Community Experience Distilled

SELinux System Administration

A comprehensive guide to walk you through SELinux access controls

Sven Vermeulen

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About the Author

Sven Vermeulen is a long term contributor to various free software projects and the author of various online guides and resources. He got his first taste of free software in 1997 and never looked back since then. In 2003, he joined the ranks of the Gentoo Linux project as a documentation developer and has crossed several roles after that, including Gentoo Foundation's trustee, council member, project leads for documentation, and (his current role) project lead for Gentoo Hardened's SELinux integration.

In this time frame, he has gained expertise in several technologies, ranging from operating system level knowledge to application servers as he used his interest in security to guide his projects further: security guides using SCAP languages, mandatory access controls through SELinux, authentication with PAM, (application) firewalling, and more.

On SELinux, he has contributed several policies to the reference policy project and participates actively in policy development and user space development projects.

Sven is an IT infrastructure architect working at a European financial institution. Secured implementation of infrastructure (and the surrounding architectural integration) is of course an important part of this. Prior to this, he graduated with an MSc in Computer Engineering at the University of Ghent and then worked as a web application infrastructure engineer with IBM WebSphere AS.

Sven is the main author of Gentoo's Handbook which covers the installation and configuration of Gentoo Linux on several architectures. He also authored the Linux Sea online publication, which is a gentle introduction to Linux for novice system administrators.

I would like to thank the SELinux community for their never-ending support in the field, especially the guys frequenting the #selinux chat channel (you know who am I referring to, especially you Dominick.) Without their assistance, I probably wouldn't have probably been able to be where I am today with SELinux. The same goes to the team members of the Gentoo Hardened project, who despite their geographically distributed nature, are always working together to get Gentoo Linux to a more secure state. Finally, I would like a to give special mention to my colleague "wokwok" for making security a fun field. His approach to security always makes me smile and ensures that this (very) broad and multi-disciplinary field is always alive and kicking.

About the Reviewers

Thomas Fischer is a Computer and IT security specialist since the last 15 years. He is experienced in most fields of IT security and is a master in different programming languages. He was the CEO of a German web and IT company over eight years, and also was also the system architect and administrator for various companies in the professional bike sport scene, Germany. He studied computer networking and security and safety engineering in Furtwangen in the Black Forest. A specialist had made talks at different conferences on the topics of web security and the Linux workstation. Thomas Fischer took part in different international IT security war games and the ICTF 2012. When he is not busy with his machine, he enjoys long distance cycling or extreme mountain bike races.

Dominick Grift has been an SELinux contributor and enthusiast. He has almost 10 years of experience in providing SELinux support to the community. He has been a reference policy contributor and co-maintainer, and Fedora SELinux policy co-maintainer.

I would like to thank the SELinux community for bringing me to the position where I am today.

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Preface

Be it for personal use or for larger enterprises, system administrators have often an ungrateful job of protecting the system from malicious attacks and undefined application behavior. Providing security to systems is a major part of their job description, and to accomplish this there are a large set of security technologies are at the administrator's disposal, such as firewalls, file integrity validation tools, configuration enforcement technologies, and many more. Major parts of system security is the authentication of users, authorization of these users, and auditing of all changes and operations made on the system. Users, however, are becoming more experienced with working around regular access controls that are designed to keep the system safe, and application vulnerabilities are often exposing much more of the system than what the application should have access to.

Fine-grained access controls and enforcement by the system are needed so that users do not need to look for workarounds, and application vulnerabilities remain within the scope of the application. Linux has replied to this demand with a flexible security architecture in which mandatory access control systems can be defined. One of these is SELinux, the security-enhanced Linux subsystem.

More and more distributions are bundling SELinux support with their offerings, making SELinux available to the mass population of Linux administrators. Yet SELinux is often found to be a daunting technology to work with. Be it due to misunderstandings or lack of information, too many times SELinux is being disabled in favor of rapid fixing of permission issues. This, however, is not fixing an issue but it is ignoring an issue and removing the safe barriers that were put in place to protect the system from them.

In this book, we will describe the SELinux concepts and show how to leverage SELinux to improve the secure state of a Linux system. Together with examples and command references, this book will offer a complete view on SELinux and how it integrates with various other components on a Linux system.

What this book covers

Chapter 1, *Fundamental SELinux Concepts*, describes SELinux covering the basic concepts of this mandatory access control system needed to understand how and why SELinux-enabled systems behave as they do.

Chapter 2, *Understanding SELinux Decisions and Logging*, focuses on the enforcement of rules within an SELinux system and how are they related to a Linux system. It explains how and what SELinux logs on the system and how SELinux can be enabled or disabled.

Chapter 3, *Managing User Logins*, teaches how to manage users and logins on a SELinux system and how to assign roles based on the user's needs. It describes the integration of SELinux with other technologies such as PAM or `sudo`, and gives us a first taste of what unconfined domains mean to an SELinux system.

Chapter 4, *Process Domains and File-level Access Controls*, describes the SELinux access control rules based on file accesses. We see how SELinux uses file contexts and process contexts and how we can interrogate the SELinux policy.

Chapter 5, *Controlling Network Communications*, introduces us to access controls on the network level. We see how the standard SELinux socket-based access controls work, and how we can leverage the Linux netfilter system to label network packets. The chapter also gives a brief introduction to the labeled IPSec and NetLabel/CIPSO support, two technologies that can transport SELinux labels across systems.

Chapter 6, *Working with SELinux Policies*, discusses how to tune SELinux policies, either through SELinux Booleans or by adding additional rules on top of the existing policy. This chapter covers how to use distribution provided tools, as well as manually maintaining additional SELinux policy modules and finish off with a set of use case-driven examples for enhancing SELinux policies.

Who this book is for

This book targets Linux system administrators who have a good understanding of how does Linux work and want to understand and work with the SELinux technology. It might also be interesting for IT architects to understand how SELinux can be positioned to enhance the security of Linux systems within their organization.

Conventions

In this book, you will find a number of styles of text that distinguish between different kinds of information. Here are some examples of these styles, and an explanation of their meaning.

Code words in text are shown as follows: "The context can be seen using the regular file listing tools such as `ls -Z` or `stat`."

A block of code is set as follows:

```
/etc/resolv.conf
/etc/mtab
/var/run/utmp
~/public_html
~/.mozilla/plugins/libflashplayer.so
```

When we wish to draw your attention to a particular part of a code block, the relevant lines or items are set in bold:

```
<VirtualHost *:80>
  DocumentRoot /var/www/sales
  ServerName sales.genfic.com
  selinuxDomainMap /etc/apache/selinux/mod_selinux.map
</VirtualHost>
```

Any command-line input or output is written as follows:

```
$ chcat -- +Customer2 index.html
```

New terms and **important words** are shown in bold. Words that you see on the screen, in menus or dialog boxes for example, appear in the text like this: "This usually is "**denied**", although some actions are explicitly marked for auditing and would result in "**granted**"".

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Tips and tricks appear like this.

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1 Fundamental SELinux Concepts

SELinux (**Security Enhanced Linux**) brings additional security measures for your Linux system to further protect the resources on the system.

In this chapter, we will cover:

- Reasons for SELinux using labels to identify resources
- The way SELinux differentiates itself from regular Linux access controls through the enforcement of security rules
- How to know these rules are provided through policy files

At the end, we will provide an overview of the differences between SELinux implementations across distributions.

Providing more security to Linux

Seasoned Linux administrators and security engineers already know that they need to have some trust in the users and processes on their system in order for the system to remain secure. Part of that is because users can attempt to exploit vulnerabilities found on the software running on the system, but a large part of it is because the secure state of the system depends on the behavior of the users. A Linux user with access to sensitive information can easily leak that out to the public, manipulate the behavior of the applications he launches, and can do many more things. The default access controls in place in a regular Linux system are discretionary, meaning it is up to the user's discretion how the access controls should behave.

The Linux **DAC** (**Discretionary Access Control**) mechanism is based on the user and/or group information of the process versus the user and/or group information of the file, directory, or other resource that is being manipulated. Consider the `/etc/shadow` file, which contains the password and account information of the local Linux accounts:

```
$ ls -l /etc/shadow
-rw------- 1 root root 1010 Apr 25 22:05 /etc/shadow
```

Without additional access control mechanisms in place, this file is readable and writable by any process that is owned by the root user, regardless of the purpose of the process on the system. The `shadow` file is a typical example of a sensitive file that we don't want to see leaked or abused in any other fashion. Yet, the moment someone has access to the file he can copy it elsewhere, for example, to their home directory or even mail it to his own computer and attempt to attack the password hashes stored within.

Another example of how Linux DAC requires trust from its users is when a database is hosted on the system. Database files themselves are (hopefully) only manageable by the runtime user of the **database management system** (**DBMS**) and the Linux root user. Properly secured systems will grant the additional users access to these files (for instance through `sudo`) by allowing these users to change their effective user ID from their personal user to the database runtime user, or even root. Those users too can analyze the database files and gain access to potentially very confidential information in the database without going through the DBMS.

But users are not the only reason of securing a system. Lots of software daemons run as the Linux root user or have significant privileges on the system. Errors within those daemons can easily lead to information leakage or might even be exploitable remote command execution vulnerabilities. Backup software, monitoring software, change management software, scheduling software, and so on, they all often run with the highest privileged account possible on a regular Linux system. Even when the administrator does not fully trust the users, their interaction with the daemons still induces a potential security risk. As such, the users still get some kind of trust in order for the system to function properly. And through that, he leaves the security of the system to the discretion of its (many) users.

Enter SELinux which provides an additional access control layer on top of the standard Linux DAC mechanism. SELinux provides a **MAC** (**Mandatory Access Control**) system that, unlike its DAC counterpart, gives the administrator full control over what is allowed on the system and what isn't. It accomplishes this by supporting a policy-driven approach on what processes are and aren't allowed to do and what not, and enforcing this policy through the Linux kernel.

The word "mandatory" here, just like the word "discretionary" before, is not chosen by accident to describe the abilities of the access control system. Both are known terms in the security research field and have been described in many other publications, including the **TCSEC** (**Trusted Computer System Evaluation Criteria**) (`http://csrc.nist.gov/publications/history/dod85.pdf`) standard (also known as the "Orange Book") by the Department of Defense, in the United States of America's in 1985. This publication has lead to the common criteria standard for computer security certification at (ISO/IEC 15408) `http://www.commoncriteriaportal.org/cc/`.

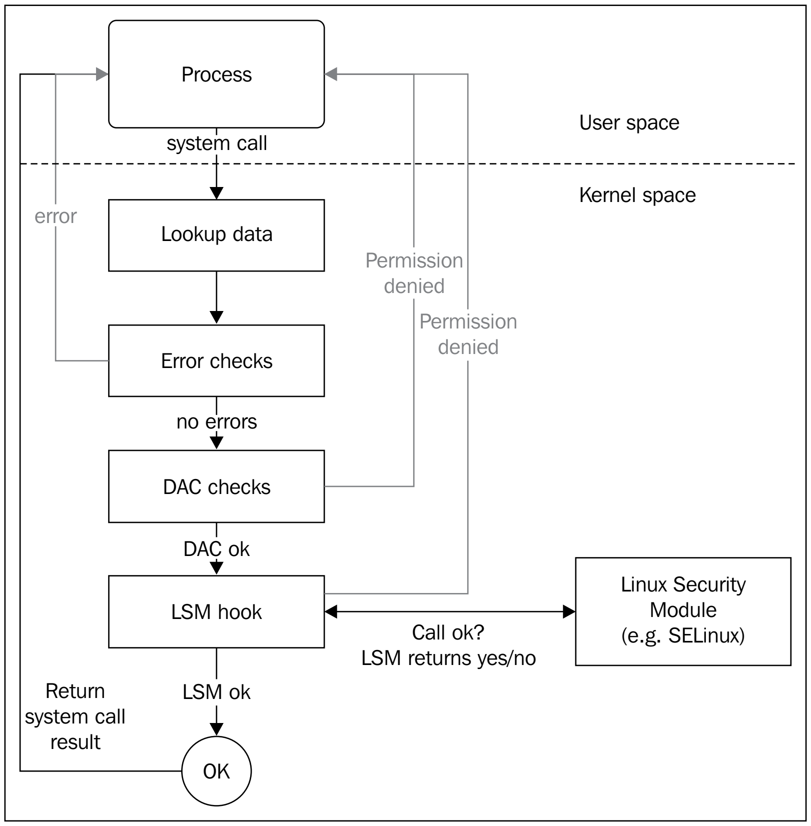
Mandatory means that access control is enforced by the operating system and defined solely by the administrator. Users and processes that do not have the permission to change the security rules cannot work around the access control; security is not left at their discretion anymore.

Linux security modules to the rescue

Consider the example of the `shadow` file again. A MAC system can be configured so that the file can only be read from and written to by particular processes. A user logged on as root cannot directly access the file or even move it around. He can't even change the attributes of the file:

```
# id
uid=0(root) gid=0(root)
# cat /etc/shadow
cat: /etc/shadow: Permission denied
# chmod a+r /etc/shadow
chmod: changing permissions of '/etc/shadow': Permission denied
```

This is enforced through rules that describe when the contents of a file can be read. With SELinux, these rules are defined in the SELinux policy and are loaded when the system boots. It is the Linux kernel itself that is responsible for enforcing the rules, and does so through **LSM** (**Linux Security Modules**).



High-level overview of how LSM is integrated in the Linux kernel

LSM has been available in the Linux kernel since version 2.6, somewhere in December 2003. It is a framework that provides "hooks" inside the Linux kernel on various locations, including the system call entry points, and allows a security implementation (for example, SELinux) to provide functions to be called when a hook is triggered. These functions can then do their magic (for instance, checking the policy and other information) and give a go / no go back to allow the call to go through or not. LSM by itself does not provide any security functionality, instead it relies on security implementations that do heavy lifting. SELinux is one of these implementations that uses LSM, but others such as TOMOYO Linux and AppArmor also use it.

SELinux versus regular DAC

SELinux does not change the Linux DAC implementation, nor can it override denials made by the Linux DAC permissions. If a regular system (without SELinux) prevents a particular access, there is nothing SELinux can do to override this decision. This is because the LSM hooks are triggered after the regular DAC permission checks have been done.

If you need to allow an additional user access to a file, you will need to look into other features of Linux such as the use of POSIX Access Control Lists through the `setfacl` and `getfacl` commands. These allow the user (not only the administrator!) to set additional access controls on files and directories, opening up the provided permission to additional users or groups.

Restricting root privileges

The regular Linux DAC allows for an all-powerful user: root. Unlike most other users on the system, a logged on root user has all the rights needed to fully manage the entire system, ranging from overriding access controls to controlling audit, changing user ID, managing the network, and many more. This is handled through a security concept called capabilities (for an overview of Linux capabilities, check out the capabilities manual page: `man capabilities`). SELinux is also able to restrict access to these capabilities in a fine-grained manner.

Due to this fine-grained authorization aspect of SELinux, even the root user can be quite confined without impacting the operations on the system. The example of accessing `/etc/shadow` previously is just one example of things that a powerful user as root still might not be able to do due to the SELinux access controls in place.

When SELinux was added to the mainstream Linux kernel, some security projects even went as far as providing public root shell access to a SELinux protected system, asking hackers and other security researchers to compromise the box. The ability to restrict root was welcomed by system administrators that sometimes need to pass on the root password or root shell to other users (for example, database administrators) that needed root privileges when their software went haywire. Thanks to SELinux, the administrator can now pass on a root shell while reassuring himself that the user only has those rights he needs, and not full system administration rights.

Enabling SELinux – not just a switch

To enable SELinux on a Linux system, it is not just a matter of enabling the SELinux LSM module within the Linux kernel. SELinux comprises not only of the kernel implementation, but also has libraries and utilities that are needed on the system. These libraries and utilities are called the SELinux userspace (`http://userspace.selinuxproject.org/trac`). Next to the userspace applications and libraries, various components on a Linux system need to be updated with SELinux-specific code, including the `init` system, core utilities, and the C library. And finally, we need a policy that tells SELinux how it should enforce access.

Because SELinux isn't just a switch that needs to be toggled, Linux distributions that support SELinux usually come with SELinux predefined and loaded: Fedora and RedHat Enterprise Linux (with its derivatives, for example, CentOS and Oracle Linux) are the most well-known examples. Other supporting distributions might not automatically have SELinux enabled but can easily support it through the installation of additional packages (which is the case for Debian and Ubuntu), and others have a well-documented approach on how to convert a system towards SELinux (for example, Gentoo and Arch Linux).

Throughout the book, examples will be shown from Gentoo and Fedora 19 (which is similar to RedHat Enterprise Linux). We opt to use these two because they have different implementation details, allowing us to show the full potential of SELinux.

Everything gets a label

In natural language, the term "context" can be used in a sentence for example, "it depends on the context". Well, with SELinux, it does depend on the context! The context of a process is what identifies the process to SELinux. SELinux has no notion of Linux process ownership and frankly doesn't care how the process is called, which process ID it has and under which account the process runs. All it wants to know is what the context is of that process. Let's look at an example context: the context of the current user (try it out yourself if you are on a SELinux enabled system):

```
$ id -Z
unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
```

The `id` command, which returns information about the current user, with the `-Z` switch (a commonly agreed switch for displaying SELinux information) shows us the context of the current user (actually the context of the id process itself when it was executing). As we can see, the context is a string representation, and looks like it has five fields (it doesn't, it has four fields. The last field just happens to contain a ':').

SELinux developers decided to use contexts (strings) instead of real process metadata as well as contexts on resources (often called labels) for its access controls. This is different to MAC systems such as AppArmor which use the path of the binary (and thus the process name) and the paths of the resources to handle permission checks. The decision to make SELinux a label-based mandatory access control was taken for various reasons, which are as follows:

- Using paths might be easier for administrators, but this doesn't allow to keep the context information close to the resource. If a file or directory is moved, remounted, or a process has a different namespace view on the files, the access controls might behave differently. With contexts, this information is retained and the system keeps controlling the resource properly.
- Contexts reveal the context of the process very well. The same binary application can be launched in different contexts depending on how it got started. The context value (for example, the one shown in the `id -Z` output earlier on) is exactly what the administrator needs. With it, he knows what the rights are of each of the running instances, but he can also deduce from it how the process might have been launched.
- Contexts also make abstraction of the object itself. We are talking now about processes and files, but this is also applicable to less tangible resources, for example: pipes (inter-process communication) or database objects. Path-based identification only works as long as you can write a path.

As an example, consider the following two sentences:

- Allow the `httpd` processes to bind to the TCP port 80
- Allow the processes labeled with "`httpd_t`" to bind to TCP ports labeled with "`http_port_t`"

In the first example, we cannot easily reuse this policy when the web server process isn't using the `httpd` binary (perhaps because it was renamed, or it isn't Apache but another web server), or when we want to have HTTP access on a different port. With the labeled approach, the binary can be called "`apache2`" or "`MyWebServer.py`"; as long as the process is labeled `httpd_t` then the policy applies. The same with the port definition, you can label port 8080 with `http_port_t` and thus allow the web servers to bind to that port as well.

The context fields

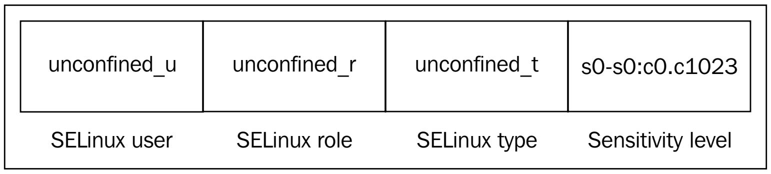
To come to a context, SELinux uses at least three, and sometimes four values. Let us look at the context of the Apache web server as an example:

```
$ ps -eZ | grep httpd
   system_u:system_r:httpd_t:s0  511  ?   00:00:00 httpd
```

As we can see, the process is assigned a context which is made up of the following fields:

- `system_u` - represents the SELinux user
- `system_r` - represents the SELinux role
- `httpd_t` - represents the SELinux type (also known as domain in case of a process)
- `s0` - represents the sensitivity

The roles can be depicted as follows:



Structure of a SELinux context, using the id -Z output as an example

When we work with SELinux, contexts are all that we need. In the majority of cases, it is the third field (called the domain or type) that is most important as the majority of SELinux policy rules (over 99 percent) consists of rules related to the interaction between two types (without mentioning roles, users, or sensitivities).

SELinux types

As mentioned, SELinux is a label-based access control mechanism. In most SELinux literature, this is fine-tuned to say that SELinux is a type enforcement mandatory access control system. This is because the type of a process (called the domain) defines the fine-grained access controls of that process with respect to itself or other types (which can be processes, files, sockets, network interfaces, and more). When some access attempts are denied, the fine-grained access controls on the type level are most likely to blame.

With type enforcement, SELinux is able to control what an application is allowed to do based on how it got executed in the first place: a web server that is launched interactively by a user will run with a different type than a web server executed through the `init` system, even though the process binary and path are the same. The web server launched from the `init` system is most likely trusted (and thus allowed to do whatever web servers are supposed to do), whereas a user launched web server is less likely to be of "normal behavior" and as such will have different privileges.

For instance, look at the following `dbus-daemon` processes:

```
# ps -eZ | grep dbus-daemon
system_u:system_r:system_dbusd_t 4531 ?        00:00:00 dbus-daemon
staff_u:staff_r:staff_dbusd_t    5266 ?        00:00:00 dbus-daemon
```

In the preceding example, one `dbus-daemon` process is the system `D-Bus daemon` running with the aptly named `system_dbusd_t` type, whereas another one is running with the `staff_dbusd_t` type assigned to it. Even though their binaries are completely the same, they both serve a different purpose on the system and as such have a different type assigned. SELinux then uses this type to govern the actions allowed by the process towards other types, including how `system_dbusd_t` can interact with `staff_dbusd_t`.

SELinux types are by convention suffixed with "`_t`", although this is not mandatory.

SELinux roles

SELinux roles - the second part of a SELinux context, enable SELinux to support role-based access controls. Although type enforcement is the most used (and known) part of SELinux, role-based access control is vital in order to keep a system secure, especially from malicious user attempts. SELinux roles are used to define which types a user processes can be in. As such, SELinux roles help define what a user can and cannot do.

On most SELinux enabled systems, the following roles are made available to be assigned to users. By convention, SELinux roles are defined with an "`_r`" suffix. Some of the roles and their descriptions are as follows:

`user_r`	This role is meant for restricted users, the `user_r` SELinux role is only allowed to have processes with types specific to end-user applications. Privileged types, for instance, those used to switch Linux user are not allowed for this role.
`staff_r`	This role is meant for non-critical operator tasks, the SELinux `staff_r` role is generally restricted to the same applications as the restricted user, but is also allowed to (a very few) more privileged types. It is the default role for operators to be in (so as to keep those users in the "least privileged" role as long as possible).
`sysadm_r`	This role is meant for system administration tasks, the `sysadm_r` SELinux role is very privileged, allowing for various system administration tasks. However, certain end user application types might not be supported (especially if those types are used for potentially vulnerable or untrusted software) to try and keep the system free from infections.

`system_r`	This role is meant for daemons and background processes, the `system_r` SELinux role is quite privileged, supporting the various daemon and system process types. However, end user application types and other administrative types are not allowed in this role.
`unconfined_r`	This role is meant for end users, the `unconfined_r` role is allowed a limited number of types, but those types are very privileged as it is meant for running any application launched by a user in a more or less unconfined manner (not restricted by SELinux rules). This role as such is only available if the system administrator wants to protect certain processes (mostly daemons) while keeping the rest of the system operations almost untouched by SELinux.

Other roles might be supported as well, such as `guest_r` and `xguest_r` (Fedora). It is wise to consult the distribution documentation for more information about the supported roles.

SELinux users

A SELinux user is different from a Linux user. Unlike the Linux user information which can change while the user is working on the system (through tools such as `sudo` or `su`), the SELinux policy will enforce that the SELinux user remains the same even when the Linux user itself has changed. Because of the immutable state of the SELinux user, specific access controls can be implemented to ensure that users cannot work around the (limited) set of permissions granted to them, even when they get privileged access. An example of such an access control is the **UBAC** (**User Based Access Control**) feature that some Linux distributions (optionally) enable, not allowing access to files of different SELinux users.

But the most important feature of SELinux users is that SELinux user definitions restrict which roles the (Linux) user is allowed to be in. Once a user is assigned a SELinux user, he cannot switch to a role that he isn't meant to be in. This is the role-based access control implementation of SELinux.

SELinux users are, by convention, defined with a "`_u`" suffix, although this is not mandatory. The SELinux users that most distributions have available are named after the role they represent, but instead of ending with "`_r`" they end with "`_u`". For instance, for the `sysadm_r` role, there is a `sysadm_u` SELinux user.

Sensitivity labels

Although not always present (some Linux distributions by default do not enable sensitivity labels), the sensitivity labels are needed for the **MLS** (**Multi-Level Security**) support within SELinux. Sensitivity labels allow classification of resources and restriction of access to those resources based on a security clearance. These labels consists of two parts: a confidentiality value (prefixed with "s") and a category value (prefixed with "c").

In many organizations and companies, documents are labeled internal, confidential, or strictly confidential. SELinux can assign processes a certain clearance level towards these resources. With MLS, SELinux can be configured to follow the Bell-LaPadula model, a security model that can be characterized by "no read up, no write down": based on a process' clearance level, that process cannot read anything with a higher confidentiality level nor write to (or communicate otherwise with) any resource with a lower confidentiality level. SELinux by itself, does not use the "internal", "confidential", and other labels. Instead, it uses numbers from `0` (lowest confidentiality) to whatever the system administrator wants to be as the highest value (this is configurable and set when the SELinux policy is built).

Categories allow for resources to be tagged with one or more categories on which access controls are also possible. The idea behind categories is to support multi-tenancy (for example, as systems hosting applications for multiple customers) within a Linux system, by having processes and resources belonging to one tenant to be assigned a particular category whereas the processes and resources of another tenant getting a different category. When a process does not have proper categories assigned, it cannot do anything with resources (or other processes) that have other categories assigned.

In that sense, categories can be seen as tags, allowing access to be granted only when the tags of the process and the target resource match.

Policies – the ultimate dictators

Enabling SELinux does not automatically start enforcement of access, if SELinux is enabled and it cannot find a policy, it will refuse to start. That is because the policy defines the behavior of the system (what should SELinux allow). Because SELinux is extremely flexible, its policy developers already started differentiating one policy implementation from another through what it calls a policy type or policy store.

A policy store contains a single policy, and only a single policy can be active on a system at any point in time. Administrators can switch a policy, although this requires the system to be rebooted, and might even require relabeling the entire system (relabeling is the act of resetting the contexts on all files and resources available on that system). The active policy on the system can be queried using `sestatus` (SELinux status) as follows:

```
# sestatus | grep "Loaded policy"
Loaded policy name:            targeted
```

In the preceding example, the currently loaded policy is named `targeted`. The policy name that SELinux will use upon its next reboot is defined in the `/etc/selinux/config` configuration file as the `SELINUXTYPE` parameter.

Most SELinux supporting distributions base their policy on the reference policy [`http://oss.tresys.com/projects/refpolicy/`], a fully functional SELinux policy set managed as a free software project. This allows distributions to ship with a functional policy set rather than having to write one themselves. Many project contributors are distribution developers, trying to push changes of their distribution to the reference policy project itself, where the changes are peer-reviewed to make sure no rules are brought into the project that might jeopardize the security of any platform.

SELinux policy store names and options

The most common SELinux policy store names are `strict`, `targeted`, `mcs`, and `mls`. None of the names assigned to policy stores are fixed though, so it is a matter of convention. Hence, it is recommended to consult the distribution documentation to verify what should be the proper name of the policy. Still, the name often gives some information about the options that are enabled on the system.

MLS status

One of the options is MLS support that can either be enabled or disabled. If disabled, then the SELinux context will not have a fourth field with sensitivity information in it, making the contexts of processes and files look as follows:

```
staff_u:sysadm_r:sysadm_t
```

To check if MLS is enabled, it is sufficient to see if the context indeed doesn't contains such a fourth field, but it can also be acquired from the `Policy MLS status` line in the output of `sestatus`:

```
# sestatus | grep MLS
Policy MLS Status:            disabled
```

Another method would be to look into the pseudo file, `/sys/fs/selinux/mls`. a value of `0` means disabled, whereas a value of `1` means enabled:

```
# cat /sys/fs/selinux/mls
0
```

Dealing with unknown permissions

Permissions (such as read, open, and lock) are defined both in the Linux kernel and in the policy itself. However, sometimes newer Linux kernels support permissions that the current policy doesn't.

A recently introduced one is `block_suspend` (to be able to block system suspension) and when that occurs, SELinux has to take the decision: as the policies are not aware of this new permission, how should it deal with the permission when triggered? SELinux can allow (assume everything is allowed to perform this action), deny (assume no one is allowed to perform this action), or reject (stop loading the policy at all and halt the system) the request. This is configured through the `deny_unknown` value.

To see the state for unknown permissions, look for the `Policy deny_unknown status` line in `sestatus`:

```
# sestatus | grep deny_unknown
Policy deny_unknown status:   denied
```

Administrators can set this for themselves in the `/etc/selinux/semanage.conf` file through the `handle-unknown` key (with allow, deny, or reject).

Supporting unconfined domains

A SELinux policy can be written as very strict, limiting applications as close as possible to their actual behavior, but it can also be written to be very liberal in what applications are allowed to do. One of the concepts available in many SELinux policies is the idea of unconfined domains. When enabled, it means that certain SELinux domains (process contexts) are allowed to do almost anything they want (of course within the boundaries of the regular Linux DAC permissions which still hold) and only a few selected are truly confined (restricted) in their actions.

Unconfined domains have been brought forward to allow SELinux to be active on desktops and servers where administrators do not want to fully restrict the entire system, but only a few of the applications running on it.

With other MAC systems, for example, AppArmor, this is inherently part of the design of the system. However, SELinux was designed to be a full mandatory access control system and thus needs to provide access control rules even for those applications that shouldn't need any. By marking these applications as unconfined, almost no additional restrictions are imposed by SELinux.

We can see if unconfined domains are enabled on the system through `seinfo`:

```
# seinfo -tunconfined_t
  unconfined_t
# seinfo -tunconfined_t
ERROR: could not find datum for type unconfined_t
```

Most distributions that enable unconfined domains call their policy `targeted`, but this is just a convention that is not always followed. Hence, it is always best to consult the policy using `seinfo` to make this sure.

User-based access control

When UBAC is enabled, certain SELinux types will be protected by additional constraints. This will ensure that one SELinux user cannot access files (or other specific resources) of another user. UBAC gives some additional control on information flow between resources, but is far from perfect. In its essence, it is made to isolate SELinux users from one another.

Many Linux distributions disable UBAC. Gentoo allows users to select if they want UBAC or not through a Gentoo `USE` flag (which is enabled by default).

Policies across distributions

As mentioned, policy store names are not standardized. What is called `targeted` in Fedora is not `targeted` in Gentoo. Of the options mentioned previously, the following table shows us how some of the policy stores are implemented across these two distributions:

Distribution	**Policy store name**	**MLS?**	**deny_ unknown**	**Unconfined domains?**	**UBAC?**
Gentoo	`strict`	No	`denied`	No	Yes (configurable)
Fedora 19	`minimum`	Yes (only `s0`)	`allowed`	Yes, but limited	No

Distribution	**Policy store name**	**MLS?**	**deny_ unknown**	**Unconfined domains?**	**UBAC?**
Gentoo	`targeted`	No	`denied`	Yes	Yes (configurable)
Fedora 19	`targeted`	Yes (only `s0`)	`allowed`	Yes	No
Gentoo	`mcs`	Yes (only `s0`)	`denied`	Yes (configurable)	Yes (configurable)
Gentoo	`mls`	Yes	`denied`	Yes (configurable)	Yes (configurable)
Fedora 19	`mls`	Yes	`allowed`	Yes	No

Other distributions might even have different names and implementation details.

Yet, besides the naming differences, many of the underlying settings can be changed by the administrator. For instance, even though Fedora does not have a `strict` policy, it does have a documented approach on running Fedora without unconfined domains. It would be wrong to state that Fedora as such does not support fully confined systems.

MCS versus MLS

In the feature table, we notice that for MLS, some policies only support a single sensitivity (`s0`). When this is the case, we call the policy an **MCS** (**Multi Category Security**) policy. The MCS policy enables sensitivity labels, but only with a single sensitivity while providing support for multiple categories (and hence the name).

With the continuous improvement made in supporting Linux in **PaaS** (**Platform as a Service**) environments, implementing proper multitenancy requires proper security isolation as a vital part of its offering.

Policy binaries

While checking the output of `sestatus`, we see that there is also a notation of policy versions:

```
# sestatus | grep version
Max kernel policy version:      28
```

As the output states, `28` is the highest policy version the kernel supports. The policy version refers to the supported features inside the SELinux policy: every time a new feature is added to SELinux, the version number is increased. The policy file itself (which contains all the SELinux rules loaded at boot time by the system) can be found in `/etc/selinux/targeted/policy` (where `targeted` refers to the policy store used, so if the system uses a policy store named `strict`, then the path would be `/etc/selinux/strict/policy`).

If multiple policy files exist, we can use the output of `seinfo` to find out which policy file is used:

```
# seinfo
Statistics for policy file: /etc/selinux/targeted/policy/policy.27
Policy Version & Type: v.27 (binary, mls)
...
```

The next table gives the current list of policy feature enhancements and the Linux kernel version in which that feature is introduced. Many of the features are only of concern to the policy developers, but knowing the evolution of the features gives us a good idea on the evolution of SELinux.

Version	Linux kernel	Description
12		It is the "Old API" for SELinux, now deprecated
15	2.6.0	It is the "New API" for SELinux
16	2.6.5	It provides conditional policy extensions
17	2.6.6	It provides IPv6 support
18	2.6.8	It adds fine-grained netlink socket support
19	2.6.12	It provides enhanced multi-level security
20	2.6.14	It doesn't access vector table size optimizations", the version (20) improved the access vector table size (it is a performance optimization).
21	2.6.19	It provides object classes in range transitions
22	2.6.25	It provides policy capabilities (features)
23	2.6.26	It provides per-domain permissive mode
24	2.6.28	It provides explicit hierarchy (type bounds)
25	2.6.39	It provides filename based transition support
26	3.0	It provides role transition support for non-process classes
27	3.5	It supports flexible inheritance of user and role for newly created objects
28	3.5	It supports flexible inheritance of type for newly created objects

By default, when a SELinux policy is built, the highest supported version as defined by the Linux kernel and libsepol (the library responsible for building the SELinux policy binary) is used. Administrators can force a version to be lower using the policy-version parameter in `/etc/selinux/semanage.conf`.

SELinux policy modules

Initially, SELinux used a single, monolithic policy approach: all possible access control rules are maintained in a single, binary policy file that the SELinux utilities then load. It quickly became clear that this is not manageable in long term, and thus the idea of developing a modular policy approach was born.

Within the modular approach, policy developers can write isolated policy sets for a particular application (or set of applications), roles, and so on. These policies then get built and distributed in their own policy modules. Platforms that need access controls for that particular application load the SELinux policy module that defines the access rules.

On some Linux distributions, these SELinux policy modules are stored inside `/usr/share/selinux`, usually within a subdirectory named after the policy store (such as "targeted" or "strict"). The policy modules that are currently loaded are always available in `/etc/selinux/targeted/modules/active` and its `modules` subdirectory.

Of all the `*.pp` files in these locations, the `base.pp` one is special. This policy module file contains core policy definitions. The remaining policy module files are "isolated" policy modules, providing the necessary rules for the system to handle applications and roles related to the module itself. For instance, the `screen.pp` module contains the SELinux policy rules for the GNU `screen` (and also `tmux`) application.

Once those files are placed on the system, the distribution package manager usually calls the `semodule` command to load the policy modules. This command then combines the files into a single policy file (for example, `policy.28`) and loads it in memory.

On Fedora, the SELinux policies are provided by the `selinux-policy-targeted` (or `-minimum` or `-mls`) package. On Gentoo, they are provided by the various `sec-policy/selinux-*` packages (Gentoo uses separate packages for each module, reducing the amount of SELinux policies that are loaded on an average system).

Summary

In this chapter, we saw that SELinux offers a more fine-grained access control mechanism on top of the Linux access control. SELinux uses labels to identify its resources and processes, based on ownership (user), role, type, and even the security sensitivity and categorization of the resource.

Linux distributions implement SELinux policies which might be a bit different from each other based on supporting features such as sensitivity labels, default behavior for unknown permissions, support for confinement levels, or specific constraints put in place, for example, UBAC. However, most of the policy rules themselves are similar.

Switching between SELinux enforcement modes and understanding the log events that SELinux creates when it prohibits a certain access, is the subject of our next chapter. In it, we will also cover how to approach the often-heard requirement of disabling SELinux and why this is the wrong solution to implement.

2
Understanding SELinux Decisions and Logging

Once SELinux is enabled on a system, it starts its access control functionality as described in the previous chapter. This however might have some unwanted side effects, so in this chapter, we will:

- Switch between SELinux in full enforcement mode (host-based intrusion prevention) versus its permissive, logging-only mode (host-based intrusion detection)
- Use various methods to toggle the SELinux state (enabled or disabled, permissive or enforcing)
- Disable SELinux protections for a single domain rather than the entire system
- Learn to interpret the SELinux log events that describe to us what activities that SELinux has prevented

We finish with an overview of common methods for analyzing these logging events in day-to-day operations.

Disabling SELinux

Perhaps a weird chapter to begin with, but disabling SELinux is a commonly requested activity. Some vendors do not support their application to be running on a platform that has SELinux enabled. Luckily, this number is reducing.

SELinux supports three major states that it can be in: `disabled`, `permissive`, and `enforcing`. These states are by default set in the `/etc/selinux/config` file, through the `SELINUX` variable as follows:

```
$ grep ^SELINUX= /etc/selinux/config
SELINUX=enforcing
```

When the system `init` triggers loading the SELinux policy, the code checks the state that the administrator has configured. The states are described as follows:

- If the state is `disabled`, then the SELinux code disables further support, making the system boot without activating SELinux.
- If the state is `permissive`, then SELinux is active but will not enforce its policy on the system. Instead, any violations against the policy will be reported but remain allowed.
- If the state is `enforcing`, then SELinux is active and will enforce its policy on the system. Violations are reported and also denied.

We can use the `getenforce` or `sestatus` command to get information about the current state of SELinux as follows:

```
# sestatus | grep mode
Current mode:          enforcing
```

Try to switch between the `enforcing` and `permissive` mode by modifying the configuration file. Reboot the system and validate through `sestatus`, that the SELinux state has indeed been changed. If we disable SELinux completely though, we might need to fix wrong (or absent) labels later. This is the reason why we switch between `enforcing` and `permissive` for now.

In many situations, administrators often want to disable SELinux when it starts preventing certain tasks. Sadly, this is similar to removing train crossing gates because it prevents them from reaching their destination in time. It might help them to get there faster next time, but remember that the gates are there to protect us.

SELinux on, SELinux off

We can toggle the SELinux state through the `/etc/selinux/config` file and reboot the system to have the changes being reflected. But this is not the only way.

Switching to permissive (or enforcing) temporarily

On most SELinux enabled systems, we can call the `setenforce` command to switch the system between `permissive` (`0`) and `enforcing` (`1`) mode. This takes effect immediately, allowing us to easily identify if SELinux is preventing access or not.

Try it out. Switch to the `permissive` mode and validate (again using `sestatus`, that the SELinux state has indeed been changed immediately as follows:

```
# setenforce 0
```

The effect of `setenforce` is the same as writing the value into the `/sys/fs/selinux/enforce` (or `/selinux/enforce`) pseudo file:

```
# echo 0 > /sys/fs/selinux/enforce
```

The ability to switch between the `permissive` and `enforcing` mode can be of interest for policy developers or system administrators who are modifying the system to use SELinux properly. This SELinux feature is called the `SELinux development` mode and is set through a kernel configuration parameter (`CONFIG_SECURITY_SELINUX_DEVELOP`). Most SELinux supporting distributions leave this feature on, but on production systems it might be of interest to disable the feature (considering that this can allow malicious users who gain enough privileges to disable SELinux altogether).

Disabling this feature usually requires rebuilding the Linux kernel, but SELinux policy developers have also thought of a different way to disallow users to toggle the SELinux state. The privileges that the users need to switch to the `permissive` mode have become 'conditional', and system administrators can easily toggle this policy to disable switching back to the `permissive` mode. Once toggled, the setting cannot be reverted if the `-P` option is provided. Without the option, the setting is only valid until the system is rebooted:

```
# setsebool -P secure_mode_policyload on
```

Switching to or from the disabled state however is not supported: once SELinux is active (in either the `permissive` or `enforcing` mode) and its policy is loaded, only then a reboot can effectively disable SELinux again.

Using kernel boot parameters

Using the `setenforce` command makes sense when we want to switch to the `permissive` or `enforcing` mode at a point in time when we have interactive access to the system. But what when we need this upon system boot?

The answer is kernel boot parameters. We can boot a Linux system with one or two parameters that take precedence towards the `/etc/selinux/config` settings as follows:

- `selinux=0` informs the system to disable SELinux completely, and is similar to `SELINUX=disabled` in the `config` file. When set, the other parameter (`enforcing`) is not consulted.

- `enforcing=0` informs the system to run SELinux in the `permissive` mode, and is similar to the `SELINUX=permissive` setting in the `config` file.
- `enforcing=1` informs the system to run SELinux in the `enforcing` mode, and is similar to the `SELINUX=enforcing` setting in the `config` file.

For instance, the following GRUB part will have SELinux enabled and run in the `permissive` mode, regardless of the `/etc/selinux/config` settings:

```
title Linux with SELinux permissive
root (hd0,0)
kernel /kernel root=/dev/md3 selinux=1 enforcing=0
initrd /initramfs
```

Support for the `selinux=` boot parameters is also enabled through a kernel configuration parameter, `CONFIG_SECURITY_SELINUX_BOOTPARAM`. The `enforcing=` boot parameter is supported through the `CONFIG_SECURITY_SELINUX_DEVELOP` configuration parameter discussed previously.

While using SELinux in production, it might be wise to either disable the options or properly protect the boot menu, for instance, by password protecting the menu and regularly verifying the integrity of the boot menu files.

Disabling SELinux protections for a single service

Since policy version 23 (which came with Linux 2.6.26), SELinux also supports a more granular approach to switch between `permissive` and `enforcing`: the use of permissive domains. As mentioned before, domains is the term which SELinux uses for types (labels) assigned to processes. With permissive domains, we can mark one particular domain as being `permissive` (and as such not enforcing the SELinux rules) even though the rest of the system is running in the `enforcing` mode.

Let's say we run a **DLNA** (**Digital Living Network Alliance**) server to serve our holiday pictures to other media devices at our place, or to present the latest company internal videos to a distributed set of monitors throughout the campus. Somehow it fails to show the media recently made available and we find out it is SELinux that is preventing it. Even though it is seriously recommended to fine-tune the policy, we might be pushed in fixing (read: working around) the problem first and implementing the fix later properly. Instead of fully disabling SELinux controls, we can put the domain in which the DLNA server runs (most likely `minidlna_t`) in the `permissive` mode:

```
# semanage permissive -a minidlna_t
```

With the same `semanage` command, we can list the currently running permissive domains (on Fedora, some domains are, by default, marked as permissive):

```
# semanage permissive -l

    Builtin Permissive Types

    openvswitch_t
    systemd_localed_t
    virt_qemu_ga_t
    ...

    Customized Permissive Types

    minidlna_t
```

When a domain is marked as permissive, the application should behave as if SELinux is not enabled on the system, making it easier for us to find out if SELinux really is the cause of a permission issue. Note though that other domains that interact with a permissive domain are themselves still governed through SELinux.

If an application requires SELinux to be disabled, it makes much more sense to mark its domain as permissive rather than disabling SELinux protections for the entire system. Look for an example service and find out what domain it runs in. Then mark this domain as permissive (and then back).

Use `ps -eZ` to see the SELinux contexts of processes.

Applications that "speak" SELinux

Most applications themselves do not have knowledge that they are running on an SELinux enabled system. When that is the case, the `permissive` mode truly means that the application behaves as if SELinux was not enabled to begin with. However, some applications actively call SELinux code. These applications can be called 'SELinux aware', because they change their behavior if SELinux is enabled, possibly regardless of SELinux being in the `permissive` or the `enforcing` mode.

When those applications run in the `permissive` mode, they can behave (quite) differently than when SELinux is completely disabled. Such applications change their behavior when SELinux is enabled, for instance to query the policy or to check for the context that it should run in. Examples of such applications are SSH login, some cron daemons as well as the core Linux utilities (which provide `ls` and `id`). As a result, they might show permission failures or different behavior based on the SELinux policy even though SELinux is not in the `enforcing` mode.

We can find out if an application is SELinux aware by checking if the application is dynamically linked with the `libselinux` library. This can be done with `scanelf` or `ldd` as follows:

```
# scanelf -n /bin/ls
 TYPE   NEEDED FILE
ET_DYN libselinux.so.1,librt.so.1,libc.so.6 /bin/ls
# ldd /bin/ls | grep selinux
        libselinux.so.1 => /lib64/libselinux.so.1 (0x00007f77702dc000)
```

Knowing if an application is SELinux aware or not can help in troubleshooting failures.

As an exercise, try to find all binaries on a system that are linked with the `libselinux` library.

SELinux logging and auditing

When SELinux is enabled, it will log (almost) every permission check that was denied. When Linux auditing is enabled, these denials are logged by the audit daemon. If not, then the regular system logger will get the denials and store them in the system logs.

Such denial messages are described with the type **AVC** (**Access Vector Cache**) as we can see from the following example:

```
type=AVC msg=audit(1369306885.125:4702304): avc:  denied  { append }
for  pid=1787 comm=72733A6D61696E20513A526567 name="oracle_audit.log"
dev=dm-18 ino=65 scontext=system_u:system_r:syslogd_t:s0 tcontext=syst
em_u:object_r:usr_t:s0 tclass=file
```

The `AVC` is part of the SELinux security subsystem in the Linux kernel that is responsible for checking and enforcing the SELinux rules. Any permission that needs to be checked is represented as an "access vector" and the cache is then consulted to see if that particular permission has been checked before or not. If it is, then the decision is taken from the cache, otherwise the policy itself is consulted. This inner working of SELinux is less relevant to most administrators, but at least now we know where the term `AVC` comes from.

Configuring SELinux' log destination

SELinux will try to use the audit subsystem when available, and will fall back to the regular system logging when it isn't.

For the Linux audit, we usually do not need to configure anything as SELinux AVC denials are logged by default. The denials will be shown in the audit logfile (`/var/log/audit/audit.log`), usually together with the system call that triggered it:

```
type=AVC msg=audit(1370115017.883:1091): avc:  denied  { write }
  for  pid=20061 comm="mount" name="utab" dev="tmpfs"
  ino=1494 scontext=user_u:user_r:user_t:s0
  tcontext=system_u:object_r:mount_var_run_t:s0 tclass=file

type=SYSCALL msg=audit(1370115017.883:1091): arch=c000003e
  syscall=2 success=no exit=-13 a0=7f0e75149879 a1=42 a2=1a4
  a3=7fff2ad134a0 items=0 ppid=19903 pid=20061 auid=1001
  uid=1001 gid=100 euid=0 suid=0 fsuid=0 egid=100 sgid=100
  fsgid=100 tty=pts2 ses=8 comm="mount" exe="/usr/bin/mount"
  subj=user_u:user_r:user_t:s0 key=(null)
```

When auditing is not enabled, we can configure the system logger to direct SELinux AVC messages into its own logfile. For instance, with the `syslog-ng` system logger, the possible configuration parameters could be as follows:

```
source kernsrc { file("/proc/kmsg"); };
destination avc { file("/var/log/avc.log"); };
filter f_avc { message(".*avc: .*"); };
log { source(kernsrc);  filter(f_avc);  destination(avc); };
```

Reading SELinux denials

The one thing every one of us will have to do many times with SELinux systems is to read and interpret SELinux denial information. When SELinux prohibits an access and there is no `dontaudit` rule in place to hide it, SELinux will log it. If nothing is logged, it was probably not SELinux that was the culprit of the failure. Remember, SELinux comes after Linux DAC checks, so if a regular permission doesn't allow a certain activity, then SELinux is never consulted.

SELinux denial messages are logged the moment SELinux prevents some access from occurring. When SELinux is in the `enforcing` mode, the application usually returns a `Permission denied` error, although sometimes it might be a bit more obscure, for example, with the following attempt of an unprivileged user using `su` to switch to root:

```
$ su -
Password: (correct password given)
su: incorrect password
```

```
Most of the time though, the error is a permission error:
$ ls /proc/1
ls: cannot open directory /proc/1: Permission denied
# ls -ldZ /proc/1
dr-xr-xr-x. root root system_u:system_r:init_t:s0      /proc/1
```

So, what does a denial message look like? The next one shows a denial from the audit subsystem. We can consult the SELinux messages in the audit or system logs. When the Linux audit subsystem is enabled, we can also use the `ausearch` command as follows:

```
# ausearch -m avc -ts recent
----
time->Fri May 31 20:05:15 2013
type=AVC msg=audit(1370023515.951:2368): avc:  denied  { search }
  for  pid=5005 comm="dnsmasq" name="net" dev="proc" ino=5403
  scontext=system_u:system_r:dnsmasq_t
  tcontext=system_u:object_r:sysctl_net_t tclass=dir
```

Let's break up this denial into its individual components. The following table gives more information about each part of the preceding denials. As an administrator, knowing how to read denials is extremely important, so take the necessary time for this, and also try it out on a SELinux system.

Field name	Description	Example
(SELinux action)	This is the action that SELinux took (or would take if run in the `enforcing` mode). This usually `denied`, although some actions are explicitly marked for auditing and would result in `granted`.	`denied`
(permissions)	These are the permissions that were checked (action performed by the process). This usually is a single permission, although it can sometimes be a set of permissions (for example, `read write`).	`{ search }`
Process ID	This is the ID of the process that was performing the action.	`for pid=5005`
Process name	The process name (command). It doesn't display any arguments to the command though.	`comm="dnsmasq"`
Target name	It is the name of the target (resource) that the process is performing an action on. If the target is a file, this usually is the filename or directory.	`name="net"`

Field name	Description	Example
Target device	It is the device on which the target resource resides. Together with the next field (inode number) this allows us to uniquely identify the resource on a system.	`dev="proc"`
Target file inode number	It is the inode number of the target file or directory. Together with the device, this allows us to find the file on the filesystem.	`ino=5403`
Source context	It is the context in which the process resides (the domain of the process).	`scontext=system_u:system_r:dnsmasq_t`
Target context	It is the context of the target resource.	`tcontext=system_u:object_r:sysctl_net_t`
Resource class	It is the class of the target resource, for example, a directory, file, socket, node, pipe, file descriptor, file system, capability, and so on.	`tclass=dir`

The previous denial can be read as follows: "SELinux has denied the search operation of the `dnsmasq` process (with PID 5005) against the "`net`" directory (with inode `5403`) within the proc device. The `dnsmasq` process runs with the `system_u:system_r:dnsmasq_t` label and the "`net`" directory has the `system_u:object_r:sysctl_net_t` label."

Some denials have different fields, which are as follows:

```
avc: denied { send_msg } for msgtype=method_call
  interface=org.gnome.DisplayManager.Settings
  member=GetValue dest=org.gnome.DisplayManager
  spid=3705 tpid=2864
  scontext=unconfined_u:unconfined_r:unconfined_t:s0-s0:c0.c1023
  tcontext=system_u:system_r:xdm_t:s0-s0:c0.c1023 tclass=dbus
```

Although it has a few different fields, it is still readable and can be read as follows: "SELinux has denied the process with PID `3705` to invoke a `DBus` remote method call (the "`GetValue`"method of the "`org.gnome.DisplayManager.Settings`" interface) against the "`org.gnome.DisplayManager`" implementation offered by process with PID `2864`. The source process runs with the "`unconfined_u:unconfined_r:unconfined_t:s0-s0.c0.c1023`" label and the target process with the "`system_u:system_r:xdm_t:s0-s0:c0.c1023`" label."

Depending on the action and the target class, SELinux uses different fields to give all the information we need to troubleshoot a problem. Try interpreting the following denial:

```
avc: denied  { name_bind } for  pid=23849
  comm="postgres" src=6030
  scontext=system_u:system_r:postgresql_t
  tcontext=system_u:object_r:unreserved_port_t
  tclass=tcp_socket
```

The preceding denial came up because the `PostgreSQL` database was configured to listen on a non-default port (`6030` instead of the default `5432`).

Identifying the problem is a matter of understanding how the operations work, and properly reading the denials. In the preceding `DBus` denial, it is difficult to troubleshoot if we do not know how `DBus` works (or how it uses message types, members, and interfaces in its underlying protocols). For troubleshooting, the denial logs give us enough to get us started. It gives a clear idea what was denied.

It is wrong to immediately consider allowing the specific denial (by adding an allow rule to the SELinux policy as described in *Chapter 6*, *Enhancing SELinux policies*) as other options exist, which are as follows:

- Giving the right label on the target resource (usually the case when the target is a non-default port, non-default location, and so on)
- Switching booleans (flags that manipulate the SELinux policy) to allow additional privileges
- Giving the right label on the source process (often the case when the source process is not installed by the distribution package manager)
- Using the application as intended instead of through other means (as SELinux only allows expected behavior), such as starting a daemon through a service (`init` script or `systemd` unit) instead of through a command line

Uncovering more denials

Policy writers can tell SELinux not to log some denials because they are expected; SELinux is able to control very fine-grained access and some applications (many, to be honest) tend to do some checks or get some permissions they never need in reality. Constantly seeing denials for those checks would clutter the logs and might trick us into allowing those calls (even when they do not influence the application at all or might even become a security hazard if allowed). Such statements are called `dontaudit` statements.

With seinfo we can see how many SELinux rules (such as allow and dontaudit) are currently loaded on the system. The semodule application can be used to rebuild the current policy without dontaudit statements, which is very useful if an application is not working properly and we think SELinux is the reason, but we don't see any denials:

```
# seinfo | grep -E '(dontaudit|allow)'
   Allow:            34631    Neverallow:           0
   Auditallow:           1    Dontaudit:         5414
   Type_member:          6    Role allow:           7
# semodule --disable_dontaudit --build
```

The semodule command can also be shortened to semodule -DB.

Now that we know where to find AVC events, let us disable the dontaudit rules and look at the logs. Notice how many denials are shown. In order not to clutter the logs, fall back to the previous state by again enabling the dontaudit rules: invoke semodule --build without the --disable_dontaudit argument.

Getting help with denials

On some distributions, additional supporting tools are available that help us identify the cause of a denial. These tools have some knowledge of the common mistakes (for instance, setting the right context on application files in order for the web server to be able to read them). Other distributions require us to use our experience to make proper decisions, supporting us through the distribution mailing lists, bug tracking sites, and other cooperation locations, for example, IRC.

setroubleshoot to the rescue

In Fedora and RedHat Enterprise Linux, additional tools are present that help us troubleshoot denials. The tools work together to catch a denial, look for a plausible solution and inform the administrator about the denial and its suggested resolutions. When used on a graphical workstation, denials can even pop up and ask the administrator to review the denials immediately. On the servers without a graphical environment, administrators can see the information in the system logs or can even configure the system to send out SELinux denial messages via e-mail.

Under the hood, it is the audit daemon that triggers its audit event dispatcher application (`audispd`). This application is built to support plugins, something the SELinux folks gratefully implemented: an application that will act as a plugin for `audispd` called `sedispatch`. The `sedispatch` application checks whether the audit event is a SELinux denial and, if so, forwards the event to `DBus` (a system bus implementation popular on Linux systems). `DBus` forwards the event then to the `setroubleshootd` application (or launches the application if it isn't running yet) which analyzes the denial and prepares feedback for the administrator. Then, when running on a workstation, `seapplet` is triggered to show a pop up on the administrator workstation. The analyzed feedback is stored on the filesystem and a message is displayed in the system logs.

Try triggering a SELinux denial (for instance, by configuring a daemon to bind to a non-default port and restarting the daemon) and see how the event is brought up.

In the system log, a message comes up, for example as follows:

```
Jun 14 12:05:43 localhost setroubleshoot: SELinux is preventing
  /usr/sbin/httpd from 'getattr' accesses on the directory
  /var/www/html/infocenter. For complete SELinux messages, run
  sealert -l 26f2a1c3-0134-458e-a69b-4ef223e20009
```

We can then see the complete explanation through the `sealert` command as mentioned in the log. The `sealert` application is a command-line application that parses the information stored by the `setroubleshoot` daemon (in `/var/lib/setroubleshoot`). Try the command and read through the output it provides: the output is lengthy, but worth reading.

The `sealert` application will provide us with a set of options to resolve the denial. In case of the Apache-related denial shown earlier, `sealert` would give us four options, each of them with a certain confidence score.

As we can see from this example, the `setroubleshoot` application has a number of plugins to analyze denials. These plugins look at a denial to check if they match a particular, well known use case (for example, when Booleans need to be changed, or when a target context is wrong) and give feedback to `setroubleshoot` about how "certain" the plugin is so that this denial can be resolved through its recommended method.

Using audit2why

If `setroubleshoot` and `sealert` are not available on the Linux distribution, we can still get some information about a denial. Although it isn't as extensible as the plugins offered by `setroubleshoot`, the `audit2why` utility (which is short for `audit2allow -w`) does provide some feedback on a denial. Sadly, it isn't always right in its deduction. Try it out against the same denial for which we used `sealert`:

```
# ausearch -m avc -ts today | audit2why
type=AVC msg=audit(1371204434.608:475): avc:  denied { getattr }
for  pid=1376 comm="httpd" path="/var/www/html/infocenter" dev="dm-1"
ino=1183070 scontext=system_u:system_r:httpd_t:s0 tcontext=unconfined_u:o
bject_r:user_home_t:s0 tclass=dir


Was caused by:
The boolean httpd_read_user_content was set incorrectly.
Description:
Determine whether httpd can read generic user home content files.


Allow access by executing:
# setsebool -P httpd_read_user_content 1
```

The `audit2why` utility here didn't consider that the context of the target location was wrong, and suggest to enable the web server permission to read user content.

Using common sense

Common sense is not easy to document, but reading a denial often leads to the right solution when we have some experience with file labels (and what they are used for). If we would look at the previous denial example (the one about `/var/www/html/infocenter`), then seeing that its context is `user_home_t` should ring a bell. `user_home_t` is used for end user home files, not system files inside `/var`.

One way to make sure that the context of the target resource is correct is to check it with `matchpathcon`. This utility returns the context as it should be according to the SELinux policy:

```
# matchpathcon /var/www/html/infocenter
/var/www/html/infocenter        system_u:object_r:httpd_sys_content_t:s0
```

Performing this on denials related to files and directories might help in finding a proper solution quickly.

Furthermore, many domains have specific manual pages that inform the reader what types are commonly used for each domain, as well as how to deal with the domain in more detail (for example, the available Booleans, common mistakes made, and so on.)

```
$ man ftpd_selinux
```

Summary

We saw how to enable and disable SELinux both on a complete system level as well as a per service level using various methods: kernel boot options, SELinux configuration file, or plain commands. One of the commands is the use of `semanage permissive`, which can disable SELinux protections for a single service.

Next, we saw where SELinux log its events and how to interpret them, which is one of the most important capabilities of an administrator when dealing with SELinux. To assist us with this interpretation, there are tools such as `setroubleshoot`, `sealert`, and `audit2why`.

In the next chapter, we will look at the first administrative task on SELinux systems: managing user accounts and their associated SELinux roles and security clearances towards the resources on the system.

3
Managing User Logins

When we log in to an SELinux enabled system, we are assigned with a default context to work in. This context contains a SELinux user part, a SELinux role, a domain, and optionally a sensitivity range.

In this chapter, we will:

- Define users that have sufficient rights to do their jobs, ranging from unprivileged users to fully privileged users, running almost without SELinux protection
- Create and assign categories and sensitivities
- Assign roles to users and use various tools to switch roles

We end the chapter by learning how SELinux integrates with the Linux authentication process.

So, who am I?

Once logged in to a system, our user will run inside a certain context. This user context defines the rights and privileges that we, as a user, have on the system. The command to obtain current user information, `id`, also supports SELinux context information. Try it out, and use the `-Z` switch as follows:

```
$ id -Z
unconfined_u:unconfined_r:unconfined_t
```

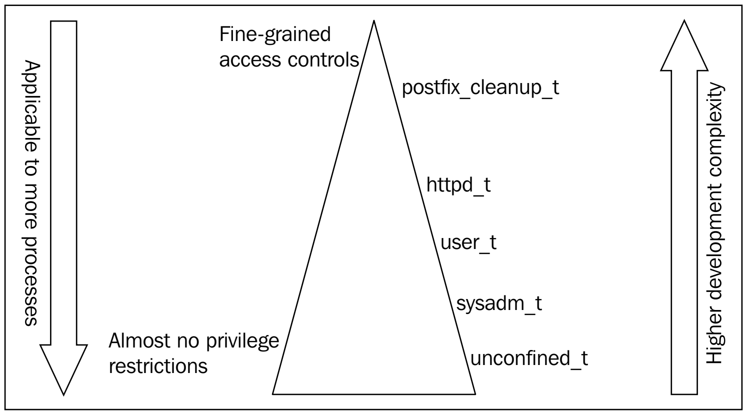
On SELinux systems with a targeted policy type, chances are very high that all users are logged in as `unconfined_u` (the first part of the context). On more restricted systems, the user can be `user_u` (regular restricted users), `staff_u` (operators), `sysadm_u` (system administrators), or any other of the SELinux user types.

The SELinux user defines the roles that the user can switch to, which themselves define the domains that the user (or his processes) can run in. By default, a fixed number of SELinux users are available on the system, but administrators can create different SELinux users. It is also the administrator's task to assign Linux logins to SELinux users.

The rationale behind unconfined

SELinux is able to provide full system confinement: each and every application runs in its own restricted environment from where it cannot break out of. But that requires fine-grained policies that are equally fast developed as the new versions of all the applications that they confine.

The following diagram shows this relation between the policies, the domain applicability towards multiple processes and the development effort. As an example, `postfix_cleanup_t` is shown as a very fine-grained policy domain (which is used for the cleanup process involved in the Postfix mail infrastructure) whereas the `unconfined_t` domain is shown as the example for a very broad, almost unlimited access domain:


Applicable to more processes
Fine-grained access controls
postfix_cleanup_t
httpd_t
user_t
sysadm_t
unconfined_t
Almost no privilege restrictions
Higher development complexity

Relationship between domain development complexity and the associated SELinux access controls

Most applications do not have a dedicated policy (although most security-sensitive or popular ones do) and policies do not adapt as fast as the applications themselves. For many servers though, this fine-grained mandatory access is not necessary. All that is needed is to confine the services that are exposed to the network. To support this, SELinux policy developers created the "unconfined" concept, that is, although still governed by SELinux, the domain or user is not really restricted.

Not only are those domains very powerful with respect to privilege, the idea is also that these domains do not need to switch to other domains (unless when they need to switch to a confined domain, of course) and that they are not restricted by constraints that are imposed on confined domains (including MLS).

An important asset in this unconfined story is the `unconfined_t` domain for the `unconfined_u` SELinux user (with the `unconfined_r` SELinux role). This is exactly the context that we get when logged in to a default Fedora installation or a Gentoo installation that uses the `targeted` policy store (or `mcs/mls` with `USE="unconfined"`).

Next to the user domains, we also have unconfined process domains for daemons and other applications. Some of these run in the `unconfined_t` domain as well, but most of them run in their own domain even though they are still unconfined. The `seinfo` tool can tell us which domains are unconfined by asking for those domains that have the `selinux_unconfined_type` attribute set as follows:

```
# seinfo -aselinux_unconfined_type -x
```

Defining a domain is unconfined or cannot be toggled by administrators, as this is a pure SELinux policy matter.

SELinux users and roles

Within SELinux systems, the moment a user logs in, the login system checks to which SELinux user his login is mapped. Then, when a SELinux user is found, the system looks up the role and domain that the user should be in.

We all are one SELinux user

When we logged in to the system and checked our context using `id -Z`, we noticed that the presented context is the same regardless of the username through which we logged in to the system. SELinux does not care which Linux user we are, as long as it knows which context we are in.

When our `login` process is triggered, a local definition file will be checked to see which SELinux user is mapped to our login. Let us take a look at the existing login mappings using `semanage login -l` as follows:

```
# semanage login -l
Login Name          SELinux User        MLS/MCS Range     Service

__default__         unconfined_u         s0-s0:c0.c1023       *
root                unconfined_u         s0-s0:c0.c1023       *
system_u            system_u             s0-s0:c0.c1023       *
```

In the output, two login names are special for SELinux: the `__default__` and `system_u` definitions:

- `__default__`: It is a catchall rule. If none of the other rules match, then the users are mapped to the SELinux user identified in the second column (SELinux user). On targeted systems, all users are mapped to the `unconfined_u` SELinux user because the policies within targeted systems are meant to confine daemons rather than users. On policy stores that do not support unconfined domains, administrators usually map regular logins to restricted SELinux users while administrative logins are mapped to the `staff_u` or `sysadm_u` SELinux users.
- The `system_u` line is meant for system processes (non-interactively logged in Linux accounts). It should never be assigned to end user logins.

The SELinux user is not the only information of a SELinux mapping. In case of an MLS-enabled system, the mapping also contains information about the sensitivity range in which the user is allowed to work (MLS/MCS Range). This way, two users might both be mapped to the `user_u` restricted SELinux user, but one might only be allowed to access the low sensitivity (`s0`) whereas another user might also have access to higher sensitivities (for example, `s1`). Or, in case of MCS, one user might be mapped to a different set of categories different from another user.

As an exercise, let us create a new Linux user called `myuser` and make sure that, when this user is logged in, the context is that of the unprivileged SELinux `user_u` user. We accomplish this using the `semanage login` tool as follows:

```
# semanage login -a -s user_u myuser
```

The `-s` parameter is used to map a login to a SELinux user, whereas sensitivity (and categories) can be handled with the `-r` parameter. In the next example, we modify the newly created mapping by limiting the user to the sensitivity range `s0-s2` and categories `c0` to `c4`:

```
# semanage login -m -r "s0-s2:c0.c4" myuser
```

The changes take effect when a new login occurs so we should force a logout for these users. The following command locks our `myuser` account, kills all the processes of that user, and unlocks the user again as follows:

```
# passwd -l myuser
Locking password for user myuser.
passwd: Success
# pkill -KILL -u myuser
# passwd -u myuser
Unlocking password for user myuser.
passwd: Success
```

Also, when an existing user is modified, we should also reset the contexts of that users' home directory (while he is not logged on). To accomplish this, use `restorecon` using the `-F` option as follows:

```
# restorecon -RF /home/myuser
```

That is quite easy. Of course, in larger environments, creating mappings this way for individual users is not manageable. In such cases, it might be better to use (primary) group information. Most regular users are part of the user's Linux group, so let us assign those users to the `user_u` SELinux user. Accounts that are in the `admins` Linux group are mapped to `sysadm_u`. To accomplish this, we use the percentage sign to tell the SELinux tools that this mapping is for groups:

```
# semanage login -a -s user_u "%users"
# semanage login -a -s sysadm_u "%admins"
```

Now that the group mappings are in place, we can remove the `myuser` individual mapping we made earlier as follows:

```
# semanage login -d myuser
```

Creating additional users

When we want to use the UBAC feature, we might not have enough facilities with the users that are available by default (which can be obtained using `semanage user -l`):

```
# semanage user -l
                Labeling   MLS/       MLS/
SELinux User    Prefix     MCS Level  MCS Range
SELinux Roles

git_shell_u     user       s0         s0                             git_
shell_r
guest_u         user       s0         s0
guest_r
root            user       s0         s0-s0:c0.c1023
staff_r sysadm_r system_r unconfined_r
…
```

Luckily, creating additional SELinux users is a breeze. In the next examples, we create a new SELinux user called `finance_u`. We configure the user with a default sensitivity (`-L s0`), its security clearance (the sensitivity range, using `-r "s0-s0:c0.c127"`), the roles the user is allowed access to (`-R user_r`), and the new SELinux username as follows:

```
# semanage user -a -L s0 -r "s0-s0:c0.c127" -R user_r finance_u
```

When the SELinux user is created, its information is made as a part of the SELinux policy, and will also result in a `seusers` file within `/etc/selinux`.

Just similar to login mappings, `semanage user` also accepts the `-m` option to modify an existing entry, or `-d` to delete one, as in the following example:

```
# semanage user -d finance_u
```

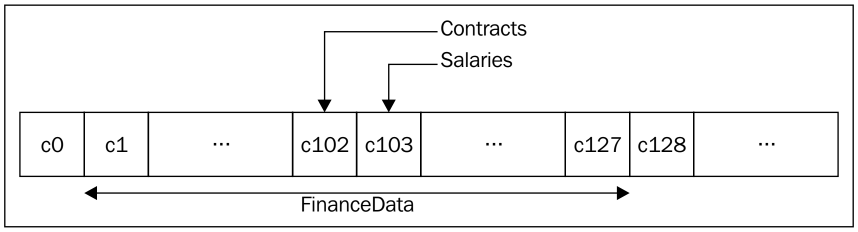
Separate SELinux users are not only interesting for UBAC, but also provide additional audit information (as SELinux users do not change during a user's session whereas the Linux effective user id can), and if the user creates files or other resources, these resources also inherit the SELinux user part in their security context.

Limiting access based on confidentiality

Sensitivity labels and their associated categories are identified through numeric values, which is great for computers but not that obvious for users. The SELinux utilities luckily support translating the levels and categories to human-readable values, even though they are still stored as numbers.

The translations are managed through the `setrans.conf` file, located in the proper policy store subdirectory within `/etc/selinux`. Inside this file, we can name specific values (for example, `s0:c102`) or ranges (similar to `s0-s0:c1.c127`) with a string that is much easier for administrators to use.

Consider our example of the `finance_u` SELinux user who was allowed access to the `c0.c127` category range. Two of the categories within that range are `c102`, which we will tag as `Contracts`, and `c103` which we will tag as `Salaries`. The `c1.c127` range will be labeled as `FinanceData`. The following diagram shows the relationship between these various categories:



Relationship of the example categories and category ranges

To accomplish this, the following code should be placed in the `setrans.conf` file:

```
s0:c102=Contracts
s0:c103=Salaries
s0-s0:c1.c127=FinanceData
```

With RedHat Enterprise Linux 6, the file needs to be edited manually. However, recent Fedora releases support the `semanage translation` command to list, create, and modify entries:

```
# semanage translation -a -T FinanceData "s0-s0:c1.c127"
```

These translations are handled by the SELinux utilities, which connect to the `mcstrans` daemon through a socket located in `/var/run/setrans` to query the `setrans.conf` file. If the daemon is not running or the communication with the daemon fails, the sensitivity and category numeric values are displayed.

We can view the available sensitivities and their human-readable counterparts using the `chcat` tool. The following one displays the default translations offered by RedHat Enterprise Linux 6:

```
$ chcat -L
s0      SystemLow
s0-s0:c0.c1023    SystemLow-SystemHigh
s0:c0.c1023    SystemHigh
```

The same `chcat` utility can be used to assign categories to users. For instance, to grant the `Salaries` category (assuming it is defined in `setrans.conf`) to the `myuser` Linux user:

```
# chcat -l -- +Salaries myuser
```

Using the preceding command, the `Salaries` category (`c103`) is granted to the Linux user `myuser`. The user mapping is immediately updated with this information. The `myuser` user needs to log out again for the changes to take effect.

Jumping from one role to another

Although we can be assigned with multiple roles, we still need to switch roles based on our needs. SELinux supports multiple methods for switching roles and sensitivities or launching applications in specific categories.

Full role switching with newrole

The SELinux `newrole` application can be used to transition from one role to another. Consider an SELinux system without unconfined domains, and where we are by default logged in as the `staff_r` role. In order to perform administrative tasks, we need to switch to the `sysadm_r` administrative role, which we can do with `newrole`.

If the SELinux user we are mapped to (for example, `sysadm_u`) is allowed to access the specified role (in the example, `sysadm_r`), then our context is changed from the previous role to the new one. Usually, this also changes the user domain.

Let's check our current context, change our role, and then check the context again to ensure that we properly switched to our role as follows:

```
$ id -Z
staff_u:staff_r:staff_t
$ newrole -r sysadm_r
Password:
$ id -Z
staff_u:sysadm_r:sysadm_t
```

Notice how the SELinux user remains constant, but the role and domain have changed.

The `newrole` application can also be used to transition to a specific sensitivity as follows:

```
$ newrole -l s0:c0.c100
```

When we switch towards another role or sensitivity, a new session is used (with a new shell). It does not change the context of the current session, nor does it exit from the current session. We can exit from our assigned role and return to the first session by exiting (through `exit`, `logout`, or *Ctrl* + *d*).

Managing role access with sudo

Most administrators use `sudo` for privilege delegation: allowing users to run certain commands in a more privileged context than the user is otherwise allowed. The `sudo` application is also capable of handling SELinux roles and types.

We can pass on the target role and type to `sudo` directly. For instance, we can tell `sudo` to switch to the database administrative role when we edit a PostgreSQL configuration file:

```
$ sudo -r dbadm_r -t dbadm_t vim /etc/postgresql/pg_hba.conf
```

However, we can also configure `sudo` through the `/etc/sudoers` file to allow users to run particular commands within a certain role/type, or get a shell within a certain context. Consider a user that has access to both the `user_r` as well as `dbadm_r` role (a role designated for database administrators). Within the `sudoers` file, the following line allows the user to run any command through `sudo` which, when triggered, will run by default run with the `dbadm_r` role and within the `dbadm_t` domain:

```
myuser ALL=(ALL) TYPE=dbadm_t ROLE=dbadm_r ALL
```

Often, `sudo` is preferred over `newrole` as most operations that we need another role for require switching effective user IDs anyway. The `sudo` application also has great logging capabilities, and we can even have commands switching role without requiring the end user to pass on the target role and type. However, it does not support changing sensitivities.

Switching to the system role

Sometimes we need to invoke applications that should not run under our current SELinux user context, but instead as the `system_u` SELinux user with the `system_r` SELinux role. This is acknowledged by the SELinux policy administrators who allow a very limited set of domains (applications) to transition even the SELinux user to a different user. One of those applications is `run_init`.

The `run_init` application is used mainly (almost exclusively) to start services on a Linux system. Through the use of this application, the daemons do not run under the user's SELinux context, but the system one instead. As an example, let us start the `mcstrans` daemon and check its context as follows:

```
# run_init /etc/rc.d/init.d/mcstrans start
# ps -Z $(pidof mcstransd)
system_u:system_r:setrans_t  7972  ?  Ss  0:00  mcstransd
```

Since release 15, Fedora used `systemd` as the service management tool which has the advantage that daemons are no longer started by the user, but by `systemd` itself on request of the user. As a result, services launched by `systemd` inherit the `system_u` SELinux user that `systemd` runs in, and therefore `run_init` is not needed there.

On Gentoo, `run_init` is integrated in the OpenRC service management tool so we do not need to explicitly call it. In Fedora (up to release 14), `run_init` is only needed when the user is in the `sysadm_r` role.

Most SELinux policies enable role-managed support for selective service management (for non-`systemd` distributions). This allows users that do not have complete system administration rights to still manipulate particular services on a Linux system if allowed by the SELinux policy. These users are to be granted the `system_r` role, but once that has been accomplished they do not need to call `run_init` to manipulate specific services anymore. The transitions happen automatically and only for the services that are assigned to the user, other services cannot be launched by these users.

For instance, the database administrative role (`dbadm_r`) can directly execute the `postgresql` service (preferably through `sudo`) as follows:

```
$ sudo /etc/rc.d/init.d/postgresql stop
```

If these users would have access to `run_init`, they can launch any service they want, requiring additional protection to access `run_init`. For this reason, the users granted with `system_r` are preferred over the `run_init` tool.

The runcon user application

The last application that can switch roles and sensitivities is the `runcon` application. `runcon` is available for all users and is used to launch a specific command as a different role, type, and/or sensitivity. It even supports changing the SELinux user.

Unlike the previous commands, `runcon` runs in the context of the user rather than its own domain, so any change in role, type, sensitivity, or even SELinux user is governed by the privileges of the user itself.

Most of the time, `runcon` is used to launch applications with a particular category. This allows users to take advantage of the MCS approach in SELinux without requiring their applications to be MCS-enabled.

For instance, to run the Firefox browser with the `Salaries` category, enter the following:

```
$ runcon -l Salaries firefox
```

This method can also be used to assign categories to daemons, but the command needs to be added in the daemon service script itself.

Getting in the right context

With all the information about SELinux users and roles, we still haven't touched how we get our context when we log in, or how we can change the type in the context.

Context switching during authentication

Traditionally, we log in to a Linux system through either a `login` process (triggered through a `getty` process) in case of a command-line login, a certain service (for example, the OpenSSH daemon), or through a graphical login manager (`xdm`, `kdm`, `gdm`, `slim`, and so on).

These services are responsible for switching our effective user ID (upon successful authentication of course) so that we are not logged on to the system as the root user. In case of SELinux systems, these processes also need to switch the SELinux user (and role) accordingly.

In theory, all these applications can be made fully SELinux aware, consulting the information we entered through `semanage user` and `semanage login`. But instead of converting all these applications, the developers decided to take the authentication route to a next level use the **PAM** (**Pluggable Authentication Modules**) services that Linux systems provide.

PAM offers a very flexible interface for handling different authentication methods on a Linux (and Unix) system. All applications mentioned earlier use PAM for their authentication steps. What SELinux does is aligns with the PAM session service to switch the context to the right one.

The following code listing is an excerpt of the Gentoo `/etc/pam.d/system-login` file, limited to the session service directives. It triggers the `pam_selinux` code as part of the authentication process as follows:

```
session         optional        pam_loginuid.so
session         required        pam_selinux.so close
session         required        pam_env.so
session         optional        pam_lastlog.so
session         include         system-auth
session         optional        pam_ck_connector.so nox11
session         required        pam_selinux.so multiple open
session         optional        pam_motd.so motd=/etc/motd
session         optional        pam_mail.so
```

The supported arguments to the `pam_selinux` code are described in the `pam_selinux` manual page. In the preceding example, the close option clears the current context (if any) whereas the open option sets the context of the user.

SELinux supports the aspect of selective contexts. The context is based on the process through which the user logs in. A perfect example of this is to differentiate administrators when they log in through the console (where they can be in the `sysadm_r` role immediately) versus log in through a remote shell, where we might want to put them in the `staff_r` role first and force them to reauthenticate (using `newrole` or `sudo`) before being given elevated privileges.

Application-based contexts

To cover application-based contexts, SELinux introduces the notion of a default context. Based on the context of the tool through which a user is logged in (or through which it executes commands), a different user context is chosen.

Inside the `/etc/selinux/targeted/contexts` directory, a file called `default_contexts` exists that uses a simple syntax. Each line starts with the context information of the parent process, and is then followed by an ordered list of all the contexts that could be picked based on the role(s) that the user is allowed to be in.

Consider the following line of code for the `sshd_t` context:

```
system_r:sshd_t:s0        user_r:user_t:s0 staff_r:staff_t:s0
sysadm_r:sysadm_t:s0 unconfined_r:unconfined_t:s0
```

This line of code mentions that when a user logs in through a process running in the `sshd_t` domain (or the process wants to set the user context because it needs to run something as a particular user), then the first role that matches a role that the user is assigned to is used.

Assume that we are assigned the roles `staff_r` and `sysadm_r` then we will log in as `staff_r:staff_t`, as that is the first match.

Next to the `default_contexts` file, there are also similar files in the `users/` subdirectory. These files are named after the SELinux user for which they take effect. If such a file exists, then its lines take precedence over the `default_contexts` file. This allows us to assign different contexts for particular SELinux users even if they share the same roles with other SELinux users. And because the precedence is line-based, we do not need to copy the entire content of the `default_contexts` file, only the line that is different is sufficient.

Let's modify the default contexts so that the `dbadm_u` SELinux user logs in with the `dbadm_r` role (with the `dbadm_t` type) when logged in through SSH. To do so, use the `sshd_t` line but set `dbadm_r:dbadm_t:s0` as the only possible context and save the result as `/etc/selinux/targeted/contexts/users/dbadm_u`:

```
system_r:sshd_t:s0  dbadm_r:dbadm_t:s0
```

To validate if our change succeeded, we can ask SELinux what will be the result of a context choice without having to parse the files ourselves. This is accomplished through the `getseuser` command, which takes two arguments, namely, the Linux user account and the context of the process that switches the user context.

As an example, to see what the context would be for the `myuser` user when he logs on through a process running in the `sshd_t` domain:

```
# getseuser myuser system_u:system_r:sshd_t
seuser:  dbadm_u, level (null)
Context 0       dbadm_u:dbadm_r:dbadm_t
```

One of the advantages of the `getseuser` command is that it asks the SELinux code what the context would be, which not only looks through the `default_contexts` file, but also checks whether the target context can be reached or not, and that there are no other constraints that prohibit the change to the context.

Summary

SELinux maps Linux users onto SELinux users and defines the roles that a user is allowed to be in through the SELinux user definitions. We learned how to manage those mappings and the SELinux users with the `semanage` application and were able to grant the right roles to the right people.

We also saw how the same commands are used to grant proper sensitivity to the user and how we can describe these levels in the `setrans.conf` file. We used the `chcat` tool to do most of the category-related management activities.

After assigning roles to the users, we saw how to jump from one role to another using `newrole`, `sudo`, `runcon`, and `run_init`. We ended this chapter with the important insight on how SELinux integrates in the Linux authentication process and how it implements application-specific contexts.

In the next chapter, we will learn to manage the labels on files and processes and see how we can query the SELinux policy rules.

4
Process Domains and File-level Access Controls

When we work on an SELinux-enabled system, gathering information about the contexts associated with the files and processes is extremely important. We also need to understand how these contexts are used in policies and what the applicable security rules are for a specific process.

In this chapter, we will:

- Work with file contexts and learn where they are stored
- Understand how contexts are assigned
- Look at how processes get into the context they are in
- Get our first taste of the SELinux policy and how we can query it

We end with another SELinux feature called constraints and how it is used to provide the user-based access control feature.

Reading and changing file contexts

Let us immediately start off with an example here: a web server hosting `dokuwiki`, a popular PHP wiki site that uses files rather than a database as its backend system.

Getting context information

The application is hosted at /var/www/localhost/htdocs/dokuwiki and stores its wiki pages (user content) in subdirectories of the data/ directory. Getting the contexts of files can easily be accomplished using the -Z option to ls. Most utilities that are able to provide feedback on contexts will try to do so using the -Z option, as we saw already with the id and ps utilities. Let's look at the context of the dokuwiki directory itself:

```
# ls -lZ /var/www/localhost/htdocs
drwxr-xr-x. 1 root root root:object_r:httpd_sys_content_t 45 May  9 20:05
dokuwiki
```

File and directory contexts are stored on the filesystem as extended attributes when the filesystem supports this. If not, the context of the files is usually defined by the mounted filesystem type or its mount options. We can query the existing extended attributes using the getfattr application as shown in the following example:

```
$ getfattr -m . -d dokuwiki
# file: dokuwiki
security.selinux="system_u:object_r:httpd_sys_rw_content_t"
```

As we can see, the security.selinux key is used for the SELinux context. The use of the security namespace enforces specific restrictions on manipulating the attribute: if no security module is loaded (for instance, SELinux is not enabled) then only processes with the CAP_SYS_ADMIN capability are able to modify this parameter (and thus influence the behavior of the SELinux system when SELinux is enabled).

Go ahead and look at the various file contexts on an SELinux-enabled system. You can also use the stat application which also provides context information, shown in the following example where we get the dokuwiki context information again:

```
$ stat dokuwiki | grep Context
Context: system_u:object_r:httpd_sys_rw_content_t
```

Getting context information from a file or directory should be as common to an administrator as getting regular access control information (read, write, and execute flags). After a while, we will notice that files are labeled based on their intended usage. An important context type is file_t, which is used when SELinux does not find any context information.

Consider the contexts of a user file in its home directory (user_home_t), a temporary directory in /tmp for a Java application (java_tmp_t), and a socket of rpcbind (rpcbind_var_run_t). All these files or directories have considerably different purposes on the filesystem, and this is reflected in their assigned contexts.

Policy writers will always try to name the context consistently, making it easier for us to understand the purpose of the file, but also to make the policy almost self documented and to detect anomalies in the file contexts.

An example of a common anomaly is when a file is moved from the user home directory to the web server location. When this occurs, it retains the `user_home_t` context as extended attributes are moved with it. As the web server process isn't allowed to access `user_home_t` by default, it will not be able to serve this file to its users.

Working with context expressions

In the SELinux policy, there is a list of regular expressions that informs the SELinux utilities and libraries what should be the context of a file. Though this expression list is not enforced on the system, it is meant for administrators to see if a context is correct or not, and for tools that need to reset contexts to what they are supposed to be. The list itself is stored on the filesystem in `/etc/selinux/strict/contexts/files` in the `file_contexts.*` files.

As an administrator, we can query parts of this list through `semanage fcontext` as follows:

```
# semanage fcontext -l
```

Not all the entries are visible through the `semanage` application though. Entries related to user home directories or that are explicitly marked to not have a hardcoded context are not visible. For those entries that do match, the output of the command is:

- A regular expression
- The classes on which the rule is applicable, but translated in a more human-readable format
- The context to assign to the resources that match the expression and class list

The class list allows us to differentiate contexts based on the resource class, which can be a regular file (`--`), a directory (`-d`), a socket (`-s`), a named pipe (`-p`), a block device (`-b`), a character device (`-c`), or a symbolic link (`-l`). When it says "all files", the line is valid regardless of the class.

The option-like statements discussed previously are used in the context list itself (on the filesystem) and is also used when we would set our own context definition.

An important property of the context list is how it is prioritized. After all, we could easily have two expressions that both match. Within SELinux, the rule that is the most specific wins. The logic used is as follows (in order):

- If line A has a regular expression, and line B doesn't, then line B is more specific
- If the number of characters before the first regular expression in line A is less than the number of characters before the first regular expression in line B, then line B is more specific
- If the number of characters in line A is less than in line B, then line B is more specific
- If line A does not map to a specific SELinux type (the policy editor has explicitly told SELinux not to assign a type), while if line B does, then line B is more specific

Consider the rules that all match `/usr/lib/pgsql/test/regress/pg_regress` (shown through the `findcon` application):

```
$ findcon /etc/selinux/strict/contexts/files/file_contexts -p /usr/lib/
pgsql/test/regress/pg_regress
/.*             system_u:object_r:default_t
/usr/.*         system_u:object_r:usr_t
/usr/(.*/)?lib(/.*)?            system_u:object_r:lib_t
/usr/lib/pgsql/test/regress(/.*)?
system_u:object_r:postgresql_db_t
/usr/lib/pgsql/test/regress/pg_regress  --
system_u:object_r:postgresql_exec_t
```

Although the other five rules match, the last one is the most specific because it does not contain any expression. If that line doesn't exist, then the line before is the most specific because the number of characters before the first regular expression is much longer than the match before, and so on.

These rules, however, only hold for the context expressions provided by the policy. If we add our own regular expressions to the system (called local context expressions), and a file matches one of our expressions, then the last expression that we added which matches the file is used.

Setting context information

When we think that the context of a file is wrong, we need to correct the context. SELinux offers several methods to do so, and some distributions even add in more. In order to be able to change contexts we do need proper rights, which are named `relabelfrom` and `relabelto`. These rights are granted on domains to indicate if the domain is allowed to change a label from a particular type (similar to `user_home_t`) and towards another type (similar to `httpd_sys_content_t`). If we find denials in the audit log related to these permissions, it means that the domain is prohibited from changing the contexts.

Assuming that we have these rights, we can use tools such as `chcon`, `restorecon` (together with `semanage`), `setfiles`, `rlpkg` (Gentoo), and `fixfiles` (Fedora). Of course, we could also use the `setfattr` command, but will be the least user friendly approach for setting contexts.

The `chcon` tool updates the context of the file (or files) directly, but does not update the context list as provided by `semanage`. Let's try this out against the `/srv/www` directory as follows:

```
$ chcon -R -t httpd_sys_content_t /srv/www
```

Another interesting approach through `chcon` is to tell it to label a file with the same context as a different file. In the next example, we use `chcon` to label `/srv/www/index.html`, similarly as the context used for the `/var/www/index.html` file:

```
$ chcon --reference /var/www/index.html /srv/www/index.html
```

If we change the context of a file through `chcon` and set it to a context different from the one in the context list, then there is a possibility that the context will be reverted later: package managers might reset the files back to their intended context, or the system administrator might trigger a full filesystem relabeling operation.

For this reason, it is seriously recommended to only use `chcon` when testing the impact of a context change. Once the change is accepted, we need to register it through `semanage`. For instance, to permanently mark `/srv/www` (and all its subdirectories) as `httpd_sys_content_t` we need to execute the following:

```
# semanage fcontext -a -t httpd_sys_content_t "/srv/www(/.*)?"
# restorecon -R /srv/www
```

What we do here is to first register `/srv/www` and its subdirectories as `httpd_sys_content_t` through `semanage`. Then, we use `restorecon` to reset the contexts (recursively) of `/srv/www` to the value registered in the context list. This is the recommended approach for setting different contexts on most resources.

These registrations are the local context expressions and are stored in a separate file (`file_contexts.local`). Considering the priority of expressions, the following will not have the expected behavior since the last rule we added takes precedence:

```
# semanage fcontext -a -t httpd_sys_content_t "/srv/www(/.*)?"
# semanage fcontext -a -t var_t "/srv(/.*)?"
```

In this example, `/srv/www` would still be labeled as `var_t` instead of `httpd_sys_content_t` because the `var_t` rule was added later.

The `semanage fcontext` application can also be used to inform SELinux that a part of the filesystem tree should be labeled as if it was elsewhere. This allows us to use different paths for application installations or file destinations, and tell `semanage` to apply the same contexts as if the destination was the default.

For instance, to have everything under `/srv/www` be labeled as `/var/www` including subdirectories, so `/srv/www/icons` gets the same context as `/ var/www/icons`,we use the `-e` option to `semanage fcontext` as follows:

```
# semanage fcontext -a -e /var/www /srv/www
```

This will create a substitution entry so that anything under `/srv/www` is labeled as if it was at the same subdirectory but under `/var/www`.

The `setfiles` application is an older one, which requires the path to the context list file itself in order to reset contexts. Although it is often used under the hood of other applications, most administrators do not need to call `setfiles` directly anymore.

Finally, we have the `rlpkg` and `fixfiles` applications. Both of the applications have a nice feature that they can be used to reset the contexts of the files of a particular application, rather than having to iterate over the files manually and running `restorecon` against them. In the next example, we use these tools to restore the contexts of the files provided by the `openssh` package:

```
# rlpkg openssh
# setfiles -R openssh restore
```

Another feature of both applications is that they can be used to relabel the entire filesystem using the options shown here as follows:

```
# rlpkg -a -r
# setfiles -f -F relabel
```

Another way of relabeling the entire system is to create a touch file called `.autorelabel` in the root filesystem and reboot (Fedora-only) as follows:

```
# touch /.autorelabel
# reboot
```

We only focused on the type part of a context. Contexts, however, also include a role part and SELinux user part. If UBAC is not enabled, then the SELinux user has no influence on any decisions, but if it is enabled, utilities such as `chcon` are able to set the SELinux user as well. The role for a file usually is `object_r` as roles currently only make sense for users (processes).

Using customizable types

Some SELinux types are meant for files whose paths cannot be accurately defined by administrators, or where the administrator does not want the context to be reset when a relabeling operation is triggered. Such types are called customizable types.

The customizable types are declared in the `customizable_types` file inside `/etc/selinux/strict/contexts`. When `restorecon` (or any other tool that wants to reset contexts to the type declared in the context list) wants to relabel a file whose context is of a type known to be a customizable type, it will not reset the context (except when the force reset option `-F` is given).

Let's take a look at the contents of this `customizable_types` file:

```
$ cat /etc/selinux/strict/contexts/customizable_types
```

As an example, we can mark a file in our home directory (in this example, the file is called `convert.sh`) as `home_bin_t`, which is a customizable type and as such will not be relabeled back to `user_home_t` when a filesystem relabeling operation is done:

```
$ chcon -t home_bin_t  ~/convert.sh
```

For now, we cannot add customizable types easily. The file needs to be edited manually, and because the file can be overwritten when a new policy package (by the distribution) is pushed to the system, it needs to be governed carefully.

Still, the use of customizable types has its advantages. As an administrator, we might want to create and support specific types usable by end users who can use `chcon` to set the context of individual files in their home directory. By having those types marked as customizable types, a relabeling operation against `/home` will not reset those contexts.

Most of the times, however, it is preferred to use `semanage fcontext` to add an expression, and `restorecon` to fix the context of the files. Take the `convert.sh` file as an example again, which would result in the following commands:

```
# semanage fcontext -a -t home_bin_t /home/myuser/convert\.sh
# restorecon /home/myuser/convert.sh
```

Inheriting the context

By default, SELinux uses context inheritance to identify what context should be assigned to a file (or directory, or socket, and so on) when it is created. It does not look at the value in the expression list (the `file_contexts.*` files). A file created in a directory with a context `var_t` will get assigned the context `var_t` as well.

There are a few exceptions to this though: type transition rules, SELinux-aware applications, or the use of `restorecond`.

Type transition rules are policy rules that force the use of a different type upon certain conditions. In the case of file contexts, such a type transition rule can be as follows: if a process running in the `httpd_t` domain creates a file in a directory labeled `var_log_t`, then the `type` identifier of the file becomes `httpd_log_t` instead of `var_log_t`.

Basically, this rule ensures that any file placed by web servers in a log directory is assigned the context specific to web server logs.

We can query these type transition rules using `sesearch`, one of the most important tools available to query the current SELinux policy. For the preceding example, we need the (source) domain and the (target) context of the directory: `httpd_t` and `var_log_t`. In the next example, we use `sesearch` to find the type transition declaration related to the `httpd_t` domain towards the `var_log_t` context:

```
$ sesearch -T -s httpd_t -t var_log_t
Found 1 semantic te rules:
   type_transition httpd_t var_log_t : file httpd_log_t;
```

The `type_transition` line is an SELinux policy rule, which maps perfectly on the description. Let's look at another set of type transition rules for the `tmp_t` label (assigned to the top directory of temporary file locations, for example, `/tmp` and `/var/tmp`):

```
$ sesearch -T -s httpd_t -t tmp_t
Found 4 semantic te rules:
   type_transition httpd_t tmp_t : file httpd_tmp_t;
   type_transition httpd_t tmp_t : dir httpd_tmp_t;
   type_transition httpd_t tmp_t : lnk_file httpd_tmp_t;
   type_transition httpd_t tmp_t : sock_file httpd_tmp_t;

Found 2 named file transition rules:
type_transition httpd_t tmp_t : file krb5_host_rcache_t "HTTP_23";
type_transition httpd_t tmp_t : file krb5_host_rcache_t "HTTP_48";
```

The policy tells us that if a file, directory, symbolic link, or socket is created in a directory labeled `tmp_t`, then this resource gets the `httpd_tmp_t` context assigned (and not the default, inherited `tmp_t` one). But it also contains two named file transitions, which is a (rather recent) addition to the SELinux policy (which is not available in RedHat Enterprise Linux 6).

With named file transitions, the policy can take into account the name of the file (or directory) created to differentiate the target context. In the preceding example, if a file named `HTTP_23` or `HTTP_48` is created in a directory labeled as `tmp_t`, then it does not get the assigned `httpd_tmp_t` context (as would be implied by the regular type transition rules), but instead the `krb5_host_rcache_t` type (used for Kerberos implementations).

Type transitions do not only give us insight into what labels are going to be assigned, but they also give us some clues as to which types are related to a particular domain. In the web server example, we already found out by querying the policy that its logfiles are most likely labeled `httpd_log_t` and its temporary files as `httpd_tmp_t`.

Next to type transition rules, contexts can be defined through the application itself if the application is SELinux-aware (that is linked with and uses SELinux libraries). If that is the case, the application can force the context of a file to be different (but only if the policy allows it of course).

Finally, contexts can also be forced by `restorecond`. The purpose of this daemon is to enforce the expression list rules onto a configured set of locations. These locations are set in its configuration file, `/etc/selinux/restorecond.conf`. The next is an example list of locations set in the `restorecond.conf` file, so that `restorecond` will react upon context changes of these files and directories:

```
/etc/resolv.conf
/etc/mtab
/var/run/utmp
~/public_html
~/.mozilla/plugins/libflashplayer.so
```

In this case, if a file that matches any of the previously created paths, `restorecond` will be notified of it (through the Linux inotify subsystem) and will relabel the file according to the expression list. In the past, the use of `restorecond` was needed because SELinux didn't support named file transitions yet, so writing `resolv.conf` in `/etc` couldn't be differentiated from writing `passwd` in `/etc`. The introduction of named file transitions has considerably reduced the need for `restorecond`.

Placing categories on files and directories

We focused primarily on changing types, but another important part is to support categories (and sensitivity levels). With `chcon`, we can add sensitivity levels and categories as follows:

```
$ chcon -l s0:c0,c2 index.html
```

Another tool that can be used for assigning categories is the `chcat` tool. With `chcat`, we can assign additional categories rather than having to iterate them again as in the case with `chcon`, and even enjoy the human-readable category levels as provided by the `setrans.conf` file:

```
$ chcat -- +Customer2 index.html
```

The context of a process

As everything in SELinux works with labels, even processes are assigned a label, also known as the domain. If a label is absent (or invalid), SELinux will show the process as `unlabeled_t`. We saw that the Apache web server runs in the `httpd_t` domain, which can be seen with the `ps -Z` command as follows:

```
# ps -eZ | grep httpd
system_u:system_r:httpd_t:s0 2270 ?        00:00:00 httpd
```

The Apache processes don't inform SELinux themselves that they need to run in the `httpd_t` domain. For that, transition rules in SELinux exist.

Transitioning towards a domain

Just as we did with files, if a process forks and creates a new process, this process inherits the context of the parent process. In case of the web server, the main process is in the `httpd_t` domain, so all the worker processes that are launched inherit the `httpd_t` domain from it.

In order to differentiate one process from another, domain transitions can be defined. A domain transition (also known as a process transition) is a rule in SELinux that tells SELinux another domain is to be used for a forked process (actually, it is when the parent process calls the `execve()` function, most likely after a `fork()`).

Similar to the files, domain transitions can be searched through using `sesearch`. Let's look into the domains that are allowed to transition to the `httpd_t` domain as follows:

```
$ sesearch -T | grep "process httpd_t"
type_transition initrc_t httpd_exec_t : process httpd_t
```

In this case, SELinux will switch the context of a launched web server to `httpd_t` if the parent process is running in the `initrc_t` domain and is executing a file labeled as `httpd_exec_t` (which is the label assigned to the `httpd` binary).

But in order for this to truly happen, a number of other permissions (next to the type transition) need to be in place. The following list describes these various permissions:

- The parent process (`initrc_t` here) needs to be allowed to transition to the `httpd_t` domain, which is governed by the `transition` privilege on the `process` class:

  ```
  $ sesearch -s initrc_t -t httpd_t -c process -p transition -A
  Found 1 semantic av rules:
     allow initrc_t httpd_t : process transition ;
  ```

- This parent process needs to have the `execute` right on the file it is launching (`httpd_exec_t`):

  ```
  $ sesearch -s initrc_t -t httpd_exec_t -c file -p execute -A
  Found 1 semantic av rules:
     allow initrc_t httpd_exec_t : file { ioctl read getattr …
  execute … open } ;
  ```

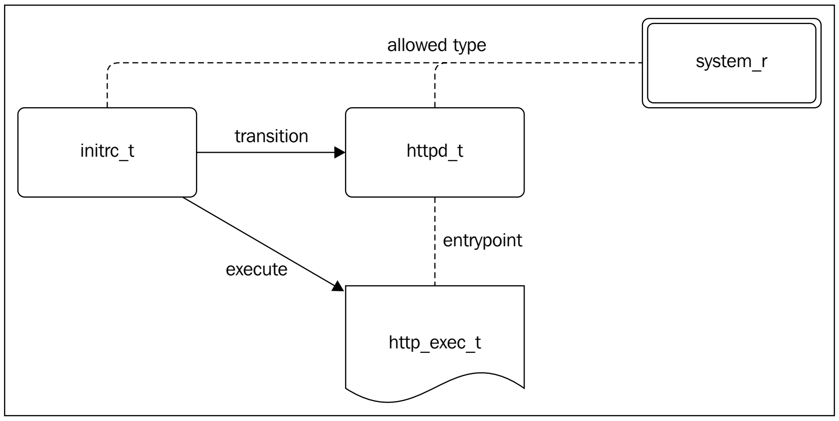
- The `httpd_exec_t` type must be identified as an entrypoint for the `httpd_t` domain. An `entrypoint` is used by SELinux to ensure a domain transition only occurs on the file(s) that should be used to get into a new domain:

  ```
  $ sesearch -s httpd_t -t httpd_exec_t -c file -p entrypoint -A
  Found 1 semantic av rules:
     allow httpd_t httpd_exec_t : file { ioctl read … entrypoint
  open } ;
  ```

- The target domain must be allowed for the role that the parent process is in. In case of system daemons, the role is `system_r`:

  ```
  $ seinfo -rsystem_r -x | grep httpd_t
  ```

A graphical representation of these rights is shown in the following diagram:



Graphical overview of the involved permissions to succesfully transition from one domain to another

Only when all these are allowed, a domain transition occurs. If not, either execution of the application fails (if the domain has no `execute` rights on the file), or it is running in the same domain as the parent process.

Other supported transitions

Regular domain transitions are the most common transitions in SELinux, but there are other transitions as well.

For instance, some applications (for example, `cron` or `login`) are SELinux aware and will specify to which domain a transition needs to be triggered. These applications call the `setexeccon()` method to specify the target domain, and do not use a type transition rule. The other requirements, however, still hold.

Some SELinux aware applications are even able to change their current context (and not just the context of the application they execute). In order to do so, the application domain needs the `dyntransition` right (one of the privileges supported for process-level activities). An example of such an application is chromium, which by default runs in the `chromium_t` domain but can transition to the `chromium_renderer_t` type. Another example is the `httpd_t` domain.

The support for dynamic transitions in `httpd_t` is to support the `mod_selinux` Apache module. With this module, requests for a particular web application can be handled in a different domain than the (main) `httpd_t` domain, even though no additional process is launched. Instead, one of the worker processes (or threads, as SELinux contexts can be put on threads as well) dynamically transitions to the security domain the administrator wants it to run in.

Working with mod_selinux

When dynamic transitions are used, we need to know if the process is single-threaded or not. If it is single-threaded, then the target domain can be "freely" chosen. However, if the process is multithreaded and we want to change the context of a single thread, then the target domain must be bounded by the current (parent) domain. SELinux will enforce this, and refuse to change to a new domain if this domain isn't bounded.

A bounded domain means that the privileges of the domain are the same or less than the permissions of the parent domain. This is a requirement because threads share the same memory segments, so SELinux is not able to control information flows between different threads. By ensuring that target domains are bounded, SELinux is able to contain the information flow within the process.

Consider a web server configuration with multiple virtual hosts; for each virtual host, a different domain can be selected through the `selinuxDomainVal` directive (or the same domain but with a different sensitivity level or category set).

```
NameVirtualHost *:80
<VirtualHost *:80>
  DocumentRoot /var/www/sales
  ServerName sales.genfic.com
  selinuxDomainVal *:s0:c1
</VirtualHost>
<VirtualHost *:80>
  DocumentRoot /var/www/hr
  ServerName hr.genfic.com
  selinuxDomainVal hr_site_t:s0
</VirtualHost>
```

The `mod_selinux` module can also select the domain (or sensitivity level and category) based on the authenticated web user. To support this, a user mapping file needs to be created that provides the target context for each authenticated user as follows:

```
someuser    *:s0:c1
otheruser    *:s0:c2
__anonymous__  anon_webapp_t:s0
*      *:s0:c0
```

The `__anonymous__` user is a special one for unauthenticated users.

This mapping file can then be referenced in the web server configuration as follows:

```
<VirtualHost *:80>
  DocumentRoot /var/www/sales
  ServerName sales.genfic.com
  selinuxDomainMap /etc/apache/selinux/mod_selinux.map
</VirtualHost>
```

We can also differentiate them based on the origin of the requests. Suppose we want to assign a different category range if the user is on one subnet than when he is connected from another subnet:

```
<VirtualHost *:80>
  DocumentRoot /var/www/sales
  ServerName sales.genfic.com
  SetEnvIf Remote_Addr "10.18.12.[0-9]+$" SELINUX_DOMAIN=*:s0:c0
  SetEnvIf Remote_Addr "10.160.18.[0-9]+$" SELINUX_DOMAIN=*:s0:c0.c5
  selinuxDomainEnv SELINUX_DOMAIN
  selinuxDomainVal anon_sales_t:s0:c0
</VirtualHost>
```

In this example, if the IP address of the user matches, then the domain mentioned in the `SELINUX_DOMAIN` variable is used. Otherwise, the context falls back to the one provided by the `selinuxDomainVal` directive. By supporting variables, more integrated approaches can be used, such as selecting the target domains through database queries.

Dealing with types, permissions, and constraints

Now that we know more about types (both in the context of processes as well as files and other resources), let's look into how these are used in the SELinux policy in more detail.

Type attributes

We have discussed the `sesearch` application already and how it can be used to query the current SELinux policy. Let us look again at the process transitions, this time on a Fedora system:

```
$ sesearch -s initrc_t -t httpd_t -c process -p transition -A
Found 1 semantic av rules:
   allow initrc_domain daemon : process transition ;
```

Even though we asked for the rules related to the `initrc_t` source and the `httpd_t` target, we get a rule back for the `initrc_domain` source and the `daemon` target. What `sesearch` did here was it told us a privilege of `initrc_t` based on a privilege assigned to an attribute.

Type attributes in SELinux are used to group multiple types and assign privileges on these groups, rather than having to assign the privileges on each type individually. In case of `initrc_domain`, the following types are all "tagged" with the `initrc_domain` attribute, which can be seen through the `seinfo` application:

```
$ seinfo -ainitrc_domain -x
   initrc_domain
      piranha_pulse_t
      initrc_t
      kdumpctl_t
      init_t
      rgmanager_t
      condor_startd_t
```

As we can see, the `initrc_t` type is indeed one of the `initrc_domain` tagged types. Similarly, the `daemon` attribute is assigned to several types (several hundreds even). So the single allow rule mentioned earlier consolidates more than a thousand rules into one (hundreds of allow rules, each for the preceding six `initrc` domains).

Attributes are being used increasingly in the policy as a way of consolidating and simplifying policy development. With `seinfo -a`, you can get an overview of all attributes supported in the current policy.

Querying domain permissions

The most common rules in SELinux are the allow rules, informing the SELinux subsystem what permissions a domain has. Allow rules using the following syntax:

```
allow <source> <destination> : <class> <permissions> ;
```

The `<source>` field is always a domain, whereas the `<destination>` field can be of any kind of type.

The `<class>` field allows us to differentiate privileges based on the resource: is it for a regular file, a directory, a TCP socket, a capability, and so on. A full overview of all supported classes can be obtained from `seinfo -c`. Each class has a set of permissions assigned to it that SELinux can control. For instance, the `sem` class (used for semaphore access) is as follows:

```
$ seinfo -csem -x
      sem
         associate
         create
         write
         unix_read
         destroy
         getattr
         setattr
         read
         unix_write
```

In the `<permissions>` field, most rules will bundle a set of permissions through the use of the `{ … }` brackets:

```
allow user_t etc_t : file { ioctl read getattr lock execute execute_
no_trans open } ;
```

This syntax allows policy developers to make very fine-grained permission controls. We can use the `sesearch` command to query through these rules. The more options that are given to the `sesearch` command, the finer-grained our search parameters become. For instance, `sesearch -A` would give us all allow rules currently in place. Adding a source (`-s`) filters the output to only show the allow rules for this domain. Adding a destination or target (`-t`) filters the output even more. Other supported options for allow rules with `sesearch` are the class (`-c`) and permission (`-p`).

The syntax also perfectly matches with the information provided by AVC denials:

```
type=AVC msg=audit(1371993742.009:15990): avc:  denied  { getattr
} for  pid=31069 comm="aide" path="/usr/lib64/postgresql-9.2/bin/
postgres" dev="dm-3" ino=803161 scontext=root:sysadm_r:aide_t tcontext
=system_u:object_r:postgresql_exec_t tclass=file
```

Allowing this particular denial would result in the following allow rule:

```
allow aide_t postgresql_exec_t : file { getattr };
```

Understanding constraints

The allow statements in SELinux however only focus on the type-related permissions. Sometimes, however, we need to restrict certain actions based on the user or role information. In SELinux, this is supported through constraints.

Constraints in SELinux are rules that are applied against a class and a set of its permissions which have to be true in order for SELinux to further allow the request. Consider the following constraint on process transitions:

```
constrain process { transition dyntransition noatsecure siginh
rlimitinh }
(
        u1 == u2
        or ( t1 == can_change_process_identity and t2 == process_user_
target )
        or ( t1 == cron_source_domain and ( t2 == cron_job_domain or
u2 == system_u ) )
        or ( t1 == can_system_change and u2 == system_u )
        or ( t1 == process_uncond_exempt )
);
```

This constraint says that the following rule(s) have to be true if a `transition`, `dyntransition`, or any of the other three mentioned process permissions is invoked:

- The SELinux user of the domain (`u1`) and target (`u2`) have to be the same
- The SELinux type of the domain (`t1`) has to have the `can_change_process_identity` attribute set and the SELinux type of the target (`t2`) has to have the `process_user_target` attribute set
- The SELinux type of the domain (`t1`) has to have the `can_system_change` attribute set and the SELinux user of the target (`u2`) has to be `system_u`
- The SELinux type of the domain (`t1`) has to have the `process_uncond_exempt` attribute set

It is through constraints that UBAC is implemented as follows:

```
u1 == u2
or u1 == system_u
or u2 == system_u
or t1 != ubac_constrained_type
or t2 != ubac_constrained_type
```

You can list the currently enabled constraints using `seinfo --constrain`, but the output expands the attributes immediately and uses a postfix notation, making it not that obvious to read.

Summary

In this chapter, we saw how file contexts are stored as extended attributes on the filesystem and where SELinux keeps its definition on what contexts are to be assigned on which files. We also learned to work with the `semanage` tool to manipulate this information.

On the process level, we got our first taste of SELinux policies, identifying when a process is launched inside a certain SELinux domain. With it, we touched the `sesearch` and `seinfo` applications to query the SELinux policy.

In the next chapter, we will expand our knowledge of protecting the operating system from a regular file, and process protection measures towards the networking-related features of SELinux.

5

Controlling Network Communications

The SELinux mandatory access controls go much beyond the file and process access controls. One of the features provided by SELinux is controlling network communications. By default, the socket-based access control mechanism is used for general network access controls, but more detailed approaches are also possible.

TCP and UDP support

When we confine network facing services, for example, web servers or database servers, we not only focus on the file-based restrictions and process capabilities, but also what network activities the services are allowed to do. Many database servers should not be able to initiate a connection themselves to other systems and, if they do, these connections should be limited to the expected services (like other database services).

The first approach on limiting this is to define what sockets a process is allowed to bind on (as a service) or connect to (as a client). In the majority of cases, the sockets are either TCP sockets or UDP sockets. In SELinux, these are mapped to the `tcp_socket` and `udp_socket` classes.

Labeling ports

In order to easily map SELinux domain accesses to the TCP or UDP ports, SELinux allows administrators to label these ports and define which domains can access what ports. When a domain tries to connect or bind to a port, the `name_connect` or `name_bind` permissions on the socket class related to the port are checked. If it fails, an `AVC` denial similar to the following one is shown:

```
type=AVC msg=audit(1372361247.465:76): avc:  denied  { name_bind } for
pid=2880 comm="apache2" src=84 scontext=system_u:system_r:httpd_t:s0
tcontext=system_u:object_r:reserved_port_t:s0 tclass=tcp_socket
```

As we can see, the `httpd_t` domain tried to bind (`name_bind permission`) against a `tcp_socket` class labeled with `reserved_port_t`, but was prevented by SELinux. In the denial, we can find out what the port number is (`src=84`).

The labels for the various ports can be seen using `semanage port`, as shown in the following example:

```
# semanage port -l | grep http_port
http_port_t                    tcp      80, 443, 488, 8008, 8009, 8443
pegasus_http_port_t            tcp      5988
```

In the preceding example, we see that the `http_port_t` label is assigned to a set of TCP ports. It comes as no surprise that daemons, for example, web servers, are policywise, allowed to bind to this port. We can check this using the `sesearch` application as follows:

```
$ sesearch -s httpd_t -t http_port_t -A
Found 1 semantic av rules:
   allow httpd_t http_port_t : tcp_socket { recv_msg send_msg name_bind }
;
```

From the output, we can imagine that there are also `recv_msg` and `send_msg` permissions. Although these are still known in the policy, they are no longer used and expected to disappear in the near future. The only permissions that are checked are the `name_bind` and `name_connect` ones.

As an administrator, we can change the label assigned to particular ports. For instance, we can assign the `http_port_t` label to port `84` using `semanage port` as follows:

```
# semanage port -a -t http_port_t -p tcp 84
```

This is the recommended approach when you have daemons assigned to run on non default ports to hide them from port scanners: instead of modifying the policy to allow the daemon to bind on other ports, just assign the same label on the non standard port as we did in the preceding example with port `84` (which is now also labeled as `http_port_t`).

Integrating with Linux netfilter

The approach with TCP and UDP ports has a few downsides. One of them is that there is no knowledge of the target host, so you cannot govern where a domain can connect to. There is also no way of limiting daemons from binding on any interface: in a multi-homed situation, we might want to make sure that a daemon only binds on the interface facing the internal network and not the Internet-facing one, or vice-versa.

In the past, SELinux allowed support for this binding issue through the interface and node labels: a domain could only be allowed to bind on one interface and not on any other, or even on a particular address (referred to as the node). This support has been deprecated for the regular network access control support because it had a flaw; there was no link between host or interface binding information and the connect or bind permission towards a particular socket.

Consider the example of a web server on a DMZ system. The web server is allowed to receive web requests from the Internet (interface `0`) as well as connect to a database in the internal network (through interface `1`) to serve the dynamic content. For SELinux, in this previous approach, this allowed the web server to bind on both interfaces, bind on the `http_port_t` socket and connect to a `postgresql_port_t` socket (or other database socket).

The flaw here is that the domain now is also allowed (SELinux wise) to connect to a PostgreSQL socket on a database the Internet, which we might not want. To fix this, packet labeling is introduced which is called SECMARK.

Packet labeling through netfilter

With packet labeling, we can use the filtering capabilities of `iptables` and `ip6tables` to assign particular labels on packets and connections. Because we can use the flexible options provided by the filtering subsystem, we can mark only the packets related to the PostgreSQL connection from our web server to the internal PostgreSQL server and allow the web server to send and receive permissions on these packets.

Because packets originating from (or going to) a database on the Internet are then marked with a default label (or an explicit label we assign it with), SELinux is able to prevent the web server in our DMZ example to connect to an Internet-hosted database, as SELinux can now control the labeled traffic.

This packet labeling uses the idea of security markings, hence the name SECMARK. Although we use the term SECMARK, there are actually two markings: one for packets (`SECMARK`) and one for connections (`CONNSECMARK`).

The filtering capabilities for which we use `iptables` (for IPv4) and `ip6tables` (for IPv6) are based on the Linux netfilter subsystem, which offers a full-featured packet filtering framework. Basically, Linux offers a set of packet matching tables based on the functionality through which the packet "flows": `filter`, `nat`, `mangle`, `raw`, and `security`. For SECMARK, the `mangle` and `security` tables are those that offer the security marking capabilities.

Next to the tables, there are also chains (where we can define a sequential set of filtering rules in) assigned to the tables, and which are used by the netfilter subsystem while it is handling a packet. By default, the netfilter subsystem comes with a set of chains (`PREROUTING`, `INPUT`, `FORWARD`, `POSTROUTING`, and `OUTPUT`) which are triggered in a well-defined flow. Custom chains can also be created (and reused), and can be referred to using rules in the predefined chains.

A rule in a chain provides a matching criterion for a packet which, if the packet indeed matches, is handled according to the target. Targets can be a custom chain, or one of the predefined resulting values `ACCEPT`, `DROP`, `QUEUE`, `RETURN`, or (in our case) `SECMARK`.

Assigning labels to packets

When no `SECMARK` related rules are loaded in the netfilter subsystem, then `SECMARK` is not enabled and none of the SELinux rules related to SECMARK permissions are checked. The network packets are not labeled, so no enforcement can be applied to them. Of course, the regular TCP/UDP socket related labels still apply.

Once a `SECMARK` rule is enabled, `SECMARK` becomes active and SELinux starts enforcing the packet label mechanism. This means that all of the network packets now need a label on them (as SELinux can only deal with labeled resources). This label is `unlabeled_t`, which does not mean that there is no label (because that is the label), but because there is no marking rule that matches this particular network packet.

Because SECMARK rules are now being enforced, all domains that interact with network packets are checked to see if they are allowed to send or receive these packets. In order to simplify management, some distributions enable send and receive rights against the `unlabeled_t` packets for all domains. Without these rules, all network services would stop functioning properly, the moment a single `SECMARK` rule is enabled.

For those systems that accept the `unlabeled_t` packets by default, we can add in a netfilter rule that automatically marks all packets, which are not labeled otherwise, with a non default label (for example, `forbidden_packet_t`). So, no `unlabeled_t` packet goes through anymore. This allows us to toggle the default acceptance of packets on and off easily without rebuilding SELinux policies.

To assign a packet, we need to define a set of rules that match a particular network flow. It is a common practice to create a separate chain for the security markings, and jump to this chain when needed. So let's start with an example of marking incoming HTTP packets (and connection) as `http_server_packet_t`, by performing the following steps:

1. First, we define the `SEL_M_HTTP` custom chain (which is an arbitrary name) for the security table. If the security table is not present on the system, we can use the mangle table as well (the security table is a recent addition and not fully integrated everywhere yet):

   ```
   # iptables -t security -N SEL_M_HTTP
   ```

2. Next, we label all packets that enter the chain as `http_server_packet_t`:

   ```
   # iptables -t security -A SEL_M_HTTP -j SECMARK --selctx
   system_u:object_r:http_server_packet_t:s0
   ```

3. Now we inform netfilter to save the state of the connection based on the security marking of the packet as follows:

   ```
   # iptables -t security -A SEL_M_HTTP -j CONNSECMARK –save
   ```

4. We end the custom chain with the `ACCEPT` target, so that the packets (and connection) are allowed (for the security table) and there are no more rules in this chain that need to be processed.

   ```
   # iptables -t security -A SEL_M_HTTP -j ACCEPT
   ```

We can now define a matching filter: incoming packets (our destination is a local network address) on port `80`, and jump to the `SEL_M_HTTP` custom chain if the packets match using the following command:

```
# iptables -t security -A INPUT -p tcp -d 192.168.1.1/24 --dport 80 -j
SEL_M_HTTP
```

That's it. With these rules in place, the matching packets are labeled as `http_server_packet_t`.

Differentiating between server and client communication

The SELinux policy provides a set of packet types by default, based on the service that is usually assigned to a particular port, and also on the function of the packet. Is it a client packet (sent or received by a client application) or a server packet (sent or received by a daemon)?

Consider the web server example again: we labeled it as `http_server_packet_t`, because it is a packet intended for the locally running web server. Systems that run a web browser which connects to a web server, however, would label these packets as `http_client_packet_t`, as they are intended as a client packet.

Although in both cases the rules can be quite equivalent (both can use similar or even the same filtering rules), this distinction shows one of the most important things to remember from the `SECMARK` labeling: the markings are local to the system and are never, ever exposed to the network (nor can they ever be used by other systems). A label is assigned the moment the packet enters the netfilter subsystem, but the moment it exits the subsystem the label is gone.

Work is being done to integrate default `SECMARK` labels in distributions, allowing us to enable the standard service packet labels easily. For now though, we will need to manage this ourselves.

Introducing labeled networking

Another approach to further fine-tune the access controls on network level is to introduce labeled networking. With labeled networking, security information is passed on between hosts (unlike SECMARK which only starts when the packet is received by the netfilter subsystem). This is also known as peer labeling, as the security information is passed on between hosts (peers).

The advantage of labeled networking is that security information is retained across the network, allowing an end-to-end enforcement on mandatory access control settings between systems, as well as retaining the sensitivity level of communication flows between systems. The major downside however is that this requires an additional network technology (protocol) that is able to manage labels on network packets or flows.

SELinux currently supports two implementations as part of the labeled networking approach: NetLabel/CIPSO and labeled IPSec. With NetLabel/CIPSO, only the sensitivity of the source domain is retained across the communication. Labeled IPSec supports transporting the entire security context with it.

In this book, we will focus on labeled IPSec and only briefly touch NetLabel/CIPSO, as labeled IPSec is much more common.

Common labeling approach

Quite some time ago, support for NetLabel/CIPSO and labeled IPSec has been merged in a common framework called netpeer. The netpeer approach introduces three additional privilege checks in SELinux: interface checking, node checking, and peer checking. These privilege checks are only active when labeled traffic is being used: without labeled traffic, these checks are simply ignored.

In the interface and node checks, the domain that is acting is the peer domain. For instance, if we are looking at the configuration from a web server perspective, the peer domain can be `httpd_t` (as that is the context of the socket), if the web server is initiating something, or `mozilla_t` (as that is the context of the web browser socket on the client) if the web server is receiving something.

Limiting flows based on the network interface

The idea behind interface checking is that each packet that comes into a system passes an ingress check on an interface, whereas a packet that goes out of a system passes an egress check. Ingress and egress are the SELinux permissions involved, whereas interfaces are given a security context.

Interface labels can be granted using the `semanage` tool, and are especially useful to assign sensitivity levels and categories to interfaces, as we will do in the following example where the categories for the `tap0` interface are set:

```
# semanage interface -a -t netif_t -r s0-s0:c0.c128 tap0
```

Similar to the other `semanage` commands, we can also view the current mappings as follows:

```
# semanage interface -l
SELinux Interface             Context
tap0                          system_u:object_r:netif_t:s0-s0:c0.c128
```

As the communication flows originate from a peer label (as with the web server and client example) we will see, on the server side, the `mozilla_t` ingress activity, and not `httpd_t` ingress. The following denial confirms this as follows:

```
type=AVC msg=audit(1372954432.866:1592): avc:  denied  { ingress
} for  pid=0 comm="swapper/1" saddr=192.168.100.1 src=40854
daddr=192.168.100.152 dest=80 netif=eth0 scontext=staff_u:staff_r:mozi
lla_t:s0 tcontext=system_u:object_r:netif_t:s0 tclass=netif
```

Accepting communication from selected hosts

Nodes represent specific hosts (or network of hosts) that data is sent towards (`sendto`) or received from (`recvfrom`) and are handled through the SELinux node class. Just like with interfaces, these can be listed and defined by the `semanage` tool. In the following example, we mark the `10.0.0.0/8` network with the `node_t` type, as follows:

```
# semanage node -a -t node_t -p tcp 10.0.0.0/8
# semanage node -l
IP Address         Netmask            Protocol Context
10.0.0.0           255.0.0.0          ipv4  system_u:object_r:node_t:s0
```

Similarly, as activity will be seen originating from the peer label, we will see the `recvfrom` activity on the server side for the `mozilla_t` peer, as shown in the following denial:

```
type=AVC msg=audit(1372954797.871:1636): avc:  denied  { recvfrom
} for  pid=0 comm="swapper/1" saddr=192.168.100.1 src=40864
daddr=192.168.100.152 dest=80 netif=eth0 scontext=staff_u:staff_r:mozi
lla_t:s0 tcontext=system_u:object_r:node_t:s0 tclass=node
```

Verifying peer-to-peer flow

The final check is a peer class check. In case of labeled IPSec, this is the label of the socket that is sending out the data (`mozilla_t`). For NetLabel/CIPSO however, the peer will be static, based on the source, as NetLabel (actually CIPSO) is only able to pass on sensitivity levels. A common label seen for Netlabel is `netlabel_peer_t`.

The following is an example of an `AVC` denial on the peer class:

```
type=AVC msg=audit(1372954885.960:1659): avc:  denied  { recv
} for  pid=9 comm="rcu_preempt" saddr=192.168.100.1 src=40870
daddr=192.168.100.152 dest=80 netif=eth0 scontext=system_u:system_r:ht
tpd_t:s0 tcontext=staff_u:staff_r:mozilla_t:s0 tclass=peer
```

As we can see, unlike the interface and node checks, peer checks have the peer domain as the target rather than the source. In this example, we saw that the `httpd_t` domain (local) does not have the right to receive traffic from the `mozilla_t` peer.

In all of theprevious examples, the process listed in the denial has nothing to do with the actual denial. This is because the denial is triggered from within a kernel subsystem rather than through a call made by a user process. As a result, an unrelated process that was interrupted while the denial was being prepared is listed.

Example – labeled IPSec

Although setting up and maintaining an IPSec setup is far beyond the scope of this book, let us look at a simple IPSec example to show how labeled IPSec is enabled on such a system. In the example, a simple IPSec tunnel is set up between two hosts.

Setting up regular IPSec

First, the `racoon` daemon is configured with information about the pre-shared key (to use during the handshake with the remote side), handshake details for the remote side, and association information for the "joined" networks. The following code is an excerpt of the `racoon` configuration file:

```
# File contains remote address with a shared key, like:
# 192.178.100.153 ThisIsABigSecret
path pre_shared_key "/etc/racoon/psk.txt";
remote 192.168.100.153 { … };
sainfo address 10.1.2.0/24 any address 10.1.3.0/24 any { … };
```

Most distributions offer sane defaults for the `racoon` configuration. In the preceding example, the `192.168.100.153` IP address is the address of the remote side, whereas, the `sainfo` address ranges are used for the VPN (`10.1.2.0/24` is local, `10.1.3.0/24` is remote).

The `setkey` information (to manipulate the IPSec SA/SP databases) looks as follows:

```
#!/usr/sbin/setkey -f
flush; spdflush;
spdadd 10.1.2.0/24 10.1.3.0/24 any -P out ipsec esp/
tunnel/192.168.1.5-192.168.100.153/require;
spdadd 10.1.3.0/24 10.1.2.0/24 any -P in ipsec esp/
tunnel/192.168.100.153-192.168.1.5/require;
```

With the following proper routing information at hand, any communication towards an address at the remote site (`10.1.3.0/24`) will go through this IPSec tunnel as follows:

```
# ip addr add 10.1.2.1/24 dev eth0
# ip route add to 10.1.3.0/24 via 10.1.2.1 src 10.1.2.1
```

Enabling labeled IPSec

To enable labeled IPSec, we need to inform IPSec to add a context on the security policy database. Once enabled, `racoon` will automatically negotiate labeled IPSec support. Adding a context to the SPD is a matter of adding a `-ctx` option to the `spdadd` commands in the `setkey` configuration. For instance, we can add the `ipsec_spd_t` context to an IPSec security policy as follows:

```
spdadd … -ctx 1 1 "system_u:object_r:ipsec_spd_t:s0" -P out ipsec …
```

With this change in place, we can see the context in the output of `setkey -DP` as shown in the following example:

```
# setkey -DP
…
10.1.2.0/24[any] 10.1.3.0/24[any] 255
        out prio def ipsec
        esp/tunnel/192.168.100.152-192.168.100.153/require
        created: Jul  4 21:45:44 2013  lastused:
        lifetime: 0(s) validtime: 0(s)
        security context doi: 1
        security context algorithm: 1
        security context length: 33
        security context: system_u:object_r:ipsec_spd_t:s0
        spid=1 seq=0 pid=3237
        refcnt=1
```

When an IPSec connection (by setting up security associations) is set up to the other site, the following set of permissions are checked:

- The SELinux domain of the client (for example, `ping_t` for the ping command or `ssh_t` for the SSH client) must have `polmatch` permissions against the `ipsec_spd_t` type through the association class

- The SELinux domain of the target on the server (for example, `kernel_t` for replying to `ping` commands, or `sshd_t` for the SSH server) must have `polmatch` permissions against the `ipsec_spd_t` type through the association class

Once set up, the following permissions are needed for the communication flow to work properly:

- The SELinux domains of the client (`ping_t` or `ssh_t`) and server (`kernel_t` or `sshd_t`) must have `sendto` rights on their own domains (actually the domain of the socket it uses, but that is almost always the type of the application itself) through the association class
- The SELinux domains of the server (`kernel_t` or `sshd_t`) and client (`ping_t` or `ssh_t`) must have receive (`recv`) rights against the client or server domains (which are known as the peer domain) through the peer class

The permissions work in both ways because the examples are using packets being sent in both ways. In case of a single direction flow, this is of course not necessary.

The huge advantage here is that the client and server contexts are sent over the wire, including the sensitivity and categories.

About NetLabel/CIPSO

With NetLabel/CIPSO support, traffic is labeled with sensitivity information that can be used across the network. Unlike labeled IPSec, no other context information is sent over. So when we see communication flows, they will originate from a single base context, but will have sensitivity labels based on the sensitivity label of the remote side.

With NetLabel, mappings are defined that inform the system which communication flows (from particular interfaces, or even from particular IP addresses), are for a certain **DOI** (**Domain Of Interpretation**). The CIPSO standard defines the DOI as a collection of systems which interpret the CIPSO label similarly, or in our case, use the same SELinux policy and configuration of sensitivity labels.

With the mappings in place, NetLabel/CIPSO will pass on the sensitivity information (and categories) between hosts. The context we will see on the communication flows will be `netlabel_peer_t`, a default context assigned to NetLabel/CIPSO originated traffic.

Through this approach, we can start daemons with a particular sensitivity range and thus only accept connections from users or clients that have the right security clearance, even on remote, NetLabel / CIPSO-enabled systems.

Summary

SELinux by default uses access controls based on the TCP and UDP ports and the sockets that are bound on them. This is configurable through the `semanage` command. More advanced communication control can be accomplished through Linux netfilter support, using the `SECMARK` labeling, and through peer labeling.

In case of `SECMARK` labeling, local firewall rules are used to map contexts to packets, which are then governed through SELinux policy. In case of peer labeling, either the application context itself (in case of labeled IPSec) or its sensitivity level (in case of netfilter/CIPSO support) is used. This allows an almost application-to-application network flow control through SELinux policies.

In the next chapter, we will see how to enhance the SELinux policy ourselves, not only through the SELinux Booleans already available, but also through the creation of additional types (which can be used for the `SECMARK` labeling), user domains, application policies, and many more.

6
Working with SELinux Policies

Until now, we have been working with an existing SELinux policy by tuning our system to deal with the proper SELinux contexts, assigning the right labels on files, directories, and even network ports. In this chapter we will:

- Manipulate conditional SELinux policy rules through booleans
- Create our own SELinux policy modules and use this to enhance the SELinux policies on our systems

Manipulating SELinux policies

One of the methods for manipulating SELinux policies is by toggling SELinux Booleans.

An SELinux Boolean is a flag that, when enabled or disabled, changes the active SELinux rules in the policy. Booleans are used by policy writers to make conditional rules which can then be triggered by administrators to enable or disable additional access controls.

For instance, a Boolean called `httpd_can_sendmail` enables additional SELinux rules to allow web servers to send mail. The web servers are then allowed to execute `sendmail`-like applications or connect to SMTP and POP ports. If the Boolean is disabled, the web server does not have these privileges.

Overview of SELinux Booleans

An overview of SELinux Booleans can be obtained using the `semanage` command with the `boolean` option. On a regular system, we can easily find over a hundred SELinux Booleans, so it is necessary to filter out the description of the Boolean we need:

```
# semanage boolean -l | grep httpd_can_sendmail
httpd_can_sendmail             (off  ,  off)  Determine whether httpd can
send mail.
```

The output not only gives us a brief description of the Boolean, but also the current value (actually, it gives us the value that is pending a policy change and the current value, but this will almost always be the same).

Another method for getting the current value of a Boolean is through the `getsebool` application as follows:

```
# getsebool httpd_can_sendmail
httpd_can_sendmail --> off
```

Changing Boolean values

We can change the value of the Boolean using `setsebool` or `togglesebool`. The latter application flips the value, whereas `setsebool` sets it to the provided value as follows:

```
# setsebool httpd_can_sendmail on
# togglesebool httpd_can_sendmail
```

After the preceding `togglesebool` happens, the value is back to `off`.

SELinux Booleans have a default state defined by the policy administrator. Changing the value using `setsebool` or `togglesebool` updates the current policy, but this does not persist across reboots. In order to keep the changes permanently, add the `-P` option to `setsebool` as follows:

```
# setsebool -P httpd_can_sendmail on
```

Another way to persist the `boolean` settings is to use `semanage boolean` as follows:

```
# semanage boolean -m -1 httpd_can_sendmail
```

In this case, the `boolean` value is modified (`-m`) to `on` (`-1`).

Persisting the changes will take a while (whereas non-persistent changes are almost instantaneous) as the SELinux policy is being rebuilt. The larger the SELinux policy on a system, the more time it takes.

Inspecting the impact of Boolean

To find out what a Boolean does, the description usually suffices, but sometimes we might want to know which SELinux rules change when a boolean is toggled. With the `sesearch` application we can query the SELinux policy, including the rules that are affected by a Boolean. To show this information in detail, we use the `-b` option (for the boolean) and `-C` option (to show conditional rules):

```
$ sesearch -b httpd_can_sendmail -ACT
    Found 33 semantic av rules:
    …
    DT allow httpd_t bin_t : dir { getattr search open } ; [ httpd_can_
    sendmail ]
    DT allow httpd_sys_script_t smtp_client_packet_t : packet { send recv
    } ; [ httpd_can_sendmail ]
    DT allow httpd_t pop_client_packet_t : packet { send recv } ; [ httpd_
    can_sendmail ]
    DT allow httpd_t smtp_port_t : tcp_socket { recv_msg send_msg name_
    connect } ; [ httpd_can_sendmail ]
    …
```

In the example, we can see the two characters, `DT`. These inform us about the state of the boolean in the policy (first character) and when the SELinux rule is enabled (second character).

The state reflects if the boolean is currently disabled (**D**) or enabled (**E**). The rule state itself tells us when the displayed rule is active: when the boolean is enabled (**T** for true) or disabled (**F** for false). So, "**DT**" means that the boolean (shown at the end of the line) is currently disabled in the policy, and that the SELinux rule will become active if the boolean is enabled.

When we query the SELinux policy, it makes sense to always add the conditional option so that we can easily see if the policy supports a certain access based on one or more Booleans. This is specially the case when we consider web servers, as the web server policy has many booleans.

```
$ sesearch -s httpd_t -t user_home_t -p read -AC
    Found 1 semantic av rules:
    DT allow httpd_t user_home_t : file { ioctl read getattr lock open } ;
    [ httpd_read_user_content ]
```

Enhancing SELinux policies

Not all situations can be perfectly defined by policy writers. At times, we will need to make modifications to the SELinux policy. As long as the changes involve adding rules, we can create additional SELinux modules to enhance the policy. If the change is more intrusive, we might need to remove an existing SELinux module and replace it with an updated one.

Let's start with SELinux policy modules.

Handling SELinux policy modules

SELinux policy modules are, as mentioned at the beginning of this book, sets of SELinux rules that can be loaded and unloaded. They are packaged as files with the `.pp` suffix and can be loaded and unloaded using the `semodule` command as follows:

```
# cd /usr/share/selinux/mcs
# semodule -i screen.pp
```

To list the current set of installed (loaded) modules, use `semodule -l`:

```
# semodule -l
aide    1.6.1
apache  2.7.0 Disabled
application     1.2.0
authlogin       2.4.2
…
```

The output shows each SELinux module with its version (as provided by the policy authors). In the example we saw that the Apache module (which provides the web server policies) is disabled: although loaded in memory, none of its rules are active on the system.

Disabling modules is not done often, but one of the reasons would be when a module (say `wikiwiki.pp`) requires another module (similar to `apache.pp` because it refers to SELinux types provided by the `apache.pp` module), but we don't want this module to be active. In that case, we can load the module (so that dependent modules can work) and disable it.

To enable or disable modules, use `semodule -e` (enable) or `-d` (disable):

```
# semodule -d apache
```

Knowing how to handle SELinux modules is important when we enhance the existing policy, as these enhancements will be done using SELinux modules.

Troubleshooting using audit2allow

When SELinux prevents certain actions, we already know it will log the appropriate denial in the audit logs. Consider the following denials:

```
type=AVC msg=audit(1373121736.897:6882): avc:  denied  { use } for
pid=15069 comm="setkey" path="/dev/pts/0" dev="devpts" ino=3 scontext=
root:sysadm_r:setkey_t:s0-s0:c0.c1023 tcontext=root:staff_r:newrole_t
:s0-s0:c0.c1023 tclass=fd
type=AVC msg=audit(1373121736.907:6883): avc:  denied  { search }
for  pid=15069 comm="setkey" name="/" dev="dm-4" ino=2 scontext=root:
sysadm_r:setkey_t:s0-s0:c0.c1023 tcontext=system_u:object_r:var_t:s0
tclass=dir
```

If there is no solution offered by `sealert` other than running `audit2allow`, and a quick investigation reveals that there are no SELinux Booleans using which we can toggle to allow this, then we only have few options left. We can refuse to handle this solution, telling the user to log in directly as `sysadm_r` (as then no `newrole` command needs to be invoked, so the file descriptor that `setkey` wants to use will not have the `newrole_t` type), but let us use this as an example to enhance the policy.

The `audit2allow` application transforms a denial or a set of denials into SELinux allow rules. Then, it can build an SELinux policy module based on these allow rules, which we can then load in memory.

```
$ grep setkey /var/log/audit/audit.log | audit2allow
#============= setkey_t ==============
allow setkey_t newrole_t:fd use;
allow setkey_t var_t:dir search;
```

Based on the denials, two allow rules are prepared. We can also ask `audit2allow` to immediately create a SELinux module as follows:

```
$ grep setkey /var/log/audit/audit.log | audit2allow -M localpolicy
```

A file called `localpolicy.pp` will be available in the current directory, which we can load in memory using `semodule -i localpolicy.pp`. We only need to do this once as the loaded modules are retained across reboots.

We can improve `audit2allow` a bit more if we tell it to use reference policy macros.

Using refpolicy macros

The reference policy project provides distributions and policy editors with a set of functions that simplify the development of SELinux policies. As an example, let us see what the macros can do with the previous example:

```
$ grep setkey /var/log/audit/audit.log | audit2allow -R
require {
        type setkey_t;
        type newrole_t;
        class fd use;
}

#============= setkey_t ==============
allow setkey_t newrole_t:fd use;
files_search_var(setkey_t)
```

As `audit2allow -R` uses an automated approach for finding potential functions, we still need to review the results carefully.

One of the rules in the example has been written as `files_search_var(setkey_t)`. This is a reference policy macro that explains a particular SELinux rule (or set of rules) in a more human-readable way. In this case, it allows the `setkey_t` domain to search through the `var_t` labeled directories.

All major distributions base their SELinux policies upon the macros and content provided by the reference policy. The list of methods we can call while building SELinux policies is available online (`http://oss.tresys.com/docs/refpolicy/api/`) but can also be installed on our local filesystem at `/usr/share/doc/selinux-base-*` (for Gentoo) or `/usr/share/doc/selinux-policy` (for Fedora).

These named methods bundle a set of rules that are related to the functionality that we, as SELinux policy administrators, want to enable. For instance, the `storage_read_tape()` method allows us to enhance the SELinux policy to allow the given domain read access on tapes.

Using selocal

On Gentoo, a script called `selocal` is available that allows administrators to add rules to the policy. These are the rules written in the raw SELinux policy or reference policy macros, and can be documented by the administrator to keep track of the changes.

For instance, to allow all domains to send and receive unlabeled packets as follows:

```
# selocal -a "allow domain unlabeled_t:packet { send recv };" -Lb
```

Going back to our example, we had `setkey_t` trying to use a `newrole_t` file descriptor. If we investigate the SELinux policy further, we can see that `newrole_t` has an attribute called `privfd`:

```
$ seinfo -tnewrole_t -x
```

One of the reference policy methods available is `domain_use_interactive_fds()`, which allows the domains to use file descriptors of types with the `privfd` attribute set. To allow this for the `setkey_t` domain using `selocal`:

```
# selocal -a "domain_use_interactive_fds(setkey_t)" -c "Needed to get
output of setkey" -L -b
```

The `selocal` application maintains a single SELinux policy module, unlike `audit2allow` where we need to continuously create new SELinux policy modules (for example, localpolicy1, localpolicy2, and so on) as time goes by. The application also builds this module for us (`-b`) and loads it in memory (`-L`).

We can of course easily list the existing set of "enhancements" that `selocal` manages:

```
# selocal -l
23: domain_use_interactive_fds(setkey_t) # Needed to get output of setkey
```

Creating our own modules

We can always maintain our own SELinux policy modules as well. To accomplish this, we need to have at least a file with the `.te` suffix (which stands for type enforcement) and optionally an `.fc` file (file context) and `.if` (interface). All these files need to have the same base name, which will be used as a module name later.

There are two "formats" in which SELinux policy modules can be written: the native one, and the reference policy one. The native one does not understand reference policy macros but remains supported (as the reference policy builds on this). Formats using the reference policy support all functions of the "native" one as well, so this format is becoming more and more popular for building and maintaining our own modules.

Building native modules

A native SELinux policy language module starts with a line defining the name of the module, followed by a set of requirements (types or attributes, classes, and permissions) and then the rules themselves, as follows:

```
module localpolicy 1.0;
require {
  type setkey_t;
  type newrole_t;
  class fd { use };
}
allow setkey_t newrole_t:fd use;
```

The `localpolicy.te` file can then be transformed into an intermediate module file as follows:

```
$ checkmodule -M -m -o localpolicy.mod localpolicy.te
```

Then, the SELinux policy module is built as follows:

```
$ semodule_package -o localpolicy.pp -m localpolicy.mod
```

The resulting `localpolicy.pp` file can then be loaded in memory using `semodule`.

Building reference policy modules

In case of a reference policy module, a similar structure as with the native format is used, but the leveraging functions provided by the various SELinux policy module definitions are as follows:

```
policy_module(localpolicy, 1.0)
gen_require('
  type setkey_t;
')
domain_use_interactive_fds(setkey_t)
```

The `localpolicy.te` file can then be built using a specific `Makefile` command on the system which transforms the functions to the raw SELinux policy rules and builds the policy packages afterwards. On Gentoo systems, `Makefile` resides in `/usr/share/selinux/mcs/include` while Fedora has it in `/usr/share/selinux/devel`:

```
$ make -f /usr/share/selinux/devel/Makefile localpolicy.pp
```

Now the `localpolicy.pp` file is created and can be loaded using `semodule -i`.

Creating roles and user domains

One of the best features of SELinux is its ability to confine end users and only grant them the rights they need to do their job. To accomplish this, we need to create a restricted user domain that these users should use (either immediately, or after switching from their standard role to the more privileged role).

Such user domains and roles need to be created through SELinux policy enhancements. These enhancements, however, require a deep understanding of the available permission checks, reference policy macros and more, which one can only obtain through experience (or assistance). Still, that shouldn't prevent us from giving a working example of how to create a special end user role and domain for the PostgreSQL administration.

The pgsql_admin role and user

First, let us look at the file. Each line is commented to explain why the various methods are used as follows:

```
policy_module(pgsql_admin, 1.0)
# Define the pgsql_admin_r role
role pgsql_admin_r;
# Create a pgsql_admin_t type that has minimal rights a regular
# user domain would need in order to work on a Linux system
userdom_base_user_template(pgsql_admin)
# Allow the pgsql_admin_t type to execute regular binaries (f.i. id)
corecmd_exec_bin(pgsql_admin_t)
# Allow the user domain to read its own selinux context
selinux_getattr_fs(pgsql_admin_t)
# Allow the user to administer postgresql, but do not fail
# if no postgresql SELinux module is loaded yet
optional_policy('
        postgresql_admin(pgsql_admin_t, pgsql_admin_r)
')
# To allow transition from staff_r to pgsql_admin_r
gen_require('
        role staff_r;
')
allow staff_r pgsql_admin_r;
```

Creating the user rights

With this policy loaded, the `pgsql_admin_r` and `pgsql_admin_t` role and types are now available. Next, we create a SELinux user called `pgsql_admin_u` that is allowed access to the `staff_r` role (for non-privileged activities), `system_r` role (for handling the PostgreSQL service) and `pgsql_admin_r` role (for administering the PostgreSQL files and commands) as follows:

```
# semanage user -a -R "staff_r system_r pgsql_admin_r" pgsql_admin_u
```

Now we need to map one or more users to this SELinux user, assuming the user is named `janedoe`, as follows:

```
# semanage login -a -s pgsql_admin_u janedoe
```

Now we need to reset the contexts of the user, as the contexts of all files now need to be changed, as follows:

```
# restorecon -RvF /home/janedoe
```

Finally we need to edit the `sudoers` file, so that every command the user launches through `sudo` will be with the `pgsql_admin_r` role (and in the `pgsql_admin_t` domain):

```
janedoe ALL=(ALL) ROLE=pgsql_admin_r TYPE=pgsql_admin_t ALL
```

With these changes in place, the user can now log in and handle PostgreSQL. By default, `janedoe` will remain logged in through the `staff_r` role (and in the `staff_t` domain), so that most end user commands work. The moment a more privileged activity needs to be launched, `janedoe` has to use `sudo`. As the user is not in the `wheel` group, using `su` to get a root shell is not possible. And through `sudo`, this and the `pgsql_admin_t` domain will fail as well as the does not have the right to execute a shell.

Still, the `pgsql_admin_t` domain has enough rights to manage PostgreSQL as `janedoe` can restart the service or even edit its configuration file:

```
$ sudo rc-service postgresql-9.2 start
* Starting PostgreSQL...    [ ok ]
$ sudo vim /etc/postgresql-9.2/pg_hba.conf
```

By updating the policy as additional rights are needed, the `pgsql_admin_t` domain can become a better match for the requirements that the user can have in his job.

Shell access

Eventually, users might want to ask for shell access, either indirectly (through `sudo`) or perhaps immediately after login (so that the user can log in to the `pgsql_admin_r` role directly). This is not a problem for SELinux, even if that would mean that the user now holds a root shell: SELinux still prevents the user from making changes that the user is not allowed to.

By adding `corecmd_exec_shell(pgsql_admin_t)`, the user is allowed to run shells. Still, because the `pgsql_admin_t` type is forced on the user, the security impact on the system is still quite low.

If we want a user to be logged in directly to the new type, a few more changes are needed.

First, we need to create a default context file for the SELinux user (in `/etc/selinux/mcs/contexts`). We can work from a copy (for instance from `staff_u`) and substitute `staff_r` with `pgsql_admin_r` everywhere. This file will tell SELinux what the default type should be when a login is handled through one of the mentioned contexts.

Next, the `/etc/selinux/mcs/default_type` file has to be updated to tell SELinux that `pgsql_admin_t` is the default type for the `pgsql_admin_r` role (as a fallback).

Finally, we need to add a few more privileges to the policy as follows:

```
# Unprivileged login shell
userdom_restricted_user_template(pgsql_admin)
# Allow sudo to be called
sudo_role_template(pgsql_admin, pgsql_admin_r, pgsql_admin_t)
```

With these changes in place, we can update the role mappings for the user to only contain `pgsql_admin_r system_r` (don't forget to reset the contexts of the user files) as follows:

```
# semanage user -m -R "pgsql_admin_r system_r" pgsql_admin_u
```

Creating new application domains

By default, Linux distributions come with many prepackaged application domains. However, we will most likely come across situations where we need to build our own application policy.

Building such a policy can be to allow a particular application to run without SELinux protections (by marking the domain as a permissive domain) or perhaps with more controls that are currently in place.

Unlike users and roles, application domains usually have file context-related information with them.

An example application domain

The following SELinux policy is for `mojomojo`, an open source, catalyst-based wiki. The code is pretty light in weight as it is a web application. Thus, calling a template for the web server module (`apache_content_template`) that provides most of the rules already:

```
policy_module(mojomojo, 1.1.0)
# Create all types based on the apache content template
apache_content_template(mojomojo)
# Needed by the mojomojo application
allow httpd_mojomojo_script_t httpd_t:unix_stream_socket rw_stream_
socket_perms;
# Network connectivity
corenet_sendrecv_smtp_client_packets(httpd_mojomojo_script_t)
corenet_tcp_connect_smtp_port(httpd_mojomojo_script_t)
corenet_sendrecv_smtp_client_packets(httpd_mojomojo_script_t)
# Additional File system access
files_search_var_lib(httpd_mojomojo_script_t)
# Networking related activities (name resolving & mail sending)
sysnet_dns_name_resolve(httpd_mojomojo_script_t)
mta_send_mail(httpd_mojomojo_script_t)
```

This is not much different from the user domain module we created earlier. Obviously, there are lots of different calls, but the method is the same. Let us look at the file context definition file (`mojomojo.fc`):

```
/usr/bin/mojomojo_fastcgi\.pl    --      gen_
context(system_u:object_r:httpd_mojomojo_script_exec_t,s0)
/usr/share/mojomojo/root(/.*)?  gen_context(system_u:object_r:httpd_
mojomojo_content_t,s0)
/var/lib/mojomojo(/.*)? gen_context(system_u:object_r:httpd_mojomojo_
rw_content_t,s0)
```

The first column is the same as we used with the `semanage fcontext` command. The `--` in the first line tells the SELinux policy that the regular expression is only for a regular file. Again, just like what we could do with `semanage fcontext`.

The last column is a reference policy macro again. The macro generates the right context as well as the target policy based on the options given. If the target policy is MLS-enabled, then the sensitivity level is also used (`s0`), otherwise it is dropped.

Creating interfaces

When we are building a policy for end user applications, we will eventually need to tell SELinux that existing (and new) roles and types are allowed to execute the new application. Although we can do this through standard SELinux rules, it is much more flexible to create an interface for this. Regular rules that refer to several types break the isolation provided by SELinux policy modules. Interfaces allow us to group rules coherently.

As an example, let us look at the interfaces of the `zosremote` module (in the `zosremote.if` file), which is as follows:

```
interface('zosremote_domtrans','
        gen_require('
                type zos_remote_t, zos_remote_exec_t;
        ')
        corecmd_search_bin($1)
        domtrans_pattern($1, zos_remote_exec_t, zos_remote_t)
')
interface('zosremote_run','
        gen_require('
                attribute_role zos_remote_roles;
        ')
        zosremote_domtrans($1)
        roleattribute $2 zos_remote_roles;
')
```

The interface file provides the following interfaces:

- `zosremote_domtrans`: It allows a given domain to transition to the `zosremote_t` domain upon executing a file labeled `zos_remote_exec_t`
- `zosremote_run`: It allows a given domain to transition to the `zosremote_t` domain, but also ensures that `zosremote_t` is allowed for the given role

The difference lies with the use: `zosremote_domtrans` will be used for transitions between applications, whereas `zosremote_run` will be used for users (and user roles). For instance, to allow our PostgreSQL user to run `zosremote` applications, we need to execute the following code:

```
zosremote_run(pgsql_admin_t, pgsql_admin_r)
```

Other uses of policy enhancements

Throughout the book, we covered quite a few technological features of SELinux. By creating our own SELinux policies, we can augment this further.

Creating customized SECMARK types

A use case for building our own policy is to create a custom `SECMARK` type and make sure that a particular domain is the only domain that is allowed to handle this communication.

The following SELinux rules create an `invalid_packet_t` type (to match packets that should not be sent out, for example, the PostgreSQL communication that is directed to the Internet rather than the internal network) and an `intranet_packet_t` type (to match packets being sent to an intranet server):

```
type invalid_packet_t;
corenet_packet(invalid_packet_t)
type intranet_packet_t;
corenet_packet(intranet_packet_t)
```

With these rules loaded, we can now create `SECMARK` rules that label packets with `invalid_packet_t` and `intranet_packet_t`.

The next step is to allow certain domains to send and receive `intranet_packet_t`. For instance, for `nginx_t` (a reverse proxy application, which is shown in the following code) it makes sense to keep this rule close to the packet definitions as they are very much related:

```
allow nginx_t intranet_packet_t:packet { send recv };
```

Using different interfaces and nodes

In the *Chapter 5, Controlling Network Communications*, we also discussed the ability to put labels on interfaces and nodes (hosts). To create types for network interfaces and nodes, the following SELinux rules can be used:

```
gen_require('
  attribute netif_type;
')
# Mark external_netif_t as a network interface.
# There is no macro for this (yet) though.
type external_netif_t, netif_type;
# Create a node for vpn addresses
type vpn_node_t;
corenet_node(vpn_node_t)
```

Once these policy enhancements are loaded, the `external_netif_t` and `vpn_node_t` interface types are available to use with `semanage interface` and `semanage node`.

Auditing access attempts

Some applications have privileges that we still want to be notified about when they are used. The Linux auditing subsystem has powerful features to be notified about various activities on the system, and SELinux enhances those capabilities by supporting the `auditallow` statement.

The `auditallow` SELinux statement has a similar syntax as the regular `allow` statement. But instead of telling SELinux that the access is allowed, it tells SELinux that the access, if it is allowed, should still be logged to the audit subsystem.

When this occurs, we will see a `granted` statement (rather than a denial) as follows:

```
# The SELinux auditallow statement; domain is an attribute that is
# assigned to all application domains.
auditallow domain etc_runtime_t:file write;
# The resulting AVC "granted" statement
type=AVC msg=audit(1373135944.183:209339): avc:  granted  { write }
for  pid=23128 comm="umount" path="/etc/mtab" dev="md3" ino=135500
scontext=pgsql_admin_u:sysadm_r:mount_t tcontext=root:object_r:etc_
runtime_t tclass=file
```

From the (`granted`) message, we can devise that the `pgsql_admin_u` SELinux user called `umount` has resulted in the modification of `/etc/mtab`.

Creating customizable types

To create a customizable type, we need to create the type definition in SELinux (which is a regular file type), grant the correct users (and applications) access to the type, and then register the type as customizable (so that a `relabel` operation does not change the type back).

For instance, we want to have a separate type for an embedded database file used by end users through the `sqlite3` command (which does not run in its own domain, it runs in the caller domain, so `user_t` or `staff_t`). By using a separate type, other access to the file (by applications that run in a different domain) is by default denied, even when those other applications have access to the (standard) `user_home_t` type:

```
gen_require('
  type user_t;
')
```

```
type mydb_embedded_t;
files_type(mydb_embedded_t)
allow user_t mydb_embedded_t:file { manage_file_perms relabel_file_
perms };
```

Next, we edit the `/etc/selinux/mcs/contexts/customizable_types` file and add the `mydb_embedded_t` type to it.

With those steps completed, all users (in the `user_t` domain) can now use `chcon` to label a file as `mydb_embedded_t` and (still) use this file through `sqlite` (or other application programs that run in the user domain).

Summary

We saw how to toggle SELinux policy Booleans using tools such as `setsebool` and to get more information about Booleans, both from their description (using `semanage boolean`) and the rules they influence (using `sesearch`).

Next, we created our own policy modules to enhance the SELinux policy using various examples such as user domain definitions, web application types, `SECMARK` types, and many more.

With all this completed, we now have all the experience needed to successfully administer a SELinux system.

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