnet`), or outside all blocks so as to apply to all clients. You should begin the file with options that you want to apply to all clients that contact the server:

```
option domain-name "example.com";
option domain-name-servers ns1.example.com, ns2.example.com;
default-lease-time 600;
max-lease-time 7200;
ddns-update-style ad-hoc;
```

Note

Statements that begin with the `option` keyword specify configuration information that gets passed directly to the client as part of the DHCP protocol. Statements without the `option` prefix are commands that control the behavior of the DHCP server itself, such as defining how the lease behavior works or specifying the valid range of IP addresses.

You'll then need at least one subnet declaration, which defines the network on which the DHCP server lives and what addresses to assign to hosts within that network. This is where you'll put statements such as `range` (which defines the pool of available IP addresses) and `option routers` (which is by its nature a subnet-specific configuration option, specifying the router that commands the network in question).

```
subnet 64.41.131.32 netmask 255.255.255.224 {
  range 64.41.131.40 64.41.131.63;
  option routers 64.41.131.162;
}
```

You can also put options such as `default-lease-time` into `subnet` blocks; these more specific definitions override the global settings for the subnets in which they appear.

There are a great many more configuration options available, which you might find necessary depending on the complexity of your network. Consult the `man dhcpd` page and the examples in `dhcpd.conf.sample` for guidance on these more specialized configurations.

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Part VI: Appendixes

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Appendix A. Command Reference and Configuration File Reference

This appendix contains a reference of common FreeBSD commands. The commands in this appendix are divided into sections based on those related to files and directories, user and permissions, system administration, and so on. Each entry gives a short description of the command along with the chapter in which more information can be found. This appendix also contains a list of some of the common FreeBSD configuration files.

Tip

For more information on any of the commands listed here, refer to the manual page for that command. Manual pages can be accessed by typing **`man`** ***`command`***, where *`command`* is the name of the command you would like more information on.

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Command Options

Most of the commands given in this appendix can be given *options*, also known as *switches* or *arguments*. To supply an option to a command, follow the command name with a space, and then with a dash, and then the letter of the option. For example, to display a directory listing in long format, the option to use is `l`. Therefore, the command looks like this:

```
ls -l
```

If the option you are supplying requires more than one character (for example, if it's a complete word), you must use a double dash before the option (an example would be `--password`). If you don't, each letter will be treated as a separate option, which can have unexpected or even destructive effects depending on what the options do.

Note that because letters are treated as separate arguments if preceded by a single dash, you can supply multiple options to a command all in a single argument. For example, to list all the files in the directory (including hidden files) as well as list the directory in the long format, you could use the following command:

```
ls -al
```

Some options take arguments of their own, which can be specified in any of several ways:

```
crontab -u frank
mysql --user=root
```

In most cases, commands that operate on files or have a certain required argument (such as the `kill` command, which must be given a process ID number to operate on) require that the options go between the command name and the required argument or filename. For example:

```
kill -1 1453
```

Be aware that these are only conventions, and there are commands that don't behave as described here. Always check the `man` page for a command you're unfamiliar with to make sure its options will behave the way you expect.

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File- and Directory-Manipulation Commands

Command	Action
`cd dirname`	Used to change to the directory *dirname*. If the path is not specified, *dirname* is assumed to be relative to the current path. (See Chapter 8, "Working with the Shell.")
`ls`	Lists the contents of the current directory. Popular options include `-l` to list the attributes of each entry, `-a` to list hidden files (which begin with dots), and `-F` to help differentiate between certain types of files. (See Chapter 8.)
`cp oldfile newfile`	Copies *oldfile* to *newfile*. If no directory path is specified for either file, they are both assumed to be in the current directory. Common options include `-R` to recursively copy a directory, `-p` to preserve permissions and ownership information, and `-i`, to perform an interactive copy that prevents the clobbering of existing files. (See Chapter 8.)
`mv oldfile newfile`	Moves *oldfile* to *newfile*. If no directory is specified for either file, they are both assumed to be in the current directory. Common options include `-i`, which performs an interactive copy that prevents the clobbering of existing files. This command is also used to rename files and directories. (See Chapter 8.)
`rm filename`	Deletes (removes) *filename*. This is a non-reversible process. The `-i` option prompts you to confirm the process, and `-f` forces the deletion and suppresses the system's warnings. The `-r` option allows you to remove the contents of directories recursively. (See Chapter 8.)
`rmdir dirname`	Removes the directory *dirname*, assuming that it is empty. (See Chapter 8.)
`touch filename`	Updates the access time on *filename*. If the file does not already exist, it is created. (See Chapter 8.)
`mkdir dirname`	Creates the directory *dirname*. The `-p` option creates all directories along the specified path if they don't already exist. (See Chapter 8.)
`ln file1 file2`	Creates a link named *file2* that serves as an alternative name for *file1*. The `-s` option creates a symbolic link, similar to a shortcut in Windows, rather than a hard link. (See Chapter 8.)
`mount filesystem mountpoint`	Mounts the filesystem represented by *filesystem* on the directory represented by *mountpoint* to make it available for use. (See Chapter 12, "The FreeBSD Filesystem.")
`umount mountpoint`	Unmounts the filesystem mounted on the directory *mountpoint*, making it unavailable for use. (See Chapter 9, "Customizing the Shell.")

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User and Permissions Management Commands

Command	Action
`chmod` *`permissions filename`*	Changes the access permissions on *`filename`*, using numeric or symbolic permissions codes. (See Chapter 13, "Users, Groups, and Permissions.")
`chown` *`username filename`*	Changes the ownership of *`filename`* to the user *`username`*. (See Chapter 13.)
`chgrp` *`groupname filename`*	Changes the group ownership of *`filename`* to the group *`groupname`*. (See Chapter 13.)
`passwd`	Changes your login password. The root user can specify a username after `passwd` to change the password of a particular user. (See Chapter 13.)
`adduser`	Runs a script that adds a new user to the system. (See Chapter 13.)
`rmuser` *`username`*	Runs a script that removes a user from the system. That user will no longer be able to log in to the system. (See Chapter 13.)
`vipw`	Allows you to edit the `/etc/master.passwd` file directly, and it updates the database upon exiting. (See Chapter 13.)

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Common Shell Commands

Command	Action
`grep` *`pattern filename`*	Searches the file *`filename`* for the specified pattern or regular expression. (See Chapter 8; also refer to Chapter 11, "Introduction to Perl Programming," for more information on regular expressions.)
`less` *`filename`*	Views the contents of *`filename`* one screen at a time. The `more` command is a synonym for `less`. (See Chapter 8.)
`cat` *`filename`*	Displays (catenates) the contents of *`filename`*. `cat` is normally used with redirection or pipes to send a file's contents through another command. (See Chapter 8.)
`wc` *`filename`*	Displays the number of words, lines, and characters in *`filename`*. (See Chapter 8.)
`diff` *`file1 file2`*	Compares the contents of *`file1`* with the contents of *`file2`* and then displays the differences between these files. You can use `-r` to recursively compare the contents of whole directories. (See Chapter 8.)
`fmt` *`filename`*	Formats *`filename`* by wrapping its lines so that it's suitable for emailing. Output is sent to `STDOUT` by default. (See Chapter 8.)
`cut` *`options filename`*	Displays only a particular column or field from tabular data in *`filename`*. Output is sent to `STDOUT` by default. (See Chapter 8.) A corresponding command, used for combining multiple files into a text table, is `paste`.
`head` *`filename`*	Displays the first 10 lines of *`filename`*. Use a different number as an option (for example, `-50`) to see that number of lines. (See Chapter 8.)
`tail` *`filename`*	Displays the last 10 lines of *`filename`*. Use a different number as an option (for example, `-50`) to see that number of lines. (See Chapter 8.)
`sort` *`filename`*	Sorts the contents of *`filename`* into alphabetical order, or (if the `-n` option is used) numerical order. Output is sent to `STDOUT` by default. (See Chapter 8.)
`cal`	Displays a calendar for the current month. The `-y` option shows all the months of the year, and `-y` *`year`* shows the specified year. (See `man cal` for more information.)
`date`	Displays the current date and time. The root user can also use this command to change the date and time. Many formatting options are available. (See `man date` for more information.)
`man` *`command`*	Displays the manual page for *`command`*. (See Chapter 8.)
`vi`	Invokes the `vi` text editor. If a filename is specified, that file will be opened. (See Chapter 6, "Working with Applications.")
`ee`	Invokes the FreeBSD Easy Editor. If a filename is specified, that file will be opened. (See Chapter 6.)

System Utilities and Maintenance-Related Commands

Command	Action
`ps`	Displays the list of processes running on the system. Common options include `-l` for a detailed list, `-a` for all processes, and `-x` to display daemon processes as well. Use `-w` for "wide" format or `-ww` to make it even wider. (See Chapter 15, "Performance Monitoring, Process Control, and Job Automation.")
`top`	Displays a continuously updated list of processes and their resource usage statistics. (See Chapter 15.)
`kill` *`n`*	In this command, *`n`* is the process ID number you want to kill. Options are available to send different signals to the process. (See Chapter 15.)
`killall` *`pname`*	In this command, *`pname`* is the name of the process to kill. All processes that match the specified name and belong to you will be killed (with a `TERM` signal). Options are available to send different signals to each process. (See Chapter 15.)
`at`	Schedules a job or command to run at a specified time. (See Chapter 15.)
`crontab` *`filename`*	Schedules jobs or commands to run on a regular basis. Options include `-e` to edit the existing `crontab` file and `-u` to specify a particular user's file. *`filename`*, which is optional, is the name of the `crontab` file you want to edit. (See Chapter 15.)
`shutdown`	Shuts down or reboots the system. A number of configuration options are available for putting the system into any of several states or modes, such as single user mode. (See Chapter 4, "Booting and Shutting Down FreeBSD.")
`reboot`	Reboots the system. A related command is `halt`, which takes the same arguments as `reboot` but shuts down the system rather than rebooting it. (See Chapter 4.)

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Printer-Related Commands

Command	Action
`lpr`	Sends a job to the printer. (See Chapter 17, "Printing.")
`lprm` *n*	In this command, *n* is a job number. This removes the job from the printer. Other options allow removing jobs for a particular user and so on. (See Chapter 17.)
`lpq`	Displays the list of jobs currently in the printer queue. (See Chapter 17.)
`lpc`	Controls the printer queues and the print daemons. (See Chapter 17.)

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Software Installation and Removal Commands

Command	Action
`pkg_info`	Displays a list of packages installed on the system, along with a short description of each package. (See Chapter 16, "Installing Additional Software.")
`pkg_add` *`packagename`*	Installs the software package *`packagename`* onto the system. The `-r` option allows `pkg_add` to fetch the package from the Internet rather than making you download it first. (See Chapter 16.)
`pkg_delete` *`packagename`*	Removes the software package *`packagename`* from the system. (See Chapter 16.)
`make`	When issued from a port directory, this command obtains the port files and builds the port. Otherwise, and more generally, it's used for compiling software based on targets specified in a file called `Makefile`. (See Chapter 16.)
`make install`	When issued from a port directory, this command installs the port if it has already been built. If not, the command obtains the necessary files and builds the port first. (See Chapter 16.)
`make deinstall`	When issued from a port directory, this command removes the installed port from the system. It will also remove any dependencies that are not required by some other installed port or package. (See Chapter 16.)
`make clean`	When issued from a port directory, this command removes the work files and object files created when building the port, reclaiming the hard disk space used by them. (See Chapter 16.)
`make distclean`	When issued from a port directory, this command removes the work files and object files created when building the port as well as the source distribution files that were obtained, reclaiming the hard disk space used by them. (See Chapter 15.)

Note

The `make clean` command does not uninstall the port, nor does it remove the original archive file that was downloaded.

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Common Configuration Files

Filename	Purpose
/etc/rc.conf	The main system configuration file that controls startup options for FreeBSD. (See Chapter 11.)
/etc/rc.d/	The directory containing rc scripts that control dozens of different system functions, such as inetd, the named name server, the ipfw firewall, and much more. Each script can take arguments of start, stop, and restart.
.login	The configuration file for C-style shells (csh and tcsh). (See Chapter 9.)
.profile	The configuration file for Bourne-style shells (sh, ksh, and bash). (See Chapter 9.)
.cshrc	Contains configuration options for C-style shells (csh, tcsh) that affect subshells as well as login shells. (See Chapter 9.)
.bashrc	Contains configuration options for the bash shell that affect subshells as well as login shells. (See Chapter 9.)
/etc/csh.login	Contains default global configuration options for C-style shells (csh and tcsh) that affect all users. (See Chapter 9.)
/etc/profile	Contains default global configuration options for Bourne-style shells (sh, ksh, and bash) that affect all users. (See Chapter 9.)
.forward	Controls email forwarding for the user in whose home directory it appears. (See Chapter 25, "Configuring Email Services.")
.xinitrc	Controls X11 options such as the window manager you choose and the user applications you want to run. (See Chapter 7, "Advanced X11 Configuration.")
/etc/X11/xorg.conf	The main configuration file for the X Window System. (See Chapter 7.)

Note

In versions of FreeBSD prior to 5.3, which contain XFree86 rather than Xorg, this file is /etc/X11/XF86Config.

Appendix B. Hardware Compatibility Lists

This appendix lists some of the hardware that FreeBSD is known to work with, as well as the video cards that are supported by the X Window System. Note that this list only applies to FreeBSD running on x86 (Intel and compatible) hardware. Also, it is not intended to be a comprehensive list of all supported hardware but rather a general guide so that you can determine whether at least most of your system is compatible with FreeBSD before you install it. A comprehensive hardware compatibility list can be found on the FreeBSD website at http://www.freebsd.org/ releases (click the Hardware Notes link next to your FreeBSD release number).

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System Requirements

Minimum requirements:

- Intel 486 series or compatible CPU
- 8MB of RAM
- 80MB of disk space

FreeBSD can take advantage of the latest in technological advances such as multiprocessor (SMP) motherboards and accelerated video cards, and particularly if you use it as a desktop workstation with KDE or GNOME, it can be as hungry for resources such as RAM and disk space as any Windows machine or Mac. The absolute minimum requirements shown here should be taken with a grain of salt; if you intend to run a modern version of FreeBSD on old hardware, whether as a way to extend the life of an old beloved chassis or to obtain the bragging rights that come from fitting useful functionality into very limited hardware, my recommended minimum configuration is:

- Intel Pentium or compatible CPU.
- 32MB of RAM.
- At least 1GB of free disk space for a full install (with X11) and space for additional third-party software. Servers may require much more space, depending on the number of users and the services the server is providing.

In addition, if you plan to run the X Window System, I recommend the following additional minimum system configuration:

- Monitor that can provide 1024x768 resolution (comfortably). A resolution of 800x600 is acceptable, but might make for a crowded desktop.
- Supported SVGA video card (see video card list) with at least 1MB of video RAM.
- At least 64MB of RAM.
- Three-button mouse.

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Supported Hardware

The following hardware is known to work with FreeBSD.

Disk Controllers (IDE/ATA)

Any generic MFM or RLL (WD1003).

Any generic IDE (WD1007).

ATA controllers.

FreeBSD supports UDMA mode on EIDE controllers that can use it.

Serial ATA (SATA) is supported for RAID controllers made by Adaptec, Dell, MegaRAID, and AMCC.

Note

USB mass storage devices (external hard disks) from most major manufacturers are supported, including Iomega, ADTEC, Logitech, Panasonic, IBM, TEAC, Sony, and others. However, booting from USB devices is likely to be problematic.

Disk Controllers (SCSI)

Note that some SCSI controllers (such as the SoundBlaster SCSI controllers) use a chipset from another manufacturer, such as Adaptec. If you don't find your actual card listed here, check to see what chipset it uses. In some cases, the chipset will be in the following list.

Adaptec:

174X series EISA SCSI controllers in standard and enhanced mode

274X/284X/2920C/294X/2950/3940/3950 (Narrow/Wide/Twin) series EISA/VLB/PCI SCSI controllers

AIC-7850, AIC-7860, AIC-7880, AIC-789X onboard SCSI controllers

1510 series ISA SCSI controllers (not for bootable devices)

152X series ISA SCSI controllers

154x series and 174x series SCSI controllers

AIC-7770 and AIC-78xx series host adapters

SCSI RAID 2120S, 2130S, 2200S, 2130SLP, 2230SLP, 5400S

AdvanSys:

All AdvanSys SCSI controllers are supported.

BusLogic:

MultiMaster "W" series host adapters, including BT-948, BT-958, and BT-9580

MultiMaster "C" series host adapters, including BT-946C, BT-956C, BT-956CD, BT-445C, BT-747C, BT-757C, BT-757CD, BT-545C, and BT-540CF

MultiMaster "S" series host adapters, including BT-445S, BT-747S, BT-747D, BT-757S, BT-757D, BT-545S, BT-542D, BT-742A, and BT-542B

MultiMaster "A" series host adapters, including BT-742A and BT-542B

Compaq:

Intelligent disk array controllers: IDA, IDA-2, IAES, SMART, SMART-2/E, SMART-2/P, SMART-2/SL; Integrated Array; and Smart Arrays 3200, 3100ES, 221, 4200, and 4250ES

DPT:

SmartCACHE Plus, SmartCACHE III, SmartRAID III, SmartCACHE IV, and SmartRAID IV SCSI/RAID are supported. The DPT SmartRAID/CACHE V is not yet supported. The DPT PM3754U2-16M SCSI RAID controller is also supported.

DTC:

3290 SCSI controller in Adaptec 1542 emulation mode

MegaRAID:

SCSI 320-x series, Enterprise 1200 series, Elite 1500 series, Express 100 series

SymBios (also NCR):

53C810, 53C810a, 53C815, 53C820, 53C825a, 53C860, 53C875, 53C875j, 53C885, and 53C896 PCI SCSI controllers, including ASUS SC-200; Data Technology DTC3130 (all variants); Diamond FirePort (all); NCR cards (all); SymBios cards (all); Tekram DC390W, 390U, and 390F; and Tyan S1365

QLogic:

1020, 1240, 2100, and 2200 series SCSI and fiber

Note

FreeBSD supports SCSI-I and SCSI-II devices. However, CD-RW and WORM devices are supported only in read-only mode by the driver included with FreeBSD. To get write access to these devices, install `cdrecord` from the FreeBSD ports tree.

Optical (CD-ROM/DVD) Drives

Any ATAPI-compliant drive

SCSI-based drives

Matsushita/Panasonic (Creative Labs SoundBlaster) proprietary drives (562/563 models)

All Sony proprietary drives

Network Cards

This section lists the network cards supported by FreeBSD. Note that many generic cards, as well as many built-in network adapters, will use one of these chipsets. Therefore, if you don't find your specific card mentioned here, see if you can find out what chipset it uses. For example, many generic network cards have an NE 2000 compatible chipset, and many built-in adapters use the Intel EtherExpress chipsetboth of which are supported by FreeBSD.

Adaptec:

Duralink PCI Fast Ethernet adapters based on the Adaptec AIC-6195 Fast Ethernet controller chip, including the following:

- ANA-62011 64-bit single-port 10/100BaseTX adapter
- ANA-62022 64-bit dual-port 10/100BaseTX adapter
- ANA-62044 64-bit quad-port 10/100BaseTX adapter
- ANA-69011 32-bit single-port 10/100BaseTX adapter
- ANA-62020 64-bit single-port 100BaseFX adapter

Allied-Telesyn:

AT1700 and RE2000

Alteon Networks:

Alteon Networks PCI Gigabit Ethernet NICs based on the Tigon 1 and Tigon 2 chipsets, including Alteon AceNIC (Tigon 1 and 2), 3Com 3c985-SX (Tigon 1 and 2), Netgear GA620 (Tigon 2), Silicon Graphics Gigabit Ethernet, DEC/Compaq EtherWORKS 1000, and NEC Gigabit Ethernet

AMD:

PCnet/PCI (79C97x series and 53C974 or 79C974)

RealTek:

8129/8139 Fast Ethernet NICs, including the following:

- Allied-Telesyn AT2550
- Allied-Telesyn AT2500TX
- Genius GF100TXR (RTL8139)
- NDC Communications NE100TX-E
- OvisLink LEF-8129TX
- OvisLink LEF-8139TX
- Netronix Inc. EA-1210 NetEther 10/100
- KTX-9130TX 10/100 Fast Ethernet
- Accton "Cheetah" EN1207D (MPX 5030/5038; RealTek 8139 clone)
- SMC EZ Card 10/100 PCI 1211-TX

Lite-On:

98713, 98713A, 98715, and 98725 Fast Ethernet NICs, including the following:

- LinkSys EtherFast LNE100TX
- NetGear FA310-TX Rev. D1
- Matrox FastNIC 10/100
- Kingston KNE110TX

Macronix:

98713, 98713A, 98715, 98715A, and 98725 Fast Ethernet NICs, including the following:

- NDC Communications SFA100A (98713A)
- CNet Pro120A (98713 or 98713A)
- CNet Pro120B (98715)
- SVEC PN102TX (98713)

Macronix/Lite-On:

PNIC II LC82C115 Fast Ethernet NICs, including the LinkSys EtherFast LNE100TX, version 2

Winbond:

W89C840F Fast Ethernet NICs, including the Trendware TE100-PCIE

Via Technologies:

VT3043 "Rhine I" and VT86C100A "Rhine II" Fast Ethernet NICs, including the Hawking Technologies PN102TX and D-Link DFE-530TX

Silicon Integrated Systems:

SiS 900 and SiS 7016 PCI Fast Ethernet NICs

Sundance Technologies:

ST201 PCI Fast Ethernet NICs, including the D-Link DFE-550TX

SysKonnect:

SK-984x PCI Gigabit Ethernet cards, including the following:

- SK-9841 1000BaseLX (single-mode fiber, single port)
- SK-9842 1000BaseSX (multimode fiber, single port)
- SK-9843 1000BaseLX (single-mode fiber, dual port)
- SK-9844 1000BaseSX (multimode fiber, dual port)

Texas Instruments:

ThunderLAN PCI NICs, including the following:

- Compaq Netelligent 10, 10/100, 10/100 Proliant, 10/100 Dual-Port, 10/100 TX Embedded UTP, 10 T PCI UTP/Coax, and 10/100 TX UTP
- Compaq NetFlex 3P, 3P Integrated, and 3P with BNC
- Olicom OC-2135/2138, OC-2325, and OC-2326 10/100 TX UTP
- Racore 8165 10/100BaseTX and 8148 10BaseT/100BaseTX/100BaseFX multipersonality cards

ADMTek:

AL981-based and AN985-based PCI Fast Ethernet NICs

ASIX Electronics:

AX88140A PCI NICs, including the Alfa Inc. GFC2204 and CNet Pro110B

Broadcom:

BCM570x series 10/100/1000baseTX interfaces, including many cards and integrated motherboard chipsets from 3Com, Dell, IBM, HP, Netgear, and SysKonnect

DEC:

EtherWORKS III NICs (DE203, DE204, and DE205)

EtherWORKS II NICs (DE200, DE201, DE202, and DE422)

DC21040-, DC21041-, or DC21140-based NICs (SMC Etherpower 8432T, DE245, and so on)

FDDI (DEFPA/DEFEA) NICs

Efficient:

ENI-155p ATM PCI

FORE:

PCA-200E ATM PCI

Fujitsu:

MB86960A/MB86965A

HP:

PC Lan+ cards (model numbers 27247B and 27252A)

Intel:

EtherExpress ISA (not recommended due to driver instability)

EtherExpress Pro/10 series

EtherExpress Pro/100B PCI Fast Ethernet

Pro/1000 series Gigabit Ethernet

Isolan:

AT 4141-0 (16 bit)

Isolink:

4110 (8 bit)

Novell:

NE1000, NE2000, and NE2100

PCI network cards emulating the NE2000, including the following:

- RealTek 8029
- NetVin 5000
- Winbond W89C940
- Surecom NE-34
- VIA VT86C926

3Com:

3C501

3C503 Etherlink II

3C505 Etherlink/+

3C507 Etherlink 16/TP

3C509

3C579

3C589 (PCMCIA)

3C590/592/595/900/905/905B/905C PCI and EISA (Fast) Etherlink III/(Fast) Etherlink XL

3C980/3C980B Fast Etherlink XL server adapter

3CSOHO100-TX OfficeConnect adapter

Toshiba:

All Toshiba Ethernet cards

PCMCIA cards:

PCMCIA Ethernet cards from IBM and National Semiconductor

Wireless Network Cards

Intersil PRISM chipset cards (required if you're building a wireless access point)

WaveLAN ISA cards by NCR, AT&T, or Lucent

Cisco Aironet 802.11b

Raytheon Raylink

Cisco AIR series

D-Link DWL series

Elecom LD-WL54 series

Fujitsu E5454 and FMV-JW481

HP NC4000

I/O Data WN-A series

Linksys WMP and WPC series

NEC PA-WL/54AG

Netgear WA series and WG series

Orinoco 8480 and 8470WD

Proxim Skyline 4030/4032

Samsung SWL-5200N

SMC 2536W-AG and 2735W

Sony PCWA series

3Com 3CRPAG175

USB Devices

USB keyboards

USB mice

USB printers and USB-toparallel printer conversion cables

USB hubs

USB scanners

Asahi Optical (Pentax) Optio 230/330 digital cameras

Sound Devices

16550 UART (Midi). (Experimental; needs a trick in the hints file.)

Advance Asound 100, 110, and Logic ALS120.

Aureal Vortex1/Vortex2 and Vortex Advantagebased sound cards by a third-party driver.

Creative Labs SB16, SB32, SB AWE64 (including Gold), Vibra16, SB PCI (experimental), SB Live! (experimental), and most SoundBlaster-compatible cards.

Creative Labs SB Midi Port (experimental) and SB OPL3 Synthesizer (experimental).

Crystal Semiconductor CS461x/462x Audio Accelerator. (The support for the CS461x Midi port is experimental.)

Crystal Semiconductor CS428x audio controller.

CS4237, CS4236, CS4232, and CS4231 (ISA).

ENSONIQ AudioPCI ES1370/1371.

ESS ES1868, ES1869, ES1879, and ES1888.

Gravis UltraSound PnP and MAX.

NeoMagic 256AV/ZX (PCI).

OPTi931 (ISA).

OSS-compatible sequencer (Midi). (Experimental.)

Trident 4DWave DX/NX (PCI).

Yamaha OPL-SAx (ISA).

FireWire (IEEE 1394) Devices

FireWire interface cards made by the following manufacturers are likely to be supported:

Adaptec

Apple

Intel

NEC

National Semiconductor

Ricoh

Sony

Sun

Texas Instruments

Bluetooth Devices

3Com/HP 3CRWB6096-A and 3CREB96

AIPTEK BR0R02

EPoX BT-DG02

Mitsumi USB

MSI MS-6967

TDK USB

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Video Cards Supported by X11

The following is a compilation of the video cards that Xorg currently supports. Each manufacturer's section is followed by the driver you need to select for it. The list was taken from the Xorg Project's website. If you cannot find an exact match for your card, see if you can find out what chipset your card uses and find a match there.

Alliance ProMotion (`apm`):

ProMotion 6420

ProMotion 6422

AT24

AT3D

AT25

Chips & Technologies (`chips`):

ct65520, ct65525, ct65530, ct65535, ct65540, ct65545, ct65546 ct65548, ct64200, ct64300, ct65550, ct65554, ct65555, ct68554, ct69000, and ct69030 chipsets

Cirrus Logic (`cirrus`):

All Cirrus Logic cards and chipsets

Cyrix (`cyrix`):

MediaGX, MediaGXi, and MediaGXm

Natsemi 'Geode'

CS5510, CS5520, CS5530, and CS5530A chipsets

Glide (`glide`):

3Dfx Voodoo 1 and 2

GLINT/Permedia (`glint`):

3Dlabs (GLINT MX, GLINT 500TX, GLINT 300SX, GLINT GAMMA, GLINT DELTA, GLINT GAMMA2, Permedia, Permedia 2, Permedia 2v, Permedia 3, R3, R4) chipsets

Texas Instruments (Permedia, Permedia 2) chipsets

Number 9 I128 (`i128`):

I128 rev 1

I128-II

I128-T2R (Ticket 2 Ride)

I128-T2R4 (Ticket 2 Ride IV)

Intel i740 (`i740`):

All Intel i740-based cards and chipsets

Intel i810 (`i810`):

810, i810-DC100, i810e, i815, 830M, 845G, 852GM, 855GM, 865G, 915G, and 915GM chipsets

Matrox (`mga`):

MGA2064W

MGA1064SG (Mystique)

MGA2164W (Millennium II)

G100 (Productiva G100)

G200 (Millennium G200 and Mystique G200)

G400 (Millennium G400, Millennium G400 MAX, Millennium G450, and Marvel G450 eTV)

G550 (Millennium G550 and Millennium G550 Dual DVI)

Neomagic (`neomagic`):

MagicGraph 128 (NM2070)

MagicGraph 128V (NM2090)

MagicGraph 128ZV (NM2093)

MagicGraph 128ZV+ (NM2097)

MagicGraph 128XD (NM2160)

MagicGraph 256AV (NM2200)

MagicGraph 256AV+ (NM2230)

MagicGraph 256ZX (NM2360)

MagicGraph 256XL+ (NM2380)

Newport (`newport`):

Newport/XL cards in SGI Indy and Indigo2

NSC (`nsc`):

GXLV (5530 companion chip), SC1200, SC1400, and GX2 (5535 companion chip)

NVIDIA (`nv`):

RIVA 128 (NV3)

RIVA TNT (NV4)

RIVA TNT2 (NV5)

GeForce 256, QUADRO (NV10)

GeForce2, QUADRO2 (NV11 & NV15)

GeForce3, QUADRO DCC (NV20)

nForce, nForce2 (NV1A, NV1F)

GeForce4, QUADRO4 (NV17, NV18, NV25, NV28)

GeForce FX, QUADRO FX (NV30, NV31, NV34, NV35, NV36, NV37, NV38)

GeForce 6XXX (NV40, NV41, NV43, NV44, NV45)

GeForce 7XXX (G70)

ATI Rage 128 (`r128`):

All ATI Rage 128-based video cards including the Rage Fury AGP 32MB, the XPERT 128 AGP 16MB, and the XPERT 99 AGP 8MB

ATI RADEON (`radeon`):

R100 (Radeon 7200)

RV100 (Radeon 7000/VE, M6)

RS100 (Radeon IGP320/M)

RV200 (Radeon 7500, M7, FireGL 7800)

RS200 (Radeon IGP330/M, IGP340/M)

RS250 (Radeon Mobility 7000 IGP)

R200 (Radeon 8500, 9100, FireGL 8800/8700)

RV250 (Radeon 9000PRO/9000, M9)

RS300 (Radeon 9100 IGP)

RS350 (Radeon 9200 IGP)

RS400 (Radeon XPRESS 200/200M IGP)

RV280 (Radeon 9200PRO/9200/9200SE, M9+)

R300 (Radeon 9700PRO/9700/9500PRO/9500/9600TX, FireGL X1/Z1; 2D only)

R350 (Radeon 9800PRO/9800SE/9800, FireGL X2; 2D only)

R360 (Radeon 9800XT; 2D only)

RV350 (Radeon 9600PRO/9600SE/9600, M10/M11, FireGL T2; 2D only)

RV360 (Radeon 9600XT; 2D only)

RV370 (Radeon X300, M22; 2D only)

RV380 (Radeon X600, M24; 2D only)

RV410 (Radeon X700, M26 PCIE; 2D only)

R420 (Radeon X800 AGP; 2D only)

R423/R430 (Radeon X800, M28 PCIE; 2D only)

R480/R481 (Radeon X850 PCIE/AGP; 2D only)

Rendition/Micron (`rendition`):

Verite V1000

Verite V2100

Verite V2200

S3 ViRGE (`s3virge`):

ViRGE (86C325)

ViRGE VX (86C988)

ViRGE DX (86C375)

ViRGE GX (86C385)

ViRGE GX2 (86C357)

ViRGE MX (86C260)

ViRGE MX+ (86C280)

Trio 3D (86C365)

Trio 3D/2X (86C362, 86C368)

S3 Savage (`savage`):

Savage3D (2D, 3D)

Savage4 (2D, 3D)

Savage2000 (2D only)

Savage/MX (2D, 3D, Dualhead)

Savage/IX (2D, 3D, Dualhead)

SuperSavage/MX (2D, 3D, Dualhead)

SuperSavage/IX (2D, 3D, Dualhead)

ProSavage PM133 (2D, 3D)

ProSavage KM133 (2D, 3D)

Twister/ProSavage PN133 (2D, 3D)

TwisterK/ProSavage KN133 (2D, 3D)

ProSavage DDR (2D, 3D)

ProSavage DDR-K (2D, 3D)

Silicon Motion (`siliconmotion`):

Lynx (SM910)

LynxE (SM810)

Lynx3D (SM820)

LynxEM (SM710)

LynxEM+ (SM712)

Lynx3DM (SM720)

Cougar3DR (SM730)

SiS/XGI (`sis`):

SiS5597/5598

SiS530/620

SiS6326/AGP/DVD

SiS300/305

SiS540

SiS630/730

SiS315/E/H/PRO

SiS550/551/552

SiS650/651/661/741

SiS330 (Xabre)

SiS760/761

XGI Volari V3/V5/V8

XGI Volari Z7

SiS USB (`sisusb`):

SiS315E/PRO chipset

3Dfx (`tdfx`):

Voodoo Banshee

Voodoo3

Voodoo4

Voodoo5

Trident (`TRident`):

Blade3D, CyberBlade series i1, i7 (DSTN), i1, i1 (DSTN), Ai1, Ai1 (DSTN), CyberBlade/e4, CyberBladeXP, CyberBladeAi1/XP, BladeXP

3DImage975, 3DImage985, Cyber9520, Cyber9525, Cyber9397, Cyber9397DVD

ProVidia 9682, 9685, Cyber9382, Cyber9385, Cyber9388

TGUI 440AGi, 9660, 9680

ISA/VLBus 8900C, 8900D, 9000, 9200CXr, Cyber9320, 9400CXi, 9440AGi (untested)

Tseng (`tseng`):

All Tseng video cards

Note

If your video card is not listed here, try the generic `vesa` or `vga` drivers.

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Appendix C. Troubleshooting Installation and Boot Problems

The first step toward resolving an installation or booting problem in FreeBSD is tracking down the problem's source. This appendix is designed to help you identify and solve some of the most common installation and booting problems. The first section covers installation problems, and the second section explains how to diagnose and resolve booting problems.

Note

This appendix is not a complete list of all the problems you could potentially encountersuch a thing would be patently impossible. Rather, it is designed to list some of the most common problems you're likely to encounter in your first days with FreeBSD, as well as possible solutions (of which, in the UNIX world, there are bound to be more than one for any given problem). Further information on troubleshooting problems can be found on the FreeBSD website at http://www.freebsd.org. The online Handbook contains troubleshooting information for many common problems. If the Handbook doesn't provide a solution, you can also post a detailed description of the problem to the freebsdquestions mailing list. More information on the FreeBSD mailing lists can be found in Appendix D, "Sources for More Information."

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Installation Problems

This section of the appendix covers problems you might encounter following the initial installation of FreeBSD and possible solutions to these problems.

Booting from Floppy Causes System to Hang or Reboot

A few things can cause a system to hang or reboot when booting from a floppy, but a bad floppy is the most likely cause. Remember that the boot image is written to the floppy without checking the format, and that the entire floppy is used regardless of how much space the disk image consumes. Even a single bad block on the floppy can cause problems. Try writing the boot disk image to a new floppy and see if it fixes the problem.

If using a new floppy does not help, and you used FTP to obtain the disk image file or to send it to the machine where you made the floppy, make sure you used binary mode and not ASCII mode during the transfer. Transferring in ASCII mode can ruin binary files.

Virus protection on the motherboard is another possible cause of this problem. You can disable this protection in the system's BIOS setup utility. Please refer to your system documentation for information on how to disable your motherboard's virus protection features.

Boot Floppy Hangs at "Probing Devices"

The boot floppy sometimes gets confused by unusual hardware on the IDE chain such as Zip and Jaz drives. If you have one of these drives, try removing it and see if the system will boot. If it does, you can install FreeBSD and then reconnect the drive after the installation is complete.

System Boots from CD, but Installer Shows That CD-ROM Was Not Found

This problem is probably caused by an improperly configured CD-ROM drive. Remember that there is space for four devices in most PCsa master and a slave on each of the two IDE chains. Some systems ship with the CD-ROM drive as a slave drive on the secondary controller and have no master drive on the secondary controller. Some CD-ROM drives cannot operate properly in slave mode. To fix this, you will need to open up the computer and use the jumpers and the indicated pin diagram to change your CD-ROM drive to the master position on its IDE chain. When your system first starts up, it usually displays a list of disks it found, including CD-ROM drives, as well as information about whether they are configured as master or slave disks.

Hard Disk Geometry Is Not Detected Properly

If FreeBSD cannot detect your hard disk geometry correctly, there are two ways this can usually be fixed:

- You first might create a small DOS partition at the beginning of the disk. This partitioning will usually cause FreeBSD to see the right geometry.
- The second way is to use the `pfdisk` program included on the DVD packaged with this book (located in the `tools` directory). `pfdisk` runs under DOS and will usually detect the proper geometry of the hard disk; you then can give the FreeBSD partition the proper geometry manually.

Micron and/or Other Systems Hang When Booting

Some Micron (and possibly other) systems have buggy PCI BIOS routines. This can cause PCI devices to be configured incorrectly when they are probed, resulting in unexpected behavior such as hangs or freezes during boot or inoperative Ethernet cards. You can work around this problem by disabling the Plug-and-Play support in the BIOS setup utility.

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Boot Problems and Other Non-installation Problems

This section covers problems related to booting as well as other noninstallation-related problems that you might encounter after a successful install.

FreeBSD Says "Missing Operating System" When Trying to Boot

This message usually means that FreeBSD did not correctly detect your hard disk's geometry when it installed. There are two solutions to this problem:

- Create a small DOS partition at the beginning of the drive and install a bare minimum copy of DOS on it (FreeDOS, an MS-DOS workalike, is available for free at http://www.freedos.org). This should cause FreeBSD to detect the right information for partitioning.
- Use the `pfdisk` program found on the DVD packaged with this book (in the `tools` directory) to detect the hard disk geometry and then set it manually in the FreeBSD partition editor.

Either way, you will have to reinstall FreeBSD to get things working.

FreeBSD's Boot Manager Hangs at "F?"

This problem, which indicates that no bootable DOS partitions (slices) are found, is usually caused by FreeBSD not detecting your hard disk geometry properly. See the preceding section for solutions to this problem.

FreeBSD's Boot Loader Says "Read Error" and Hangs

Once again, this is usually caused by FreeBSD not detecting the hard disk geometry correctly. See the preceding two sections for solutions to this problem.

No Boot Manager; System Boots Right into Windows

Either the boot manager didn't get installed when you installed FreeBSD or something you did in Windows (`fdisk /mbr`, for example) clobbered the FreeBSD boot manager. Fortunately, it is relatively easy to restore.

1. Boot from the included DVD or from the installation floppies you created.
2. After you have gotten into the Sysinstall program, select Configure and then Fdisk (see Chapter 2, "Installing FreeBSD," if you need a refresher on Sysinstall).
3. If you have multiple hard disks in your system, you will be prompted for which system you want to run `fdisk` on. Select the primary disk that your system boots from.
4. When you are in `fdisk`, simply select W to write the changes. You will be given a warning telling you that this should be done only when making changes to an existing installation. Select Yes and press Enter.
5. When the system asks what to do about the boot loader, select Master Boot Record.

After you have completed this process, the boot manager should be back in operation.

FreeBSD Detects Less RAM Than Is Really in the System

FreeBSD can't always get the proper amount of memory in your system from the BIOS. Usually, this results in FreeBSD detecting only 64MB of RAM, even if you really have more.

To fix this problem, you will need to add the following option to the kernel configuration file:

```
options         "MAXMEM=n"
```

Here, *n* is the amount of memory you have in kilobytes. Remember that in binary math, a kilobyte is actually 1,024 bytes instead of 1,000 bytes. Thus, if you have 512MB of RAM, you'll need to enter **524288** as the number here.

After you have made this change, you will need to rebuild the kernel (see Chapter 18, "Kernel Configuration," for detailed information on rebuilding the kernel).

FreeBSD Complains "Device Not Configured" While Trying to Mount a CD-ROM Drive

This problem can be caused by a few things, as follows:

- The CD-ROM drive might be empty; simply insert a CD and try again.
- The second possibility is that an ATAPI CD-ROM drive is configured as the slave drive on the secondary controller and there is no master drive on the controller. You will need to reconfigure your CD-ROM drive as the master if this is the case (you usually can do this reconfiguration using the jumpers on the back of the CD-ROM drive).
- If you have a SCSI CD-ROM drive, the drive might not be getting enough time to answer the bus reset request when the kernel is started. If this is the case, find the `options SCSI_DELAY` line in the kernel configuration file and increase the time. (The time is given in milliseconds. By default, it is set to `5000`, or 5 seconds. You might start by doubling it to a value of `10000`.) You will then need to rebuild the kernel (see Chapter 18).

Programs Crash with Signal 11 Errors

This problem is somewhat like an "illegal operation" error in Windows. It basically means that a program tried to access memory that was not allocated to it. This could be the result of a bug in the program or, if it is occurring with utilities included with FreeBSD, a bug in FreeBSD itself.

A third potential cause of this problem is flaky hardware. If the problem occurs at random points while compiling software, you can be almost sure that old or faulty hardware is the culprit. Common hardware causes for such problems include defective RAM, a CPU that is overheating (Is your CPU fan running? Are you overclocking?), defective cache memory, or a marginal power supply.

You can isolate hardware problems by booting your system into a different operating system, such as Knoppix, a Linux distribution that runs entirely from CD (meaning that you don't have to install it on your hard drive in order to see whether it has the same problems on your hardware that FreeBSD does). Knoppix is available for free at http://www.knoppix.net. Another option is memtest86 (http://www.memtest86.com), which you can download and burn to a bootable CD that can be used to diagnose potential memory problems.

Strange Error Messages (such as "proc size mismatch") Occur When Running **`top`**, **`ps`**, and Other System Utilities

This type of error is almost always caused by your world and your kernel being out of sync, usually because they're based on different states of the source code. Often, the problem stems from using `make world` to build the system from source and then failing to build a new kernel. The reverse could also be true: You built a new kernel with sources that you downloaded but did not do a `make world` first.

Because it is much quicker to rebuild the kernel than to rebuild the world, the simplest solution is to try making a new kernel and rebooting first (see Chapter 18 for detailed information on rebuilding the kernel).

If rebuilding the kernel doesn't fix the problem, try rebuilding the world. (See Chapter 19, "Keeping Up to Date with FreeBSD," for details on doing a `make world`.)

Finally, if neither of these options solves the problem, getting the latest source (see Chapter 19), making the world, and then rebuilding the kernel should get your system back on its feet.

Forgotten Root Password

If you have forgotten your root password, you can boot into single user mode to recover it.

To get into single user mode, reboot the system and then choose Option 4, Boot FreeBSD in Single User Mode, from the loader menu. When you are asked which shell to use, simply press Enter for the default. You should then get a root user prompt that looks like this:

```
#
```

At the prompt, type **`mount -u /`** and then press Enter to remount the root filesystem in read/write mode. Then, type **`mount -a`** to mount all the other filesystems. You can now type **`passwd root`** to change the password for the root account. (If this doesn't work, use **`/usr/bin/passwd root`**.) You will not be asked for the old password. Simply enter the new password you would like to use, press Enter, reenter it to confirm it, and press Enter again. Finally, reboot your system with **`shutdown -r now`**.

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Appendix D. Sources for More Information

FreeBSD has a large and growing community of users and developers. Many sources of information are available on FreeBSD and related products. This appendix lists some of those sources.

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FreeBSD-Specific Resources

This section provides resources on websites, mailing lists, technical lists, and more.

Websites

www.freebsd.org

This is the official website of the FreeBSD project. It is the place to go for news, updates, and information on ports and packages. It is also where the online handbook and various tutorials are located.

www.freebsddiary.org

This site is a goldmine of FAQS and how-to articles on a large number of subjects. It is also the home of some FreeBSD discussion forums.

www.freshports.org

The place to get the latest news regarding new and updated FreeBSD ports, and to subscribe to notifications regarding ports that interest you.

www.freebsdmall.com

The source for purchasing all things FreeBSD. Here, you can get CDs, T-shirts, jackets, mouse pads, coffee mugs, hats, books, and so on. You can also purchase professional support services for FreeBSD here.

Mailing Lists

Mailing lists are places where those in the FreeBSD community can share information and post questions that others subscribed to the list can view and respond to. There are several benefits to being subscribed to the various mailing lists, including being notified of problems with the source tree, security hazards, and so on.

All these mailing lists are official ones moderated by members of the FreeBSD core team and user community. Each one is dedicated to a specific function, such as ports, announcements, the -STABLE branch, and so on. To subscribe to any of the lists, send an email to majordomo@freebsd.org with the following in the body of the message:

```
subscribe list-name
```

`list-name` is the name of the list you want to subscribe to. You can unsubscribe from any list to which you're subscribed by sending an email to majordomo@freebsd.org with the following in the body of the message:

```
unsubscribe list-name
```

Many of the lists are high volume and will generate a lot of email. To avoid this, you can subscribe to many of the lists in digest form. If you do this, you will only be sent an email from each list you subscribe to when the number of messages posted has exceeded 100KB. All the messages will be sent in a single email.

Caution

If you decide to unsubscribe from a list, make sure you address the message to majordomo@freebsd.org, not to the actual mailing list address. Posting the unsubscribe message to the mailing list instead of to the Majordomo program will have two undesirable effects: First, it won't unsubscribe you. Instead your unsubscribe message will be posted to the list for the whole world to see. Second, it will irritate the list members (most of whom are seasoned UNIX veterans with little patience for newbies). Getting on their bad side isn't much of a way to start your UNIX administration career.

General Lists

Anyone can subscribe to and participate in the general lists. However, you should read the list's guidelines (which will be sent to you when you subscribe) before posting to the list. Here are the general lists, along with a short description of what each one is used for.

The complete set of mailing lists, as well as web-based searchable interfaces to their archives, can be found at http://www.freebsd.org/community/mailinglists.html.

cvs-all

Changes made to the FreeBSD source tree are posted to this list. This is a read-only list, and of interest only to hard-core developers who like reading through mountains of C code.

freebsd-advocacy

A list for discussing the benefits of FreeBSD and different ways of promoting FreeBSD.

freebsd-announce

Important announcements regarding FreeBSD. This is a read-only list that is designed to be low in volume.

freebsd-arch

Discussions regarding system architecture and design.

freebsd-bugbusters

FreeBSD users discussing how the FreeBSD bug database works.

freebsd-bugs

Bug reports for FreeBSD. Note that you should not actually send bug reports to this list. Rather, you should submit a problem report into the bug database using the form located at http://www.freebsd.org/send-pr.html (or the `send-pr` program in FreeBSD). Your submitted problem report will then be posted on the list for those subscribed to it to see, as well as be tracked in the database.

freebsd-chat

A general, nontechnical discussion for members of the FreeBSD community.

freebsd-current

If you are tracking the CURRENT branch of FreeBSD, you *need* to be subscribed to this list. Among other things, reading this list can prevent you from "making world" when the source tree is broken and possibly rendering your system unusable. You should not be tracking CURRENT unless you are technically savvy and are willing to deal with problems like this. This means that you should not post general "how-to" questions to this list. Only technical questions regarding behavior in CURRENT should be posted to this list. For other types of questions, you will either not get a response at all or will likely be told to repost your question in freebsd-questions.

freebsd-isp

A discussion list for Internet service providers using FreeBSD. Note that this list is for providers, not users. In other words, if you are having problems getting FreeBSD to connect to your Internet service provider, this is *not* the place to post any questions.

freebsd-jobs

If you are a FreeBSD guru looking for a job, you can find job announcements on this list. If you are an employer and need a FreeBSD guru, you can post your "help wanted" ad to this list.

freebsd-policy

This read-only list is for the FreeBSD core team to discuss changes in the development policy for FreeBSD.

freebsd-questions

The place to post technical questions about FreeBSD. If you post a question here, be specific. In other words, don't post a question that says "I can't get `pppd` to work. What am I doing wrong?" Such a question is not useful at all for troubleshooting, and though it might seem like a good way to send out a distress call, all it tends to do is annoy other list subscribers. To get a useful answer, you will need to provide details, such as the contents of any error messages that are written to the logs, what kind of configuration you are trying to use, relevant sections of configuration files (`.conf` files), and so on. Also, be polite and don't flame the list if you don't get an answer right away. Remember, the people staffing this list are here on their own time and are all volunteers. Most of them have real jobs and are devoting part of their free time to reading and responding to this list. No one on this list gets paid to help you. Note that you do not need to be subscribed to this list in order to post to it. However, make sure you provide a valid email address so that people have a place to send answers to your questions.

freebsd-security-notifications

This is a list that all FreeBSD users should follow. It's where notifications regarding FreeBSD security holes are posted as soon as they're discovered, as well as instructions for fixing the holes. There is no better way to stay apprised of critical security information than subscribing to this list.

freebsd-stable

This list is for discussions regarding the STABLE source tree. As with CURRENT, if you are tracking STABLE, you *need* to be subscribed to this list. Although serious problems that can break the distribution and can render a system unbootable are much more rare in STABLE than in CURRENT, they can and do occur. The FreeBSD developers and committers are only human, and like everyone else, they occasionally make mistakes. This list will tell you when there are problems with the tree and also let you know when it is safe to use the tree again. Note that general technical or how-to questions should not be posted to this list. Such questions should be posted to freebsd-questions.

freebsd-test

If you're seized with the urge to send out a message reading "Testing, testing, 1, 2, 3..." this list, not any of the others, is the place to send it. Use this list for making sure that your mail messages are reaching the FreeBSD servers.

Technical Lists

There are many different technical (developers) lists for FreeBSD-related issues, such as porting to different platforms, porting various software to FreeBSD, using FreeBSD in embedded systems, and so on. Because these lists are not of interest to most people, they will not be listed or described here. However, a full list of the technical lists can be obtained at http://www.freebsd.org/doc/handbook/eresources.html.

As the category suggests, these lists are quite technical in nature, and likely to be of interest only to developers. Do not post questions of a general nature to any lists considered "technical lists." Virtually all these lists have guidelines for the way they are to be used.

Therefore, you should read the charter that is emailed to you when subscribing to any of these lists before posting to them.

Caution

The technical lists tend to be primarily only for advanced FreeBSD users. Posting how-to questions and off-topic material to this list will get you no answers at best and will get you flamed at worst.

Usenet Newsgroups for FreeBSD

The following FreeBSD-related newsgroups are available on Usenet (contact your ISP to find out what news server you should be using to access Usenet):

- comp.unix.bsd.freebsd.announce

- comp.unix.bsd.freebsd.misc

IRC Channels

For users of Internet Relay Chat (IRC), several channels are available for obtaining live FreeBSD help. I'm not going to list all of them here because some of them are general discussion channels in which the topics are rarely about FreeBSD. Here are the two in which you are likely to be able to get assistance from actual FreeBSD users:

- On EFNet: `#freebsdhelp`
- On Undernet: `#freebsd`

Tip

You will also find FreeBSD-related channels on the Freenode network, which is particularly popular with open-source programmers. Use http://irc.netsplit.de/ to search for such available channels.

Note that depending on the time of day you show up, these channels might have a lot of people in them and still be very quiet. Though it may look like people are ignoring you, that's probably not the case. Many people are working and are simply logged in to the channel as well. Also, during periods of high network congestion, IRC can have very high lag times between when you post your message and when some people actually get it. Keep this in mind as well when you don't seem to be getting any responses (you might consider switching to a different server if it seems your lag time is very high).

Expect to be treated the way you treat others on IRC. If you are rude because you are not getting answers or are not getting the answers you want, expect people to ignore you or respond rudely to you (a channel operator might ban you from the channel, as well).

Remember, like those on the freebsd-questions mailing list, no one here is paid to help you. People on IRC are helping you on their own free time, so keep that in mind before you get mad at them.

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Other BSD-Related Resources

These resources are related to BSD in general but are not FreeBSD-specific. Because FreeBSD is the most popular of the BSD-based operating systems, most of these resources apply to FreeBSD to a large degree. You will find coverage of other BSD-related things here as well, though.

Websites

www.freebsd.org

This site is, of course, the official home page for the FreeBSD project. It is the first place to go for the latest information about FreeBSD releases, security advisories, and so on.

www.daemonnews.org

The premier site for news on all things BSD-related. This site has forums and runs how-to articles. It is also home of the "Source Wars" comics (at http://darby.daemonnews.org).

www.serverwatch.com

This site allows you to track the usage of different operating systems to make sure FreeBSD is staying firmly in the game against its doughty competitors.

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Other Internet Resources

This section covers other resources on the Internet that are somehow related to FreeBSD in a general sense. Included in this section are the home pages for some of the software used and described in this book.

Websites

www.x.org

This is the home page for the X.org Foundation and the Xorg project, which is the free implementation of the X Window System (X11) included with FreeBSD. This is where you will find documentation and such related to the X11 system.

www.gnu.org

The home page for the GNU (a recursive acronym that stands for GNU's Not UNIX) project. Many of the utilities included with FreeBSDsuch as the GCC compiler, the GAWK pattern-matching language, the Emacs editor, and the f77 FORTRAN compilerare from the GNU project. This site contains information on almost all the GNU project's software.

www.gnome.org

The home page for the GNOME Desktop Environment project. GNOME news, tutorials, and so on can be found here.

www.kde.org

The home page for the K Desktop Environment project. KDE news and tutorials are available here, as well as documentation on the many applications built for KDE.

www.apache.org

This is the home page for the Apache web server projectthe most popular web server in the world. It is free and is the web server of choice for FreeBSD. This site also contains information about projects that can be used to extend Apache's functionality, such as PHP, Perl, TCL, and more.

www.mysql.com

MySQL is the open-source SQL database most commonly used with FreeBSD. This site contains documentation, tutorials, and many other resources for the MySQL database software.

www.postgresql.org

The site for PostgreSQL, another open-source SQL database available for FreeBSD. PostgreSQL has more features than MySQL but tends to be somewhat slower.

www.php.net

The home page of the embedded scripting language of choice for building web-based applications. PHP is an open-source competitor to Active Server Pages (ASP), and is most commonly used for linking websites to databases. It integrates well with MySQL and PostgreSQL.

www.perl.com

This site includes information and tutorials on the Perl programming language, which is not a part of FreeBSD but underlies a lot of commonly used utilities such as the Majordomo mailing list manager and the vast majority of CGI programs written for dynamic websites.

www.python.org

The home page for the Python programming language, which is a popular alternative to Perl.

www.sendmail.org

The home page of the ubiquitous Sendmail mail transfer agent, which is the default MTA included with FreeBSD.

www.postfix.org

The home page for a popular alternative mail transfer agent for Sendmail. Postfix is a drop-in replacement for Sendmail. New users will find it much easier to configure than Sendmail.

www.osnews.com

Although it is not FreeBSD-specific, this news site often contains articles of general interest to FreeBSD users and sometimes runs FreeBSD-specific articles.

Usenet Newsgroups

The following nonFreeBSD-specific newsgroups are available on Usenet (contact your ISP to find out what news server you should be using to access Usenet).

General UNIX Newsgroups

These newsgroups cover topics that are not specific to FreeBSD but are of interest to UNIX users in general. For example, they cover UNIX administration practices, general UNIX security issues, general UNIX shell use, and so on.

- `comp.security.unix`
- `comp.sources.unix`
- `comp.unix.admin`

- `comp.unix.advocacy`
- `comp.unix.misc`
- `comp.unix.programmer`
- `comp.unix.questions`
- `comp.unix.shell`
- `comp.unix.user-friendly`

X11 Newsgroups

- `comp.emulators.ms-windows.wine`
- `comp.windows.x`
- `comp.windows.x.announce`
- `comp.windows.x.apps`
- `comp.windows.x.i386unix`
- `comp.windows.x.intrinsics`
- `comp.windows.x.motif`
- `comp.windows.x.pex`

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