RS Switch Router
RapidOS
User Guide

Release 9.4

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REGULATORY COMPLIANCE INFORMATION

This product complies with the following:

SAFETY

UL 1950; CSA C22.2, No. 950; 73/23/EEC; EN 60950; IEC 950

ELECTROMAGNETIC

FCC Part 15; CSA C108.8; 89/336/EEC; EN 55022; EN 61000-3-2

COMPATIBILITY (EMC)

EN 61000-3-3; EN 50082-1, AS/NZS 3548; VCCI V-3

REGULATORY COMPLIANCE STATEMENTS

Note Complies with Part 68, FCC rules.
FCC Registration Number 6TGUSA-46505-DE-N
Riverstone Networks, Inc.
Model WICT1-12
Made in U.S.A.

FCC COMPLIANCE STATEMENT

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment uses, generates, and can radiate radio frequency energy and if not installed in accordance with the operator's manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause interference in which case the user will be required to correct the interference at his own expense.

Warning Changes or modifications made to this device that are not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

INDUSTRY CANADA COMPLIANCE STATEMENT

This digital apparatus does not exceed the Class A limits for radio noise emissions from digital apparatus set out in the Radio Interference Regulations of the Canadian Department of Communications.

Le présent appareil numérique n'émet pas de bruits radioélectriques dépassant les limites applicables aux appareils numériques de la class A prescrites dans le Règlement sur le brouillage radioélectrique édicté par le ministère des Communications du Canada.

NOTICE: The Industry Canada label identifies certified equipment. This certification means that the equipment meets telecommunications network protective, operational, and safety requirements as prescribed in the appropriate Terminal Equipment Technical Requirements document(s). The department does not guarantee the equipment will operate to the user's satisfaction.

Before installing this equipment, users should ensure that it is permissible to be connected to the facilities of the local telecommunications company. The equipment must also be installed using an acceptable method of connection. The customer should be aware that compliance with the above conditions may not prevent degradation of service in some situations.

Repairs to certified equipment should be coordinated by a representative designated by the supplier. Any repairs or alterations made by the user to this equipment, or equipment malfunctions, may give the telecommunications company cause to request the user to disconnect the equipment.

Users should ensure for their own protection that the electrical ground connections of the power utility, telephone lines, and internal metallic water pipe system, if present, are connected together. This precaution may be particularly important in rural areas.

CAUTION: Users should not attempt to make such connections themselves, but should contact the appropriate electric inspection authority, or electrician, as appropriate.

NOTICE: The Ringer Equivalence Number (REN) assigned to each terminal device provides an indication of the maximum number of terminals allowed to be connected to a telephone interface. The termination on an interface may consist of any combination of devices subject only to the requirement that the sum of the Ringer Equivalence Numbers of all the devices does not exceed 5.

VCCI COMPLIANCE STATEMENT

This is a Class A product based on the standard of the Voluntary Control Council for Interference by Information Technology Equipment (VCCI). If this equipment is used in a domestic environment, radio disturbance may arise. When such trouble occurs, the user may be required to take corrective actions.

この装置は，情報処理装置等電波障害自主規制協議会（ＶＣＣＩ）の基準に基づくクラスＡ情報技術装置です。この装置を家庭環境で使用すると電波妨害を引き起こすことがあります。この場合には使用者が適切な対策を講ずるよう要求されることがあります。

BSMI (TAIWAN BUREAU OF STANDARDS, METROLOGY AND INSPECTION, MINISTRY OF ECONOMIC AFFAIR)WARNING:

Warning: This is a Class A product. In a domestic environment this product may cause radio interference..

警告使用者：
這是甲類的資訊產品，在居住的環境中使用時，可能會造成
干擾，在這種情況下，使用者會被要求採取某些適當的對

SAFETY INFORMATION: CLASS 1 LASER TRANSCEIVERS

This product may use Class 1 laser transceivers. Read the following safety information before installing or operating this product.

The Class 1 laser transceivers use an optical feedback loop to maintain Class 1 operation limits. This control loop eliminates the need for maintenance checks or adjustments. The output is factory set and does not allow any user adjustment. Class 1 laser transceivers comply with the following safety standards:

- 21 CFR 1040.10 and 1040.11, U.S. Department of Health and Human Services (FDA)
- IEC Publication 825 (International Electrotechnical Commission)
- CENELEC EN 60825 (European Committee for Electrotechnical Standardization)

When operating within their performance limitations, laser transceiver output meets the Class 1 accessible emission limit of all three standards. Class 1 levels of laser radiation are not considered hazardous.

INFORMACIÓN SOBRE LA SEGURIDAD: TRANSMISOR/RECEPTOR LASER DE CLASE 1

Este producto puede utilizar transmisores/receptores láser de Clase 1. Lea la siguiente información de seguridad antes de instalar u operar este producto.

Los transmisores / receptores láser de Clase 1 utilizan un circuito óptico de control de retroalimentación para mantenerse dentro de los límites operativos de la Clase 1. Debido al uso del circuito de control, no es necesario llevar a cabo ajustes o revisiones de mantenimiento. La potencia ha sido configurada en la

fábrica y no puede ser ajustada por el usuario. Los transmisores / receptores láser de Clase 1 cumplen con las siguientes normas de seguridad:

- 21 CFR 1040.10 y 1040.11, Departamento de Salud y Servicios Humanos de los Estados Unidos (Administración de Alimentos y Fármacos)
- Publicación 825 de la IEC (Comisión Internacional Electrotécnica)
- CENELEC EN 60825 (Comité Europeo para la Estandarización Electrotécnica)

Al operar el equipo dentro de sus limitaciones de rendimiento, la potencia del transmisor / receptor láser cumple con los límites de emisión de las tres normas anteriores para los equipos de Clase 1. Los niveles de radiación permitidos por la Clase 1 no se consideran peligrosos.

LASER RADIATION AND CONNECTORS

When the connector is in place, all laser radiation remains within the fiber. The maximum amount of radiant power exiting the fiber (under normal conditions) is –12.6 dBm or 55 x 10^{-6} watts.

Removing the optical connector from the transceiver allows laser radiation to emit directly from the optical port. The maximum radiance from the optical port (under worst case conditions) is 0.8 W cm^{-2} or 8 x 10^{3} W m^{2} sr–1.

Do not use optical instruments to view the laser output. The use of optical instruments to view laser output increases eye hazard. When viewing the output optical port, power must be removed from the network adapter.

RADIACIÓN LÁSER Y CONECTORES

Una vez que el conector se encuentra en su sitio, toda la radiación láser permanece dentro de la fibra. La cantidad máxima de poder radiante que emana de la fibra (bajo condiciones normales) es de –12.6 dBm ó 55 x 10^{-6} vatios.

La remoción del conector óptico del transmisor / receptor permite que la radiación láser sea emitida directamente desde el puerto óptico. La radiación máxima emitida por el puerto óptico (en el peor de los casos) es de 0.8 W cm^{-2} ó 8 x 10^{3} W m^{2} sr–1.

No utilice instrumentos ópticos para visualizar la potencia del láser. El uso de instrumentos ópticos para visualizar la potencia del láser aumenta el riesgo de presentar lesiones en los ojos. Al visualizar la potencia del puerto óptico, es necesario cortar la corriente del adaptador de la red.

SAFETY INFORMATION: WICT1-12 T1 CARD

Warning To reduce the risk of fire, use only No. 26 AWG or larger telecommunication line cord.

Warning Para reducir el riesgo de un incendio, únicamente utilice un conductor del número 26 AWG o mayor para la línea de telecomunicaciones.

CONSUMER INFORMATION AND FCC REQUIREMENTS

1. This equipment complies with Part 68 of the FCC rules, FCC Registration Number 6TGUSA-46505-DE-N Riverstone Networks Inc. Model WICT1-12 Made in the USA. On the DS1/E1 WAN Module of this equipment is a label that contains, among other information, the FCC registration number and Ringer Equivalence Number (REN) for this equipment. If requested, provide this information to your telephone company.
2. The REN is useful to determine the quantity of devices you may connect to your telephone and still have all those devices ring when your number is called. In most, but not all areas, the sum of the REN's of all devices should not exceed five (5.0). To be certain of the number of devices you may connect to your line, as determined by the REN, you should call your local telephone company to determine the maximum REN for your calling area.
3. If your DS1/E1 WAN Module causes harm to the telephone network, the Telephone Company may discontinue your service temporarily. If possible, they will notify you in advance. But if advance notice isn't practical, you will be notified as soon as possible. You will be advised of your right to file a complaint with the FCC.
4. Your telephone company may make changes in its facilities, equipment, operations, or procedures that could affect the proper operation of your equipment. If they do, you will be given advance notice so as to give you an opportunity to maintain uninterrupted service.
5. If you experience trouble with this equipment DS1/E1 WAN Module, please contact Riverstone Networks Inc., 5200 Great America Parkway, Santa Clara, CA 95054, 408 878-6500, for repair/warranty information. The Telephone Company may ask you to disconnect this equipment from the network until the problem has been corrected or you are sure that the equipment is not malfunctioning.
6. There are no repairs that can be made by the customer to the DS1/E1 WAN Module.
7. This equipment may not be used on coin service provided by the Telephone Company. Connection to party lines is subject to state tariffs. (Contact your state public utility commission or corporation commission for information).

EQUIPMENT ATTACHMENT LIMITATIONS NOTICE

The Industry Canada label identifies certified equipment. This certification means that the equipment meets the telecommunications network protective, operational and safety requirements as prescribed in the appropriate Terminal Equipment Technical Requirements document(s). The Department does not guarantee the equipment will operate to the user's satisfaction.

Before installing this equipment, users should ensure that it is permissible to be connected to the facilities of the local telecommunications company. The equipment must also be installed using an acceptable method of connection. The customer should be aware that the compliance with the above conditions may not prevent degradation of service in some situations.

Repairs to certified equipment should be coordinated by a representative designated by the supplier. Any repairs or alterations made by the user to this equipment, or equipment malfunctions, may give the telecommunications company cause to request the user to disconnect the equipment.

Users should ensure for their own protection that the electrical ground connections of the power utility, telephone lines and internal metallic water pipe system, if present, are connected together. This precaution may be particularly important in rural areas.

Caution: Users should not attempt to make connections themselves, but should contact the appropriate electric inspection authority, or electrician, as appropriate.

NOTICE: The Ringer Equivalence Number (REN) assigned to each terminal device provides an indication of maximum number of terminals allowed to be connected to a telephone interface. The termination on an interface may consist of any combination of devices subject only to the requirement that the sum of the Ringer Equivalence Numbers of all the devices does not exceed 5.

RIVERSTONE NETWORKS, INC.
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9. **LIMITATION OF LIABILITY.** Your exclusive remedy for any claim in connection with the Licensed Materials and the entire liability of Riverstone are set forth in the Riverstone Standard Limited Warranty. Except to the extent provided there, if any, IN NO EVENT WILL RIVERSTONE OR ITS AFFILIATES OR SUPPLIERS BE LIABLE FOR ANY LOSS OF USE, INTERRUPTION OF BUSINESS, LOST PROFITS OR LOST DATA, OR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES OF ANY KIND, REGARDLESS OF THE FORM OF ACTION, WHETHER IN CONTRACT, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY OR OTHERWISE, EVEN IF RIVERSTONE OR ITS AFFILIATE OR SUPPLIER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGE, AND WHETHER OR NOT ANY REMEDY PROVIDED SHOULD FAIL OF ITS ESSENTIAL PURPOSE. THE TOTAL CUMULATIVE LIABILITY TO YOU, FROM ALL CAUSES OF ACTION AND ALL THEORIES OF LIABILITY, WILL BE LIMITED TO AND WILL NOT EXCEED THE PURCHASE PRICE OF THE LICENSED MATERIALS PAID BY YOU. YOU ACKNOWLEDGE THAT THE AMOUNT PAID FOR THE LICENSED MATERIALS REFLECTS THIS ALLOCATION OF RISK.

10. **GENERAL**. The provisions of the Agreement are severable and if any one or more of the provisions hereof are illegal or otherwise unenforceable, in whole or in part, the remaining provisions of this Agreement shall nevertheless be binding on and enforceable by and between the parties hereto. Riverstone's waiver of any right shall not constitute waiver of that right in future. This Agreement (including the documents it incorporates) constitutes the entire understanding between the parties with respect to the subject matter hereof, and all prior agreements, representations, statements and undertakings, oral or written, are hereby expressly superseded and canceled. No purchase order shall supersede this Agreement. The rights and obligations of the parties to this Agreement shall be governed and construed in accordance with the laws of the State of California, excluding the UN Convention on Contracts for the International Sale of Goods and that body of law known as conflicts of laws. Any dispute in connection with the Licensed Materials will be resolved in state or federal courts located in Santa Clara County, California, U.S.A.. You consent to the personal jurisdiction of and waive any objections to venue in such courts.

RIVERSTONE STANDARD WARRANTY

A. Product Warranty

i. RIVERSTONE warrants that each unit of Hardware Products will be free from defects in material and workmanship for a period of one (1) year from the date of shipment.

ii. Breach of warranty will be enforceable against RIVERSTONE only if written notice of such breach is received by RIVERSTONE within the applicable warranty period.

iii. If a warranty claim is invalid for any reason, PURCHASER will be charged for services performed and expenses incurred by RIVERSTONE in repairing, handling and shipping the returned item.

iv. Expendable parts, such as fuses, lamps, filters, and other parts that are regularly replaced due to normal use are excluded from this warranty.

v. As to replacement parts supplied for a Product or repairs performed to a Product during the original warranty period for such Product, the warranty period on the replacement part or the repaired part shall terminate thirty (30) days after shipment or upon the termination of the warranty period applicable to the original item, whichever is longer.

vi. As to any out-of-warranty parts repaired, modified or replaced by RIVERSTONE at RIVERSTONE's regular charges, the warranty period with respect to the material and workmanship hereunder shall expire thirty (30) days after the date of shipment of said part.

B. Software Warranty. The only warranty RIVERSTONE makes to PURCHASER in connection with the Licensed Materials is that the media upon which the Licensed Materials are recorded will be replaced without charge, if RIVERSTONE in good faith determines that the media was defective and not subject to misuse.

C. Return to Factory.

i. If Parts, Products or Licensed Materials under warranty are claimed to be defective, RIVERSTONE must be notified by PURCHASER prior to the return of said Part, Product, or Licensed Materials. Within ten (10) days of the date of said notification RIVERSTONE will provide PURCHASER with a valid Return Material Authorization number, the location to which PURCHASER must return the shipment claimed to be defective, and the method of transportation. In no event will RIVERSTONE accept any returned part or Product which does not have a valid Return Material Authorization number.

ii. Within ten (10) days of receipt of notice from RIVERSTONE requiring return, PURCHASER shall deliver said shipment to a carrier at PURCHASER's facilities as aforesaid.

iii. Within thirty (30) days of receipt of same, RIVERSTONE shall use reasonable efforts to fix or replace, at its option, any defective Product or Licensed Material which RIVERSTONE has determined to be under warranty.

iv. Transportation costs relating to warranty claims will be borne by RIVERSTONE only in cases where repair or replacement is made and authorized pursuant hereto, but any applicable duties will be paid by PURCHASER. If no warranty repair or replacement was required, all transportation costs will be borne by PURCHASER. "Emergency" transportation costs shall be borne by PURCHASER or its Customer.

D. Installation Warranty: RIVERSTONE warrants that all Installation Services rendered pursuant hereto shall be accomplished in a good and workmanlike manner and shall be free of defects in workmanship for a period of ninety (90) days from the date that such services were rendered.

E. General

i. The above warranties are for the benefit of and shall apply only to PURCHASER.

ii. RIVERSTONE's warranties shall not apply to any Product or Licensed Material which has been subjected to accident, neglect, misuse, abuse, vandalism, negligence in transportation or handling, failure of electric power, air conditioning, humidity control, causes other than ordinary use, or causes beyond RIVERSTONE's control, or if the Product or Licensed Material was not properly maintained by PURCHASER during the warranty period.

iii. There shall be no warranty or liability for any Product or Licensed Materials which have been modified by PURCHASER without RIVERSTONE's prior written approval.

iv. Parts or Replacement Products or Licensed Materials outside the scope of these warranties or with respect to Product(s) or Licensed Material out-of-warranty will be furnished at the established charges of RIVERSTONE then

in effect.

v. RIVERSTONE shall have full and free access to the Products and Licensed Materials at PURCHASER's Customer's site, if required.

vi. RIVERSTONE shall not be responsible for failure to furnish Parts due to causes beyond its control. RIVERSTONE shall not be required to replace any Part if it would be impractical for RIVERSTONE personnel to do so because of unauthorized alterations to the Products or its unauthorized connection by mechanical or electrical means to another system or device.

F. Limitation of Liability

i. THESE WARRANTIES AND RIVERSTONE'S AND ITS AFFILIATES LIABILITY AND PURCHASER'S REMEDIES WITH RESPECT THERETO, AS SET FORTH HEREIN, ARE EXCLUSIVE AND EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES, LIABILITIES, REMEDIES, EXPRESS OR IMPLIED, INCLUDING ANY OBLIGATION, LIABILITY, RIGHT, CLAIM, OR REMEDY IN TORT, WHETHER OR NOT ARISING FROM NEGLIGENCE OF RIVERSTONE OR ITS AFFILIATES, ACTUAL OR IMPUTED, AND NO WARRANTIES, EXPRESS OR IMPLIED REPRESENTATIONS, PROMISES OR STATEMENTS HAVE BEEN MADE BY RIVERSTONE OR ITS AFFILIATES UNLESS CONTAINED IN THIS AGREEMENT. NO WARRANTY, EXPRESS OR IMPLIED, IS MADE HEREIN THAT THE LICENSED MATERIALS, PRODUCTS OR ANY PARTS ARE MERCHANTABLE, OR FIT OR SUITABLE FOR THE PARTICULAR PURPOSES FOR WHICH THE LICENSED MATERIALS, PRODUCTS OR PARTS MAY BE ACQUIRED BY PURCHASER. IN NO EVENT SHALL RIVERSTONE OR ITS AFFILIATES BE LIABLE TO PURCHASER FOR ANY INDIRECT, INCIDENTAL, OR CONSEQUENTIAL DAMAGES INCLUDING WITHOUT LIMITATION, LOSS OF DATA, OR PROFITS, WHETHER CLAIMED BY REASON OF BREACH OF WARRANTY OR OTHERWISE, AND WITHOUT REGARD TO THE FORM OF ACTION IN WHICH SUCH CLAIM IS MADE.

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iii. Notwithstanding anything contained herein to the contrary, the total maximum liability of RIVERSTONE and it's Affiliates under this warranty is limited, at the option of RIVERSTONE, to either

(a) RIVERSTONE's use of reasonable efforts to repair any item, or part thereof; or

(b) RIVERSTONE's use of reasonable efforts to replace any item, or part thereof, or any shipment as to which any defect is claimed by PURCHASER and duly verified by RIVERSTONE; or

(c) The refund of the purchase price.

DECLARATION OF CONFORMITY ADDENDUM

Application of Council Directive(s)	89/336/EEC 73/23/EEC
Manufacturer's Name	Riverstone Networks, Inc.
Manufacturer's Address	5200 Great America Parkway Santa Clara, CA 95054
Conformance to Directive(s)/Product Standards	EC Directive 89/336/EEC EC Directive 73/23/EEC EN 55022 EN 50082-1 EN 60950
Equipment Type/Environment	Networking equipment for use in a commercial or light-industrial environment

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1 INTRODUCTION

This manual provides information for configuring the Riverstone RS Switch Router software. It details the procedures and provides configuration examples. If you have not yet installed the RS, use the instructions in the *Riverstone RS Switch Router Getting Started Guide* to install the chassis and perform basic setup tasks, then return to this manual for more detailed configuration information.

1.1 RELATED DOCUMENTATION

The Riverstone RS Switch Router documentation set includes the following items. Refer to these other documents to learn more about your product.

For Information About	See
Installing and setting up the RS	*Riverstone RS Switch Router Getting Started Guide*
Syntax for CLI commands	*Riverstone RS Switch Router Command Line Interface Reference Manual*

1.2 DOCUMENT CONVENTIONS

Commands shown in this manual use the following conventions:

Convention	Description
boldface	Indicates commands and keywords that you enter as shown.
<*italics*>	Indicates arguments for which you supply values.
[**x**] or [<*italics*>] or [**x** <*italics*>]	Keywords and arguments within a set of square brackets are optional.
x|y|z|<*italics*> or [**x|y|z|**<*italics*>]	Keywords or arguments separated by vertical bars indicate a choice. Select one keyword or argument.
{**x|y|z|**<*italics*>}	Braces group required choices. Select one keyword or argument.

2 MAINTAINING CONFIGURATION FILES

This chapter provides information about configuration files in the Riverstone RS Switch Router (RS). It explains the different types of configuration files and the different procedures involved in changing, displaying, saving, and backing up the files.

2.1 CONFIGURATION FILES

The *Riverstone RS Switch Router Getting Started Guide* introduced the following configuration files used by the RS:

- **Startup** – The configuration file that the RS uses to configure itself when the system is powered on. The Startup configuration remains even when the system is rebooted.
- **Active** – The commands from the Startup configuration file and any configuration commands that you have made active from the scratchpad. The active configuration remains in effect until you power down or reboot the system.

Caution The active configuration remains in effect only during the current power cycle. If you power off or reboot the RS without saving the active configuration changes to the Startup configuration file, the changes are lost.

- **Scratchpad** – The configuration commands you have entered during a CLI session. These commands are temporary and do not become active until you explicitly make them part of the active configuration.

Because some commands depend on other commands for successful execution, the RS scratchpad simplifies system configuration by allowing you to enter configuration commands in any order, even when dependencies exist. When you activate the commands in the scratchpad, the RS sorts out the dependencies and executes the command in the proper sequence.

The following figure illustrates the configuration files and the commands you can use to save your configuration:

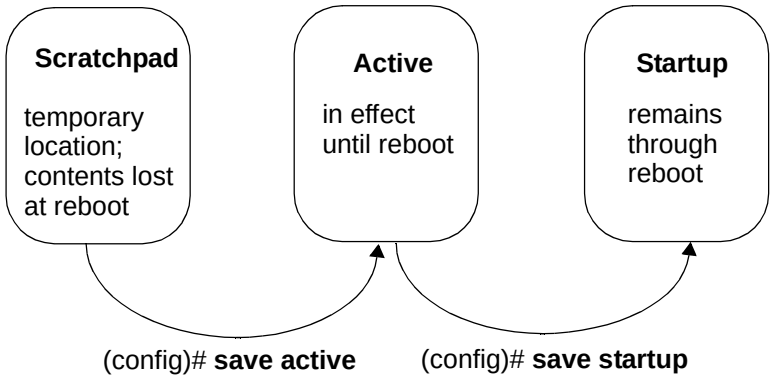


Figure 2-1 Commands to save configurations

2.1.1 Changing Configuration Information

The RS provides many commands for changing configuration information.

Use the **negate** command on a specific line of the active configuration to "disable" a feature or function which has been enabled.

Table 2-1 Commands to change configuration information

Task	Command
Enable Mode:	
Copy between scratchpad, active configuration, startup configuration, TFTP server, RCP server, or URL.	**copy** <*source*> **to** <*destination*>
Configure Mode:	
Erase commands in scratchpad.	**erase scratchpad**
Erase startup configuration.	**erase startup**
Negate one or more commands by line numbers.	**negate** <*line number*>
Negate commands that match a specified command string.	**no** <*string*>
Save scratchpad to active configuration.	**save active**
Save active configuration to startup.	**save startup**

2.1.2 Displaying Configuration Information

The following table lists the commands that are useful for displaying the RS's configuration information.

Table 2-2 Commands to display configuration information

Task	Command
Enable Mode:	
Show active configuration of the system.	**system show active**
Show the non-activated configuration changes in the scratchpad.	**system show scratchpad**
Show the startup configuration for the next reboot.	**system show startup**
Configure Mode:	
Show active configuration of the system.	**show active**
Show the non-activated configuration changes in the scratchpad.	**show scratchpad**
Show the startup configuration for the next reboot.	**show startup**
Show the running system configuration, followed by the non-activated changes in the scratchpad.	**show**
Compare activated commands with the startup configuration file.	**diff** <*filename*> | **startup**

The **show** and **system show** commands display the commands in the order they were executed. You can change this sequence to alphabetical order by using the **system set show-config** command.

2.1.3 Activating the Configuration Commands in the Scratchpad

The configuration commands you have entered using procedures in this chapter are in the Scratchpad but have not yet been activated. Use the following procedure to activate the configuration commands in the scratchpad.

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Ensure that you are in Configure mode by entering the **configure** command in the CLI.
3. Enter the following command:

```
save active
```

The CLI displays the following message:

```
Do you want to make the changes Active? [y]
```

4. Type **y** to activate the changes.

Note If you exit the Configure mode (by entering the **exit** command or pressing **Ctrl+Z**), the CLI will ask you whether you want to make the changes in the scratchpad active.

2.1.4 Saving the Active Configuration to the Startup Configuration File

After you save the configuration commands in the scratchpad, the control module executes the commands and makes the corresponding configuration changes to the RS. However, if you power off or reboot the RS, the new changes are lost. Use the following procedure to save the changes into the Startup configuration file so that the RS reinstates the changes when you reboot the software.

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Enter the following command to copy the configuration changes in the Active configuration to the Startup configuration:

```
copy active to startup
```

3. When the CLI displays the following message, enter **yes** to save the changes.

```
Are you sure you want to overwrite the Startup configuration? [n]
```

Note You also can save active changes to the Startup configuration file from within Configure mode by entering the **save startup** command.

The new configuration changes are added to the Startup configuration file stored in the control module's boot flash.

2.1.5 Viewing the Current Configuration

To view the current configuration:

1. Ensure that you are in Enable mode by entering the **enable** command in the CLI.
2. Enter the following command to display the status of each command line:

```
system show active-config
```

The CLI displays the active configuration file with the following possible annotations:

- Commands without errors are displayed without any annotation.
- Commands with errors are annotated with an "E."

- If a particular command has been applied such that it can be expanded on additional interfaces/modules, it is annotated with a “P”. For example, if you enable STP on all ports in the current system, but the RS contains only one module, then the command to enable STP will be applied at a later date when more modules have been added.

  A command like **`stp enable et.*.*`** would be displayed as follows:

```
P: stp enable et.*.*
```

  This indicates that it is only partially applied. If you add more modules to the RS at a later date and then update the configuration file to encompass all of the available modules in the RS, then the **`P:`** portion of the above command line would disappear when this configuration file is displayed.

  If a command that was originally configured to encompass all of the available modules on the RS becomes only partially active (after a hotswap or some such chassis reconfiguration), then the status of that command line automatically changes to indicate a partial completion status, complete with **`P:`**.

Note Commands with no annotation or annotated with **`P:`** are not in error.

2.1.6 Backing Up and Restoring Configuration Files

When you save the startup configuration file, the RS stores it in three places: in the bootflash and the PC card of the primary control module, and if there is a redundant control module, in its PC flash card as well. It is recommended that you store a backup of the startup configuration file in the boot flash of the control module and on a central server. Use the **`copy`** command in Enable mode to store a backup copy of the startup configuration file in the control module, backup control module (if applicable), and on a server:

`copy startup to backup-CM|tftp-server|rcpserver|`<*filename*>|<*url*>

For example, to make a backup in the control module, specify the following command in Enable mode:

```
copy startup to startup.bak
```

If the startup file becomes corrupted, the RS uses its default configuration. You can then use the copy command to copy the backup file to the startup, as shown in the following example:

```
copy startup.bak to startup
```

Use the **`file`** commands in Enable mode to display, rename, and delete the configuration files stored on the primary control module:

Table 2-3 File commands

Display a directory of the files in the bootflash or in the PC card.	**file dir** <*device*>
Display the contents of a file in the bootflash.	**file type [**<*device*>**:]**<*filename*>
Delete the specified file.	**file delete [**<*device*>**:]**<*filename*>
Copy a file to a different device and/or filename.	**file copy [**<*device1*>**:]**<*source-filename*> **[**<*device2*>**:]**<*dest-filename*>
Erase all files on the specified device.	**file reformat** <*device-name*>
Rename a file.	**file rename [**<*device*>**:]**<*source-filename*> <*dest-filename*>

Note The **file** commands apply to devices and files in the primary Control Module. You cannot display, delete, or rename files in the backup Control Module. You can, however, use the CLI **copy** command to copy configuration files from the primary Control Module to the backup Control Module.

2.1.7 Specifying Primary and Backup Configuration Files

When the RS boots up, it uses the startup configuration file to configure itself. Use the **system set sys-config** command in Enable mode to specify both a primary and secondary configuration file. When the RS boots, it will try to use the primary configuration file. If for some reason the RS cannot use the file, then it automatically uses the secondary configuration file. Following is an example:

```
rs# system set sys-config primary config_a secondary config_b
```

2.2 BACKING UP AND RESTORING SYSTEM IMAGE FILES

When you boot up the system, the RS boots up the system image off the PC flash card. The PC flash card contains the run-time image (the PC flash may store up to two images, depending on its capacity) and the startup configuration file.

It is recommended that a backup of the system image be stored on a central server in the unlikely event that the system image becomes corrupted or deleted from the PC flash card. Use the **system set bootprom** command in Enable mode to set parameters for the RS to boot the system image remotely over a network.

```
rs# system set bootprom netaddr <IPaddr> netmask <IPnetmask> tftp-server <IPaddr>
[backup-tftp-server <IPaddr>] [tftp-gateway <IPaddr>] [primary-image <path>]
[backup-image <path>]
```

When you set the RS to boot from a TFTP server, you can specify both a primary and a backup TFTP server. Use the **system set bootprom** command in Enable mode to set the IP address for both servers. When you reboot the RS, it tries to boot from the primary TFTP server first. If that server is unavailable, the RS automatically tries to boot from the backup TFTP server.

The following example specifies the IP addresses of the primary and backup TFTP servers:

```
rs# system set bootprom tftp-server 134.141.172.5 backup-tftp-server 134.141.178.5
```

To view the boot PROM parameters and verify the IP addresses of the TFTP servers, use the **system show bootprom** command as shown in the following example

```
rs# system show bootprom
Boot Prom's parameters for TFTP network booting:
 Network address             : 0.0.0.0
 Network mask                : 0.0.0.0
 TFTP server                 : 134.141.172.5
 Gateway to reach TFTP server: 0.0.0.0
 Backup TFTP server          : 134.141.178.5
 Primary bootsource          : /rs803
 Backup bootsource           : /qa/ros803
```

The following example shows the messages displayed on the console as the RS boots up. It tries to boot from the primary TFTP server *(134.141.172.5)* and when it is unable to do so, it boots from the backup TFTP server *(134.141.178.5)*.

```
.
.
.
Autoboot in 2 seconds - press RETURN to abort and enter prom


primary source: tftp://134.141.172.5/qa/ros803
couldn't open 134.141.172.5:qa/ros803 for reading
  Kernel not found or lost in transmission
secondary source: tftp://134.141.178.5/qa/ros803
 File: version (874 bytes)
  Build location: host 'cmbuild0' by 'mhaydt'
  Version: 8.0.3.0-A06
.
.
.
```

For even greater redundancy, you can specify a primary and backup system image. Use the **system set bootprom** command in Enable mode to specify both the primary and secondary system image files. When you reboot the RS, it tries to boot the primary system image from the primary TFTP server and from the backup TFTP server. If that fails, then the RS tries to boot the backup system image from the primary TFTP server, and then from the backup TFTP server.

The following example specifies the primary and backup system images:

```
rs# system set bootprom primary image rs803 backup-image /qa/ros803
```

Use the **system show bootprom** command to display your settings:

```
rs# system show bootprom
Boot Prom's parameters for TFTP network booting:
 Network address             : 0.0.0.0
 Network mask                : 0.0.0.0
 TFTP server                 : 134.141.123.3
 Gateway to reach TFTP server: 0.0.0.0
 Backup TFTP server          : 134.141.178.5
 Primary bootsource          : /rs803
 Backup bootsource           : /qa/ros803
```

The following example shows the messages the RS displays on the console as it tries to boot the system image software.

```
.
.
.
Autoboot in 2 seconds - press RETURN to abort and enter prom
primary source: tftp://134.141.123.3/rs803
couldn't open 134.141.123.3:rs803 for reading
  Kernel not found or lost in transmission
secondary source: tftp://134.141.178.5/rs803
couldn't open 134.141.178.5:rs803 for reading
  Kernel not found or lost in transmission
primary source: tftp://134.141.123.3/qa/ros803
couldn't open 134.141.123.3:qa/ros803 for reading
  Kernel not found or lost in transmission
secondary source: tftp://134.141.178.5/qa/ros803
 File: version (874 bytes)
  Build location: host 'cmbuild0' by 'mhaydt'
  Version: 8.0.3.0-A06
.
.
.
```

As shown in the example, the RS tried to boot the primary system image (*rs803*) from the primary TFTP server *(134.141.123.3)*, and then from the backup TFTP server *(134.141.178.5)*. When the RS was unable to boot the primary image, it tried to boot the backup system image *(qa/ros803)* from the primary TFTP server, and then from the backup TFTP server.

Note If the RS has a backup Control Module (CM), changes made to the primary CM using the **`system set bootprom`** command are not automatically propagated to the backup CM. You must specify this command on the backup CM as well.

If the RS boots up from the PC flash card and cannot find a valid image, it goes into boot prom mode. If the en0 interface is configured and connected to a network, you can download an image to the PC flash by using the **`system image add`** command in Enable mode. If the en0 interface has not been configured, then you will need to configure it by specifying the following: IP address and netmask of the RS, IP address of the TFTP server, and IP address of the default gateway. Use the following commands in boot mode:

`set net-addr` *<IP-address>*
`set netmask` *<netmask>*
`set boot-addr` *<tftp-server address>*
`set gateway` *<IP-address of default gateway>*

Then, boot the RS by specifying the following command:

`boot` *<directory/filename of the image file to boot from>*

Alternatively, you can use the **`set boot source`** command:

```
set boot source <filename>
```

Once the RS has booted from the TFTP server image through en0, you can add the new image to the PC card by using the **`system image add`** command.

Additionally, you can use the following commands to display, add, and delete system images:

Table 2-4 System image commands

Copy a system software image to the RS.	**`system image add`** *<IPaddr-or-hostname> <filename>* **`[primary-cm|backup-cm] [slot0|slot1]`**
Select a system software image for booting.	**`system image choose`** *<filename>* **`|none [primary-cm|backup-cm] [slot0|slot1]`**
Select a secondary system software image for booting.	**`system image secondary-choose`** *<filename>* **`|none [primary-cm|backup-cm] [slot0|slot1]`**
Copy a system software image from one PC card to another.	**`system image copy slot0|slot1`** *<filename>* **`slot0|slot1 [`***<filename>***`]`**
List system software images on the PC flash card.	**`system image list primary-cm|backup-cm|all`**
Delete a system software image file from the PC flash card.	**`system image delete`** *<filename>* **`primary-cm|backup-cm slot0|slot`**

2.3 CONFIGURING SYSTEM SETTINGS

In addition to the initial settings described in the *Getting Started Guide*, there are additional system features which you can set on the RS.

2.3.1 Setting Daylight Saving Time

Daylight saving time (DST) on the RS can be set three different ways:

- According to specific days. For example, from the first Sunday of April to the last Saturday of October.
- According to specific dates. For example, from April 1st to October 31st.
- By setting the RS's time forward by an hour.

When you specify the **system set dst-changing** command or the **system set dst-fixed** command in the active configuration file, the RS automatically updates the time based on the parameters you entered. When a time change happens, the RS automatically sends an informational message about the time change. Enter one of the following commands in Configure mode to set DST according to specific days or dates:

Set DST according to specific days.	**system set dst-changing s_wk** <*value*> **s_dow** <*value*> **s_mo** <*value*> **s_hr** <*value*> **s_min** <*value*> **e_wk** <*value*> **e_dow** <*value*> **e_mo** <*value*> **e_hr** <*value*> **e_min** <*value*>
Set DST according to specific dates.	**system set dst-fixed s_mo** <*value*> **s_day** <*value*> **s-hr** <*value*> **s_min** <*value*> **e_mo** <*value*> **e_day** <*value*> **e_hr** <*value*> **e_min** <*value*>

When you set DST by setting the time forward by an hour, saving it to the active configuration file automatically activates the command, causing the time to immediately change forward one hour. Use the **negate** command to set the time back. Enter the following command in Configure mode to move the time forward by an hour:

Set the time forward by one hour.	**system set dst-manual**

2.3.2 Configuring a Log-in Banner

Configure the RS to display a banner when it is booted up. You can specify a text string or the name of a file on a TFTP server.

Display a log-in banner.	**system set login banner** [<*string*> | **none|file-name** <*name*>

2.3.3 Setting the BootPROM Escape Character

When you boot the RS, you can interrupt the normal boot process and enter Boot mode. By default, you would do this by pressing the “Esc” key. You can change this default and use a character instead of the “ESC” key to interrupt the boot process. Use the **system set bootprom** command in Enable mode to specify the character, then save the command to the startup configuration file. In the following example, the character “x” is specified.

```
rs# system set bootprom esc-char x
```

Therefore, when the RS reboots and the character “x” is typed, the RS will interrupt its boot process and enter Boot mode. To change back to the default, enter the **system set bootprom** command with the keyword **ESC** as shown in the following example:

```
rs# system set bootprom esc-char ESC
```

3 USING THE CLI

This chapter provides information about the RS's Command Line Interface (CLI). It also includes example configuration which show how to use the CLI commands to configure the RS.

CLI commands are grouped by subsystems. For example, the set of commands that let you configure and display IP routing table information all start with **ip**. Within the set of **ip** commands are commands such as **set**, **show**, **start**, **stop**, **configure**, etc. The complete set of commands for each subsystem is described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

3.1 COMMAND MODES

The CLI provides access to four different command modes. Each command mode provides a group of related commands. This section describes how to access and list the commands available in each command mode and explains the primary uses for each command mode.

3.1.1 User Mode

After you log in to the RS, you are automatically in User mode. The User commands available are a subset of those available in Enable mode. In general, the User commands allow you to display basic information and use basic utilities such as ping.

The User mode command prompt consists of the RS name followed by the angle bracket (>), as shown below:

```
rs>
```

The default name is RS unless it has been changed during initial configuration. Refer to the *Riverstone RS Switch Router Getting Started Guide* for the procedures for changing the system name.

3.1.2 Enable Mode

Enable mode provides more facilities than User mode. You can display critical features within Enable mode including router configuration, access control lists, and SNMP statistics. To enter Enable mode from the User mode, enter the command **enable** (or **en**), then supply the password when prompted.

The Enable mode command prompt consists of the RS name followed by the pound sign(#):

```
rs#
```

To exit Enable mode and return to User mode, either type **exit** and press Return, or press Ctrl+Z.

3.1.3 Configure Mode

Configure mode provides the capabilities to configure all features and functions on the RS. These include router configuration, access control lists and spanning tree. To enter Configure mode, enter the command **config** from Enable mode.

Note As mentioned previously, up to four Telnet sessions can be run simultaneously on the RS. All four sessions can be in Configure mode at the same time, so you should consider limiting access to the RS to authorized users.

The Configure mode command prompt consists of the RS name followed by **(config)** and a pound sign (#):

```
rs(config)#
```

To exit Configure mode and return to Enable mode, either type **exit** and press Return, or press Ctrl+Z.

3.1.4 Boot PROM Mode

If your RS does not find a valid system image on the external PC flash, the system might enter programmable read-only memory (PROM) mode. You should then reboot the RS (enter the command **reboot** at the boot PROM prompt) to restart the system. If the system fails to reboot successfully, please call Technical Support to resolve the problem.

For information on how to upgrade the boot PROM software and boot using the upgraded image, see the *Riverstone RS Switch Router Getting Started Guide*.

3.2 ESTABLISHING TELNET SESSIONS

You can establish a management connection to the RS by connecting a terminal to the management port of the RS and by establishing a telnet connection to a remote host. To establish a telnet connection, connect your network to the 10/100 MDI port on the RS.

Note The RS allows up to four simultaneous telnet or secure shell (SSH) sessions. For more information about using SSH sessions, see Chapter 27, *"Security Configuration."*

There are commands that allow you to monitor telnet use and to end a specific telnet session. You can also specify the number of minutes a serial or telnet connection can remain idle before the connection is terminated by the control module. The default is 5 minutes. You can disable this feature, by setting the time-out value to zero.

Table 3-1 Telnet commands

Display the last five connections to the RS.	**system show telnet-access**
Specify time-out value for a serial or telnet connection.	**system set idle-time-out serial|telnet** <*num*>
Show current users and session IDs.	**system show users**
End the specified telnet session.	**system kill telnet-session** <*session-id*>

Additionally, you can telnet to another RS during a CLI session. To start a telnet session to another RS, enter the following command in User or Enable mode.

Open a telnet session to another RS.	**telnet** <*hostname-or-IPaddr*> [**socket** <*socket-number*>]

To end your telnet session, simply type **exit**.

3.2.1 Telnet Sessions with a Backup Control Module

The following section describes how to communicate with a backup Control Module on RS switch routers that support multiple Control Modules. Multiple control modules are supported on the RS 8000, RS 8600, RS 16000, RS 32000, and the RS 38000.

You can establish communication with the backup CM: through a telnet session from the primary CM to the backup CM using the keyword **`backup-cm`**. For Instance, the following example shows a telnet session from the primary CM to the backup CM.

```
telnet RS1
------------------------------------------------------------------------
RS 8000 System Software, Version 9.0
Copyright (c) 2000-2001 Riverstone Networks
System started on 2001-04-24 09:37:35
------------------------------------------------------------------------


Press RETURN to activate console . . .


rs1> enable
rs1#
rs1# telnet backup-cm
Trying 127.0.0.1, port 10130 ...
Connected to 127.0.0.1.
Escape character is '^]'.


------------------------------------------------------------------------
RS 8000 System Software, Version 9.0
Copyright (c) 2000-2001 Riverstone Networks, Inc.
System started on 2001-04-19 14:40:57
------------------------------------------------------------------------



Press RETURN to activate console . . .

rs1>$
```

Notice in the previous example that the prompt displays a dollar sign ($). This indicates that the display belongs to the backup CM. The dollar sign also appears if you connect to the backup CM through its console port.

When connected to the backup CM, you are provided with only a sub-set of the commands available on the primary CM.

For example, enter Enable mode on the backup CM, and then enter the help command (**?**). This produces the following output:

```
rs1>$enable

rs1#$?
 cli                    - Modify the command line interface behavior
 enable                 - Enable privileged user mode
 exit                   - Exit current mode
 file                   - File manipulation commands
 logout                 - Log off the system
 reboot                 - Reboot the system
 system                 - Show system global parameters
rs1#$
```

Notice that most of the Enable mode functionality is missing and there is no access to Configure mode. However, the backup CM does provide access to both the **file** and **system** facilities. These facilities allow you to do the following on the backup-CM:

- Copy files
- Delete files
- Rename files
- Reformat the file system
- List system images
- Choose system images

Note Also, you can enter the **reboot** command from the backup CM, however, the command reboots only the backup CM – the primary CM is not affected.

3.3 SETTING CLI PARAMETERS

The RS provides various commands for controlling the behavior and display of the CLI. The **cli set command completion** command controls the behavior of the CLI when you enter commands. When you turn on command completion, the CLI attempts to automatically complete a command that is partially entered. Typing enough characters of a command keyword to uniquely identify it and pressing the space bar to move to the next word, causes the CLI to complete the command word and move on.

To set command completion, enter the following command in either Configure mode or Enable mode. In Configure mode, the command turns on or off command completion for the entire system. In Enable mode, the command affects the current login session of the user issuing the command.

Turn on or turn off command completion.	**cli set command completion on|off**

The **cli set history** command specifies the number of commands that will be stored in the command history buffer. Commands stored in the buffer can be recalled without having to type the complete command again. When you hit the ↑ key, the CLI displays the commands that were entered, from the most recent. To specify the number of commands stored in the command history buffer, enter the following command in User or Configure mode.

Set the size of the command history buffer.	**cli set history size** <*num*> **|default|maxsize**

Alternatively, you can display all the commands that were executed during a CLI session. To display the CLI commands, enter the following command in User mode.

Display command history.	**cli show history**

The CLI also provides commands for setting the terminal display. Use the following commands to set and display terminal settings.

Task	**Command**
User Mode	
Set the terminal display.	**cli set terminal rows** <*num*> **columns** <*num*>
Display terminal settings.	**cli show terminal**
Enable Mode	
Display system messages.	**cli terminal monitor on|off**

3.4 GETTING HELP WITH CLI COMMANDS

Interactive help is available from CLI by entering the question mark (?) character at any time. The help is context-sensitive; the help provided is based on where in the command you are. For example, if you are at the User mode prompt, enter a question mark (?) as shown in the following example to list the commands available in User mode:

```
rs> ?
 aging - Show L2 and L3 Aging information
 cli - Modify the command line interface behavior
 dvmrp - Show DVMRP related parameters
 enable - Enable privileged user mode
```

```
 exit - Exit current mode
 file - File manipulation commands
 help - Describe online help facility
 igmp - Show IGMP related parameters
 ip-redundancy - Show IP Redundancy information (VRRP)
 l2-tables - Show L2 Tables information
 logout - Log off the system
 multicast - Configure Multicast related parameters
 ping - Ping utility
 pvst - Show Per Vlan Spanning Tree Protocol (PVST)
                          parameters
 sfs - Show SecureFast Switching (SFS) parameters
 statistics - Show or clear RS statistics
 stp - Show STP status
 telnet - Telnet utility
 traceroute - Traceroute utility
 vlan - Show VLAN-related parameters
```

You can also type the **?** character while entering in a command line to see a description of the parameters or options that you can enter. Once the help information is displayed, the command line is redisplayed as before but without the ? character. The following is an example of invoking help while entering a command:

```
rs(config)# load-balance create ?
 group-name               - Name of this Load Balanced group of servers
 vip-range-name           - Name of this Virtual IP range
rs(config)# load-balance create
```

If you enter enough characters of a command keyword to uniquely identify it and press the space bar, the CLI attempts to complete the command. If you do not enter enough characters or you enter the wrong characters, CLI cannot complete the command. For example, if you enter the following in Enable mode and press the spacebar as indicated:

```
rs# system show e[space]
```

CLI completes the command as follows:

```
rs# system show environmental
```

If you are entering several commands for the same subsystem, you can enter the subsystem name from CLI. Then, execute individual commands for the subsystem without typing the subsystem name in each time. For example, if you are configuring several entries for the IP routing table, you can simply enter **ip** at the CLI Configure prompt. The prompt changes to indicate that the context for the commands to be entered has changed to that of the IP subsystem. If you type a **?**, only those commands that are valid for the IP subsystem are displayed. The following is an example:

```
rs(config)# ip
rs(config)(ip)# ?
 add                      - Add a static route
 dos                     - Configure specific denial of service features
 disable                  - Disable certain IP function
 enable                   - Enable certain IP function
 helper-address           - Specify IP helper address for an interface
 l3-hash                  - Change IP hash variant for channel
 set                      - Set ip stack properties
 Ctrl-z                   - Exits to previous level
 top                      - Exits to the top level
rs(config)(ip)# [Ctrl-Z]
rs(config)#
```

3.5 LINE EDITING COMMANDS

The RS provides line editing capabilities that are similar to Emacs, a Unix text editor. For example, you can use certain line editing keystrokes to move forward or backward on a line, delete or transpose characters, and delete portions of a line. To use the line editing commands, you need to have a VT-100 terminal or terminal emulator. The line editing commands that you can use with CLI are detailed in the following table.

Table 3-2 CLI line editing commands

Command	Resulting Action
Ctrl-a	Move to beginning of line
Ctrl-b	Move back one character
Ctrl-c	Abort current line
Ctrl-d	Delete character under cursor
Ctrl-e	Move to end of line
Ctrl-f	Move forward one character
Ctrl-g	Abort current line
Ctrl-h	Delete character just priority to the cursor
Ctrl-i	Insert one space (tab substitution)
Ctrl-j	Carriage return (executes command)
Ctrl-k	Kill line from cursor to end of line
Ctrl-l	Refresh current line

Table 3-2 CLI line editing commands (Continued)

Command	Resulting Action
Ctrl-m	Carriage return (executes command)
Ctrl-n	Next command from history buffer
Ctrl-o	None
Ctrl-p	Previous command from history buffer
Ctrl-q	None
Ctrl-r	Refresh current line
Ctrl-s	None
Ctrl-t	Transpose character under cursor with the character just prior to the cursor
Ctrl-u	Delete line from the beginning of line to cursor
Ctrl-v	None
Ctrl-w	None
Ctrl-x	Move forward one word
Ctrl-y	Paste back what was deleted by the previous Ctrl-k or Ctrl-w command. Text is pasted back at the cursor location
Ctrl-z	If inside a subsystem, it exits back to the top level. If in Enable mode, it exits back to User mode. If in Configure mode, it exits back to Enable mode.
ESC-b	Move backward one word
ESC-d	Kill word from cursor's current location until the first white space.
ESC-f	Move forward one word
ESC-BackSpace	Delete backwards from cursor to the previous space (essentially a delete-word-backward command)
SPACE	Attempts to complete command keyword. If word is not expected to be a keyword, the space character is inserted.
!*	Show all commands currently stored in the history buffer.
!#	Recall a specific history command. '#' is the number of the history command to be recalled as shown via the '!*' command.
"<string>"	Opaque strings may be specified using double quotes. This prevents interpretation of otherwise special CLI characters.

3.6 NAMING RS PORTS

The term port refers to a physical connector on a line card installed in the RS. The figure below shows to 1000base-SX ports on a line card.

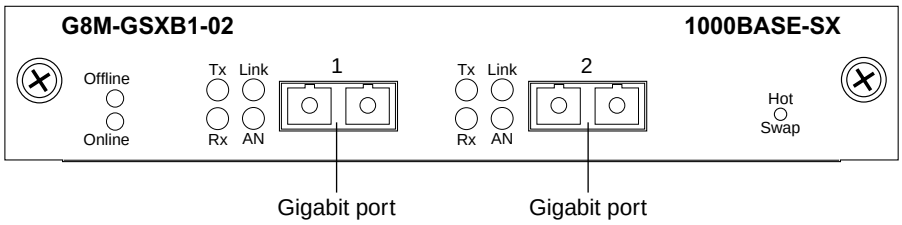


Figure 3-1 1000-Base-SX line card

At the CLI, each port is referred to RS in the following manner:

- Channelized WAN ports:

  <*type*>.<*slot-number*>.<*port-number*>[:<*channel-number*>][.<*vc*>]

- All other ports, including unchannelized T1/E1:

  <*type*>.<*slot-number*>.<*port-number*>[.<*vc*>]

Where:

<*type*> is the type of line card and is one of the following:

`at` – Asynchronous Transfer Mode (ATM)

`cm` – Cable Modem Termination System (CMTS)

`e1` – Channelized E1

`e3` – Clear Channel E3

`et` – 10 Base-*X*/100 Base-*X* Ethernet

`gi` – 1000 Base-*X* Gigabit Ethernet

`hs` – Dual HSSI WAN

`se` – Serial WAN

`so` – Packet-over-SONET (POS)

`t1` – Channelized T1

`t3` – Channelized T3 or Clear Channel T3

<*slot-number*> is determined by the RS model and the physical slot in which the line card is installed. On the RS 1000 and RS 3000 the slot number is printed on the side of each slot. On the RS 8000, RS 8600, RS 32000, and RS 38000 a legend on the fan tray shows slot number of each slot.

<*port-number*> is the number assigned to the physical connector on the line card. The range and assignment of port numbers varies by chassis and the type of line card.

For example, the port name **et.2.8** refers to a port on the Ethernet line card that is located in slot 2, connector 8, while the port name **gi.3.2** refers to a port on the Gigabit Ethernet line card located in slot 3, connector 2.

There are a few shortcut notations to reference a range of port numbers. For example:

- **et.(1-3).(1-8)** references all the following ports: **et.1.1** through **et.1.8**, **et.2.1** through **et.2.8**, and **et.3.1** through **et.3.8**
- **et.(1,3).(1-8)** references the following ports: **et.1.1** through **et.1.8**, and **et.3.1** through **et.3.8**
- **et.(1-3).(1,8)** references the following ports: **et.1.1**, **et.1.8**, **et.2.1**, **et.2.8**, **et.3.1**, **et.3.8**

The assignment of port numbers by line card is shown in Table 3-3:

Table 3-3 Port numbers for line cards

Line Card	Port Numbering (left-to-right)								
10/100 Base TX	1	2	3	4	5	6	7	8	
100 Base FX	3 1	4 2		7 5	8 6				
1000 Base SX/LX	1	2							
1000 Base LLX	1								
Quad Serial WAN	1,2	3,4							
HSSI WAN	1	2							
SONET (OC-3c)	1	2	3	4					
SONET (OC-12c)	1	2							
ATM (OC-3)	1	2							
16-slot 10/100 Base TX	2 1	4 3	6 5	8 7		10 9	12 11	14 13	16 15
Channelized T1 WIC	1	2							
Channelized E1 WIC	1	2							
Channelized T3 and Channelized E3 on the RS 8000 and the RS 8600	1	2							
Channelized T3 and Channelized E3 on the RS 32000 and the RS 38000	1	2	3	4					
Multi-rate WAN Module with a Channelized T1 or Channelized E1 WIC in each slot	1[1]	2	3	4					

Table 3-3 Port numbers for line cards (Continued)

Line Card	Port Numbering (left-to-right)						
Multi-rate WAN Module with a Clear Channel T3 or Clear Channel E3 WIC in each slot	1[1]		3				1 3
DOCSIS/EuroDOCSIS CMTS	1 US[2]	2 US	3 US	4 US	1 DS-IF[3]		
DOCSIS/EuroDOCSIS CMTS	1 US	2 US	3 US	4 US	5 US	6 US	1 DS-IF

1 – The port numbering, when using a Clear Channel T3 or E3 WIC with a Channelized T1 or E1 WIC depends on the slot in which the WIC is placed. For example, if a Clear Channel WIC is in the first slot, and a Channelized WIC in the second, then the port numbers will be 1, 3, and 4. If the position of the WICs are reversed, then the numbering will be 1, 2, and 3.

2 – Upstream port

3 – Downstream-Intermediate Frequency port

3.6.1 Channel Numbers

A channel number is the number assigned to the timeslots on a T1/E1 line card connector or the T1/E1 channels on a T3/E3 line card connector. For Channelized T1 and E1, and fractional T1 and E1 line cards, a channel always refers to a timeslot.

Channels can be specified by a single channel number, a comma-separated list of channel numbers, or a range of channel numbers. For a channel range, specify a *start-channel* and an *end-channel* – the *end-channel* value must be greater than the *start-channel* value.

For other port types, including unchannelized T1 and E1, omit the <*channel-number*> and the preceding colon (:). The <*vc*> parameter is still permitted for Frame Relay encapsulation. See Table 3-4.

Table 3-4 Channelized T1, E1 and T3 channel ranges

Range	WAN Module
1 to 24	Channelized T1
1 to 31	Channelized E1
1 to 28*	Channelized T3

* Each of these T1 lines contain 24 timeslots, where each timeslot can be considered a channel.

The following examples show the different channel specifications for T1:

`t1.3.2:5-8` – T1 line card in slot 3, port 2, and timeslots 5 through 8

`t1.3.1:(1-4,6,7)` – T1 line card in slot 3, port 1, and timeslots 1 through 4 and timeslots 6 and 7

`t3.4.2.3:1-16` – T3 line card in slot 4, port 2, T1 channel 3, and timeslots 1 through 16

3.7 MULTI-USER MODE

Multi-user mode provides the ability to give several users access to the RS CLI and control which commands each user can access. For example, if you are setting up a multi-tiered customer support organization, you may want to restrict CLI command capabilities of your first-level personnel. Second-level personnel may require more CLI command capabilities. Ultimately, you may want one or more high-level personnel to have full access to the RS CLI.

User access is configured by placing the RS into *multi-user* mode, assigning *privilege levels* to users, and defining which commands each privilege level can execute. There are 16 privilege levels: 0 through 15. Privilege level 15 (super user) has access to all CLI commands, while all other privilege levels must have their CLI commands explicitly defined.

The following three commands are used to start multi-user access and to define CLI capabilities:

`system set access-mode` – Changes the access mode from single-user to multi-user.

`system set user` – Defines user names, their passwords, and their privilege level.

`privilege` – Defines which CLI commands can be accessed by each privilege level.

3.7.1 Setting Up Multi-User Access

The following is a step-by-step example of setting up a user with minimal CLI access capabilities.

1. Place the RS into multi-user mode by entering the following command from Configuration mode:

```
rs(config)# system set access-mode multi-user
```

2. Set up a level 15 access account (super user) for yourself. This provides you access to all CLI commands. Enter the following:

```
rs(config)# system set user root password abc123 privilege 15
```

Caution Even if you later plan to give no one super user privileges, it's a good idea to set up an initial account with privilege level 15. When first working with the multi-user mode and privileges, it's possible to lock yourself out of your own RS switch Router. Having a super user account keep a lockout from occurring.

3. Create a minimum access level user named **`tier1`** by entering the following:

```
rs(config)# system set user tier1 password junior privilege 1
```

Note When entering passwords using the **`system set user`** command, passwords are not hashed on the screen. However, within the configuration file, these passwords appear as encrypted strings.

4. Use the **privilege** command to set up the minimum set of commands for level 1 users. Notice that the mode (either Enable or Configure) must be set, and that the command is entered as a string within quotes:

```
rs(config)# privilege enable level 1 command “enable”
rs(config)# privilege enable level 1 command “exit”
rs(config)# privilege enable level 1 command “configure”
rs(config)# privilege configuration level 1 command “exit”
```

The four commands above allow a level 1 user to enter and exit both the Enable and Configure mode. However, they do not allow the level 1 user to execute any commands within either of these modes. For any user below level 15, each command accessible to them must be entered using the **privilege** command.

5. Continuing with this example, use the privilege command to add additional commands to the level 1 set:

```
rs(config)# privilege enable level 1 command “cmts show modems all-ports”
rs(config)# privilege enable level 1 command “cmts show event-log local”
rs(config)# privilege configuration level 1 command “cmts set event-log alert
local-log”
rs(config)# privilege configuration level 1 command “cmts set event-log warning
local-log”
rs(config)# privilege configuration level 1 command “cmts set event-log error
local-log”
```

The commands above, allow level 1 users to execute the CMTS Enable an Configure mode commands displayed within the quotes.

Note Higher privilege levels inherit all command capabilities of all lower privilege levels. For instance, if a second privilege level (level 2) is defined, level 2 users automatically inherits all of the capabilities of level 1 users.

Note when using multi-user mode, use the **enforce-system-passwords** option of the **system set access-mode multi-user** command to use system passwords for the Enable and Diag modes.

3.7.2 Wildcard Option

From the example above, it should be apparent that whatever privilege level you assign, an extensive number of configuration commands need to be entered to define exactly what each privilege level is allowed to do.

For example, entering the following command line allows privilege level 1 users the ability to ping a particular IP address:

```
rs(config)# privilege enable level 1 command “ping 124.141.56.72”
```

However, the RS allows for the use of a wildcard symbol (*) to represent values within command lines. The wildcard is used to represent variables and keywords. For instance, considering the ping example above, level 1 users can be given the ability to ping any IP address by entering the following:

```
rs(config)# privilege enable level 1 command “ping *”
```

Because the IP address is a variable within the command line, it can be replaced by the wildcard symbol. As a result, level 1 users can now ping all IP addresses.

Suppose the next level of customer support (**tier2**) is allowed to create IP VLANs and apply interfaces to VLANs. The following example shows how the wildcard option is used to provide the flexibility to add VLANs and interfaces of any name and IP address:

```
rs(config)# system set user tier2 password midkid privilege 2
rs(config)# privilege configuration level 2 command “vlan create * ip”
rs(config)# privilege configuration level 2 command “interface create ip *
address-netmask * vlan *”
```

In the example above, the first line created the level 2 privilege group, **tier2**. The second line gives level 2 users the ability to create an IP VLAN with any name. The third line gives level 2 users the ability to create an interface with any name, to specify any address/subnet mask pair, and to assign the interface to any valid VLAN.

The following is a list the variable objects for which the wildcard (*) can be substituted.

- VLAN name
- Number – Decimal, hexadecimal, floating-point, binary, 1 or 0 used as a switch
- Numerical range
- String (user, interface name, port name, password, and so on)
- Keyword – where a keyword is the only valid entry, such as **enable** or **disable**
- IP address or IP address list
- Subnet mask
- MAC address or MAC address list
- Conditional expressions
- Module number
- Slot number
- Time – Hour, minute, second, and date
- List of logical port names

Note When negating configuration commands from within multi-user mode, not only do you need sufficient permission to use the **negate** command, but you must also have sufficient permission to run the commands you are negating

3.7.3 Configuring Multi-User Mode RADIUS Authentication

Setting the RS to multi-user mode allows multiple users to access the RS and provides the ability to control which commands each user can access. (For information on configuring the RS for multi-user mode, refer to Section 3.7.1, *"Setting Up Multi-User Access."*) When the RS is in multi-user mode, you can configure a RADIUS server to authenticate each user *and* to indicate the user's privilege level. To accomplish this, the RADIUS servers' user database must be configured to return the Riverstone-User-Level attribute along with an Access-Accept response. The Riverstone-User-Level is a Riverstone vendor-specific attribute defined in the dictionary file. (The latest revision of the dictionary file can be found on Riverstone's website.) The value of this attribute is an integer from 0 to 15 that indicates the desired privilege level.

If the RADIUS server does not include a Riverstone-User-Level attribute in the Access-Accept response, the RS will look for the standard RADIUS Service-Type attribute. If the value of this attribute is 6 (Administrative), the RS treats this as if the user has level 15 privileges, providing full access to the system. Any other value will be the same as if the attribute is not there; RapidOS will place the user at access level 1. Whenever both Riverstone-User-Level and Service-Type attributes are present in an Access-Accept response, the Riverstone-User-Level always takes precedence.

4 HOT SWAPPING LINE CARDS AND CONTROL MODULES

4.1 HOT SWAPPING OVERVIEW

Hot swapping is the ability to replace a line card, Control Module, or GBIC (in the RS 32000 and RS 38000 only) while the RS is operating. Hot swapping allows you to remove or install line cards without switching off or rebooting the RS. Swapped-in line cards are recognized by the RS and begin functioning immediately after they are installed.

On the RS 8000 and RS 8600, you can hot swap line cards and secondary control modules. On the RS 8600, you can also hot swap the secondary switching fabric module. On the RS 32000 and RS 38000, you can hot swap the GBICs, in addition to the line cards and secondary control modules.

Caution Take appropriate care when removing line cards from the RS. They may be hot to the touch.

Warning The RS and its components are sensitive to static discharge. Use an antistatic wrist strap and observe all static precautions when hot swapping the RS's components.

This chapter provides instructions for the following tasks:

- Hot swapping line cards
- Hot swapping secondary Control Modules
- Hot swapping the secondary Switching Fabric Module (RS 8600 only)
- Hot swapping the GBIC (RS 32000 and RS 38000 only)

4.2 HOT SWAPPING LINE CARDS

The procedure for hot swapping a line card consists of deactivating the line card, removing it from its slot in the RS chassis, and installing a new line card in the slot.

4.2.1 Deactivating the Line Card

To deactivate the line card, do one of the following:

- Press the Hot Swap button on the line card. The Hot Swap button is recessed in the line card's front panel. Use a pen or similar object to reach it.

  When you press the Hot Swap button, the Offline LED lights. Figure 4-1 shows the location of the Offline LED and Hot Swap button on a 1000Base-SX line card.

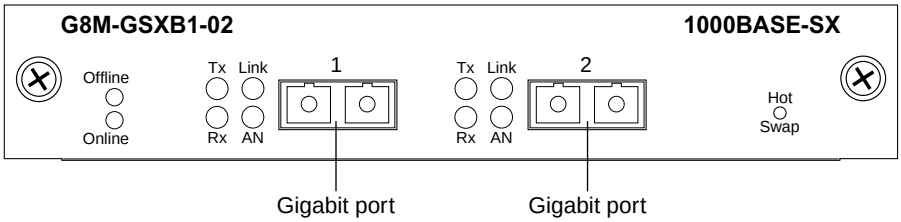


Figure 4-1 Location of offline LED and hot swap button on a 1000Base-SX line card

- Use the **`system hotswap out`** command in the CLI. For example, to deactivate the line card in slot 7, enter the following command in Enable mode:

```
rs# system hotswap out slot 7
```

After you enter this command, the Offline LED on the line card lights, and messages appear on the console indicating the ports on the line card are inoperative.

Note If you have deactivated a line card and want to activate it again, simply pull it from its slot and push it back in again. (Make sure the Offline LED is lit before you pull out the line card.) The line card is activated automatically.

Alternately, if you have not removed a line card you deactivated with the **`system hotswap out`** command, you can reactivate it with the **`system hotswap in`** command. For example, to reactivate a line card in slot 7, enter the following command in Enable mode:

```
rs# system hotswap in slot 7
```

4.2.2 Removing the Line Card

To remove a line card from the RS:

1. Make sure the Offline LED on the line card is lit.

Warning Do not remove the line card unless the Offline LED is lit. Doing so can cause the RS to crash.

2. Loosen the captive screws on each side of the line card.
3. Carefully remove the line card from its slot in the RS chassis.

4.2.3 Installing a New Line Card

To install a new line card:

1. Slide the line card all the way into the slot, firmly but gently pressing the line card fully in place to ensure that the pins on the back of the line card are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

2. Tighten the captive screws on each side of the line card to secure it to the chassis.

   Once the line card is installed, the RS recognizes and activates it. The Online LED button lights.

4.3 HOT SWAPPING ONE TYPE OF LINE CARD WITH ANOTHER

You can hot swap one type of line card with another type. For example, you can replace a 10/100Base-TX line card with a 1000Base-SX line card. The RS can be configured to accommodate whichever line card is installed in the slot. When one line card is installed, configuration statements for that line card are used; when you remove the line card from the slot and replace it with a different type, configuration statements for the new line card take effect.

To set this up, you must include configuration statements for *both* line cards in the RS configuration file. The RS determines which line card is installed in the slot and uses the appropriate configuration statements.

For example, you may have an RS with a 10/100Base-TX line card in slot 7 and want to hot swap it with a 1000Base-SX line card. If you include statements for both line cards in the RS configuration file, the statements for the 1000Base-SX take effect immediately after you install it in slot 7.

4.4 HOT SWAPPING A SECONDARY CONTROL MODULE

If you have a secondary Control Module installed on the RS, you can hot swap it with another Control Module or line card.

Warning You can only hot swap an *inactive* Control Module. You should never remove the active Control Module from the RS. Doing so will crash the system.

The procedure for hot swapping a Control Module is similar to the procedure for hot swapping a line card. You must deactivate the Control Module, remove it from the RS, and insert another Control Module or line card in the slot.

4.4.1 Deactivating the Control Module

To deactivate the Control Module:

1. Determine which is the secondary Control Module.

   Control Modules can reside in slot CM or slot CM/1 on the RS. Usually slot CM contains the primary Control Module, and slot CM/1 contains the secondary Control Module. On the primary Control Module, the Online LED is lit, and on the secondary Control Module, the Offline LED is lit.

Note The Offline LED on the Control Module has a different function from the Offline LED on a line card. On a line card, it means that the line card has been deactivated. On a Control Module, a lit Offline LED means that it is standing by to take over as the primary Control Module if necessary; it does *not* mean that the Control Module has been deactivated.

2. Press the Hot Swap button on the secondary Control Module.

   When you press the Hot Swap button, all the LEDs on the Control Module (including the Offline LED) are deactivated. Figure 4-2 shows the location of the Offline LED and Hot Swap button on a Control Module.

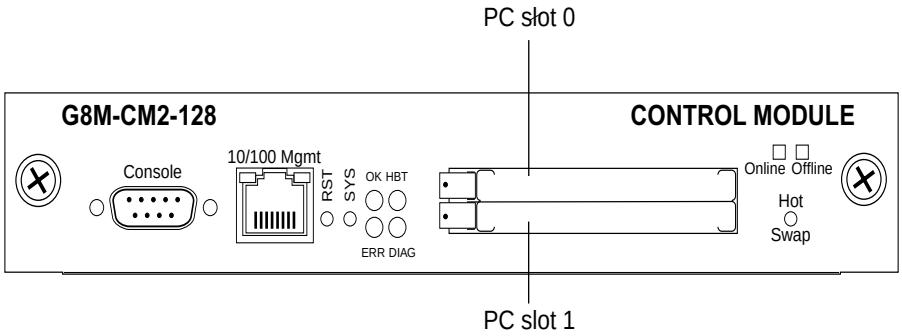


Figure 4-2 Location of offline LED and hot swap button on a control module

You can also use the **`system hotswap out`** command in the CLI to deactivate the Control Module. For example, to deactivate the secondary Control Module in slot CM/1, enter the following command in Enable mode:

```
rs# system hotswap out slot 1
```

After you enter this command, the Offline LED on the Control Module lights, and messages appear on the console indicating the Control Module is inoperative.

4.4.2 Removing the Control Module

To remove a Control Module from the RS:

1. Make sure that *none* of the LEDs on the Control Module are lit.
2. Loosen the captive screws on each side of the Control Module.
3. Carefully remove the Control Module from its slot in the RS chassis.

4.4.3 Installing a Control Module

To install a new Control Module or line card into the slot:

Note You can install either a line card or a Control Module in slot CM/1, but you can install *only* a Control Module in slot CM.

1. Slide the Control Module or line card all the way into the slot, firmly but gently pressing it in place to ensure that the pins on the back of the card are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

2. Tighten the captive screws on each side of the Control Module or line card to secure it to the chassis.
   - On a line card, the Online LED lights, indicating it is now active.
   - On a secondary Control Module, the Offline LED lights, indicating it is standing by to take over as the primary Control Module if necessary.

4.5 HOT SWAPPING A SWITCHING FABRIC MODULE (RS 8600 ONLY)

The RS 8600 has slots for two Switching Fabric Modules. While the RS 8600 is operating, you can install a second Switching Fabric Module. If two Switching Fabric Modules are installed, you can hot swap one of them.

When you remove one of the Switching Fabric Modules, the other goes online and stays online until it is removed or the RS 8600 is powered off. When the RS 8600 is powered on again, the Switching Fabric Module in slot “Fabric 1,” if one is installed there, becomes the active Switching Fabric Module.

Warning You can only hot swap a Switching Fabric Module if two are installed on the RS 8600. If only one Switching Fabric Module is installed, and you remove it, the RS 8600 will crash.

The procedure for hot swapping a Switching Fabric Module is similar to the procedure for hot swapping a line card or Control Module. You deactivate the Switching Fabric Module, remove it from the RS, and insert another Switching Fabric Module in the slot.

Note You cannot deactivate the Switching Fabric Module with the **`system hotswap`** command.

To deactivate the Switching Fabric Module:

1. Press the Hot Swap button on the Switching Fabric Module you want to deactivate.

   The Online LED goes out and the Offline LED lights. Figure 4-3 shows the location of the Offline LED and Hot Swap button on a Switching Fabric Module.

Figure 4-3 Location of offline LED and hot swap button on a switching fabric module

4.5.1 Removing the Switching Fabric Module

To remove the Switching Fabric Module:

1. Loosen the captive screws on each side of the Switching Fabric Module.
2. Pull the metal tabs on the Switching Fabric Module to free it from the connectors holding it in place in the chassis.
3. Carefully remove the Switching Fabric Module from its slot.

4.5.2 Installing a Switching Fabric Module

To install a Switching Fabric Module:

1. Slide the Switching Fabric Module all the way into the slot, firmly but gently pressing to ensure that the pins on the back of the module are completely seated in the backplane.

Note Make sure the circuit card (and not the metal plate) is between the card guides. Check both the upper and lower tracks.

2. Tighten the captive screws on each side of the Switching Fabric Module to secure it to the chassis.

4.6 HOT SWAPPING A GBIC (RS 32000 AND RS 38000 ONLY)

The Gigabit Ethernet line cards have slots for GBICs that can be installed at any time. You can hot swap the GBICs installed in the line cards, as well as the line cards themselves. (For information on hot swapping line cards, see Section 4.2, *"Hot Swapping Line Cards."*)

Warning The GBIC and the host gigabit Ethernet line cards are sensitive to static discharge. Use an antistatic wrist strap and observe all static precautions when you remove or install a GBIC. Failure to do so could result in damage to the GBIC and the host line card. Always leave the GBIC in the antistatic bag or an equivalent antistatic container until it is ready to be installed.

4.6.1 Removing a GBIC from the Line Card

To remove a GBIC from its slot on the line card:

1. Remove any cables connected to the GBIC.
2. Locate the extractor tabs on either side of the GBIC.
3. Using thumb and forefinger, compress the extractor tabs on both sides of the GBIC and pull it out of the line card. See Figure 4-4.
4. If storing or shipping the GBIC, insert the rubber dust protector into the GBIC to protect the fiber ports.

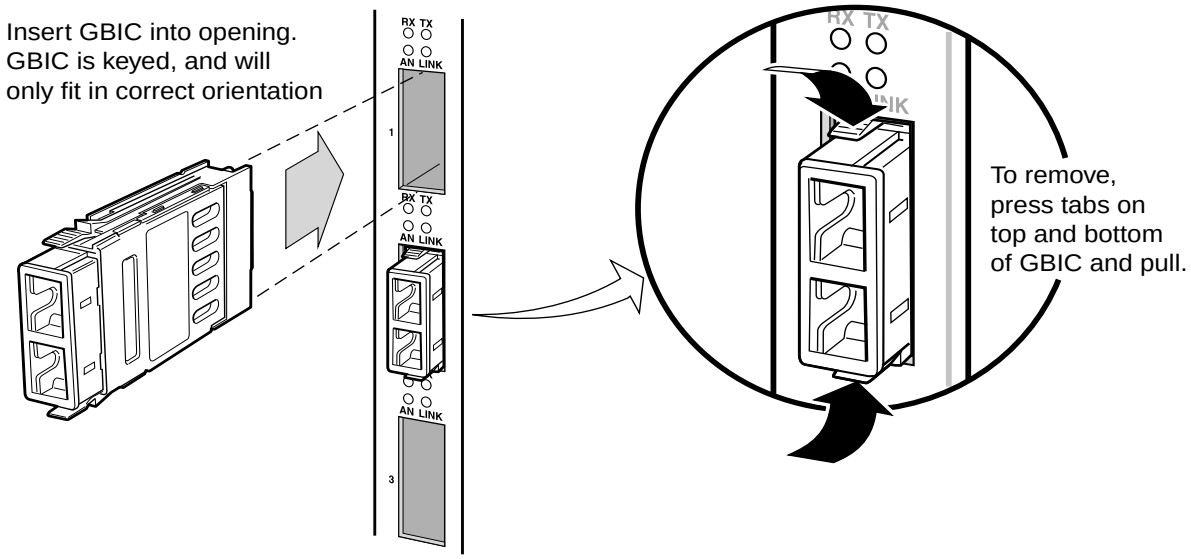


Figure 4-4 Installing and removing a GBIC.

4.6.2 Installing a GBIC into the Line Card

Install the GBIC into the line card as follows:

1. Hold the GBIC with the network port facing away from the line card. The 20-pin connector should be facing toward the empty GBIC slot of the line card.
2. The alignment slot on the GBIC must line up with the alignment guides inside the GBIC slot. The top of the GBIC must be next to the hinged side of the GBIC slot door of the line card.
3. Gently insert the GBIC module into the GBIC slot opening in the line card. The GBIC door on the line card folds in and the hinges engage the alignment slots on the sides of the GBIC module.

Note If the GBIC module does not go in easily, do not force it. If the GBIC is not oriented properly, it will stop about one quarter of the way into the slot and it should not be forced any further. Remove and reorient the GBIC module so that it slides easily into the slot.

4. Push the GBIC module in until the connector engages the 20-pin port. The GBIC is now installed.

4.7 HOT SWAPPING A WIC

Note Hot swapping WICs is not yet supported.

5 SMARTTRUNK CONFIGURATION GUIDE

This chapter explains how to configure SmartTRUNKs on the RS. A SmartTRUNK is Riverstone's technology for load balancing and load sharing across a number of ports. SmartTRUNKs are used for building high-performance, high-bandwidth links between Riverstone's switching platforms. A SmartTRUNK is a group of two or more physical ports that have been combined into a single logical port. Multiple physical connections between devices are aggregated into a single, logical, high-speed path that acts as a single link. As flows are set up on the SmartTRUNK, traffic is balanced across all ports in the combined link, balancing overall available bandwidth.

SmartTRUNKs can also interoperate with switches, routers, and servers from other vendors. SmartTRUNKs allow administrators the ability to increase bandwidth at congestion points in the network, eliminating potential traffic bottlenecks. SmartTRUNKs also provide improved data link resiliency – if one link in a SmartTRUNK fails, its flows are distributed among the remaining links.

Note For detailed descriptions of the SmartTRUNK commands, see the "SmartTRUNK commands" section of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

SmartTRUNKs are compatible with all RS features, including VLANs, STP, VRRP, and so on. SmartTRUNK operation is supported over different media types and a variety of technologies including 10/100 Mbps Ethernet, Gigabit Ethernet, and Packet over Sonet (PoS).

Note SmartTRUNKs are not supported on Advanced Services Module (ASM) ports where rate shaping features are enabled.

5.1 CONFIGURING SMARTTRUNKS

Steps for creating and configuring a SmartTRUNK:

1. Create a SmartTRUNK and specify its control protocol.
2. Add physical ports to the SmartTRUNK.
3. Specify the policy for how flows are allocated on the SmartTRUNK's ports. This step is optional, and two flow set up policies are supported:

- Round-robin – Flows are set up on ports sequentially.
- Link-utilization – A new flow is established on the port that is currently the least utilized (the default).

4. Specify whether the SmartTRUNK uses SmartTRUNK Load Redistribution (SLR). This step is optional. SLR allows the SmartTRUNK to dynamically move flows from port-to-port to take the best advantage of each link's current bandwidth.

5.1.1 Creating a SmartTRUNK

When creating a SmartTRUNK, assign a name to the SmartTRUNK and then select its control protocol. The choices for control protocol are: DEC Hunt Group control protocol, Link Aggregation Control Protocol (LACP), or no control protocol:

DEC Hunt Group – Can be used to connect a SmartTRUNK to another RS, Cabletron devices (such as the SmartSwitch 6000 or SmartSwitch 9000), or Digital GIGAswitch/Router. The Hunt Group protocol is useful for detecting errors like transmit/receive failures and misconfiguration.

LACP – If you are configuring the SmartTRUNK for 802.3ad link aggregation, specify the Link Aggregation Control protocol (LACP). LACP is limited to SmartTRUNKs comprised of Ethernet ports only, and all ports within the SmartTRUNK must have the same bandwidth, i.e., either all 10/100 Mbps Ethernet ports or all Gigabit Ethernet ports.

No Control Protocol – Can be used to connect the SmartTRUNK to another RS. Also, if you are connecting the SmartTRUNK to a device that does not support either DEC Hunt Group or LACP control protocols, such as those that support Cisco's EtherChannel technology, specify no control protocol. Only link failures are detected in this mode.

Here is an example of creating a SmartTRUNK named **st.1**, which uses no control protocol:

```
rs(config)#smarttrunk create st.1 protocol no-protocol
```

Note Use the **no-llap-ack** parameter only when the selected protocol is **huntgroup**.

5.1.2 Adding Physical Ports to the SmartTRUNK

You can add any number of 10/100 Ethernet, Gigabit Ethernet, or PoS ports to a SmartTRUNK, and ports can span across any number of line cards. If one link should go down, traffic is redirected seamlessly to the remaining operational links.

SmartTRUNK Port Limitations

Ports added to a SmartTRUNK must meet the following criteria:

- Running in full duplex mode
- Be a member of the default VLAN

- If using LACP as the control protocol, ports must be all Ethernet and their bandwidth must be the same (either all 10/100 Mbps Ethernet or Gigabit Ethernet, but not both).

Here is an example of adding ports **et.3.1** through **et.3.8** to a SmartTRUNK:

```
rs(config)#smarttrunk add ports et.3.1-8 to st.1
```

5.1.3 Specifying Traffic Load Policy

The default policy for assigning flows on the ports of a SmartTRUNK is “link-utilization,” where flows are assigned to the least-used ports in the SmartTRUNK. The other policy for assigning flows to ports is “round-robin,” where flows are assigned to ports on a sequential basis.

The traffic distribution policy only affects the initial assignment of L2 and L3 flows to a given port. If a link in the SmartTRUNK goes down, the flows are remapped to a different port in the same SmartTRUNK. If the flows assigned to a particular port in the SmartTRUNK exceed the bandwidth of the port, packets are dropped even if there is bandwidth available on other ports in the SmartTRUNK, unless SmartTRUNK Load Redistribution (SLR) is used. See Section 5.4, *"SmartTRUNK Load Redistribution"* for information about configuring SLR.

5.2 SMARTTRUNK EXAMPLE CONFIGURATION

Figure 5-1 shows a network design based on SmartTRUNKs. R1 is an RS operating as a router, while R2 and R3 are RSs operating as switches.

Timesaver To view the configuration of any device in the example below, click on that device's image.

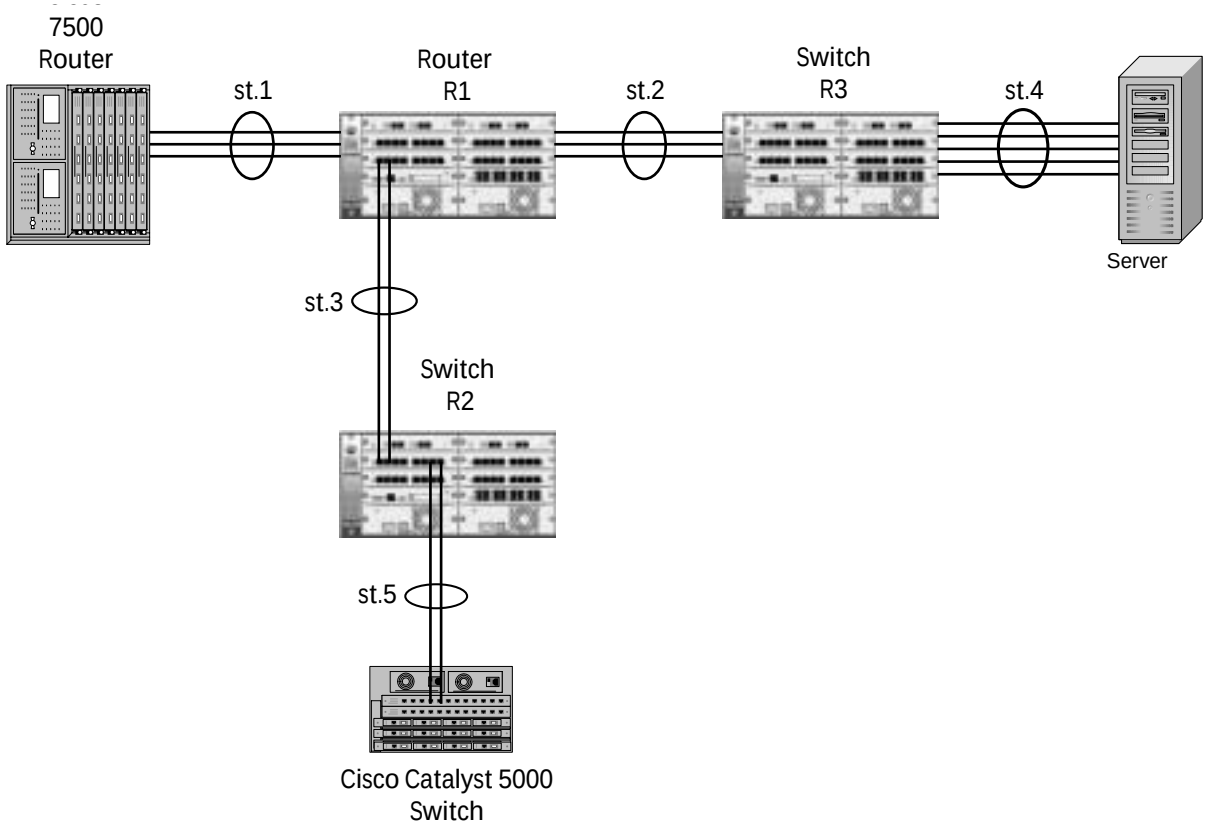


Figure 5-1 SmartTRUNK configuration example

The following is the configuration for the Cisco 7500 router:

```
interface port-channel 1
ip address 10.1.1.1 255.255.255.0
ip route-cache distributed
interface fasteth 0/0
no ip address
channel-group 1
```

The following is the configuration for the Cisco Catalyst 5000 switch:

```
set port channel 3/1-2 on
```

The following is the SmartTRUNK configuration for the RS labeled ‘R1’ in the diagram:

```
smarttrunk create st.1 protocol no-protocol
smarttrunk create st.2 protocol huntgroup
smarttrunk create st.3 protocol huntgroup
smarttrunk add ports et.1(1-2) to st.1
smarttrunk add ports et.2(1-2) to st.2
smarttrunk add ports et.3(1-2) to st.3
interface create ip to-cisco address-netmask 10.1.1.2/24 port st.1
interface create ip to-s1 address-netmask 11.1.1.2/24 port st.2
interface create ip to-s2 address-netmask 12.1.1.2/24 port st.3
```

The following is the SmartTRUNK configuration for the RS labeled ‘R3’ in the diagram:

```
smarttrunk create st.2 protocol huntgroup
smarttrunk create st.4 protocol no-protocol
smarttrunk add ports et.1(1-2) to st.2
smarttrunk add ports et.2(1-2) to st.4
```

The following is the SmartTRUNK configuration for the RS labeled ‘R2’ in the diagram:

```
smarttrunk create st.3 protocol huntgroup
smarttrunk create st.5 protocol no-protocol
smarttrunk add ports et.1(1-2) to st.3
smarttrunk add ports et.2(1-2) to st.5
```

Note Notice in the example above that because R1 and R2 are operating only as switches (layer-2 traffic only), their SmartTRUNKs were not assigned to interfaces.

5.3 CONFIGURING THE LINK AGGREGATION CONTROL PROTOCOL (LACP)

You can configure Riverstone’s SmartTRUNK to support the 802.3ad Link Aggregation Control Protocol (LACP). When you do so, the SmartTRUNK is treated as the aggregator. As an aggregator, the SmartTRUNK presents a standard IEEE 802.3 service interface and communicates with the MAC client. The aggregator binds to one or more ports, is responsible for distributing frames from a MAC client to its attached ports, and for collecting received frames from the ports and passing them to the MAC client transparently.

You can enable LACP on all 10/100 Ethernet and Gigabit Ethernet ports on the RS. LACP ports exchange LACP PDUs with their peers and form one or more Link Aggregation Groups (LAGs). After joining a LAG, the port attaches to an appropriate aggregator (SmartTRUNK). However, for a port to attach to an aggregator, the following parameters must match between the port and the aggregator:

- Port’s **`port-key`** must equal the aggregator’s **`actor-key`**
- aggregator’s **`partner-key`** must equal the port’s **`partner-key`**

- aggregator's **port-type** must equal the port's **port-type** (10/100 or Gigabit Ethernet)
- aggregator's **aggregation** must equal the port's **aggregation** (**aggregatable** or **individual**)
- If specified by the user, the aggregator's **partner-system-priority** and **partner-system-id** (MAC) must equal the port's **partner-system-priority** and **partner-system-id** (MAC).

Note All ports on which LACP is enabled are devoted solely to LACP. All ports controlled by any aggregator must have the same bandwidth.

5.3.1 Configuring SmartTRUNKs for LACP

Note For a complete description of all parameters associated with the following LACP commands, see the *Riverstone Networks Command Line Interface Reference Manual.*

Caution Do not use the **smarttrunk add ports** command to add ports when using LACP.

1. Create a SmartTRUNK and specify the LACP control protocol.:

```
rs(config)#smarttrunk create st.1 protocol LACP
```

2. Enable the LACP protocol on the SmartTRUNK's ports and specify a port key number using the **lacp set port** command. Here is an example:

```
rs(config)#lacp set port gi.1.1,gi.2.1 enable port-key 10
```

Configure the aggregator's (SmartTRUNK's) LACP properties using the **lacp set aggregator** command. Here is an example:

```
rs(config)#lacp set aggregator st.1 port-type gigabit-Ethernet actor-key 10
partner-key 20
```

Note that the following parameters must be specified when using the **lacp set aggregator** command:

port-type – Specifies whether the ports associated with the aggregator are 10/100 Ethernet ports or Gigabit Ethernet ports.

actor-key – Specifies the administrative key of the aggregator.

partner-key – Specifies the administrative key of its partner system.

5.3.2 LACP Configuration Example

Consider the following full-mesh topology: Each RS is connected to the other RSs by aggregators. For the sake of simplicity, each Link Aggregation Group (LAG) consists of just two links. Each link consists of either 10/100 Ethernet or Gigabit Ethernet. Notice the LACP restriction that each LAG must contain links of identical bandwidth only (either all 10/100 Ethernet or Gigabit Ethernet, but not both).

Timesaver To view the configuration of any of the RSs in the example below, click on that switch's image.

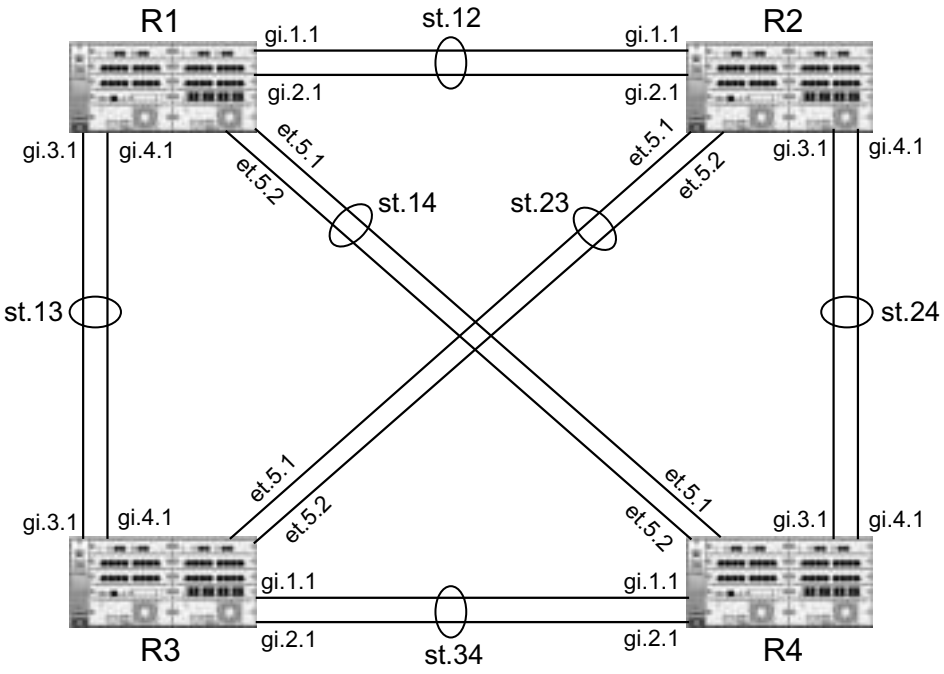


Figure 5-2 LACP configuration example

R1, R2, R3, and R4 are connected by aggregators (SmartTRUNKs) **st.12**, **st13**, **st.14**, **st.23**, **st.24**, and **st.34**. Notice that **st.12**, **st.13**, **st.24**, and **st.34** consist of Gigabit Ethernet links, while **st.14** and **st.23** consist of 10/100 Ethernet links. Table 5-1 shows the relationship between the aggregators, the RS switches, and the ports contained within the LAGs that bind to their respective aggregator.

Table 5-1 Aggregator – RS – port relationship

AGGREGATOR	RS SWITCHES	PORTS
st.12	R1	gi.1.1, gi.1.2
	R2	gi.1.1, gi.1.2
st.13	R1	gi.3.1, gi.4.1

Table 5-1 Aggregator – RS – port relationship (Continued)

AGGREGATOR	RS SWITCHES	PORTS
	R3	gi.3.1, gi.4.1
st.14	R1	et.5.1, et.5.2
	R4	et.5.1, et.5.2
st.23	R2	et.5.1, et.5.2
	R3	et.5.1, et.5.2
st.24	R2	gi.3.1, gi.4.1
	R4	gi.3.1, gi.4.1
st.34	R3	gi.1.1, gi.1.2
	R4	gi.1.1, gi.1.2

Configuration for R1:

```
smarttrunk create st.12 protocol lacp
smarttrunk create st.13 protocol lacp
smarttrunk create st.14 protocol lacp
lacp set aggregator st.12 port-type gigabit-Ethernet actor-key 10 partner-key 20
lacp set aggregator st.13 port-type gigabit-Ethernet actor-key 10 partner-key 30
lacp set aggregator st.14 port-type 10-100-Ethernet actor-key 11 partner-key 41
lacp set port gi.1.1,gi.2.1 enable port-key 10
lacp set port gi.3.1,gi.4.1 enable port-key 10
lacp set port et.5.1,et.5.2 enable port-key 11
stp set protocol-version rstp
stp enable port st.(12,13,14)
```

Configuration for R2:

```
smarttrunk create st.12 protocol lacp
smarttrunk create st.23 protocol lacp
smarttrunk create st.24 protocol lacp
lacp set aggregator st.12 port-type gigabit-Ethernet actor-key 20 partner-key 10
lacp set aggregator st.23 port-type 10-100-Ethernet actor-key 21 partner-key 31
lacp set aggregator st.24 port-type gigabit-Ethernet actor-key 20 partner-key 40
lacp set port gi.1.1,gi.2.1 enable port-key 20
lacp set port gi.3.1,gi.4.1 enable port-key 20
lacp set port et.5.1,et.5.2 enable port-key 21
stp set protocol-version rstp
stp enable port st.(12,23,24)
```

Configuration for R3:

```
smarttrunk create st.13 protocol lacp
smarttrunk create st.23 protocol lacp
smarttrunk create st.34 protocol lacp
lacp set aggregator st.13 port-type gigabit-Ethernet actor-key 30 partner-key 10
lacp set aggregator st.23 port-type 10-100-Ethernet actor-key 31 partner-key 21
lacp set aggregator st.34 port-type gigabit-Ethernet actor-key 30 partner-key 40
lacp set port gi.1.1,gi.2.1 enable port-key 30
lacp set port gi.3.1,gi.4.1 enable port-key 30
lacp set port et.5.1,et.5.2 enable port-key 31
stp set protocol-version rstp
stp enable port st.(13,23,34)
```

Configuration for R4:

```
smarttrunk create st.14 protocol lacp
smarttrunk create st.24 protocol lacp
smarttrunk create st.34 protocol lacp
lacp set aggregator st.14 port-type 10-100-Ethernet actor-key 41 partner-key 11
lacp set aggregator st.24 port-type gigabit-Ethernet actor-key 40 partner-key 20
lacp set aggregator st.34 port-type gigabit-Ethernet actor-key 40 partner-key 30
lacp set port gi.1.1,gi.2.1 enable port-key 40
lacp set port gi.3.1,gi.4.1 enable port-key 40
lacp set port et.5.1,et.5.2 enable port-key 41
stp set protocol-version rstp
stp enable port st.(14,24,34)
```

Note Notice that the **`partner-key`** specified in each configuration is the **`port-key`** of the corresponding ports on the RS at the other end of the SmartTRUNK.

5.4 SMARTTRUNK LOAD REDISTRIBUTION

SmartTRUNK Load Redistribution (SLR) monitors all ports within a SmartTRUNK for utilization. If a port begins to become overloaded, SLR automatically moves some of the port's flows to other, less utilized ports within the SmartTRUNK. SLR is enabled for the entire SmartTRUNK, and can be used in unison with any control protocol or load policy (see Section 5.1.3, *"Specifying Traffic Load Policy"* and Section 5.3.1, *"Configuring SmartTRUNKs for LACP"*).

Note When a SmartTRUNK is created, one of the ports is elected for sending and receiving layer-2 multicast and broadcast traffic. SLR leaves these layer-2 multicast or broadcast flows unaffected.

Note Each time a redistribution is performed by SLR, an SNMP trap is generated.

5.4.1 SLR Water-marks

SLR uses "water-marks," based on percentage port utilization, to determine whether flows on a port need to be redistributed to other ports within the SmartTRUNK.

SLR uses the three following user-defined water-marks:

- Low water-mark (**`lwm`**) – Used by SLR to detect whether a port is under utilized; the default is 20% of bandwidth
- Medium water-mark (**`mwm`**) – Used by SLR as a baseline of normal port utilization; the default is 50% of bandwidth
- High water-mark (**`hwm`**) – Used by SLR to detect whether a port is over utilized; the default is 80% of bandwidth

Note Water-marks are set on a per-SmartTRUNK basis, i.e., water-marks cannot be set on a per-port basis.

5.4.2 Polling intervals

SLR uses two intervals to perform load redistribution:

Status Interval – Interval in which port utilization information is gathered; the default is one second.

Redistribution Interval – Interval in which SLR considers flows for redistribution. The Redistribution Interval is the number of Status Intervals that must pass before flows are considered for redistribution.The Redistribution Interval relates to a number of Status Intervals, as opposed to being a measure of time; the default is 5 Status Intervals.

To determine the length of time in seconds for one Redistribution Interval, multiply the Status Interval by the Redistribution Interval value. For example, using the defaults,

Status Interval = 1 second

Redistribution Interval = 5 Status Intervals

then

1 * 5 = 5 seconds per Redistribution Interval.

Note To avoid flows "bouncing" back and forth between ports, SLR uses the rule that no moved flow can be returned to the port from which it was moved until at least one Redistribution Interval has passed.

Creating an SLR Enabled SmartTRUNK

The following is an example of creating a SmartTRUNK that uses SLR:

1. Create a SmartTRUNK (**st.4**) — the control protocol is irrelevant to this example:

```
rs(config)# smarttrunk create st.4 protocol no-protocol
```

2. Assign ports **et.4.1** through **et.4.4** to the SmartTRUNK:

```
rs(config)# smarttrunk add ports et.4.1-4 to st.4
```

3. Accept SLR's defaults and enable SLR on the SmartTRUNK.

```
rs(config)# smarttrunk set load-redistribution-params st.4
```

To show the SmartTRUNK SLR configuration on **st.4**, enter the following command from Enable mode:

```
rs# smarttrunk show load-redistribution-params st.4 configuration

   st.4 configuration:
        Intervals (in seconds):
            Stats Interval           1 seconds
            Redistribute Interval    5 Stats Intervals
        Port Watermarks:
            HWM                      80%
            MWM                      50%
            LWM                      20%
        Options:
            Verbose                  False
            Redistribute L2 Flows    True
            Redistribute IP Flows    False
            Ignore LWM Event         True
            Stats Discard            3 Stats Intervals
            Max Flow Search Attempts 100
```

To monitor SmartTRUNK SLR activity on **st.4**, enter the following command from Enable mode:

```
rs# smarttrunk show load-redistribution-params st.4 statistics

    st.4        Link    Moving Avg   Over     Above    Above    Below    Below     Port
    Output  Utilization    Load     Capacity   HWM      MWM      MWM      LWM    Capacity
    Ports    %capacity   %capacity  History  History  History  History  History    Mb/s
   -------- ----------- ----------- -------- -------- -------- -------- -------- ---------
   et.4.1      38.46       38.46          0        0        0      306        0      100
   et.4.2      57.70       57.70          0        0      304        0        0      100
   et.4.3      57.70       57.69          0        0      198        0        0      100
   et.4.4      76.92       76.92          0        0      198        0        0      100

   st.4: 1 redistributions in the last 0 Hr, 10 Min, 10 Sec
rs#
```

Notice that **statistics** displays the following values on a per-port basis:

- port name
- port capacity in bandwidth
- link utilization and its exponential moving average
- instances when water-marks have been exceeded

Also note that **statistics** reports how many flows have been redistributed since they were last cleared.

To see only a summary of the redistribution activities, enter smarttrunk **show load-redistribution-params st.4 summary** while in Enable mode.

To clear the SLR statistics, use the following command in Enable mode:

```
rs# smarttrunk clear load-distribution st.4
```

5.4.3 Additional Controls Provided by SLR

SmartTRUNK Load Redistribution is primarily intended for use where large numbers of layer-2 flows are deployed to carry traffic transparently. In this environment, SLR provides automatic load-balancing of flows on SmartTRUNKs consisting of any number of ports. However, the smarttrunk **set load-redistribution-params** command provides a number of parameters for enabling and tuning the behavior of SLR. The following sections describe two of these parameters.

Note For a detailed description of all the **load-redistribution-params** parameters, see the SmartTRUNK section in the *Riverstone Network RS Switch Router Command Line Interface Reference Manual.*

Redistribution of IP Flows

The **smarttrunk set load-redistribution-params** command is used to specify the redistribution of layer-3 flows by setting the **ip-redistribute** parameter. For example:

```
rs(config)#smarttrunk set load-redistribution-params st.4 redistribute-ip
```

Layer-3 flows, as well as layer-2 flows, will now be affected by SLR on SmartTRUNK **st.4**.

Typically, IP (layer-3) flows are short-lived compared to layer-2 flows. For example, a customer decides to surf the web. As the customer moves from site to site, layer-3 flows are established and then torn down. Depending on the amount of time the customer spends at each site, these layer-3 flows could be fairly short-lived. In this case, it would be a waste of switch resources to redistribute these flows along with the layer-2 flows. On the other hand, if you provide a service that requires long-lived layer-3 flows (for example, streaming video), you may want to consider including Layer-3 flows for redistribution.

Using Low Water-Mark Events

A low water-mark event occurs than traffic on a SmartTRUNK port falls below the low water-mark threshold. By default, SLR ignores low water-mark events. However, low water mark events can help SLR to determine whether a port is being under utilized. If a port experiences many low water mark events, SLR will attempt to even out traffic across the SmartTRUNK by redistributing flows to the under utilized port.

The **smarttrunk set load-redistribution-params** command is used to specify the use of low water-mark events by setting the **dont-ignore-lwm-events** parameter. For example:

```
rs(config)#smarttrunk set load-redistribution-params st.4 dont-ignore-lwm-events
```

However, using low water-mark events with SmartTRUNKs that contain ports of widely varying bandwidth can cause problems. This is why low water-mark events are disabled by default. To understand why using low water-mark events can be an issue, consider the following scenario:

- A SmartTRUNK consists of five 100 Megabit Ethernet ports and one Gigabit Ethernet port, and **dont-ignore-lwm-events** is specified.
- By default, the low water-mark is set at 20%. This means that on the 100 Megabit ports 20% of bandwidth is 20 Megabits/sec, while on the Gigabit Ethernet port, 20% of bandwidth is 200 Megabits/sec.
- The large bandwidth of the Gigabit Ethernet port causes it to trigger many low water-mark events, which indicate to SLR that the Gigabit Ethernet link is vastly under utilized. As a result, most flows are moved to the Gigabit Ethernet port, while the remaining links go under utilized.

The best use for low water-mark events is with SmartTRUNKs that are made up of links that have equal bandwidth. In such configurations, low water-mark events combine with high water-mark events to increase the efficiency of SLR's redistribution process.

6 BRIDGING CONFIGURATION GUIDE

The Riverstone RS Switch Router provides the following bridging functions:

- Compliance with the IEEE 802.1D standard
- Compliance with the IEEE 802.1w standard (Rapid STP)
- Compliance with the IEEE 802.1Q standard
- Compliance with the IGMP multicast bridging standard
- Wire-speed address-based bridging or flow-based bridging
- Ability to logically segment a transparently bridged network into virtual local-area networks (VLANs), based on physical ports or protocol (IP or IPX or bridged protocols like Appletalk)
- Frame filtering based on MAC address for bridged and multicast traffic
- Integrated routing and bridging, which supports bridging of intra-VLAN traffic and routing of inter-VLAN traffic

6.1 SPANNING TREE (IEEE 802.1D)

Spanning tree (IEEE 802.1d) allows bridges to dynamically discover a subset of the topology that is loop-free. In addition, the loop-free tree that is discovered contains paths to every LAN segment.

6.2 VLAN TAGGING (IEEE 802.1Q)

VLAN tagging (IEEE 802.1Q) allows more than one VLAN over a link, called a *trunk port*. The 802.1Q tagging process keeps traffic from each VLAN separate. 802.1p also is supported with 802.1Q, providing the ability to identify the traffic priority of each flow.

6.3 BRIDGING MODES (FLOW-BASED AND ADDRESS-BASED)

The RS provides the following types of wire-speed bridging:

Address-based bridging - The RS performs this type of bridging by looking up the destination address in an L2 lookup table on the line card that receives the bridge packet from the network. The L2 lookup table indicates the exit port(s) for the bridged packet. If the packet is addressed to the RS' own MAC address, the packet is routed rather than bridged.

Flow-based bridging - The RS performs this type of bridging by looking up an entry in the L2 lookup table containing both the source and destination addresses of the received packet in order to determine how the packet is to be handled.

The RS ports perform address-based bridging by default but can be configured to perform flow-based bridging instead, on a per-port basis. A port cannot be configured to perform both types of bridging at the same time.

The RS performance is equivalent when performing flow-based bridging or address-based bridging. However, address-based bridging is more efficient because it requires fewer table entries while flow-based bridging provides tighter management and control over bridged traffic.

Note Flow bridging mode is not supported for MPLS LSRs.

6.4 VLAN OVERVIEW

Virtual LANs (VLANs) are a means of dividing a physical network into several logical (virtual) LANs. The division can be done on the basis of various criteria, giving rise to different types of VLANs. For example, the simplest type of VLAN is the port-based VLAN. Port-based VLANs divide a network into a number of VLANs by assigning a VLAN to each port of a switching device. Then, any traffic received on a given port of a switch *belongs* to the VLAN associated with that port.

VLANs are primarily used for broadcast containment. A layer-2 (L2) broadcast frame is normally transmitted all over a bridged network. By dividing the network into VLANs, the *range* of a broadcast is limited, i.e., the broadcast frame is transmitted only to the VLAN to which it belongs. This reduces the broadcast traffic on a network by an appreciable factor.

6.4.1 RS VLAN Support

The RS supports the following type of VLANs:

- Port-based VLANs
- Protocol-based VLANs

Port-based VLANs

Ports of L2 devices (switches, bridges) are assigned to VLANs. Any traffic received by a port is classified as belonging to the VLAN to which the port belongs. For example, if ports 1, 2, and 3 belong to the VLAN named “Marketing”, then a broadcast frame received by port 1 is transmitted on ports 2 and 3. It is not transmitted on any other port.

Protocol-based VLANs

Protocol-based VLANs divide the physical network into logical VLANs based on protocol. When a frame is received at a port, its VLAN is determined by the protocol of the packet. For example, there could be separate VLANs for IP, IPX and Appletalk. An IP broadcast frame will only be sent to all ports in the IP VLAN.

VLANs and the RS

VLANs are an integral part of the RS family of switching routers. The RS switching routers can function as layer-2 (L2) switches as well as fully-functional layer-3 (L3) routers. Hence they can be viewed as a switch and a router in one box. To provide maximum performance and functionality, the L2 and L3 aspects of the RS switching routers are tightly coupled.

The RS can be used purely as an L2 switch. Frames arriving at any port are bridged and not routed. In this case, setting up VLANs and associating ports with VLANs is all that is required. You can set up the RS switching router to use port-based VLANs, protocol-based VLANs, or a mixture of the two types.

The RS can also be used purely as a router, i.e., each physical port of the RS is a separate routing interface. Packets received at any interface are routed and not bridged. In this case, no VLAN configuration is required. Note that VLANs are still created implicitly by the RS as a result of creating L3 interfaces for IP. However, these implicit VLANs do not need to be created or configured manually.

Most commonly, an RS is used as a combined switch and router. For example, it may be connected to two subnets S1 and S2. Ports 1-8 belong to S1 and ports 9-16 belong to S2. The required behavior of the RS is that intra-subnet frames be bridged and inter-subnet packets be routed. In other words, traffic between two workstations that belong to the same subnet should be bridged, and traffic between two workstations that belong to different subnets should be routed.

The RS switching routers use VLANs to achieve this behavior. This means that a L3 subnet (i.e., an IP subnet) is mapped to a VLAN. A given subnet maps to exactly one and only one VLAN. With this definition, the terms *VLAN* and *subnet* are almost interchangeable.

To configure an RS as a combined switch and router, the administrator must create VLANs whenever multiple ports of the RS are to belong to a particular VLAN/subnet. Then the VLAN must be *bound to* an L3 interface so that the RS knows which VLAN maps to which IP subnet.

Ports, VLANs, and L3 Interfaces

The term *port* refers to a physical connector on the RS, such as an ethernet port. Each port must belong to at least one VLAN. When the RS is unconfigured, each port belongs to a VLAN called the “default VLAN.” By creating VLANs and adding ports to the created VLANs, the ports are moved from the default VLAN to the newly created VLANs.

Unlike traditional routers, the RS has the concept of logical interfaces rather than physical interfaces. An L3 interface is a logical entity created by the administrator. It can contain more than one physical port. When an L3 interface contains exactly one physical port, it is equivalent to an interface on a traditional router. When an L3 interface contains several ports, it is equivalent to an interface of a traditional router which is connected to a layer-2 device such as a switch or bridge.

Explicit and Implicit VLANs

As mentioned earlier, VLANs can either be created explicitly by the administrator (explicit VLANs) or are created implicitly by the RS when L3 interfaces are created (implicit VLANs).

6.5 ACCESS PORTS AND TRUNK PORTS (802.1P AND 802.1Q SUPPORT)

The ports of an RS can be classified into two types, based on VLAN functionality: **access ports** and **trunk ports**. By default, a port is an access port. An access port can belong to at most one VLAN of the following types: IP, IPX or bridged protocols. The RS can automatically determine whether a received frame is an IP frame, an IPX frame or neither. Based on this, it selects a VLAN for the frame. Frames transmitted out of an access port contain no special information about the VLAN to which they belong. These frames are classified as belonging to a particular VLAN based on the protocol of the frame and the VLAN configured on the receiving port for that protocol.

For example, if port 1 belongs to VLAN *IPX_VLAN* for IPX, VLAN *IP_VLAN* for IP and VLAN *OTHER_VLAN* for any other protocol, then an IP frame received by port 1 is classified as belonging to VLAN *IP_VLAN*.

You can use the **`port enable 8021p`** command to tag frames transmitted from access ports with a one-byte, 802.1p class of service (CoS) value. The CoS value indicates the frame's priority. There are 8 CoS values, 0 is the lowest priority and 7 is the highest.

Trunk ports (802.1Q) are usually used to connect one VLAN-aware switch to another. They carry traffic belonging to several VLANs. For example, suppose that RS A and B are both configured with VLANs V1 and V2.

Then a frame arriving at a port on RS A must be sent to RS B, if the frame belongs to VLAN V1 or to VLAN V2. Thus the ports on RS A and B which connect the two RS's together must belong to both VLAN V1 and VLAN V2. Also, when these ports receive a frame, they must be able to determine whether the frame belongs to V1 or to V2. This is accomplished by "tagging" the frames, i.e., by prepending information to the frame in order to identify the VLAN to which the frame belongs. In the RS switching routers, trunk ports normally transmit and receive tagged frames only. (The format of the tag is specified by the IEEE 802.1Q standard.) If you configure Spanning Tree Protocol, frames are transmitted as untagged frames. You can also configure native VLANs to enable 802.1Q trunk ports to receive and transmit untagged frames. For additional information, see Section 6.9.5, *"Configuring Native VLANs."*

6.6 CONFIGURING RS BRIDGING FUNCTIONS

6.6.1 Configuring Address-based or Flow-based Bridging

The RS ports perform address-based bridging by default but can be configured to perform flow-based bridging instead of address-based bridging, on a per-port basis. A port cannot be configured to perform both types of bridging at the same time.

The RS performance is equivalent when performing flow-based bridging or address-based bridging. However, address-based bridging is more efficient because it requires fewer table entries while flow-based bridging provides tighter management and control over bridged traffic.

For example, the following illustration shows a router with traffic being sent from port A to port B, port B to port A, port B to port C, and port A to port C.

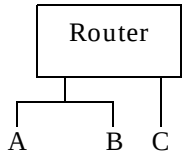


Figure 6-1 Router traffic going to different ports

The corresponding bridge tables for address-based and flow-based bridging are shown below. As shown, the bridge table contains more information on the traffic patterns when flow-based bridging is enabled compared to address-based bridging.

Address-Based Bridge Table	Flow-Based Bridge Table
A (source)	A → B
B (source)	B → A
C (destination)	B → C
	A → C

With the RS configured in flow-based bridging mode, the network manager has "per flow" control of layer-2 traffic. The network manager can then apply Quality of Service (QoS) policies or security filters based on layer-2 traffic flows.

To enable flow-based bridging on a port, enter the following command in Configure mode.

Configure a port for flow-based bridging.	**`port flow-bridging`** <*port-list*>|**`all-ports`**

To change a port from flow-based bridging to address-based bridging, enter the following command in Configure mode:

Change a port from flow-based bridging to address-based bridging.	**`negate`** <*line-number of active config containing command*>**:** **`port flow-bridging`** <*port-list*>|**`all-ports`**

6.6.2 Configuring MAC Address Limits on Ports

On the RS, you can limit the number of MAC addresses learned on a port, on a per VLAN basis. This is useful for trunk ports that belong to multiple VLANs that each represent a different customer.

For example there are Denial of Service (DoS) attacks originating from one customer's VLAN which is on a trunk port with multiple VLANs. The DoS attacks could consume a large number of L2 entries on the port, causing traffic on the other VLANs to be dropped. It could also cause hash collisions and reduced performance. Limiting the number of MAC addresses for each VLAN on that port ensures that the DoS attacks originating from one VLAN do not affect the other customer VLANs on the port.

When a port is in address bridging mode, the limit applies to the number of source and destination MAC addresses. Once the limit is reached for a particular VLAN on a particular port, all frames with an L2 miss are dropped, including all L3 traffic on that port and VLAN. Therefore, if an interface has been configured on the port, routed traffic on that interface will be stopped. When existing non-management entries are deleted or aged out of the L2 lookup table, then the MAC limit count is decremented and new L2 entries can be learned again until the limit is reached.

The following example configures a VLAN and sets the MAC address limit for the VLAN on the port:

```
rs(config)# vlan create blue ip
rs(config)# vlan add ports et.3.1 to blue
rs(config)# port enable mac-limit 5000 ports et.1.3 vlan blue
```

When you configure a MAC address limit on a VLAN and port, the existing entries in the L2 table are cleared. The L2 entries are also cleared when you disable the MAC address limit.

To verify the MAC address limits configured for a specific port, use the **`port show mac-limit`** command as shown in the following example:

```
rs# port show mac-limit et.3.1

Port       Vlan         Mac Limit    Current macs
----       ----         ---------    ------------
et.3.1     blue         5000         0
```

To view MAC address limits for all the ports, specify the **`all-ports`** option.

Note For stackable VLANs, MAC address limits can be applied on the backbone VLAN only.

6.7 CONFIGURING SPANNING TREE

The RS supports per VLAN spanning tree (PVST). By default, all the VLANs defined belong to the default spanning tree. You can create a separate instance of spanning tree using the following command:

Create spanning tree for a VLAN.	**pvst create spanningtree** *vlan-name <string>*

By default, spanning tree is disabled on the RS. To enable spanning tree on the RS, perform the following tasks on the ports where you want spanning tree enabled.

Enable spanning tree on one or more ports for default spanning tree.	**stp enable port** *<port-list>*
Enable spanning tree on one or more ports for a particular VLAN.	**pvst enable port** *<port-list>* **spanning-tree** *<string>*

Note For WAN and ATM, there is a limit to the number of VCs on which STP or PVST can run. For the RS 8000/8600, the limit is 128 VCs; for the RS 38000, the limit is 64 VCs.

6.7.1 Using Rapid STP

You can specify the use of “rapid” STP, defined by IEEE 802.1w. This protocol, also known as Fast Spanning Tree, is designed to reduce network recovery time.

Note RSTP works only on ports where STP is already enabled (with the **stp enable port** command).

To enable rapid STP, enter the following command in Configure mode:

Enable rapid STP	**stp set protocol-version rstp**

Note This command is not supported with per-VLAN spanning tree.

6.7.2 Adjusting Spanning-Tree Parameters

You may need to adjust certain spanning-tree parameters if the default values are not suitable for your bridge configuration. Parameters affecting the entire spanning tree are configured with variations of the bridge global configuration command. Interface-specific parameters are configured with variations of the bridge-group interface configuration command.

Note Only network administrators with a good understanding of how bridges and the Spanning-Tree Protocol work should make adjustments to spanning-tree parameters. Poorly chosen adjustments to these parameters can have a negative impact on performance. A good source on bridging is the IEEE 802.1d specification.

Setting the Bridge Priority

You can globally configure the priority of an individual bridge when two bridges tie for position as the root bridge, or you can configure the likelihood that a bridge will be selected as the root bridge. The lower the bridge's priority, the more likely the bridge will be selected as the root bridge. This priority is determined by default; however, you can change it.

To set the bridge priority, enter the following command in Configure mode:

Set the bridge priority for default spanning tree.	**stp set bridging priority** <*num*>
Set the bridge priority for a particular PVST instance.	**pvst set bridging spanning-tree** <*string*> **priority** <*num*>

Setting a Port Priority

You can set a priority for an interface. When two bridges tie for position as the root bridge, you configure an interface priority to break the tie. The bridge with the lowest interface value is elected.

To set an interface priority, enter the following command in Configure mode:

Establish a priority for a specified interface for default spanning tree.	**stp set port** <*port-list*> **priority** <*num*>
Establish a priority for a specified interface for a particular PVST instance.	**pvst set port** <*port-list*> **spanning-tree** <*string*> **priority** <*num*>

Assigning Port Costs

Each interface has a port cost associated with it. By convention, the port cost is 1000/data rate of the attached LAN, in Mbps. You can set different port costs.

To assign port costs, enter the following command in Configure mode:

Set a different port cost other than the defaults for default spanning tree.	**stp set port** <*port-list*> **port-cost** <*num*>
Set a different port cost other than the defaults for a particular PVST instance.	**pvst set port** <*port-list*> **spanning-tree** <*string*> **port-cost** <*num*>

Adjusting Bridge Protocol Data Unit (BPDU) Intervals

You can adjust BPDU intervals as described in the following sections:

- Adjust the Interval between Hello BPDUs
- Define the Forward Delay Interval
- Define the Maximum Idle Interval

Adjusting the Interval between Hello BPDUs

You can specify the interval between hello BPDUs. To adjust this interval, enter the following command in Configure mode:

Specify the interval between hello BPDUs for default spanning tree.	**stp set bridging hello-time** <*num*>
Specify the interval between hello BPDUs for a particular PVST instance.	**pvst set bridging spanning-tree** <*string*> **hello-time** <*num*>

Defining the Forward Delay Interval

The forward delay interval is the amount of time spent listening for topology change information after an interface has been activated for bridging and before forwarding actually begins.

To change the default interval setting, enter the following command in Configure mode:

Set the default of the forward delay interval for default spanning tree.	**stp set bridging forward-delay** <*num*>
Set the default of the forward delay interval for a particular PVST instance.	**pvst set bridging spanning-tree** <*string*> **forward-delay** <*num*>

Defining the Maximum Age

If a bridge does not hear BPDUs from the root bridge within a specified interval, it assumes that the network has changed and recomputes the spanning-tree topology.

To change the default interval setting, enter the following command in Configure mode:

Change the amount of time a bridge will wait to hear BPDUs from the root bridge for default spanning tree.	**stp set bridging max-age** <*num*>
Change the amount of time a bridge will wait to hear BPDUs from the root bridge for a particular PVST instance.	**pvst set bridging spanning-tree** <*string*> **max-age** <*num*>

Changing the STP State of VLAN Ports

When STP is enabled, RS ports move from initalization state at power-up to blocking, listening, learning, and then forwarding states. Ports in forwarding state forward frames received from an attached segment or from another port. Ports in blocking state discard frames received from an attached segment or from another port. You can change the STP state of a port for a particular VLAN. To do this, use the **stp force port** command. In the following example, the first command adds the ports et.1.5 and et.4.7 to the SmartTRUNK st.1. The second command changes the STP state of the ports to blocking.

```
rs(config)# smarttrunk add ports et.1.5,et.4.7 to st.1
rs(config)# stp force port st.1 state blocking vlan-name default
```

Use the **stp show vlan-port-state** command to display the STP state of a VLAN port. The following example shows the STP states of the ports that were changed to blocking state with the **stp force port** command.

```
rs# stp show vlan-port-state st.1 vlan-name default
Port    State
----    -----
et.1.5  Forced-Blocking
et.4.7  Forced-Blocking
```

6.7.3 STP Dampening

STP creates a loop free, active topology in a network by placing ports in a forwarding or blocking state. When a port moves to the forwarding state, it transitions from listening, to learning, and then to forwarding. Whenever this transition happens, there is a chance that some traffic may be lost. If this port state transition happens rarely, the traffic loss is insignificant. On the other hand, if this happens frequently, it can adversely affect the network. STP dampening addresses this issue.

When a root port stops receiving BPDUs from the root bridge, a new root port is selected. If the original root port starts receiving BPDUs from the root bridge once again and STP dampening is enabled on the port, traffic is not immediately switched back to it. Instead, the port is monitored until it satisfies a stability condition, which is that it receives a certain number of STP configuration BPDUs during a specified period of time. If the port satisfies this condition, then it is considered stable and traffic is switched back to it. Otherwise, it remains in an unstable state and is continuously monitored until it satisfies the stability condition. This feature ensures that ports are stable before they move to a forwarding state and traffic is switched back to them.

Note that dampening will not occur if the port on which STP dampening is enabled goes down and comes up again. Instead, traditional STP configuration occurs.

To enable STP dampening on a port, enter the following command in Configure mode:

Enable STP dampening on a port.	**stp set port** <*port-list*> **dampening enable**

Note STP dampening cannot be used in conjunction with RSTP.

The RS has defaults for the period of time a port will be monitored (10 seconds) and the number of BPDUs that need to be received (10) during this period. You can change these defaults by entering the following command in Configure mode:

Set parameters for STP dampening.	**stp set bridging damp-monitor-time** <*seconds*> **damp-bpdu-count** <*number*>

6.7.4 Tunneling STP

The RS provides the ability to tunnel STP BPDUs across MPLS or VLAN backbones. This allows customers within VPNs to enable Spanning Tree for their equipment without the STP BPDUs being interpreted or interfering with the provider's equipment.

Use the **stp tunnel mpls** command to tunnel STP BPDUs across an LSP, and use the **stp tunnel vlan-encapsulated** command to tunnel STP BPDUs through a specified VLAN backbone (see Figure 6-2 and Figure 6-3).

For detailed parameter descriptions of STP tunneling commands, see the *"Riverstone Networks Command Line Interface Manual."*

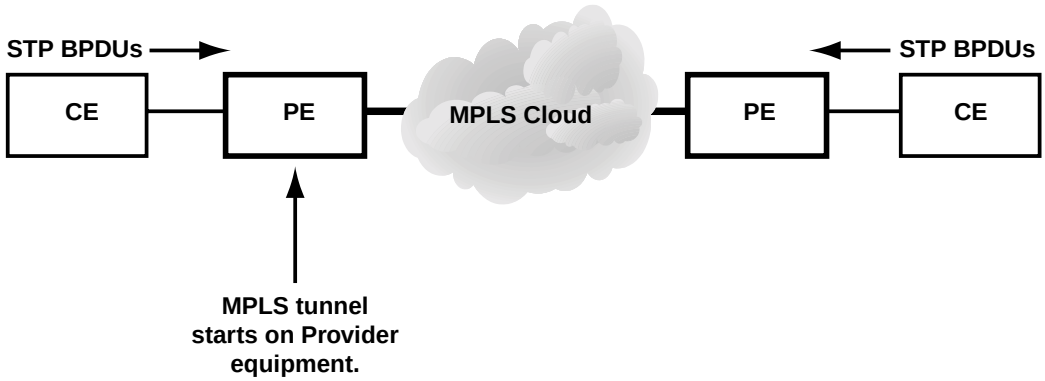


Figure 6-2 Tunneling STP through MPLS LSP

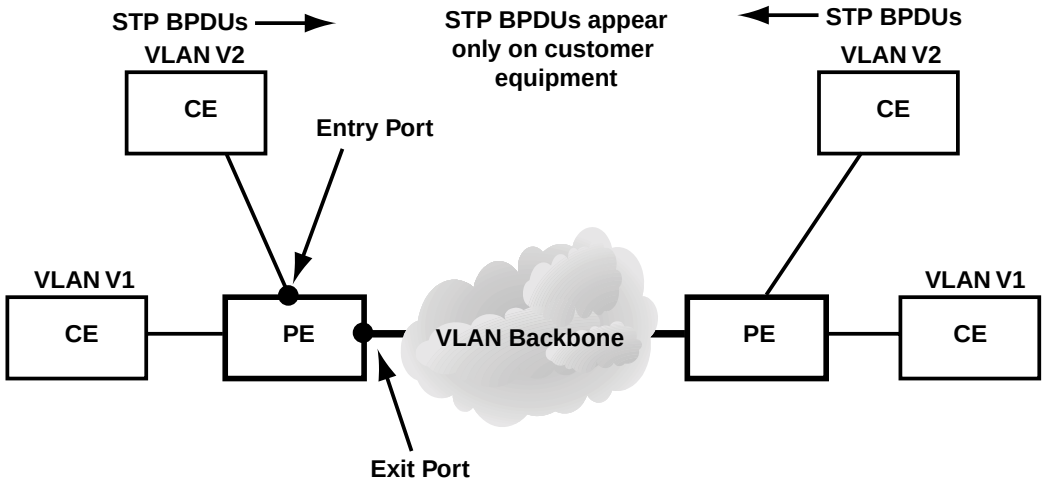


Figure 6-3 Tunneling STP through a VLAN backbone

6.7.5 Rapid Ring STP

Rapid STP (RSTP) and STP normally operate between switches over ports on VLANs. When a VLAN extends across a core network, there can be substantial convergence delays with RSTP when network changes occur. You can use the Rapid Ring STP (RRSTP) feature to define an RSTP domain based on topology—i.e., specified ports on the RS—instead of based on VLANs. While Rapid Ring STP limits the exchange of BPDU messages to specific ports, data traffic is not limited to the ring.

In Figure 6-4, four ports on S1 belong to the same VLAN, however two of the ports belong to one ring and the other two ports belong to another ring.

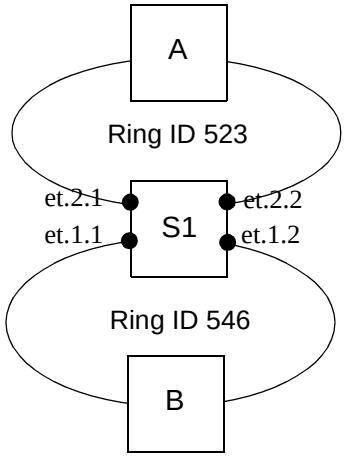


Figure 6-4 Single VLAN with two rings

To configure Rapid Ring STP on S1, do the following:

1. Enable rapid STP:

```
rs(config)# stp set protocol-version rstp
```

2. Create the rings (ring IDs 546 and 523) for rapid STP:

```
rs(config)# stp rer-create ring ring_id 546
rs(config)# stp rer-create ring ring_id 523
```

3. Add ports to each ring. The ports can be in different VLANs, but each port can only be in one ring.

```
rs(config)# stp rer-add ports et.1.1,et.1.2 to 546
rs(config)# stp rer-add ports et.2.1,et.2.2 to 523
```

4. Enable the rings. The following command enables *all* STP rings configured on the RS:

```
rs(config)# stp rer-enable
```

You can also enable a specific ring ID with the **`stp rer-enable ring ring_id`** <*id*> command.

Ports on a router cannot belong to more than one ring. Therefore, you cannot apply ring STP to the topology shown in Figure 6-5.

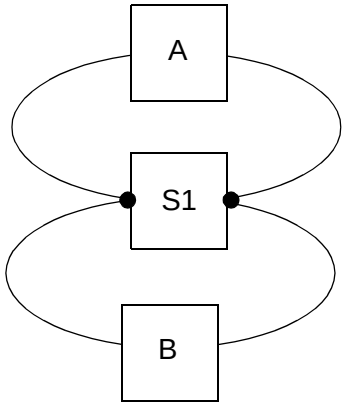


Figure 6-5 Rings on same port (Rapid Ring STP cannot be applied)

You *cannot* apply Rapid Ring STP in topologies in which there would be redundant routers between access and core rings (also known as “redundant links”). In Figure 6-6, S1 and S2 are redundant routers between the ring on which A resides and the ring on which B resides. (Note that if S1 fails, traffic can still pass between A and B via S2.) Rapid Ring STP cannot be enabled in this topology, as a loop would still exist between the links between S1 and S2.

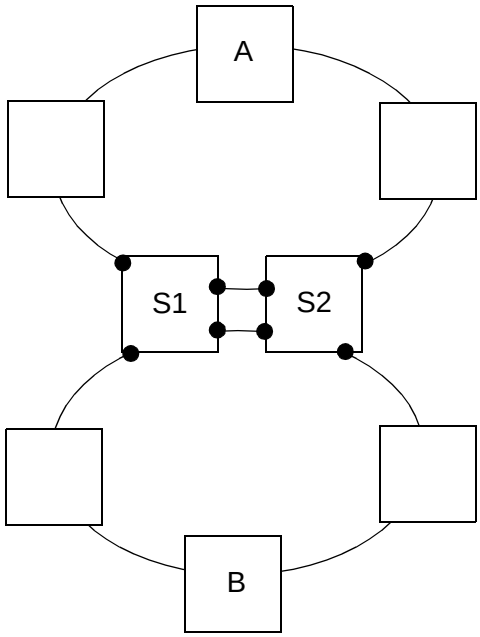


Figure 6-6 Redundant links topology (Rapid Ring STP cannot be applied)

Use the **`stp show ring-port-info`** command in Enable mode to display STP bridge and port information for a ring:

```
rs# stp show ring-port-info ring_id 546
Status for Spanning Tree Instance 546
Bridge ID : 8000:00e063343b8e
Root bridge : 8000:00e063343b8e
To Root via port : n/a
Ports in bridge : 0
Max age : 20 secs
Hello time : 2 secs
Forward delay : 15 secs
Topology changes : 0
Last Topology Chg: 6 days 19 hours 44 min 15 secs ago
                                                                  Designated
Port   Priority  Cost   STP      State      Designated-Bridge Port
----   --------  ----   ---      -----      ---------------- ----------
et.1.1 001       00010  Enabled  Forwarding 8000:00e063343b8e 00 00
et.1.2  001        00010  Enabled   Forwarding  8000:00e063343b8e  00 00
```

6.8 PORT-VLAN LOOP DETECTION

VLAN loop detection provides a way to detect and resolve loops that can occur on VLANs. Loop detection relies on monitoring RS ports within VLANs for source MAC address moves. Specifically, if source MAC addresses begin moving between two ports within a VLAN, a loop is assumed to exist somewhere on the VLAN. In response, one or more of the VLAN's ports are blocked to resolve the loop (see Figure 6-7).

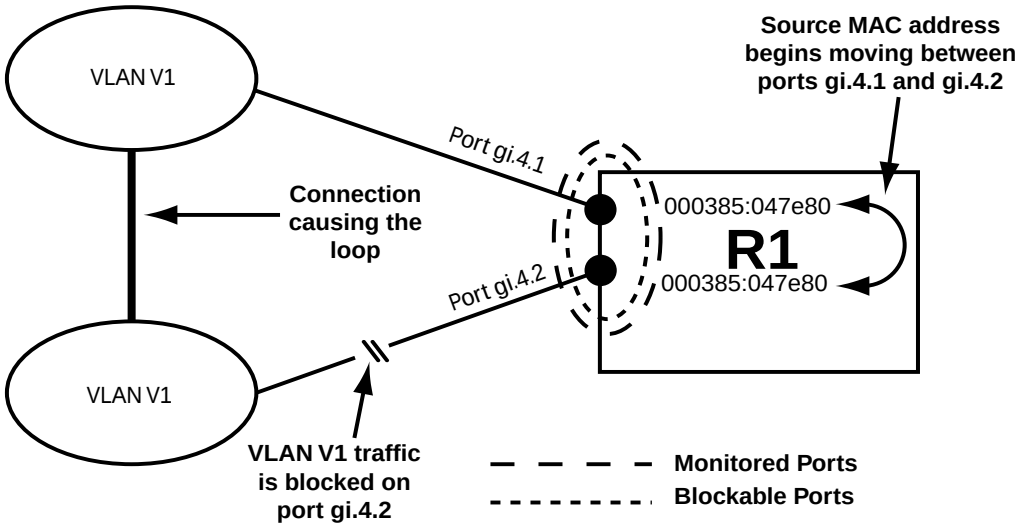


Figure 6-7 Loop detection on a VLAN

Loop detection uses 802.1Q to determine which VLAN traffic (if any) should be blocked if the moving source addresses involve a trunk port. Notice in Figure 6-8 that a loop exists on VLAN V1, however, part of V1 is connected through the single port gi.4.1, while the rest of V1 is connected through port gi.4.2, which is a trunk port. If loop detection decides that the VLAN V1 traffic should be blocked on port gi.4.2 (the trunk port), only VLAN V1's traffic is blocked, while traffic from the other VLANs is allowed through port gi.4.2.

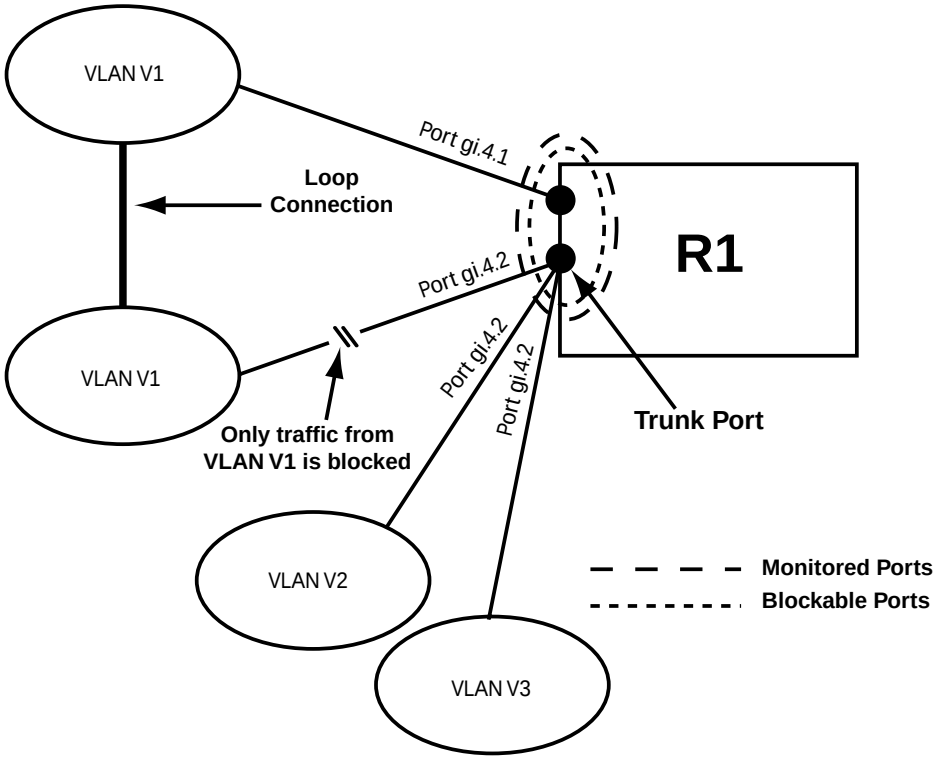


Figure 6-8 Loop detection involving a trunk port

Note If Spanning Tree Protocol (STP) is enabled while loop detection is enabled, STP takes precedence over loop detection.

Note Loop detection takes precedence over MAC limiting.

6.8.1 Configuring Loop Detection

Use the port enable loop-detection command to configure VLAN loop detection on the RS. When setting up loop detection the following parameters must be specified.

- A name for the loop detection service

- A list of blockable ports – Those ports on which blocking can be performed
- A list of monitored ports – Those ports that are monitored for moving source MAC addresses
- A move frequency threshold – Sets the number of times within a second that a MAC move occurs during any five second period before a port is blocked
- A VLAN name or a list of VLANs identified by their id numbers
- If tunneling VLANs using a port-port FEC, packets can be coming from any VLAN. To account for this, specify the **mpls-port-port** option to check VLAN traffic on the LSP

Additionally, it is necessary to set the **retry-timeout**. Once a port is blocked, the **retry-timeout** specifies the length of time in seconds before a port is unblocked. If **retry-timeout** is set to zero, a blocked port is never unblocked.

The following is an example of enabling loop detection:

```
rs(config)# port enable loop-detection loop-check1 blockable-ports et.1.4-6
monitor-ports et.1.3-6 move-frequency-threshold 10 retry-timeout 0 vlan V1
```

Notice the following in the example above:

- The name of the loop-detection service is **loop-check1**
- The blockable ports are from **et.1.4** to **et.1.6**
- The monitored ports are from **et.1.3** to **et.1.6**
- The **move-frequency-threshold** is set to **10** MAC address moves per second between monitored ports during any five second period
- The **retry-timeout** is zero (**0**): Ports are never unblocked
- The the name of the VLAN to monitor is **V1**

Notice also that the number of monitored ports is larger (by one port) than the number of blockable ports. This can be done to assure that while a port is being monitored for source MAC address moves, that port (in this case **et.1.3**) will never be blocked regardless of whether it is experiencing MAC moves (see Figure 6-9). Only those ports specified as blockable ports will be blocked (**et.1.4** to **et.1.6**).

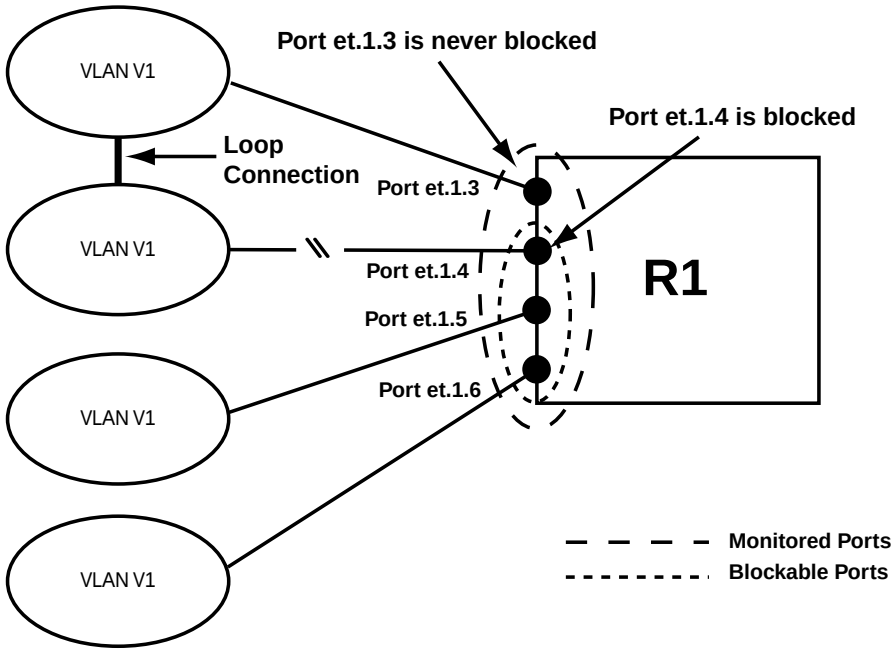


Figure 6-9 The difference between monitored and blockable ports

6.8.2 Using Loop Detection

The following are several things to keep in mind when enabling loop detection.

How Ports Are Selected for Blocking

When the **`move-frequency-threshold`** is reached, the port *from which* the source MAC address last moved is blocked if possible. If it is not possible to block the *from* port, the port *to which* the source MAC address has moved is blocked. This can happen if, for instance, if the port from which the MAC address last moved is a monitored port but not a blockable port (see Figure 6-10).

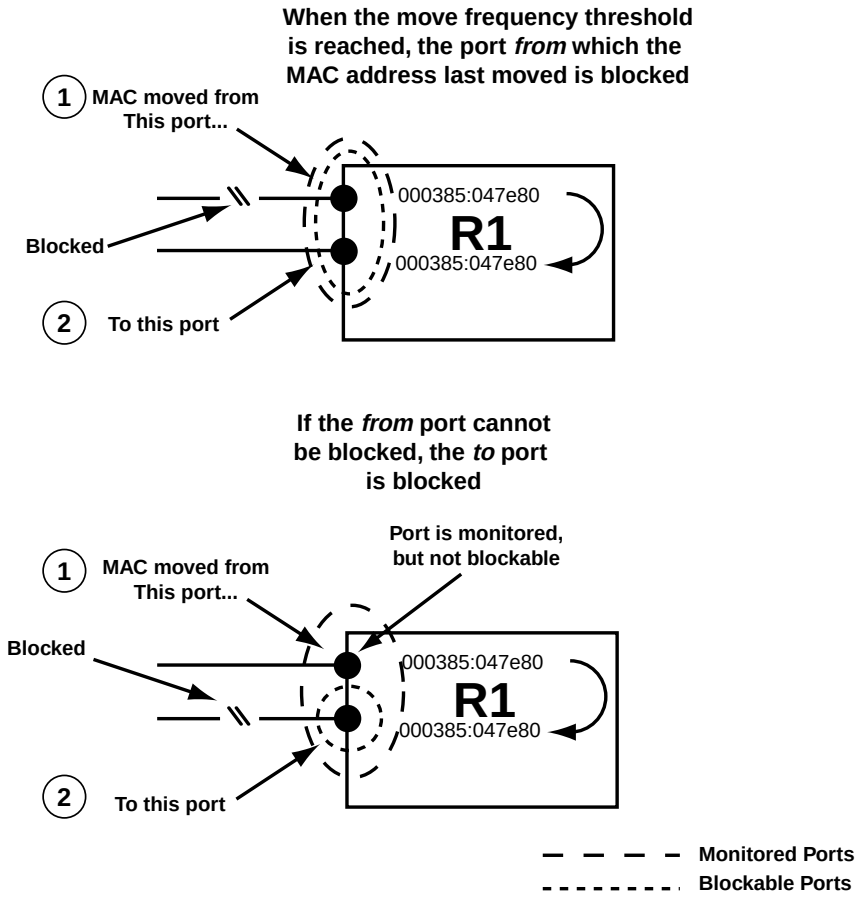


Figure 6-10 How loop detection ports are blocked

If no blockable ports are specified (only monitored ports are specified), the *from* port is blocked if the move threshold is reached. For example:

```
rs(config)# port enable loop-detection abc monitor-ports et.1.1-2
move-frequency-threshold 10 vlan V1
```

The command line above specifies that ports **et.1.1** and **et.1.2** are monitored, but it contains no ports for blocking. As a result if the **move-frequency-threshold** is reached, the *from* ports is blocked (see Figure 6-11).

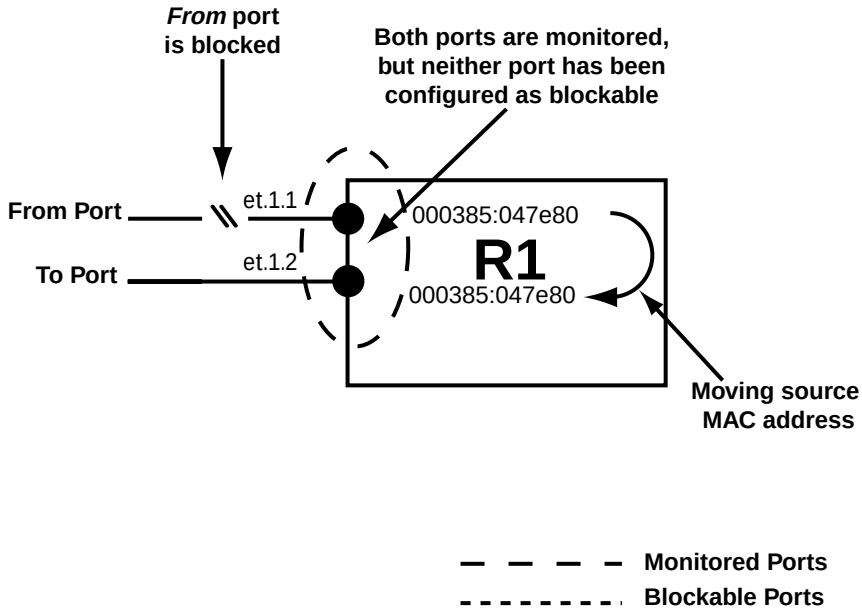


Figure 6-11 Both ports are blocked if only port monitoring is specified

If ports are specified as blockable using the **`block-both-ports`** keyword, both ports between which source MAC addresses are moving will be blocked.

For example, the following blocks both **`gi.4.1`** and **`gi.4.2`** if the move threshold is reached (seeFigure 6-12):

```
rs(config)# port enable loop-detection prof-1 blockable-ports block-both-ports
monitor-ports gi.4.1-2 vlan v1 move-frequency-threshold 10
```

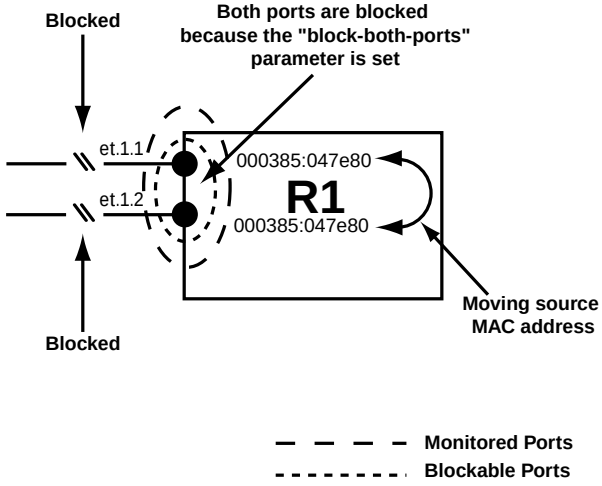


Figure 6-12 Blocking behavior if using block-both-ports parameter

Retry-Timeout behavior

The retry timer is designed to be dynamic when responding to VLAN ports that are in a state of persistent looping. For example, port A and port B are both monitored and blockable. If a source MAC address moves between port A and B such that it exceeds the move threshold, port A is blocked. When the retry timer (say, 5 seconds) runs out, port A is unblocked. However, if port A and B exceed the move threshold again, port A is blocked again. At this point, the retry timer doubles itself and does not unblock port A until 10 seconds has elapsed. If port A and B continue to reach the move threshold each time port A is unblocked, the retry timer continues to double itself before unblocking port A (5 seconds, 10 seconds, 20 seconds, 40 seconds, 80 seconds and so on).

Ports Available to Loop Detection

Loop detection can be enabled only on the following ports types:

- Ethernet
- Gigabit Ethernet
- SONET
- SmartTRUNKS

Loop detection cannot be enabled on the following ports: Frame Relay, channelized or unchannelized T1/E1/T3/E3, or serial such as HSSI.

Clearing Ports and Statistics

Use the **`port clear loop-detection-block`** command from the Enable mode to clear blocked port VLAN associations.

For example, the following clears the blocked port **`gi.4.1`** belonging to VLAN **`V1`**:

```
rs# port clear loop-detection-block port gi.4.1 vlan v1
```

Viewing Loop Detection Status

Use the **port show loop-detection-status** command from Enable mode to view the status of loop detection. Information within the display can be arranged in different ways depending on which of the viewing options (**policies**, **port**, or **vlan**) is selected.

The following is an example of the use of the **port show loop-detection-status** command. It is assumed that a VLAN named **V1** and id number **300** already exists and its ports are monitored and blockable by the policy, **pol-1**.

```
rs# port show loop-detection-status policies pol-1
Loop detection status
---- --------- ------
        Policy - pol-1
        ------
                Monitor Ports     - et.2.(1-2)
                Blockable Ports   - et.2.(1-2)
                Vlans             - 300
                Move Frequency    - 2
                Retry Timeout     - 60


rs# port show loop-detection-status vlan V1
Loop detection status
---- --------- ------
Vlan V1

Port         State        Policy
----         -----        ------
et.2.1       OPEN         pol-1
et.2.2       OPEN         pol-1


rs# port show loop-detection-status ports all-ports
Loop detection status
---- --------- ------
Port et.2.1


Vlan         State        Policy
----         -----        ------
V1           OPEN         pol-1

Port et.2.2

Vlan         State        Policy
----         -----        ------
V1           OPEN         pol-1
```

6.9 CONFIGURING A PORT- OR PROTOCOL-BASED VLAN

To create a port or protocol based VLAN, perform the following steps in the Configure mode.

1. Create a port or protocol based VLAN.
2. Add physical ports to a VLAN.

6.9.1 Creating a Port or Protocol Based VLAN

To create a VLAN, enter the following command in Configure mode.

Create a VLAN.	**vlan create** <*vlan-name*> <*type*> **id** <*num*>

6.9.2 Adding Ports to a VLAN

To add ports to a VLAN, enter the following command in Configure mode.

Add ports to a VLAN.	**vlan add ports** <*port-list*> **to** <*vlan-name*>

6.9.3 Configuration Examples

VLANs are used to associate physical ports on the RS with connected hosts that may be physically separated but need to participate in the same broadcast domain. To associate ports to a VLAN, you must first create a VLAN and then assign ports to the VLAN. This section shows examples of creating an IP or IPX VLAN and a DECnet, SNA, and AppleTalk VLAN.

Creating an IP or IPX VLAN

In this example, servers connected to port gi.1.(1-2) on the RS need to communicate with clients connected to et.4.(1-8). You can associate all the ports containing the clients and servers to an IP VLAN called ‘BLUE’.

First, create an IP VLAN named ‘BLUE’

```
rs(config)# vlan create BLUE ip
```

Next, assign ports to the ‘BLUE’ VLAN.

```
rs(config)# vlan add ports et.4.(1-8),gi.1.(1-2) to BLUE
```

Creating a non-IP/non-IPX VLAN

In this example, SNA, DECnet, and AppleTalk hosts are connected to et.1.1 and et.2.(1-4). You can associate all the ports containing these hosts to a VLAN called ‘RED’ with the VLAN ID 5.

First, create a VLAN named ‘RED’

```
rs(config)# vlan create RED sna dec appletalk id 5
```

Next, assign ports to the ‘RED’ VLAN.

```
rs(config)# vlan add ports et.1.1, et.2.(1-4) to RED
```

6.9.4 Configuring VLAN Trunk Ports

The RS supports standards-based VLAN trunking between multiple RS’s as defined by IEEE 802.1Q. 802.1Q adds a header to a standard Ethernet frame which includes a unique VLAN ID per trunk between two RS’s. These VLAN IDs extend the VLAN broadcast domain to more than one RS.

To configure a VLAN trunk, enter the following command in the Configure mode.

Configure 802.1Q VLAN trunks.	**vlan make** <*port-type*> <*port-list*>

You can enable the collection of VLAN statistics on 10/100 and Gigabit Ethernet ports configured as 802.1Q trunk ports. To do so, use the **port enable per-vlan-stats** command. Then, you can display the statistics by using the **port show per-vlan-stats** command as illustrated in the following example:

```
rs# port show per-vlan-stats port et.10.4
Traffic Statistics for Port et.10.4, VLAN red (VLAN ID 2):
Inbound
   Octets:                 107,196,271 octets
   Frames:                     134,940 frames

Outbound
   Octets:                 105,965,469 octets
   Frames:                     133,549 frames

Traffic Statistics for Port et.10.4, VLAN blue (VLAN ID 3):
Inbound
   Octets:                 354,072,575 octets
   Frames:                     446,763 frames

Outbound
   Octets:                 347,463,892 octets
   Frames:                     435,218 frames
```

6.9.5 Configuring Native VLANs

On the RS, trunk ports normally transmit and receive tagged frames only. To enable a trunk port to receive and transmit untagged frames, use the **vlan set native-vlan** command to configure a "native VLAN." A native VLAN is the VLAN that is assigned to receive and transmit untagged frames. You can use native VLANs when you use trunk ports on the RS to connect to VLAN-unaware devices. When the RS receives untagged frames from the VLAN-unaware devices, it assigns them to the native VLAN.

You can specify one native VLAN for each protocol type supported by the RS. All untagged frames of a particular protocol received on the trunk port are assigned to the protocol's native VLAN. You can also use the **all** option of the **vlan set native-vlan** command to set the native VLAN for all protocols, or use the **auto** option to specify the native VLAN for all protocols supported by the specified VLAN.

Consider the following example:

```
!Configure the trunk port
vlan make trunk-port et.2.1
!Create the VLANs and add the trunk port
vlan create red ip
vlan create blue ip
vlan create white ip
vlan create green ipx
vlan create yellow ipx
vlan add ports et.2.1 to red
vlan add ports et.2.1 to blue
vlan add ports et.2.1 to green
vlan add ports et.2.1 to white
vlan add ports et.2.1 to yellow
!Specify the native VLAN
vlan set native-vlan et.2.1 ip red
vlan set native-vlan et.2.1 ipx yellow
```

The trunk port et.2.1 belongs to five VLANs, three are three IP VLANs and two are IPX VLANs. VLAN RED is the native IP VLAN, and VLAN YELLOW is the native IPX VLAN. Therefore, when the RS receives untagged IP frames on port et.2.1, it will assign them to VLAN RED. If the RS receives untagged IPX frames on port et.2.1, it will assign them to VLAN YELLOW. When frames from VLAN RED or YELLOW are transmitted out of et.2.1, the frames will be untagged.

To use the **all** or **auto** option the VLAN being made the native VLAN shuould be a port-based VLAN. By using a port-based VLAN, the RS is not restricted to accepting untagged frames from a particular protocol.

Consider the following example:

```
!Configure the trunk port
vlan make trunk-port et.2.1
!Create the VLANs and add the trunk port
vlan create orange port-based
vlan create red ip
vlan create blue ip
vlan create white ip
vlan create green ipx
vlan create yellow ipx
vlan add ports et.2.1 to red
vlan add ports et.2.1 to blue
vlan add ports et.2.1 to green
vlan add ports et.2.1 to white
vlan add ports et.2.1 to yellow
!Specify the native VLAN
vlan set native-vlan et.2.1 all orange
```

By creating a port-based VLAN (ORANGE), that VLAN can be assigned as the native VLAN for all protocols.

If the VLAN specified to be the native VLAN is associated with a particular protocol, and if the **auto** option is specified for the native VLAN, the native VLAN will accept untagged frames from only the native VLAN's protocol.

Consider the following example:

```
!Configure the trunk port
vlan make trunk-port et.2.1
!Create the VLANs and add the trunk port
vlan create red ip
vlan create blue ip
vlan create yellow ipx
vlan add ports et.2.1 to red
vlan add ports et.2.1 to blue
vlan add ports et.2.1 to yellow
!Specify the native VLAN
vlan set native-vlan et.2.1 auto red
```

The native VLAN (RED) will accept untagged frames from only IP packets. All other protocol types will be dropped.

Note Native VLANs cannot be set on trunk ports configured with the **untagged** option of the **vlan make trunk-port** command.

Note Native VLANs cannot be set on ports that are running MPLS. MPLS internally creates a native VLAN for its signalling purposes.

You can view native VLANs as shown in the following example:

```
rs# port show vlan-info et.2.1

[Native vlans are printed in boldface]
Port           Type    IP        IPX       Bridging  ATALK     DEC       SNA   IPv6
-------------- ------- --------- --------- --------- --------- --------- --------- ---------
et.2.1         trunk   red      yellow

                       DEFAULT   DEFAULT   DEFAULT   DEFAULT   DEFAULT   DEFAULT   DEFAULT
                       blue

                       white

                       red

                                 green

                                 yellow

rs#
```

6.9.6 Configuring a Range of VLAN IDs

You can create a number of VLANs at one time with the **vlan create-range** command. This command allows you to create multiple VLANs by specifying a range of VLAN ID numbers. For example, the following command creates nine VLANs with VLAN IDs 12 through 20:

```
rs(config)# vlan create-range 12-20 port-based
```

You can use the **vlan add-to-vlan-range** command to add a trunk port to a number of VLANs at one time. In the following example, the first command makes port et.1.9 a trunk port. The **vlan add-to-vlan-range** command then adds the port to the nine VLANs with VLAN IDs 12-20:

```
rs(config)# vlan make trunk-port et.1.9
rs(config)# vlan add-to-vlan-range ports et.1.9 to 12-20
```

The **vlan show** command shows that the port et.1.9 has been added to VLANs 12 through 20:

```
rs# vlan show
VID      VLAN Name        Used for                          Ports
---      ---------        --------                          -----
1        DEFAULT          IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.(1-16)
2        SYS_L3_et.1.1    IP                                et.1.1
3        SYS_L3_t1port-   IP                                t1.2.1:1
4        SYS_L3_t1port-   IP                                t1.2.1:2
12       12               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
13       13               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
14       14               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
15       15               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
16       16               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
17       17               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
18       18               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
19       19               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
20       20               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
```

Note that you can also specify a VLAN ID or VLAN name with the **vlan show** command to display information about a specific VLAN:

```
rs# vlan show id 20
VID      VLAN Name        Used for                          Ports
---      ---------        --------                          -----
20       20               IP,IPX,ATALK,DEC,SNA,IPv6,L2      et.1.9
```

6.10 VLAN TRANSLATION

Metro service providers are often faced with the need to translate one VLAN ID (VID) to another. On the RS, you can configure a VLAN translation filter to translate a frame's VID to another VID, and forward traffic to a specified set of ports.

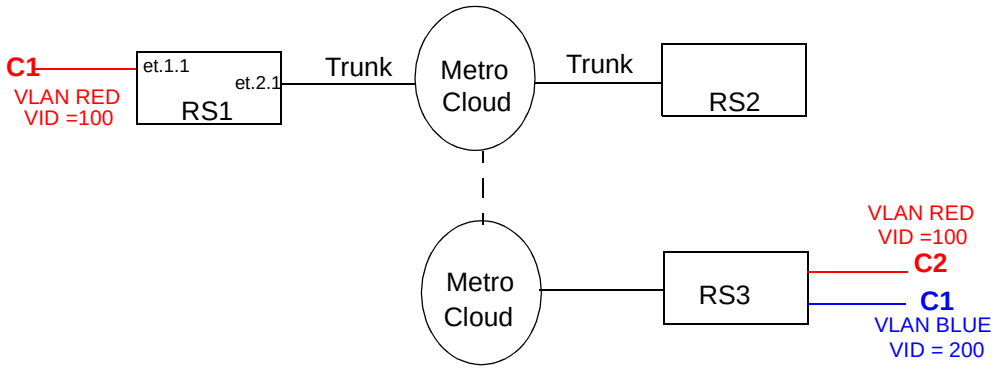
The VLAN translation filter specifies the input port(s) and input VLAN ID, the output port(s) and the output VLAN ID, and the destination and/or source MAC address. VLAN translation filters are configured and applied at the input port. Then when the input port receives a frame to be bridged that matches the filter, it switches the frame's VID to the output VID and forwards the frame to the specified output port(s).

When you configure the filter, you can also specify that the reverse mapping be applied to traffic flowing in the opposite direction (i.e., the input port becomes the output port and the input VLAN becomes the output VLAN), enabling the reverse traffic to be forwarded accordingly.

6.11 CONFIGURATION EXAMPLES

Following are typical scenarios in which VLAN translation is used. In the first example, one VLAN translation filter is used to translate the VID of frames flowing in both directions of traffic. In the second example, a different filter is applied in each direction of traffic.

In the following diagram, the metro provider assigned Customer 1 (C1) to VLAN RED (VID = 100) on RS1 and to VLAN BLUE (VID = 200) on RS3. The metro provider previously assigned Customer 2 (C2) to VLAN RED on RS3.



The two metro clouds are then connected, resulting in the provider having two different customers (C1 and C2) with the same VID on the same MAN. The metro provider could reassign the VIDs so they do not overlap. But this would require the customers to change their configurations. The more efficient alternative is to configure a VLAN translation filter and apply it to port et.1.1 on RS1.

Following is the configuration for RS1:

```
Configure the VLANs and add ports to them.
rs(config)# vlan make trunk port et.2.1
rs(config)# vlan create red ip id 100
rs(config)# vlan add ports et.1.1,et.2.1 to red
rs(config)# vlan create blue ip id 200

rs(config)# vlan add ports et.2.1 to blueConfigure the VLAN translation filter.
rs(config)# filters add vlan-switching name c1 in-port-list et.1.1 out-port-list
et.2.1 input-vlan 100 output-vlan 200 dest-mac any reverse-mapping policy-id 100
```

When port et.1.1 receives frames that match the configured filter, it switches the frames' VID from 100 to 200 and forwards the frames to et.2.1. The **reverse mapping** parameter in the **filters add vlan-switching** command specifies that VLAN translation is also applied to the traffic in the reverse direction. Thus, when port et.2.1 receives frames to be bridged with a VID of 200, it switches the VID to 100 and forwards it to port et.1.1.

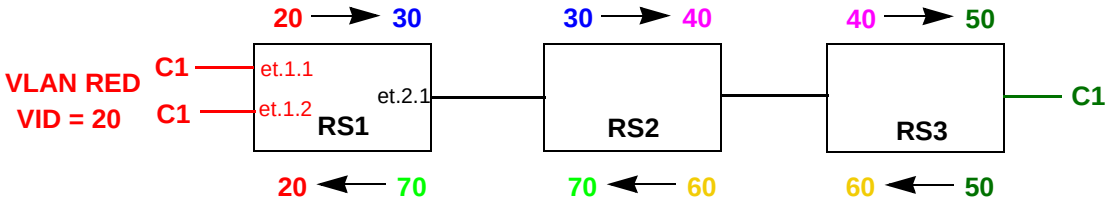
Use the **filter show vlan-switch** command to display information about the translated VLANs.

```
rs# filters show vlan-switch in-vlan 100

Name:           100
----
Direction:      flow
Restriction:    allow-to-go
In VLAN:        100
Out VLAN:       200
Mac VLAN:       4195
Source MAC:     any
Dest MAC:       any
In-List ports:  et.1.1
Out-List ports: et.2.1
rs#
```

In the following example, the VIDs are treated similar to MPLS transport labels. On RS1, ports et.1.1 and et.1.2 belong to VLAN RED, which has a VID of 20. The VID of incoming frames on these ports is translated from 20 to 30, while the VID of the reverse traffic coming in on port et.2.1 is translated from 70 to 20.

.



In the example, a different VLAN translation filter is applied to each direction of traffic; traffic flowing in one direction uses a VLAN translation scheme that is different from the one used in the reverse direction. Following is the configuration for RS1:

.

Configure the VLANs and add ports to them.

```
rs(config)# vlan make trunk port et.2.1
rs(config)# vlan create red ip id 20
rs(config)# vlan add ports et.1.(1,2),et.2.1 to red
rs(config)# vlan create blue ip id 30
rs(config)# vlan add ports et.2.1 to blue
rs(config)# vlan create green ip id 70
rs(config)# vlan add ports et.2.1 to green
```

Configure the VLAN translation filters; one for each direction of traffic. In this case, the ***reverse-mapping*** *parameter is not specified.*

```
rs(config)# filters add vlan-switching name c100a in-port-list et.1.(1,2)
out-port-list et.2.1 input-vlan 20 output-vlan 30 policy-id 100
rs(config)# filters add vlan-switching name c100b in-port-list et.2.1 out-port-list
et.1.(1,2) input-vlan 70 output-vlan 20 policy-id 200
```

6.11.1 Restrictions

Note the following restrictions on configuring and using VLAN translation:

1. VLAN translation and VLAN stacking cannot be implemented on the same ports.
2. You cannot enable L4 bridging on a VLAN to which a VLAN translation filter is applied.
3. VLAN translation is not supported on ports that are running MPLS.
4. When used with other L2 filters, the L2 filters are applied to the input VID only, and not to the translated VID.
5. Vlan translation filters can translate customer BPDUs if the STP forwarder is enabled, using the **`stp set forward-tagged-bpdu`** command.

6. VLAN translation is supported on Ethernet line cards only.
7. You cannot apply to the same input port two or more VLAN translation filters mapped to the same translated VLAN.

6.12 DHCP RELAY AGENT FOR FLAT LAYER-4 BRIDGED VLANS

The RS switch routers support DHCP relay agent (also known as Option 82) functionality across layer-2 bridged VLANs, which are also running layer-4 bridging.

On a VLAN where the relay agent is enabled, a *circuit ID* is attached to the packets. The circuit ID consists of the RS' base MAC address, the port number on which the packet was received, and the VLAN on which the packet was received.

When the relay agent is enabled, packets that already contains relay agent information are dropped on the assumption that the information was fabricated by the DHCP client. Also, if the packet will become too large if the relay agent information is added, the packet is forwarded without adding the relay agent information.

Relay agent information contained within DHCPOFFER and DHCPACK packets is stripped off to keep the DHCP client from seeing it.

The following is an example of activating the DHCP relay agent on a newly created VLAN:

```
rs(config)# vlan create op82 ip
rs(config)# vlan add port et.5.1 to op82
rs(config)# vlan enable l4-bridging on op82
rs(config)# ip helper-address relay-agent-info circuit-id mac-port-vlan vlan op82
```

Note Notice that layer-4 bridging must be enabled on the VLAN for the relay agent to work.

6.13 CONFIGURING LAYER-2 FILTERS

Layer-2 security filters on the RS allow you to configure ports to filter specific MAC addresses. When defining a Layer-2 security filter, you specify to which ports you want the filter to apply. For details on configuring Layer-2 filters, refer to Chapter 27, *"Security Configuration."* You can specify the following security filters:

- Address filters

  These filters block traffic based on the frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Address filters are always configured and applied to the input port.
- Port-to-address lock filters

  These filters prohibit a user connected to a locked port or set of ports from using another port.
- Static entry filters

These filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port.

- Secure port filters

  A secure filter shuts down access to the RS based on MAC addresses. All packets received by a port are dropped. When combined with static entries, however, these filters can be used to drop all received traffic but allow some frames to go through.

- Authorization filters

  An authorization filter authenticates client based on their MAC address. It contains a list of end-station MAC addresses that are authorized to transmit traffic through the port. For additional information on this fetaure, refer to Section 27.2, *"Port-Based Authentication."*

6.14 MONITORING BRIDGING

The RS displays bridging statistics and configurations contained in the RS.

To display bridging information, enter the following commands in Enable mode.

Show IP routing table.	**ip show routes**
Show all MAC addresses currently in the l2 tables.	**l2-tables show all-macs**
Show l2 table information on a specific port.	**l2-tables show port-macs**
Show information the master MAC table.	**l2-tables show mac-table-stats**
Show information on a specific MAC address.	**l2-tables show mac**
Show information on MACs registered.	**l2-table show bridge-management**
Show all VLANs.	**vlan show**

6.15 GARP/GVRP

The Generic Attribute Registration Protocol (GARP) is a generic attribute dissemination mechanism. In the case of the GARP VLAN Registration Protocol (GVRP), the attribute is the VLAN ID (VID).

GVRP uses GARP Protocol Data Units (PDUs) to register and de-register VLAN IDs on ports. When you enable GVRP on the RS and one of its ports receives a GVRP request for an existing VLAN to which it does *not* belong, GVRP registers the VLAN ID on the port, effectively adding the port to the VLAN. For example, VLAN RED is configured on ports et.1.1 and et.1.2 of the RS. Port et.1.3 receives a GVRP request for VLAN RED, of which it is not a member. If GVRP is enabled on port et.1.3, it will autmoatically become a member of VLAN RED and pass traffic for this VLAN. But if GVRP is *not* enabled on port et.1.3, VLAN registration will not occur, and traffic for VLAN RED will never reach port et.1.3.

GVRP also provides a mechanism for dynamically creating and removing VLANs. When you turn on dynamic VLAN creation and the RS receives a request for a VLAN that does not exist on the RS, GVRP dynamically creates that VLAN and adds the port that received the request.

GVRP propagates this VLAN information throughout the active topology, enabling all GVRP-aware devices to dynamically establish and update their knowledge of VLANS and their members, including the ports through which those members can be reached. (For details on GARP refer to IEEE 802.1d. For details on GVRP, refer to IEEE 802.1q.)

Note GVRP will only add a port to a VLAN if the port is an 802.1q trunk port.

GARP/GVRP provides the following benefits:

- The administrator is not required to know ahead of time which VLANS should be configured on the network.
- The administrator does not have to manually configure all VLANS on the network.
- It prunes unnecessary traffic if a VLAN goes down.

6.15.1 Running GARP/GVRP with STP

Anytime GARP /GVRP configures a VLAN or adds ports to a VLAN, this information needs to be propagated on all other ports that are part of the active topology. If STP is disabled, this includes all ports, except the input port. If STP is enabled, this includes all ports that are in the forwarding mode, except the input port.

6.15.2 Configuring GARP/GVRP

To configure GARP/GVRP on the RS, you should do the following:

1. Enable GVRP functionality on the RS. (GVRP is disabled on the RS by default.)
2. Enable GVRP on individual ports. (GVRP is disabled on all ports on the RS by default.)

You can optionally set the following features by using the **`garp`** and **`gvrp`** commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*:

- Enable dynamic VLAN creation. (This feature is disabled by default.) When you enable this feature, VLANs will be created dynamically when there is a GVRP request for a VLAN that does not exist on the RS. In addition, you will still be able to configure VLANs manually through the CLI.
- Set a port's registration mode to *forbidden*. Registration modes refer to whether VLAN IDs can be dynamically registered or de-registered on a port. You can set a port's mode to forbidden to prevent it from being dynamically added to a VLAN. Setting a port to "forbidden registration" de-registers all VLANS (except VLAN 1) and prevents further VLAN registration on the port.
- Set a port's status to *non-participating*. When you do so, the specified ports will not send GARP PDUs.
- Change the default values for the following GARP timers:
  - leaveall timer default is 10,000 ms
  - leave timer default is 600 ms (When configuring the leave timer, its value should be three times that of the join timer.)
  - join timer default is 200 ms

Note For GARP to operate properly, all layer-2 connected devices should have the same GARP timer values.

6.15.3 Configuration Example

Consider the following configuration example.

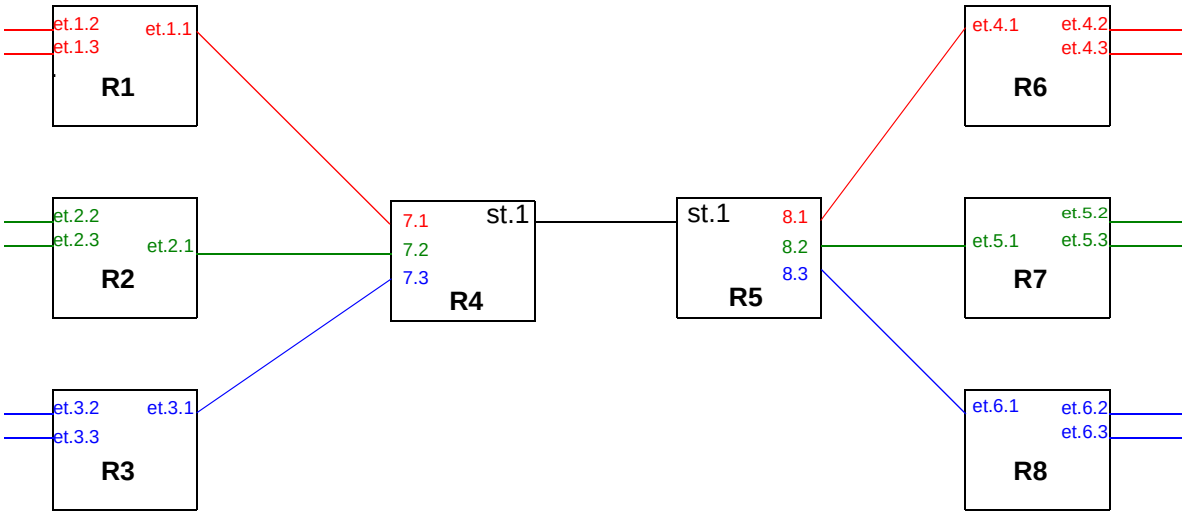


Figure 6-13 Using GARP/GVRP on a network

Routers R4 and R5 pass traffic between two networks. The administrator used the CLI to configure the following VLANs:

- VLAN RED on ports et.1.1- 1.3 on R1, and on et.4.1 - 4.3 on R6.
- VLAN GREEN on ports et.2.1- 2.3 on R2, and on et.5.1 - 5.3 on R7.
- VLAN BLUE on ports et.3.1- 3.3 on R3, and on et.6.1 - 6.3 on R8.

No VLANs were configured on R4 and R5. Instead, dynamic VLAN creation was enabled. So when any of the edge routers (R1, R2, R3, R6, R7, or R8) send a request for a VLAN to the core routers (R4 and R5), and the VLAN does not exist on the core routers, that VLAN is dynamically created on the port of the router that received the request.

For example, R4 receives a receives a request for VLAN RED on port 7.1. VLAN RED is created dynamically on port 7.1 of R4. This is then propagated across the bridged LAN to all the other routers. If dynamic VLAN creation was not enabled on R4, it would have dropped the traffic for VLAN RED.

The following is the configuration for R1:

Create VLAN RED as a port-based VLAN and add ports to it.

```
vlan create red port-based
vlan add ports et.1.1-3 to vlan red
```

Enable GVRP

```
gvrp start
```

Enable GVRP on ports et.1.1-3.

```
gvrp enable ports et.1.1-3
```

Ports et.1.2 and 1.3 do not need to send GARP PDUs because they are connected to devices that are not running GVRP. Therefore, we should set their status to non-participating.

```
gvrp set applicant status non-participant et.1.2-3
```

The following is the configuration for R4:

Create the SmartTRUNK.

```
smarttrunk create st.1 protocol no-protocol
```

Add ports to the SmartTRUNK.

```
smarttrunk add ports et.1.1-3 to st.1
```

Enable GVRP

```
gvrp start
```

Enable GVRP on ports st.1, and et.7.1-3.

```
gvrp enable ports st.1, et.7.1-3
```

Enable dynamic VLAN creation so when R1, R2, or R3 sends a request for a VLAN, it will dynamically be created on R4.

```
gvrp enable dynamic vlan-creation
```

Note that because dynamic VLAN creation was enabled on R4, we did not have to manually configure any VLAN on R4.

6.16 TUNNELING VLAN PACKETS ACROSS MANS

The “stackable” VLAN feature on the RS allows you to tunnel multiple VLANs through a metropolitan area network (MAN) over a single backbone VLAN. This feature provides the following benefits:

- Traffic for multiple VLANs, or traffic for multiple customers, can be aggregated to run through a MAN over a single backbone VLAN. The RS supports a maximum of 4094 customers or VLANs and up to 4094 backbone VLANs.
- Spanning tree and rapid spanning tree protocols can be run in customer-specific VLANs; no reconfiguration of customer-specific VLANs is needed.
- Per-VLAN spanning tree can be run in the backbone VLAN.

6.16.1 Stackable VLAN Components

The following figure illustrates the basic components of the stackable VLAN. Routers R1 and R2 switch traffic for customers C1 and C2 through the MAN. Ports et.2.1 on R1 and et.6.1 on R2 belong to customer C1’s VLAN, “BLUE” while ports et.3.1 on R1 and et. 7.1 on R2 belong to customer C2’s VLAN, “GREEN.” Traffic entering any of these four ports are tagged with the appropriate customer VLAN ID (BLUE or GREEN) in an IEEE 802.1q header.

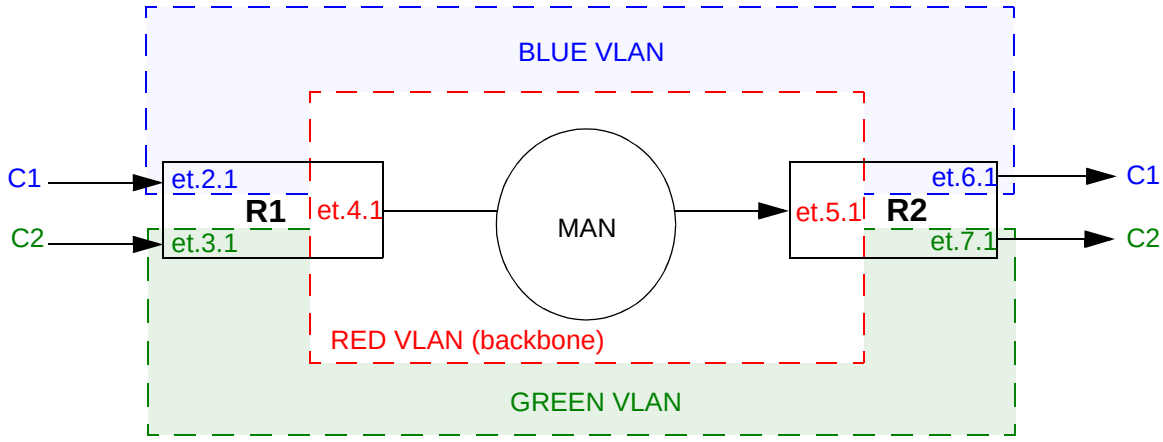


Figure 6-14 Stackable VLAN components

- The VLAN RED is the *backbone VLAN*, which allows traffic from various VLANs to be tunneled through the MAN.
- Ports et.4.1 on R1 and et.5.1 on R2 are *tunnel backbone ports*, which are trunk ports through which the VLAN traffic is tunneled. Tunnel backbone ports must be configured as trunk ports so that they maintain the encapsulated 802.1q header. You configure these ports as both trunk ports and tunnel backbone ports with the **`stackable-vlan`** option of the **`vlan make trunk-port`** CLI command.
- Ports et.2.1 and et.3.1 on R1 are *tunnel entry ports*, which are access ports on which the VLAN traffic to be tunneled enters R1. Ports et. 6.1 and et.7.1 on R2 are *tunnel exit ports*, which are access ports on which the tunneled traffic exits R2. You configure the mapping of the tunnel entry and tunnel exit ports to the backbone VLAN with the **`vlan enable stackable-vlan`** CLI command.

Note Tunnel entry and exit port are configured as access ports. These ports can receive 802.1q-tagged traffic.

In Figure 6-14, customer C1 tags outgoing traffic with the VLAN ID BLUE in the 802.1q headers. Customer C1's traffic enters the tunnel entry port et.2.1 on R1. On R1, the tunnel entry port et.2.1 is mapped to the backbone VLAN RED. The BLUE-tagged packet received on port et.2.1 is encapsulated with an 802.1q header with VLAN RED's tag before it is bridged out on the tunnel backbone port et.4.1. (The original 802.1q header with the VLAN BLUE ID is now part of the data portion of the packet.) On R2, the RED 802.1q header is stripped off before the packet is sent out on et.6.1. The packet is sent out the tunnel exit port as a tagged packet with the original BLUE 802.1q header.

If an untagged packet arrives on a tunnel entry port, normal layer 2 processing takes place. If the packet needs to be flooded, it will be flooded on all ports in the customer VLAN.

If a broadcast or multicast packet arrives on a tunnel entry port, the packet is flooded on all ports that belong to the backbone VLAN as well as any other ports that belong to that VLAN. If a unicast packet arrives on a tunnel entry port, the packet is sent out a particular backbone VLAN port.

The 802.1p priority of a packet is preserved throughout the MAN. The RS hardware uses the control priority in the L2 table entry. If there is no L2 table entry for the packet, the 802.1p priority contained in the 802.1q header is used.

Normally, access ports can belong to only one VLAN of a particular protocol type, such as IP. The RS allows tunnel entry and exit ports to be added to multiple VLANs. Note, however, that only ports that are configured with the **`stackable-vlan`** option of the **`vlan make access-port`** command can be added to more than one VLAN of the same protocol type.

GARP and/or GVRP can be enabled on tunnel backbone ports.

Note You *cannot* enable L4 bridging on stackable VLANs. Also, do not use the **`stp set vlan-disable`** command on routers where you are configuring stackable VLANs.

6.16.2 Configuration Examples

This section contains configuration examples for the following scenarios:

- Multiple customers, with each customer having its own VLAN
- Multiple customers sharing a common VLAN
- Single VLAN with multiple tunnel entry ports
- STP or GVRP in customer VLANs tunneled over the backbone VLAN
- Multiple VLANs on a single tunnel entry/exit port
- Sending untagged packets over stackable VLANs

Multiple Customer VLANs

In Figure 6-15, traffic for customer C1's VLAN (BLUE) and for customer C2's VLAN (GREEN) is tunneled through the backbone VLAN (RED).

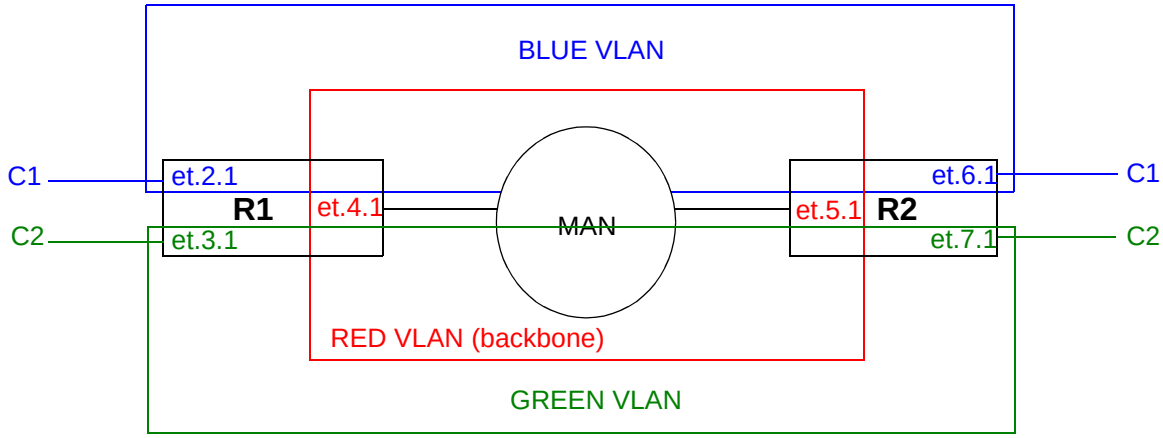


Figure 6-15 Multiple customers with different VLANs

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to GREEN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

Multiple Customers with Common VLANs

In Figure 6-16, customers C1 and C2 are connected to the MAN, with both customers using the same VLAN (BLUE). To ensure that traffic for C1 is not sent to C2 and vice versa, the backbone VLAN for each customer must be different. Therefore, traffic for customer C1 will be sent on the backbone VLAN RED, while traffic for customer C2 will be sent on the backbone VLAN GREEN. Note that the trunk port on each router is part of both backbone VLAN RED and backbone VLAN GREEN.

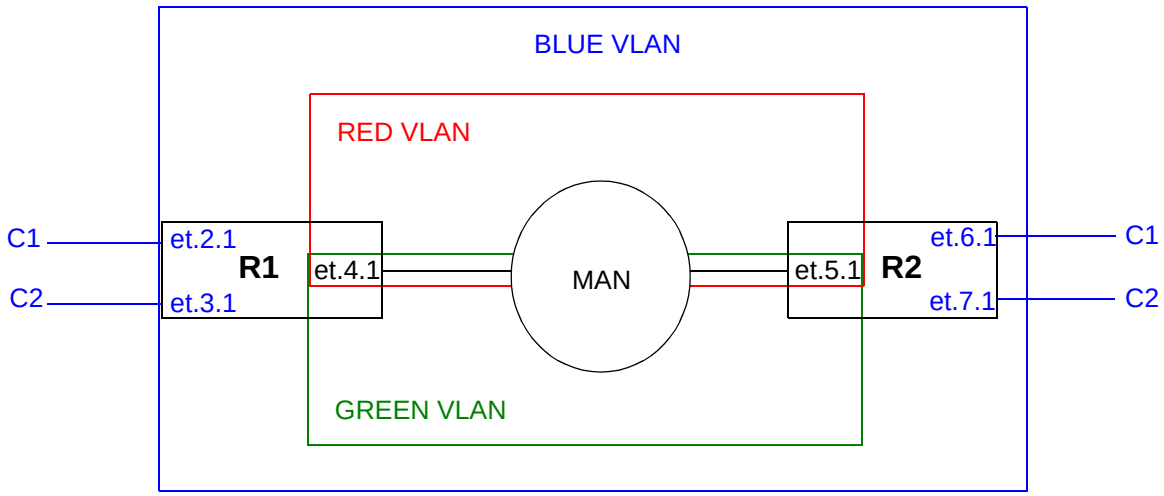


Figure 6-16 Multiple customers with common VLANs

The following is the configuration for R1:

```
! Create 2 backbone VLANs and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to BLUE VLAN
vlan add ports et.2.1, et.3.1 to BLUE
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Add et.4.1 to both RED and GREEN backbone VLANs
vlan add ports et.4.1 to RED
vlan add ports et.4.1 to GREEN
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan GREEN
```

The following is the configuration for R2:

```
! Create 2 backbone VLANs and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to BLUE VLAN
vlan add ports et.6.1, et.7.1 to BLUE
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Add et.5.1 to both RED and GREEN backbone VLANs
vlan add ports et.5.1 to RED
vlan add ports et.5.1 to GREEN
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan GREEN
```

Tunnel entry or exit ports can be spread across routers. In Figure 6-17, customers C1 and C3 use the VLAN BLUE, while customers C2 and C4 use the VLAN GREEN. The backbone VLAN for each customer must be different to ensure that traffic for C1 is not sent to C3, traffic for C2 is not sent to C4, etc. Therefore, traffic for customer C1 and C2 will be sent on the backbone VLAN RED, while traffic for customer C3 and C4 will be sent on the backbone VLAN PURPLE.

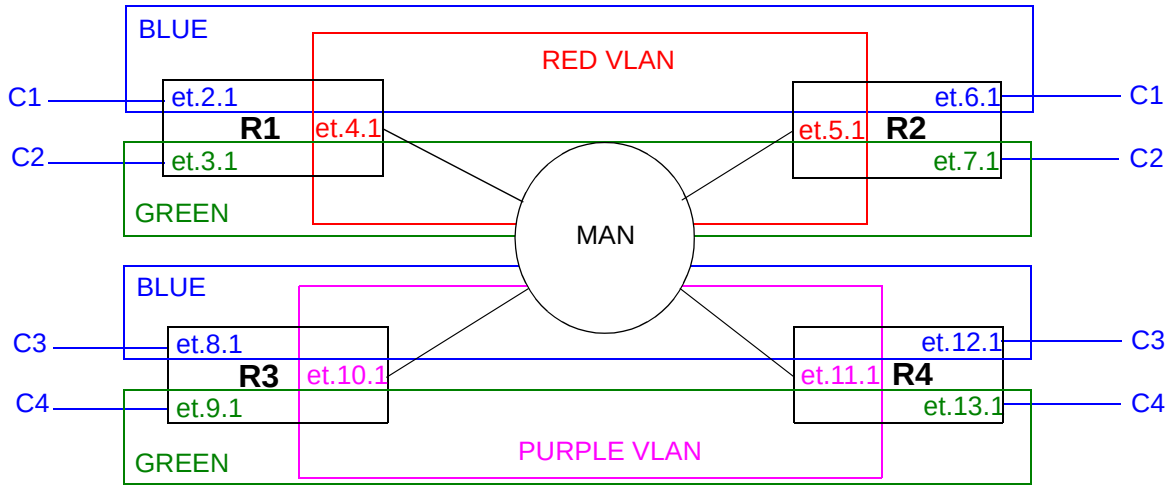


Figure 6-17 Multiple customers with common VLANs across multiple routers

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.5.1 to RED
vlan add ports et.7.1 to GREEN
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

The following is the configuration for R3:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create PURPLE port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.8.1 to BLUE
vlan add ports et.9.1 to GREEN
vlan add ports et.10.1 to PURPLE
! Make et.10.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.10.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.8.1 backbone-vlan PURPLE
vlan enable stackable-vlan on et.9.1 backbone-vlan PURPLE
```

The following is the configuration for R4:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create PURPLE port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.11.1 to PURPLE
vlan add ports et.12.1 to BLUE
vlan add ports et.13.1 to GREEN
! Make et.11.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.11.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.12.1 backbone-vlan PURPLE
vlan enable stackable-vlan on et.13.1 backbone-vlan PURPLE
```

Single VLAN with Multiple Tunnel Entry Ports

In Figure 6-18, customer C1 has a VLAN BLUE with multiple tunnel entry ports (et.2.1 and et.3.1 on R1) and multiple tunnel exit ports (et.6.1 and et.7.1 on R2).

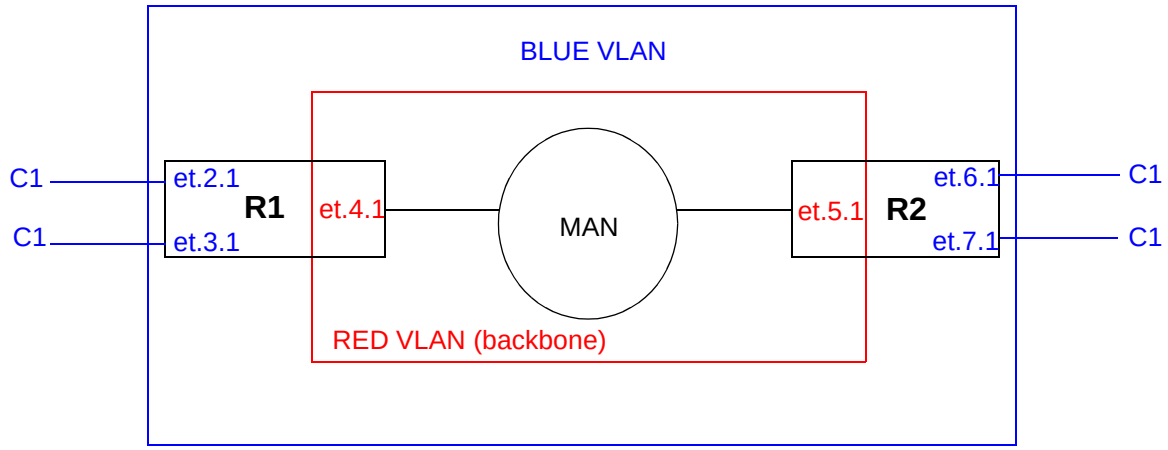


Figure 6-18 Customer VLAN with multiple tunnel entry/exit ports

The following is the configuration for R1:

```
! Create backbone VLAN and customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to VLANs
vlan add ports et.2.1, et.3.1 to BLUE
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create backbone VLAN and customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to VLANs
vlan add ports et.6.1, et.7.1 to BLUE
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

The following is an example where a customer VLAN has multiple tunnel entry or exit ports spread across routers. Figure 6-19 shows customers C1 and C2 sharing the VLAN BLUE. Traffic for customer C1 can arrive on tunnel entry ports on routers R1, R2, or R3. Broadcast or multicast traffic arriving on et.2.1 on R1 is tunneled on backbone VLAN RED and will be seen by C1 users on R2 and R3. C2 users on R4 will not see the C1 traffic since the tunnel backbone port on R4 belongs to the backbone VLAN PURPLE.

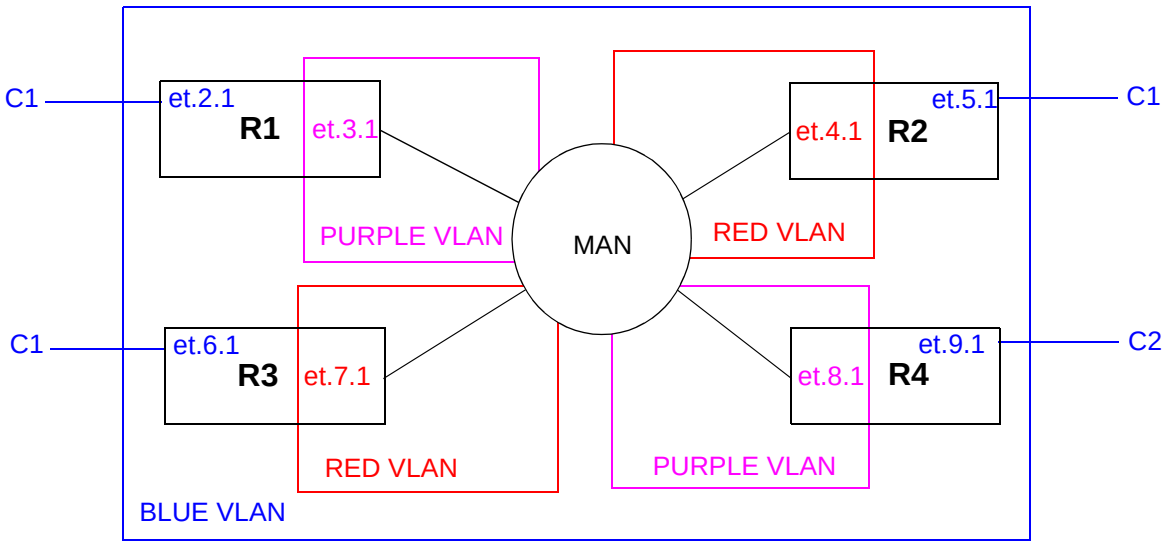


Figure 6-19 Customer VLAN with multiple tunnel entry ports across multiple routers

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create PURPLE port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to PURPLE
! Make et.3.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.3.1 stackable-vlan
! Map tunnel entry port to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan PURPLE
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.4.1 to RED
vlan add ports et.5.1 to BLUE
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.5.1 backbone-vlan RED
```

The following is the configuration for R3:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to RED
! Make et.7.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.7.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
```

The following is the configuration for R4:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create PURPLE port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.8.1 to PURPLE
vlan add ports et.9.1 to BLUE
! Make et.8.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.8.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.9.1 backbone-vlan PURPLE
```

Note If you do not want multicast or broadcast traffic from C1 on R1 to be seen by C1 on R3, then configure a different backbone VLAN on R3.

STP/GVRP in Customer VLANs Tunneled over Backbone VLAN

STP, RSTP, or GARP/GVRP can be run in the customer VLANs which are tunneled over the backbone VLAN. The customer VLAN does not need to be reconfigured in order to be tunneled.

In Figure 6-20, traffic for customer C1's VLAN (BLUE) and for customer C2's VLAN (GREEN) is tunneled through the backbone VLAN (RED). STP is enabled in the customer VLAN BLUE on the customer routers C1R1 and C1R2 for customer C1.

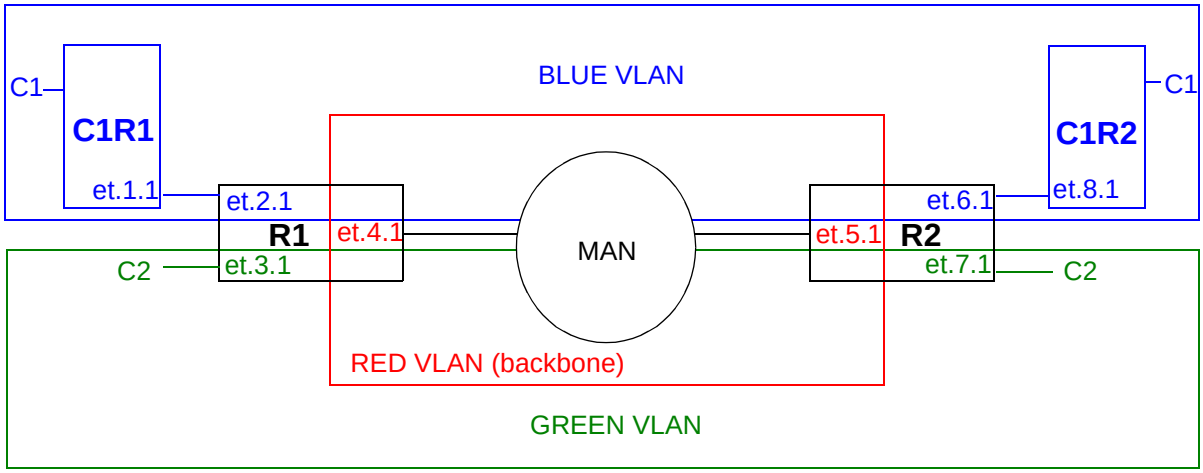


Figure 6-20 STP enabled in customer VLANs

The following configuration statements on C1R1 enable STP on port et.1.1, the port that is connected to the tunnel entry port.

```
! Create customer VLAN
vlan create BLUE port-based
! Add port to VLAN
vlan add ports et.1.1 to BLUE
! Make port et.1.1 a trunk port
vlan make trunk-port et.1.1
! Enable STP on et.1.1
stp enable port et.1.1
! Optional STP configurations
stp set bridging hello-time 3
```

The following configuration statements on C1R2 enable STP on port et.8.1, the port that is connected to the tunnel exit port.

```
! Create customer VLAN
vlan create BLUE port-based
! Add port to VLAN
vlan add ports et.8.1 to BLUE
! Make port et.8.1 a trunk port
vlan make trunk-port et.8.1
! Enable STP on et.8.1
stp enable port et.8.1
```

The configuration of the tunnel entry/exit ports and tunnel backbone ports on R1 and R2 are identical to those shown in the earlier example in Figure 6-15:

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add port to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to GREEN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel exit ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

Multiple VLANs on a Single Tunnel Entry Port

Tunnel entry and exit ports are access ports. Normally, access ports can belong to only one VLAN of a particular protocol type. With stackable VLANs, traffic for multiple VLANs can enter a tunnel entry port to be tunneled over the backbone VLAN. In this case, the tunnel entry port must belong to all the VLANs that are to be tunneled. Use the **stackable-vlan** option of the **vlan make access-port** command to allow the tunnel entry port to be added to any number of VLANs.

In Figure 6-21, customers C1, C2, C3, C4, and C5 each have a VLAN that will use port et.2.1 on R1 as the tunnel entry port. On R2, port et.6.1 will be the tunnel exit port for traffic for all five VLANs.

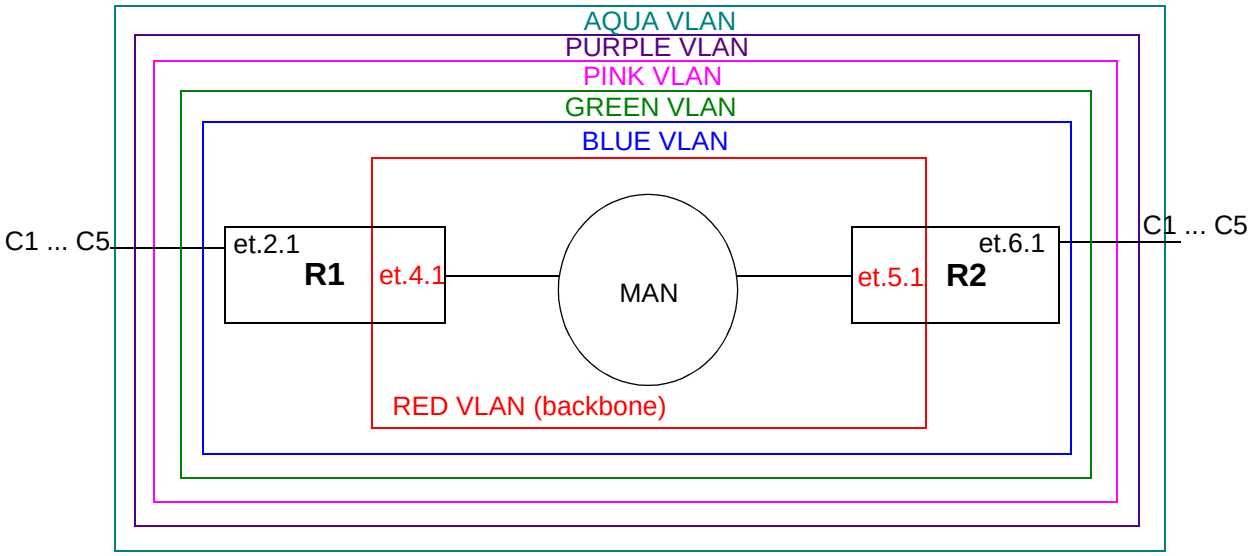


Figure 6-21 Multiple VLANs on single tunnel entry port

The following is the configuration for R1:

```
! Create backbone VLAN
vlan create RED port-based
! Create customer VLANs
vlan create BLUE port-based
vlan create GREEN port-based
vlan create PINK port-based
vlan create PURPLE port-based
vlan create AQUA port-based
! Make et.2.1 an access port that can belong to > 1 VLAN
vlan make access-port et.2.1 stackable-vlan
! Add ports to VLANs
vlan add ports et.2.1 to BLUE
vlan add ports et.2.1 to GREEN
vlan add ports et.2.1 to PINK
vlan add ports et.2.1 to PURPLE
vlan add ports et.2.1 to AQUA
! Add port to backbone VLAN
vlan add ports et.4.1 to RED
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

Note Note that in the above configuration, the commands that add port et.2.1 to more than one VLAN must be issued *before* the command to map the port to the backbone VLAN. That is, the **`vlan add ports`** commands must occur *before* the **`vlan enable stackable-vlan`** command. Once the **`vlan enable stackable-vlan`** command is issued, ports cannot be added to or removed from the customer VLANs.

The following is the configuration for R2:

```
! Create backbone VLAN
vlan create RED port-based
! Create customer VLANs
vlan create BLUE port-based
vlan create GREEN port-based
vlan create PINK port-based
vlan create PURPLE port-based
vlan create AQUA port-based
! Make et.6.1 an access port that can belong to > 1 VLAN
vlan make access-port et.6.1 stackable-vlan
! Add ports to VLANs
vlan add ports et.6.1 to BLUE
vlan add ports et.6.1 to GREEN
vlan add ports et.6.1 to PINK
vlan add ports et.6.1 to PURPLE
vlan add ports et.6.1 to AQUA
! Add port to backbone VLAN
vlan add ports et.5.1 to RED
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Map tunnel entry ports to backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED
```

6.16.3 Sending Untagged Packets over Stackable VLANs

You can transport either untagged or 802.1q tagged packets across stackable VLANs. Both tagged and untagged traffic can use the same tunnel entry port to be transported across a backbone VLAN.

To transport tagged or untagged packets over a backbone VLAN:

1. Tunnel entry and exit ports must be configured as stackable VLAN access ports. To do this, use the command **`vlan make access-port`** <*port*> **`stackable-vlan`**.
2. The tunnel entry/exit port and the tunnel backbone port on the router need to belong to the same customer VLAN. The tunnel backbone port is a trunk port that will belong to both the backbone VLAN and the customer VLAN.
3. When mapping the tunnel entry and exit ports to the backbone VLAN with the **`vlan enable stackable-vlan`** command, specify the **`untagged-vlan`** <*vlan*> option.

The following configuration example shows how to transport tagged and untagged packets over a backbone VLAN. In Figure 6-15, traffic for customer C1's VLAN (BLUE) and for customer C2's VLAN (GREEN) is tunneled through the backbone VLAN (RED). Customer C1's VLAN traffic will be transported tagged or untagged.

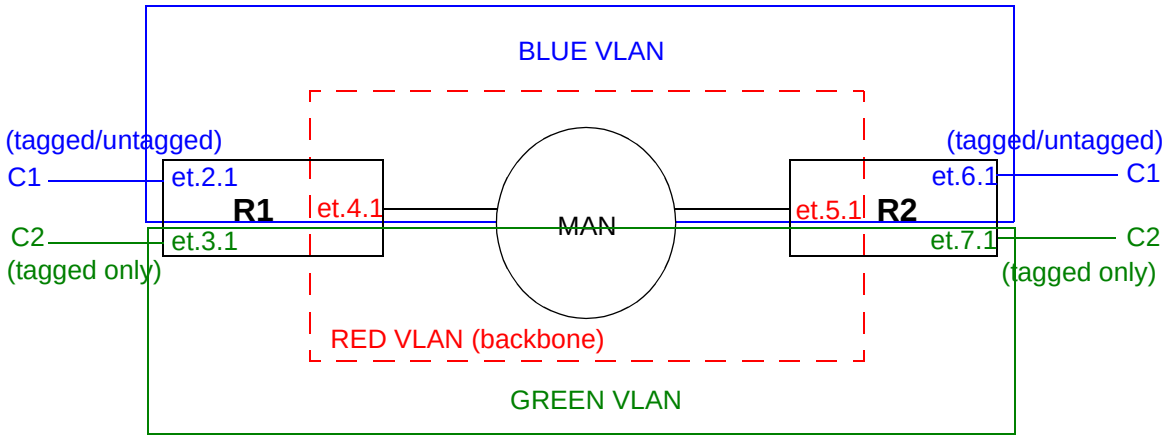


Figure 6-22 Tagged and untagged VLAN traffic

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1 to GREEN
vlan add ports et.4.1 to RED
vlan add ports et.4.1 to BLUE
! Make et.4.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.4.1 stackable-vlan
! Make et.2.1 a stackable VLAN access port
vlan make access-port et.2.1 stackable-vlan
! Map tunnel entry ports to the backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED untagged-VLAN BLUE
vlan enable stackable-vlan on et.3.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 2 customer VLANs
vlan create RED port-based
vlan create GREEN port-based
vlan create BLUE port-based
! Add ports to each VLAN
vlan add ports et.6.1 to BLUE
vlan add ports et.7.1 to GREEN
vlan add ports et.5.1 to RED
vlan add ports et.5.1 to BLUE
! Make et.5.1 both a trunk port and a tunnel backbone port
vlan make trunk-port et.5.1 stackable-vlan
! Make et.6.1 a stackable VLAN access port
vlan make access-port et.6.1 stackable-vlan
! Map tunnel exit ports to the backbone VLAN
vlan enable stackable-vlan on et.6.1 backbone-vlan RED untagged-vlan BLUE
vlan enable stackable-vlan on et.7.1 backbone-vlan RED
```

Multiple Customers in a Ring Topology

The **`vlan make trunk port stackable-vlan`** command has a **`transit`** option that enables a trunk port to bridge packets based on the backbone VLAN when there is no mapping between the original VLAN and the backbone VLAN or when the packet's destination is not known.

Figure 6-23 illustrates a ring topology wherein all the trunk ports are also tagged as transit ports. On R1, the access port et.2.1 is in Customer 1's VLAN (VLAN BLUE) and is mapped to the backbone VLAN RED. Customer C1's traffic is encapsulated with VLAN RED's tag before it is forwarded out the tunnel backbone port et.3.1.

Port et.4.1 on R2 is a trunk port that is also tagged as a transit port. Therefore when it receives the packet from R1, port et.4.1 bridges the packet based on the backbone VLAN (VLAN RED) to the trunk port et.3.1 on R2.

If port et.4.1 on R2 had *not* been a transit port, then the RED 802.1q header would have been stripped off and the packet would have been dropped because there is no VLAN BLUE on R2.

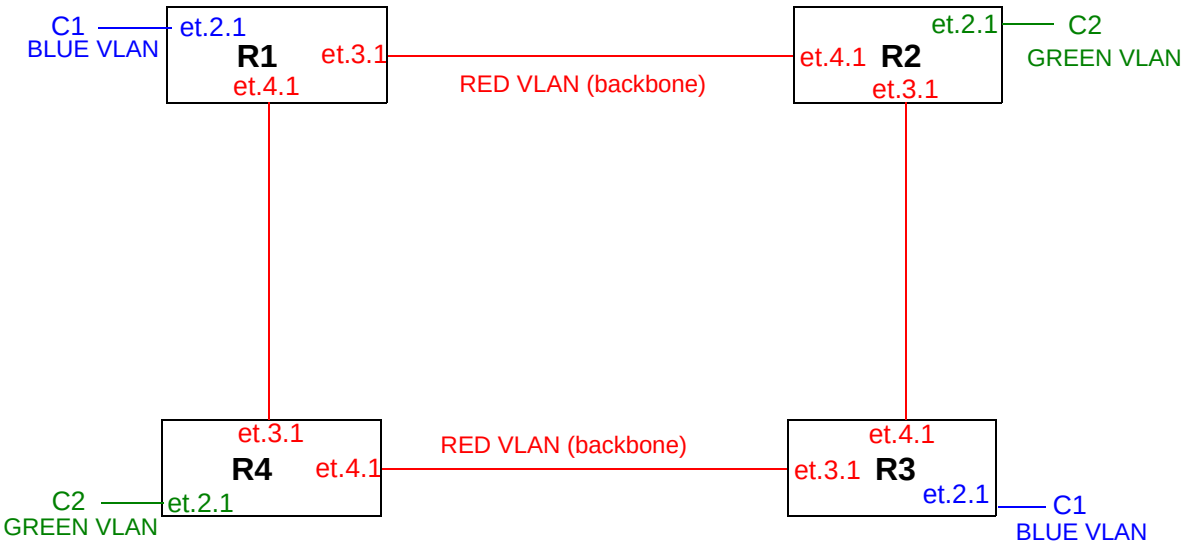


Figure 6-23 Multiple customers in a ring

The following is the configuration for R1:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1,et.4.1 to RED
! Make et.3.1 and et.4.1 both trunk ports and tunnel backbone ports. Specify the transit option.
vlan make trunk-port et.3.1,et.4.1 stackable-vlan transit
! Make et.2.1 a stackable VLAN access port
vlan make access-port et.2.1 stackable-vlan
! Map the tunnel entry port to the backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

The following is the configuration for R2:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
! Add ports to each VLAN
vlan add ports et.2.1 to GREEN
vlan add ports et.3.1,et.4.1 to RED
! Make et.3.1 and et.4.1 both trunk ports and tunnel backbone ports. Specify the transit option.
vlan make trunk-port et.3.1,et.4.1 stackable-vlan transit
! Make et.2.1 a stackable VLAN access port
vlan make access-port et.2.1 stackable-vlan
! Map the tunnel entry port to the backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

The following is the configuration for R3:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create BLUE port-based
! Add ports to each VLAN
vlan add ports et.2.1 to BLUE
vlan add ports et.3.1,et.4.1 to RED
! Make et.3.1 and et.4.1 both trunk ports and tunnel backbone ports. Specify the transit option.
vlan make trunk-port et.3.1,et.4.1 stackable-vlan transit
! Make et.2.1 a stackable VLAN access port
vlan make access-port et.2.1 stackable-vlan
! Map the tunnel entry port to the backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

The following is the configuration for R4:

```
! Create 1 backbone VLAN and 1 customer VLAN
vlan create RED port-based
vlan create GREEN port-based
! Add ports to each VLAN
vlan add ports et.2.1 to GREEN
vlan add ports et.3.1,et.4.1 to RED
! Make et.3.1 and et.4.1 both trunk ports and tunnel backbone ports. Specify the transit option.
vlan make trunk-port et.3.1,et.4.1 stackable-vlan transit
! Make et.2.1 a stackable VLAN access port
vlan make access-port et.2.1 stackable-vlan
! Map the tunnel entry port to the backbone VLAN
vlan enable stackable-vlan on et.2.1 backbone-vlan RED
```

6.16.4 Displaying Stackable VLAN Information

Use the **vlan show stackable-vlan** command to display the configuration of stackable VLANs on the RS. For example,

```
rs# vlan show stackable-vlan
Stackable VLAN Information
==========================

(14 10): 4385
   Applied On: et.4.2
   Flooded On:
  Trunk Ports: et.4.1
Untagged Vlan: none

(13 10): 4386
   Applied On: et.4.3
   Flooded On:
  Trunk Ports: et.4.1
Untagged Vlan: none


Stackable VLAN Trunk Ports:   et.4.1
Stackable VLAN Access Ports:
Stackable VLAN Transit Ports:
```

Table 6-1 Field Description for vlan show stackable-vlan

FIELD	DESCRIPTION
Numbers in parenthesis	The ID number of the VLAN followed by the ID number of the backbone VLAN.
Applied on:	The tunnel entry/exit port that were configured with the **vlan enable stackable-vlan** command.
Flooded on:	The ports on which multicast, broadcast, or unknown unicast packets are flooded.
Trunk Ports:	The trunk ports, configured with the **vlan make trunk-port** command for that VLAN.
Untagged VLAN:	VLANs that are not using 802.1Q tagging.
Stackable VLAN Trunk Ports	The tunnel backbone ports, configured with the **stackable-vlan** option of the **vlan make trunk-port** command.

Table 6-1 Field Description for vlan show stackable-vlan (Continued)

FIELD	DESCRIPTION
`Stackable VLAN Access Ports:`	Tunnel entry ports configured by the **`stackable-vlan`** option of the **`vlan make access-port`** command. These access ports can belong to more than one VLAN of the same protocol type. This allows multiple VLANs to use the same tunnel entry port.
`Stackable VLAN Transit Ports:`	Ports configured by the The **`transit`** option of the **`vlan make trunk port stackable-vlan`** command. Enables a trunk port to bridge packets based on the backbone VLAN when there is no mapping between the original VLAN and the backbone VLAN or when the packet's destination is not known.

6.17 VLAN AGGREGATION

In traditional ISP networks, each customer is allocated an IP subnet based on initial and projected needs for IP addresses. This can lead to problems with IP address consumption. For each allocated subnet, three IP addresses are used: one for the subnet number, one for the directed broadcast address, and one for the default gateway address. A customer who reaches the maximum number of addresses allowed by its IP subnet must be allocated another subnet; as IP addresses that are unused by one customer cannot be used by any other customer.

The VLAN aggregation feature allows multiple VLANs to use the same IP subnet and default gateway address. This feature conserves IPv4 addresses while allowing hosts to remain in separate virtual broadcast domains. With VLAN aggregation, customers are assigned to *sub-VLANs*, which belong to a *super-VLAN*. While each sub-VLAN is a separate broadcast domain, all sub-VLANs use the default gateway IP address of the super-VLAN. IP traffic between sub-VLANs are routed through the super-VLAN. Hosts in the sub-VLAN are allocated IP addresses from the super-VLAN subnet. When a customer needs an additional IP address, the next available IP address within the super-VLAN subnet is allocated; the default gateway address remains the same.

Figure 6-24 shows a network with three VLANs, each of which belongs to a different customer. Both actual and future (represented by shaded boxes) host deployments are shown. For example, customer A currently has hosts A1 and A2 in VLAN A, but customer A will also need an additional eight IP addresses for future host connections. Customer B currently has hosts B1 and B2 in VLAN B, and will need three additional host IP addresses. Customer C has only one host in VLAN C and will not need any additional hosts.

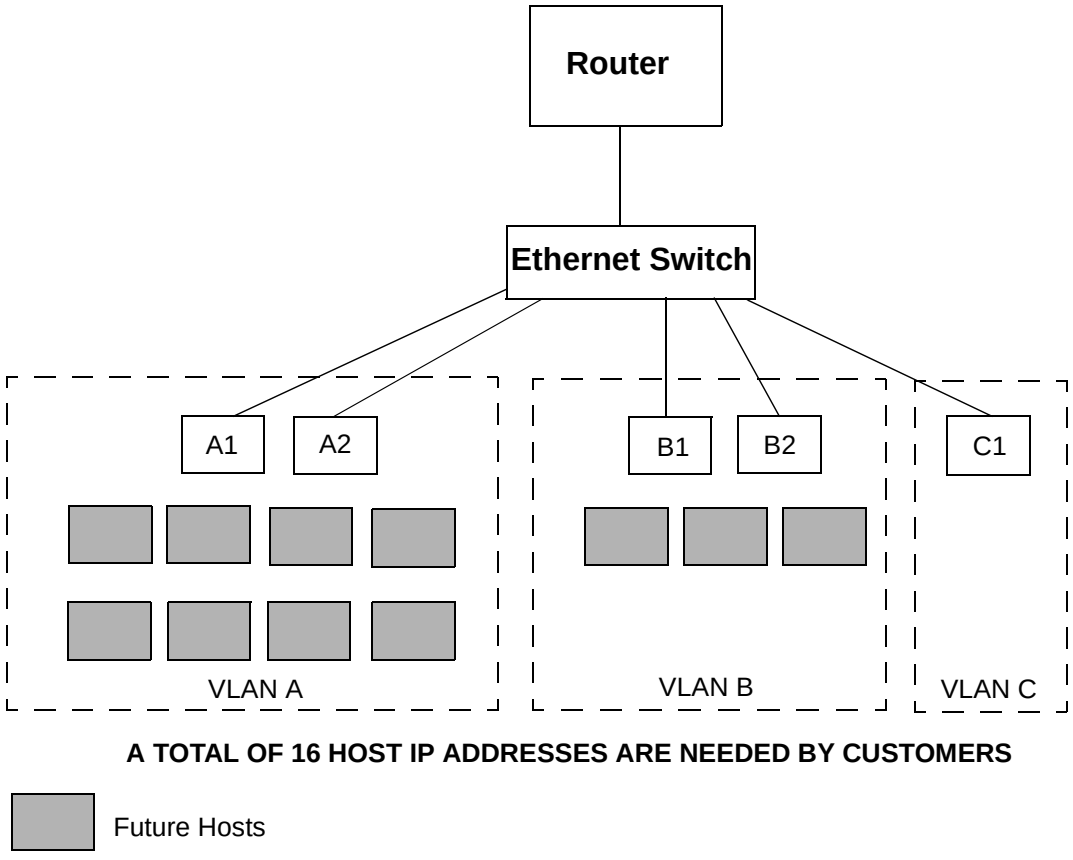


Figure 6-24 IP address allocation in customer VLANs

In the traditional per-VLAN IP subnet allocation, customer A would be assigned an IP subnet of 10.1.1.0/28 that provides 16 IP addresses (even though the customer requires only 10 addresses). See Table 6-2 for subnet allocations without VLAN aggregation. Because the first IP address in the subnet is used for the subnet number and the last IP address in the subnet is used for the directed broadcast address, the number of usable IP addresses for each customer is reduced by 2, as shown by the "Number of Usable IP Addresses" column in Table 6-2. In addition, one IP address of each subnet is used for the router as the default gateway address for the subnet. Therefore, the number of IP addresses for use by each customer is reduced by 3, as shown by the "Number of Available Host IP Addresses" column.

Table 6-2 Customer IP address allocation without VLAN aggregation

Customer	Allocated IP Subnet	Number of Allocated IP Addresses	Number of Usable IP Addresses [a]	Gateway IP Address [b]	Number of Available Host IP Addresses
A	10.1.1.0/28	16	14	10.1.1.1	13
B	10.1.1.16/29	8	6	10.1.1.17	5
C	10.1.1.24/30	4	2	10.1.1.25	1
Total IP Addresses:		28	22		19

a. The first allocated IP address is used for the subnet number. The last allocated IP address is used for the directed broadcast address.
b. One IP address is assigned to the router and is used as the default gateway address for the subnet. In this example, the first usable IP address is assigned to the router.

In the above example, the optimal subnet allocation provides for 28 IP addresses, while the total number of host IP addresses *needed* by all customers is only 16 addresses. And any unused IP addresses that are allocated to one customer cannot be used by another customer.

Another problem is that even though a total of 28 IP addresses are allocated to the customers, only 19 addresses are available for use as host addresses. A total of 9 IP addresses are consumed for the subnet number, directed broadcast, and default gateway. Further, customer C would not be able to add any additional host addresses without being allocated a new subnet, with a different subnet number, directed broadcast, and default gateway address.

With the VLAN aggregation feature, hosts in the customers' sub-VLANs are allocated IP addresses from the super-VLAN subnet 10.1.1.0/24. Since there is only one subnet, the first IP address in the subnet, 10.1.1.0, is used for the subnet number, while the last IP address, 10.1.1.255, is used for the directed broadcast address. And all sub-VLANs use the default gateway IP address of 10.1.1.1. See Table 6-3 for address allocations with VLAN aggregation.

Table 6-3 Customer IP address allocation with VLAN aggregation

Customer	Allocated IP Subnet [a]	Gateway IP Address [b]	Range of Allocated IP Addresses	Number of Allocated IP Addresses	Number of Available Host IP Addresses
A	10.1.1.0/24	10.1.1.1	10.1.1.2 - 10.1.1.11	10	
B	10.1.1.0/24	10.1.1.1	10.1.1.12 - 10.1.1.16	5	
C	10.1.1.0/24	10.1.1.1	10.1.1.17	1	
Total IP Addresses:				16	236

a. The first allocated IP address (10.1.1.0) is used for the subnet number. The last allocated IP address (10.1.1.255) is used for the directed broadcast address.
b. In this example, the first usable IP address for the subnet (10.1.1.1) is assigned to the router and is used as the default gateway IP address for the subnet

With VLAN aggregation, a total of only 3 IP addresses is needed for the subnet number, directed broadcast, and default gateway in the example network. And the total number of 16 IP addresses allocated to the hosts is exactly what the customers require. Contrast that with the non-aggregated VLAN address allocation shown in Table 6-2, where 28 IP addresses are allocated to customer VLANs, with 9 addresses being consumed by the subnet number, directed broadcast, and default gateway addresses.

Additionally, the super-VLAN subnet can provide up to 236 additional host addresses for existing and new customers. For example, if customer C needs a second host IP address, the next available address, 10.1.1.17, is assigned. The default gateway address remains the same.

6.17.1 Configuring VLAN Aggregation

This section describes how to configure a super-VLAN and its sub-VLANs. In Figure 6-25, the super-VLAN is configured on the RS router with the subnet 10.1.1.0/24. The sub-VLANs A, B, C, D, E, and F belong to the super-VLAN and use the IP address of the RS 10.1.1.1 as the default gateway.

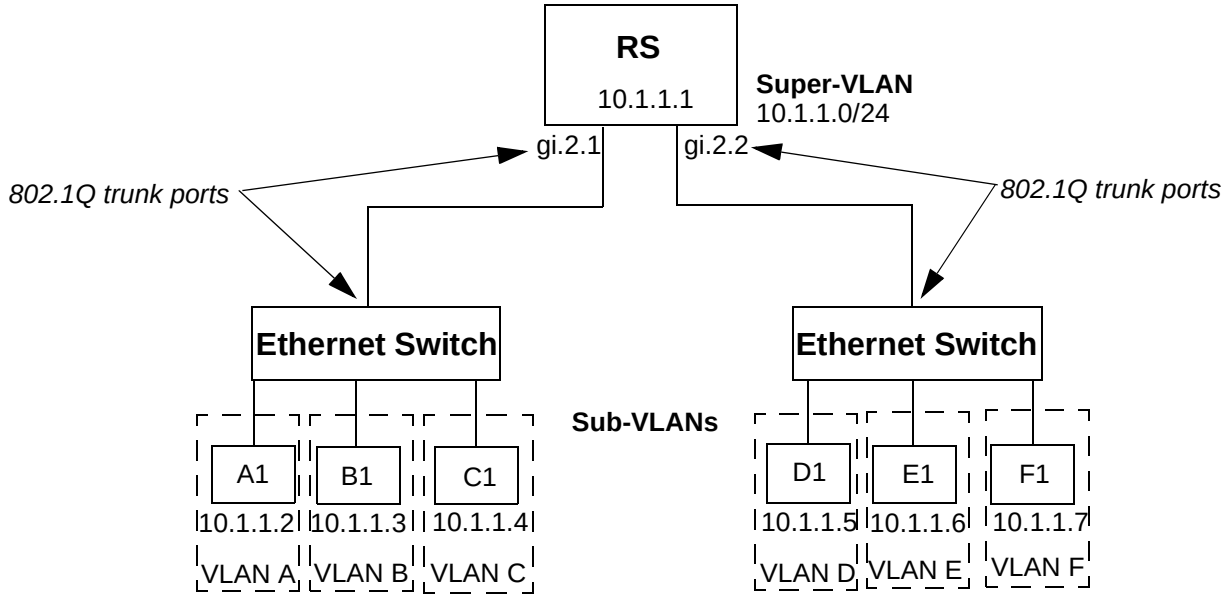


Figure 6-25 Super-VLAN and sub-VLANs

Router Configuration

Note IP traffic between sub-VLANs is *routed* through the super-VLAN. Configure IP forwarding and the appropriate routing protocols on the RS on which the super-VLAN is configured.

To configure the VLAN aggregation feature on an RS router, do the following:

1. Create the super-VLAN and assign the IP subnet range to it. The super-VLAN cannot be a port-based VLAN. For example, the following commands create the super-VLAN 'super1' with the subnet 10.1.1.1/24:

```
rs(config)# vlan create super1 ip id 100
rs(config)# interface create ip sup-int vlan super1 address-netmask 10.1.1.1/24
```

2. Create each sub-VLAN. Configure the ports that connect to the Ethernet Switches as 802.1Q trunk ports and add the appropriate trunk port to each sub-VLAN. For example, the following commands create the sub-VLANs ‘subA,’ ‘subB,’ ‘subC,’ ‘subD,’ ‘subE,’ and ‘subF.’ The 802.1Q port gi.2.1 is added to subA, subB, and subC and port gi.2.2 is added to subD, subE, and subF.

```
rs(config)# vlan create subA port-based id 10
rs(config)# vlan create subB port-based id 20
rs(config)# vlan create subC port-based id 30
rs(config)# vlan create subD port-based id 40
rs(config)# vlan create subE port-based id 50
rs(config)# vlan create subF port-based id 60
rs(config)# vlan make trunk-port gi.2.1
rs(config)# vlan make trunk-port gi.2.2
rs(config)# vlan add ports gi.2.1 to subA
rs(config)# vlan add ports gi.2.1 to subB
rs(config)# vlan add ports gi.2.1 to subC
rs(config)# vlan add ports gi.2.2 to subD
rs(config)# vlan add ports gi.2.2 to subE
rs(config)# vlan add ports gi.2.2 to subF
```

Note Make sure that the VLAN ID that you configure for the super-VLAN is different from the VLAN IDs configured for the sub-VLANs.

3. Add the 802.1Q trunk ports to the super-VLAN. For example:

```
rs(config)# vlan add ports gi.2.1 to super1
rs(config)# vlan add ports gi.2.2 to super1
```

4. Bind the super-VLAN to the sub-VLANs. For example:

```
rs(config)# vlan bind super-vlan super1 to subA
rs(config)# vlan bind super-vlan super1 to subB
rs(config)# vlan bind super-vlan super1 to subC
rs(config)# vlan bind super-vlan super1 to subD
rs(config)# vlan bind super-vlan super1 to subE
rs(config)# vlan bind super-vlan super1 to subF
```

Note Routing between sub-VLANs is *disabled* by default. To enable routing between sub-VLANs, issue the **`vlan enable inter-subvlan-routing`** command on the router.

Ethernet Switch Configuration

On the Ethernet Switch, configure the following:

- Assign each host an IP address from the super-VLAN subnet. For each host, configure the address of the RS as the gateway address. (Host IP and default gateway addresses can be provided by DHCP.)
- Configure a port-based VLAN for each customer who will be connected to the switch.
- Add an access (non-802.1Q) port for each host connection to each customer VLAN.
- Configure the port that will provide the connection to the RS as an 802.1Q trunk port. Add this port to each customer VLAN. This port must be configured as a trunk port, as it will used to transport all customer VLAN information to and from the RS.

Figure 6-26 shows the sub-VLANs on RS switches ‘RS1’ and ‘RS2.’ Example commands to configure the sub-VLANs on RS1 and RS2 follow.

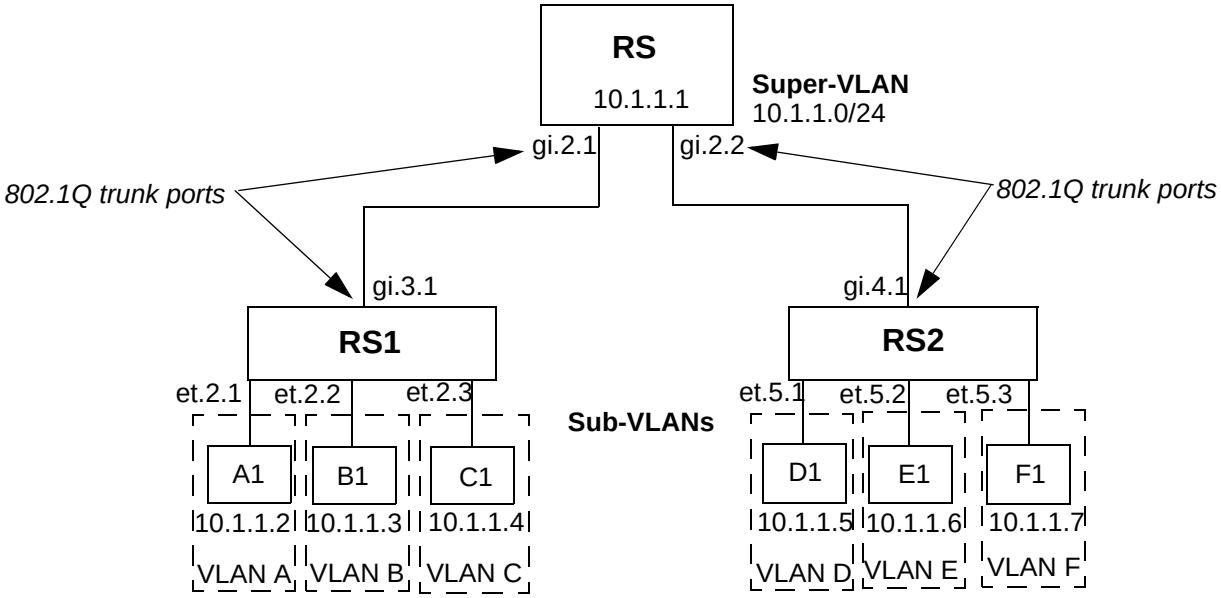


Figure 6-26 Super-VLAN and sub-VLANs with RS switches

The following commands configure the sub-VLANs subA, subB, and subC on RS1:

```
rs(config)# vlan create subA port-based id 10
rs(config)# vlan create subB port-based id 20
rs(config)# vlan create subC port-based id 30
rs(config)# vlan make trunk-port gi.3.1
rs(config)# vlan add ports gi.3.1,et.2.1 to subA
rs(config)# vlan add ports gi.3.1,et.2.2 to subB
rs(config)# vlan add ports gi.3.1,et.2.3 to subC
```

The following commands configure the sub-VLANs subD, subE, and subF on RS2:

```
rs(config)# vlan create subD port-based id 40
rs(config)# vlan create subE port-based id 50
rs(config)# vlan create subF port-based id 60
rs(config)# vlan make trunk-port gi.4.1
rs(config)# vlan add ports gi.4.1,et.5.1 to subD
rs(config)# vlan add ports gi.4.1,et.5.2 to subE
rs(config)# vlan add ports gi.4.1,et.5.3 to subF
```

6.17.2 Multicast

By default, multicast is sub-VLAN aware and processes group subscriptions on a per-sub-VLAN basis.

6.17.3 Restrictions

Note the following restrictions on configuring and using the VLAN aggregation feature:

- L4 bridging is not supported.
- Features such as ACLs and rate-limiting can only be specified on a per-IP address basis.

7 ATM CONFIGURATION GUIDE

This chapter provides an overview of the Asynchronous Transfer Mode (ATM) features available for the Riverstone RS Switch Router. ATM is a cell switching technology used to establish multiple connections over a physical link. In addition, you can configure each of these connections with its own traffic parameters, providing more control over specific connections within a network.

The ATM line card provides an ATM interface, allowing integration of ATM with Ethernet and other interfaces within a network topology supported by the Riverstone RS Switch Router. This chapter discusses the following tasks:

- Configuring ATM ports
- Configuring virtual channels
- Traffic shaping
- Managing traffic
- Bridging ATM traffic
- Routing ATM traffic
- Configuring point-to-point connections (PPP)
- Operations, Administration, and Management (OAM)

7.1 CONFIGURING ATM PORTS

You can use two different ATM line cards on the RS, the ATM multi-rate line card and the ATM-OC12 line card. The multi-rate line card has two available slots for various Physical Layer (PHY) interface cards. These PHY cards provide the media-specific portion of an ATM interface. The ATM-OC12 line card provides one logical connection through two physical ports (Link1 and Link 2). For additional information on these modules, refer to the *Riverstone RS Switch Router Getting Started Guide*.

This section describes the various commands you can use to control the functionality of the ports on the ATM line cards. Use the “at” prefix when specifying an ATM port in the CLI commands. For example, the first port on slot 5 would be “at.5.1.”

7.1.1 Configuring SONET Parameters

ATM utilizes synchronous optical network (SONET) encapsulation to transmit cells through a link. You can configure the following SONET features on the ATM line cards:

- Set the Circuit-ID
- Set SONET/SDH Framing
- Set Loopback Mode
- Enable Path Tracing
- Enable Payload Scrambling
- Enable Stream Scrambling

Note For a complete description of the SONET features, refer to Section 8, *"Packet-over-SONET Configuration Guide."* Refer to the SONET chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a description of the SONET commands.

Configuring Automatic Protection Switching (APS) on the ATM OC-12 Line Card

You can configure APS on the ATM OC-12 line card. This allows for redundancy for the ATM port in case there is an interruption or failure on a link. APS specifies a working port (primary) and a protecting port (backup).

The ATM OC-12 line card has two physical ports: **Link1** and **Link2**. However, there is only one logical port. The **Link1** port is the working port (primary port), and **Link2** is the protecting port (backup port). Note that you cannot configure a connection on the **Link2** port that is different from the **Link 1** port. The **Link2** port operates identically to the **Link1** port, acting solely as the backup port in the case of link interruption or failure.

Note Refer to the SONET Chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a complete description of the APS commands available on the Riverstone RS Switch Router.

7.1.2 Setting Parameters for the Multi-Rate Line Card

On the multi-rate line card you can do the following:

- Enable cell scrambling for the PDH (plesiochronous digital hierarchy) physical (PHY) interfaces available on the ATM line card, such as the T3 and E3 PHYs.
- Select the format for mapping ATM cells into PDH (plesiochronous digital hierarchy) T3 and E3 frames.
- Change the default number of bits allocated for the Virtual Path Identifier (VPI).

Cell Scrambling

Cell scrambling is useful for optimizing the transmission density of the data stream. Since all transmissions use the same source clock for timing, scrambling the cell using a random number generator converts the data stream to a more random sequence. This ensures optimal transmission density of the data stream.

Note Refer to the SONET Chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for information about cell scrambling on SONET PHY interfaces.

In the following example, cell scrambling is enabled on port at.5.1:

```
rs(config)# atm set port at.5.1 pdh-cell-scramble on
```

Cell Mapping

The ATM cells are mapped into a PDH (E3, T3) frame using two different mapping formats. The default mapping format for the ATM multi-rate line card is *direct* ATM cell mapping (default). For compatibility purposes, you can change the mapping format to physical layer convergence protocol (PLCP) as shown in the following example:

```
rs(config)# atm set port at.5.1 cell-mapping plcp
```

VPI Bit Allocation

The VPI defines a virtual path. A virtual path is a bundling of virtual channels transversing across the same physical connection. The actual number of virtual paths and virtual channels available on an ATM port depends upon how many bits are allocated for the VPI and VCI, respectively.

The number of bits allocated define the number of VPI and VCI values available for that port. The following equations define the number of virtual paths and virtual channels:

# of virtual paths = 2^n; where *n* is the number of bits allocated for VPI

# of virtual channels = $2^{(12-n)}$; where (12-*n*) is the number of bits allocated for VCI, and *n* is the number of bits allocated for VPI

The ATM OC-12 line card has a preset bit allocation scheme for the VPI/VCI pair which *cannot* be changed: 4 bits set for VPI and 12 bits set for VCI. The ATM multi-rate line card has a default bit allocation of 1 bit allocated for the VPI and 11 bits allocated for the VCI. This default bit allocation scheme provides a VPI range=(0,1) and # of virtual channels=2^n=2^{11}=2048. If you require more VPIs, you will need to set your VPI bits to some number higher than 1. But because there are only 12 bits available for VPI/VCI pairs on an ATM port, the more bits you allocate for VPI, the fewer bits remain for VCI.

The bit allocation command allows you to set the number of bits allocated for the VPI on the ATM multi-rate line card; the remaining number of bits are allocated for VCI. In the following example, the VPI bit allocation for port at.5.1 is set to 2:

```
rs(config)# atm set port at.5.1 vpi-bits 2
```

7.1.3 Displaying Port Information

You can display the parameters set for an ATM port. The following is an example of the information that is displayed with the **atm show port-settings** command for a PDH PHY interface:

```
rs(atm-show)# port-settings at.9.1
Port information for Slot 9, Port 1:
    Port Type:          T3 ATM coaxial cable
    Xmt Clock Source:   Local
    Scramble Mode:      Payload
    Line Coding:        B3ZS
    Cell Mapping:       Direct
    Framing             Cbit-Parity
    VC Mode:            1 bit of VPI, 11 bits of VCI
    Service Definition: user-default-OC3
        Service Class:      UBR
        Peak Bit Rate:      Best Effort
        Sustained Bit Rate: 0 Kbits/sec (0 cps)
        Maximum Burst Size: 0 cells
        Encapsulation Type: VC-MUX
        F5-OAM:             Requests & Responses
```

The following is an example of the information that is displayed with the **atm show port-settings** command for a SONET PHY interface:

```
rs(atm-show)# atm show port-settings at.7.1
Port information for at.7.1:
    Port Type:            SONET STS-3c MMF
    Media Type:           SONET
    Xmt Clock Source:     Local
    VC Mode:              1 bit of VPI, 11 bits of VCI
    Reservable Bandwidth: 309057 CPS, 131040168 bits/sec
    OAM Timers:           Detect Up: 15, Down: 15
    Service Definition:   default-OC3
        Service Class:      UBR
        Peak Bit Rate:      Best Effort
        Encapsulation Type: LLC Multiplexing
        Traffic Type:       RFC-1483, multi-protocol
        F5-OAM:             Responses Only
```

7.2 CONFIGURING VIRTUAL CHANNELS

A virtual channel is a point-to-point connection that exists within a physical connection. You can create multiple virtual channels within one physical connection, with each virtual channel having its own traffic profile.

The combination of VPI and VCI is known as the VPI/VCI pair, and identifies the virtual channel. Hence, if a VC is configured with a certain VPI/VCI pair on one end of the physical link, the port at the other end must have the same VPI/VCI pair to complete the connection.

Note Never use VCI numbers 0 through 31. These VCIs are used for signaling purposes.

In the following example, a virtual channel on slot 5, port 1 is created with a VPI of 1 and a VCI of 100

```
rs(config)# atm create vcl port at.5.1.1.100
```

After you configure a virtual channel you can apply traffic shaping and QoS parameters to manage the traffic on the VC. For traffic shaping parameters, refer to *"Traffic Shaping."* For information on QoS, refer to *"Traffic Management."*

7.2.1 Gathering Traffic Statistics (OC-12)

Enabling traffic statistics allows you to gather and display various statistics about the virtual channel, including "RMON-like" statistics, counts of frames sent and received, unicast/broadcast/multicast frames sent and received, etc

In the following example, traffic statistics are enabled on port 5.1.1.100

```
rs(config)# atm set vcl port at.5.1.1.100 traffic-stats-enable
```

To display traffic statistics for a virtual channel, use the **atm show port-stats** command as shown in the following example:

```
rs# atm show port-stats port at.5.1.1.100
PORT = 1, VPI = 1, VCI = 100
                                      Received    Transmitted
                                      --------    -----------
SAR statistics:
    Packets discarded                        0              0
    Packets Reassembled/Segmented          119            119
    Received cells                         119            119
AMAC statistics:
    Unicast                                  0              0
    Multicast                                0              0
    Broadcast                                0              0
    Discarded                                0              0 (includes sent to ACPU)
    <64 bytes                                0              0
    63<  <256                                0              0
    255< <1519                               0              0
    >1518                                    0              0
                                       Enabled        Up/Down
                                       -------        -------
OAM status                                  No            N/A
Statistics Cleared      * Never Cleared *
```

Note that the last line of the example shows that the statistics were never cleared. You can clear traffic statistics on a port by using the **atm clear stats** command.

7.3 TRAFFIC SHAPING

You can set traffic parameters for a virtual channel by specifying a service category. A service category defines bandwidth characteristics and delay guarantees. You can then apply a different service category to each virtual channel. This gives you more control of your network resources, and more options to accommodate different user needs.

You can define the following service categories:

Unspecified Bit Rate (UBR) — This service category is strictly best effort and runs at the available bandwidth. Users may limit the bandwidth by specifying a PCR value. The SCR and MBS are ignored. This service class is intended for applications that do not require specific traffic guarantees. UBR is the **default**.

Constant Bit Rate (CBR)	This service category provides a guaranteed constant bandwidth specified by the Peak Cell Rate (PCR). This service requires only the PCR value. The Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS) values are ignored. This service category is intended for applications that require constant cell rate guarantees such as uncompressed voice or video transmission.
Non Real-Time Variable Bit Rate	This service category provides a guaranteed constant bandwidth (specified by the SCR), but also provides for peak bandwidth requirements (specified by the PCR). This service category requires the PCR, SCR, and MBS options and is intended for applications that can accommodate bursty traffic with no need for real-time guarantees.
Real-Time Variable Bit Rate	This service category provides a guaranteed constant bandwidth (specified by the SCR), but also provides for peak bandwidth requirements (specified by the PCR). This service category requires the PCR, SCR, and MBS options and is intended for applications that can accommodate bursty real-time traffic such as compressed voice or video.
Available Bit Rate (ABR)	This service category guarantees a minimum cell rate only, intended for best effort applications. This service category is currently unsupported.

After you define a service category, you apply it to a VC. An important concept when applying service profiles is the concept of *inheritance*. Since a service profile can be applied to a virtual channel, virtual path, or an ATM port, the actual connection can inherit the service profile from any one of the three. The virtual channel will inherit the service profile that is directly applied on it. If no service profile was applied to the virtual channel, the connection will inherit the service profile applied to the virtual path. If no service profile was applied to the virtual path, then the connection will inherit the service profile applied to the ATM port. If no service profile was applied to the port, then the default service class UBR is applied.

The following example defines a service profile named ‘cbr1m’ where CBR is the service category and peak cell rate is set to 10000 kcells/second. The service profile is then applied to the VC (VPI=0, VCI=100) on ATM port at.1.1:

```
rs(config)# atm define service cbr1m srv-cat cbr pcr 10000
rs(config)# atm apply service cbr1m port at.1.1.0.100
```

To display information about the service you configured, use the **`atm show service`** command as shown in the following example:

```
rs# atm show service cbr1m
cbr1m
    Service Class:      CBR
    Peak Bit Rate:      10000 Kbits/sec (23584 CPS)
    Encapsulation Type: LLC Multiplexing
    Traffic Type:       RFC-1483, multi-protocol
    F5-OAM:             Responses Only
```

7.4 TRAFFIC MANAGEMENT

The ATM line cards provide different methods for managing traffic. On the ATM multi-rate line card you can use the following QoS policies to control ATM traffic: Strict Priority, Weighted Fair Queueing (WFQ), or WFQ with Strict Priority.

On the ATM OC-12 line card you can prioritize traffic by configuring virtual channel (VC) groups. Each VC within a VC group can be assigned one (or more) of four internal levels: low, medium, high, and control. These levels prioritize the separate VCs, and as a result prioritize the traffic passing through the separate VCs within the VC group.

7.4.1 Configuring QoS (Multi-Rate Line Card)

You can use the QoS parameters ((**`qos-control`**, **`qos-low`**, **`qos-medium`**, **`qos-high`**) of the **`atm define service`** command to set the following QoS policies on the ATM multi-rate line card:

- Strict Priority (Default)

  Separate buffer space is allocated to each of the following four queues: control, high, medium and low. Buffered traffic is forwarded in the following order: traffic in the control queue is forwarded first, followed by traffic in the high queue, medium queue, and finally, the low queue. When using strict priority, no control packets are dropped if the rate of the control packets is less then the VC's rate. But if the rate of control packets exceeds the VC's rate, then some control packets must be dropped.

  This policy ensures that critical traffic reaches its destination even if the exit ports for the traffic are experiencing greater-than-maximum utilization. To prevent traffic from queues that are forwarded first from starving traffic from other queues, you can apply the WFQ queuing policy to set a minimum bandwidth for each queue.

- Weighted Fair Queuing

  When you use WFQ, you divide the VC’s bandwidth and assign percentages to each queue (control, high, medium and low). These percentages must be at least 10%, and must total 100%. This queueing policy is set on a per-port basis.

- Weighted Fair Queuing with Strict Priority

  With this combination of Strict Priority and WFQ, the control queue gets potentially all of the link bandwidth. The remaining bandwidth is shared among the other priorities, according to the user-specified percentages. With this policy, you specify percentages for the high, medium, and low queues only.

Note Currently, QoS only supports packets of Ethernet size 1514 and smaller. For packets larger than this, the accuracy of QoS cannot be guaranteed.

QoS is triggered only when there is congestion on the link (i.e., the transmit queue for any VC reaches a pre-determined depth). Until congestion occurs, the traffic is transmitted on a first-come-first-serve basis, and may not match the requested percentages.

Relative Latency

Use the **qos-relative-latency** parameter of the **atm define service** command to set a value for relative latency. Increasing relative latency can increase the accuracy of the achieved rates. This is because each queue has a quota of bytes to transmit, and the packets that are sent may not exactly equal that quota. Therefore there is going to be either excess bytes sent, or a shortage of bytes sent. When a packet to transmit exceeds the quota, an implementation could choose to send the packet and go over the quota, or not send it and go under the quota. This feature allows an excess number to be sent, so up to 1499 extra bytes can be sent during a period. This is a significant number when the byte count for a queue is around 1500; however, its affect decreases as the byte count increases.

Increasing the relative latency also increases the amount of time that a queue waits to transmit a packet after it has used up its quota. For example, if a queue with weight 10 used up its quota before the other queues had transmitted, it would potentially have to wait for the other 90 percent of the total byte count to be sent before it could send again. The time is dependent upon the VC's rate.

For configurations in which a latency sensitive application has a low percentage of a slow link speed, it is best to put that application on the control queue and use "WFQ with strict priority." Optionally, you can set the relative latency to 1, as long as the achieved rates are accurate.

Additionally, when increasing relative latency values, you should also consider increasing the size of the buffers. This is because packets may be held off for longer times.

Decreasing relative latency has the effect of:

- Decreasing worst case latency seen by a bursty flow.
- Decreasing buffer requirements for the VC.
- Possibly decreasing the achievable accuracy of the selected weights.

Controlling Buffers for Each VC

When VCs queue data, they consume memory resources on the ATM card. By default, the hardware limits the number of internal buffers that each VC can use (21 * 240 bytes) for each queue. Generally, you should not have to set the number of internal buffers. However, if a bursty application is suffering loss (i.e., jumpy video), then you can increase the buffers for that queue by using the QoS buffering parameters (**qos-buffering-control**, **qos-buffering-low**, **qos-buffering-medium**, **qos-buffering-high**) of the **atm define service** command. The best way to determine the correct setting is to use a network analyzer to find the maximum burst, or to determine the correct settings through experimentation.

7.4.2 Configuring Virtual Channel Groups (OC-12)

A virtual channel group is a grouping of up to four separate virtual channels. This grouping of virtual channels is treated as one large virtual circuit. This is due to the fact that the VC group is seen as one virtual interface by the IP layer. For example, OSPF will see a point-to-point connection instead of multiple connections for all the virtual channels within the VC group.

Each VC within a virtual channel group can be assigned one (or more) of four internal priority levels: low, medium, high, and control. These internal priority levels apply to IP packets.

In addition to assigning an internal priority level for a VC, you can also designate a VC within the VC group to carry broadcast/multicast traffic.

This feature is advantageous in the case where different priority traffic needs to travel between two end devices. The end devices can essentially share one logical connection (through the VC group) while still prioritizing data up to four different levels. If a connection becomes oversubscribed and packets start dropping, using a VC group ensures that the data traffic passing between the two end devices are ranked by importance.

Creating a Virtual Channel Group

To configure a VC group, you should:

1. Create the VCs using the **`atm create vcl`** command.
2. Create the VC group using the **`atm create group`** command.
3. Add up to four separate virtual channels to the group using the atm add vcl command. You can also set a priority level for each VC within the VC group, as well as designate one of the VCs to handle broadcast-multicast traffic.

   If you add less than four virtual channels to a VC group, the next lower priority virtual channel will handle the traffic that lacks a particular VC for its priority. For example, you add two VCs (one low priority and one high priority) to a VC group. If a medium priority packet comes in, then the next lower priority VC, the VC low, will handle the packet.

Applying Service Profiles to VC Groups

Either the virtual channel or the VC group may have a service profile applied, but not both. You must first negate the separate service profiles from each virtual channel before trying to apply a service profile to the whole VC group, and vice versa.

It is recommended that you pay special attention when selecting the ATM service parameters for the VCs with different IP priorities. For example, control priority needs to have some dedicated bandwidth allocated while the low priority VC could have UBR defined with no dedicated bandwidth.

7.4.3 Traffic Management Configuration Example

The examples in this section show how you can manage traffic using QoS policies on the ATM multi-rate line card, and using VC groups on the ATM OC-12 line card.

Suppose you are a network administrator in charge of managing a network with three Client workstations (Client1, Client2, Client3) and a server. You are using two RS’s to connect and manage traffic between the server and the clients.

Your network requirements are as follows:

- Traffic from the Server heading to Client1 is assigned high priority in the event that the connection becomes oversubscribed.
- Traffic from the Server heading to Client2 is assigned medium priority in the event that the connection becomes oversubscribed.
- Traffic from the Server heading to Client3 is assigned low priority in the event that the connection becomes oversubscribed.
- All routing protocol control packets are assigned control priority.

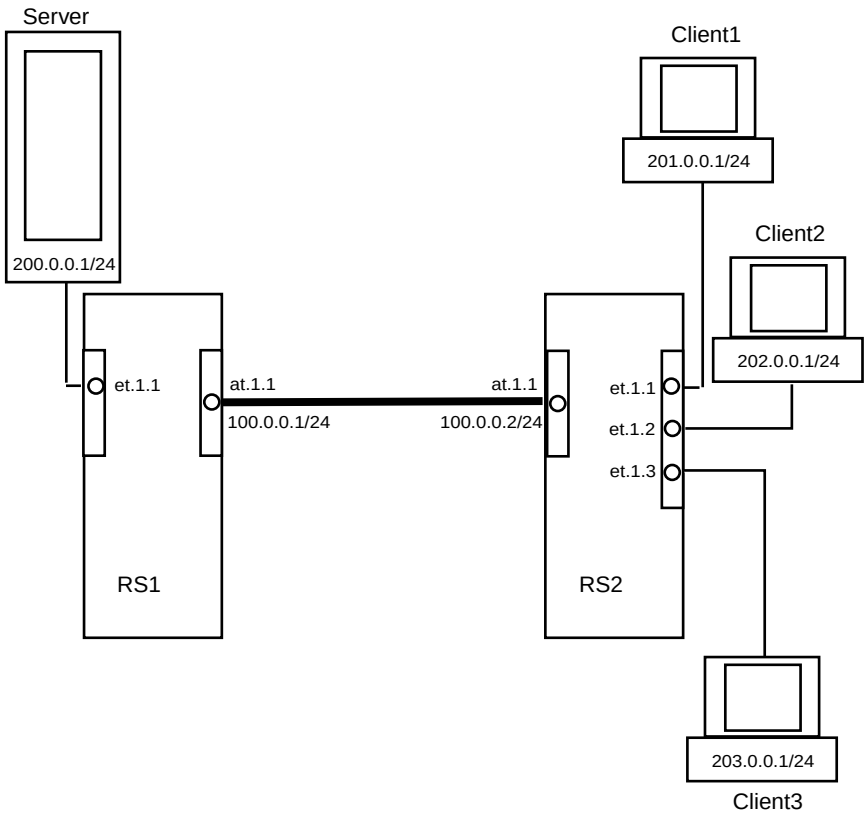


Figure 7-1 Traffic management sample configuration

The following sections illustrate how to accommodate the network requirements if the RS's are connected through ATM multi-rate line cards, and if the RS's are connected through ATM OC-12 line cards.

Configuring QoS Policies (Multi-Rate Line Card)

If the routers in Figure 7-1 were connected through ATM multi-rate line cards, then you would use QoS policies to manage the traffic.

Following are the steps and commands used to configure RS1 in the example:

Create a virtual channel.
```
atm create vcl port at.1.1.0.100
```

Configure an interface on the ATM port.
```
interface create ip atm1 address-netmask 100.0.0.1/24 port at.1.1.0.100
```

Configure an interface on the ethernet port to which the server is connected.
```
interface create ip 200.0.0.1/24 port et.1.1
```

Configure a static IP route to the 3 different clients, specifying the VC interface as the gateway.
```
ip add route 201.0.0.1/24 gateway 100.0.0.2/24
ip add route 202.0.0.1/24 gateway 100.0.0.2/24
ip add route 203.0.0.1/24 gateway 100.0.0.2/24
```

Set the priority levels for the different flows on RS1. This step is necessary in differentiating the priority levels of traffic data intended for the different clients.
```
qos set ip to_client1 high 200.0.0.1/24 201.0.0.1/24
qos set ip to_client2 medium 200.0.0.1/24 202.0.0.1/24
qos set ip to_client3 low 200.0.0.1/24 203.0.0.1/24
```

Define and apply the QoS policy, which in this example is WFQ with Strict Priority. Therefore a percentage is not specified for the control queue.
```
atm define service vcl_qos qos-low 20 qos-medium 30 qos-high 50
atm apply service vcl_qos port at.1.1.0.100
```

Following are the steps and commands for configuring RS2 in the example:

Create the virtual channel on RS2
```
atm create vcl port at.1.1.0.100
```

Configure an interface on the ATM port.
```
interface create ip atm1 address-netmask 100.0.0.2/24 port at.1.1.0.100
```

Configure an interface on the ethernet port to which each client is connected.
```
interface create ip 201.0.0.1/24 port et.1.1
interface create ip 202.0.0.1/24 port et.1.2
interface create ip 203.0.0.1/24 port et.1.3
```

Configuring Virtual Channels Groups (OC-12)

If the RS's in Figure 7-1 were connected through ATM OC-12 line cards, you would use VC groups to manage the traffic. Following are the steps and commands for configuring RS1 in the example:

Create the virtual channels.

```
atm create vcl port at.1.1.0.100
atm create vcl port at.1.1.0.101
atm create vcl port at.1.1.0.102
atm create vcl port at.1.1.0.103
```

Create a virtual channel group 'vg.1' on slot number 1 of RS1.

```
atm create group vg.1 slot 1
```

Add the 4 virtual channels into the VC group. This step also identifies the priority level for each of the 4 virtual channels within the group.

```
atm add vcl at.1.1.0.100 to vg.1 priority low
atm add vcl at.1.1.0.101 to vg.1 priority medium
atm add vcl at.1.1.0.102 to vg.1 priority high
atm add vcl at.1.1.0.103 to vg.1 priority control
```

Configure an IP address for the VC group.

```
interface create ip vcg1 address-netmask 100.0.0.1/24 port vg.1
```

Configure a static IP route to the 3 different clients, specifying the VC group interface as the gateway.

```
ip add route 201.0.0.1/24 gateway 100.0.0.2/24
ip add route 202.0.0.1/24 gateway 100.0.0.2/24
ip add route 203.0.0.1/24 gateway 100.0.0.2/24
```

Set the priority levels for the different flows on RS1. This step is necessary in differentiating the priority levels of traffic data intended for the different clients. Note that control packets are assigned to control priority levels by default.

```
qos set ip to_client1 high 200.0.0.1/24 201.0.0.1/24
qos set ip to_client2 medium 200.0.0.1/24 202.0.0.1/24
qos set ip to_client3 low 200.0.0.1/24 203.0.0.1/24
```

Following are the steps and commands for configuring RS2:

```
Create the same virtual channels on RS2.
rs2(config)# atm create vcl port at.1.1.0.100
atm create vcl port at.1.1.0.101
atm create vcl port at.1.1.0.102
atm create vcl port at.1.1.0.103

Create the virtual channel group 'vg.1' on slot number 1 of RS2.
atm create group vg.1 slot 1

Add the virtual channels to the VC group created on RS2.
atm add vcl at.1.1.0.100 to vg.1 priority low
atm add vcl at.1.1.0.101 to vg.1 priority medium
atm add vcl at.1.1.0.102 to vg.1 priority high
atm add vcl at.1.1.0.103 to vg.1 priority control

Configure an IP address for the VC group.
interface create ip vcg1 address-netmask 100.0.0.2/24 port vg.1
```

Use the **`atm show vcgroup`** command to display information about a virtual channel group:

```
rs# atm show vcgroup port vg.1
Port           Control      High         Medium       Low          Bcast
               Vpi  Vci     Vpi  Vci     Vpi  Vci     Vpi  Vci
vg.1     Conf  1    103     1    102     1    101     1    100     LOW
vg.1     Actv  0    0       0    0       0    0       0    0
rs#
```

7.5 BRIDGING ATM TRAFFIC

The ATM modules support both flow-based and address-based bridging. Like all the other RS modules, the ATM modules perform address-based bridging by default, but can be configured to perform flow-based bridging. The ATM multi-rate line card supports IP-based VLANs, and the ATM OC-12 line card supports IP and IPX-based VLANs. You can configure an ATM port as an 802.1Q trunk port, enabling it to carry traffic for multiple VLANs. For additional information on the RS bridging functions, refer to Section 6, *"Bridging Configuration Guide."*

Note The ATM modules do not support the Spanning Tree Protocol.

The following example illustrates how you can use bridging and VLANs to accommodate different networking requirements on an ATM module. In the network diagram, there are two client groups, VLAN A and VLAN B. These two client groups have very different needs and requirements for their users. VLAN A consists of users who need access to a high bandwidth connection able to support video conferencing. VLAN B consists of users who require less bandwidth and are mainly concerned with email and server backup traffic.

There are two separate VLANs in this network, VLAN A and VLAN B. VLAN A is connected to ethernet port et.5.1, and VLAN B is connected to ethernet port et.6.2.

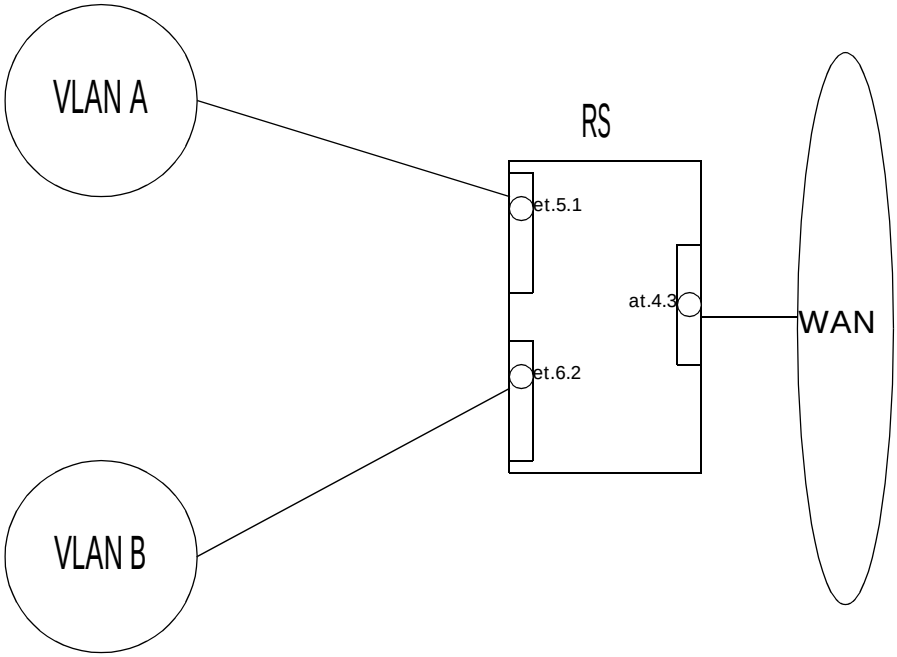


Figure 7-2 Bridging ATM traffic configuration example

Following are the configuration steps for the example:

```
Apply an interface on both ethernet ports.
rs(config)# interface create ip subnetA address-netmask 11.1.1.1/24
port et.5.1 up
rs(config)# interface create ip subnetB address-netmask 11.1.2.1/24
port et.6.2 up

Create two virtual channels, one for each type of traffic.
rs(config)# atm create vcl port at.4.3.0.100
rs(config)# atm create vcl port at.4.3.0.101

Create the VLANs: VLAN A with ID number 1, and VLAN B with ID number 2.
rs(config)# vlan create VLAN_A ip id 1
rs(config)# vlan create VLAN_B ip id 2

Add the virtual channels to each VLAN.
rs(config)# vlan add ports et.5.1,at.4.3.0.100 to VLAN_A
rs(config)# vlan add ports et.6.2,at.4.3.0.101 to VLAN_B

Define a service class for VLAN A where CBR is the service category and peak cell rate is set to
100000 kcells/second to ensure proper support for video conferencing.
rs(config)# atm define service vlanA srv-cat cbr pcr 100000

Define a service class for VLAN B where UBR is the service category.
rs(config)# atm define service vlanB srv-cat ubr

Apply the appropriate service category to each VC.
rs(config)# atm apply service vlanA port at.4.3.0.100
rs(config)# atm apply service vlanB port at.4.3.0.101
```

7.5.1 Configuring Cross-Connects

You can configure a cross-connect on the RS to switch packets from a VC on one port to a second VC on another port. This is similar to ATM switching functionality, but packets instead of cells are switched. To configure the cross-connects, you need to specify the cross-connected ports; then all traffic that is received on one VC is tunneled to the other VC.

To switch packets between two ATM ports, specify the **`atm set cross-connect`** command on one of the ports. For example, to configure a cross-connect between at.1.1.0.100 and at.2.1.0.101, enter the following:

```
rs (config)# atm set cross-connect at.1.1.0.100 to at.2.1.0.101
```

Note You can configure cross-connects on the multi-rate line card only.

7.5.2 Limiting MAC Addresses Learned on a VC

You can limit the number of MAC addresses learned on a VC. This security feature prevents users from purposely filling the L2 tables. You can set the limit between 0 and 127. However, at least one MAC address should be allowed on each VC.

When you specify a limit for the number of MAC addresses learned, that limit applies only to the additional MAC addresses that will be learned after the command was entered. If you specify a limit of 10 MAC addresses and the RS has already learned 3, then the total number of MAC addresses that can be learned on the VC is 13. But once enough MAC addresses have aged out to bring the number of addresses learned to below the limit you set, then the maximum number of MAC addresses learned will not exceed the limit.

Use the **`atm define service`** command to configure a service that specifies a MAC address limit. Then, apply the service to the VC. The following example limits the number of MAC addresses learned on at.1.1.0.100.

```
atm define service mac1 mac-addr-limit 10
atm apply service mac1 port at.1.1.0.100
```

7.6 ROUTING ATM TRAFFIC

Configuring IP interfaces for ATM modules is generally the same as for WANs and LANs. You assign an IP address to each interface and configure routing protocols such as OSPF or BGP. You can configure the IP interface on a physical port or as part of a VLAN. The ATM multi-rate line card supports IP-based VLANs, and the ATM OC-12 line card supports IP and IPX-based VLANs.

Creating an interface on an ATM port assigns a network IP address and submask on that port, and assigns it to a specified VC (VPI/VCI pair). Since a VC is a connection in the ATM Layer only, creating an interface for an ATM port is necessary to establish a connection in the IP network layer.

The following example illustrates how you can use routing on an ATM module to accommodate different requirements from two client groups using only one ATM physical connection. This is accomplished by setting up two VCs on the ATM port, each with its own service profiles and bandwidth.

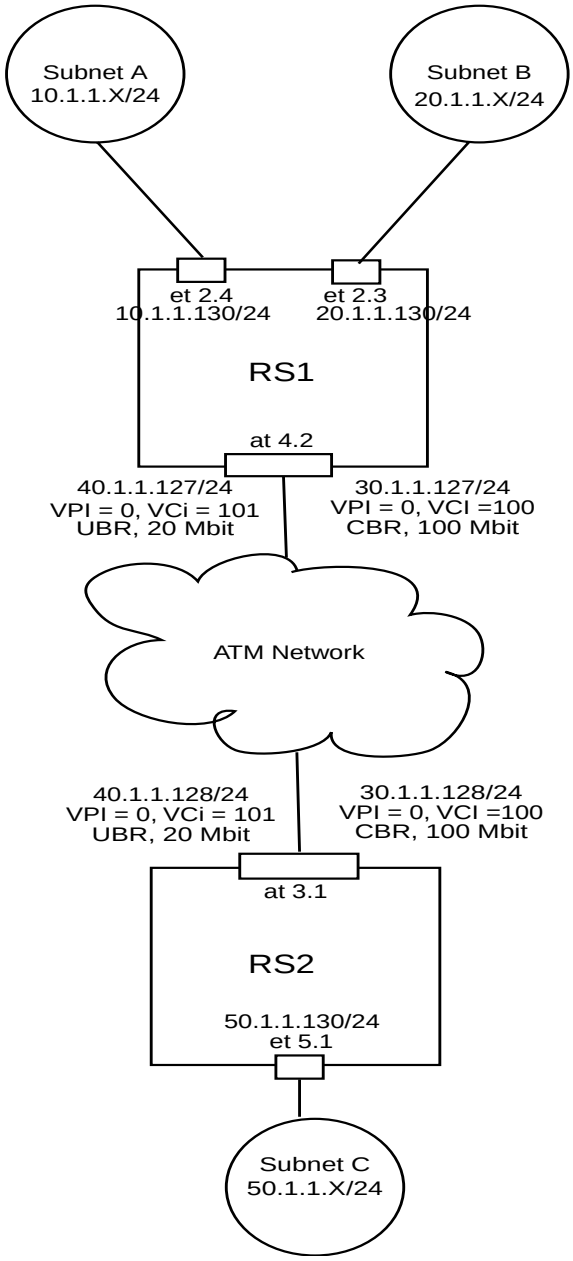


Figure 7-3 Routing ATM traffic configuration example

Suppose you are a network administrator in charge of managing a network with two client groups: Subnet A and Subnet B. These two client groups have very different bandwidth needs and requirements for their respective users. Subnet A consists of users who need access to a high bandwidth connection, able to support video conferencing. Subnet B consists of users who require less stringent requirements and are mainly concerned with email and server backup type traffic.

Configuration is done in two steps. The first step is to configure the network for traffic from Subnet A and Subnet B to Subnet C. The second step is to configure the network for traffic from Subnet C to Subnet A and Subnet B and assign ACLs to place subnets on correct VCLs. Now all traffic between Subnet A and Subnet C travels over the 20 Mbit VCL, while all traffic between Subnet B and Subnet C travels over the 100 Mbit VCL.

Following is the configuration for RS1:

Configure an interface on each ethernet port.

```
rs1(config)# interface create ip subnetA address-netmask 10.1.1.130/24
port et.2.4 up
rs1(config)# interface create ip subnetB address-netmask 20.1.1.130/24
port et.2.3 up
```

Create the virtual channels.

```
rs1(config)# atm create vcl port at.4.2.0.100
rs1(config)# atm create vcl port at.4.2.0.101
```

Configure an interface on each ATM port.

```
rs1(config)# interface create ip ubrservice address-netmask
40.1.1.127/24 peer-address 40.1.1.128/24 port at.4.2.0.101 up
rs1(config)# interface create ip cbrservice address-netmask
30.1.1.127/24 peer-address 30.1.1.128/24 port at.4.2.0.100 up
```

Define the ATM service profiles.

```
rs1(config)# atm define service ubrservice srv-cat ubr pcr-kbits 20000
rs1(config)# atm define service cbrservice srv-cat cbr pcr-kbits 100000
```

Apply the ATM service profiles.

```
rs1(config)# atm apply service ubrservice port at.4.2.0.101
rs1(config)# atm apply service cbrservice port at.4.2.0.100
```

Create IP ACLs.

```
RS1(config)# acl subnetAtoCacl permit 10.1.1.0/24 any any any
rs1(config)# acl subnetBtoCacl permit 20.1.1.0/24 any any any
```

Specify a gateway for each IP policy.

```
rs1(config)# ip-policy subnetAtoCpolicy permit acl subnetAtoCacl
next-hop-list 40.1.1.128/24 action policy-first
rs1(config)# ip-policy subnetBtoCpolicy permit acl subnetBtoCacl
next-hop-list 30.1.1.128/24 action policy-first
```

Apply the IP policies to the ethernet ports.

```
rs1(config)# ip-policy subnetAtoCpolicy apply interface subnetA
rs1(config)# ip-policy subnetBtoCpolicy apply interface subnetB
```

Following is the configuration for RS2:

```
Configure an interface on the ethernet port that leads to Subnet C.
rs2(config)# interface create ip subnetC address-netmask 50.1.1.130/24
port et.5.1 up

Create the virtual channels on port at.4.2.
rs2(config)# atm create vcl port at.3.1.0.100
rs2(config)# atm create vcl port at.3.1.0.101

Configure an interface for each VC.
rs2(config)# interface create ip ubrservice address-netmask
40.1.1.128/24 peer-address 40.1.1.127/24 port at.3.1.0.101 up
rs2(config)# interface create ip cbrservice address-netmask
30.1.1.128/24 peer-address 30.1.1.127/24 port at.3.1.0.100 up

Define the ATM service profiles.
rs2(config)# atm define service ubrservice srv-cat ubr pcr-kbits 20000
rs2(config)# atm define service cbrservice srv-cat cbr pcr-kbits 100000

Apply the ATM service profiles.
rs2(config)# atm apply service ubrservice port at.3.1.0.101
rs2(config)# atm apply service cbrservice port at.3.1.0.100

For traffic from subnet C to subnets A and B, create IP ACLs.
rs2(config)# acl subnetCtoAacl permit 50.1.1.0/24 10.1.1.0/24 any any
rs2(config)# acl subnetCtoBacl permit 50.1.1.0/24 20.1.1.0/24 any any

Specify a gateway for each IP policy.
rs2(config)# ip-policy subnetCtoApolicy permit acl subnetCtoAacl
next-hop-list 40.1.1.127/24 action policy-first
rs2(config)# ip-policy subnetCtoBpolicy permit acl subnetCtoBacl
next-hop-list 30.1.1.127/24 action policy-first

Apply IP policies to the Ethernet ports.
rs2(config)# ip-policy subnetCtoApolicy apply interface subnetC
rs2(config)# ip-policy subnetCtoBpolicy apply interface subnetC
```

7.6.1 Peer Address Mapping

You can map a peer address to a specific virtual channel. This allows you to set the destination address for a virtual channel using the **`atm set peer-addr`** command. This way, a virtual channel can be dedicated to handle traffic between two specific devices.

Mapped addresses are useful when you do not want to specify the peer address for the ATM port using the **`interface create`** command. This would be the case if the interface is created for a VLAN and there are many peer addresses on the VLAN. If any of the peers on the VLAN do not support InArp or IPCP/IPXCP, then a mapped address must be configured to determine the destination address.

Note Specify a peer address if the RS is handling VC-mux encapsulated traffic.

In the following example, a connection is established between a video server and three video clients (Video Client 1, Video Client 2, and Video Client 3). The video server routes data through the RS to the video clients. Traffic passes to the video clients through three separate virtual channels. Each virtual channel has a unique service profile.

In addition, the RS is transmitting VC-mux encapsulation traffic. Peer address mapping is used to associate a particular destination address with each VC. This allows the RS to route traffic to a specific client without multicasting to every virtual channel.

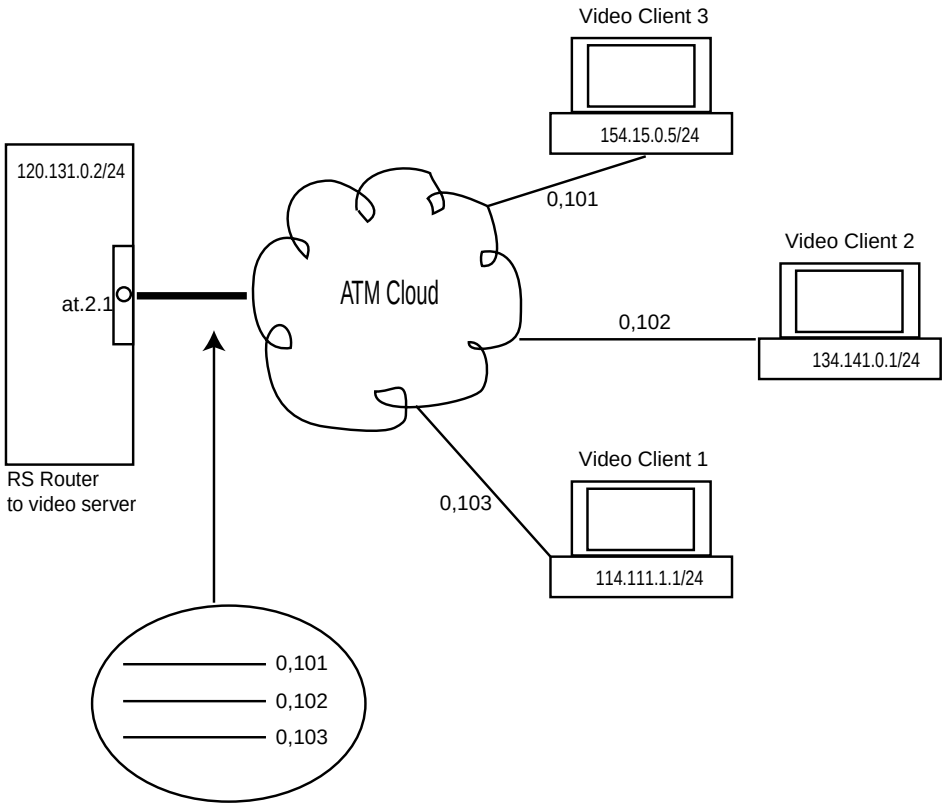


Figure 7-4 Peer address mapping configuration example

Following is the configuration for the RS:

```
Create the virtual channels that will connect to each video client.
rs(config)# atm create vcl port at.2.1.0.101
rs(config)# atm create vcl port at.2.1.0.102
rs(config)# atm create vcl port at.2.1.0.103

Create a VLAN called 'video' which supports all protocols.
rs(config)# vlan create video ip id 20

Add the VCs to the VLAN.
rs(config)# vlan add ports at.2.1.0.101 to video
rs(config)# vlan add ports at.2.1.0.102 to video
rs(config)# vlan add ports at.2.1.0.103 to video

Configure the interface and associate it with the VLAN.
rs(config)# interface create ip atm-video address-netmask
120.131.0.2/24 vlan video

Assign a peer address to each VC (for VC-mux encapsulation traffic).
rs(config)# atm set peer-addr port at.2.1.0.101 ip-address
114.111.1.1/24
rs(config)# atm set peer-addr port at.2.1.0.102 ip-address
134.141.0.1/24
rs(config)# atm set peer-addr port at.2.1.0.103 ip-address
154.15.0.5/24
```

7.7 CONFIGURING PPP (OC-12)

You can configure a point-to-point protocol (PPP) connection between a VC on the OC-12 line card on the RS and another device. When you define a service profile for the VC, you should specify **ppp** for the traffic parameter. You can also do the following:

- specify parameters for the transmission of Configure-NAK, Terminate-Nak, and Configure-Request packets
- enable/disable Magic Numbers
- enable/disable the transmission of Echo Request and Reply packets
- set PPP authentication

For a complete description of PPP, refer to Chapter 32, *"WAN Configuration."*

Note This feature is *not* valid for the ATM multi-rate line card.

The following example illustrates how to configure a PPP connection between a DSL modem and the RS. It uses CHAP authentication on an AAA server for the PPP connection.

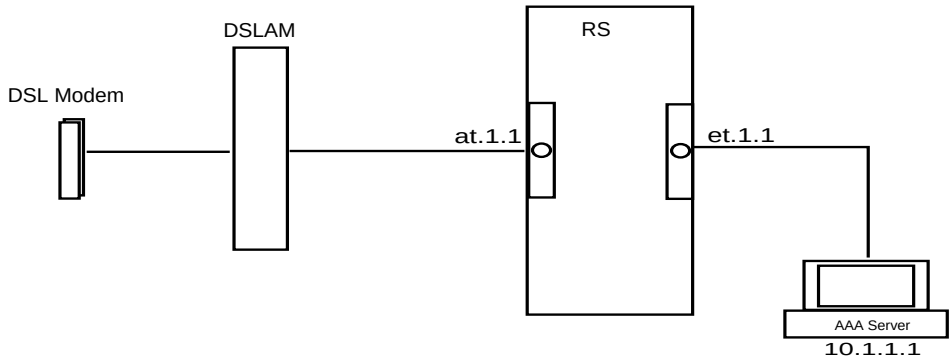


Figure 7-5 PPP configuration example

Following is the configuration for the RS:

Create a virtual channel for the PPP connection.
```
rs(config)# atm create vcl port at.1.1.0.200
```

Define the PPP service profile.
```
rs(config)# atm define service cm1 srv-cat rt-vbr encaps vc-mux traffic
ppp ppp-auth chap
```

Apply the service profile to the VC.
```
atm apply service cm1 port at.2.1.0.200
```

For this configuration example, configure RADIUS for PPP authentication on an AAA server.
```
rs(config)# radius set key secretpassword
```

Identify the AAA server.
```
rs(config)# radius set server 10.1.1.1
```

Enable RADIUS authentication.
```
rs(config)# radius enable
```

To display PPP (Point-to-Point Protocol) statistics for an ATM OC-12 line card, use the **`atm show ppp`** command as shown in the following example:

```
rs# atm show ppp port all
-------------------------------------------
at.5.1:
Total LCP            (Enabled/Up): 0/0
Total IP             (Enabled/Up): 0/0
Total IPX            (Enabled/Up): 0/0
Total Bridging       (Enabled/Up): 0/0
Total Authentication (Enabled/Up): 0/0

    Virtual Path Identifier:        1
    Virtual Channel Identifier:     100
    LCP  Status:              Disabled/Down
    IP  Status:               Disabled/Down
    IPX  Status:              Disabled/Down
    Bridging  Status:         Disabled/Down
    Authentication  Status:   Disabled/Down
    Authentication  Type:     None/None
```

7.8 OPERATION, ADMINISTRATION AND MANAGEMENT (OAM)

Operation, Administration and Management (OAM) flows are used for the exchange of operations information. They perform management functions, such as performance monitoring and fault management at the physical and ATM layers.

There are 5 types of OAM flows (F1 through F5). F1 through F3 flows are carried within the SONET framing structure at the physical layer, and F4 and F5 flows are carried within the ATM cells at the ATM layer. The RS supports the transmission of both the F4 and F5 flows. These are used to detect and propagate a failure in a permanent virtual circuit (PVC) so devices on the path can re-establish the PVC along an alternate path.

F4 flows carry operations information for virtual paths, and F5 flows carry operations information for virtual channels. F4 and F5 flows can traverse from one end of the connection to the other end (end-to-end flow), or from one connection point to another (segment flow).

OAM F4 and F5 flows use the following types of cells:

- loopback cells to verify connectivity on the PVC
- alarm indication signal (AIS) and remote defect indication (RDI) cells to detect and propagate a fault along the path

7.8.1 Connection Verification

OAM loopback capabilities are supported on the RS' ATM Multi-Rate line card and OC-12 line card. By default, the RS responds to all loopback requests. However, you can also have the RS automatically generate periodic loopback requests by defining a service in which OAM is specified and applying it to the VC.

The following example defines the service *oam1* and applies it to port at.5.1.

```
rs(config)# atm define service oam1 oam end-to-end
rs(config)# atm apply service oam1 port at.5.1
```

When you specify the **oam** option in the **atm define service** command, you need to specify whether the OAM cells will loopback at the end of the PVC (**end-to-end**) or at the end of the segment (**segment**). In the previous example, the OAM cells loopback at the end of the PVC (**end-to-end**).

By default, the RS sends four OAM segment loopback requests at one second intervals. The Multi-Rate line card supports the **atm ping** command to generate loopback cells on demand. When you use the **atm ping** command, you can change the default number of pings and specify end-to-end loopback requests. Following is an example:

```
rs# atm ping port at.2.1.1 count 5 end-to-end
```

The location ID in the OAM loopback cell identifies the point(s) on the PVC where the loopback is to occur. To "discover" the location IDs of all the other devices in the path, use the **discover** option of the **atm ping** command. To send an OAM cell with a specific location ID, use the **location-id** parameter.

Use the **atm set port** command to specify a location ID. When you do so, it enables the RS to be "discovered" and to be specified in loopback requests from other devices along the path.

```
rs(config)# atm set port location-id
```

7.8.2 Fault Detection and Propagation

The ATM Multi-Rate line card also supports the generation and processing of OAM AIS and RDI cells. These are used for detecting and propagating failures on a PVC. To enable this feature, define a service in which it is enabled as shown in the following example:

```
rs(config)# atm define service serv1 ais-rdi-enable
rs(config)# atm apply service serv1 port at.5.1
```

When a link or interface goes down or if the RS receives an AIS or RDI cell on a VC, the RS marks the interface as down and sends AIS cells to all downstream VCs affected by the failure. The RS also sends RDI cells upstream on the same VC to let the remote ends know about the failure. Thus all devices on the PVC will know that the path is down and that an alternate path needs to be established. These cells are similar to the SONET level AIS/FERF cells, but these are on a per-VC basis.

Note This feature is available for the Multi-Rate line card only.

Use the **atm set port** command to specify the number of consecutive AIS/RDI cells received before the VC is brought down and the number of seconds within which no AIS/RDI cells are received before the VC is brought back up. The following example specifies that 5 AIS/RDI cells must be received before the VC is brought down and 5 seconds with no AIS/RDI cells received must elapse before the VC is brought up:

```
rs(config)# atm set port at.5.1 ais-up 5 ais-down 5
```

Use the **atm show vcl** command to view the AIS/RDI status as shown in the following example:

```
rs# atm show vcl port at.1.1.0.100
VCL Table Contents for at.1.1:
    Virtual Path Identifier:    0
    Virtual Channel Identifier: 100
    QOS Settings:               Disabled
    Priority Settings:          Default values
    Cross Connect:              at.1.2.0.100
    Force Bridge Format:        Disabled
    AAL:                        AAL 5
    Administrative Status:      Up
    Operational Status:         Down
    AIS/RDI Status:             Fault Present
    Last State Change:          54
    Service Definition:         ais
        Service Class:      UBR
        Peak Bit Rate:      Best Effort
        Encapsulation Type: LLC Multiplexing
        Traffic Type:       RFC-1483, multi-protocol
        F5-OAM:             Responses Only
        MAC Address Limit:  Disabled
        AIS/RDI Support:    Enabled
```

8 PACKET-OVER-SONET CONFIGURATION GUIDE

This chapter explains how to configure and monitor Packet-over-SONET (PoS) on the RS. See the **`sonet`** commands section of the *Riverstone RS Switch Router Command Line Interface Reference Manual* for a description of each command.

PoS requires installation of the OC-3c or OC-12c PoS line cards in an RS 8000 or an RS 8600. The OC-3c line card has four PoS ports, while the OC-12c line card has two PoS ports. You must use the “so” prefix for PoS interface ports. For example, you would specify the first PoS port located at router slot 13, port 1 as “so.13.1.”

By default, PoS ports are set for point-to-point protocol (PPP) encapsulation. The only other supported encapsulation type is bridged Ethernet over PPP.

Note While PoS ports use PPP encapsulation, other PPP characteristics such as service profiles, encryption, compression, and MLP bundles are not supported for PoS ports.

By default, PoS ports are configured to receive a maximum transmission unit (MTU) size of 1522 octets. The actual MTU size used for transmissions over a PoS link is a result of PPP negotiation. For transmission of “jumbo frames” (MTUs up to 65535 octets), you can increase the MTU size of the PoS port. The MTU must be set at the port level.

8.1 CONFIGURING IP INTERFACES FOR POS LINKS

Configuring IP interfaces for PoS links is generally the same as for WANs and for LANs. You assign an IP address to each interface and define routing mechanisms such as OSPF or RIP as with any IP network. You can configure the IP interface on the physical port or you can configure the interface as part of a VLAN for PoS links. You can also configure multiple IP addresses for each interface, as described in Section 10.2, *"Configuring IP Interfaces and Parameters"*.

When creating the IP interface for a PoS link, you can either specify the peer address if it is known (*static* address), or allow the peer address to be automatically discovered via IPCP negotiation (*dynamic* address). If the peer address is specified, any address supplied by the peer during IPCP negotiation is ignored.

IP interfaces for PoS links can have primary and secondary IP addresses. The primary addresses may be either dynamic or static, but the secondary address must be static. This is because only the primary addresses of both the local and peer devices are exchanged during IP Control Protocol (IPCP) negotiation.

Source filtering and ACLs can be applied to an IP interface for a PoS link. Unlike WAN ports, the applied filter or ACL presents no limitation. Different filters can be configured on different PoS ports.

8.2 CONFIGURING PACKET-OVER-SONET LINKS

To configure a Packet-over-SONET link:

1. On the RS, assign an interface to the PoS port to which you will connect via fiber cable in a point-to-point link. Assign an IP address and netmask to the interface. If possible, determine the peer address of the interface at the other end of the point-to-point link. In the following example, the port so.13.1 on the RS will be associated with the interface pos11:

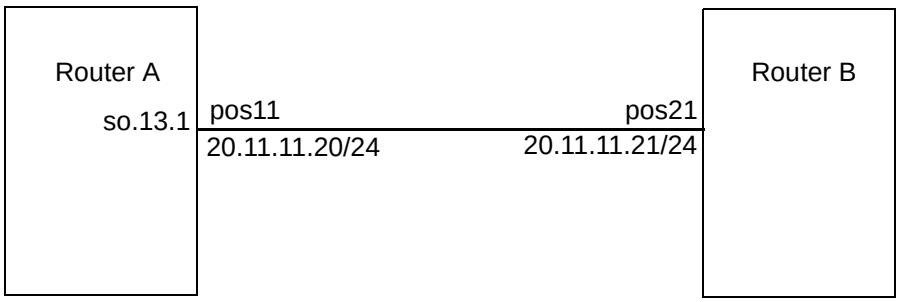


Figure 8-1 Configuring PoS links

2. Create a PPP interface with the **`interface create`** command, specifying the IP address and netmask for the interface on the RS:

```
rs(config)# interface create ip pos11 address-netmask 20.11.11.20/24
port so.13.1
```

When you create the point-to-point interface as shown above, the RS creates an implicit VLAN called "SYS_L3_<*interface-name*>." In the above example, the RS creates the VLAN 'SYS_L3_pos11.'

3. Specify the peer address of the other end of the connection. This is optional.
4. If you want to increase the MTU size on a port, specify the parameter **`mtu`** with the **`port set`** command and define a value up to 65535 (octets). See Section 10.3, *"Configuring Jumbo Frames"* for more information.
5. Specify the bit error rate thresholds, if necessary. For more information, see Section 8.4, *"Specifying Bit Error Rate Thresholds"*
6. Modify any other PoS operating parameters, as needed. The following table lists the operating parameters that you can modify and the configuration commands that you use.

Table 8-1 PoS optional operating parameters

Parameter	Default Value	Configuration Command
Framing	SONET	**sonet set** <*port*> **framing sdh|sonet**
Loopback	Disabled	**sonet set** <*port*> **loopback**
Path tracing	(none)	**sonet set** <*port*> **pathtrace**
Circuit identifier	(none)	**sonet set** <*port*> **circuit-id**
Frame Check Sequence	32-bit	**sonet set** <*port*> **fcs-16-bit**
Scrambling	Enabled	**sonet set** <*port*> **no-scramble**

8.3 CONFIGURING AUTOMATIC PROTECTION SWITCHING

Automatic protection switching (APS) provides a mechanism to support redundant transmission circuits between SONET devices. The RS supports the following APS features:

- Linear network topology. Ring topologies are not supported.
- 1+1 switching. Each working line is protected by one protecting line and the same signal is transmitted on both the working and protecting lines. The two transmission copies that arrive at the receiving end are compared, and the best copy is used. If there is a line failure or line degradation, the end node switches the connection over to the protecting line.

Note In APS terminology, *bridge* means to transmit identical traffic on both the working and protecting lines, while *switch* means to select traffic from either the protecting line or the working line.

- Unidirectional switching, where one set of line terminating equipment (LTE) can switch the line independent of the other LTE. Bidirectional switching (where both sets of LTEs perform a coordinated switch) is not supported.
- Revertive switching. You can enable automatic switchover from the protecting line to the working line after the working line becomes available.

If the working circuit is disrupted or the bit error rates on the working circuit exceed the configured thresholds, traffic is automatically switched over to the protecting circuit. Any physical or logical characteristics configured for the working port are automatically applied to the protecting port. This includes the IP address and netmask configured for the interface, spanning tree protocol (STP), per-VLAN spanning tree (PVST), etc. Therefore, there is no need to configure the protecting port separately. Any command applied to the PoS working port is mirrored onto the protecting port automatically.

8.3.1 Configuring Working and Protecting Ports

APS on the RS requires configuration of a working port and a corresponding protecting port. You can configure any number of pairs of PoS ports for APS. The limit is the number of PoS ports on the RS. If one module should go down, the remaining ports on other modules will remain operational.

Note The protecting port can be on the same slot or located on a different slot as the working port, but they must reside on the *same* RS. You *cannot* configure APS operation for working and protecting ports on two *different* RS's.

The working and protecting port must support identical optical carrier rates. For example, if the working port operates at OC-12, the protecting port must also be OC-12.

The protecting port must not have been used in an active configuration. After being configured as the protecting port, it cannot be explicitly configured except for the APS properties. The protecting port automatically inherits the configuration of the working port.

To configure a working and a protecting PoS port, enter the following command in Configure mode:

Configure working and protecting PoS ports.	**sonet set** <*working-port*> **protection 1+1 protected-by** <*protecting-port*>

To manage the working and protecting PoS interfaces, enter the following commands in Configure mode:

Prevent a working port from switching to a protecting port. This command can only be applied to a port configured as a protecting port.	**sonet set** <*port*> **protection-switch lockoutprot**
Force a switch to the specified port. This command can be applied to either the working or protecting port.	**sonet set** <*port*> **protection-switch forced**
Manually switch the line to the specified port. This command can be applied to either the working or protecting port.	**sonet set** <*port*> **protection-switch manual**

Note You can only specify one option, **lockoutprot**, **forced** or **manual**, for a port. Also, an option can be applied to *either* the working port or the protecting port, but not *both* working and protecting ports at the same time.

To return the circuit to the working interface after the working interface becomes available, enter the following commands in Configure mode:

Enable automatic switchover from the protecting interface to the working interface after the working interface becomes available. This command can only be applied to a protecting port.	**sonet set** <*port*> **revertive on|off**
Sets the number of minutes after the working interface becomes available that automatic switchover from the protecting interface to the working interface takes place. The default value is 5 minutes.	**sonet set** <*port*> **WTR-timer** <*minutes*>

8.4 SPECIFYING BIT ERROR RATE THRESHOLDS

If the bit error rate (BER) on the working line exceeds that of the configured thresholds, the receiver automatically switches over to the protecting line.

BER is calculated with the following:

BER = errored bits received/total bits received

The default BER thresholds are:

- Signal degrade BER threshold of 10^{-6} (1 out of 1,000,000 bits transmitted is in error). Signal degrade is associated with a “soft” failure. Signal degrade is determined when the BER exceeds the configured rate.
- Signal failure BER threshold of 10^{-3} (1 out of 1,000 bits transmitted is in error). Signal failure is associated with a “hard” failure. Signal fail is determined when any of the following conditions are detected: loss of signal (LOS), loss of frame (LOF), line alarm indication bridge and selector signal (AIS-L), or the BER threshold exceeds the configured rate.

To specify different BER thresholds, enter the following commands in Enable mode:

Specify signal degrade BER threshold.	**sonet set** <*port*> **sd-ber** <*number*>
Specify signal failure BER threshold.	**sonet set** <*port*> **sf-ber** <*number*>

8.5 MONITORING POS PORTS

To display PoS port configuration information, enter one of the following commands in Enable mode:

Show framing status, line type, and circuit ID of the optical link.	**sonet show medium** *<port list>*
Show working or protecting line, direction, and switch status.	**sonet show aps** *<port list>*
Show received path trace.	**sonet show pathtrace** *<port list>*
Show loopback status.	**sonet show loopback** *<port list>*
Show alarms and errors on SONET ports.	**sonet show alarms** *<port list>*

Note The RS supports graceful PPP failover as a part of the Hitless Protection System (HPS), which allows the RS to continue providing services even if it has to restart. PPP failover is on by default. This feature prevents PPP sessions on PoS from flapping and causing momentary interruptions to data traffic when the RS reboots.

The following table describes additional monitoring commands for IP interfaces for PoS links, designed to be used in Enable mode:

Display bridge NCP statistics for specified PoS port.	**ppp show stats ports** *<port name>* **bridge-ncp**
Display IP NCP statistics for specified PoS port.	**ppp show stats ports** *<port name>* **ip-ncp**
Display link-status statistics for specified PoS port.	**ppp show stats ports** *<port name>* **link-status**
Display summary information for specified PoS port.	**ppp show stats ports** *<port name>* **summary**

8.6 EXAMPLE CONFIGURATIONS

This section shows example configurations for PoS links.

8.6.1 APS PoS Links Between RS's

The following example shows APS PoS links between two RS's, router A and router B.

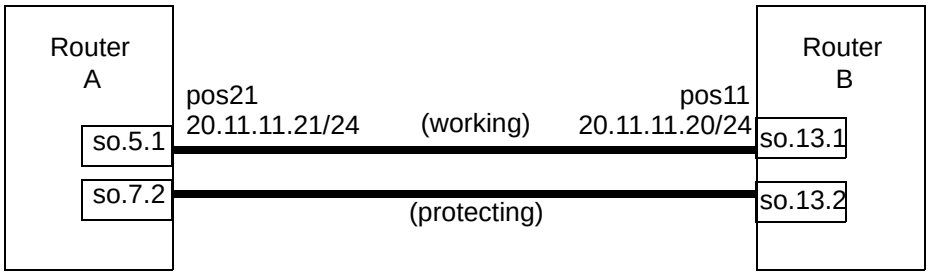


Figure 8-2 Automatic protection switching between two routers

The following is the configuration for router A:

```
interface create ip pos21 address-netmask 20.11.11.21/24 port so.5.1
sonet set so.7.1 protection 1+1 protected-by so.7.2
```

The following is the configuration for router B:

```
interface create ip pos11 address-netmask 20.11.11.20/24 port so.13.1
sonet set so.13.1 protection 1+1 protected-by so.13.2
```

8.6.2 PoS Link Between the RS and a Cisco Router

The following example shows a PoS link between an RS, router A, and a Cisco 12000 series Gigabit Switch Router, router B.

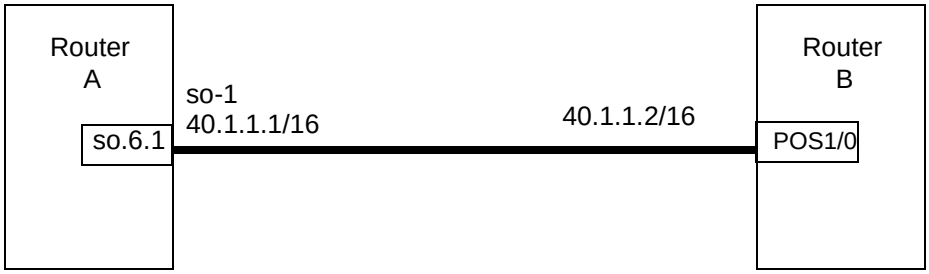


Figure 8-3 PoS link between the RS and a CISCO router

The following is the configuration for router A:

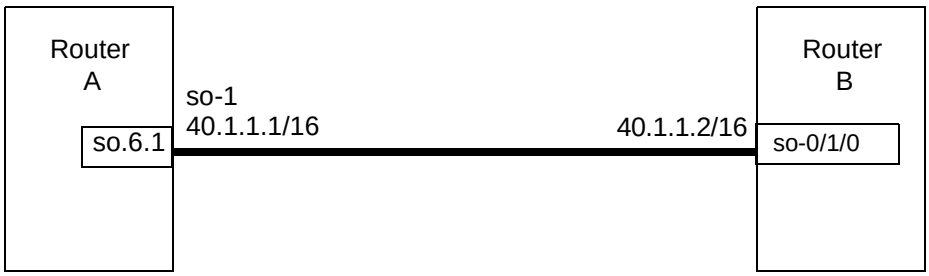
```
interface create ip so-1 address-netmask 40.1.1.1/16 port so.6.1
```

The following is the configuration for router B:

```
interface POS1/0
 ip address 40.1.1.2 255.255.0.0
 no ip directed-broadcast
 encapsulation ppp
 crc 32
 pos scramble-atm
 pos flag c2 22
```

8.6.3 PoS Link Between the RS and a Juniper Router

The following example shows a PoS link between an RS, router A, and a Juniper router, router B.



The following is the configuration for router A:

```
interface create ip so-1 address-netmask 40.1.1.1/16 port so.6.1 peer-address
40.1.1.2
```

Note When you create an IP interface on the RS for a PoS link with a Juniper router, you *must* specify the **peer-address** parameter. Otherwise, IP Control Protocol (IPCP) negotiations will fail.

The following is the configuration for router B:

```
root# set interfaces so-0/1/0 unit 0 family inet address 40.1.1.2/16
root# set interfaces so-0/1/0 encapsulation ppp
root# set interfaces so-0/1/0 sonet-options fcs 32
```

8.6.4 Bridging and Routing Traffic Over a PoS Link

The following example shows how to configure a VLAN ‘v1’ that includes the PoS ports on two connected RS’s, router A and router B. Bridged or routed traffic is transmitted over the PoS link.

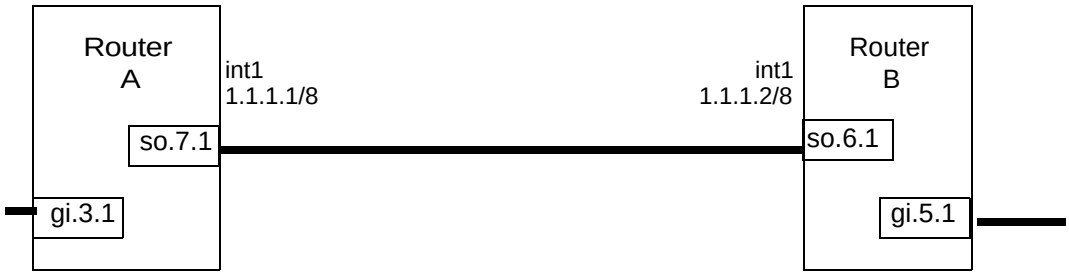


Figure 8-4 VLAN with PoS links

The following is the configuration for router A:

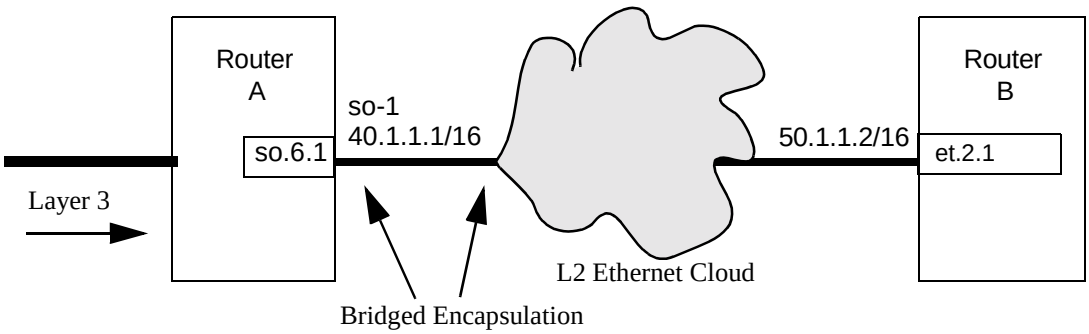
```
port set so.7.1 mtu 65535
stp enable port so.7.1
vlan create v1 port-based id 10
vlan add ports so.7.1,gi.3.1 to v1
interface create ip int1 address-netmask 1.1.1.1/8 vlan v1
```

The following is the configuration for router B:

```
port set so.6.1 mtu 65535
stp enable port so.6.1
vlan create v1 port-based id 10
vlan add ports so.6.1,gi.5.1 to v1
interface create ip int1 address-netmask 1.1.1.2/8 vlan v1
```

8.6.5 PoS Link Through a Layer 2 Cloud

The following example shows a PoS link between Router A and Router B. Both routers are connected by a PPP connection that goes through a L2 cloud, a Layer 2 switch.



The packets forwarded across the L2 Ethernet cloud must contain certain Ethernet MAC headers. Otherwise, the packets will be dropped at the edge of the cloud, in this case a L2 switch.

To encapsulate an Ethernet MAC header in the PPP frames, the port ‘so.6.1’ PoS port and its peer at the edge of the cloud must be set in the Ethernet bridged encapsulation mode.

To enable Ethernet bridged encapsulation on port ‘so.6.1’ for PPP traffic:

```
ppp set ppp-encaps-bgd ports so.6.1
```

Note PoS ports that will be trunk ports (i.e., support the 802.1q protocol) *must* be configured for bridged encapsulation. See the documentation for the **`ppp set ppp-encaps-bgd`** command in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

9 DHCP CONFIGURATION GUIDE

The Dynamic Host Configuration Protocol (DHCP) server on the RS provides dynamic address assignment and configuration to DHCP capable end-user systems, such as Windows 95/98/NT and Apple Macintosh systems. You can configure the server to provide a dynamic IP address from a pre-allocated pool of IP addresses or a static IP address. You can also configure parameters for use by the clients, such as default gateway and network masks, and system-specific parameters, such as NetBIOS Name Server and NetBIOS node type of the client.

The amount of time that a particular IP address is valid for a system is called a *lease*. The RS maintains a *lease database* which contains information about each assigned IP address, the MAC address to which it is assigned, the lease expiration, and whether the address assignment is dynamic or static. The DHCP lease database is stored in flash memory and can be backed up on a remote TFTP or RCP server. You can configure the intervals at which updates to the lease database (and backup) are done. Upon system reboot, the lease database will be loaded either from flash memory or from the TFTP or RCP server.

Note The RS DHCP server is not designed to work as the primary DHCP server in an enterprise environment with hundreds or thousands of clients that are constantly seeking IP address assignment or reassignment. A standalone DHCP server with a redundant backup server may be more suitable for this enterprise environment.

If you are using a DHCP server to provide IP addresses to user systems, you can also use DHCP to install entries in the Address Resolution Protocol (ARP) table on the RS. Using DHCP to install ARP entries helps prevent spoofing of ARP requests by unauthorized users. For more information about using DHCP to install ARP entries on the RS, see Section 10.4.4, *"Using DHCP to Install ARP Entries."*

9.1 CONFIGURING DHCP

By default, the DHCP server is not enabled on the RS. You can selectively enable DHCP service on particular interfaces and not others. To enable DHCP service on an interface, you must first define a DHCP *scope*. A scope consists of a pool of IP addresses and a set of parameters for a DHCP client. The parameters are used by the client to configure its network environment, for example, the default gateway and DNS domain name.

To configure DHCP on the RS, you must configure an IP address pool, client parameters, and optional static IP address for a specified scope. Where several subnets are accessed through a single port, you can also define multiple scopes on the same interface and group the scopes together into a “superscope.”

9.1.1 Configuring an IP Address Pool

To define a pool of IP addresses that the DHCP server can assign to a client, enter the following command in Configure mode:

Define pool of IP addresses to be used by clients.	**dhcp** <*scope*> **define pool** <*ip-range*>

9.1.2 Configuring Client Parameters

You can configure the client parameters shown in the table below.

Table 9-1 Client parameters

Parameter	Value
address-mask	Address/netmask of the scope's subnet (This parameter is *required* and must be defined *before* any other client parameters are specified.)
broadcast	Broadcast address
bootfile	Client boot file name
dns-domain	DNS domain name
dns-server	IP address of DNS server
gateway	IP address of default gateway
lease-time	Amount of time the assigned IP address is valid for the system
netbios-name-server	IP address of NetBIOS Name Server (WINS server)
netbios-node-type	NetBIOS node type of the client
netbios-scope	NetBIOS scope of the client

To define the parameters that the DHCP server gives the clients, enter the following command in Configure mode:

Define client parameters.	**dhcp** <*scope*> **define parameters** <*parameter*> <*value*>...

9.1.3 Configuring a Static IP Address

To define a static IP address that the DHCP server can assign to a client with a specific MAC address, enter the following command in Configure mode:

Define static IP address for a particular MAC address.	**dhcp** <*scope*> **define static-ip** <*ipaddr*> **mac-address** <*macaddr*> [<*parameter*> <*value*>...]

9.1.4 Grouping Scopes with a Common Interface

You can apply several scopes to the same physical interface. For example, scopes can define address pools on different subnets that all are accessed through the same RS port. In this case, scopes that use the same interface must be grouped together into a "superscope."

To attach a scope to a superscope, enter the following command in Configure mode:

Attach a scope to a superscope.	**dhcp** <*scope*> **attach superscope** <*name*>

Note Ensure that the superscope is not associated with multiple interfaces. DHCP packets will not be able to be sent on different subnets if they exist on different physical interfaces.

9.1.5 Configuring DHCP Server Parameters

You can configure several "global" parameters that affect the behavior of the DHCP server itself.

To configure global DHCP server parameters, enter the following commands in Configure mode:

Specify a remote location to back up the lease database.	**dhcp global set lease-database** <*url*>
Specify the intervals at which the lease database is updated.	**dhcp global set commit-interval** <*hours*>

9.2 UPDATING THE LEASE DATABASE

After each client transaction, the DHCP server does not immediately update the information in the lease database. Lease update information is stored in flash memory and flushed to the database at certain intervals. You can use the **`dhcp global set commit-interval`** command to specify this interval; the default is one hour.

To force the DHCP server to immediately update its lease database, enter the following command in Enable mode:

Force the server to update its lease database.	**`dhcp flush`**

9.3 MONITORING THE DHCP SERVER

To display information from the lease database:

Show lease database information.	**`dhcp show binding [active|expired|static]`**

To display the number of allocated bindings for the DHCP server and the maximum number allowed::

Show the number of allocated bindings for the DHCP server.	**`dhcp show num-clients`**

9.4 DHCP CONFIGURATION EXAMPLES

The following configuration describes DHCP configuration for a simple network with just one interface on which DHCP service is enabled to provide both dynamic and static IP addresses.

1. Create an IP VLAN called ‘client_vlan’.

```
vlan create client_vlan ip
```

2. Add all Fast Ethernet ports in the RS to the VLAN ‘client_vlan’.

```
vlan add port et.*.* to client_vlan
```

3. Create an IP interface called ‘clients’ with the address 10.1.1.1 for the VLAN ‘client_vlan’.

```
interface create ip clients address-netmask 10.1.1.1./16 vlan
client_vlan
```

4. Define DHCP network parameters for the scope ‘scope1’.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 lease-time 24 dns-domain acme.com dns-server 10.2.45.67
netbios-name-server 10.1.55.60
```

5. Define an IP address pool for addresses 10.1.1.10 through 10.1.1.20.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

6. Define another IP address pool for addresses 10.1.1.40 through 10.1.1.50.

```
dhcp scope1 define pool 10.1.1.40-10.1.1.50
```

7. Define a static IP address for 10.1.7.5.

```
dhcp scope1 define static-ip 10.1.7.5 mac-address 08:00:20:11:22:33
```

8. Define another static IP address for 10.1.7.7. and give it a specific gateway address of 10.1.1.2.

```
dhcp scope1 define static-ip 10.1.7.7 mac-address
08:00:20:aa:bb:cc:dd gateway 10.1.1.2
```

9. Specify a remote lease database on the TFTP server 10.1.89.88.

```
dhcp global set lease-database tftp://10.1.89.88/lease.db
```

10. Specify a database update interval of every 15 minutes.

```
dhcp global set commit-interval 15
```

9.5 CONFIGURING SECONDARY SUBNETS

In some network environments, multiple logical subnets can be imposed on a single physical segment. These logical subnets are sometimes referred to as “secondary subnets” or “secondary networks.” For these environments, the DHCP server may need to give out addresses on different subnets. The DNS server, DNS domain, and WINS server may be the same for clients on different secondary subnets, however, the default gateway will most likely be different since it must be a router on the client’s local subnet.

The following example shows a simple configuration to support secondary subnets 10.1.x.x and 10.2.x.x.

1. Define the network parameters for ‘scope1’ with the default gateway 10.1.1.1.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 dns-domain acme.com dns-server 10.1.44.55
```

2. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

3. Define the network parameters for ‘scope2’ with the default gateway 10.2.1.1.

```
dhcp scope2 define parameters address-netmask 10.2.0.0/16 gateway
10.2.1.1 dns-domain acme.com dns-server 10.1.77.88
```

4. Define the address pool for ‘scope2’.

```
dhcp scope2 define pool 10.2.1.40-10.2.1.50
```

5. Create a superscope ‘super1’ that includes ‘scope1’.

```
dhcp scope1 attach superscope super1
```

6. Include ‘scope2’ in the superscope ‘super1’.

```
dhcp scope2 attach superscope super1
```

Since there are multiple pools of IP addresses, the pool associated with ‘scope1’ is used first since ‘scope1’ is applied to the interface before ‘scope2’. Clients that are given an address from ‘scope1’ will also be given parameters from ‘scope1,’ which includes the default gateway 10.1.1.1 that resides on the 10.1.x.x subnet. When all the addresses for ‘scope1’ are assigned, the server will start giving out addresses from ‘scope2’ which will include the default gateway parameter 10.2.1.1 on subnet 10.2.x.x.

9.6 SECONDARY SUBNETS AND DIRECTLY-CONNECTED CLIENTS

A directly-connected client is a system that resides on the same physical network as the DHCP server and does not have to go through a router or relay agent to communicate with the server. If you configure the DHCP server on the RS to service directly-connected clients on a secondary subnet, you must configure the secondary subnet using the **`interface add ip`** command. The **`interface add ip`** command configures a secondary address for an interface that was previously created with the **`interface create ip`** command.

The following example shows a simple configuration to support directly-connected clients on a secondary subnet.

1. Create an interface ‘clients’ with the primary address 10.1.1.1.

```
interface create ip clients address-mask 10.1.1.1/16 port et.1.1
```

2. Assign a secondary address 10.2.1.1 to the interface ‘clients’.

```
interface add ip clients address-mask 10.2.1.1/16
```

3. Define the network parameters for ‘scope1’ with the default gateway 10.1.1.1.

```
dhcp scope1 define parameters address-netmask 10.1.0.0/16 gateway
10.1.1.1 dns-domain acme.com dns-server 10.1.44.55
```

4. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.1.1.10-10.1.1.20
```

5. Define the network parameters for ‘scope2’ with the default gateway 10.2.1.1.

```
dhcp scope2 define parameters address-netmask 10.2.0.0/16 gateway
10.2.1.1 dns-domain acme.com dns-server 10.1.77.88
```

6. Define the address pool for ‘scope2’.

```
dhcp scope2 define pool 10.2.1.40-10.2.1.50
```

7. Create a superscope ‘super1’ that includes ‘scope1’.

```
dhcp scope1 attach superscope super1
```

8. Include ‘scope2’ in the superscope ‘super1’.

```
dhcp scope2 attach superscope super1
```

For clients on the secondary subnet, the default gateway is 10.2.1.1, which is also the secondary address for the interface ‘clients’.

9.7 INTERACTING WITH RELAY AGENTS

For clients that are not directly connected to the DHCP server, a relay agent (typically a router) is needed to communicate between the client and the server. The relay agent is usually only needed during the initial leasing of an IP address. Once the client obtains an IP address and can connect to the network, the renewal of the lease is performed between the client and server without the help of the relay agent.

The default gateway for the client must be capable of reaching the RS’s DHCP server. The RS must also be capable of reaching the client’s network. The route must be configured (with static routes, for example) or learned (with RIP or OSPF, for example) so that the DHCP server can reach the client.

The following example shows a simple configuration to support clients across a relay agent.

1. Create an interface ‘clients’ with the primary address 10.1.1.1.

```
interface create ip clients address-mask 10.1.1.1/16 port et.3.3
```

2. Define a static route to the 10.5.x.x. subnet using the gateway 10.1.7.10 which tells the DHCP server how to send packets to the client on the 10.5.x.x subnet.

```
ip add route 10.5.0.0/16 gateway 10.1.7.10
```

3. Define the network parameters for ‘scope1’ with the default gateway 10.5.1.1 (the relay agent for the client).

```
dhcp scope1 define parameters address-netmask 10.5.0.0/16 gateway
10.5.1.1 dns-domain acme.com
```

4. Define the address pool for ‘scope1’.

```
dhcp scope1 define pool 10.5.1.10-10.5.1.20
```

10 IP ROUTING CONFIGURATION GUIDE

The RS supports standards-based TCP, UDP, and IP. This chapter describes how to configure IP interfaces and general non-protocol-specific routing parameters.

10.1 IP ROUTING PROTOCOLS

The RS supports standards-based unicast and multicast routing. Unicast routing protocol support includes Interior Gateway Protocols and Exterior Gateway Protocols. Multicast routing protocols are used to determine how multicast data is transferred in a routed environment.

10.1.1 Unicast Routing Protocols

Interior Gateway Protocols are used for routing networks that are within an “autonomous system,” a network of relatively limited size. All IP interior gateway protocols must be specified with a list of associated networks before routing activities can begin. A routing process listens to updates from other routers on these networks and broadcasts its own routing information on those same networks. The RS supports the following Interior Gateway Protocols:

- Routing Information Protocol (RIP) Version 1, 2 (RFC 1058, 1723). Configuring RIP for the RS is described in Chapter 12, *"RIP Configuration Guide."*
- Open Shortest Path First (OSPF) Version 2 (RFC 1583). Configuring OSPF for the RS is described in Chapter 13, *"OSPF Configuration Guide."*
- Intermediate System-Intermediate System (IS-IS) (RFC 1142). Configuring IS-IS for the RS is described in Chapter 14, *"IS-IS Configuration Guide."*.

Exterior Gateway Protocols are used to transfer information between different “autonomous systems”. The RS supports the following Exterior Gateway Protocol:

- Border Gateway Protocol (BGP) Version 3, 4 (RFC 1267, 1771). Configuring BGP for the RS is described in Chapter 15, *"BGP Configuration Guide."*

Note Riverstone’s implementation of the above routing protocols is based on GateD. In these routing protocols, a newer issuance of a command overwrites all existing version(s) of the same command, even if they are not negated from the configuration.

10.1.2 Multicast Routing Protocols

IP multicasting allows a host to send traffic to a subset of all hosts. These hosts subscribe to group membership, thus notifying the RS of participation in a multicast transmission.

Multicast routing protocols are used to determine which routers have directly attached hosts, as specified by IGMP, that have membership to a multicast session. Once host memberships are determined, routers use multicast routing protocols, such as DVMRP, to forward multicast traffic between routers.

The RS supports the following multicast routing protocols:

- Distance Vector Multicast Routing Protocol (DVMRP) RFC 1075
- Internet Group Management Protocol (IGMP) as described in RFC 2236

The RS also supports the latest DVMRP Version 3.0 draft specification, which includes mtrace, Generation ID and Pruning/Grafting. Configuring multicast routing for the RS is described in Chapter 19, *"Routing Policy Configuration."*

10.2 CONFIGURING IP INTERFACES AND PARAMETERS

You can configure an IP interface to a single port or to a VLAN. This section provides an overview of configuring IP interfaces.

Interfaces on the RS are logical interfaces. Therefore, you can associate an interface with a single port or with multiple ports:

- To associate an interface with a single port, use the **`port`** option with the **`interface create`** command.
- To associate an interface with multiple ports, first create an IP VLAN and add ports to it, then use the vlan option with the **`interface create`** command.

The **`interface create ip`** command creates and configures an IP interface. Configuration of an IP interface can include information such as the interface's name, IP address, netmask, broadcast address, and so on. You can also create an interface in a disabled (**down**) state instead of the default enabled (**up**) state.

Note You must use either the **`port`** option or the **`vlan`** option with the **`interface create`** command.

10.2.1 Configuring IP Interfaces to Ports

You can configure an IP interface directly to a physical port. Each port can be assigned multiple IP addresses representing multiple subnets connected to the physical port. For example, to assign an IP interface 'RED' to physical port et.3.4, enter the following:

```
rs(config)# interface create ip RED address-netmask
10.50.0.0/255.255.0.0 port et.3.4
```

To configure a secondary address of 10.23.4.36 with a 24-bit netmask (255.255.255.0) on the IP interface int4:

```
rs(config)# interface add ip int4 address-netmask 10.23.4.36/24
```

10.2.2 Configuring IP Interfaces for a VLAN

You can configure one IP interface per VLAN. Once an IP interface has been assigned to a VLAN, you can add a secondary IP address to the VLAN. To create a VLAN called IP3, add ports et.3.1 through et.3.4 to the VLAN, then create an IP interface on the VLAN:

```
rs(config)# vlan create IP3 ip

rs(config)# vlan add ports et.3.1-4 to IP3

rs(config)# interface create ip int3 address-netmask 10.20.3.42/24 vlan IP3
```

To configure a secondary address of 10.23.4.36 with a 24-bit netmask (255.255.255.0) on the IP interface int4:

```
rs(config)# interface add ip int3 address-netmask 10.23.4.36/24 vlan IP3
```

10.2.3 Specifying Ethernet Encapsulation Method

The Riverstone RS Switch Router supports two encapsulation types for IP. Use the **`interface create ip`** command to configure one of the following encapsulation types on a per-interface basis:

- Ethernet II: The standard ARPA Ethernet Version 2.0 encapsulation, which uses a 16-bit protocol type code (the default encapsulation method).
- 802.3 SNAP: SNAP IEEE 802.3 encapsulation, in which the type code becomes the frame length for the IEEE 802.2 LLC encapsulation (destination and source Service Access Points, and a control byte).

10.2.4 Unnumbered Interfaces

The Riverstone RS Switch Router allows you to create unnumbered IP interfaces. In the case where an interface is one end of a point-to-point connection, it is not necessary to associate a particular IP address to that interface. This is because in a point-to-point connection, packet traffic is going to the other end (or peer) only, and are not routed to any other destination. Therefore, assigning a unique IP address to that interface wastes addresses within the address pool allocated by the netmask.

Unnumbered interfaces allows you to use another interface's IP address instead. In essence, you are configuring the unnumbered interface to borrow the IP address from another interface. This way, the unnumbered interface is not using a unique IP address only for itself, thus you are conserving addresses within the address pool.

To configure the unnumbered interface 'int3' and borrow the IP address from IP interface 'int1':

```
rs(config)# interface create ip int3 unnumbered int1
```

10.2.5 Using 31-Bit Prefixes on Point-to-Point Links

The RS supports the use of 31-bit network prefixes for interface IP addresses on point-to-point links, as described in *RFC 3021, Using 31-Bit Prefixes on IPv4 Point-to-Point Links.* This feature conserves IP address space on point-to-point links.

Traditionally, subnets used network prefixes that were at the most, 30 bits in length. This resulted in 4 addresses per link, as shown inTable 10-1:

- 2 host addresses (1.1.1.1/30 and 1.1.1.2/30)
- the IP address with all 0s in the host bits, which is normally interpreted as the network address (1.1.1.0/30)
- the IP address with all 1s in the host bits, which is normally interpreted as the directed broadcast address (1.1.1.3/30)

Table 10-1

Binary Format (network prefix underlined)	**Dotted Decimal Format**
00000001.00000001.00000001.00000000	1.1.1.0/30
00000001.00000001.00000001.00000001	1.1.1.1/30
00000001.00000001.00000001.00000010	1.1.1.2/30
00000001.00000001.00000001.00000011	1.1.1.3/30

Using a 31-bit network prefix leaves 1 bit for the host number, resulting in only two addresses, as shown in the following example:

Table 10-2

Binary Format (network prefix underlined)	**Dotted Decimal Format**
00000001.00000001.00000001.0000000 0	1.1.1.0/31
00000001.00000001.00000001.0000000 1	1.1.1.1/31

Since point-to-point connections have only two identifiable end points, using 31-bit network prefixes for point-to-point links is more efficient and economical, in terms of address space. Each point-to-point link uses 2 instead of 4 addresses, effectively reducing by half the amount of IP address space used by point-to-point links.

The following example configures an interface on one end of a point-to-point link. Note that the IP address has a 31-bit network prefix.

```
rs1(config)# interface create ip eth1 address-netmask 1.1.1.0/31 port et.4.13
rs1(config)# save active
%VLAN-I-ADDSUCCESS, 1 port et.4.13 successfully added to VLAN SYS_L3_eth1
%INTERFACE-I-CREATEDIF, Interface eth1 was successfully created.
```

You can view the interface information, as shown in the following example:.

```
rs1# interface show ip eth1
Interface eth1:
    Admin State:          up
    Operational State:    lower layer down
    Capabilities:         <BROADCAST,SIMPLEX,MULTICAST>
    Configuration:
       VLAN:              SYS_L3_eth1
       Ports:             et.4.13
       MTU:               1500
       MAC Encapsulation: ETHERNET_II
       MAC Address:       00:E0:63:04:08:C0
       IP Address:        1.1.1.0/31 --> 1.1.1.1  (broadcast: 255.255.255.255)
```

Note the peer addresses and broadcast address of the interface. Using 31-bit network prefixes leaves only two possible values for the host bit: 0 and 1, which are traditionally used for the network and broadcast address respectively. On point-to-point links with 31-bit network prefixes, the RS will interpret these as host addresses instead. In addition, because the directed broadcast address is used as a host address, only limited broadcast (255.255.255.255) will be allowed on 31-bit IP network prefixes.

Note On the RS, you can configure an IP interface to a single port or to a VLAN. You can use the 31-bit prefix IP address on an interface configured for a single port only. You cannot use this feature for an interface configured on a VLAN.

10.3 CONFIGURING JUMBO FRAMES

Certain RS line cards support jumbo frames (frames larger than the standard Ethernet frame size of 1518 bytes).

To transmit frames of up to 65535 octets, you increase the maximum transmission unit (MTU) size from the default of 1522. You must set the MTU at the port level with the **port set mtu** command. You can also set the MTU at the IP interface level; if you set the MTU at the IP interface level, the MTU size must be less than the size configured for each port in the interface. Note that the interface MTU only determines the size of the packets that are forwarded in software.

In the following example, the ports gi.3.1 through gi.3.8 are configured with an MTU size of 65535 octets. Ports gi.3.1 through gi.3.4 are configured to be part of the interface 'int3,' with an MTU size of 50000 octets.

```
rs(config)# port set gi.3.1-8 mtu 65535

rs(config)# vlan create JUMBO1 ip

rs(config)# vlan add ports gi.3.1-4 to JUMBO1

rs(config)# interface create ip int3 mtu 50000 address-netmask 10.20.3.42/24
vlan JUMBO1
```

If you do *not* set the MTU at the interface level, the actual MTU of the interface is the lowest MTU configured for a port in the interface. In the following example, port gi.3.1 is configured with an MTU size of 50022 octets while ports gi.3.2-8 are configured with an MTU size of 65535 octets. The interface MTU will be 50000 octets (50022 octets minus 22 octets of link layer overhead).

```
rs(config)# port set gi.3.1 mtu 50022

rs(config)# port set gi.3.2-8 mtu 65535

rs(config)# vlan create JUMBO1 ip

rs(config)# vlan add ports gi.3.1-4 to JUMBO1

rs(config)# interface create ip int3 address-netmask 10.20.3.42/24 vlan
JUMBO1
```

10.4 CONFIGURING ADDRESS RESOLUTION PROTOCOL (ARP)

The RS allows you to configure Address Resolution Protocol (ARP) table entries and parameters. ARP is used to associate IP addresses with media or MAC addresses. Taking an IP address as input, ARP determines the associated MAC address. Once a media or MAC address is determined, the IP address/media address association is stored in an ARP cache for rapid retrieval. Then the IP datagram is encapsulated in a link-layer frame and sent over the network.

10.4.1 Configuring ARP Cache Entries

To create an ARP entry for the IP address 10.8.1.2 at port et.4.7 for 15 seconds:

```
rs# arp add 10.8.1.2 mac-addr 08:00:20:a2:f3:49 exit-port et.4.7
keep-time 15
```

To create a permanent ARP entry for the host *nfs2* at port et.3.1:

```
rs(config)# arp add nfs2 mac-addr 080020:13a09f exit-port et.3.1
```

To remove the ARP entry for the host 10.8.1.2 from the ARP table:.

```
rs# arp clear 10.8.1.2
```

To clear the entire ARP table.

```
rs# arp clear all
```

If the Startup configuration file contains **arp add** commands, the Control Module re-adds the ARP entries even if you have cleared them using the **arp clear** command. To permanently remove an ARP entry, use the **negate** command or **no** command to remove the entry.

10.4.2 Unresolved MAC Addresses for ARP Entries

When the RS receives a packet for a host whose MAC address it has not resolved, the RS tries to resolve the next-hop MAC address by sending ARP requests. Five requests are sent initially for each host, one every second.

You can configure the RS to drop packets for hosts whose MAC addresses the RS has been unable to resolve. To enable dropping of packets for hosts with unresolved MAC addresses:

```
rs# arp set drop-unresolved enabled
```

When you enable packets to be dropped for hosts with unresolved MAC addresses, the RS will still attempt to periodically resolve these MAC addresses. By default, the RS sends ARP requests at 5-second intervals to try to resolve dropped entries.

To change the interval for sending ARP requests for unresolved entries to 45 seconds:

```
rs# arp set unresolve-timer 45
```

To change the number of unresolved entries that the RS attempts to resolve to 75:

```
rs# arp set unresolve-threshold 75
```

10.4.3 Configuring Proxy ARP

The RS can be configured for proxy ARP. The RS uses proxy ARP (as defined in RFC 1027) to help hosts with no knowledge of routing determine the MAC address of hosts on other networks or subnets. Through proxy ARP, the RS will respond to ARP requests from a host with a ARP reply packet containing the RS MAC address. Proxy ARP is enabled by default on the RS. The following example disables proxy ARP on all interfaces:

```
rs(config)# ip disable-proxy-arp interface all
```

10.4.4 Using DHCP to Install ARP Entries

If you are using a Dynamic Host Configuration Protocol (DHCP) server to provide IP addresses to user systems, you can also use DHCP to install entries in the Address Resolution Protocol (ARP) table on the RS. Using DHCP to install ARP entries helps prevent spoofing of ARP requests by unauthorized users.

To use DHCP to install ARP entries, specify the **snoop-l2-l3-info** parameter with the **ip helper-address** command. This parameter causes the RS to examine DHCP acknowledgement packets sent from the DHCP server to the client on the specified interface. The information in the DHCP acknowledgement packet is used to resolve MAC addresses (layer 2) to IP addresses (layer 3) for the ARP entries. Note that when DHCP is used to install ARP entries, client ARP requests that contain different MAC addresses than those in the DHCP-installed entries are dropped. You can still use all **arp** and **rarpd** commands, and proxy ARP will operate as usual.

The following example command causes DHCP packets on the interface ‘int1’ from the DHCP server at 10.1.4.5 to be examined for ARP information:

```
rs(config)# ip helper-address interface int1 10.1.4.5 snoop-l2-l3-info
```

As shown in the above example, you do not need to specify the DHCP port number as an option; only DHCP packets are examined. The age-out of the DHCP client’s ARP entry is set to the DHCP lease period for that client. DHCP renewal requests and acknowledgements are also examined. Thus, if an ARP entry already exists for a client, the age-out is replaced with the new DHCP lease period.

Note If the RS is rebooted while this feature is enabled, ARP entries are lost but DHCP clients will still have valid leases. Until the DHCP clients renew and the RS is again able to examine acknowledgements from the server, unicast traffic from the clients cannot be returned. Therefore, Riverstone recommends that you only use this feature on routers with redundant CMs installed, or where DHCP clients have very short renewal intervals.

10.5 CONFIGURING REVERSE ADDRESS RESOLUTION PROTOCOL (RARP)

Reverse Address Resolution Protocol (RARP) works exactly the opposite of ARP. Taking a MAC address as input, RARP determines the associated IP address. RARP is useful for X-terminals and diskless workstations that may not have an IP address when they boot. They can submit their MAC address to a RARP server on the RS, which returns an IP address.

Configuring RARP on the RS consists of two steps:

1. Letting the RS know which IP interfaces to respond to
2. Defining the mappings of MAC addresses to IP addresses

10.5.1 Specifying IP Interfaces for RARP

The **rarpd set interface** command allows you to specify which interfaces the RS's RARP server responds to when sent RARP requests. You can specify individual interfaces or all interfaces. To cause the RS's RARP server to respond to RARP requests from interface int1:

```
rs(config)# rarpd set interface int1
```

10.5.2 Defining MAC-to-IP Address Mappings

The **rarpd add** command allows you to map a MAC address to an IP address for use with RARP. When a host makes a RARP request on the RS, and its MAC address has been mapped to an IP address with the **rarp add** command, the RARP server on the RS responds with the IP address that corresponds to the host's MAC address. To map MAC address 00:C0:4F:65:18:E0 to IP address 10.10.10.10:

```
rs(config)# rarpd add hardware-address 00:C0:4F:65:18:E0 ip-address
10.10.10.10
```

There is no limit to the number of address mappings you can configure.

Optionally, you can create a list of mappings with a text editor and then use TFTP to upload the text file to the RS. The format of the text file must be as follows:

```
MAC-address1 IP-address1
MAC-address2 IP-address2
...
MAC-addressn IP-addressn
```

Then place the text file on a TFTP server that the RS can access and enter the following command in Enable mode:

```
rs# copy tftp-server to ethers
TFTP server? <IPaddr-of-TFTP-server>
Source filename? <filename>
```

10.5.3 Monitoring RARP

You can use the following commands to obtain information about the RS's RARP configuration:

Display the interfaces to which the RARP server responds.	**rarpd show interface**
Display the existing MAC-to-IP address mappings	**rarpd show mappings**
Display RARP statistics.	**statistics show rarp** <*InterfaceName*>**|all**

10.6 CONFIGURING DNS PARAMETERS

The RS can be configured to specify DNS servers, which supply name services for DNS requests. You can specify up to three DNS servers.

To configure three DNS servers and configure the RS's DNS domain name to "mrb.com":

```
rs(config)# system set dns server "10.1.2.3 10.2.10.12 10.3.4.5" domain
mrb.com
```

10.7 CONFIGURING IP SERVICES (ICMP)

The RS provides ICMP message capabilities including ping and traceroute. The **ping** command allows you to determine the reachability of a certain IP host, while the **traceroute** command allows you to trace the IP gateways to an IP host.

10.8 CONFIGURING IP HELPER

The **ip helper-address** command allows the user to forward specific UDP broadcast from one interface to another. Typically, broadcast packets from one interface are not forwarded (routed) to another interface. However, some applications use UDP broadcast to detect the availability of a service. Other services, for example BOOTP/DHCP require broadcast packets to be routed so that they can provide services to clients on another subnet. An IP helper can be configured on each interface to have UDP broadcast packets forwarded to a specific host for a specific service or forwarded to all other interfaces.

You can configure the RS to forward UDP broadcast packets received on a given interface to all other interfaces or to a specified IP address. You can specify a UDP port number for which UDP broadcast packets with that destination port number will be forwarded. By default, if no UDP port number is specified, the RS will forward UDP broadcast packets for the following six services:

- BOOTP/DHCP (port 67 and 68)
- DNS (port 53)
- NetBIOS Name Server (port 137)

- NetBIOS Datagram Server (port 138)
- TACACS Server (port 49)
- Time Service (port 37)

To forward UDP broadcast packets received on interface int1 to the host 10.1.4.5 for the six default UDP services:

```
rs(config)# ip helper-address interface int1 10.1.4.5
```

To forward UDP broadcast packets received on interface int2 to the host 10.2.48.8 for packets with the destination port 111 (port mapper):

```
rs(config)# ip helper-address interface int2 10.2.48.8 111
```

To forward UDP broadcast packets received on interface int3 to all other interfaces:

```
rs(config)# ip helper-address interface int3 all-interfaces
```

10.9 CONFIGURING DIRECT BROADCAST

Directed broadcast packets are network or subnet broadcast packets which are sent to a router to be forwarded as broadcast packets. They can be misused to create Denial Of Service attacks. The RS protects against this possibility by ***not*** forwarding directed broadcasts, by default. To enable the forwarding of directed broadcasts, use the **`ip enable directed-broadcast`** command.

You can configure the RS to forward all directed broadcast traffic from the local subnet to a specified IP address or all associated IP addresses. This is a more efficient method than defining only one local interface and remote IP address destination at a time with the **`ip-helper`** command when you are forwarding traffic from more than one interface in the local subnet to a remote destination IP address.

To enable directed broadcast forwarding on the “int4” network interface:

```
rs(config)# ip enable directed-broadcast interface int4
```

10.10 CONFIGURING DENIAL OF SERVICE (DOS) PROTECTION FEATURES

By default, the RS installs flows in the hardware so that packets sent as directed broadcasts are dropped in hardware if directed broadcast is not enabled on the interface where the packet is received. You can disable this feature, causing directed broadcast packets to be processed on the RS even if directed broadcast is not enabled on the interface receiving the packet.

Similarly, the RS installs flows to drop packets destined for the RS for which service is not provided by the RS. This prevents packets for unknown services from slowing the CPU. You can disable this behavior, causing these packets to be processed by the CPU.

Enter the following to cause directed broadcast packets to be processed on the RS, even if directed broadcast is not enabled on the interface receiving the packet:

```
rs(config)# ip dos disable directed-broadcast-protection
```

Enter the following to allow packets destined for the RS (that do not have a service defined for them on the RS), to be processed by the RS's CPU:

```
rs(config)# ip dos disable port-attack-protection
```

Denial of Service (DOS) attacks can take the form of flooding packets of various types over the RS. Because of this, the RS provides the ability to rate limit the traffic on specific ports as well as rate limit specific packet types. Table 10-3 lists those objects on which the RS allows rate limiting:

Table 10-3 Rate limited objects to prevent DOS attacks

Parameter	Value	Meaning
bgp	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000. The default is no rate limiting.
icmp	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000. This value is required.
igmp	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000. This value is required.
ospf	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000. The default is no rate limiting.
port	<*port-list*>	Specifies a port or list of ports on which to enable rate limiting.
l2-miss	<*num*>	Specifies the traffic to rate limit as layer-2 address misses. Numerical value is between 3000 and 1000000000.
l3-miss	<*num*>	Specifies the traffic to rate limit as layer-3 address misses. Numerical value is between 3000 and 1000000000.
tcp-sfr	<*num*>	Specifies the traffic to rate limit as TCP three-way handshaking traffic. Numerical value is between 3000 and 1000000000.
ttl-expired	<*num*>	Specifies the traffic to rate limit as packets with expired Time to Live counts. Numerical value is between 3000 and 1000000000.
unknown-route	<*num*>	Specifies the traffic to rate limit as packets containing unknown routes. Numerical value is between 3000 and 1000000000.
rip	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 30000 to 10000000.

Table 10-3 Rate limited objects to prevent DOS attacks

Parameter	Value	Meaning
`vrrp`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`ldp-hello`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`ldp-session`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`rsvp`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`snmp`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`ssh`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.
`telnet`	<*num*>	<*num*> is the rate limit in bps. The range of values for this field is 3000 to 10000000.

For example, to rate limit TCP-SFR traffic to **`10000`** bits-per-second, which comes through port **`gi.4.1`**, enter the following:

```
rs(config)# ip dos rate-limit port gi.4.1 tcp-sfr 10000
```

Rate limiting not only restricts traffic through the switch-fabric, but can also protects the RS' CPU from DOS attacks. Notice in Table 10-3 that **`l2-misses`**, **`l3-misses`**, and **`unknown-routes`** are all traffic that would normally be bound for the CPU. However, rate limiting can keep these objects from flooding the CPU.

10.11 MONITORING IP PARAMETERS

The RS provides display of IP statistics and configurations contained in the routing table. Information displayed provides routing and performance information.

The **ip show** commands display IP information, such as routing tables, TCP/UDP connections, and IP interface configuration, on the RS. The following example displays all established connections and services of the RS.

```
rs# ip show connections
Active Internet connections (including servers)
Proto Recv-Q Send-Q  Local Address          Foreign Address
(state)
tcp        0      0  *:gated-gii           *:*                    LISTEN
tcp        0      0  *:http                *:*                    LISTEN
tcp        0      0  *:telnet              *:*                    LISTEN
udp        0      0  127.0.0.1:1025         127.0.0.1:162
udp        0      0  *:snmp                 *:*
udp        0      0  *:snmp-trap            *:*
udp        0      0  *:bootp-relay          *:*
udp        0      0  *:route                *:*
udp        0      0  *:*                    *:*
```

The following example displays the contents of the routing table. It shows that some of the route entries are for locally connected interfaces (“directly connected”), while some of the other routes are learned from RIP.

```
rs# ip show routes
Destination                Gateway                   Owner     Netif
-----------                -------                   -----     -----
10.1.0.0/16               50.1.1.2                 RIP      to-linux2
10.2.0.0/16               50.1.1.2                 RIP      to-linux2
10.3.0.0/16               50.1.1.2                 RIP      to-linux2
10.4.0.0/16               50.1.1.2                 RIP      to-linux2
14.3.2.1                   61.1.4.32                  Static    int61
21.0.0.0/8                50.1.1.2                 RIP      to-linux2
30.1.0.0/16                directly connected         -        to-goya
50.1.0.0/16                directly connected         -
to-linux2
61.1.0.0/16                directly connected         -         int61
62.1.0.0/16               50.1.1.2                 RIP      to-linux2
68.1.0.0/16                directly connected         -         int68
69.1.0.0/16               50.1.1.2                 RIP      to-linux2
127.0.0.0/8                127.0.0.1                  Static    lo
127.0.0.1                  127.0.0.1                  -         lo
210.11.99.0/24             directly connected         -         int41
```

To display additional IP information, enter the following command in Enable mode:

Show ARP table entries.	**arp show all**
Show IP interface configuration.	**interface show ip**
Show DNS parameters.	**system show dns**

10.12 L3 FORWARDING MODES

When an RS port receives a packet for routing, it matches the packet's flow against those found in the L3 flow table.

- If a match is found, the packet is forwarded to the exit port and transmitted.
- If a match is not found, the packet is forwarded to the CPU and the destination is looked up in the Forwarding Information Base (FIB).
  - If the destination is found in the FIB, then the packet is forwarded to the next hop. In addition, the CPU updates the L3 flow table so subsequent packets with the same flow are automatically forwarded without being sent to the CPU.
  - If the destination is not found in the FIB, the RS drops the packet.

A port's forwarding mode determines which fields make up a packet's flow.. Each forwarding mode defines a flow differently. The RS ports can operate in any one of the following forwarding modes:

- application-based forwarding (default)
- hardware routing table (HRT)
- destination-based forwarding
- host-flow-based forwarding
- custom forwarding

10.12.1 Configuring Forwarding Modes

The RS operates in application-based forwarding mode by default. Except for HRT, which is configured by slot, you can set forwarding modes by port. To see which mode a port is in, use the **`ip show mode`** command, as shown in the following example:

```
rs1# ip show mode port all-ports
Port     Mode
----     ----
so.3.1   Flow (Default) + HRT
so.3.2   Flow (Default)
et.4.1   Dest
et.4.2   Flow (Default)
et.4.3   Flow (Default)
et.4.4   Flow (Default)
et.4.5   Host
et.4.6   Flow (Default)
et.4.7   Flow (Default)
et.4.8   Flow (Default)
et.4.9   Flow (Default)
et.4.10  Flow (Default)
et.4.11  Flow (Default)
et.4.12  Flow (Default)
et.4.13  Flow (Default)
et.4.14  Flow (Default)
et.4.15  Flow (Default)
et.4.16  Flow (Default)
gi.9.1   Flow (Default) + HRT
gi.9.2   Flow (Default) + HRT
```

10.12.2 Application-Based Forwarding

By default, all the RS ports use application-based forwarding, where a flow is defined by the following fields:

- Source IP address
- Destination IP address
- Source Socket
- Destination Socket
- ToS
- Port of Entry
- Protocol

Application-based forwarding is compatible with all the RS features and provides the most granularity when defining ACLs and QoS parameters. Additionally, it enables you to track Layer-3 statistics on the type of traffic travelling through the network.

10.12.3 Hardware Routing Table (HRT)

The Hardware Routing Table (HRT) facility speeds the forwarding of packets and reduces potential bottlenecks to the CPU. When HRT is enabled, each line card stores a copy of the FIB on its own memory. When the software FIB is updated, the FIBs in the hardware are updated, as well. If a packet enters a line card with HRT enabled, and that packet does not have an entry in the line card's hardware FIB, the packet is dropped.

Note HRT is not supported on the following modules: HSSI, Serial.

The advantage of HRT routing is that with the exception of management protocols (such as SSH), packets almost never get sent to the CPU, saving considerable cycle time. The exception to this is when traffic performs an operation that is incompatible with HRT. If this occurs, HRT is suspended and traffic is placed into flow-mode until the incompatible operation ceases – once ceased, the port is returned to HRT mode.

The following is a list of HRT-incompatible facilities:

- LFAP
- rate limiting
- NAT/LS-NAT
- QoS
- MPLS
- Port Mirroring
- Web Cache Redirect
- Trunking
- SmartTRUNKs
- L4 Bridging
- Ingress WRED

HRT Version Selection

Three versions of HRT are supported on RS platforms: HRT version 1, HRT version 2, and HRT version 2-enhanced. Table 10-4 describes the difference between HRT versions.

Table 10-4 Differences between HRT versions

HRT Version	Multipath Support	Enhanced FIB Support	Supported Line Cards
HRT v1	NO	NO	All generation 2 and 3 ASIC based line cards.
HRT v2*	YES	NO	All generation 4 and 5 ASIC RS 8000 and RS 8600 line cards.
HRT v2-enhanced	YES	YES	All generation 5 line cards with extended memory.

* Several **`hrt show`** commands use M and E to identify HRT v2 and v2-enhanced. The *M* appears for HRT v2, and stands for *"Multipath."* Both the M and E appear for HRT v2-enhanced, where the *E* stands for *"Enhanced FIB Support."*

Note that Multipath support allows traffic to flow on one of four paths. A hashing algorithm is used to assign traffic to its path. This hashing algorithm basically ensures that the distribution of traffic on the paths is random.

Note Only four multi-paths are supported. If more than four multi-paths are configured, only the first four will be used.

Enhanced FIB support indicates that the line card can store a larger number of routes in HRT memory.

By default, the RS is configured to use HRT version 1. However, the HRT version used by the RS can be changed using the **`hrt set version`** command from Configure mode. Note that the HRT version is a global parameter. In other words, all line cards use whichever version of HRT is set in the RS' configuration by the **`hrt set version`** command.

The following is an example of changing the HRT version to HRT v2:

```
rs(config)# hrt set version v2
```

Note The RS 16000 and RS 38000 always operate in HRT v2-enhanced mode – the above command has no effect on these platforms.

To view the compatibility of line cards with versions of HRT, enter the **hrt show ports all-ports** command in Enable mode. The following is an example:

```
rs# hrt show ports all-ports

HRT Port Information:
---------------------
Legend:
        M : Multipath,  E: Enhanced FIB
        NA: Current HRT version is not supported

        Current HRT version on this platform is: HRT v2 (M)
        Current internal priority for HRT forwarded traffic is: High
        HRT is administratively enabled on slots: 9


         Supported     Version       Admin      Operational
Port     HRT Version   Active        Status     Status
----     -----------   ----------    ------     -----------
so.3.1   HRT v2 (E M)  HRT v2 (M)    Disabled   Disabled (Administratively)
so.3.2   HRT v2 (E M)  HRT v2 (M)    Disabled   Disabled (Administratively)
et.4.1   --NA--            -            -        -
et.4.2   --NA--            -            -        -
et.4.3   --NA--            -            -        -
et.4.4   --NA--            -            -        -
et.4.5   --NA--            -            -        -
et.4.6   --NA--            -            -        -
et.4.7   --NA--            -            -        -
NP.7.3   HRT v1        --NA--        Disabled   Disabled (Administratively)
NP.7.4   HRT v1        --NA--        Disabled   Disabled (Administratively)
gi.8.1   --NA--            -            -        -
gi.8.2   --NA--            -            -        -
gi.9.1   HRT v2 (M)    HRT v2 (M)    Enabled    Enabled
gi.9.2   HRT v2 (M)    HRT v2 (M)    Enabled    Disabled (Port has no IP Interface)
```

Notice the versions displayed under the “Supported HRT Version” column. This indicates what version of HRT can be set on the RS. For example, if the Supported HRT Version column contained only “`HRT v1`,” HRT v2 and v2-enhanced could not be used.

HRT Traffic Priority

By default, HRT forwards all traffic using the *“low”* internal priority. However, the priority HRT uses to forward traffic can be set using the **hrt set priority-level** command to use any of the internal priorities – *low, medium, high,* or *control*. Note that *“control”* is the highest priority, and it typically reserved for forwarding traffic consisting of routing PDUs and control information.

The following is an example of setting the HRT traffic priority to high:

```
rs(config)# hrt set priority-level high
```

Keep in mind that the HRT traffic priority is a global command, and cannot be set on a per-slot or per-port basis.

Enabling HRT

Once an HRT version is selected, HRT is enabled on a per-module (slot) basis using the **hrt enable** command in Configure mode. The following example enables HRT on slot 9.

```
rs(config)# hrt enable slot 9
```

To view slots that are running HRT and their memory usage, use the **hrt show summary** command as shown in the following example:

```
rs# hrt show summary
HRT Summary:
-----------
Legend:
        M : Multipath,  E: Enhanced FIB
        NA: Current HRT version is not supported

        Current HRT version on this platform is: HRT v2 (M)
        Current internal priority for HRT forwarded traffic is: high
        HRT is administratively enabled on slots: 9 11

        HRT Memory Size    :   7936 KB
        HRT Memory Free    :   7921 KB
No ports are operating in HRT mode
```

Notice that according to the legend in the example above that HRT is set to v2, and that the HRT internal traffic priority is set to high.

To display HRT information by port, use the **hrt show ports** command. Specify the **detailed** option, as shown in the example, to display the time when HRT was last enabled/disabled on a port.

The following example shows the **hrt show ports** command display for ports **gi.9.1** and **gi.9.2**:

```
rs# hrt show ports gi.9.1-2 detailed

HRT Port Information:
--------------------
Legend:
        M : Multipath,  E: Enhanced FIB
        NA: Current HRT version is not supported

        Current HRT version on this platform is: HRT v2 (M)
        Current internal priority for HRT forwarded traffic is: High
        HRT is administratively enabled on slots: 9 11

Port                    : gi.9.1
Supported HRT Version   : HRT v2 (M)
HRT Version Active      : HRT v2 (M)
HRT Admin Status        : Enabled
HRT Operational Status  : Enabled
HRT last enabled at     : 2003-03-25 13:22:54
HRT last disabled at    : 2003-03-24 11:02:26
-------------------------------------------------

Port                    : gi.9.2
Supported HRT Version   : HRT v2 (M)
HRT Version Active      : HRT v2 (M)
HRT Admin Status        : Enabled
HRT Operational Status  : Disabled (Port has no IP Interface)
HRT last enabled at     : Never
HRT last disabled at    : 2003-03-24 11:02:26
-------------------------------------------------
```

HRT and ACLs

HRT is not compatible with all ACLs. For example, HRT is not compatible with destination address-based ACL or ToS only ACLs. Use the **hrt test acl-compatibility** command to check whether a specified ACL is compatible with HRT. As shown in the following example, you can specify **all-acls** to verify the compatibility of all configured ACLs:

```
rs# hrt test acl-compatibility all-acls

HRT ACL Compatibility Test:
|              ACL        |        HRT Compatibility        |
-------------------------------------------------------------
|   Source1               |   ACL is compatible with HRT    |
|   Dest1                 |   ACL is NOT compatible with HRT|
|   Source2               |   ACL is compatible with HRT    |
|   Dest2                 |   ACL is NOT compatible with HRT|
|   ToS1                  |   ACL is NOT compatible with HRT|
|   pol1                  |   ACL is compatible with HRT    |
-------------------------------------------------------------
```

If the specified ACL does not exist, the information in the following example is displayed:

```
rs# hrt test acl-compatibility acl100

HRT ACL Compatibility Test:
|              ACL        |        HRT Compatibility        |
-------------------------------------------------------------
|   acl100                |       ACL does not exist        |
-------------------------------------------------------------
```

If an ACL is compatible with the HRT, that ACL is automatically written into hardware.

Finding a Route in HRT

Use the **hrt find route** command to check whether a route to a specified destination is in the hardware FIB. This command is similar to the **ip find route** command. The only difference is when you use **ip find route**, the RS tries to find the route in the software FIB only. When you use the **hrt find route** command, the RS first looks for the route in the software FIB. If this lookup fails, the RS stops looking. If this lookup succeeds, the RS looks for the route in the hardware FIB of the specified module.

If a route to the specified destination exists in the hardware FIB, the RS will display the route information, as shown in the following example. It displays the details for the route to the destination, 21.1.1.10:

```
rs# hrt find route 21.1.1.10 slot 3
Software FIB details for destination: 21.1.1.10
        Uses Route               : 21.1.1.0
        Netmask                  : 255.255.255.0
        Gateways                 : 100.1.1.2  101.1.1.2

HRT details for destination: 21.1.1.10
         Use of HRT entry        :Always use this HRT entry to forward packets
         Number of Next Hops     :2
         Next Hop Information
          1) Exit Port           : at.2.1
             Next Hop MAC Address : 02e063:201064
          2) Exit Port           : at.2.1
             Next Hop MAC Address : 02e063:2010c8
```

Configuring ICMP Redirect

The RS sends ICMP redirect messages when it receives packets that have the same entry and exit ports. When HRT is enabled, you can set a threshold for these types of packets. The following example sets the threshold to 10.

```
rs1(config)# hrt set icmp icmp-redirect-count 10
```

Once the number of packets received by the RS reaches the specified threshold (10 in this example), the RS sends one ICMP redirect message to the originating device. As a rule, one redirect message is sent each time the redirect count reaches its set value.

HRT and IP Policy-Based Forwarding

Policy-based forwarding on source addresses is supported by all versions of HRT. Through policy-based forwarding, a packet from a particular source IP address is forwarded to its next-hop gateway using the hardware FIB, and bypassing the need to be process packets through software.

Configuring an IP policy consists of the following tasks:

- Defining an ACL-profile
- Associating the profile with an IP policy
- Applying the IP policy to an interface

Configuring an IP policy-based route

An ACL-profile specifies the criteria that packets must meet to be eligible for IP policy routing. ACL-profiles are defined using the **acl** command. For IP policy routing, the RS uses the packet-related information from the **acl** command and ignores the other fields.

For example, the following **acl** command creates an ACL-profile called “prof1” for IP packets coming from network 9.1.0.0:

```
rs(config)# acl prof1 permit ip 9.1.0.0/16 any any any
```

Note ACLs for non-IP protocols cannot be used for IP policy routing.

Once the ACL-profile is defined using the **acl** command, the ACL-profile is associated with an IP policy by entering one or more **ip-policy** statements. An **ip-policy** statement specifies the next-hop gateway (or gateways) where packets matching a profile are forwarded.

For example, the following command creates an IP policy called “p1” and specifies that packets matching profile “prof1” are forwarded to next-hop gateway 10.10.10.10:

```
rs(config)# ip-policy p1 permit acl prof1 next-hop-list 10.10.10.10
```

IP policies can be created that prevent packets from being forwarded. For example, the following command creates an IP policy called “p2” that prevents packets matching prof1 from being forwarded by the IP policy:

```
rs(config)# ip-policy p2 deny acl prof1
```

In this case, packets matching the specified ACL-profile are not forwarded even using the FIB for **policy-first** policies, which is the only policy type used by HRT.

An IP policy can contain more than one **ip-policy** statement. For example, an IP policy can contain one statement that sends all packets matching an ACL-profile to one next-hop gateway, and another statement that sends packets matching a different ACL-profile to a different next-hop gateway. In HRT, packets are acted upon according to the policy with the ACL that has the longest prefix-matched source IP address.

For example, consider the following example:

```
rs(config)# acl prof1 permit ip 10.1.0.0/16
rs(config)# acl prof2 permit ip 10.1.1.0/24
rs(config)# ip-policy p3 permit acl prof1 next-hop-list 20.1.1.10
rs(config)# ip-policy p3 permit acl [rpf2 next-hop-list 30.1.1.10
```

Packets with the source address of **10.1.1.10** are forwarded to **30.1.1.10**, while packets with source address of **10.1.12.10** are forwarded to **20.1.1.10**.

The forwarding occurs because the next-hop is based on the longest prefix match. Notice that **10.1.1.10** matches 24-bits within ACL **prof2**, while the best the **10.1.12.10** can do is match 16-bits within ACL **prof1**.

HRT IP Policy-Based Forwarding Limitations

There are several limitations with HRT policy-based forwarding t keep in mind when using this feature. The following is a list of these limitations.

- ACLs and IP policy-based forwarding are not supported on the same interface at the same time. For example, if there are two interfaces on a slot, you cannot configure ACLs on one interface and policy-based forwarding on the other. If this is done, HRT is disabled on the ports of the interface on which the later command is applied.
- An ACL that passes the **hrt test acl-compatibility** command may still be illegal to use with HRT policy-based routing.
- HRT is disabled if ACLs and IP policies are applied together on an interface at the same time.
- Only *source* IP-based IP Policies are supported.
- Only *Policy-First* type IP policies are supported.
- It is possible that some IP policies can disable HRT on an interface, especially if there are conflicting IP policies on the same interface.
- Only directly connected next-hops are supported when running IP policies in HRT mode. If a next-hop is not directly connected, the HRT policy-based route entry is removed from the HRT.
- Configuring IP policies on an interface does not result in HRT being disabled on other interfaces on the same slot. This means that if policy-based routing is configured on one interface of a slot, packets arriving on any other ports on the same slot (and possibly belonging to another interface) will be forwarded according to the policy-based routing rules.
- The Pinger option must be configured for all IP policies.
- If there is more than one interface on a slot, and different IP Policies are configured on the interfaces, the union of the IP Policies will be applied to the entire slot.

Note See Chapter 23, *"IP Policy-Based Forwarding Configuration"* for detailed information regarding IP policies. Also, see Chapter 26, *"Access Control List Configuration"* for detailed information regarding ACLs.

10.12.4 Destination-Based Forwarding

When an RS port is in destination-based forwarding mode, it installs a new flow for each new destination. It uses the following flow information from IP unicast packets:

- Destination IP address
- ToS
- Port of Entry
- Protocol

For multicast packets, the RS uses the source IP address in addition to the fields it uses to define a flow in unicast packets.

The following example sets port et.4.1 to destination-based forwarding mode:

```
rs(config)# ip set port et.4.1 forwarding mode destination-based
```

10.12.5 Host-Flow-Based Forwarding

When an RS port is in host-flow-based forwarding mode, it uses the following flow information to make its forwarding decisions:

- Source IP address
- Destination IP address
- ToS
- Port of Entry
- Protocol

The following example sets port et.4.3 to host-flow-based forwarding mode:

```
rs(config)# ip set port et.4.3 forwarding mode host-flow-based
```

When you set a port to host-flow-based forwarding, you can use ACLs that use both the source and destination IP addresses. In addition, you can track statistics between two hosts.

10.12.6 Custom Forwarding

You can configure the RS to use a custom forwarding profile to identify a packet's flow. A custom forwarding profile is used to wildcard specific fields in the IP header.

Define the custom forwarding profile, apply it to a slot, then enable it on a per port basis. The ports on which the custom forwarding profile is not enabled will use the default forwarding mode.

The fields that can be wildcarded are as follows:

- Source IP Address (SIP)
- Destination IP Address (DIP)

- Protocol
- Source Socket
- Destination Socket
- Type of Service (TOS)

Configuring a Profile

To configure a custom forwarding profile:

- define the profile, with the **`ip define custom-forwarding-profile`** command
- apply the profile to a slot, with the **`ip apply custom-forwarding-profile`** command
- enable the profile on a specific port, with the **`ip enable custom-forwarding-mode`** command

The following example configures the custom forwarding profile *a100* and enables it on port gi.9.1:

```
rs(config)# ip define custom-forwarding-profile a100 dip-host-wildcard
dst-sock-wildcard sip-host-wildcard src-sock-wildcard
rs(config)# ip apply custom-forwarding-profile a100 slot 9
rs(config)# ip enable custom-forwarding-mode port gi.9.1
```

In the example, only port gi.9.1 will use the custom forwarding profile to forward packets. All other ports in slot 9 will use the default forwarding mode.

Use the **`ip show custom-forwarding-profile`** command to view the configured profiles, as shown in the following example:

```
rs# ip show custom-forwarding-profile all

Profile a100:
protocol wildcarding is disabled
sip wildcarding is enabled
dip wildcarding is enabled
src socket wildcarding is enabled
dest socket wildcarding is enabled
TOS  wildcarding is disabled
```

Using Custom Forwarding with Other RS Features

Custom forwarding profiles are used to wildcard certain fields in the IP header. This can cause incompatibility with various RS features that require that these fields not be wildcarded. Whenever custom forwarding is enabled on a port, the RS checks for compatibility with other features that the port supports. Conversely, when a feature is applied to an interface or VLAN with ports in custom forwarding mode, the RS also checks for compatibility.

Access Control Lists (ACLs)

An ACL specifies various fields on the IP header which it uses to filter packets. When an ACL is applied to an interface, the RS checks to see if any of the ports on the interface have custom forwarding enabled. For any port in which custom forwarding is enabled, the RS makes an additional check that the fields specified in the ACL are not

wildcarded by the custom forwarding profile. If this happens, the RS generates an error. Conversely, when a port in custom forwarding mode is added to an interface, VLAN or SmartTRUNK, the RS checks for compatibility between the custom profile and the existing ACLs.

Network Address Translation (NAT)

NAT requires the source IP address and sometimes the source socket for address translation. Thus, whenever NAT is enabled, the RS checks if the source IP and source socket are wildcarded on an interface or if a custom forwarding profile is applied to a NAT enabled interface.

Rate Limiting

Rate limiting uses ACLs to limit traffic rate. Thus, the RS performs a compatibility check when a port is configured to support both custom forwarding and rate limiting.

Quality of Service (QoS)

QoS policies applied at L3, require certain fields in the IP header, such as source IP and destination IP. The RS performs a compatibility check when a QoS policy is applied to a port in forwarding mode.

L4 Bridging

L4 bridging is incompatible with custom forwarding profiles. Therefore a port cannot support l4 bridging and custom forwarding at the same time.

10.13 INSTALLING MPLS LSP ROUTES IN THE FIB

10.13.1 Basic Functionality

Normally, MPLS LSPs are not installed in the RIB or FIB, which makes them inaccessible for routing.

Using the **`ip-router global set install-lsp-routes`** command, you can

- Install LSP routes in the Internet Unicast RIB and permit *all* routing protocols to utilize these routes. Due to their default preference, installing LSP routes in the Internet Unicast RIB usually means that they are also selected to be installed in the Unicast FIB.
- Install LSP routes in the LSP RIB and grant BGP *exclusive* access to LSP routes, allowing BGP *only* to use MPLS paths in resolving next hops. Under this scheme, other routing protocols are not permitted to use LSP routes and LSP routes are not installed in the Internet Unicast RIB.
- Install LSP routes into both the Internet Unicast FIB and LSP FIB.

MPLS LSP routes contain the host address for each LSP's egress router. Using these tunnels, an ingress router can forward packets to the destination egress router.

Without this capability, routing protocols must rely on conventional routes in the FIB for routing. With this capability, if a next hop happens to be the egress point on a pre-defined MPLS tunnel, the routing protocol can utilize this tunnel to forward to the next hop.

10.13.2 Configuration

By default, routing protocols must rely on conventional routes in the FIB for routing. Use the **`ip-router global set install-lsp-routes on`** command to install LSP routes in the Internet Unicast RIB and permit *all* routing protocols to utilize these routes for calculating IGP shortcuts. Due to their default preference, installing LSP routes in the Internet Unicast RIB usually means that they are also selected to be installed in the Unicast FIB.

```
RS(config)# ip-router global set install-lsp routes on
```

Use the **`ip-router global set install-lsp-routes bgp`** command to grant BGP *exclusive* access to LSP routes, allowing BGP to use MPLS paths, *in addition to* other routes in the FIB, in resolving next hops. Under this scheme, MPLS routes are only installed in the LSP RIB and other routing protocols are not permitted to use them.

```
RS(config)# ip-router global set install-lsp routes bgp
```

10.13.3 Usage Notes, Rules, and Restrictions

Choosing Between Conventional FIB Routes and LSP Routes

- When routing protocols have a choice between conventional FIB routes and LSP routes, the route with the highest preference is chosen. You can affect this choice by using the **<*protocol*> set preference** command to specify desired IGP preferences and the **mpls set label-switch-path preference** command to specify preferences for MPLS LSPs.

Caution Using these commands overrides default preferences and may alter the normal routing process.

- If multiple paths with identical preferences exist between conventional routes and LSP routes, routing protocols prefer LSP routes over conventional routes by default.

LSP Removed or Fails

- When a routing protocol selects an LSP to use, it installs that LSP into its forwarding engine as the transport method of choice for the associated next hop. If the LSP is removed or fails, the path is removed from the FIB and all RIBs, as well as from that protocol's forwarding engine. This forces the routing protocol to select another path to the next hop from all available routes, including other LSP routes.

10.14 CONFIGURING ROUTER DISCOVERY

The router discovery server on the RS periodically sends out router advertisements to announce the existence of the RS to other hosts. The router advertisements are multicast or broadcast to each interface on the RS on which it is enabled and contain a list of the addresses on the interface and the preference of each address for use as a default route for the interface. A host can also send a router solicitation, to which the router discovery server on the RS will respond with a unicast router advertisement.

On systems that support IP multicasting, router advertisements are sent to the 'all-hosts' multicast address 224.0.0.1 by default. You can specify that broadcast be used, even if IP multicasting is available. When router advertisements are sent to the all-hosts multicast address or an interface is configured for the limited broadcast address 255.255.255.255, the router advertisement includes all IP addresses configured on the physical interface. When router advertisements are sent to a net or subnet broadcast, then only the address associated with the net or subnet is included.

To start router discovery on the RS, enter the following command in Configure mode:

```
rs(config)# rdisc start
```

The **rdisc start** command lets you start router discovery on the RS. When router discovery is started, the RS multicasts or broadcasts periodic router advertisements on each configured interface. The router advertisements contain a list of addresses on a given interface and the preference of each address for use as the default route on the interface. By default, router discovery is disabled.

The **rdisc add address** command lets you define addresses to be included in router advertisements. If you configure this command, only the specified hostname(s) or IP address(es) are included in the router advertisements. For example:

```
rs(config)# rdisc add address 10.10.5.254
```

By default, all addresses on the interface are included in router advertisements sent by the RS. The **rdisc add interface** command lets you enable router advertisement on an interface. For example:

```
rs(config)# rdisc add interface rs4
```

If you want to have only specific addresses included in router advertisements, use the **rdisc add address** command to specify those addresses.

The **rdisc set address** command lets you specify the type of router advertisement in which the address is included and the preference of the address for use as a default route. For example, to specify that an address be included only in broadcast router advertisements and that the address is ineligible to be a default route:

```
rs#(config) rdisc set address 10.20.36.0 type broadcast preference
ineligible
```

The **rdisc set interface** command lets you specify the intervals between the sending of router advertisements and the lifetime of addresses sent in a router advertisement. To specify the maximum time between the sending of router advertisements on an interface:

```
rs#(config) rdisc set interface rs4 max-adv-interval 1200
```

To display router discovery information:

```
rs# rdisc show all


Task State: <Foreground NoResolv NoDetach> ❶

    Send buffer size 2048 at 812C68F8
    Recv buffer size 2048 at 812C60D0

Timers:

    RouterDiscoveryServer Priority 30

        RouterDiscoveryServer_RS2_RS3_IP <OneShot>
            last: 10:17:21 next: 10:25:05  ❷

Task RouterDiscoveryServer:
    Interfaces:
        Interface RS2_RS3_IP: ❸
            Group 224.0.0.1: ❹
                minadvint 7:30 maxadvint 10:00 lifetime 30:00 ❺

                Address 10.10.5.254: Preference: 0 ❻

    Interface policy:
        Interface RS2_RS3_IP* MaxAdvInt 10:00 ❼
```

Legend:

1. Information about the RDISC task.
2. Shows when the last router advertisement was sent and when the next advertisement will be sent.
3. The interface on which router advertisement is enabled.
4. Multicast address.
5. Current values for the intervals between the sending of router advertisements and the lifetime of addresses sent in a router advertisement.
6. IP address that is included in router advertisement. The preference of this address as a default route is 0, the default value.
7. Shows configured values for the specified interface.

10.15 SETTING MEMORY THRESHOLDS

The routing information base (RIB) is stored in memory in the RS. There are four configurable thresholds that represent the percentages of the available memory that is used for storing RIB entries.

The default memory thresholds are shown in Table 10-5. You can use the **`ip-router global set memory-threshold`** command to change the thresholds.

Table 10-5 Default Memory Thresholds

Threshold Level	Percentage of Memory
level-1	**70**
level-2	**73**
level-3	**76**
level-4	**80**

When a level-1, level-2, or level-3 threshold is reached, the RS may delete routes in the RIB or not add new routes to the RIB, depending upon the routing protocol. When threshold level-4 is reached (by default, 80% of available memory used by the RIB), no new routes are added.

Table 10-6 shows what actions the RS takes in updating the RIB when each threshold is reached.

Table 10-6 RIB Updates When Memory Threshold is Reached

Route Protocol	Threshold	Action
OSPF/ IS-IS	level-1 level-2 level-3 level-4	Updates are processed as usual.
RIP	level-1	• A new RIP route is added only if it is the *only* RIP route to the given destination. • Maximum of 2 routes allowed to a given destination. If there are more than 2 routes to a given destination, the least preferred route(s) are deleted.
	level-2	• A new RIP route is added only if is an active RIP route to the given destination.
	level-3	• Only one route is allowed to a given destination. If there is more than one route to a given destination, the least preferred route is deleted.
	level-4	No new routes are added.

Table 10-6 RIB Updates When Memory Threshold is Reached

Route Protocol	Threshold	Action
BGP	level-1 level-2	• A new BGP route is added only if it is the *only* BGP route to the given destination. • Maximum of 3 routes allowed to a given destination. If there are more than 3 routes to a given destination, a new route replaces an existing route.
	level-3	• Maximum of 2 routes allowed to a given destination. If there are more than 2 routes to a given destination, a new route replaces an existing route.
	level-4	No new routes are added.

The **`ip-router show summary drops`** command shows information about routes that were deleted or not added due to low memory, as well as the current threshold settings.

10.16 CONFIGURATION EXAMPLES

10.16.1 Assigning IP Interfaces

To enable routing on the RS, you must assign an IP interface to a VLAN. To assign an IP interface named ‘RED’ to the ‘BLUE’ VLAN, enter the following command:

```
rs(config)# interface create ip RED address-netmask
10.50.0.1/255.255.0.0 vlan BLUE
```

You can also assign an IP interface directly to a physical port.

11 VRRP CONFIGURATION GUIDE

This chapter explains how to set up and monitor the Virtual Router Redundancy Protocol (VRRP) on the RS. VRRP is defined in RFC 2338.

End host systems on a LAN are often configured to send packets to a statically configured default router. If this default router becomes unavailable, all the hosts that use it as their first hop router become isolated on the network. VRRP provides a way to ensure the availability of an end host's default router.

This is done by assigning IP addresses that end hosts use as their default route to a "virtual router." A Master router is assigned to forward traffic designated for the virtual router. If the Master router should become unavailable, a backup router takes over and begins forwarding traffic for the virtual router. As long as one of the routers in a VRRP configuration is up, the IP addresses assigned to the virtual router are always available, and the end hosts can send packets to these IP addresses without interruption.

11.1 CONFIGURING VRRP

This section presents three sample VRRP configurations:

- A basic VRRP configuration with one virtual router
- A symmetrical VRRP configuration with two virtual routers
- A multi-backup VRRP configuration with three virtual routers

11.1.1 Basic VRRP Configuration

Figure 11-1 shows a basic VRRP configuration with a single virtual router. Routers R1 and R2 are both configured with one virtual router (`VRID=1`). Router R1 serves as the Master and Router R2 serves as the Backup. The four end hosts are configured to use 10.0.0.1/16 as the default route. IP address 10.0.0.1/16 is associated with virtual router `VRID=1`.

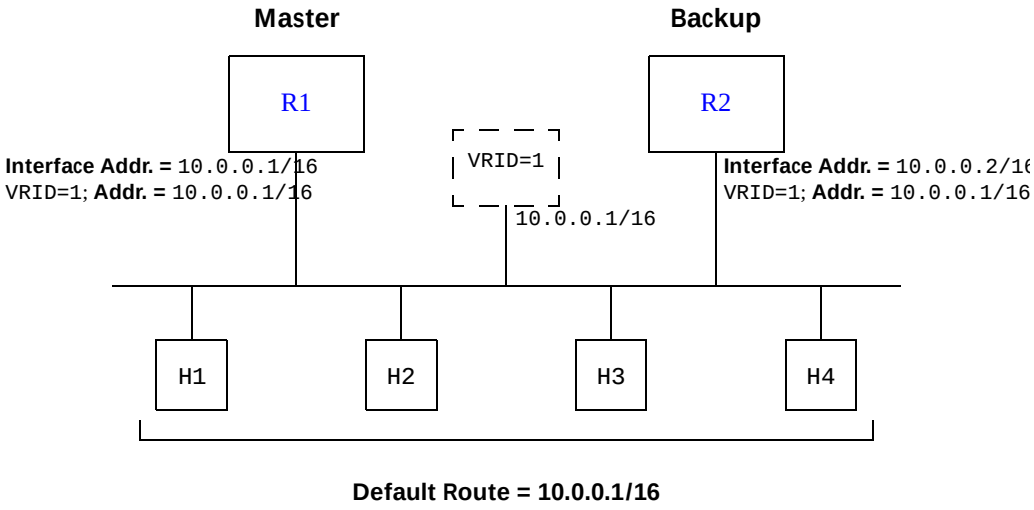


Figure 11-1 Basic VRRP configuration

If Router R1 should become unavailable, Router R2 would take over virtual router `VRID=1` and its associated IP addresses. Packets sent to 10.0.0.1/16 would go to Router R2. When Router R1 comes up again, it would take over as Master, and Router R2 would revert to Backup.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 11-1.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
4: ip-redundancy start vrrp 1 interface test
```

Line 1 adds IP address 10.0.0.1/16 to interface test, making Router R1 the owner of this IP address. Line 2 creates virtual router `VRID=1` on interface test. Line 3 associates IP address 10.0.0.1/16 with virtual router `VRID=1`. Line 4 starts VRRP on interface test.

In VRRP, the router that owns the IP address associated with the virtual router is the Master. Any other routers that participate in this virtual router are Backups. In this configuration, Router R1 is the Master for virtual router `VRID=1` because it owns 10.0.0.1/16, the IP address associated with virtual router `VRID=1`.

Configuration for Router R2

The following is the configuration file for Router R2 in Figure 11-1.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
4: ip-redundancy start vrrp 1 interface test
```

The configuration for Router R2 is nearly identical to Router R1. The difference is that Router R2 does not own IP address 10.0.0.1/16. Since Router R2 does not own this IP address, it is the Backup. It will take over from the Master if it should become unavailable.

11.1.2 Symmetrical Configuration

Figure 11-2 shows a VRRP configuration with two routers and two virtual routers. Routers R1 and R2 are both configured with two virtual routers (`VRID=1` and `VRID=2`).

Router R1 serves as:

- Master for `VRID=1`
- Backup for `VRID=2`

Router R2 serves as:

- Master for `VRID=2`
- Backup for `VRID=1`

This configuration allows you to load-balance traffic coming from the hosts on the 10.0.0.0/16 subnet and provides a redundant path to either virtual router.

Note This is the recommended configuration on a network using VRRP.

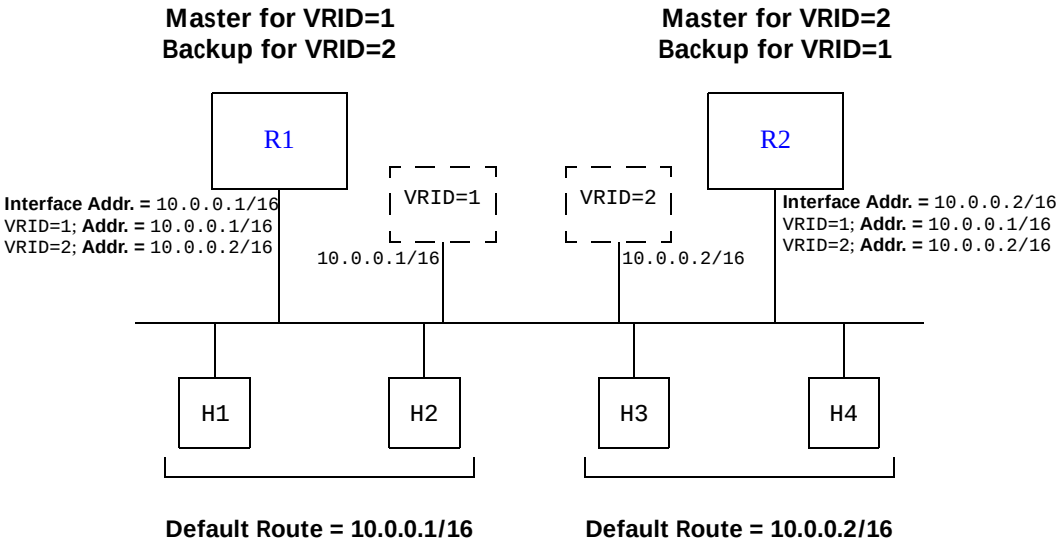


Figure 11-2 Symmetrical VRRP configuration

In this configuration, half the hosts use 10.0.0.1/16 as their default route, and half use 10.0.0.2/16. IP address 10.0.0.1/16 is associated with virtual router `VRID=1`, and IP address 10.0.0.2/16 is associated with virtual router `VRID=2`.

If Router R1, the Master for virtual router `VRID=1`, goes down, Router R2 would take over the IP address 10.0.0.1/16. Similarly, if Router R2, the Master for virtual router `VRID=2`, goes down, Router R1 would take over the IP address 10.0.0.2/16.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 11-2.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
     !
4: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
5: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
     !
6: ip-redundancy start vrrp 1 interface test
7: ip-redundancy start vrrp 2 interface test
```

Router R1 is the owner of IP address 10.0.0.1/16. Line 4 associates this IP address with virtual router `VRID=1`, so Router R1 is the Master for virtual router `VRID=1`.

On line 5, Router R1 associates IP address 10.0.0.2/16 with virtual router `VRID=2`. However, since Router R1 does not own IP address 10.0.0.2/16, it is not the default Master for virtual router `VRID=2`.

Configuration of Router R2

The following is the configuration file for Router R2 in Figure 11-2.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
     !
4: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
5: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
     !
6: ip-redundancy start vrrp 1 interface test
7: ip-redundancy start vrrp 2 interface test
```

On line 1, Router R2 is made owner of IP address 10.0.0.2/16. Line 5 associates this IP address with virtual router `VRID=2`, so Router R2 is the Master for virtual router `VRID=2`. Line 4 associates IP address 10.0.0.1/16 with virtual router `VRID=1`, making Router R2 the Backup for virtual router `VRID=1`.

11.1.3 Multi-Backup Configuration

Figure 11-3 shows a VRRP configuration with three routers and three virtual routers. Each router serves as a Master for one virtual router and as a Backup for each of the others. When a Master router goes down, one of the Backups takes over the IP addresses of its virtual router.

In a VRRP configuration where more than one router is backing up a Master, you can specify which Backup router takes over when the Master goes down by setting the priority for the Backup routers.

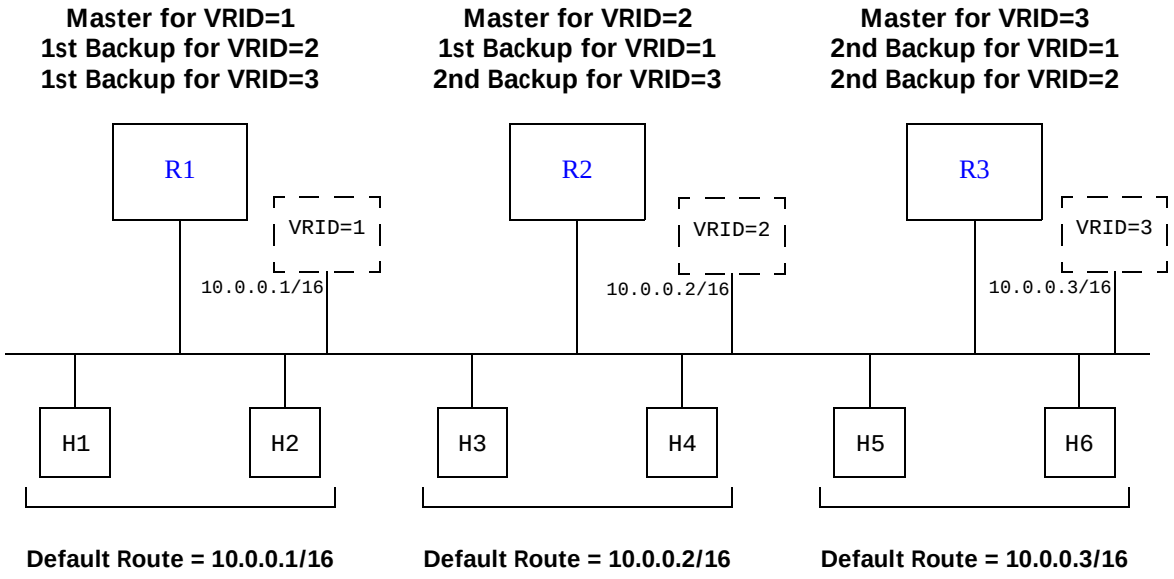


Figure 11-3 Multi-Backup VRRP configuration

In this configuration, Router R1 is the Master for virtual router VRID=1 and the primary Backup for virtual routers VRID=2 and VRID=3. If Router R2 or R3 were to go down, Router R1 would assume the IP addresses associated with virtual routers VRID=2 and VRID=3.

Router R2 is the Master for virtual router VRID=2, the primary backup for virtual router VRID=1, and the secondary Backup for virtual router VRID=3. If Router R1 should fail, Router R2 would become the Master for virtual router VRID=1. If both Routers R1 and R3 should fail, Router R2 would become the Master for all three virtual routers. Packets sent to IP addresses 10.0.0.1/16, 10.0.0.2/16, and 10.0.0.3/16 would all go to Router R2.

Router R3 is the secondary Backup for virtual routers VRID=1 and VRID=2. It would become a Master router only if both Routers R1 and R2 should fail. In such a case, Router R3 would become the Master for all three virtual routers.

Configuration of Router R1

The following is the configuration file for Router R1 in Figure 11-3.

```
1: interface create ip test address-netmask 10.0.0.1/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 2 interface test priority 200
9: ip-redundancy set vrrp 3 interface test priority 200
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Router R1's IP address on interface test is 10.0.0.1. There are three virtual routers on this interface:

- VRID=1 – IP address=10.0.0.1/16
- VRID=2 – IP address=10.0.0.2/16
- VRID=3 – IP address=10.0.0.3/16

Since the IP address of virtual router VRID=1 is the same as the interface's IP address (10.0.0.1), then the router automatically becomes the address owner of virtual router VRID=1.

A priority is associated with each of the virtual routers. The priority determines whether the router will become the Master or the Backup for a particular virtual router. Priorities can have values between 1 and 255. When a Master router goes down, the router with the next-highest priority takes over the virtual router. If more than one router has the next-highest priority, the router that has the highest-numbered interface IP address becomes the Master.

If a router is the address owner for a virtual router, then its priority for that virtual router is 255 and cannot be changed. If a router is ***not*** the address-owner for a virtual-router, then its priority for that virtual router is 100 by default, and can be changed by the user.

Since Router R1 is the owner of the IP address associated with virtual router VRID=1, it has a priority of 255 (the highest) for virtual router VRID=1. Lines 8 and 9 set Router R1's priority for virtual routers VRID=2 and VRID=3 at 200. If no other routers in the VRRP configuration have a higher priority, Router R1 will take over as Master for virtual routers VRID=2 and VRID=3, should Router R2 or R3 go down.

The following table shows the priorities for each virtual router configured on Router R1.

Virtual Router	Default Priority	Configured Priority
VRID=1 – IP address=10.0.0.1/16	255 (address owner)	255 (address owner)
VRID=2 – IP address=10.0.0.2/16	100	200 (see line 8)
VRID=3 – IP address=10.0.0.3/16	100	200 (see line 9)

Configuration of Router R2

The following is the configuration file for Router R2 in Figure 11-3.

```
1: interface create ip test address-netmask 10.0.0.2/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 1 interface test priority 200
9: ip-redundancy set vrrp 3 interface test priority 100
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Line 8 sets the backup priority for virtual router VRID=1 to 200. Since this number is higher than Router R3's backup priority for virtual router VRID=1, Router R2 is the primary Backup, and Router R3 is the secondary Backup for virtual router VRID=1.

On line 9, the backup priority for virtual router VRID=3 is set to 100. Since Router R1's backup priority for this virtual router is 200, Router R1 is the primary Backup, and Router R2 is the secondary Backup for virtual router VRID=3.

The following table shows the priorities for each virtual router configured on Router R2.

Virtual Router	Default Priority	Configured Priority
VRID=1 – IP address=10.0.0.1/16	100	200 (see line 8)
VRID=2 – IP address=10.0.0.2/16	255 (address owner)	255 (address owner)
VRID=3 – IP address=10.0.0.3/16	100	100 (see line 9)

Note Since 100 is the default priority, line 9, which sets the priority to 100, is actually unnecessary. It is included for illustration purposes only.

Configuration of Router R3

The following is the configuration file for Router R3 in Figure 11-3.

```
1: interface create ip test address-netmask 10.0.0.3/16 port et.1.1
     !
2: ip-redundancy create vrrp 1 interface test
3: ip-redundancy create vrrp 2 interface test
4: ip-redundancy create vrrp 3 interface test
     !
5: ip-redundancy associate vrrp 1 interface test address 10.0.0.1/16
6: ip-redundancy associate vrrp 2 interface test address 10.0.0.2/16
7: ip-redundancy associate vrrp 3 interface test address 10.0.0.3/16
     !
8: ip-redundancy set vrrp 1 interface test priority 100
9: ip-redundancy set vrrp 2 interface test priority 100
     !
10: ip-redundancy start vrrp 1 interface test
11: ip-redundancy start vrrp 2 interface test
12: ip-redundancy start vrrp 3 interface test
```

Lines 8 and 9 set the backup priority for Router R3 at 100 for virtual routers `VRID=1` and `VRID=2`. Since Router R1 has a priority of 200 for backing up virtual router `VRID=2`, and Router R2 has a priority of 200 for backing up virtual router `VRID=1`, Router R3 is the secondary Backup for both virtual routers `VRID=1` and `VRID=2`.

The following table shows the priorities for each virtual router configured on Router R3.

Virtual Router	Default Priority	Configured Priority
`VRID=1` – IP address=10.0.0.1/16	100	100 (see line 8)
`VRID=2` – IP address=10.0.0.2/16	100	100 (see line 9)
`VRID=3` – IP address=10.0.0.3/16	255 (address owner)	255 (address owner)

Note Since 100 is the default priority, lines 8 and 9, which set the priority to 100, are actually unnecessary. They are included for illustration purposes only.

11.2 ADDITIONAL CONFIGURATION

This section covers settings you can modify in a VRRP configuration, including backup priority, advertisement interval, pre-empt mode, and authentication key.

11.2.1 Setting the Backup Priority

As described in Section 11.1.3, *"Multi-Backup Configuration"*, you can specify which Backup router takes over when the Master router goes down by setting the priority for the Backup routers. To set the priority for a Backup router, enter the following command in Configure mode:

To specify 200 as the priority used by virtual router 1 on interface int1:

```
rs(config)# ip-redundancy set vrrp 1 interface int1 priority 200
```

The priority can be between 1 (lowest) and 254. The default is 100. The priority for the IP address owner is 255 and cannot be changed.

11.2.2 Setting the Warmup Period

When the Master router goes down, the Backup router takes over. When an interface comes up, the Master router may become available and take over from the Backup router. Before the Master router takes over, it may have to update its routing tables. You can specify a warmup period, in seconds, during which the Master router can update its routing information before it preempts the existing Master router.

To specify a warmup period for a Master router before it takes over:

```
rs(config)# ip-redundancy set vrrp 1 warmup-period 20
```

The warmup period can be between 1 and 180 seconds. The default is 30 seconds.

11.2.3 Setting the Advertisement Interval

The VRRP Master router sends periodic advertisement messages to let the other routers know that the Master is up and running. By default, advertisement messages are sent once each second. To change the VRRP advertisement interval, enter the following command in Configure mode:

To set the advertisement interval to 3 seconds*:*

```
rs(config)# ip-redundancy set vrrp 1 interface int1 adv-interval 3
```

11.2.4 Setting Pre-empt Mode

When a Master router goes down, the Backup with the highest priority takes over the IP addresses associated with the Master. By default, when the original Master comes back up again, it takes over from the Backup router that assumed its role as Master. When a VRRP router does this, it is said to be in *pre-empt mode*. Pre-empt mode is enabled by default on the RS. You can prevent a VRRP router from taking over from a lower-priority Master by disabling pre-empt mode. To do this, enter the following command in Configure mode:

To prevent a Backup router from taking over as Master from a Master router that has a lower priority*:*

```
rs(config)# ip-redundancy set vrrp 1 interface int1 preempt-mode
disabled
```

Note If the IP address owner is available, then it will always take over as the Master, regardless of whether pre-empt mode is on or off.

11.2.5 Setting an Authentication Key

By default, no authentication of VRRP packets is performed on the RS. You can specify a clear-text password to be used to authenticate VRRP exchanges. To enable authentication, enter the following command in Configure mode

To authenticate VRRP exchanges on virtual router 1 on interface int1 with a password of ‘yago’*:*

```
rs(config)# ip-redundancy set vrrp 1 interface int1 auth-type text
auth-key yago
```

Note The RS does not currently support the IP Authentication Header method of authentication.

11.3 MONITORING VRRP

The RS provides two commands for monitoring a VRRP configuration: **`ip-redundancy trace`**, which displays messages when VRRP events occur, and **`ip-redundancy show`**, which reports statistics about virtual routers.

11.3.1 ip-redundancy trace

The **ip-redundancy trace** command is used for troubleshooting purposes. This command causes messages to be displayed when certain VRRP events occur on the RS. To trace VRRP events, enter the following commands in Enable mode:

Display a message when any VRRP event occurs. (Disabled by default.)	**ip-redundancy trace vrrp events enabled**
Display a message when a VRRP router changes from one state to another; for example Backup to Master. (Enabled by default.)	**ip-redundancy trace vrrp state-transitions enabled**
Display a message when a VRRP packet error is detected. (Enabled by default.)	**ip-redundancy trace vrrp packet-errors enabled**
Enable all VRRP tracing.	**ip-redundancy trace vrrp all enabled**

11.3.2 ip-redundancy show

The **ip-redundancy show** command reports information about a VRRP configuration.

To display information about all virtual routers on interface int1:

```
rs# ip-redundancy show vrrp interface int1

VRRP Virtual Router 100 - Interface int1
----------------------------------------
Uptime                 0 days, 0 hours, 0 minutes, 17 seconds.
State                  Backup
Priority               100 (default value)
Virtual MAC address    00005E:000164
Advertise Interval     1 sec(s) (default value)
Preempt Mode           Enabled (default value)
Authentication         None (default value)
Primary Address        10.8.0.2
Associated Addresses   10.8.0.1
                       100.0.0.1

VRRP Virtual Router 200 - Interface int1
----------------------------------------
Uptime                 0 days, 0 hours, 0 minutes, 17 seconds.
State                  Master
Priority               255 (default value)
Virtual MAC address    00005E:0001C8
Advertise Interval     1 sec(s) (default value)
Preempt Mode           Enabled (default value)
Authentication         None (default value)
Primary Address        10.8.0.2
Associated Addresses   10.8.0.2
```

To display VRRP statistics for virtual router 100 on interface int1*:*

```
rs# ip-redundancy show vrrp 1 interface int1 verbose

VRRP Virtual Router 100 - Interface int1
----------------------------------------
Uptime                  0 days, 0 hours, 0 minutes, 17 seconds.
State                   Backup
Priority                100 (default value)
Virtual MAC address     00005E:000164
Advertise Interval      1 sec(s) (default value)
Preempt Mode            Enabled (default value)
Authentication          None (default value)
Primary Address         10.8.0.2
Associated Addresses    10.8.0.1
                        100.0.0.1

Stats:
  Number of transitions to master state           2
  VRRP advertisements rcvd                        0
  VRRP packets sent with 0 priority               1
  VRRP packets rcvd with 0 priority               0
  VRRP packets rcvd with IP-address list mismatch 0
  VRRP packets rcvd with auth-type mismatch       0
  VRRP packets rcvd with checksum error           0
  VRRP packets rcvd with invalid version          0
  VRRP packets rcvd with invalid VR-Id            0
  VRRP packets rcvd with invalid adv-interval     0
  VRRP packets rcvd with invalid TTL              0
  VRRP packets rcvd with invalid 'type' field     0
  VRRP packets rcvd with invalid auth-type        0
  VRRP packets rcvd with invalid auth-key         0
```

To display VRRP information, enter the following commands in Enable mode.

Display information about all virtual routers.	**ip-redundancy show vrrp**

11.4 VRRP CONFIGURATION NOTES

- The Master router sends keep-alive advertisements. The frequency of these keep-alive advertisements is determined by setting the Advertisement interval parameter. The default value is 1 second.
- If a Backup router doesn't receive a keep-alive advertisement from the current Master within a certain period of time, it will transition to the Master state and start sending advertisements itself. The amount of time that a Backup router will wait before it becomes the new Master is based on the following equation:

  Master-down-interval = (3 * advertisement-interval) + skew-time

  The skew-time depends on the Backup router's configured priority:

Skew-time = ((256 - Priority) / 256)

Therefore, the higher the priority, the faster a Backup router will detect that the Master is down. For example:

- Default advertisement-interval = 1 second
- Default Backup router priority = 100
- Master-down-interval = time it takes a Backup to detect the Master is down

  = (3 * adv-interval) + skew-time

  = (3 * 1 second) + ((256 - 100) / 256)

  = 3.6 seconds

- If a Master router is manually rebooted, or if its interface is manually brought down, it will send a special keep-alive advertisement that lets the Backup routers know that a new Master is needed immediately.
- A virtual router will respond to ARP requests with a virtual MAC address. This virtual MAC depends on the virtual router ID:

  virtual MAC address = 00005E:0001*XX*

  where *XX* is the virtual router ID

  This virtual MAC address is also used as the source MAC address of the keep-alive Advertisements transmitted by the Master router.
- If multiple virtual routers are created on a single interface, the virtual routers must have unique identifiers. If virtual routers are created on different interfaces, you can reuse virtual router IDs.

  For example, the following configuration is valid:

```
ip-redundancy create vrrp 1 interface test-A
ip-redundancy create vrrp 1 interface test-B
```

- As specified in RFC 2338, a Backup router that has transitioned to Master will not accept telnet sessions or field SNMP requests directed at the virtual router's IP address.

  Not responding allows network management to notice that the original Master router (i.e., the IP address owner) is down

Note A Backup router that has transitioned to Master will not respond to pings unless the **`ip-redundancy set vrrp`** <*vrrp number*> **`interface`** <*interface name*> **`respond-to-ping enabled`** command is entered into the RS's configuration.

12 RIP CONFIGURATION GUIDE

This chapter describes how to configure the Routing Information Protocol (RIP) on the Riverstone RS Switch Router. RIP is a distance-vector routing protocol for use in small networks. A router running RIP broadcasts updates at set intervals. Each update contains paired values where each pair consists of an IP network address and an integer distance to that network. RIP uses a hop count metric to measure the distance to a destination. RIP selects the route with the lowest metric as the best route. The metric is a hop count representing the number of gateways through which data must pass in order to reach its destination. The longest path that RIP accepts is 15 hops. If the metric is greater than 15, a destination is considered unreachable and the RS discards the route. RIP assumes that the best route is the one that uses the fewest gateways, that is, the shortest path.

The Riverstone RS Switch Router provides support for RIP Version 1 (described in RFC 1058) and Version 2 (described in RFC 1723). The RS implements plain text and MD5 authentication methods for RIP Version 2.

The protocol independent features that apply to RIP are described in Chapter 10, *"IP Routing Configuration Guide."*

12.1 CONFIGURING RIP

By default, RIP is disabled on the RS and on each of the attached interfaces. To configure RIP on the RS, follow these steps:

1. Start the RIP process by entering the **`rip start`** command.
2. Use the **`rip add interface`** command to inform RIP about the attached interfaces.

12.1.1 Enabling and Disabling RIP

To enable or disable RIP, enter one of the following commands in Configure mode.

Enable RIP.	**`rip start`**
Disable RIP.	**`rip stop`**

12.1.2 Configuring RIP Interfaces

To configure RIP in the RS, you must first add interfaces to inform RIP about attached interfaces.

To add RIP interfaces, enter the following commands in Configure mode.

Add interfaces to the RIP process.	**rip add interface** <*interfacename-or-IPaddr*>
Add gateways from which the RS will accept RIP updates.	**rip add trusted-gateway** <*interfacename-or-IPaddr*>
Define the list of routers to which RIP sends packets directly, not through multicast or broadcast.	**rip add source-gateway** <*interfacename-or-IPaddr*>

12.2 CONFIGURING RIP PARAMETERS

No further configuration is required, and the system default parameters will be used by RIP to exchange routing information. These default parameters may be modified to suit your needs by using the **rip set interface** command.

RIP Parameter	Default Value
Version number	RIP v1
Check-zero for RIP reserved parameters	Enabled
Whether RIP packets should be broadcast	Choose
Preference for RIP routes	100
Metric for incoming routes	1
Metric for outgoing routes	0
Authentication	None
Update interval	30 seconds

To change RIP parameters, enter the following commands in Configure mode.

Set RIP Version on an interface to RIP V1.	**rip set interface** <*interfacename-or-IPaddr*>**|all version 1**
Set RIP Version on an interface to RIP V2.	**rip set interface** <*interfacename-or-IPaddr*>**|all version 2**
Specify that RIP V2 packets should be multicast on this interface.	**rip set interface** <*interfacename-or-IPaddr*>**|all type multicast**

Specify that RIP V2 packets that are RIP V1-compatible should be broadcast on this interface.	**rip set interface** <*interfacename-or-IPaddr*>**|all type broadcast**
Change the metric on incoming RIP routes.	**rip set interface** <*interfacename-or-IPaddr*>**|all metric-in** <*num*>
Change the metric on outgoing RIP routes.	**rip set interface** <*interfacename-or-IPaddr*>**|all metric-out** <*num*>
Set the authentication method to simple text up to 8 characters.	**rip set interface** <*interfacename-or-IPaddr*>**|all authentication-method simple**
Set the authentication method to MD5.	**rip set interface** <*interfacename-or-IPaddr*>**|all authentication-method md5**
Specify the metric to be used when advertising routes that were learned from other protocols.	**rip set default-metric** <*num*>
Enable automatic summarization and redistribution of RIP routes.	**rip set auto-summary disable|enable**
Specify broadcast of RIP packets regardless of number of interfaces present.	**rip set broadcast-state always|choose|never**
Check that reserved fields in incoming RIP V1 packets are zero.	**rip set check-zero disable|enable**
Enable acceptance of RIP routes that have a metric of zero.	**rip set check-zero-metric disable|enable**
Enable poison revers, as specified by RFC 1058.	**rip set poison-reverse disable|enable**
Specify the maximum number of RIP routes maintained in the routing information base (RIB). The default is 4.	**rip set max-routes** <*number*>
Disable multipath route calculation for RIP routes.	**rip set multipsth off**

Configuring RIP Route Preference

You can set the preference of routes learned from RIP.

To configure RIP route preference, enter the following command in Configure mode.

Set the preference of routes learned from RIP.	**rip set preference** <*num*>

12.2.1 Configuring RIP Route Default-Metric

You can define the metric used when advertising routes via RIP that were learned from other protocols. The default value for this parameter is 16 (unreachable). To export routes from other protocols into RIP, you must explicitly specify a value for the default-metric parameter. The metric specified by the default-metric parameter may be overridden by a metric specified in the export command.

To configure default-metric, enter the following command in Configure mode.

Define the metric used when advertising routes via RIP that were learned from other protocols.	**rip set default-metric** <*num*>

For <*num*>, you must specify a number between 1 and 16.

12.3 MONITORING RIP

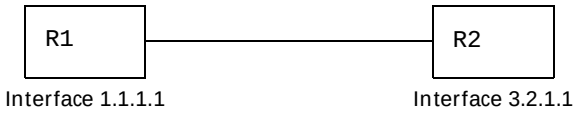
The *rip trace* command can be used to trace all rip request and response packets.

To monitor RIP information, enter the following commands in Enable mode.

Show all RIP information.	**rip show all**
Show RIP export policies.	**rip show export-policy**
Show RIP global information.	**rip show globals**
Show RIP import policies.	**rip show import-policy**
Show RIP information on the specified interface.	**rip show interface** <*Name or IP-addr*>
Show RIP interface policy information.	**rip show interface-policy**
Show detailed information of all RIP packets.	**rip trace packets detail**
Show detailed information of all packets received by the router.	**rip trace packets receive**
Show detailed information of all packets sent by the router.	**rip trace packets send**
Show detailed information of all request received by the router.	**rip trace request receive**
Show detailed information of all response received by the router.	**rip trace response receive**
Show detailed information of response packets sent by the router.	**rip trace response send**

Show detailed information of request packets sent by the router.	**rip trace send request**
Show RIP timer information.	**rip show timers**

12.4 CONFIGURATION EXAMPLE




```
! Example configuration
!
! Create interface R1-if1 with ip address 1.1.1.1/16 on port et.1.1 on
R-1
interface create ip R1-if1 address-netmask 1.1.1.1/16 port et.1.1
!
! Configure rip on R-1
rip add interface R1-if1
rip set interface R1-if1 version 2
rip start
!
!
! Set authentication method to md5
rip set interface R1-if1 authentication-method md5
!
!  Change default metric-in
rip set interface R1-if1 metric-in 2
!
! Change default metric-out
rip set interface R1-if1 metric-out 3
```

13 OSPF CONFIGURATION GUIDE

Open Shortest Path First Routing (OSPF) is a shortest path first or link-state protocol. The RS supports OSPF Version 2.0, as defined in RFC 2328. OSPF is an interior gateway protocol that distributes routing information between routers in a single autonomous system. OSPF chooses the least-cost path as the best path. OSPF is suitable for complex networks with a large number of routers because it provides equal-cost multi-path routing where packets to a single destination can be sent via more than one interface simultaneously.

In a link-state protocol, each router maintains a database that describes the entire AS topology, which it builds out of the collected link state advertisements of all routers. Each participating router distributes its local state (i.e., the router's usable interfaces and reachable neighbors) throughout the AS by flooding. Each multi-access network that has at least two attached routers has a designated router and a backup designated router. The designated router floods a link state advertisement for the multi-access network and has other special responsibilities. The designated router concept reduces the number of adjacencies required on a multi-access network.

OSPF allows networks to be grouped into areas. Routing information passed between areas is abstracted, potentially allowing a significant reduction in routing traffic. OSPF uses four different types of routes, listed in order of preference:

- Intra-area
- Inter-area
- Type 1 ASE
- Type 2 ASE

Intra-area paths have destinations within the same area. Inter-area paths have destinations in other OSPF areas. Both types of Autonomous System External (ASE) routes are routes to destinations external to OSPF (and usually external to the AS). Routes exported into OSPF ASE as type 1 ASE routes are supposed to be from interior gateway protocols (e.g., RIP) whose external metrics are directly comparable to OSPF metrics. When a routing decision is being made, OSPF will add the internal cost to the AS border router to the external metric. Type 2 ASEs are used for exterior gateway protocols whose metrics are not comparable to OSPF metrics. In this case, the external cost from the AS border router to the destination is used in the routing decision.

The RS supports the following OSPF functions:

- Definition of areas, including stub areas and NSSAs (RFC 1587).
- Opaque LSAs (RFC 2370)
- Authentication: Simple password and MD5 authentication methods are supported within an area.
- Configuration of virtual links
- Configuration of parameters at the area, interface or global level. Parameters that can be configured include retransmission interval, interface transmit delay, router priority, router dead and hello intervals, and authentication key.

- Route Redistribution: Routes learned via RIP, BGP, or any other sources can be redistributed into OSPF. OSPF routes can be redistributed into RIP or BGP. For information on Route Redistribution, refer to Chapter 19, *"Routing Policy Configuration"*.

13.1 CONFIGURING OSPF

To configure OSPF on the RS, perform the following tasks:

- Set the router ID.
- Enable OSPF
- Create the OSPF area
- Add interfaces to the area
- If necessary, configure virtual links
- Optionally, configure parameters at the global, area, and/or interface level.
- Optionally, enable OSPF graceful restart.

13.2 SETTING THE ROUTER ID

The router ID uniquely identifies the RS. To set the router ID to be used by OSPF, enter the following command in Configure mode.

Set the RS' router ID.	**ip-router global set router-id** <*hostname-or-IPaddr*>

If you do not explicitly specify the router ID, then an ID is chosen implicitly by the RS. A secondary address on the loopback interface (the primary address being 127.0.0.1) is the most preferred candidate for selection as the RS' router ID. If there are no secondary addresses on the loopback interface, then the default router ID is set to the address of the first interface that is in the up state that the RS encounters (except the interface en0, which is the Control Module's interface). The address of a non point-to-point interface is preferred over the local address of a point-to-point interface. If the router ID is implicitly chosen to be the address of a non-loopback interface, and if that interface were to go down, then the router ID is changed. When the router ID changes, an OSPF router has to flush all its LSAs from the routing domain.

If you explicitly specify a router ID, then it would not change, even if all interfaces were to go down.

13.3 ENABLING OSPF

OSPF is disabled by default on the RS.

To enable or disable OSPF, enter one of the following commands in Configure mode.

Enable OSPF.	**ospf start**
Disable OSPF.	**ospf stop**

13.4 CONFIGURING OSPF AREAS

OSPF areas are a collection of subnets that are grouped in a logical fashion. Each area maintains its own link state database. The area topology is known only within the area. A router maintains a separate link state database for each area to which it is connected.

The RS supports the configuration of multiple OSPF areas, as well as three special types of areas:

- backbone - The backbone is responsible for distributing routing information between non-backbone areas. OSPF areas communicate with other areas via the backbone area. The OSPF area backbone contains all area border routers (ABRs).
- stub - A stub area is not used as a transit area. Routers within a stub area route internal traffic only.
- not-so-stubby area (NSSA) - NSSAs are similar to stub areas, except that certain AS external routes may be imported into NSSAs in a limited fashion.

On the RS, you can create multiple OSPF areas, but at least one of them should be an area backbone. To configure an OSPF area, including a stub area or an NSSA, enter the following command in Configure mode. To configure a backbone area, use the **backbone** keyword with the following command.

Create an OSPF area.	**ospf create area** *<area-num>* **|backbone**

After you create an area, you can set its parameters as described in Section 13.8, *"Configuring OSPF Parameters."* To define a stub area, refer to Section 13.4.2, *"Configuring Stub Areas."* To define NSSAs, refer to Section 13.4.3, *"Configuring Not-So-Stubby Areas (NSSA)."*

13.4.1 Configuring Summary Ranges

To reduce the amount of routing information propagated between areas, you can configure summary-ranges on Area Border Routers (ABRs). On the RS, summary-ranges are created using the **ospf add summary-range** command – the networks specified using this command describe the scope of an area. Intra-area Link State Advertisements (LSAs) that fall within the specified ranges are not advertised into other areas as inter-area routes. Instead, the specified ranges are advertised as summary network LSAs.

Add a network to an OSPF area for summarization.	**ospf add network|summary-range** *<IPaddr-mask>* **to-area** *<area-addr>* **| backbone [restrict] [host-net]**

13.4.2 Configuring Stub Areas

Information about routes which are external to the OSPF routing domain is not sent into a stub area. Instead, if the **stub-cost** parameter is specified, the ABR generates a default external route into the stub area for destinations outside the OSPF routing domain. The **stub-cost** specifies the cost to be used to inject a default route into a stub area. If this parameter is not specified, no default route is injected into the OSPF stub area.

To define an OSPF stub area, enter the following command in Configure mode.

Specify an OSPF area to be a stub area.	**ospf set area** <*area-num*> **stub [no-summary][stub-cost** <*num*>**]**

The RS provides two ways to reduce the number of summary link advertisements (LSA Type 3) sent into a stub area. To prevent the router from sending any Type 3 LSAs into the stub area, specify the **no-summary** keyword with the **ospf set area** command. This makes the stub area a totally stub area with no Type 3 LSAs going through the stub. Alternatively, you can configure summary filters to filter out specific summary LSAs from the stub area. Use this command for Type 3 LSA you want to block. Type 3 LSAs that are not specified in this command will be sent into the stub area.

To filter specific summary LSAs from a stub area, enter the following command in Configure mode:

Configure summary filters.	**ospf add summary-filters to area** <*area-ID*>**|backbone[filter** <*number-or-string*>**][network** <*IPaddr-mask*>**]|all|default|exact|refines| between** <*number*>**|host-net**

Additionally, there may be interfaces that are directly attached to the router and therefore should be advertised as reachable from the router. To specify an interface that is directly attached, such as a loopback interface, together with its cost, enter the following command in Configure mode.

Add a stub host to an OSPF area.	**ospf add stub-host to-area** <*area-ID*>**|backbone cost** <*num*>

13.4.3 Configuring Not-So-Stubby Areas (NSSA)

NSSAs are similar to stub areas, in that they cannot be used as transit areas. But unlike stub areas, NSSAs can originate and advertise Type-7 LSAs. Type-7 LSAs carry external route information within an NSSA. They are advertised only within a single NSSA; they are not flooded into the backbone area or any other area by border routers. (Type-7 LSAs have the same syntax as Type-5 LSAs, except for the link state type.) In addition, NSSA border routers translate Type-7 LSAs into Type-5 LSAs and flood them to all Type-5 capable areas.

The RS supports the configuration of NSSAs and the ability to add networks to an NSSA. To define an area as an NSSA, enter the following command in Configure mode:

Configures an NSSA.	**ospf set area** *<area-number>* **nssa nssa-cost** *<number>*

- The **nssa-cost** parameter specifies the cost used to inject a default route into an NSSA area. If this parameter is not specified, no default route is injected into the NSSA area.

To add a network to an NSSA area, enter the following command in Configure mode:

Adds an NSSA network to an NSSA.	**ospf add nssa-network** *<IPaddr-mask>* **to area** *<area-addr>* **[restrict][host-net]**

- The **restrict** keyword is used to prevent the network from being advertised in Type 7 LSAs.

13.5 CONFIGURING OSPF INTERFACES

To configure an interface for OSPF, first configure an IP interface using the **interface create** command, then add the interface to an OSPF area. To add an IP interface to an area enter the following command in Configure mode:

Add an interface to an OSPF area.	**ospf add interface** *<name-or-IPaddr>* **to-area** *<area-addr>* **|backbone [type broadcast|non-broadcast| point-to-multipoint]**

When adding the interface to an area, you have the option of specifying the interface type. The Riverstone RS Switch Router can run OSPF over a variety of physical connections: serial connections, LAN interfaces, ATM, or Frame Relay. The OSPF configuration supports four different types of interfaces.

- LAN. An example of a LAN interface is an Ethernet. The RS will use multicast packets on LAN interfaces to reach other OSPF routers. By default, an IP interface attached to a VLAN that contains LAN ports is treated as an OSPF broadcast network. To add this type of interface to an area, use the **type broadcast** option with the **ospf add interface** command.

- Point-to-Point. A point-to-point interface can be a serial line using PPP. By default, an IP interface associated with a serial line that is using PPP is treated as an OSPF point-to-point network. For additional information on configuring this type of interface, refer to Section 13.5.3, *"Configuring Interfaces for Point-to-Point Networks."*
- Non-Broadcast Multiple Access (NBMA). An example of an NBMA network is a fully-meshed Frame Relay or ATM network with virtual circuits. To add this type of interface, use the **`type non-broadcast`** option of the **`ospf add interface`** command. For additional information on configuring this type of interface, refer to Section 13.5.1, *"Configuring Interfaces for NBMA Networks."*
- Point-to-Multipoint (PMP). Point-to-multipoint connectivity is used when the network does not provide full connectivity to all routers in the network. To add this type of interface, use the **`type point-to-multipoint`** option of the **`ospf add interface`** command. For additional information on configuring this type of interface, refer to Section 13.5.2, *"Configuring Interfaces for Point-to-Multipoint Networks."*

13.5.1 Configuring Interfaces for NBMA Networks

Because there is no general multicast for these networks, each neighboring router that is reachable over the NBMA network must be specified, so that routers can poll each other. The RS unicasts packets to other routers in the NBMA network.

To specify a neighboring router that is reachable over the NBMA network, enter the following command in Configure mode:

Specify an OSPF NBMA neighbor.	**`ospf add nbma-neighbor`** <*hostname-or-IPaddr*> **`to-interface`** <*name-or-IPaddr*> **`[eligible]`**

13.5.2 Configuring Interfaces for Point-to-Multipoint Networks

As in the case of NBMA networks, a list of neighboring routers reachable over a PMP network should be configured so that the router can discover its neighbors.

To specify a reachable neighbor on a point-to-multipoint network, enter the following command in Configure mode:

Specify an OSPF point-to-multipoint neighbor.	**`ospf add pmp-neighbor`** <*IPaddr*> **`to-interface`** <*name-or-IPaddr*>

13.5.3 Configuring Interfaces for Point-to-Point Networks

By default, OSPF packets are multicast to neighbors on an OSP point-to-point network. If an IP interface that is using PPP is to be treated as an OSPF broadcast network, then use the **`type broadcast`** option of the **`ospf add interface`** command. But if a remote neighbor does not support multicasting and you would like to unicast OSPF packets, enter the following command in Configure mode:

Force point-to-point interfaces to unicast OSPF packets.	**`ospf set interface`** <*name-or-IPaddr*> **`no-multicast`**

13.6 CONFIGURING OSPF INTERFACE PARAMETERS

The RS provides a number of parameters that are set at the interface level. To set OSPF interface parameters, enter the following command in Configure mode:

Set OSPF interface parameters.	**`ospf set interface`** <*name-or-IPaddr*> **`|all [state disable|enable][cost`** <*num*>**`][no-multicast] [retransmit-interval`** <*num*>**`][transit delay`** <*num*>**`] [priority`** <*num*>**`][hello-interval`**<*num*>**`] [router-dead-interval`**<*num*>**`][poll-interval`**<*num*>**`] [key-chain`** <*num*>**`][authentication-method none|simple|md5][advertise subnet on|off] [passive]`**

This section describes parameters that are of special significance to interfaces. For information about parameters that can be set globally, refer to Section 13.8, *"Configuring OSPF Parameters."*

13.6.1 Setting the Interface State

OSPF interfaces that are added to an area are enabled by default. You can disable them by using the **`state disable`** option with the **`ospf set interface`** command.

13.6.2 Setting the Default Cost of an OSPF Interface

The RS calculates the default cost of an OSPF interface using the reference bandwidth and the interface bandwidth. The default reference bandwidth is 1000. It can be changed by using the **`ospf set ref-bwdth`** command.

A VLAN that is attached to an interface could have several ports of differing speeds. The bandwidth of an interface is represented by the highest bandwidth port that is part of the associated VLAN. The cost of an OSPF interface is inversely proportional to this bandwidth. The cost is calculated using the following formula:

Cost = reference bandwidth * 1,000,000 / *interface bandwidth (in bps)*

The following is a table of the port types and the OSPF default cost associated with each type:

Table 13-1 OSPF default cost per port type

Port Media Type	Speed	OSPF Default Cost
Ethernet 1000	1000 Mbps	2
Ethernet 10/100	100 Mbps	20
Ethernet 10/100	10 Mbps	200
WAN (T1)	1.5 Mbps	1333
WAN (T3)	45 Mbps	44

13.7 CREATING VIRTUAL LINKS

In OSPF, virtual links can be established:

- To connect an area via a transit area to the backbone
- To create a redundant backbone connection via another area

Each ABR must be configured with the same virtual link. Note that virtual links cannot be configured through a stub area.

To configure virtual links, enter the following commands in the Configure mode.

Create a virtual link.	**ospf add virtual-link** <*number-or-string*> **neighbor** <*IPaddr*> **transit-area** <*area-id*>
Set virtual link parameters.	**ospf set virtual-link** <*number-or-string*> **[state disable|enable] [cost** <*num*>**] [retransmit-interval** <*num*>**] [transit-delay** <*num*>**] [priority** <*num*>**] [hello-interval** <*num*>**] [router-dead-interval** <*num*>**] [poll-interval** <*num*>**] [key-chain** <*num*>**] [authentication-method none|simple|md5] [no-multicast]**

Note For information on the virtual link parameters, refer to the next section, Section 13.8, *"Configuring OSPF Parameters."*

13.8 CONFIGURING OSPF PARAMETERS

The RS provides several parameters that can be set at the global (router) level, at the area level, and at the interface level. Parameters set at the interface level take precedence over those set at the area level, and parameters set at the area level take precedence over "global" parameters. The following table lists the parameters that can be set at all three levels.

Parameter	Description
advertise-subnet	Indicates whether the point-to-point interface will be advertised as a subnet.
authentication method	Specifies the authentication method used within the area.
hello-interval	Specifies the length of time between the transmission of hello packets.
poll-interval	Specifies the interval at which OSPF packets will be sent, before an adjacency is established with a neighbor.
priority	Specifies the router's priority during the Designated Router election.
retransmit-interval	The interval between LSA retransmissions.
router-dead interval	The interval the router waits after receiving no Hello packets from its neighbor before considering it as down.
transit delay	The estimated time it takes to transmit an LSA update.

13.8.1 Configuring OSPF Global Parameters

The following sections describe parameters that can be set only at the global level.

Configuring the Routing Table Recalculation

The default interval between the recalculation of the routing table is 5 seconds. You can change this interval, if necessary. Increasing the interval allows more time wherein routing changes can occur. Or, you can set it to 0, for the recalculation to occur immediately, one after the other.

To configure the interval between routing table recalculations, enter the following command in Configure mode:

Set the interval between routing table recalculations.	**ospf set spf-holdtime** <*number*>

Configuring Autonomous System External (ASE) Link Advertisements

Because of the nature of OSPF, the rate at which ASEs are flooded may need to be limited. The following parameters can be used to adjust those rate limits. These parameters specify the defaults used when importing OSPF ASE routes into the routing table and exporting routes from the routing table into OSPF ASEs.

To specify AS external link advertisements parameters, enter the following commands in Configure mode:

Specifies how often a batch of ASE link state advertisements will be generated and flooded into OSPF. The default is 1 time per second.	**ospf set export-interval** <*num*>
Specifies how many ASEs will be generated and flooded in each batch. The default is 250.	**ospf set export-limit** <*num*>
Specifies AS external link advertisement default parameters.	**ospf set ase-defaults [preference** <*num*>**]| [cost** <*num*>**]|[type** <*num*>**] | [inherit-metric] [tag** <*num*>**] [as}**

Configuring Support for Opaque LSAs

The RS supports opaque LSAs as defined in RFC 2370. This ability is turned off by default because it can enlarge the link state database unnecessarily.

To turn on support for RFC 2370 opaque LSAs, enter the following command in Configure mode:

Enables the processing of opaque LSAs on the RS.	**ospf set opaque-capability on|off**

Setting Route Preference

Preference is the value the RS routing process uses to determine the order of routes to the same destination in a single routing database. The active route is chosen by the lowest preference value.

A default preference is assigned to each source from which the RS routing process receives routes. The default preference value for OSPF routes is 10. You can change the default preference by entering the following command in Configure mode:

Set the preference value for routes learned from OSPF.	**ospf set preference** <*number*>

For additional information on how the RS uses preference values, refer to Chapter 19, *"Routing Policy Configuration"*.

Setting the Reference Bandwidth

The RS uses the reference bandwidth to calculate the cost of an OSPF interface. The default reference bandwidth is 1000. You can change this value by entering the following command in Configure mode:

Set the reference bandwidth.	**ospf set ref-bwdth** <*number*>

Setting the SPF Interval

The routing algorithm used by OSPF is the shortest path first (SPF) algorithm. OSPF executes this algorithm after events that result in changes in the topology. The RS uses certain timers to control SPF recalculations. You can use the **ospf set spf-interval** command to change the following defaults:

- the maximum interval, which is the maximum number of seconds between SPF recalculations. The default is 10 seconds.
- the initial interval, which is the number of seconds an SPF recalculation is delayed after an initial event occurs. The default is 5000 milliseconds.

  An event is considered an "initial event" if it occurs after two times the maximum interval. For example, if the maximum interval is 10 seconds, and an event occurs after 20 seconds (2 * 10 = 20 seconds), then that event is considered an "initial event" and the RS waits the initial interval before executing an SPF recalculation.
- the incremental interval, which is the number of seconds an SPF recalculation is delayed after subsequent events occur. The default is 5000 milliseconds. This is variable and increases until it reaches the maximum interval.

In the following example, the initial and incremental values are each set to 1000 milliseconds:

```
rs(config)# ospf set spf-interval initial 1000 incremental 1000
```

Based on the example, the RS executes an SPF recalculation as follows:

- after the first trigger event, the RS waits the initial interval, which is 1000 milliseconds, to execute the SPF recalculation
- after the second event, the RS waits the incremental interval, which is 1000 milliseconds, to execute the SPF recalculation
- after the third and each succeeding event, the RS waits 2 times the previous interval to execute the SPF recalculation. Therefore:
  - after the third event, the RS waits 2000 milliseconds (2 seconds)
  - after the fourth event, the RS waits 4000 milliseconds (4 seconds)
  - after the fifth event, the RS waits 8000 milliseconds (8 seconds)
  - after the sixth and any succeeding events, the RS waits 10 seconds only (the maximum interval).

Once the network calms down, if no trigger event occurs within 20 seconds (2 * maximum interval = 20 seconds), then the RS treats the next event as an initial event.

Configuring OSPF Graceful Shutdown

OSPF graceful shutdown enables a router that is shutting down to help neighboring routers route around it. It does so by instructing its neighbors to bypass its links when charting paths in the network. The neighbors begin ignoring the presence of the router that is shutting down before it actually shuts down, thus avoiding network interruptions. With this feature enabled, the RS sets the metrics on each of its links to the maximum metric and floods this information to all of its neighbors. When the neighbors recompute the shortest-path first algorithm using the new metric, they will prefer any link with a lower metric to the links on the router that is shutting down.

Note Assigning the maximum metric to a link renders the link highly undesirable, but still usable. A path may still utilize the link if no substitutable links with a lower metric are available.

Configure OSPF graceful shutdown globally using the **`ospf set max-metric-rtr`** command and on a per-routing instance basis using the **`routing-instance ospf set max-metric-rtr`** command. As long as either of these commands is in effect, the RS will continue to advertise the maximum metric to its neighbors on a global or on a per-routing instance basis. To restore normal metric advertisements, remove the relevant command from the active configuration using the **`negate`** or **`no`** command.

OSPF LSA Pacing

By default, OSPF refreshes the self-originated LSAs that it generates to its neighbors every 30 seconds. This can lead to network congestion. The OSPF LSA pacing feature prevents this type of network congestion by refreshing LSAs in groups rather than all at once. The RS implements OSPF LSA pacing by setting the LSA Age to a random value at the time it generates the LSA. This random value is chosen so that the LSAs are grouped into five groups for refresh purposes. This feature is on by default.

13.9 MULTIPATH

The RS also supports OSPF and static Multi-path. If multiple equal-cost OSPF or static routes have been defined for any destination, then the RS “discovers” and uses all of them. The RS will automatically learn up to four equal-cost OSPF or static routes and retain them in its forwarding information base (FIB). The forwarding module then installs flows for these destinations in a round-robin fashion.

13.10 OSPF GRACEFUL RESTART

OSPF graceful restart is one of a set of protocol-based graceful restart features on the ROS developed with the goal of making the RS "hitless," which means that the service performed by the RS continues to function even if it has to restart. This feature is defined in the IETF “Hitless OSPF Restart” Internet Working Draft.

Note In both the Riverstone documentation and the RS command-line interface (CLI), the terms “hitless restart” and “graceful restart” are used interchangeably.

Without graceful restart capabilities, OSPF restarts are costly for network resources. Neighbor after neighbor within the network have to be told that the restarting router’s routes are unreachable, which causes recalculation of routes and sub-optimal routes to be used, only to be told seconds later that the restarted router’s routes are back.

To prevent this temporary route flapping across the network, OSPF graceful restart relies on the Forwarding Information Base (FIB) of the restarting router being preserved across a restart, which allows the router to continue forwarding traffic during the restart.

The following section outlines the basic functionality of OSPF graceful restart.

13.10.1 Basic Functionality

The basic functionality of OSPF graceful restart is described in this section. Important restrictions, exceptions, and corner-case considerations are presented later, in section 13.10.5

In order to accomplish an OSPF graceful restart, the restarting router must have OSPF graceful restart enabled. Its neighbors (helpers) must be sufficiently configured to support OSPF graceful restart. In addition, the restarting router must be a dual control module system. Section 13.10.3 covers the configurations needed. The following assumes that these conditions are met on both the restarting router and its neighbors.

OSPF Graceful Restart Capability Advertisement

OSPF routers use a new link-local Opaque LSA, called the Grace LSA, to signal a restart to neighbors. This LSA includes the following fields, which are used to convey information during a restart. These fields are described in detail later.

OSPF Grace LSA Fields (Partial List)
Advertising Router
LS Age
Grace Period (in seconds)
Reason for Hitless Restart
IP Interface Address of Restarting Router

Table 13-2OSPF Grace LSA Fields

The Restart Process

This section describes the restart process.

Successful Failover

In dual control module systems, the FIB is mirrored between the primary and backup control modules. During normal system operation, the FIB on the backup control modules is incrementally updated to reflect ongoing changes to the FIB on the primary control module.

In OSPF graceful restart, while the primary control module restarts, the backup control module takes over and uses this learned FIB to maintain existing flows and permit new flows to be established. Copies of the Router and Network LSAs are also mirrored. However, since the whole OSPF LSA database is not mirrored between the two modules, the RS needs to resynchronize its LSA database with neighbors. To allow time to do this, it must signal its restart to neighbors.

During the Restart: The Restarter

To signal the restart, the router transmits a Grace LSA out each OSPF interface. This Grace LSA includes an LS Age of 0 and the Grace Period that the router is requesting in seconds. The Grace Period is a user-set value (in seconds) that communicates to neighbors how long they should shield the restart from the rest of the network.

During the restart, the restarting router attempts to reestablish all of its former adjacencies by exchanging LSAs with helper neighbors. In addition to synchronizing its link-state database with neighbors, the restarter also does the following:

- It does *not* originate LSAs with LS types 1-5 or 7. This forces other routers in the OSPF domain to calculate routes based on the LSAs that the restarter originated *prior* to the restart.
- It does not modify or flush received self-originated LSAs. It accepts them as valid for the time being, waiting until after the restart to deal with them.
- It runs the SPF algorithm to return virtual links to operation and makes changes in the RIB based on SPF calculations. However, it does not make any changes to the FIB based on the calculations. Instead, it routes using the forwarding entries installed before the restart.
- If the restarter was the Designated Router (DR) on a segment before the restart, it elects itself as the DR again.

In all other aspects, the restarter follows standard OSPF operating procedures. It forwards traffic, discovers neighbors using Hellos, elects DRs and Backup Designated Routers (BDRs), and synchronizes its link-state database (LSDB) with its neighbors.

Periodically, the restarter builds (without installing or flooding) its Router LSAs (Type 1) and compares them to the Router LSAs that it generated prior to the restart. On the segments where the restarter is a DR, it also builds and compares Network LSAs (Type 2) to those received. If the built and received LSAs are the same, the restarter considers all adjacencies to be reestablished and successfully exits graceful restart.

The following events can cause the restarter to *un*successfully terminate graceful restart.

- It receives inconsistent LSAs

  During the course of database updates, receiving an LSA from a neighbor that is inconsistent with pre-restart LSAs signals one of the following:

  - The neighbor does not support OSPF graceful restart
  - The neighbor never received the restarter's Grace LSA
  - For whatever reason, the neighbor terminated its helper mode

Without neighbor support, the restarter cannot shield the restart from the rest of the network. Therefore, the restarter aborts graceful restart.

- Network topology changes

  If an unrelated network topology change occurs during the restart, a network disruption becomes unavoidable. This causes helpers to abort helper mode and makes it pointless for the restarter to shield its own restart from the rest of the network.

  This situation is a subset of the "receiving inconsistent LSAs" event. The restarter is alerted about a potential network topology change when it receives an inconsistent LSA.

- Grace period expires

  Helper neighbors only support and shield the restart for the duration of the grace period that the restarter requests in its Grace LSA. If this time elapses without the restarter achieving database synchronization, it must abort graceful restart.

During the Restart: The Helpers

Upon receiving the restarter's Grace LSA, all of helpers (the restarter's neighbors that support OSPF graceful restart) check to make sure that the following required conditions are met.

- The helper neighbor must be in *a full adjacency* with the restarter.
- No changes to the link-state database in LS types 1-5 or 7 must have occurred since the beginning of the grace period specified by the Grace LSA. This ensures that the rest of the network has not changed since the restart. The helper uses the LS Age of the Grace LSA to tell how long ago the restart occurred. This is possible because the restarter zeroed the LS Age field before sending out the Grace LSA.
- The helper must be user configured to act as a helper for the restarter. See section 13.10.3 for the various levels of helper support that you can configure on a router.

As long as these conditions hold true, the neighbor enters helper mode for the restarter on the associated network segment and performs the following tasks:

- Continue to monitor the network for other topology changes. As long as there are none, shield the restart from the rest of the network by continuing to announce the restarting router and the link as valid in its LSAs. This avoids triggering disruptive SPF runs throughout the domain. Since the forwarding state is preserved in the restarter's backup control module and traffic can continue through it, shielding the restart is acceptable.
- If the restarter was the DR on a network segment, continue to maintain the restarter as the DR on that segment until helper mode ends.

Exiting Restart: The Restarter

If all goes well, the restarter achieves a synchronized database and can successfully exit graceful restart. It determines whether this condition is met by building its Router LSAs (Type 1) and any Network LSAs (Type 2) based on the information that it has exchanged with its neighbors during the restart. If the built and received LSAs are the same, the restarter considers all adjacencies to be reestablished and successfully exits graceful restart.

Whether successful or unsuccessful, before exiting graceful restart, the restarter performs several tasks:

- Reoriginates all of the Router LSAs (Type 1) for its attached areas.
- If the restarter was the DR on a segment, it reoriginates all Network LSAs (Type 2) for that segment as well.

- The restarter reruns SPF calculations and installs the results into the FIB and RIB, originating additional LSAs as needed. Recall that earlier, when the restarter ran SPF calculations to restore virtual links, it did not install or flush any results.
- The restarter cleans up the RIB and FIB, removing LSAs and routes that are no longer valid, as well as flushing the Grace LSAs that it originated to indicate the restart.

On exiting graceful restart, the router reverts back to normal OSPF operation.

Exiting Restart: The Helpers

A helper successfully exits helper mode for a restarter when that restarter flushes its Grace LSAs, indicating successful termination of graceful restart.

Other events can cause the helper to prematurely abort helper operations:

- The grace period requested by the restarter in the Grace LSA expires.
- The helper receives an LSA of LS types 1-5 or 7 whose content has changed. A change in LSA content indicates a network topology change, which forces termination of graceful restart on both the restarter and helpers.

When the helper exits helper mode, it recalculates the DR for the segment. If it is the DR, it reoriginates Network LSAs (Type 2) for that segment. It reoriginates Router LSAs (Type 1) for the segment's OSPF areas, and if the segment is a virtual link, for the virtual link's transit area as well.

Summary

Provided that the network topology remains unchanged and the restarting router is able to synchronize its database within the grace period, OSPF graceful restart permits the restarter to remain on the forwarding path and ensures that the restart does not interrupt the network.

If network topology changes are detected during OSPF graceful restart, all routers abort graceful restart and revert back to standard OSPF operation for safety.

13.10.2 Timers and Flags

The following is a summary of the timers that OSPF graceful restart uses:

Grace Period

Description	The restarter transmits this timer in its Grace LSA. This timer tells neighbors how long they should shield the restart from the rest of the network.
Instantiation	This is a global timer.
Set By	Use the **`ospf set hitless-grace-period`** command to set this timer.
Default	When not specified in the configuration, the default of 60 seconds is used.
Cancellation	The RS cancels the Grace timer once it has achieved database synchronization and can successfully exit graceful restart.
Expiration	Helper neighbors only support and shield the restart for the duration of the Grace period that the restarter requests in its Grace LSA. If this time elapses without the restarter achieving database synchronization, it must abort graceful restart and resume normal OSPF operation. When the Grace timer expires, helpers exit helper mode for the associated restarter and resume normal OSPF operation.

LS Age

Description	This field in the Grace LSA allows helpers to tell whether the requested Grace period has expired.
Instantiation	The LS Age is a field included in every Grace LSA transmitted by the restarter.
Set By	The restarter sets the LS Age to 0 before transmitting a Grace LSA.
Usage	The helper compares the requested Grace period to the LS Age to tell if the Grace period has expired. Since the LS Age is set to 0 before the restarter transmits the Grace LSA, it indicates the amount of time that has elapsed since the restart began. The Grace period expires when the LS Age becomes greater than the Grace period.

13.10.3 Configuration

By default, OSPF graceful restart and helper capabilities are both *disabled*. Both of these must be enabled for graceful restart.

Since the Grace LSA is an Opaque LSA, Opaque-capability support for RFC 2370 Opaque LSAs must also be enabled. By default, this capability is enabled. If it has been disabled, you must reenable it for graceful restart. Routers that do not support Opaque-LSAs should continue to interoperate with those that do support them.

Use the following procedures to enable these capabilities.

Configuring the Restarter

To configure OSPF graceful restart on a router, you must do three things:

1. Reenable Opaque-capability support for RFC 2370 Opaque LSAs if it has been disabled.
2. Enable the OSPF graceful restart capability. When not specified in the configuration, this capability is disabled by default.
3. Set the Grace period. The Grace period is communicated to neighbors in the Grace LSA. It tells helper neighbors how long to allot the restarter for recovery after a graceful restart. Even though a Grace LSA is sent out each OSPF interface, the Grace period is configured globally for the router. If no value is specified, the default is 30 seconds.

Configuring the Helper

To configure helper support for the OSPF graceful restart capability on a router, you must do three things:

1. Reenable Opaque-capability support for RFC 2370 Opaque LSAs if it has been disabled.
2. Enable helper capability for OSPF graceful restart using the **`ospf set ... hitless-helper`** commands. You can enable this capability globally, on a per-area, or per-interface basis. When not specified in the configuration, this capability is not applied by default. The following table summarizes the helper status of an interface based on the user-set (or default) helper status on the router, that interface, and the area of that interface. In the table,
   - 'Default' means no explicit configuration
   - 'Disabled' means that the user has disabled helper capability for this interface/area/router using the **`disable`** keyword
   - 'Enabled' means that the user has enabled helper capability for this interface/area/router using the **`enable`** keyword

Global	Area	Interface	Helps ?
Default	Default	Default	No
Default	Default	Disable	No
Default	Default	Enable	Yes
Default	Disable	Default	No
Default	Disable	Disable	No
Default	Disable	Enable	Yes
Default	Enable	Default	Yes
Default	Enable	Disable	No
Default	Enable	Enable	Yes
Disable	Default	Default	No
Disable	Default	Disable	Yes
Disable	Default	Enable	No
Disable	Disable	Default	No
Disable	Disable	Disable	No
Disable	Disable	Enable	Yes
Disable	Enable	Default	Yes
Disable	Enable	Disable	No
Disable	Enable	Enable	Yes
Enable	Default	Default	Yes
Enable	Default	Disable	Yes
Enable	Default	Enable	No
Enable	Disable	Default	No
Enable	Disable	Disable	No
Enable	Disable	Enable	Yes
Enable	Enable	Default	Yes
Enable	Enable	Disable	No
Enable	Enable	Enable	Yes

Table 13-3Helper Capability Settings

3. Specify the Grace interval to wait. The restarter communicates the Grace period to neighbors in the Grace LSA. It tells helper neighbors how long to allot the restarter for recovery after a graceful restart. You can specify the maximum and minimum Grace periods for which to lend helper support.

The RS waits for, at most, the lower of the restarter's requested time and the user-set maximum. If the restarter requests 150 seconds and the user-set maximum is 150 seconds, the RS waits for 150 seconds. If the restarter requests 151 seconds and the user-set maximum is 150 seconds, the RS only waits for 150 seconds.

If the requested time is less than the user-set minimum, the RS does not help in the restart.

If no value is specified, the default is no maximum and no minimum.

These configuration tasks are discussed in detail below.

Both: Enable Opaque-LSA Support (Optional: This capability is on by default.)

The following example enables Opaque-capability support for RFC 2370 Opaque LSAs on the RS. When not specified in the configuration, this capability is enabled by default:

```
RS(config)# ospf set opaque-capability on
```

Restarter: Enable OSPF Graceful Restart

The following example enables OSPF graceful restart capabilities on the RS. When not specified in the configuration, this capability is disabled by default:

```
RS(config)# ospf set hitless-restart enable
```

Restarter: Set Grace Period

The following example sets the OSPF graceful restart Grace period on the RS to 90 seconds. If no value is specified, the default is 60 seconds:

```
RS(config)# ospf set hitless-grace-period 90
```

Helper: Enable Helper Support

The following example globally enables *helper* support for OSPF graceful restart on the RS. When not specified in the configuration, this capability is not applied:

```
RS(config)# ospf set hitless-helper enable
```

The following example enables *helper* support for OSPF graceful restart on the *area* backbone. When not specified in the configuration, this capability is not applied:

```
RS(config)# ospf set area backbone hitless-helper enable
```

The following example enables *helper* support for OSPF graceful restart on *interface* Ethernet 2.1. When not specified in the configuration, this capability is not applied:

```
RS(config)# ospf set interface et.2.1 hitless-helper enable
```

Helper: Set Maximum Grace Period To Support

The following example specifies that irrespective of the Grace Period requested, the RS only provides helper support for a maximum of 150 seconds. When not specified in the configuration, the default is no maximum:

```
RS(config)# ospf set hitless-max-grace-period 150
```

Helper: Set Minimum Grace Period To Support

The following example specifies that helper support should only be extended to restarters who request a Grace period *equal to or greater* than 15 seconds. When not specified in the configuration, the default is no minimum:

```
RS(config)# ospf set hitless-min-grace-period 15
```

Both: Disable Opaque-LSA Support

The following example *disables* support for RFC 2370 Opaque LSAs on this router. When not specified in the configuration, Opaque-LSA support is enabled by default. Disabling this function means that this router is unable to process Grace LSAs used in OSPF graceful restart and is unable to support that capability:

```
RS(config)# ospf set opaque-capability off
```

Restarter: Disable OSPF Graceful Restart

The following example *disables* the OSPF graceful restart capability on this router. When not specified in the configuration, OSPF graceful restart is off by default:

```
RS(config)# ospf set hitless-restart disable
```

Helper: Disable Helper Support

The following example globally *disables* the ability of this router to help a remote restarting router. When not specified in the configuration, helper support is off by default. Disabling helper support means that this router does not shield any restarts from the rest of the network:

```
RS(config)# ospf set hitless-helper disable
```

The following example *disables* helper support for OSPF graceful restart on *area* backbone. When not specified in the configuration, helper support is off by default. Disabling helper support on the backbone means that this router does not shield a restart occurring in the backbone from the rest of the network:

```
RS(config)# ospf set area backbone hitless-helper disable
```

The following example *disables* helper support for OSPF graceful restart on *interface* Ethernet 2.1. When not specified in the configuration, helper support is off by default. Disabling helper support on an interface means that this router does not shield a restart occurring on that interface from the rest of the network:

```
RS(config)# ospf set interface et.2.1 hitless-helper disable
```

13.10.4 Example

Sample Configuration

In the following sample configuration,

- OSPF graceful restart is enabled.
- OSPF graceful restart helper capability is enabled.
- Opaque LSA-processing capability is enabled.
- The Grace period is set to 90 seconds.
- The maximum Grace period to assist in an OSPF graceful restart is 149. (Only Grace periods *less than* the set maximum are assisted.)
- The minimum Grace period to assist in an OSPF graceful restart is 16. (Only Grace periods *more than* the set minimum are assisted.)

```
Running system configuration:
       !
       ! Last modified from Console on 2002-03-20 03:45:39
       !
   1 : interface create ip et.7.1 address-netmask 172.20.216.180/22 port et.7.1 up
   2 : interface add ip et.7.1 address-netmask 10.110.0.180/16
   3 : interface add ip lo0 address-netmask 12.23.34.45/24
       !
   4 : ip-router global set trace-state on
   5 : ip-router global set router-id 12.23.34.45
       !
   6 : ospf create area backbone
   7 : ospf add interface et.7.1 to-area backbone
   8 : ospf set opaque-capability on
   9 : ospf set hitless-restart enable
  10 : ospf set hitless-helper enable
  11 : ospf set hitless-grace-period 90
  12 : ospf set hitless-max-grace-period 150
  13 : ospf set hitless-min-grace-period 15
  14 : ospf start
       !
...
```

Viewing the Graceful Restart Process

You can use the **ospf trace mohr-restart** and **ospf trace mohr-helper** commands to enable tracing and observe the active OSPF-specific code-path tracing messages that show the progress of OSPF graceful restart during a restart.

Caution Be careful when you turn on tracing, because the amount of messages that result can overwhelm your screen output. To turn off tracing, simply negate the command.

After turning on tracing using the **ip-router global set trace-state on** command, you can use the **ospf trace mohr-restart** command to view OSPF graceful restart in action on a restarting router.

In the trace output below, standard console logs display details about how the restart process is progressing. OSPF graceful restart and helper capabilities are enabled on both the restarter and its neighbors. The relevant OSPF graceful restart messages are in **bold**.

```
2002-03-21 11:54:59 %HBT-W-HBTTAKEOVER, Taking over mastership from peer CM
2002-03-21 11:54:59 %HBT-I-MASTERCPUFAIL, active 'Control Module (CM2)' in slot CM/1 has failed
2002-03-21 11:54:59 %SYS-I-SANITY_CHECK, Failover Sanity Check on modules: 0x0.
2002-03-21 11:54:59 %SYS-I-SANITY_CHECK, Failover Sanity Check on modules: 0x0.
```

2002-03-21 11:55:01 %SYS-I-MULTICPU, additional CPU Module(s) detected in slot CM/1
2002-03-21 11:55:03 %HBT-I-FAILOVERCOMPLETE, CPU failover completed
2002-03-21 11:55:07 %OSPF-I-MOHRENTERED, Entering OSPF hitless restart learning phase.
2002-03-21 11:55:07 %OSPF-I-MOHRSNDGRACE, Sending grace LSAs
2002-03-21 11:55:17 %SNMP-I-ENABLED, SNMP Agent enabled
2002-03-21 11:55:17 %SNMP-I-SENT_TRAP, Sending notification coldStart to management station
2002-03-21 11:55:33 %OSPF-I-MOHREXITED, Exiting OSPF hitless restart learning phase (reason: Success)
2002-03-21 11:55:33 %OSPF-I-MOHRRUNSPF, Schedule an spf run
2002-03-21 11:55:37 %OSPF-I-MOHRREPLAYSO, Replaying saved self orig. LSAs (to fix seq nums)
2002-03-21 11:55:37 %OSPF-I-MOHRTRANSSO, Transmitting all self orig. LSAs
2002-03-21 11:55:37 %OSPF-I-MOHRREPLAYSO, Replaying saved self orig. LSAs (to flush any stale info.)
2002-03-21 11:55:37 %OSPF-I-MOHRFLSHGRACE, Flushing grace LSAs
2002-03-21 11:56:00 %SYS-I-ACTIVECFGTOBACKUP, active configuration updated on Backup CM
2002-03-21 11:56:00 %OSPF-I-MOHRTIDYUP, Freeing up shadow data structures on MASTER
2002-03-21 11:56:00 %SYS-I-ACTIVECFGTOBACKUP, active configuration updated on Backup CM
2002-03-21 11:56:00 %OSPF-I-MOHRSENDSTOSLAVE, Begin sending OSPF data from MASTER to SLAVE

Using the **`ospf trace mohr-helper`** command, you can view a helper router entering and leaving helper mode. OSPF graceful restart and helper capabilities are enabled on both the restarter and the neighbor.

The relevant OSPF graceful restart messages are in **bold**.

2002-02-21 17:30:00 %OSPF-I-MOHRSTARTHELPING, Start OSPF hitless help for rtid=38.38.38.38, if=201.135.89.195, reason=CPU
2002-02-21 17:30:11 %OSPF-I-MOHRSTOPHELPING, Stop OSPF hitless help for rtid=38.38.38.38, if=201.135.89.195, reason=Success

13.10.5 Usage Notes, Rules, and Restrictions

The following items are required for OSPF graceful restart:

Enable Graceful Restart On Other Relevant Protocols

- As the Internet Engineering Task Force (IETF) points out in its working draft on BGP graceful restart, there is little benefit deploying any IGP Graceful Restart in an AS whose IGPs and EGP are tightly coupled (i.e., EGP and IGPs would both restart), and EGPs have no similar graceful restart capability. To reap the full benefits of OSPF graceful restart, make sure that you also enable graceful restart on all collaborating routing protocols.

Dual Control Module System

- Since OSPF graceful restart relies on the FIB being preserved from the primary control module to the secondary control module, the restarting router must be a dual control module system.

Note Observe the following usage notes on dual control module systems:

1. Failure on the secondary control module while the primary control module is running has no impact on the OSPF sessions running on the primary.

2. When setting the IP address that the RS uses during boot exchange with the trivial file transfer protocol (TFTP) boot server, avoid using the same address on any of the IP interfaces configured in the CLI. On a dual control module system, this can cause ARP/IP-reuse issues as the secondary takes over. (This IP address is set using the **`system set bootprom`** command.)

The following additional notes, rules, and restrictions apply to the OSPF graceful restart feature:

Single Control Module Systems

- Single control module systems can be helpers, but cannot gracefully restart themselves because they lack the capability of preserving the FIB across a restart.

No Helper Neighbor

- Some OSPF routers are not capable of supporting or have been configured not to support OSPF graceful restart. Other routers are configured not to support OSPF graceful restart within certain parameters. Neighbors that cannot support a restart do not hide the restart from the rest of the network. They begin routing around the restarter and cease to advertise the newly down adjacencies. The restarter is alerted to this when it receives an LSA that is inconsistent with its pre-start Router LSAs. Since a topology changes makes a network disruption unavoidable, the restarter (and all other active helpers) abort graceful restart and resume normal OSPF operations.

Partial Helpers

- You can configure a router to only support graceful restart on certain interfaces/areas. This may lead to a situation where a router is configured to help a restarter on some network segments but not on others. In practice, this leads to unsuccessful termination of graceful restart since the partial-helper will not continue to advertise adjacencies on segments where it is not helping.

Note Be sure to avoid this situation in configurations by extending a consistent level of support to any particular neighbor across all of the router's interfaces/areas.

Two-Way Neighbors

- Note that only fully-adjacent neighbors enter Helper mode for the restarter. Two-way neighbors ignore the Grace LSA and do not enter Helper mode. This is correct behavior for the following reasons:
  - In *legal* network topologies, two-way neighbors only occur in broadcast networks where a DR and BDR already exist. In this case, the DR acts as Helper for the restarter and assumes responsibility for alerting the network if graceful restart must be unsuccessfully aborted.
  - In the rare and *illegal* network where the only two neighbors are both ineligible for DR/BDR election, the two-way neighbor still does not alert the network to any changes except those occuring on the physical level—i.e., the interface going down. In a successful graceful restart, the transfer of control between primary and secondary modules ensures that the interface remains in the Up state while the router continues forwarding traffic and maintaining flows. Since physical connectivity remains intact, the two-way neighbor does nothing by default.

Supporting Multiple Simultaneous Restarts

- A single router is allowed to simultaneously support multiple restarting neighbors.

Manual Reboots

- Manually rebooting or clearing OSPF connections does not activate OSPF graceful restart. On a dual control module system, if the primary is rebooted via the CLI, control is not transferred to the secondary. Only spontaneous crashes or reloads will activate the OSPF graceful restart feature. (The exception to this occurs when the user manually forces a control module mastership change using the **`system redundancy change-mastership`** command.)

Routing Instances

- The RS supports OSPF graceful restart on a per-routing instance basis. The commands in this section configure OSPF graceful restart on the main instance only. Configure routing instance graceful restart exactly as you would the main instance, but identify the routing instance by prefacing each commands with the string '**`routing-instance`** <*name*>'.

13.11 ALTERNATIVE AREA BORDER ROUTER (ABR)

The RS automatically supports the alternative ABR implementation, as defined in the IETF "Alternative OSPF ABR Implementations" Internet Working Draft. This feature improves the behavior of a router connected to multiple areas without a backbone attachment. Behavior modifications allow the alternative ABR to successfully forward routes to the backbone and other areas despite not being actively attached to the backbone.

Note The RS implements the alternative ABR feature automatically. No configuration changes are necessary.

Riverstone's OSPF implementation considers a router to be an ABR if it satisfies three requirements:

- Has one or more non-backbone areas actively attached. As defined in the IETF working draft, "An area is considered *actively attached* if the router has at least one interface in that area in the state other than Down."
- Has Area 0 configured.
- Has an interface in the Up state in Area 0. This requirement is satisfied even if the adjacent interface on the Area 0 peer is in the Down state, as long as the ABR's interface in Area 0 has not been administratively shut down (ex. using the **`interface down`** or **`port disable`** command), it will continue to function as an ABR.

If an ABR that is actively attached to more than one non-backbone area ceases to satisfy the above Area 0 requirements (configured and an interface in the Up state), it begins to function as an Alternative ABR, provided that its non-backbone areas are connected to the backbone themselves.

Note For meaningful routing to occur, the areas that the Alternative ABR connects must be connected to the backbone themselves. As the IETF draft reiterates, "[This feature does] not obviate the need of virtual link configuration in case an area has no physical backbone connection at all. The methods described here improve the behavior of a router connecting two or more *backbone-attached* areas."

13.12 OSPF CONFIGURATION EXAMPLES

For all examples in this section, refer to the configuration shown in Figure 13-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
```

```
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.90.1.2
 ip add route 160.1.5.0/24 gateway 120.90.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```

13.12.1 Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We will export these static routes as type-2 OSPF routes. The interface routes will be redistributed as type-1 OSPF routes.

1. Create an OSPF export destination for type-1 routes to redistribute certain routes into OSPF as type 1 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```

2. Create an OSPF export destination for type-2 routes to redistribute certain routes into OSPF as type 2 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

3. Create a Static export source to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

4. Create a Direct export source to export interface/direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy for redistributing all interface routes and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
```

13.12.2 Exporting All RIP, Interface & Static Routes to OSPF

We will also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 13-1, RIP Version 2 is configured on the interfaces of routers R1 and R2, which are attached to the sub-network 120.190.0.0/16.

We will redistribute these RIP routes as OSPF type-2 routes and associate the tag 100 with them. Router R1 will also redistribute its static routes as type 2 OSPF routes. The interface routes will be redistributed as type 1 OSPF routes.

Router R1 will redistribute its OSPF, OSPF-ASE, RIP, Static and Interface/Direct routes into RIP.

1. Enable RIP on interface 120.190.1.1/16.

```
rip add interface 120.190.1.1
rip set interface 120.190.1.1 version 2 type multicast
```

2. Create an OSPF export destination for type-1 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type
    1 metric 1
```

3. Create an OSPF export destination for type-2 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type
    2 metric 4
```

4. Create an OSPF export destination for type-2 routes with a tag of 100.

```
ip-router policy create ospf-export-destination ospfExpDstType2t100
    type 2 tag 100 metric 4
```

5. Create a RIP export source.

```
ip-router policy create rip-export-source ripExpSrc
```

6. Create a Static export source.

```
ip-router policy create static-export-source statExpSrc
```

7. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy for redistributing all interface, RIP and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source
    directExpSrc network all
ip-router policy export destination ospfExpDstType2 source
    statExpSrc network all
ip-router policy export destination ospfExpDstType2t100 source
    ripExpSrc network all
```

9. Create a RIP export destination.

```
ip-router policy create rip-export-destination ripExpDst
```

10. Create OSPF export source.

```
ip-router policy create ospf-export-source ospfExpSrc type OSPF
```

11. Create OSPF-ASE export source.

```
ip-router policy create ospf-export-source ospfAseExpSrc type
    OSPF-ASE
```

12. Create the Export-Policy for redistributing all interface, RIP, static, OSPF and OSPF-ASE routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc
    network all
ip-router policy export destination ripExpDst source ripExpSrc
    network all
ip-router policy export destination ripExpDst source directExpSrc
    network all
ip-router policy export destination ripExpDst source ospfExpSrc
    network all
ip-router policy export destination ripExpDst source ospfAseExpSrc
    network all
```

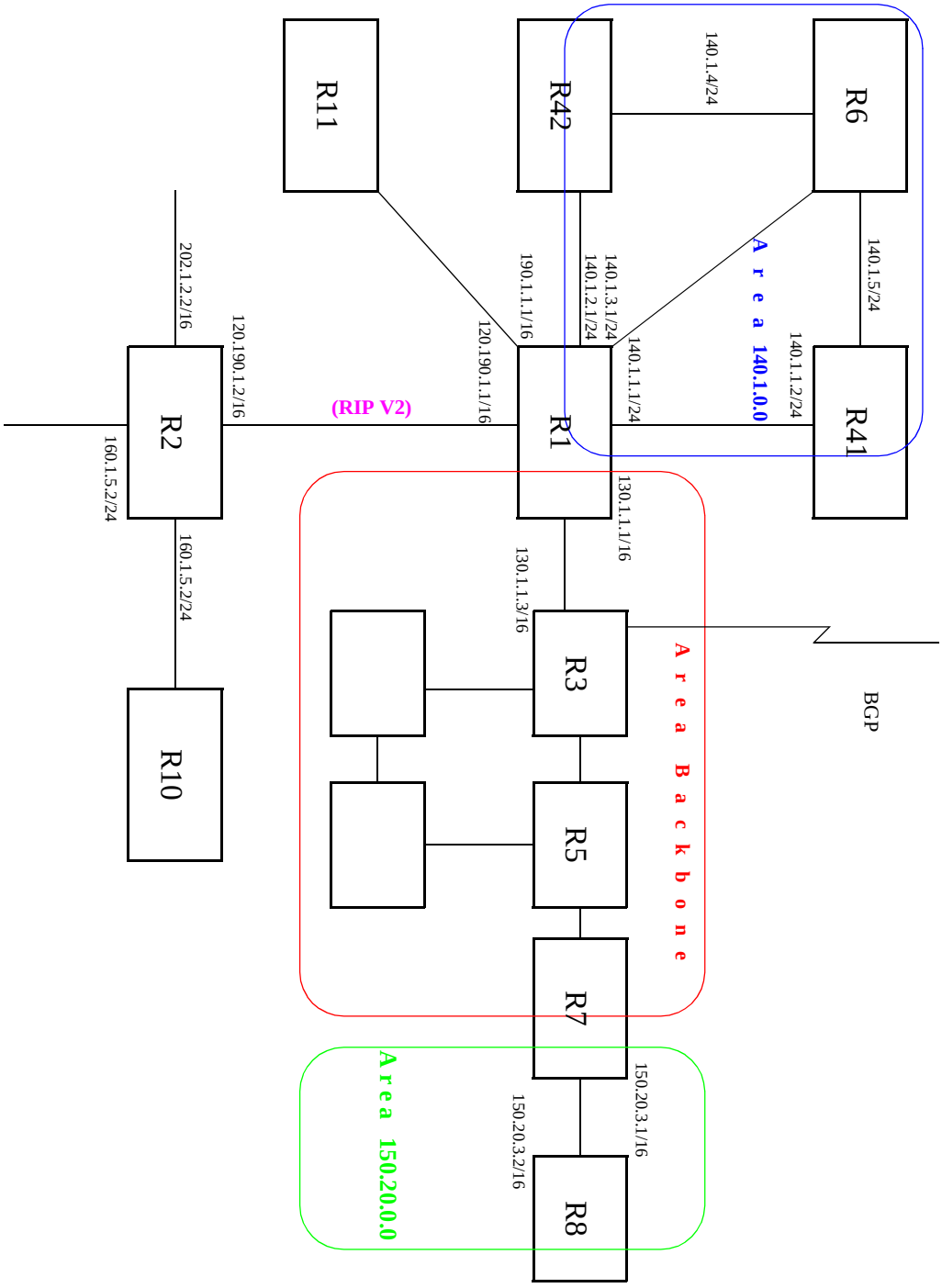


Figure 13-1 Exporting to OSPF

14 IS-IS CONFIGURATION GUIDE

This chapter provides an overview of the Intermediate System-Intermediate System (IS-IS) routing protocol features available for the Riverstone RS Switch Router.

IS-IS is a link state hierarchical routing protocol. In IS-IS, a router is an Intermediate System (IS), and a routing sub domain is an area. An IS-IS area can contain a number of routers and end devices. Routing within an area is handled by Level 1 routers, and routing between different areas is handled by Level 2 routers. An IS can route Level 1 and/or Level 2 traffic.

The IS-IS routing protocol is based on "shortest path first" calculations, similar to the OSPF routing protocol. Intermediate Systems exchange link state information by transmitting Link State Protocol Data Units (LSPs). (LSPs are exchanged between same level routers only.) Each IS maintains its own LSP database.

To configure the RS to run IS-IS, you should perform the following tasks:

- Define the area to which the router will belong.
- Configure IS-IS interfaces.
- Start IS-IS.

Optionally, you can modify the default IS-IS parameters that are set globally and on a per-interface basis.

14.1 DEFINING AN IS-IS AREA

An IS-IS area is a network sub domain that consists of routers and the end devices connected to them. All routers in an area maintain detailed routing information about destinations within the area. When you define the area of the RS, all its interfaces belong to that area. Interfaces on an RS cannot belong to separate areas.

To define the IS-IS area to which the RS will belong, enter the following command in Configure mode:

Defines an IS-IS area.	**`isis add area`** <*string*>

14.2 CONFIGURING IS-IS INTERFACES

IS-IS is disabled on all RS interfaces by default. To enable IS-IS on an interface, first configure an IP interface using the **`interface create`** command. Then, enable IS-IS on the interface. You can enable IS-IS on all IP interfaces by specifying the **`all`** keyword.

To enable IS-IS on an interface, enter the following command in Configure mode:

Creates an IS-IS interface on a router.	**isis add interface** <*string*>**|all**

14.3 ENABLING IS-IS ON THE RS

IS-IS is disabled on the RS by default. To enable IS-IS on the RS, enter the following command in Configure mode:

Enables IS-IS on the router.	**isis start**

14.4 SETTING IS-IS GLOBAL PARAMETERS

The RS provides global IS-IS parameters which control the router's operating level, timers, authentication, and other IS-IS functions. The following sections discuss the global IS-IS parameters that you can modify to better suit your routing environment.

14.4.1 Setting the IS Operating Level

An IS can be configured to route Level 1 and/or Level 2 traffic. Level 1 routing handles all intra-domain traffic, (all traffic within an IS-IS area). Level 2 routing handles all inter-domain traffic (all traffic between different IS-IS areas).

On the RS, you can set the operating level for the router and on a per-interface basis. The default level for both the router and its interfaces is Level 1- and-2. You may change the default for either or both. If you do so, keep in mind that the operating level of the interfaces must agree with the operating level of the RS. Therefore if a router's operating level is set to Level 1 or to Level 2, its interfaces should be set to the same level. But if the interfaces will be routing both Level 1 and Level 2 traffic, then you should set the router's level to Level 1-and-2.

To set the router's operating level, enter the following command in Configure mode:

Sets the IS-IS level for a router.	**isis set level 1|2|1-and-2**

14.4.2 Setting the PSN Interval

On point-to-point subnetworks, an IS sends a Partial Sequence Number PDU (PSNP) to acknowledge each LSP it receives. PSNPs contain the following information: LSP ID, the LSP's sequence number, the LSP's Checksum and the LSP's Remaining Lifetime.

To set the time interval between PSNP transmissions, enter the following command in Configure mode:

Sets the PSNP interval.	**isis set psn-interval** <*number*>

14.4.3 Setting the System ID

A system ID is a unique 12 hexadecimal number that uniquely identifies the IS in the routing domain. A system ID is assigned to the IS by default, but can be overwritten using the following command.

To set the system ID for an IS, enter the following command in Configure mode:

Sets the system ID for a router.	**isis set system-id** <*string*>

Note that once the system ID is set, it cannot be changed without disabling and reenabling IS-IS.

14.4.4 Setting the SPF Interval

The routing algorithm used by IS-IS is the shortest path first (SPF) algorithm. IS-IS executes this algorithm after events that result in changes in the topology. The RS uses certain timers to control SPF recalculations. You can use the **`isis set spf-interval`** command to change the following defaults for each level:

- the maximum interval, which is the maximum number of seconds between SPF recalculations. The default is 10 seconds.
- the initial interval, which is the number of seconds an SPF recalculation is delayed after an initial event occurs. The default is 5500 milliseconds.

  An event is considered an "initial event" if it occurs after two times the maximum interval. For example, if the maximum interval is 10 seconds, and an event occurs after 20 seconds (2 * 10 = 20 seconds), then that event is considered an "initial event" and the RS waits the initial interval before executing an SPF recalculation.
- the incremental interval, which is the number of seconds an SPF recalculation is delayed after subsequent events occur. The default is 5500 milliseconds. This is variable and increases until it reaches the maximum interval.

In the following example, the initial and incremental values are each set to 1000 milliseconds for Level 1 and Level 2:

```
rs(config)# isis set spf-interval level 1-and-2 initial 1000 incremental 1000
```

Based on the example, the RS executes an SPF recalculation as follows:

- after the first trigger event, the RS waits the initial interval, which is 1000 milliseconds, to execute the SPF recalculation
- after the second event, the RS waits the incremental interval, which is 1000 milliseconds, to execute the SPF recalculation
- after the third and each succeeding event, the RS waits 2 times the previous interval to execute the SPF recalculation. Therefore:
  - after the third event, the RS waits 2000 milliseconds (2 seconds)
  - after the fourth event, the RS waits 4000 milliseconds (4 seconds)
  - after the fifth event, the RS waits 8000 milliseconds (8 seconds)
  - after the sixth and succeeding events, the RS waits 10 seconds only (the maximum interval).

Once the network calms down, if no trigger event occurs within 20 seconds (2 * maximum interval = 20 seconds), then the RS treats the next event as an initial event.

14.4.5 Setting the LSP Generation Interval

By default, the IS periodically generates an LSP. In addition, an LSP is also generated when certain events result in topological changes, for example an adjacency or circuit up/down event or a change in circuit metrics. When such events occur, IS-IS generates updated LSPs. You can use the **`isis set lsp-gen-interval`** command to control various intervals that affect the generation of LSPs. They are as follows:

- the maximum interval, which is the maximum number of seconds between the generation of LSPs. Decreasing this interval could result in faster convergence, but may also affect CPU performance. The default is 5 seconds.
- the initial interval, which is the number of seconds the RS waits to generate updated LSPs after an initial event occurs. The default is 50 milliseconds.
- the incremental interval, which is the number of seconds the RS waits to generate updated LSPs after subsequent events occur. The default is 5000 milliseconds.

In the following example, the initial and incremental intervals are set to 1000 milliseconds for Level 1 and Level 2:

```
rs(config)# isis set lsp-gen-interval level 1-and-2 initial 1000 incremental 1000
```

Based on the preceding example, the RS generates LSPs as follows:

- after the first trigger event, the RS waits the initial interval, which is 1000 milliseconds, to generate updated LSPs
- after the second event, the RS waits the incremental interval, which is 1000 milliseconds, to generate updated LSPs
- after the third and each succeeding event, the RS waits 2 times the previous interval. Therefore:
  - after the third event, the RS waits 2000 milliseconds (2 seconds)
  - after the fourth event, the RS waits 4000 milliseconds (4 seconds)
  - after the fifth event, the RS waits 8000 milliseconds (8 seconds)
  - after the sixth and succeeding events, the RS waits up to 10 seconds only (the maximum interval).

Once the network calms down, if no trigger events occur within 20 seconds (2 * maximum interval = 20 seconds), then the RS treats the next event as an initial event.

14.4.6 Setting the Overload Bit

The IS-IS protocol provides a feature for routers to signal each other when they cannot record the complete LSP database. (This occurs when a router has run out of memory.) When a router experiences memory overload, it sets its overload bit in its LSPs. The other routers will then route packets to that router's directly connected networks, but will not use it to route transit traffic until its overload bit is cleared. In the RS, you can manually set the router's overload bit so it functions only as an end system.

To set the router's overload bit, enter the following command in Configure mode:

Sets the overload bit.	**`isis set overload-bit`**

14.4.7 Setting IS-IS Authentication

The RS supports four levels of authentication for IS-IS: authentication between neighbors, within an area, within a domain, and authentication of SNPs. The first three levels of authentication can use either MD5 or simple authentication. (For additional information about these authentication methods, refer to Chapter 19.1.5, *"Authentication."*) The following sections describe each level of authentication.

Authentication Between Neighbors

This level of authentication controls the exchange of hello packets between neighbors. All Level 1 interfaces should use the same method of authentication, and all Level 2 interfaces should use the same authentication method. If connecting interfaces have different types of authentication, they will not be able to exchange hello packets or form adjacencies.

To specify the authentication method between neighbors, enter the following command in Configure mode:

Sets the authentication method for the interface.	**isis set interface** <*string*> **authentication-method md5|simple key-chain** <*string*>

Authentication Within an Area

This level of authentication controls the exchange of Level 1 LSPs. Routers which do not have the same authentication at this level will be able to form adjacencies, but *will not* be able to exchange Level 1 LSPs. To configure authentication within an area, enter the following command in Configure mode:

Sets the authentication method for an area.	**isis set area-key-chain** <*string*> **authentication-method none|md5|simple**

Authentication Within a Routing Domain

This type of authentication controls the exchange of LSPs between areas. Routers which do not have the same authentication at this level will not be able to exchange Level 2 LSPs. To configure authentication within a routing domain, enter the following command in Configure mode:

Sets the authentication method for a routing domain.	**isis set domain-key-chain** <*string*> **authentication-method none|md5|simple**

SNP Authentication

This type of authentication controls the processing of SNPs (both CSNPs and PSNPs). When the router receives an SNP, it authenticates it by checking the password (which is the same as the password set using the **isis set interface password** command).

To configure SNP authentication, enter the following command in Configure mode:

Sets authentication for SNPs.	**isis set require-snp-auth**

14.4.8 Configuring IS-IS Graceful Shutdown

IS-IS graceful shutdown enables a router that is shutting down to help neighboring routers route around it. It does so by instructing its neighbors to bypass its links when charting paths in the network. The neighbors begin ignoring the presence of the router that is shutting down before it actually shuts down, thus avoiding network interruptions. With this feature enabled, the RS sets the metrics on each of its links to the maximum metric and floods this information to all of its neighbors. When the neighbors recompute the shortest-path first algorithm using the new metric, they will prefer any link with a lower metric to the links on the router that is shutting down.

Note Assigning the maximum metric to links is not equivalent to setting the overload bit. The overload bit signals that a router's databases may be corrupted. Assigning the maximum metric to a link renders the link highly undesirable, but still usable. A path may still utilize the link if no substitutable links with a lower metric are available.

Configure IS-IS graceful shutdown globally using the **isis set max-metric** command. As long as this command is in effect, the RS will continue to advertise the maximum metric to all of its neighbors. To restore normal metric advertisements, remove this command from the active configuration using the **negate** or **no** command.

14.5 SETTING IS-IS INTERFACE PARAMETERS

The interfaces on the RS have default IS-IS parameter values. These parameters control various IS-IS functions and features on the interfaces, such as their operating level, metrics, and timers.

To set parameters for an IS-IS interface, enter the following command in Configure mode:

Configures an IS-IS interface on a router.	**isis set interface** <*interface-name-or IPaddr*> **[level 1|2|1-and-2] [metric** <*number*>**] [priority** <*number*>**] [hello-interval** <*number*>**] [dis-hello-interval** <*number*>**] [hello-multipler** <*number*>**] [csn-interval** <*number*>**] [lsp-interval**<*number*>**] [max-burst** <*number*>**] [passive] [retransmit-interval** <*number*>**] [authentication-method none|md5|simple] [key-chain** <*string*>**] [l1-csn-interval** <*number*>**] [l1-dis-hello-interval**<*number*>**] [l1-hello-interval** <*number*>**] [l1-hello-multipler** <*number*>**] [l1-metric** <*number*>**] [l1-priority** <*number*>**] [l2-csn-interval** <*number*>**] [l2-dis-hello-interval**<*number*>**] [l2-hello-interval** <*number*>**] [l2-hello-multipler** <*number*>**] [l2-metric** <*number*>**] [l2-priority** <*number*>**][mesh-group]**<*number*>

The following sections describe some of the parameters used by the IS-IS interfaces. For a detailed description of this command and its parameters, refer to the **isis commands** chapter in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

14.5.1 Setting the Interface Operating Level

The default operating level for the router and its interfaces is Level 1-and-2. If you change the default, note that the operating level of the router's IS-IS interfaces should be synchronized with the operating level of the router. (For additional information, refer to Section 14.4.1, *"Setting the IS Operating Level,"*.)

14.5.2 Setting Interface Parameters for a Designated Intermediate System (DIS)

On a broadcast network, routers elect a DIS, which advertises all links to the attached routers. The following parameters are used during DIS election and by the interface, if it is elected as the DIS. These parameters can be set globally, or for Level-1 or Level-2 interfaces only.

- Priority
  The router's priority for the Designated Intermediate System (DIS) election. The router with the highest priority becomes the DIS. To ensure that a router does not become the DIS, set this parameter to 0. To increase a router's chance of becoming a DIS, set this parameter to the highest value, which is 127. In case of a tie, the router with the highest System ID becomes the DIS. The default priority is 64.
- DIS Hello Interval
  The hello-interval used if the router becomes the DIS. The default hello-interval is 3.
- CSN Interval
  The interval at which the router will multicast Complete Sequence Number PDUs (CSNPs), if the router becomes the DIS. CSNPs contain a list of all LSPs in the database in addition to information used by the other routers to determine whether they have synchronized LSP databases. The default csn-interval is 10.

14.5.3 Setting IS-IS Interface Timers

The IS-IS protocol uses a variety of timers, some of which can be modified at the interface level. The timers have default values which you can change when needed. These are as follows:

- Hello Interval
  The interval at which hello packets are sent.
- Hello Multiplier
  The number of hello-intervals a router does not receive a hello-packet from its neighbor before it considers its neighbor as down.
- LSP Interval
  The interval between the transmission f LSPs.
- Retransmit Interval
  The interval a router waits before it retransmits an LSP.

14.5.4 Setting Mesh Group Membership

The **mesh-group** parameter allows for the assignment of interfaces to *mesh groups*, as defined in RFC 2973. Mesh groups are used within full-mesh, point-to-point topologies to limit the amount of flooding of LSPs. Each interface in a particular mesh group will not forward an LSP if the LSP is received on a port that belongs to that mesh group. Mesh groups are identified by numbers, and range from 0 to 2147483647. Assigning an interface to mesh group 0 (zero), sets that interface to not forward any LSPs, regardless of the interface on which it is received.

The following is an example of assigning a set of interfaces to mesh groups:

```
rs(config)# isis set interface gig1 mesh-group 10
rs(config)# isis set interface gig2 mesh-group 10
rs(config)# isis set interface gig3 mesh-group 10
rs(config)# isis set interface gig4 mesh-group 0
```

In the example above, interfaces **gig1** through **gig3** will not forward an LSPs if the LSP is received by any interface in mesh group 10. Additionally, interface **gig4** will not forward an LSP, regardless of the interface on which it is received.

14.6 IS-IS GRACEFUL RESTART

IS-IS graceful restart is one of a set of protocol-based graceful restart features on the ROS developed with the goal of making the RS "hitless," which means that the service performed by the RS continues to function even if it has to restart. This feature is defined in the IETF “Restart Signaling for ISIS” Internet Working Draft.

Without graceful restart capabilities, IS-IS restarts are costly for network resources. Neighbor after neighbor within the network have to be told that the restarting router’s routes are unreachable, which causes recalculation of routes and sub-optimal routes to be used, only to be told seconds later that the restarted router’s routes are back.

To prevent this temporary route flapping across the network, IS-IS graceful restart relies on the Forwarding Information Base (FIB) of the restarting router being preserved across a restart, which allows the router to continue forwarding traffic during the restart. IS-IS graceful restart includes a new mechanism for a router to signal that it is restarting to its neighbors. It also devises a new way of ensuring correct resynchronization of the LSP database that does not involve cycling the restarting adjacency through the down state, thus avoiding costly network interruptions and SPF recalculations.

The following section outlines the basic functionality of IS-IS graceful restart.

14.6.1 Basic Functionality

The basic functionality of IS-IS graceful restart is described in this section and illustrated in the section, *"Illustration."* Important restrictions, exceptions, and corner-case considerations are presented later, in section 14.6.5, *"Usage Notes, Rules, and Restrictions."*

In order to accomplish an IS-IS graceful restart, both the restarting router and its neighbors must have IS-IS graceful restart enabled. In addition, the restarting router must be a dual control module system. The following assumes that these conditions are met on both the restarting router and its neighbors (helpers).

IS-IS Graceful Restart Capability Advertisement

IS-IS routers use a new Restart TLV in the IIH PDU to signal a restart to neighbors. This TLV includes the following flags and fields, which are used to convey information during a restart. These fields are described in detail later.

IS-IS Restart TLV Fields
Restart Request (RR)
Restart Acknowledgement (RA)
Remaining Hold Time (in seconds, required only when the RA bit is set)

Table 14-1IS-IS Restart TLV Fields

All IS-IS routers capable of graceful restart or supporting graceful restart include this TLV in their IIH PDUs. If both neighbors support the capability, then a graceful restart can be accomplished.

The Restart Process

The restart mechanism works on three levels:

- The individual IS-IS interfaces
- The two IS-IS link-state database (LSDB) levels, and
- The IS-IS instances.

A given interface can only be defined within a single IS-IS instance. Each IS-IS instance maintains it’s own LSDB at each level (1 and 2).

Phase 1: Successful Failover

In dual control module systems, the FIB is mirrored between the primary and backup control modules. During normal system operation, the FIB on the backup control modules is incrementally updated to reflect ongoing changes to the FIB on the primary control module.

In IS-IS graceful restart, while the primary control module restarts, the backup control module takes over and uses this learned FIB to maintain existing flows and permit new flows to be established. However, since the IS-IS LSP database is not mirrored between the two modules, the backup control module needs to signal its restart and resynchronize its LSP database(s) with neighbors.

Phase 2: IIH Request and Acknowledgement Exchange

After assuming control, the backup control module broadcasts a Restart Request IIH out all of its IS-IS interfaces. A Restart Request IIH is an IIH with the **Restart Request (RR) bit** set in the Restart TLV. Simultaneously, the backup control module starts three timers, T1, T2, and T3 (discussed in detail later).

Upon receiving this, all neighbors that support IS-IS graceful restart (aka "helpers") do the following:

- If the helper has a full adjacency to the restarter, leave the adjacency in the "Up" state and do *not* refresh it. *Un*like usual, the holding timer is not adjusted, nor is the adjacency reinitialized or LSPs regenerated. This avoids triggering disruptive SPF runs throughout the domain.
- Acknowledge the restart request by sending an IIH containing a TLV with
  - The **RR** bit cleared,
  - The **Restart Acknowledgement (RA) bit** set, and
  - The **Remaining Hold Time** field set to the time, in seconds, before the holding timer on this adjacency is due to expire.
- While the restart is taking place, hide the restart from the rest of the network by not withdrawing the routes learned via the restarter. Since the forwarding state is preserved in the restarter's backup control module and traffic can continue through it, shielding the restart is acceptable.

Once the restarter receives the helper's Acknowledgement IIH, the adjacency between them is reestablished.

Phase 3: CSNP and LSP Updates

Next, *one* helper per segment does the following:

- Marks all relevant LSPs for resynchronization with the restarter by setting the SRMflags in the LSP database on the adjacency concerned. As mentioned before, this helper continues forwarding traffic as though all routes were valid. Since the forwarding state is preserved in the restarter's backup control module and traffic can continue through it, shielding the restart is acceptable.
- Sends the restarter CSNPs describing the set of LSPs marked for resynchronization.
- Sends all marked LSPs to the restarter as a part of the normal update process.

On point-to-point links, there is only one helper—the directly-connected neighbor. On broadcast networks, this is the helper with the highest LnRouterPriority, with highest source MAC address breaking ties. Usually (unless the DIS is the restarter), this is also the DIS on that LAN segment.

After sending the Restart Request IIH, the restarting router waits to receive acknowledgements, CSNPs, and LSPs from neighbors. It uses the CSNPs and LSPs to build its own LSP database. It also uses the timers T1, T2, and T3 to limit the length of various stages in LSP database resynchronization. These timers are started together at the beginning of the graceful restart and described in detail below.

T1 is a user-set *per-interface* timer that controls how long the restarter waits for an Acknowledgement IIH and CSNPs from a helper neighbor on an interface. If T1 expires without the restarter receiving both an acknowledgement and CSNPs on an interface, the restarter retransmits the Restart Request IIH out that interface and continues waiting.

Once the restarter has both an Acknowledgement IIH and CSNPs from an interface, it cancels the T1 timer for that interface and waits for the set of full LSPs to arrive via the usual update process. The CSNPs it receives from each neighbor describe the set of LSPs that are currently held by that neighbor. Synchronization cannot be complete until all these LSPs have been received.

Phase 4: Database Synchronization

To keep track of which LSPs it still needs, the restarter records the LSPIDs contained in the first complete set of CSNPs received over each interface, along with their remaining lifetime, into *per-LSP database level* waiting lists. (CSNPs with a remaining lifetime of zero are not recorded.) As LSPs arrive, they are entered into the appropriate (L1 or L2) database and compared against entries in the appropriate waiting list. CSNP entries that match arrived LSPIDs are deleted from the waiting list. CSNP entries with a short remaining lifetime that expire before they can be matched are also removed from the waiting list. This helps to ensure that the RS does not wait indefinitely for an LSP that will never arrive.

When the waiting list for a particular database becomes empty, that database is deemed to be synchronized.

The RS uses the user-set *per-LSP database level* timer, **T2**, to limit how long it waits for LSPs before declaring a database to be synchronized. The T2 for each database is cancelled when the waiting list for that database becomes empty *and* when all T1s have been cancelled. If T2 expires before the waiting list empties, the RS stops waiting and considers that database to be synchronized.

In addition to T1 and T2, the RS maintains a third timer, **T3**, that indicates how long it has after a restart to achieve synchronization. This global timer is initialized to an arbitrarily large interval (65535 seconds), but is set to the minimum of the Remaining Hold Times received in Acknowledgement IIHs. As each Acknowledgement IIH arrives, the Remaining Hold Time is compared against the current value of T3. If the Remaining Hold Time is less, T3 is reset to the Remaining Hold Time. Since neighbors set the Remaining Hold Time to indicate how long they are willing to wait before resetting the adjacency, it is a suitable limit to the length of resynchronization. T3 is cancelled when all T2s are canceled or expire. If T3 expires before all T2s are cancelled, the router sets the ‘overload’ bit for the unsynchronized databases and returns to normal updates.

After the waiting list for a database becomes empty, the RS has all the LSPs that it needs to synchronize that database and cancels the T2 timer for that database. According to the IETF working draft, “At this point the local database is guaranteed to contain all the LSP(s) (either the same sequence number, or a more recent sequence number) which were present in the neighbors’ databases at the time of re-starting. LSPs that arrive in a neighbor’s database after the time of re-starting may, or may not, be present, but the normal operation of the update process [guarantees] that they will eventually be received. At this point the local database is deemed to be ‘synchronized’.”

Phase 5: Run SPF, Recompute Routes, and Regenerate Updates

Only after it receives all updates from its peers and synchronizes *all* databases does the restarted router run the SPF algorithm, perform route selection, update the RIB and FIB, and send new updates. Since the timer T3 establishes the absolute limit on resynchronization, the restarter waits until T3 is cancelled or expires before running the SPF algorithm, updating the forwarding tables, and flooding new LSPs. There are several reasons for this:

- This waiting ensures that the first updates sent out by a router after it restarts reflect the current network state as completely as possible.

- To avoid unnecessary routing churn in other routers, ‘own’ LSPs generated by the restarter must be the same as those previously present in the network, assuming that no changes have occurred. Therefore, it is important that LSPs not be regenerated and flooded before all the adjacencies have been reestablished and databases synchronized.
- In the case of a L1/L2 restarter, waiting for the other database to be synchronized before LSP flooding ensures that inter-level information has a chance to be propagated, and inter-level LSPs regenerated and included in the update.

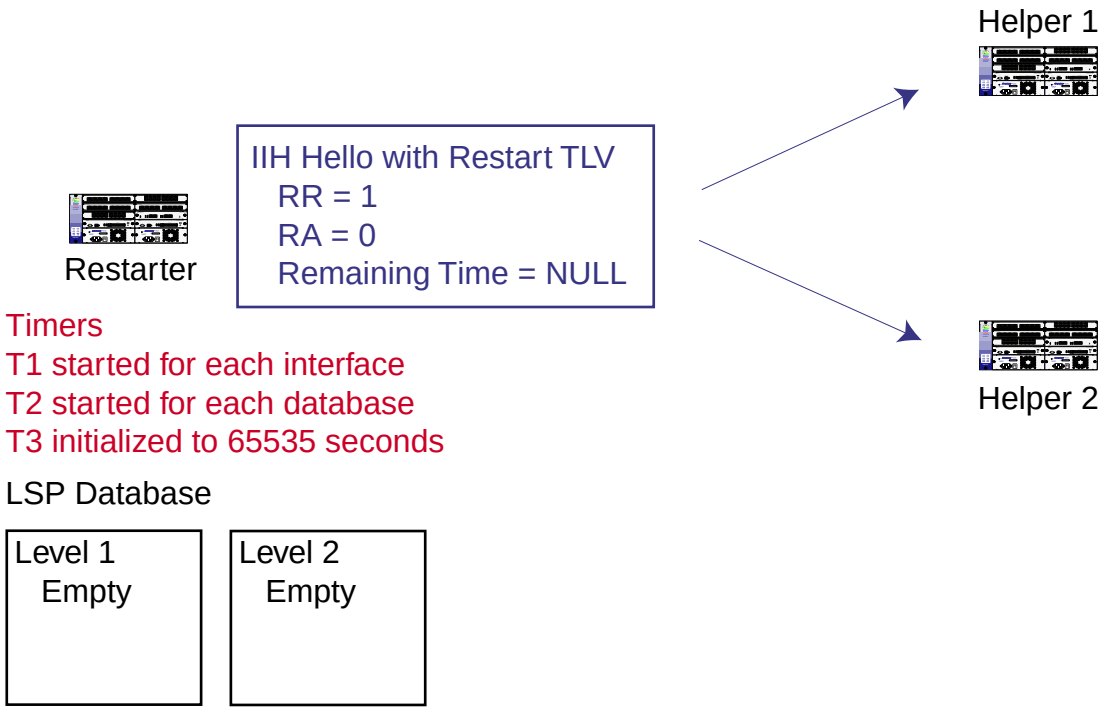
Thereafter, normal IIHs are transmitted with all the Restart TLV fields cleared. The adjacency and all updates are maintained as usual.

Illustration

The following illustrates this process in a successful IS-IS graceful restart.

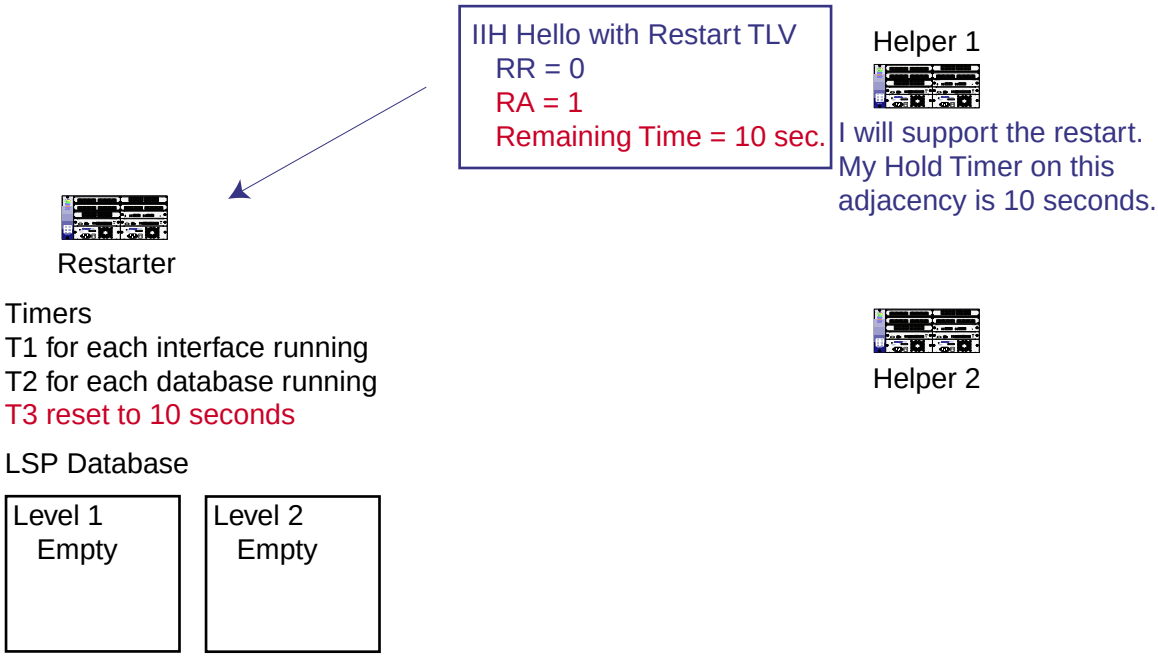
1. The RS Restarts

The restarter restarts, transferring control from the primary control module to the secondary, and continuing to forward routes using the mirrored FIB. The LSP database is not mirrored and is lost, creating a need for database resynchronization. The restarter sends an Restart Request IIH out both interfaces and starts the timers T1, T2, and T3.



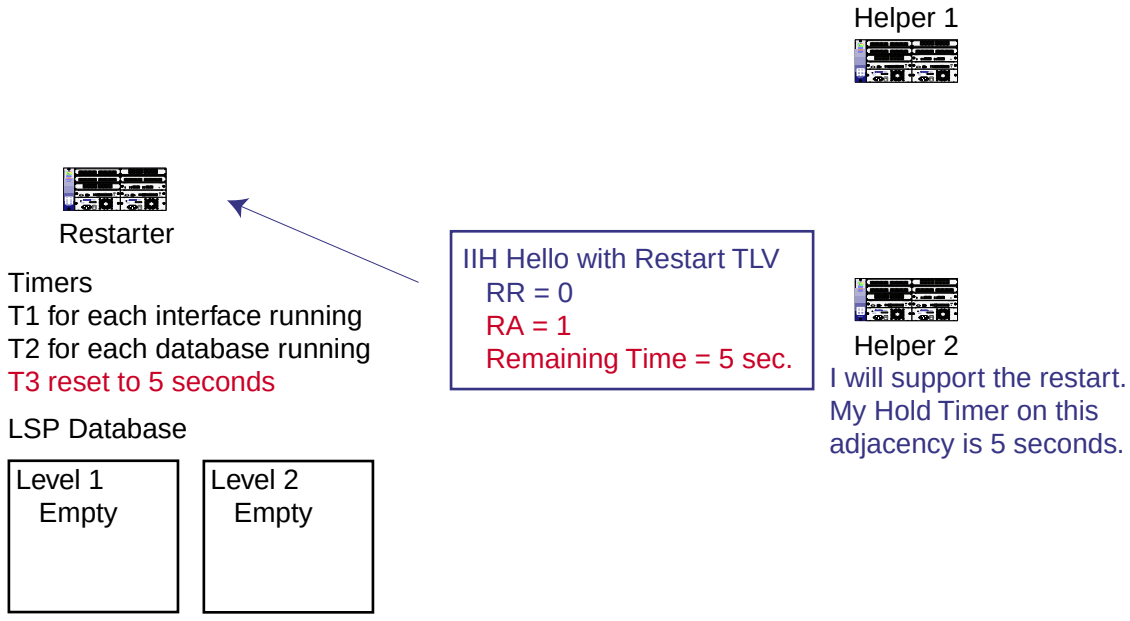
2. Helper 1 Acknowledges

Helper 1 acknowledges the restart in its own Restart Acknowledgement IIH. Since it is lower than the current T3, the restarter resets its T3 timer to the Remaining Time indicated in Helper 1’s acknowledgement.



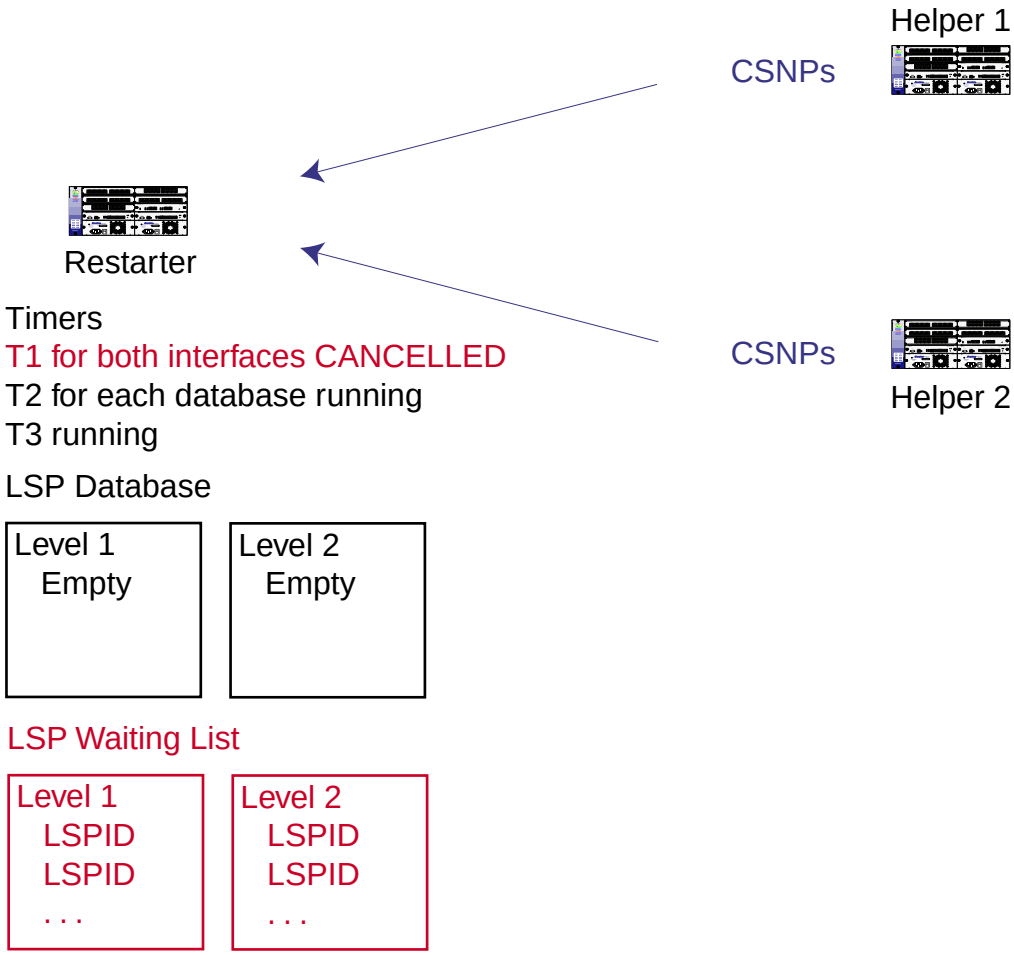
3. Helper 2 Acknowledges

Helper 2 acknowledges the restart in its own Restart Acknowledgement IIH. Since it is lower than the current T3, the restarter resets its T3 timer to the Remaining Time indicated in Helper 2's acknowledgement.



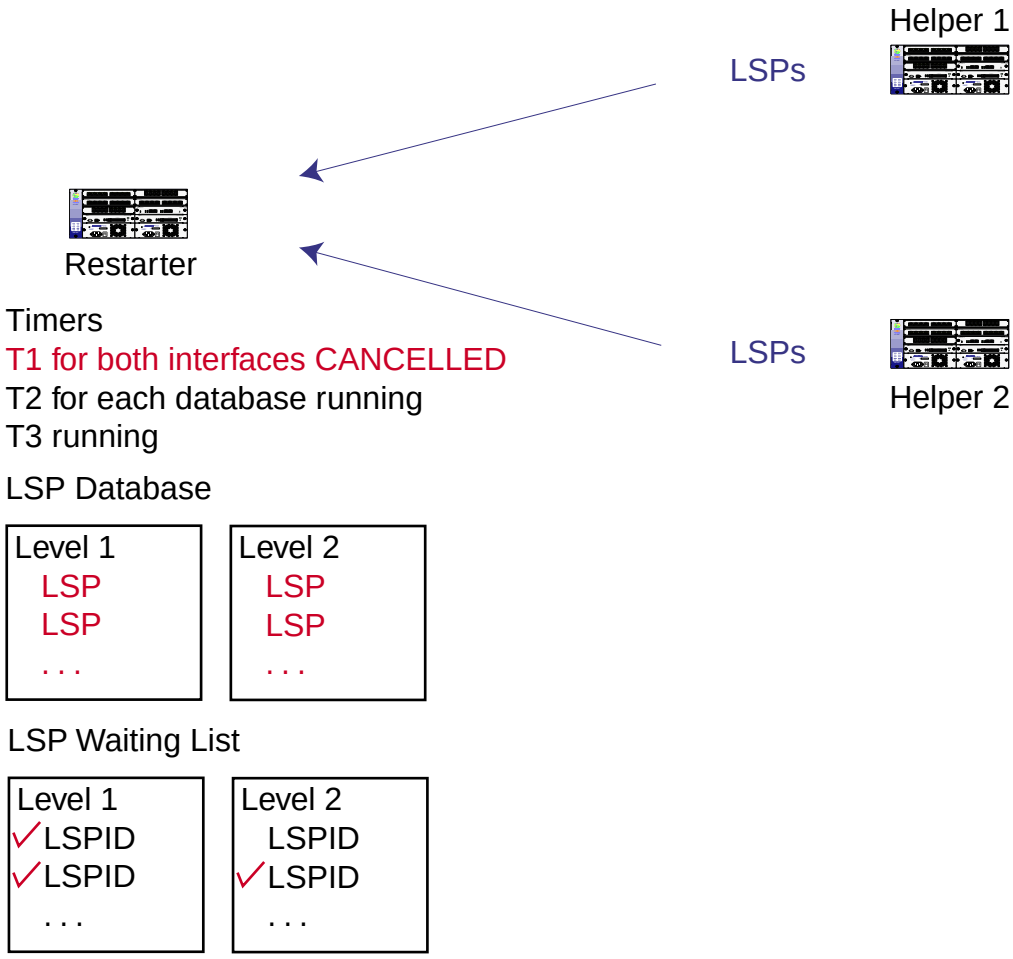
4. Both Helpers Send CSNPs To the Restarter

Both helpers send CSNPs describing their LSP databases to the restarter, who records all the LSPIDs received into two separate waiting lists—one for each database. After all the CSNPs are received, the restarter cancels the T1 timer for both interfaces.



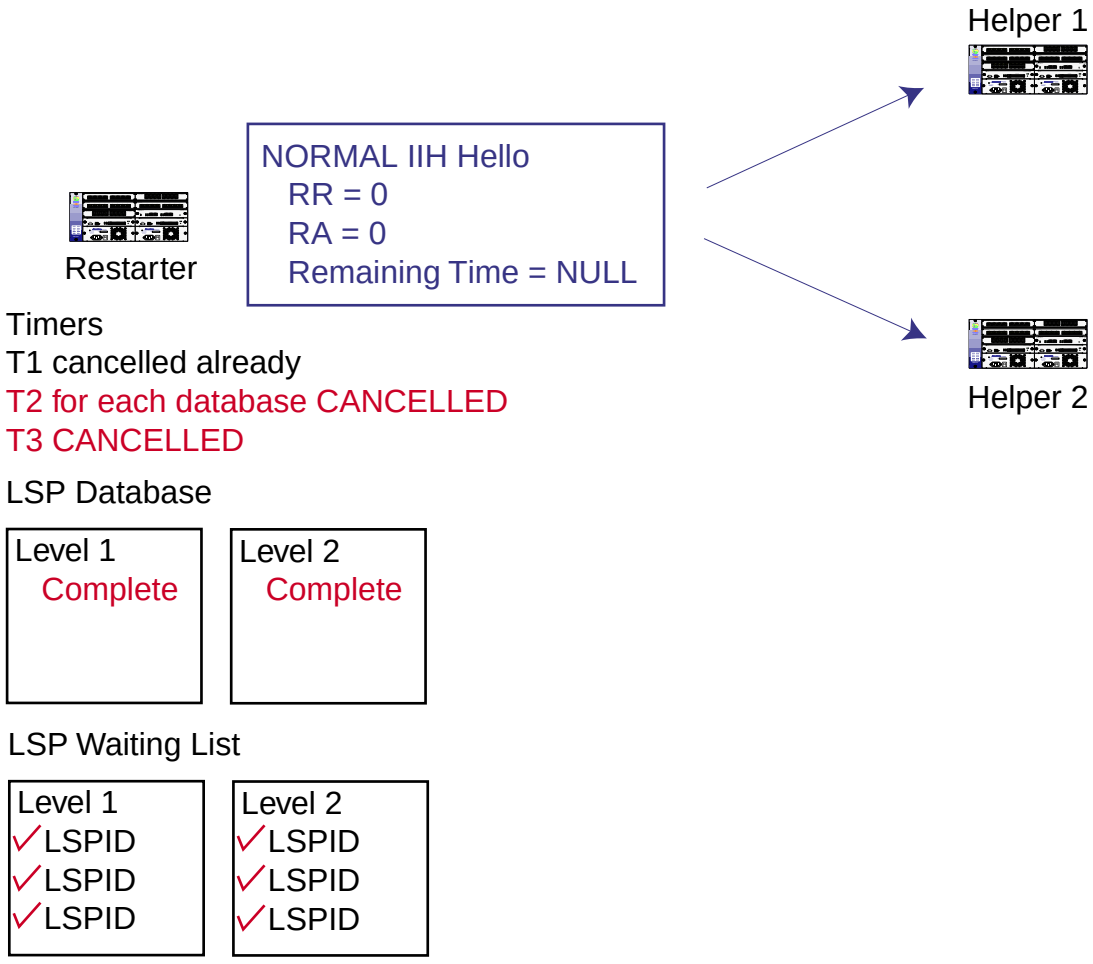
5. Both Helpers Send LSPs To the Restarter

Both helpers send LSPs (described in their earlier CSNPs) to the restarter. The restarter records the LSPs in its LSP databases and checks them off the waiting lists.



6. Synchronization Achieved, Normal Operation Resumes

After receiving all the LSP on the waiting lists, the restarter completes database synchronization and cancels both T2 and T3 timers. The restarter then resumes normal operation by sending both helpers normal IIH PDUs with all the fields in the Restart TLV zeroed.



14.6.2 Timers and Flags

The following is a summary of the timers that IS-IS graceful restart uses:

T1 Timer

Description	After sending a Restart Request IIH, this timer indicates how long the RS waits for an Acknowledgement IIH and a set of CSNPs on an interface before resending the Restart Request IIH.
One Per	An instance of T1 is maintained per interface.
Set By	Use the **`isis set restart t1-timer`** command to set this timer *for all interfaces.*
Default	When not specified in the configuration, the default of 3 seconds is used.
Initialization	The RS starts the T1, T2, and T3 timers all at the same time—at the beginning of restart.
Cancellation	The RS cancels the T1 timer for an interface once it receives both an Acknowledgement IIH and CSNPs on that interface.
Expiration	When the T1 timer for an interface expires, the RS retransmits the Restart Request IIH on that interface and resets the timer. Set the number of times that the RS retries before giving up using the **`isis set restart t1-retries`** command. The default is 5 times.

T2 Timer

Description	This timer indicates how long the RS waits for LSP database synchronization.
One Per	An instance of T2 is maintained for each database (Level-1 or Level-2).
Set By	Use the **`isis set restart t2-timer`** command to set this timer *for all LSP database levels*.
Default	When not specified in the configuration, the default of 60 seconds is used.
Initialization	The RS starts the T1, T2, and T3 timers all at the same time—at the beginning of restart.
Cancellation	The RS cancels the T2 timer for a database once it has received all the LSPs described in the first set of CSNPs from its neighbors. At this point, the RS considers that database to be synchronized. It tracks which LSPs have been received by keeping a waiting list of LSPIDs for each database and deleting entries whose LSPs have been received or whose remaining lifetime becomes zero.
Expiration	When the T2 timer for a database expires, even if entries remain on its waiting list, the RS considers that database to be synchronized.

T3 Timer

Description	This timer indicates how long the RS has after a restart to achieve synchronization.
One Per	This is a global timer.
Set By	This timer is set by the RS, not the user.
Default	T3 is initialized to an arbitrarily large interval (65535 seconds), but is set to the minimum of the Remaining Hold Times received in Acknowledgement IIHs. As each Acknowledgement IIH arrives, the Remaining Hold Time is compared against the current value of T3. If the Remaining Hold Time is less, T3 is reset to the Remaining Hold Time. Since neighbors set the Remaining Hold Time to indicate how long they are willing to wait before resetting the adjacency, it is a suitable limit to the length of resynchronization.
Initialization	The RS starts the T1, T2, and T3 timers all at the same time—at the beginning of restart.
Cancellation	The RS cancels the T3 timer once all the T2 timers expire or are cancelled. At this point, the RS considers that database to be synchronized and proceeds to run the SPF algorithm, update the forwarding tables, and flood newly generated LSPs.
Expiration	See discussion in section 14.6.5, *"Usage Notes, Rules, and Restrictions."*

14.6.3 Configuration

By default, IS-IS graceful restart is on and the timers T1, T2, and T3 are set to the above values.

You can configure IS-IS graceful restart in the following areas:

- Change the T1 timer setting for *all* interfaces.
- Change the number of T1 timer retries for *all* interfaces.
- Change the T2 timer for *all* LSP database levels.
- Enable or disable the IS-IS graceful restart feature on this router. When not specified in the configuration, restart is enabled by default.
- Enable or disable the ability of this router to help a remote restarting router. When not specified in the configuration, the helper function is on by default. If disabled, the Restart TLV is not included in the IIH PDU.

The following example sets the IS-IS graceful restart T1 timer for *all* interfaces on the RS to 5 seconds:

```
RS(config)# isis set restart t1-timer 5
```

The following example sets the number of T1 timer retries for *all* interfaces on the RS to 8:

```
RS(config)# isis set restart t1-retries 8
```

The following example sets the IS-IS graceful restart T2 timer for *all* LSP database levels on the RS to 90 seconds:

```
RS(config)# isis set restart t2-timer 90
```

The following example *enables* the IS-IS graceful restart capability globally on the RS. When not specified in the configuration, this capability is enabled by default.

```
RS(config)# isis set restart restart enable
```

The following example *disables* the IS-IS graceful restart capability globally on the RS. When not specified in the configuration, this capability is enabled by default.

```
RS(config)# isis set restart restart disable
```

The following example *enables* the ability of this router to help a remote restarting router. When not specified in the configuration, the helper function is on by default.

```
RS(config)# isis set restart helper enable
```

The following example *disables* the ability of this router to help a remote restarting router. When not specified in the configuration, the helper function is on by default. Disabling the helper function means that this router does not include the Restart TLV in its IIH PDUs.

```
RS(config)# isis set restart helper disable
```

14.6.4 Example

Sample Configuration

The following sample configuration sets the

- T1 timer to 30 seconds
- T2 timer to 120 seconds, and
- Number of T1 retries to 10 times

Since the IS-IS graceful restart and helper capabilities are on by default, the commented-out lines are unnecessary except to re-enable them if they are ever disabled.

```
Running system configuration:
       !
       ! Last modified from Console on 2002-03-20 03:45:39
       !
   1 : interface create ip et.7.1 address-netmask 172.20.216.180/22 port et.7.1 up
   2 : interface add ip et.7.1 address-netmask 10.110.0.180/16
   3 : interface add ip lo0 address-netmask 12.23.34.45/24
       !
   4 : ip-router global set trace-state on
   5 : ip-router global set router-id 172.20.216.180
       !
   6 : isis add area 49.1111
   7 : isis add interface et.7.1
   8 : isis set level 1
   9C: // isis set restart restart enable
  10C: // isis set restart helper enable
  11 : isis set restart t1-timer 30
  12 : isis set restart t2-timer 120
  13 : isis set restart t1-retries 10
  14 : isis start
       !
  15 : system set name "rs180"
  16 : system set idle-timeout serial 0 telnet 0
       !
  17 : isis trace system
```

Viewing the Graceful Restart Process

Three commands are available to help you view IS-IS restart: **`isis show restart`**, **`isis show adjacency detail`**, and **`isis show circuit detail`**.

isis show restart

You can use the **`isis show restart`** command to view the IS-IS restart configuration parameters and current status. This command output summarizes all the IS-IS restart information available for this router.

The following sample output is from a non-restarting router:

```
RS# isis show restart
IS-IS Restart

Configuration
   Restart capability   : enabled
   Provide restart help : enabled
   Timer T1             :  3
   Timer T1 Retries     :  5
   Timer T2             : 60

Status
   Not in restart.
```

The following example shows a restart in progress:

```
RS# isis show restart
IS-IS Restart

Configuration
   Restart capability   : enabled
   Provide restart help : enabled
   Timer T1             : 3 secs
   Timer T1 Retries     : 5
   Timer T2             : 60 secs

Status
   Restart   : In progress      (37 seconds remaining)
   Level 1   : Not synchronized (48 seconds remaining)
   Level 2   : Synchronized
   Circuits  :
      Interface     Ack  CSNP  T1   Retries
      ip0            y     y    -     2
      ip1            n     y    1     4
      ip2            n     n    3     4
```

isis show adjacency detail

You can use the **`isis show adjacency detail`** command to view detailed restart information for an adjacency. The following is a sample output display:

```
RS# isis show adjacency detail
Adjacencies

Circuit name: ip0
     Number of level-1 Adjacencies: 1
     System: rs180
     Snpa: 0:2:85:d:b4:80
     State: up     Type: l1-is     Pri: 1     Hold: 22
     Time created: 2002-02-28 16:05:52
     Uptime: 0 days 0 hrs 17 mins 38 secs
     Areas: 49.1111
     Supported protocols: inet4
     Neighbor Ifaddr: 172.20.216.180
     Mesh Group: not-defined  Mesh State: inactive
     Restart aware: yes    Restarting: no
```

In this example,

- The **`Restart aware`** value indicates whether the adjacent router is including the Restart TLV in it's Hello PDUs.
- The **`Restarting`** value indicates whether the adjacent router has entered restart by setting the RR bit in its Restart TLV. If this is the case, this value remains "yes" until a restart TLV with the RR bit cleared is received from that router.

isis show circuit detail

Use the **`isis show circuits detail`** command to show the restart status for circuits.

The following sample output is from a non-restarting router:

```
RS# isis show circuits detail
Circuits

Name: ip0       CirID: 3        Index: 1        Encap: iso      Level: 1
Snpa: 0:e0:63:67:e7:31
Mtu: 1497       LSP Interval: 100
Level 1:
          Priority: 1     Lanid: 0000.baba.baba.03
          Flags: <dis>
          Number of active Level-1 adjacencies: 1
          Metric: 10     Hello(s): 10     Hello Multiplier: 3
          Mesh Group: not-defined  Mesh State: inactive
          Restart: not active
```

The following example shows a restart in progress:

```
RS# isis show circuits detail
Circuits

Name: ip0       CirID: 3        Index: 1        Encap: iso      Level: 1
Snpa: 0:e0:63:67:e7:31
Mtu: 1497       LSP Interval: 100
Level 1:
          Priority: 1     Lanid: 0000.baba.baba.03
          Flags: <dis>
          Number of active Level-1 adjacencies: 1
          Metric: 10     Hello(s): 10     Hello Multiplier: 3
          Mesh Group: not-defined  Mesh State: inactive
          Restart:  Ack(y) CSNP(n) T1(2) Retries(4)
```

Tracing

After turning on tracing using the **`ip-router global set trace-state on`** command, you can use the **`isis trace system`** command to observe the active IS-IS-specific code-path tracing messages that show the progress of IS-IS graceful restart during a restart.

Caution Be careful when you turn on tracing, because the amount of messages that result can overwhelm your screen output. To turn off tracing, simply negate the command.

The following trace output shows IS-IS graceful restart in action on an RS that has one IS-IS peer. IS-IS graceful restart and helper capabilities are enabled on both.

The relevant IS-IS graceful restart messages are in **bold**. Annotated text in *italics* highlight the process.

```
2002-03-22 08:10:01 %HBT-I-MASTERCPUFAIL, active 'Control Module (CM3)' in slot CM has failed

2002-03-22 08:10:01 %SYS-I-SANITY_CHECK, Failover Sanity Check on modules: 0x0.

2002-03-22 08:10:01 %SYS-I-SANITY_CHECK, Failover Sanity Check on modules: 0x0.

2002-03-22 08:10:04 %SYS-I-MULTICPU, additional CPU Module(s) detected in slot CM

2002-03-22 08:10:04 %HBT-I-FAILOVERCOMPLETE, CPU failover completed

2002-03-22 08:10:04 %HBT-I-NOHITLESSPROT, Hitless recovery for protocol OSPF is not enabled

2002-03-22 08:10:04 %HBT-I-HITLESSCMSTATECHANGE, Hitless CM state change from SLAVE to MASTER

2002-03-22 08:10:05 %SSH-I-DISABLED, ssh server disabled - no keys available


[IS-IS restart kicks in now.]
```

-01-01 00:00:51 ISIS RESTART: isis_restart_begin: enabled

[IS-IS restart is enabled. At this point, we initialize the T1, T2, and T3 timers to the default/user-set levels and send our neighbor an IIH with a Restart TLV that has the RR bit set. (Not visible in trace output.)]

-01-01 00:00:51 ISIS RESTART: option - RR(0) RA(64) REM(3)

[We receive an Acknowledgement IIH from our helper neighbor that includes a Restart TLV with the RA bit set and the Remaining Hold Time included. This indicates to us that our neighbor supports IS-IS graceful restart and will cooperate with our restart by shielding it from the rest of network.]

*[Receiving an Acknowledgement IIH on this interface causes us to reset the single global T3 timer to the Remaining Hold Time received if the Remaining Hold Time is lower than our current T3. In our case, we initialized T3 to 65535. The Remaining Hold Time received is 3. So we reset T3 to 3. (***rem_time***=Remaining Hold Time received in Restart TLV in IIH from neighbor) (***timer***=old T3 value)* timer *is set to* rem_time *if* rem_time < timer*.*

-01-01 00:00:51 ISIS RESTART: isis_restart_adjust_t3: (rem_time=3)(timer=65535)

-01-01 00:00:51 ISIS RESTART: isis_restart_circuit_got_ack: (et.7.1)(cont)

[This message indicates that we have received an Acknolwedgement IIH on this interface. However, the "cont" means that we must still wait for CSNP(s) and LSPs from our neighbor to use in synchronizing our database before we generate and send routing updates. This waiting ensures that the first updates we send out after the restart reflect the current network state as completely as possible.]

-01-01 00:00:51 ISIS ADJ: adjacencyStateChange 00.00ba.baba.ba up

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lsp: (1)(0000.ac14.d8b4.0000)(lsp added)

[We receive our first LSP from our helper neighbor. This is not a concern because LSPs may be received before the CSNPs that describe them—a situation that the restart process properly handles.]

-01-01 00:00:52 ISIS EVENT: sequenceNumberSkip

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lsp: (1)(0000.ac14.d8b4.0300)(lsp added)

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lsp: (1)(0000.baba.baba.0000)(lsp added)

[We continue receiving LSPs from our helper neighbor. We now have LSPs (0000.ac14,d9b4.0000) and (0000.ac14.d8b4.0300).]

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lspid: (et.7.1)(1)(0000.ac14.d8b4.0000)(lsp already received)

[We receive and process our first LSPID, which our helper neighbor sends to us in a CSNP. In this case, however, we had already processed this LSP (0000.ac14,d9b4.0000).]

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lspid: (et.7.1)(1)(0000.ac14.d8b4.0300)(lsp already received)

-01-01 00:00:52 ISIS RESTART: isis_restart_received_lspid: (et.7.1)(1)(0000.baba.baba.0000)(lsp already received)

[We continue receiving and processing CSNPs from our helper neighbor, some of which contain LSPIDs of LSPs that we have already processed.]

-01-01 00:00:52 ISIS RESTART: isis_restart_check_csnp_range: (et.7.1)(0000.0000.0000.0000)(ffff.ffff.ffff.ffff)(self complete)

[We complete the processing of CSNP PDUs. In this case, one PDU covers all LSPIDs in the helper's database.]

-01-01 00:00:52 ISIS RESTART: isis_restart_circuit_got_csnp: (et.7.1)(end)

[All the CSNPs have been received on this interface. We mark the circuit as complete, cancel the T1 timer for this interface (not visible from trace output), and proceed with database resynchronization.]

-01-01 00:00:52 ISIS RESTART: isis_restart_end_circuit: (et.7.1)

-01-01 00:00:52 ISIS RESTART: isis_restart_end_level: (1)

-01-01 00:00:52 ISIS RESTART: isis_restart_end:

-01-01 00:00:52 ISIS RESTART: isis_restart_end_level: (1)

-01-01 00:00:52 ISIS RESTART: isis_restart_end_level: (2)

-01-01 00:00:52 ISIS RESTART: isis_restart_end_circuit: (et.7.1)

[The database levels are both synchronized. We cancel the T2 and T3 timers, run SPF on both databases, update the RIB and FIB, and send routing updates. Then we successfully exit graceful restart.]

The following trace output shows the changes that take place on the helper neighbor as its IS-IS peer restarts. IS-IS graceful restart and helper capabilities are both enabled on this router.

The relevant IS-IS graceful restart messages are in **bold**. Annotated text in *italics* highlight the process.

-01-01 00:11:47 ISIS RESTART: option - RR(128) RA(0) REM(0)

[We receive an IIH from the restarter that contains the Restart TLV with the RR bit set. This indicates to us that we should leave the adjacency we have with this neighbor in the 'Up' state and hide the restart from the rest of the network by not withdrawing the routes learned via this neighbor. Immediately, we send back an Acknowledgement IIH with the RA bit set and the Remaining Hold Time field set to the time, in seconds, before the holding timer on this adjacency is due to expire.]

```
-01-01 00:11:47 ISIS RESTART: isis_restart_check_send_csnp: (ip0)(will send csnps)

[We are the helper on this segment and must help the restarter synchronize its database.
Therefore, we mark all the LSPs concerning this adjacency for resynchronization in our own
database. Then we send our neighbor CSNPs to describe these LSPs and eventually the LSPs
themselves.]
```

14.6.5 Usage Notes, Rules, and Restrictions

The following items are required for IS-IS graceful restart:

Enable Graceful Restart On Other Relevant Protocols

- As the Internet Engineering Task Force (IETF) points out in its working draft on BGP graceful restart, there is little benefit deploying any IGP Graceful Restart in an AS whose IGPs and EGP are tightly coupled (i.e., EGP and IGPs would both restart), and EGPs have no similar graceful restart capability. To reap the full benefits of IS-IS graceful restart, make sure that you also enable graceful restart on all collaborating routing protocols.

Dual Control Module System

- Since IS-IS graceful restart relies on the FIB being preserved from the primary control module to the secondary control module, the restarting router must be a dual control module system.

Note Observe the following usage notes on dual control module systems:

1. Failure on the secondary control module while the primary control module is running has no impact on the IS-IS sessions running on the primary.

2. When setting the IP address that the RS uses during boot exchange with the trivial file transfer protocol (TFTP) boot server, avoid using the same address on any of the IP interfaces configured in the CLI. On a dual control module system, this can cause ARP/IP-reuse issues as the secondary takes over. (This IP address is set using the **`system set bootprom`** command.)

The following additional notes, rules, and restrictions apply to the IS-IS graceful restart feature:

Single Control Module Systems

- Single control module systems can support IS-IS graceful restart, but cannot gracefully restart themselves.

No Helper Neighbor

- Some IS-IS routers are not capable of supporting or have been configured not to support IS-IS graceful restart. When a non-helper receives the IIH PDU with the Restart TLV from a restarter, it ignores the TLV and treats that as it would any hello. It refreshes the adjacency if it has one and creates one if it didn't. On a point-to-point link, it sets the SRMflags. Then it sends back its own IIH, with no Restart TLV, to the restarter and proceeds with normal update exchanges.
- The restarter treats receiving an IIH not containing the Restart TLV like an acknowledgement, since it indicates that the neighbor does not support graceful restart. The neighbor will have reinitialized this adjacency and, on point-to-point links, set its SRMflags, which ensures eventual database synchronization. On broadcast links, the usual operation of the update process also guarantees eventual synchronization. However, since no CSNP will arrive on point-to-point links and no CSNP is guaranteed to arrive on broadcast links, the restarter cancels T1 and considers synchronization to be complete.
- If no neighbor is reachable over an interface, the user-set number of T1 retries ensures that the restarter does not wait indefinitely for a reply. After that number of retries, the restarter cancels the T1 timer for that interface.

Start v. Restart

- An IS-IS router with graceful restart enabled also uses the T2 timer during normal starts. The following table outlines several differences that exist between a normal start and a graceful *re*start:

Starting For the First Time	**Restart**
A router starting for the first time transmits its zeroth LSPs with the 'overload' bit set to indicate that it does not have a complete set of LSPs and other routers should not route through it or use its updates to compute routes. While the timer T2 is running, the 'overload' bit remains set through all subsequent transmissions of the zeroth LSP.	A restarting router does not transmit any LSPs until it has achieve database synchronization.
When all the T2 timers have been cancelled, the router starting for the first time regenerates the LSPs with the overload bit cleared and floods normally.	A restarting router does not run SPF, update the RIB and FIB, or flood routing updates while the timer T3 is running.

T2 Expires Before Waiting List Is Empty

- If T2 expires before the waiting list of LSPIDs for that database level is empty, the RS considers that database to be complete and does not set any 'overload' bits for that database.

T3 Expires Before T2

- If the T3 timer expires before one or more T2s expire or are cancelled, this indicates that the synchronization process is taking longer than the minimum holding time of the neighbors. In this case, the RS does the following:
  - Set the ‘overload’ bit for the database of the that T2 to indicate that it is not yet synchronized. The own LSPs for this database will continue to have the ‘overload’ bit set until T2 has been cancelled, as in the case of starting for the first time, described in the section, *"Start v. Restart."*
  - Floods updates normally
  - Transmits normal IIHs (with all the Restart TLV fields cleared) over all interfaces to cause neighbors to refresh their adjacencies.

DIS

- Since the goal of IS-IS graceful restart is to minimize network interruptions as much as possible, this feature does *not* affect the DIS designation on broadcast networks.

Manual Reboots

- Manually rebooting or clearing IS-IS connections does not activate IS-IS graceful restart. On a dual control module system, if the primary is rebooted via the CLI, control is not transferred to the secondary. Only spontaneous crashes or reloads will activate the IS-IS graceful restart feature. (The exception to this is when the user manually forces a control module mastership change using the **`system redundancy change-mastership`** command.)

Simultaneous Restarts

- Having the RR and RA bits both set in the same IIH implies that the sending router is responding to the restart request of another router, but is itself restarting. In practice, a router that is restarting will not be able to assist another restarting router.

Routing Instances

- The RS supports IS-IS graceful restart on a per-routing instance basis. The commands in this section configure IS-IS graceful restart on the main instance only. Configure routing instance graceful restart exactly as you would the main instance, but identify the routing instance by prefacing each commands with the string ‘**`routing-instance`** <*name*>’.

14.7 DISPLAYING IS-IS INFORMATION

The RS provides a number of commands which you can use to view information about your IS-IS configuration. The **`isis show all`** command displays all the router's IS-IS tables. Individual tables may also be viewed using the commands in the following table.

Displays IS-IS adjacencies.	**`isis show adjacencies [detail]`**
Displays information about the other router on the circuit.	**`isis show circuits [detail]`**
Displays IS-IS export policies.	**`isis show export-policies`**
Displays IS-IS global parameters.	**`isis show globals`**
Displays Link State PDU (LSP) database information.	**`isis show lsp-database level1|2 [detail][id`**<*string*>**`][summary]`**
Display IS-IS graceful restart properties	**`isis show restart`**
Displays IS-IS timers.	**`isis show timers`**

Note For additional information about the **`isis show`** commands, their parameters, or the fields in the output, refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

14.7.1 IS-IS Sample Configuration

Consider the following network configuration. The network shown consists of 11 routers subdivided into four IS-IS areas.

Figure 14-1 shows the network topology. Figures 11 through 14 provide a detailed illustration of each area.

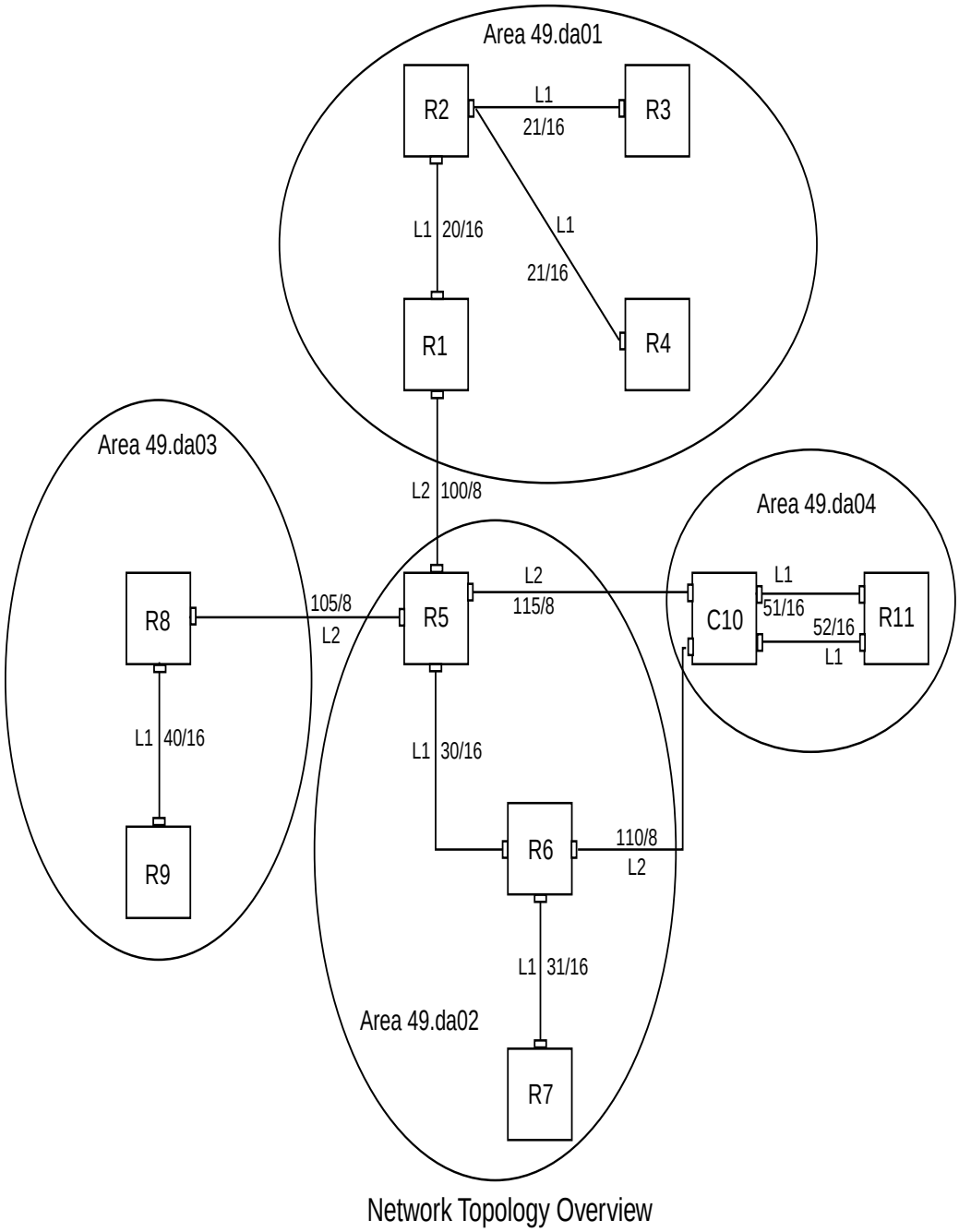


Figure 14-1 Network overview

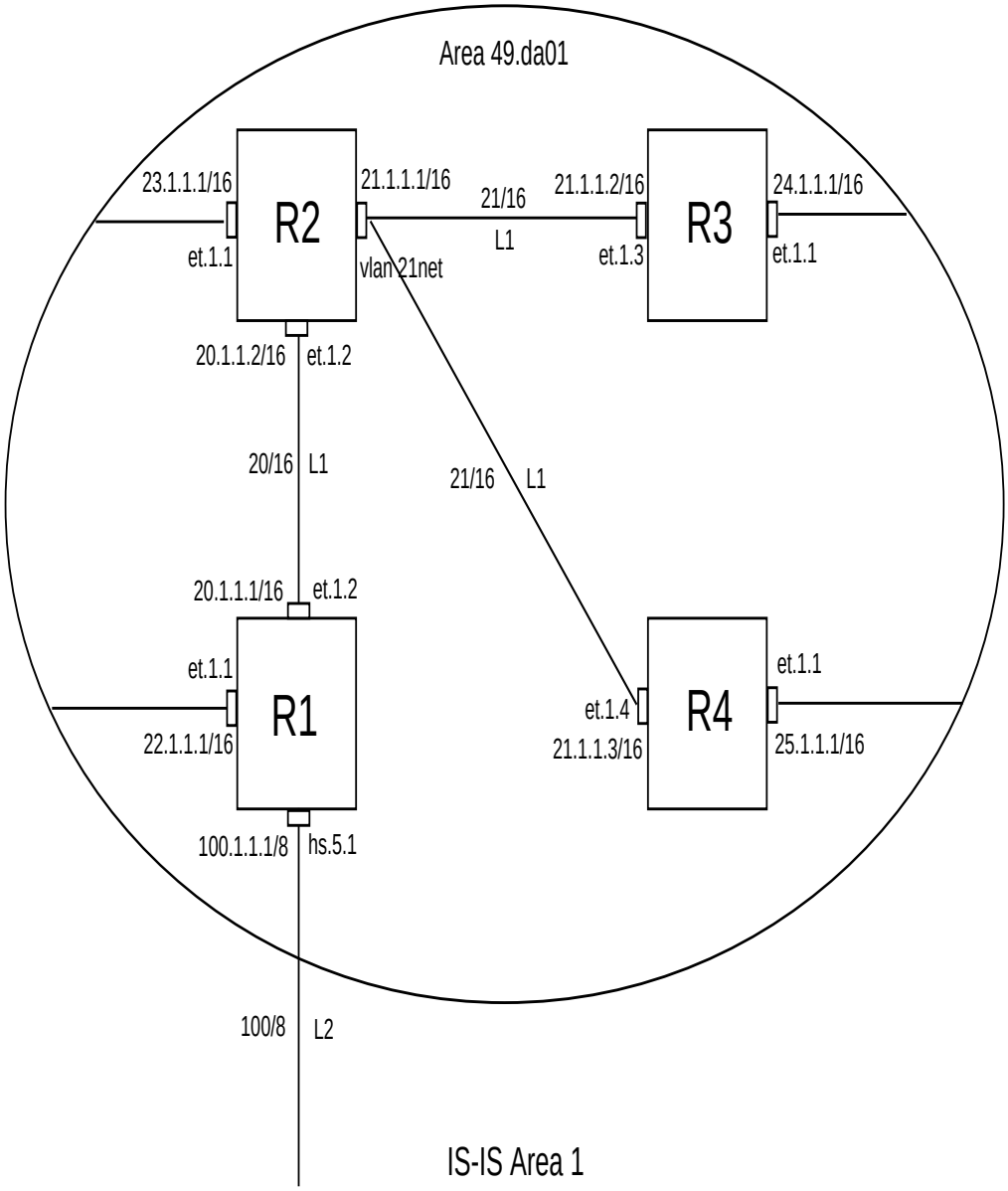


Figure 14-2 Area 1 detailed view

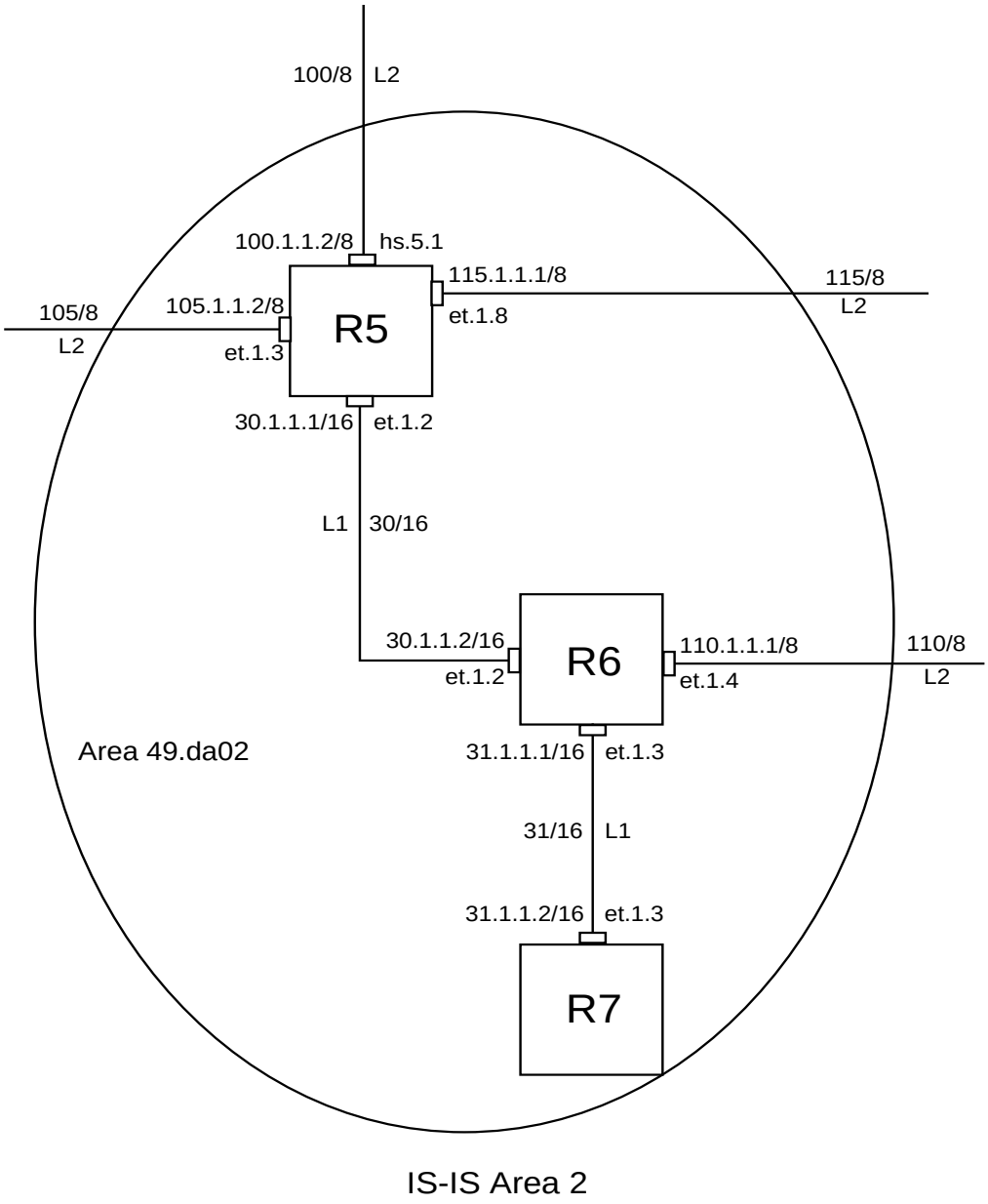


Figure 14-3 Area 2 detailed view

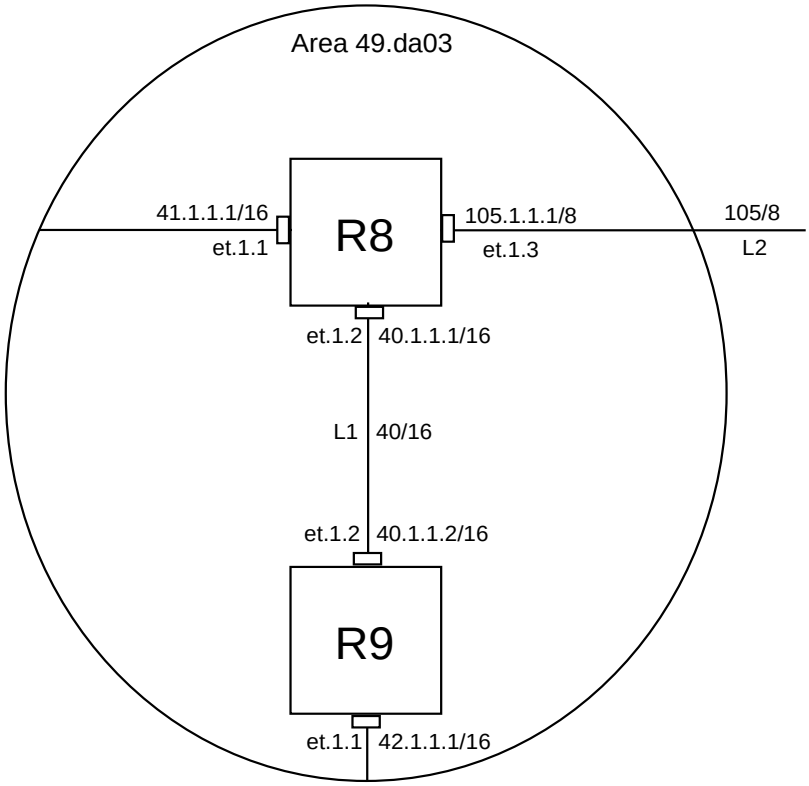


Figure 14-4 Area 3 detailed view

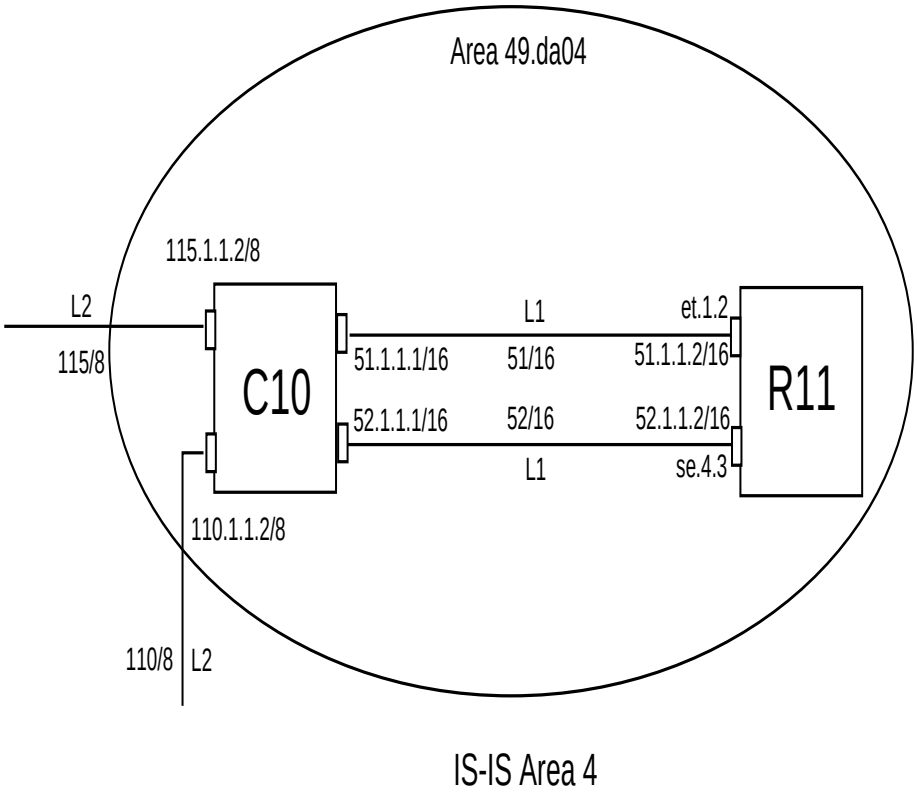


Figure 14-5 Area 4 detailed view

The following sections show the configuration for each router within this network. Note that explanations (in *italics*) precede each command or set of commands.

R1 Configuration

The following is the configuration for R1 in Area 1. R1 has a Level 1 IS-IS interface and a Level 2 IS-IS interface.

```
R1(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-29 12:13:03
     !
To configure the WAN port hs.5.1:
 1 : port set hs.5.1 wan-encapsulation ppp speed 45000000 clock
internal-clock-51mhz
     !
To configure IP interfaces:
 2 : interface create ip 20net address-netmask 20.1.1.1/16 port et.1.2
 3 : interface create ip 22net address-netmask 22.1.1.1/16 port et.1.1
 4 : interface create ip 100net address-netmask 100.1.1.1/8 port hs.5.1
     !
To configure router R1's area:
 5 : isis add area 49.da01
To enable IS-IS on each interface:
 6 : isis add interface 20net
 7 : isis add interface 22net
 8 : isis add interface 100net
To set IS-IS parameters for each interface:
 9 : isis set interface 20net encap iso priority 10 metric 10 level 1
10 : isis set interface 22net encap iso priority 10 metric 10 level 1
11 : isis set interface 100net encap iso priority 10 metric 10 level 2
To set the IS-IS level of router R1:
12 : isis set level 1-and-2
To start IS-IS on router R1:
13 : isis start
     !
```

R2 Configuration

The following is the configuration for router R2 in Area 1:

```
R2(config)# sh
Running system configuration:
To configure the IP VLAN, 21net:
 1 : vlan create 21net ip
 2 : vlan add ports et.1.3,et.1.4 to 21net
     !
To configure ports et.1.1 and et.1.2, and VLAN 21net as separate IP
interfaces:
 3 : interface create ip 23net address-netmask 23.1.1.1/16 port et.1.1
 4 : interface create ip 21net address-netmask 21.1.1.1/16 vlan 21netvlan
 5 : interface create ip 20net address-netmask 20.1.1.2/16 port et.1.2
     !
To configure router R2's area:
 6 : isis add area 49.da01
To enable IS-IS on each IP interface:
 7 : isis add interface 23net
 8 : isis add interface 21net
 9 : isis add interface 20net

To set IS-IS parameters for each interface:
10 : isis set interface 23net encap iso priority 10 metric 10 level 1
11 : isis set interface 21netvlan encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R2:
12 : isis set level 1
13 : isis set interface 20net encap iso level 1 priority 10 metric 10
To start IS-IS on router R2:
14 : isis start
     !
```

R3 Configuration

The following is the configuration for router R3 in Area 1:

```
R3(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 22:48:47
     !
To configure IP interfaces:
 1 : interface create ip 21net address-netmask 21.1.1.2/16 port et.1.3
 2 : interface create ip 24net address-netmask 24.1.1.1/16 port et.1.1
     !
To configure router R3's area:
 3 : isis add area 49.da01
To enable IS-IS on each interface:
 4 : isis add interface 21net
 5 : isis add interface 24net
To set parameters for each interface:
 6 : isis set interface 21net encap iso priority 10 metric 10 level 1
 7 : isis set interface 24net encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R3:
 8 : isis set level 1-and-2
To start IS-IS on router R3:
 9 : isis start
      !
```

R4 Configuration

The following is the configuration for R4 in Area 1:

```
R4(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 17:50:12
     !
To configure IP interfaces:
 1 : interface create ip 21net address-netmask 21.1.1.3/16 port et.1.4
 2 : interface create ip 25net address-netmask 25.1.1.1/16 port et.1.1
     !
To configure router R4's area:
 3 : isis add area 49.da01
To enables IS-IS on each interface:
 4 : isis add interface 21net
 5 : isis add interface 25net
To set parameters for each interface:
 6 : isis set interface 21net encap iso priority 10 metric 10 level 1
 7 : isis set interface 25net encap iso priority 10 metric 10 level 1
To set the IS-IS level of router R4:
 8 : isis set level 1-and-2
To start IS-IS on router R4:
 9 : isis start
     !
```

R5 Configuration

The following is the configuration for R5 in Area 2:

```
R5(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 09:31:01
     !
To set WAN encapsulation for port hs.5.1:
 1 : port set hs.5.1 wan-encapsulation ppp speed 45000000 clock
internal-clock-51mhz
     !
To create IP interfaces:
 2 : interface create ip 35net port et.1.8 address-netmask 35.1.1.2/16
 3 : interface create ip 100net address-netmask 100.1.1.2/8 port hs.5.1
 4 : interface create ip 30net address-netmask 30.1.1.1/16 port et.1.2
 5 : interface create ip 105net address-netmask 105.1.1.2/16 port et.1.3
 6 : interface add ip en0 address-netmask 10.50.3.4/16
     !
To set BGP parameters:
 7 : ip-router global set router-id 30.1.1.1
 8 : ip-router global set autonomous-system 64977
     !
 9 : ip add route 100.100.100.100 interface 35net
     !
10 : bgp create peer-group bgpfeed type external autonomous-system 64901
11 : bgp add peer-host 35.1.1.1 group bgpfeed
12 : bgp start
     !
To configure the IS-IS area:
13 : isis add area 49.da02

To enable IS-IS on each interface:
14 : isis add interface 100net
15 : isis add interface 30net
16 : isis add interface 105net
To set parameters for each interface:
17 : isis set interface 100net level 2 encap iso priority 10 metric 10
18 : isis set interface 30net level 2 encap iso priority 10 metric 10
19 : isis set interface 105net level 2 encap iso priority 10 metric 10
To set the IS-IS level of router R5:
20 : isis set level 1-and-2
To start IS-IS on R5:
21 : isis start
     !
To redistribute static routes into IS-IS:
22 : ip-router policy redistribute from-proto static to-proto isis
To redistribute BGP routes into IS-IS:
23 : ip-router policy redistribute from-proto bgp to-proto isis source-as 64901
     !
```

R6 Configuration

The following is the configuration for R6 in Area 2:

```
R6(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 08:36:43
     !
To configure IP interfaces:
 1 : interface create ip 110net address-netmask 110.1.1.1/8 port et.1.4
 2 : interface create ip 31net address-netmask 31.1.1.1/16 port et.1.3
 3 : interface create ip 30net address-netmask 30.1.1.2/16 port et.1.2
     !
To configure an OSPF interface for the backbone area:
 4 : ospf create area backbone
 5 : ospf add interface 31net to-area backbone
To starts OSPF:
 6 : ospf start
     !
To configure the IS-IS area of router R6:
 7 : isis add area 49.da02

To enable IS-IS on each interface:
 8 : isis add interface 30net
 9 : isis add interface 110net
To set parameters for each interface:
10 : isis set interface 110net level 2 priority 10 metric 10 encap iso
11 : isis set interface 30net encap iso level 2 priority 10 metric 10
To set the IS-IS level of router R6:
12 : isis set level 1-and-2
To start IS-IS on router R6:
13 : isis start
     !
To redistribute IS-IS routes into OSPF:
14 : ip-router policy redistribute from-proto isis to-proto ospf
     !
```

R7 Configuration

The following is the configuration for R7 in Area 2:

```
R7(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-04 15:18:34
     !
To configure an IP interface:
 1 : interface create ip 31net address-netmask 31.1.1.2/16 port et.1.3
     !
To configure and start OSPF:
 2 : ospf create area backbone
 3 : ospf add interface 31net to-area backbone
 4 : ospf start
     !
```

R8 Configuration

The following is the configuration for R8 in Area 3:

```
R8(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-07-06 09:33:34
     !
To configure IP interfaces:
 1 : interface create ip 40net address-netmask 40.1.1.1/16 port et.1.2
 2 : interface create ip 41net address-netmask 41.1.1.1/16 port et.1.1
 3 : interface create ip 105net address-netmask 105.1.1.1/8 port et.1.3
     !
To configure the IS-IS area of R8:
 4 : isis add area 49.da03
To enable IS-IS on each interface:
 5 : isis add interface 40net
 6 : isis add interface 41net
 7 : isis add interface 105net
To set the IS-IS level of router R8:
 8 : isis set level 1-and-2
To set the parameters of each interface:
 9 : isis set interface 40net encap iso level 1 priority 10 metric 10
10 : isis set interface 41net encap iso level 1 priority 10 metric 10
11 : isis set interface 105net encap iso level 2 priority 10 metric 10
To start IS-IS on router R8:
12 : isis start
     !
```

R9 Configuration

The following is the configuration for R9 in Area 3:

```
R9(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 11:32:26
     !
To create IP interfaces:
 1 : interface create ip 40net address-netmask 40.1.1.2/16 port et.1.2
 2 : interface create ip 42net address-netmask 42.1.1.1/16 port et.1.1
     !
To configure the IS-IS area of router R9:
 3 : isis add area 49.da03
To enable IS-IS on each interface:
 4 : isis add interface 40net
 5 : isis add interface 42net
To set the parameters for each interface:
 6 : isis set interface 40net encap iso level 1 priority 10 metric 10
 7 : isis set interface 42net encap iso level 1 priority 10 metric 10
To set the IS-IS level of router R9:
 8 : isis set level 1
To start ISIS on R9:
 9 : isis start
     !
```

C10 Configuration

The following is the configuration for the C10 Cisco router in Area 4:

```
Router#sh ru
Building configuration...

Current configuration:
!
version 11.2
no service password-encryption
no service udp-small-servers
no service tcp-small-servers
!
hostname Router
!
!
clns routing
!
interface Serial0/0
 ip address 52.1.1.1 255.255.0.0
 ip router isis 49.0004
 encapsulation ppp
 no keepalive
 no peer default ip address
 isis circuit-type level-1
 isis priority 10 level-1
!
interface Serial0/1
 no ip address
 shutdown
!
interface Serial0/2
 no ip address
 shutdown
!
interface Serial0/3
 no ip address
 shutdown
!
interface Ethernet1/0
 ip address 51.1.1.1 255.255.0.0
 ip router isis 49.0004
 isis circuit-type level-1
 isis priority 10 level-1
!
```

C10 Configuration (continued)

```
interface Ethernet1/1
 ip address 110.1.1.2 255.0.0.0
 ip router isis 49.0004
 isis circuit-type level-2-only
 isis priority 10 level-1
!
interface Ethernet1/2
 ip address 111.1.1.2 255.0.0.0
 ip router isis 49.0004
 isis circuit-type level-2-only
 isis priority 10 level-1
!
interface Ethernet1/3
 no ip address
 shutdown
!
interface Ethernet1/4
 no ip address
 shutdown
!
interface Ethernet1/5
 no ip address
 shutdown
!
router isis 49.0004
 net 49.0004.0200.3301.0101.00
!
router bgp 5
 neighbor 198.92.70.24 remote-as 10
 neighbor 198.92.70.24 route-map in5 in
!
no ip classless
!
!
line con 0
line aux 0
line vty 0 4
 login
!
end
```

R11 Configuration

The following is the configuration for R11 in Area 4:

```
R11(config)# sh
Running system configuration:
     !
     ! Last modified from Console on 2000-06-28 10:19:40
     !
To configure the WAN port se.4.3:
 1 : port set se.4.3 wan-encapsulation ppp speed 45000000
     !
To configure IP interfaces:
 2 : interface create ip 52net address-netmask 52.1.1.2/16 port se.4.3
 3 : interface create ip 51net address-netmask 51.1.1.2/16 port et.1.2
 4 : interface add ip en0 address-netmask 10.50.3.11/16
     !
To configure the IS-IS area of router R11:
 5 : isis add area 49.0004
To enable IS-IS on each interface:
 6 : isis add interface 51net
 7 : isis add interface 52net
To set the IS-IS level of router R11:
 8 : isis set level 1
To set the parameters for each interface:
 9 : isis set interface 51net level 1 encap iso priority 10 metric 10
10 : isis set interface 52net level 1 encap iso priority 10 metric 10
To start IS-IS on the router:
11 : isis start
     !
```

15 BGP CONFIGURATION GUIDE

The Border Gateway Protocol (BGP) is an exterior gateway protocol that allows IP routers to exchange network reachability information. BGP became an internet standard in 1989 (RFC 1105) and the current version, BGP-4, was established in 1994 (RFC 1771). BGP is typically run between Internet Service Providers (ISPs). It is also frequently used by multi-homed ISP customers, as well as in large commercial networks.

Autonomous systems (ASs) that wish to connect their networks together must agree on a method of exchanging routing information. Interior gateway protocols (IGPs) such as RIP and OSPF may be inadequate for this task since they were not designed to handle multi-AS, policy, and security issues. Similarly, using static routes may not be the best choice for exchanging AS-AS routing information because there may be a large number of routes, or the routes may change often.

Note This chapter uses the term *Autonomous System* throughout. An AS is defined as a set of routers under a central technical administration that has a coherent interior routing plan and accurately portrays to other ASs what routing destinations are reachable by way of it.

In an environment where using static routes is not feasible, BGP is often the best choice for an AS-AS routing protocol. BGP prevents the introduction of routing loops created by multi-homed and meshed AS topologies. BGP also provides the ability to create and enforce policies at the AS level, such as selectively determining which AS routes are to accept and advertise to BGP peers.

15.1 THE RS BGP IMPLEMENTATION

The RS routing protocol implementation, ROSRD, is a modular software program that consists of core services, a routing database, and protocol modules that support multiple routing protocols (Routing Information Protocol (RIP) versions 1 and 2, Open Shortest Path First (OSPF) version 2, BGP version 4, and Integrated Intermediate System-to-Intermediate System (IS-IS) routing protocol.)

BGP can be configured with the RS command line interface (CLI).

15.2 BASIC BGP TASKS

This section describes the basic tasks necessary to configure BGP on the RS. Due to the abstract nature of BGP, many BGP designs can be extremely complex. For any one BGP design challenge, there may only be one solution out of many that is relevant to common practice.

When designing a BGP configuration, it may be prudent to refer to information in RFCs, Internet drafts, and books about BGP. Some BGP designs may also require the aid of an experienced BGP network consultant.

Basic BGP configuration involves the following tasks:

- Setting the autonomous system number
- Setting the router ID
- Creating a BGP peer group
- Adding a BGP peer host
- Starting BGP
- Configuring BGP graceful restart
- Propagating routes to peers
- Route Selection
- Using AS path regular expressions
- Using AS path prepend
- Creating BGP confederations
- Removing private autonomous system numbers
- Creating community lists
- Using route maps
- Using MPLS LSPs to resolve next hop
- Using BGP accounting

15.2.1 Setting the Autonomous System Number

An autonomous system number identifies your autonomous system to other routers. To set the autonomous system number for the RS, enter the following command in Configure mode.

Set the router's autonomous system number.	**ip-router global set autonomous-system** <*num1*> **loops** <*num2*>

The **autonomous-system** <*num1*> parameter sets the AS number for the router. Specify a number from 1 to 65535. The **loops** <*num2*> parameter controls the number of times the AS may appear in the AS path. The default is 1.

15.2.2 Setting the Router ID

The router ID uniquely identifies the RS. To set the router ID to be used by BGP, enter the following command in Configure mode.

Set the router ID.	**ip-router global set router-id** <*IPaddr*>

If you do not explicitly specify the router ID, then an ID is chosen implicitly by the RS. A secondary address on the loopback interface (the primary address being 127.0.0.1) is the most preferred candidate for selection as the router ID. If there are no secondary addresses on the loopback interface, then the default router ID is set to the address of the first interface that is in the up state that the RS encounters (except the interface en0, which is the Control Module's

interface). The address of a non point-to-point interface is preferred over the local address of a point-to-point interface. If the router ID is implicitly chosen to be the address of a non-loopback interface, and if that interface were to go down, then the router ID changes. When the router ID changes, an OSPF router has to flush all its LSAs from the routing domain.

If you explicitly specify a router ID, it does not change even if all interfaces go down. Therefore, this option is recommended for increasing network stability.

15.2.3 Configuring a BGP Peer Group

A BGP peer group is a group of neighbor routers that have the same update policies. To configure a BGP peer group, enter the following command in Configure mode:

Configure a BGP peer group.	**bgp create peer-group** <*number-or-string*> **autonomous-system** <*number*> **[type** {**external|routing**}] **[proto any|rip|ospf|ospf-ase|static]** **[interface** <*interface-name-or-ipaddr*>**|all]**

where:

peer-group <*number-or-string*>
Is a group ID, which can be a number or a character string.

type Specifies the type of BGP group you are adding. This parameter is optional. If not specified, then the RS derives it automatically. You can specify one of the following:

- **external** In the classic external BGP group, full policy checking is applied to all incoming and outgoing advertisements. The external neighbors must be directly reachable through one of the machine's local interfaces.
- **routing** An internal group which uses the routes of an interior protocol to resolve forwarding addresses. Type Routing groups will determine the immediate next hops for routes by using the next hop received with a route from a peer as a forwarding address, and using this to look up an immediate next hop in an IGP's routes. Such groups support distant peers, but need to be informed of the IGP whose routes they are using to determine immediate next hops. This implementation comes closest to the IBGP implementation of other router vendors.

autonomous-system <*number*>
Specifies the autonomous system of the peer group. Specify a number from 1 to 65535.

This defines the autonomous system of the peer group. For each peer host that you add to the group, you can either adopt the peer group's autonomous system number or specify a different remote AS using the **bgp set peer-host remote-as** command.

proto Specifies the interior gateway protocol (IGP) to use in resolving BGP next hops.

interface <*name-or-IPaddr*> | **all**
Interfaces whose routes are carried via the IGP for which third-party next hops may be used instead. Use only for type Routing group. Specify the interface or **all** for all interfaces.

Due to memory limitations, the RS restricts the number of peers that a router can have by assigning each type of peer a point value and requiring that the total points for peers not exceed 175. Point values are as follows:

Peer Type	Point Value
External Peer	1
Internal Peer	1
External-Gateway Peer	2
Total points for all peers must not exceed	**175**

For example, a router that has only one type of peer can have a maximum of 87 external-gateway peers, 175 external peers, or 175 internal peers. A router with multiple peer types must have a point total that does not exceed 175. A router that already has 50 external-gateway peers configured (for a total of 100 points), for example, can have 75 more external or internal peers.

Caution Despite the theoretical maximum of 87 allowable external-gateway peers, for safer operation, do not exceed 85.

Note The maximum of 175 external or internal peers assumes that the peers are in relatively few peer groups. More peer groups require more memory and pose further limits.

The available memory also limits the number of BGP routes that can be stored in the forwarding information base.

Memory Size	Number of 1-Gateway BGP Routes that Can Be Stored In FIB
150 megabits	150 K routes
500 megabits	500 K routes

Note The above limits apply to BGP routes with one gateway. BGP routes with more than one gateway are more memory intensive. Having a large number of multi-gateway BGP routes decreases the total number of routes that can be stored in the FIB.

15.2.4 Adding a BGP Peer

To add BGP peers to existing BGP peer groups, enter the following command in Configure mode.

Add a host to a BGP peer group.	**bgp add peer-host** <*ipaddr*> **group** <*number-or-string*>

You can specify either a peer group identifier or a peer host IP address when creating an export destination for BGP routes (with the **ip-router policy create bgp-export-destination** command), a source for exporting BGP routes into other protocols (with the **ip-router policy create bgp-export-source** command), or a source for importing BGP routes (with the **ip-router policy create bgp-import-source** command).

Setting BGP Peer Attributes

To set or change parameters for a BGP peer, enter the following command in Configure mode.

Set or change attributes for a BGP peer.	**bgp set peer-host** <*ipaddr*> <*option*>

For example, for each peer host, you can either adopt its peer group's autonomous system number or specify a different remote AS using the **bgp set peer-host remote-as** command.

15.2.5 Starting BGP

BGP is disabled by default. To start BGP, enter the following command in Configure mode.

Start BGP.	**bgp start**

15.2.6 Configuring BGP Graceful Restart

BGP graceful restart is one of a set of protocol-based graceful restart features on the ROS developed with the goal of making the RS "hitless," which means that the service performed by the RS continues to function even if it has to restart. This feature is defined in the IETF "Graceful Restart Mechanism for BGP" Internet Working Draft.

Without graceful restart capabilities, BGP restarts are costly for network resources. Peer after peer within the network have to be told that the restarting router's routes are unreachable, which causes recalculation of routes and sub-optimal routes to be used, only to be told seconds later that the restarted router's routes are back.

To prevent this temporary route flapping across the network, BGP graceful restart relies on the Forwarding Information Base (FIB) of the restarting router being preserved across a restart, which allows the router to continue forwarding traffic during the restart.

The following section outlines the basic functionality of BGP graceful restart.

Basic Functionality

The basic functionality of BGP graceful restart is described in this section and illustrated in Figure 15-1, *"BGP Graceful Restart."* Important restrictions, exceptions, and corner-case considerations are presented later. It is worth noting now that in order to accomplish a BGP graceful restart, both the restarting router and its peers must have BGP graceful restart configured. In addition, the restarting router must be a dual control module system. The following assumes that these conditions are met on both the restarting router and its peers.

BGP Graceful Restart Capability Advertisement

When BGP initializes, an RS with BGP graceful restart configured advertises its graceful restart capability in the BGP 'Open' messages that it sends to establish peering. This advertisement includes an estimate of how long it expects to take before fully recovering upon a restart (**`restart-time`**) and the **`restart-flag`**, described later. If both peers support the capability, then a graceful restart can be accomplished.

During the Restart

In dual control module systems, the FIB is mirrored between the primary and backup control modules. During normal system operation, the FIB on the backup control modules is incrementally updated to reflect ongoing changes to the FIB on the primary control module.

In BGP graceful restart, while the primary control module restarts, the backup control module takes over and uses this learned FIB to maintain existing flows and permit new flows to be established. At this point, the RS sends an 'Open' message to its peers. Two flags are set in this 'Open' message, the **`restart-flag`** to indicate that it has restarted, and the **`forwarding-flag`** to indicate that it has preserved the FIB over the restart.

TCP connections cannot be maintained during a restart. Because of this, other applications that rely on TCP for reliable transport, like telnet and BGP sessions, also terminate during a restart. While the restart is taking place, the restarting router's peers hide the restart from the rest of the network by not withdrawing the routes learned via the restarting router. The peers mark these routes as 'stale' but continue forwarding traffic as though the routes were valid. Since the forwarding state is preserved in the restarting router's backup control module and traffic can continue through it, shielding the restart is acceptable.

Note When the underlying datalink is lost, the TCP connection remains up until it times out.

After the Restart: The Restarted Router

Once the RS restarts, it must re-establish a new BGP session with its peers.

It first listens to routing updates sent by its peers. While receiving these updates, the restarted router looks for the **`End-of-RIB`** marker. The **`End-of-RIB`** marker is an empty update message that is sent by all BGP speakers to indicate the end of routing updates. The restarted router uses the **`End-of-RIB`** marker to tell when a peer has finished sending it updates.

Only after it receives all updates from its peers does the restarted router perform route selection and send new updates for all of its existing routes to refresh its peers' stale routes. This waiting ensures that the first updates sent out by a router after it restarts reflect the current network state as completely as possible.

If a peer never sends an **End-of-RIB** marker, however, the restarted router does not need to wait indefinitely to start route selection. The **resync-time** timer is used to put an upper bound on the amount of time the restarted router must wait. This timer is started as the primary control module initializes, is deleted if the number of outstanding **End-of-RIB**s reaches zero, and expires if any of the participating peers fail to send an **End-of-RIB** within **resync-time** seconds. If this timer expires, a route flush occurs on the restarted router, as in a normal BGP restart.

After the Restart: The Peers

After the restart, peers first send routing updates to refresh the restarted router's routing table. Then they wait for routing updates from the restarted router to renew their stale routes. However, some of the restarted router's former routes may have disappeared during the restart. Since the restarted router only sends explicit updates on its current routes, how can its peers determine if a stale route has disappeared and should be flushed from their routing tables?

The peers look for the **End-of-RIB** marker from the restarted router. This marker tells them when the restarted router is finished sending updates, and when it is safe to delete any remaining stale routes from the restarted router.

Just like the restarted router, a peer also limits the time that it will wait for the **End-of-RIB** from the restarted router with the **resync-time** timer. It starts this timer when the BGP session is re-established (reaches Established state) after a failure. It deletes this timer when an **End-of-RIB** marker is received from the failed peer. If the timer expires before the **End-of-RIB** is received from the restarted router, any remaining stale routes from that remote peer are deleted.

Summary

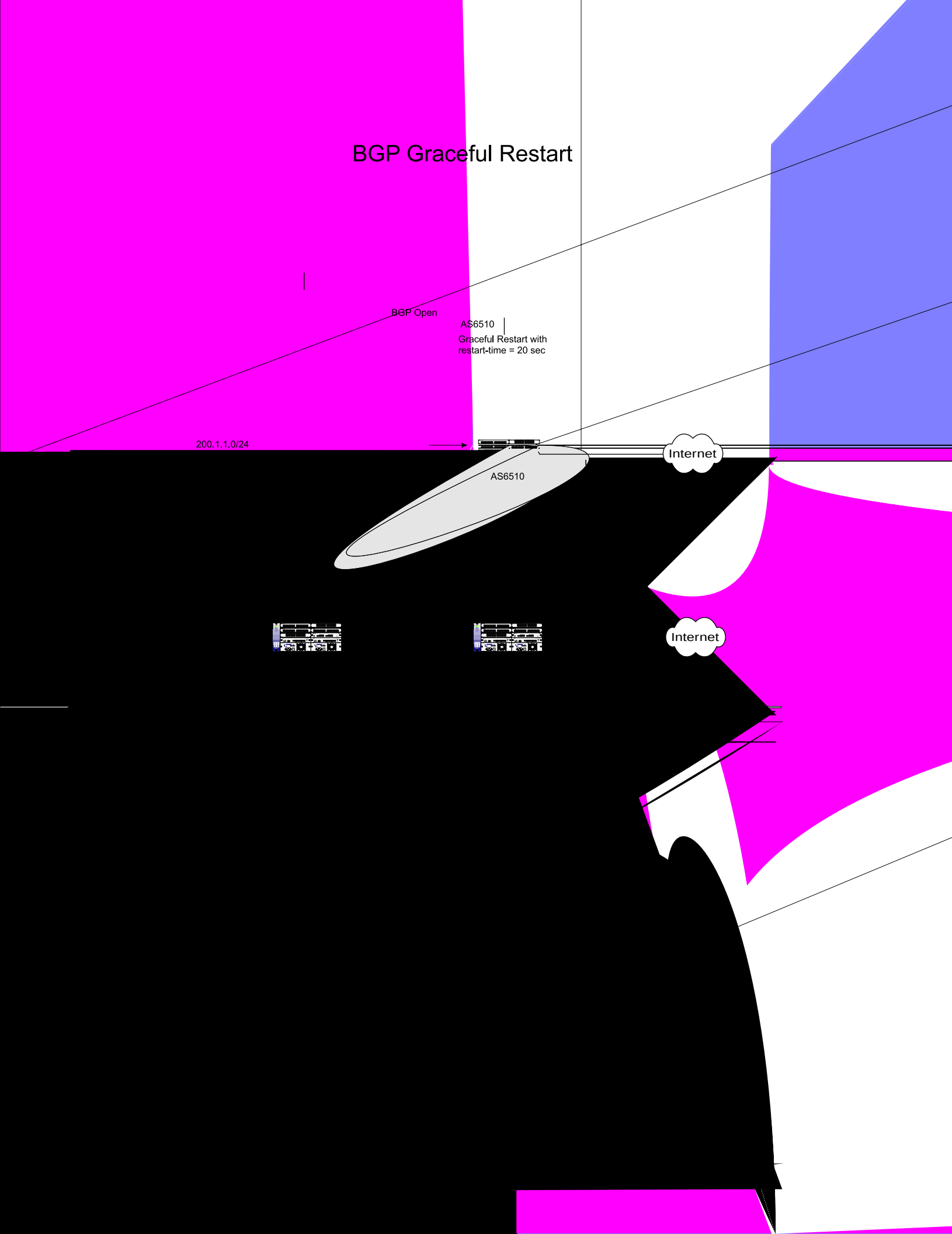
In summary, the network is unaffected and no route flapping occurs if a BGP router recovers after a restart by:

- reaching Established state on a new BGP session with its peers within **restart-time**, and
- sends updates on its current routes within **resync-time**.

If the restarting router fails to restart or does not resend updates on its current routes on time, its peers delete all stale routes and communicate the changes to the rest of the network.

The following illustrates this process in a successful BGP graceful restart.

BGP Graceful Restart



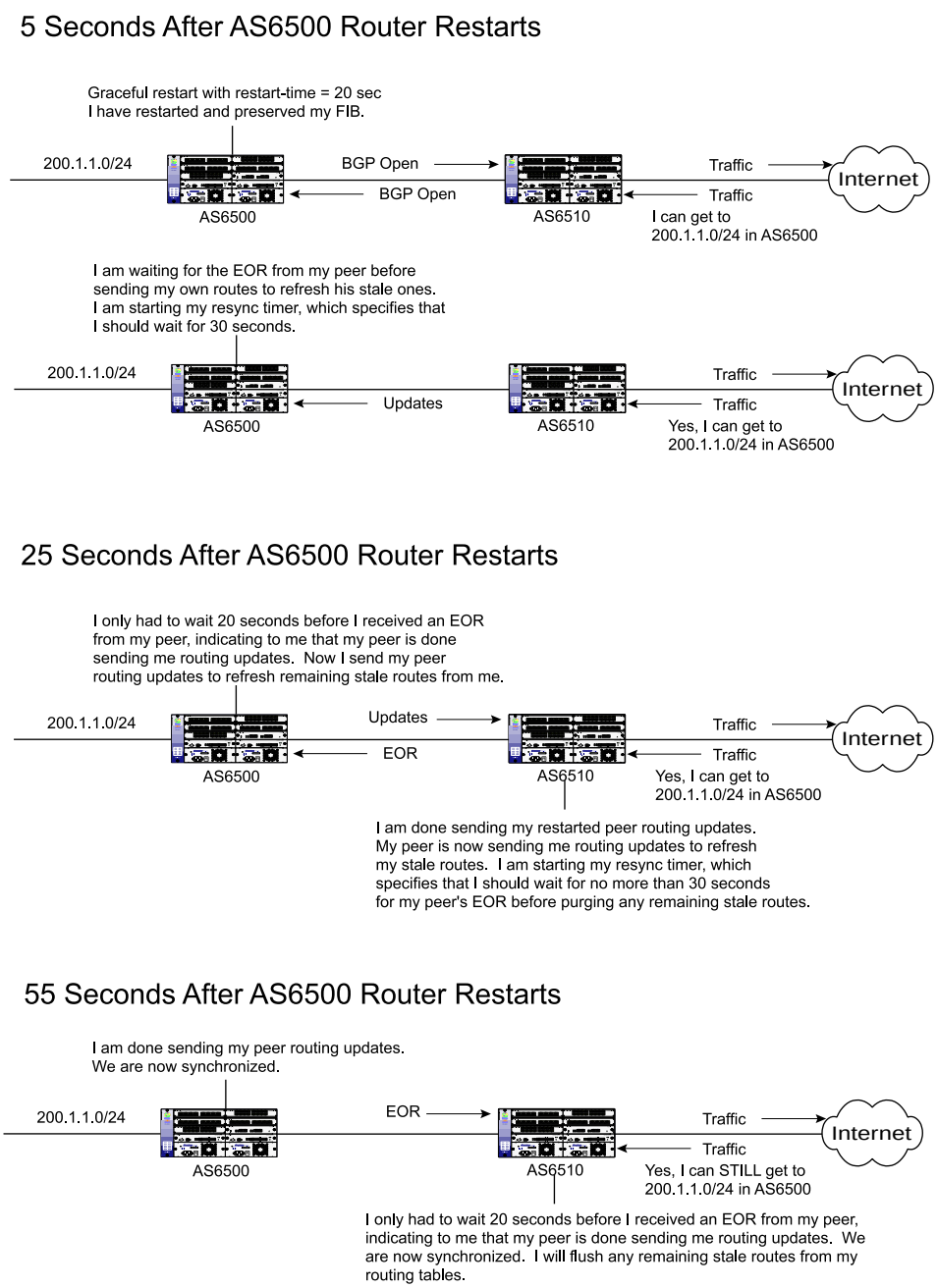


Figure 15-1 BGP Graceful Restart

Timers and Flags

Below is a summary of the timers and flags that BGP graceful restart uses.

Table 15-1 BGP graceful restart timers

Timer	Description
restart-time	This is a user set worst-case estimate of how long it will take the restarting router to recover from a system failure. The RS communicates this to its peers in its own BGP 'Open' message. BGP graceful restart depends on the restarting router being able to recover and reach Established state on a new BGP session with its peers within this time limit. Use the **bgp set peer-group restart-time** and **bgp set peer-host restart-time** commands to set this timer for the peer group or host. When not set, the default value is the Holdtime.
resync-time	This is a global timer set for the BGP routing process on a router. Once the restarted router has established a new BGP session with its peers, the peers use this user-set timer to limit how long they wait for the restarted router to refresh all of its routes before deleting any remaining stale routes from the restarted router. The restarted router also uses this timer to limit how long it waits for the **End-of-RIB** marker from its peers before sending its own routing updates. Use the **bgp set resync-time** command to set this timer globally for the BGP routing process. The minimum value for this timer is 20 seconds. The default is 60 seconds. The maximum is 300 seconds.

Table 15-2 BGP graceful restart flags

Flag	Description
restart-flag	The restarted router sets this flag in its BGP 'Open' message when it is restarted by any means other than user reboot. (The exception to this is when the user manually forces a control-module mastership change using the **system redundancy change-mastership** command.)

Table 15-2 BGP graceful restart flags (Continued)

Flag	Description
forwarding-flag	The restarted router sets this flag in its BGP 'Open' message to indicate that the FIB has been preserved over a restart.
End-of-RIB	An empty update message that is sent by all BGP speakers to indicate the end of routing updates. Both the restarted router and its peers use this marker to determine when the other has completed routing updates after the restart. The restarted router does not commence sending its own updates until it has received this marker from all of its peers, unless the **resync-time** timer expires. The restarted router's peers delete any remaining stale routes from the restarted router when they receive this marker from the restarted router.

Configuration

By default, BGP graceful restart is off. To configure BGP graceful restart on a router, you must do three things:

For each host or peer group:

1. Turn on BGP graceful restart.
2. Set the desired **restart-time**.

For the BGP routing process:

3. Set the desired **resync-time**.

Note After configuring BGP graceful restart, you must reset the peer relationship in order for changes to take effect. Resetting the peer also updates the output of show commands, such as **bgp show neighbor**, to reflect the change in capabilities.

The following example turns on BGP graceful restart for BGP peer *group* 20:

```
RS(config)# bgp set peer-group 20 graceful-restart
```

The following example turns on BGP graceful restart for BGP peer *host* 6.1.2.2, which is in peer group 30:

```
RS(config)# bgp set peer-host 6.1.2.2 group 30 graceful-restart
```

The following example sets the **restart-time** for BGP peer *group* 20 to 180 seconds:

```
RS(config)# bgp set peer-group 20 restart-time 180
```

The following example sets the **restart-time** for BGP peer *host* 6.1.2.2 to 10 seconds:

```
RS(config)# bgp set peer-host 6.1.2.2 group 30 restart-time 10
```

Finally, the following example sets the **resync-time** for the global BGP routing process to 150 seconds:

```
RS(config)# bgp set resync-time 150
```

Example

Viewing the Graceful Restart Process

After turning on tracing using the **ip-router global set trace-state on** command, you can use the **bgp trace local-options normal** command to observe active BGP-specific code-path tracing messages that show the progress of BGP graceful restart during a restart. You can also view BGP graceful restart capability advertisements sent in BGP 'Open' messages using the **bgp trace packet details** command.

Caution Be careful when you turn on tracing, because the amount of messages that result can overwhelm your screen output. To turn off tracing, simply negate the command.

In the above examples, you configured BGP graceful restart on host 6.1.2.2. You also configured the **restart-time** timer for host 6.1.2.2 to 10 seconds and its global BGP **resync-time** timer to 150 seconds.

The following trace output shows BGP graceful restart in action on host 6.1.2.2. The relevant BGP graceful restart messages are in **bold**. Annotated text in *italics* highlight the process.

```
-11-19 09:54:48 bgp_connect_start: peer 6.1.2.1 (External AS 65186)

-11-19 09:54:48 bgp_peer_connected: connection established with 6.1.2.1 (External AS 65186)

-11-19 09:54:48 bgp_set_gr_resync_timer: Start resync timer (failover side)

[We start our global resync timer.]


-11-19 09:54:48 bgp_gr_set_resync_peer: peer 6.1.2.1 (External AS 65186) - waiting for resync.
Now waiting for 1 peers
```

[So far, we are waiting for an EOR from 1 peer, host 6.1.2.1.]

```
-11-19 09:54:48 bgp_send: sending 47 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:48
-11-19 09:54:48 BGP SEND 6.1.2.2+1031 -> 6.1.2.1+179
-11-19 09:54:48 BGP SEND message type 1 (Open) length 47
-11-19 09:54:48 BGP SEND version 4 as 150 holdtime 180 id 1.1.1.2 optional parameter length 18
-11-19 09:54:48 BGP SEND Optional parameter capabilities (18 bytes): MPCap: Inet Uni, Route
Refresh:, Graceful Restart:Restart timer = 10,  restarting. Uni-IP was saved.
```

[We send an OPEN message indicating that we have restarted, preserved IP Unicast routes, and that it should take us less than 10 seconds to reach Established state with our peers again.]

```
-11-19 09:54:48
-11-19 09:54:49 bgp_recv_open: called for peer 6.1.2.1 (External AS 65186)
-11-19 09:54:49
-11-19 09:54:49 BGP RECV 6.1.2.1+179 -> 6.1.2.2+1031
-11-19 09:54:49 BGP RECV message type 1 (Open) length 41
-11-19 09:54:49 BGP RECV version 4 as 65186 holdtime 180 id 1.1.1.1 optional parameter length 12
-11-19 09:54:49 BGP RECV Optional parameter capabilities (12 bytes): MPCap: Inet Uni,
Graceful Restart:Restart timer = 180, not restarting.
```

[We receive an OPEN message from our peer, 6.1.2.1, saying that it did not restart, but will cooperate with our BGP graceful restart by shielding this knowledge from the rest of network.]

```
-11-19 09:54:49 bgp_send: sending 19 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:49 bgp_read_message: 6.1.2.1 (External AS 65186): 0 bytes buffered
-11-19 09:54:49 bgp_recv_open: called for peer 6.1.2.1 (External AS 65186)
-11-19 09:54:49 bgp_set_flash: setting flash/new policy routines for BGP_65186
-11-19 09:54:49 bgp_set_reinit: setting reinit routine for BGP_65186
```

```
-11-19 09:54:49 bgp_recv_change: peer 6.1.2.1 (External AS 65186) receiver changed to
bgp_recv_v4_update
-11-19 09:54:49 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)
-11-19 09:54:49 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 0 octets 0
updates 0 routes
-11-19 09:54:49 bgp_send: sending 19 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 45 octets 1
update 1 route
-11-19 09:54:50 bgp_rt_policy_peer: flash update 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 0 routes ready 0 deferred
-11-19 09:54:50 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 53 octets 1
update 3 routes
-11-19 09:54:50 bgp_rt_policy_peer: flash update 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 0 routes ready 0 deferred
-11-19 09:54:50 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 50 octets 1
update 3 routes
-11-19 09:54:50 bgp_rt_policy_peer: flash update 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 0 routes ready 0 deferred
-11-19 09:54:50 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 49 octets 1
update 2 routes
-11-19 09:54:50 bgp_rt_policy_peer: flash update 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 0 routes ready 0 deferred
-11-19 09:54:50 bgp_recv_v4_update: receiving updates from 6.1.2.1 (External AS 65186)2001
-11-19 09:54:49 %SNMP-I-SENT_TRAP, Sending notification bgpEstablished to management station
-11-19 09:54:50 bgp_recv_v4_update: peer 6.1.2.1 (External AS 65186) received an End of RIB

[Remote peer, host 6.1.2.1, finishes sending us its initial routes.]



-11-19 09:54:50 bgp_recv_v4_update: Resync now waiting for 0 peers

[With this, our count of outstanding EORs now reaches zero, so we stop the resync timer and flush
our outbound routes. We can now send our peer, 6.1.2.1, our Routing Information Base (RIB).]



-11-19 09:54:50 bgp_gr_rt_flush: Flushing active routes on recovering node
-11-19 09:54:50 bgp_delete_gr_resync_timer: Deleting system-wide Graceful Restart resync timer
-11-19 09:54:50 bgp_rt_policy_peer: initial update 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 1 route ready 0 deferred
-11-19 09:54:50 bgp_set_write: initiating write routine for peer 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_send_set: setting task write routine for peer 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_recv_v4_update: done with 6.1.2.1 (External AS 65186) received 93 octets 2
updates 2 routes
-11-19 09:54:50 bgp_write_ready: write ready for peer 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_send_peer: sending to 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_send: sending 45 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_send_v4_eor: peer 6.1.2.1 (External AS 65186), sending End of RIB

[We have finished sending our RIB to peer 6.1.2.1. We conclude our update by sending an EOR.]

-11-19 09:54:50 bgp_send: sending 23 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_rt_send_peer: peer 6.1.2.1 (External AS 65186) sent 1 route no routes deferred
-11-19 09:54:50 bgp_send: sending 19 bytes to 6.1.2.1 (External AS 65186)
-11-19 09:54:50 bgp_set_send: removing task write routine from peer 6.1.2.1 (External AS 65186)
-11-19 09:54:51 bgp_rt_policy_peer: flash update 6.1.2.1 (External AS 65186)
-11-19 09:54:51 bgp_rt_policy_peer: 6.1.2.1 (External AS 65186) 0 routes ready 0 deferred
```

The following trace output shows the changes that take place on host 6.1.2.1 as its peer, host 6.1.2.2, restarts. An ‘Open’ message arrives from host 6.1.2.2 for a session that is already in the Established state. Since BGP graceful restart is also configured on host 6.1.2.1, it starts a new session and marks all routes previously received from its peer as ‘stale’. After the restart, host 6.1.2.1 sends its peer routing updates, and then receives routing updates in return that refresh these stale routes.

Text in bold show the relevant BGP graceful-restart messages. Annotated text in italics highlight the process.

```
-11-19 19:12:58
-11-19 19:12:58 BGP RECV 6.1.2.2+1025 -> 6.1.2.1
-11-19 19:12:58 BGP RECV message type 1 (Open) length 47
-11-19 19:12:58 BGP RECV version 4 as 150 holdtime 180 id 1.1.1.2 optional parameter length 18
-11-19 19:12:58 BGP RECV Optional parameter capabilities (18 bytes): MPCap: Inet Uni, Route
Refresh:, Graceful Restart:Restart timer = 10,  restarting. Uni-IP was saved.

[Our remote peer, host 6.1.2.2, indicates that it is restarting and expects to re-establish a
session with us within 10 seconds.]



-11-19 19:12:58
-11-19 19:12:58 bgp_get_open: peer 6.1.2.2+1025 (proto): unsupported AFI 1 with SAFI 1
-11-19 19:12:58 NOTIFICATION sent to 6.1.2.2 (External AS 150): code 6 (Cease) data

[We close our old BGP session with host 6.1.2.2 by sending it an official NOTIFY message.]



-11-19 19:12:58 bgp_send: sending 21 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:58
-11-19 19:12:58 BGP SEND 6.1.2.1 -> 6.1.2.2+1035
-11-19 19:12:58 BGP SEND message type 3 (Notification) length 21
-11-19 19:12:58 BGP SEND Notification code 6 (Cease) subcode 0 (unused)
-11-19 19:12:58
-11-19 19:12:58 bgp_pp_recv: dropping 6.1.2.2 (External AS 150), connection collision(2) prefers
6.1.2.2+1025 (proto)
-11-19 19:12:58 bgp_peer_close: closing peer 6.1.2.2 (External AS 150), state is 6 (Established)



-11-19 19:12:58 bgp_rt_mark_stale: Route 6.1.2/255.255.255 marked stale

[We mark all old routes from our restarting peer as ‘stale’.]



-11-19 19:12:58 bgp_reset_reinit: resetting reinit routine for BGP_150
-11-19 19:12:58 bgp_reset_flash: resetting flash/new policy routes for BGP_150
-11-19 19:12:58 bgp_init_gr_restart_timer: peer 6.1.2.2 (External AS 150) - starting restart timer

[We start the restart timer, giving our peer 10 seconds to recover and re-establish a session with
us. This is the time that they indicated the restart would take in their last OPEN message to us.]



-11-19 19:12:58 bgp_send: sending 41 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:58
-11-19 19:12:58 BGP SEND 6.1.2.1 -> 6.1.2.2+1025
-11-19 19:12:58 BGP SEND message type 1 (Open) length 41
-11-19 19:12:58 BGP SEND version 4 as 65186 holdtime 180 id 1.1.1.1 optional parameter length 12
-11-19 19:12:58 BGP SEND Optional parameter capabilities (12 bytes): MPCap: Inet Uni, Graceful
Restart:Restart timer = 180, not restarting.
```

[We indicate to our peer that we do support BGP graceful restart and our restart timer is 180 seconds. But we will not be restarting at this time. Since we support BGP graceful restart, our peer knows that we will continue to monitor their status and withhold knowledge of their restart from the rest of the network until the restart timer expires.]

```
-11-19 19:12:58
-11-19 19:12:58 bgp_send: sending 19 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:58 bgp_recv_change: peer 6.1.2.2 (External AS 150) receiver changed to bgp_recv_open
-11-19 19:12:58 bgp_recv_open: called for peer 6.1.2.2 (External AS 150)
-11-19 19:12:58 bgp_delete_gr_restart_timer: peer 6.1.2.2 (External AS 150) - deleting restart
timer
```

[Since our peer, host 6.1.2.2, has sent us an OPEN message to initiate another BGP session, we no longer need the restart timer. So we delete it.]

```
-11-19 19:12:58 bgp_init_peer_resync_timer: peer 6.1.2.2 (External AS 150) - starting resync timer
```

[Now we start a resync timer for this peer, giving them time to finish sending us new updates for their existing routes. If the resync timer expires, we will flush any remaining stale routes from this peer.]

```
-11-19 19:12:58 bgp_set_flash: setting flash/new policy routines for BGP_150
-11-19 19:12:58 bgp_set_reinit: setting reinit routine for BGP_150
-11-19 19:12:58 bgp_recv_change: peer 6.1.2.2 (External AS 150) receiver changed to
bgp_recv_v4_update
-11-19 19:12:58 bgp_recv_v4_update: receiving updates from 6.1.2.2 (External AS 150)
-11-19 19:12:58 bgp_recv_v4_update: done with 6.1.2.2 (External AS 150) received 19 octets 0
updates 0 routes
-11-19 19:12:58 bgp_rt_policy_peer: initial update 6.1.2.2 (External AS 150)
-11-19 19:12:58 bgp_rt_policy_peer: 6.1.2.2 (External AS 150) 11 routes ready 0 deferred
-11-19 19:12:58 bgp_set_write: initiating write routine for peer 6.1.2.2 (External AS 150)
-11-19 19:12:58 bgp_send_set: setting task write routine for peer 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_write_ready: write ready for peer 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_rt_send_peer: sending to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_send: sending 45 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_send: sending 53 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_send: sending 50 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_send: sending 49 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_send: sending 51 bytes to 6.1.2.2 (External AS 150)
-11-19 19:12:59 bgp_rt_send_v4_eor: peer 6.1.2.2 (External AS 150), sending End of RIB
```

[First, we send updates for our routes to our peer. This ensures that they have the most current network knowledge before they send us updates. We indicate that we are finished by sending an End-of-RIB.]

```
-11-19 19:13:00 bgp_send: sending 23 bytes to 6.1.2.2 (External AS 150)
-11-19 19:13:00 bgp_rt_send_peer: peer 6.1.2.2 (External AS 150) sent 11 routes no routes deferred
-11-19 19:13:00 bgp_send: sending 19 bytes to 6.1.2.2 (External AS 150)
-11-19 19:13:00 bgp_set_send: removing task write routine from peer 6.1.2.2 (External AS 150)
-11-19 19:13:00 bgp_recv_v4_update: receiving updates from 6.1.2.2 (External AS 150)
-11-19 19:13:00 bgp_recv_v4_update: - Stale Route 6.1.2/255.255.255 refreshed
-11-19 19:13:00 bgp_recv_v4_update: done with 6.1.2.2 (External AS 150) received 45 octets 1 update
1 route
```

[Now our peer sends us their updates, which allow us to refresh the stale route in our RIB.]

```
-11-19 19:13:00 bgp_recv_v4_update: receiving updates from 6.1.2.2 (External AS 150)
-11-19 19:13:00 bgp_recv_v4_update: peer 6.1.2.2 (External AS 150) received an End or RIB
-11-19 19:13:00 bgp_delete_peer_resync_timer: peer 6.1.2.2 (External AS 150) - deleting resync
timer
```

[When we receive an End-of-RIB from our restarted peer, we know that they are done sending us updates, and we can delete the resync timer for this peer. We delete any remaining stale routes.]

```
-11-19 19:13:00 bgp_recv_v4_update: done with 6.1.2.2 (External AS 150) received 23 octets 1 update
0 routes
-11-19 19:13:01 bgp_recv_v4_update: receiving updates from 6.1.2.2 (External AS 150)
-11-19 19:13:01 bgp_recv_v4_update: done with 6.1.2.2 (External AS 150) received 19 octets 0
updates 0 routes
```

Viewing Stale Routes

You can see how many and which routes are stale on the RS by viewing the summary or detail of routes in the RIB.

View the summary of routes in the RIB with the **`ip-router show summary`** command. The following is a sample display output that shows three stale BGP routes in the RIB:

```
Summary of routes in RIB
------- -- ------ -- ---
Number of Unique routes : 5021
Number of routes        : 5040
Kernel routes           : 0
Direct routes           : 8
Static routes           : 4
RIP routes              : 5000
OSPF routes             : 13
OSPF ASE routes         : 0
ISIS level 1 routes     : 8
ISIS level 2 routes     : 7
BGP routes              : 6
Stale BGP routes        : 3
Other Protocol routes   : 0
Hidden routes           : 10
Install LSP routes      : disabled
```

View detailed information on routes in the RIB with the **`ip-router show rib detail`** command. The following is a sample display output of the details on a stale BGP route in the RIB:

```
172.20.220.154   mask 255.255.255.255
            entries 1    announce 1
            TSI:
                BGP 172.20.217.8 (External AS 65) no metrics
                        Instability Histories:
                        *        BGP    Preference: 170
            *NextHop: 6.1.2.2            Interface: 6.1.2.1(ip2)
            State: <Ext Gateway ActiveU Unicast MergeCandidate Stale>
            Local AS: 65186    Peer AS:   150
            Age: 2:14    Metric: -1    Metric2: 100    Tag: 0
            Task: BGP_150.6.1.2.2
            Announcement bits(2):
                3-KRT 5-BGP_65.172.20.217.8+179
            AS Path: (65186) 150 Incomplete (Id 3)
```

Usage Notes, Rules, and Restrictions

The following items are required for BGP graceful restart:

- As the Internet Engineering Task Force (IETF) points out in its working draft on BGP graceful restart, "[T]here is little benefit deploying BGP Graceful Restart in an AS whose IGPs and BGP are tightly coupled (i.e., BGP and IGPs would both restart), and IGPs have no similar Graceful Restart capability." To reap the full benefits of BGP graceful restart, make sure that you also enable graceful restart on relevant interior gateway protocols (IGPs).
- Since BGP graceful restart relies on the FIB being preserved from the primary control module to the secondary control module, the restarting router must be a dual control module system.

Note Observe the following usage notes on dual control module systems:

1. Both control modules must be fully booted before a BGP graceful restart failover will convey to its peers that it has preserved routes (by setting the **`forwarding-flag`**).

2. Failure on the secondary control module while the primary control module is running has no impact on the BGP sessions running on the primary.

3. When setting the IP address that the RS uses during boot exchange with the trivial file transfer protocol (TFTP) boot server, avoid using the same address on any of the IP interfaces configured in the CLI. On a dual control module system, this can cause ARP/IP-reuse issues as the secondary takes over. (This IP address is set using the **`system set bootprom`** command.)

The following additional notes, rules, and restrictions apply to the BGP graceful restart feature:

A BGP connection can be interrupted in one of three ways:

- manual reboot,
- spontaneous (non-user) reboot, or
- interface going down.

The BGP graceful restart feature is designed primarily to handle the spontaneous reboot. In this case, as discussed before, the restarting router sends an 'Open' message to alert its peers that it is initiating a graceful restart. Upon receiving this message, the peers terminate the BGP connection with the restarting router and start the **restart-time** timer.

BGP behaves differently, however, when the BGP connection is terminated by a manual reboot or interface going down. These two cases are discussed below.

Manual Reboots

- Manually rebooting or clearing BGP connections does not activate BGP graceful restart. On a dual control module system, if the primary is rebooted via the CLI, control is not transferred to the secondary. Only spontaneous crashes or reloads will activate the BGP graceful restart feature. (The exception to this is when the user manually forces a control module mastership change using the **system redundancy change-mastership** command.)

Interface Down

- When the BGP connection is interrupted by an interface going down, unlike in the case of a spontaneous reboot, the peers do not immediately treat the event as indication of a BGP graceful restart. In this situation, the default BGP behavior is to start the **holdtime** timer and wait for the remote peer to re-establish the connection within **holdtime** seconds. Only if this fails to happen and the **holdtime** timer expires do the remote peers recognize a failover and start the **restart-time** timer. So in the case of an interface going down, the restarting router potentially has **holdtime** plus **restart-time** seconds in which to reinitiate a connection after completing a restart.

Single Control Module Systems

- BGP peers send the BGP graceful restart capability advertisement in the 'Open' message to indicate how much of the BGP graceful restart feature the peer supports. Even on a single control module system, this capability is communicated if BGP graceful restart is enabled (either on the host itself or for its peer group). For a single control module system, this advertisement conveys that the RS is unable to preserve peer routes if it crashes, a behavior that conforms to the recommended minimum functionality in the IETF draft, but it will shield the rest of the network in a peer's graceful restart.

Systems Incompatible with BGP Graceful Restart

- If a remote peer does not recognize or understand the BGP graceful restart capability, it may send a BGP 'Notify' message complaining about it, and then terminate the session. The router will disable the graceful restart capability and reattempt to connect.

Simultaneous Restarts

- Recall that the restarted router does not send any routing updates of its own until it has finished listening to the routing updates sent by its peers. It knows when a peer is finished sending updates when it sees a **End-of-RIB** marker from the peer. This waiting ensures that the first updates sent out by a router after it restarts reflect the current network state as completely as possible.

  If two peers restart at the same time, the above rule would *not* cause them to enter a deadlock situation where both peers are waiting for the other to send an **End-of-RIB** marker before sending its own updates. In this case, the BGP graceful restart capability advertisement sent in the 'Open' message by each restarted router when they try to re-establish a BGP session will have the **restart-flag** set. The **restart-flag** indicates to each peer that the other has also restarted. This causes them not to wait for the other's **End-of-RIB** marker before sending their own updates, thus avoiding a deadlock.

No Dynamic Renegotiation of BGP Graceful Restart Capabilities

- Currently, BGP peers do not dynamically renegotiate graceful restart capabilities. If any peer is *configured* with BGP graceful restart *after* it has established BGP session(s), those session(s) must be re-established before the graceful restart configuration will take affect on all of the configured router's peers. This is because peers rely on BGP 'Open' messages to advertise their graceful restart capabilities. 'Open' messages are only sent to establish or re-establish sessions.
- For the same reason, *changes* made to a peer's BGP graceful restart capabilities *after* it has established BGP session(s) are not dynamically propagated to its peers. For those changes to take, you must reset all established BGP peering relationships after making any changes to the BGP graceful restart capabilities of either peer.
- Resetting the peer also updates the output of show commands, such as **`bgp show neighbor`**, to reflect changes in capabilities.

Routing Instances

- The RS does not supports BGP graceful restart on a per-routing instance basis. The RS only supports BGP graceful restart on the main instance. The commands in this section configure BGP graceful restart on the main instance only.

Multiprotocol-BGP

- The RS does not supports Multiprotocol-BGP (MP-BGP) graceful restart.

15.2.7 Propagating Routes to Peers

The RS allows you to control which routes the BGP routing process propagates to a BGP peer using the **`bgp advertise network`** command.

By default, this command creates and propagates aggregate routes. To propagate non-aggregate routes, use the **`no-aggregate`** option in this command.

Configuration Examples

The following example configures the BGP routing process to create and advertise an *aggregate* route of 1.2.0.0/16 to its peers.

```
RS(config)# bgp advertise network 1.2.0.0/16
```

The following example configures the BGP routing process to create and advertise a *non-aggregate* (exact) route of 1.2.0.0/16 to its peers.

```
RS(config)# bgp advertise network 1.2.0.0/16 no-aggregate
```

Usage Notes, Rules, and Restrictions

Observe the following usage guidelines when using this feature:

- The route you wish to propagate must exist in the routing table (either as a static route or a route learned from an interior gateway protocol (IGP).)
- If you provide no mask, you must specify the address as a natural network. The BGP process does not perform automatic truncation.

  For example, if you wish to propagate network 10.1.1.0/24, but you do not specify a mask, as the following illustrates, a route for 10.0.0.0/8, the natural network of 10.1.1.0, would be propagated.

```
RS(config)# bgp advertise network 10.1.1.0
```

  To propagate network 10.1.1.0/24 instead of 10.0.0.0/8, you must specify the mask, as the following illustrates.

```
RS(config)# bgp advertise network 10.1.1.0/24
```

The next two rules only apply to IGP routes. Routes learned via BGP are not influenced by the **`bgp advertise network`** command.

- If you do specify a mask, that mask must match the IGP route mask *exactly.* For example, if you have a static route for network 11.1.1.0/24, a **`bgp advertise network`** command for 11.1.0.0/16 would not result in any route propagation. The **`bgp advertise network`** command must be for network 11.1.1.0/24 as well.
- As a corollary of the above, when natural masks are enforced for IGP and static routes, the address you supply to the **`bgp advertise network`** command must be consistent with the IGP masks.

15.2.8 Route Selection

When one BGP route has multiple gateways (sources), the RS uses the following selection criteria, in the order presented, to select among them. The chosen route is installed in the FIB, and the remaining backup routes are installed in the RIB.

BGP Route Selection Rules

1. Prefer the route with the *smallest* preference number.
2. Prefer the route with the *highest* BGP local preference number (Local_Pref).
3. Prefer the route with the *shortest* AS path.
4. Compare the AS path Origin value. Prefer the route with an ‘IGP’ origin, then an ‘EGP’ origin, and finally, an ‘incomplete’ origin.
5. Prefer the route with the *smallest* multi-exit discriminator (MED). This step is only performed if the candidate routes all originated from the same neighboring AS.
6. Prefer the route whose next_hop is closer, with respect to the IGP distance.
7. Prefer the route from an EBGP source over one from an IBGP source.

8. Prefer the route from the router with the lowest router ID.

15.2.9 Using AS-Path Regular Expressions

AS path regular expressions are used as one of the parameters for determining which routes are accepted and which routes are advertised. An AS path regular expression is a regular expression where the alphabet is the set of AS numbers from 1 through 65535.

The following wildcards and operators can be used to build a regular expression:

" "	(quotation marks)	Encloses an AS path regular expression
()	(parentheses)	Used to group expressions within the AS path regular expression
.	(period)	Matches any AS number
*****	(asterisk	Matches zero or more repetitions of the preceding expression
+	(plus sign)	Matches one or more repetitions of the preceding expression
?	(question mark)	Matches zero or one repetition of the preceding expression
	(space)	And
|	(vertical line)	Or

A set of AS numbers is delimited by the **[]** (square bracket) symbols. The set can be a list of AS numbers separated by a space or a range of AS numbers separated by a **-** (dash). A **^** (circumflex) prepended to a list of AS numbers means that valid members are those AS numbers that are *not* in the list. Note that a null or empty string is not an instance in the alphabet, therefore the set [^700] does not match an empty string.

For example:

"."	Matches any single AS number as the AS path.
"700.*"	Matches all AS paths coming from an AS that starts with 700.
".* [^700 800]"	Matches all paths that do not end with AS numbers 700 and 800 and have at least one AS.
"[1-64999]*"	Matches a path that has only valid exterior AS numbers.
"700 800 [^100]"	Matches AS numbers 700 and 800 and any other AS number except 100.
"700 800 [^100]?"	Matches AS numbers 700 and 800 and any other AS number except 100, or no additional AS numbers in the path.
"700|800"	Matches either 700 or 800 with no additional AS numbers in the path.

AS Path Regular Expression Examples

In the following example, routes from AS 61972 and 61678 that have traversed AS 3561 are imported. The first command creates an AS path regular expression with the identifier 'mciAspath' to match AS paths that include AS 3561. The next two commands specify the AS path regular expression identifier to match routes imported from AS 61972 and 61678.

```
ip-router policy create aspath-regular-expression mciAspath  ".* 3561 .*"
ip-router policy create bgp-import-source bisrc61972 aspath-regular-expression
    mciAspath autonomous-system 61972 origin any
ip-router policy create bgp-import-source bisrc61678 aspath-regular-expression
     mciAspath autonomous-system 61678 origin any
ip-router policy import source bisrc61972 network all preference 160
ip-router policy import source bisrc61678 network all preference 170
```

To import all routes (.* matches all AS paths) with the default preference:

```
ip-router policy create aspath-regular-expression allAspaths ".*"
ip-router policy create bgp-import-source allOthers aspath-regular-expression
     allAspaths origin any sequence-number 20
ip-router policy import source allOthers network all
```

To export all active routes from 284 or 813 or 814 or 815 or 816 or 3369 or 3561 to autonomous system 64800.

```
ip-router policy create aspath-regular-expression someAspath
     ".*(284|813|814|815|816|3369|3561) .*"
ip-router policy create bgp-export-destination to-64800 autonomous-system 64800
ip-router policy create aspath-export-source allRoutes aspath-regular-expression
     someAspath origin any protocol all
ip-router policy export destination to-64800 source allRoutes network all
```

15.2.10 Using the AS Path Prepend Feature

When BGP compares two advertisements of the same prefix that have differing AS paths, the default action is to prefer the path with the lowest number of transit AS hops; in other words, the preference is for the shorter AS path length. The AS path prepend feature is a way to manipulate AS path attributes to influence downstream route selection. AS path prepend involves inserting the originating AS into the beginning of the AS prior to announcing the route to the exterior neighbor.

Lengthening the AS path makes the path less desirable than would otherwise be the case. However, this method of influencing downstream path selection is feasible only when comparing prefixes of the same length because an instance of a more specific prefix always is preferable.

On the RS, the number of instances of an AS that are put in the route advertisement is controlled by the **`as-count`** option of the **`bgp set peer-host`** command.

The following is an example:

```
#
# insert two instances of the AS when advertising the route to this peer
#
bgp set peer-host 194.178.244.33 group nlnet as-count 2
#
# insert three instances of the AS when advertising the route to this
# peer
#
bgp set peer-host 194.109.86.5 group webnet as-count 3
```

Notes on Using the AS Path Prepend Feature

Use the **as-count** option for external peer-hosts only.

If the **as-count** option is entered for an active BGP session, routes will ***not*** be resent to reflect the new setting. To have routes reflect the new setting, you must restart the peer session. To do this:

1. Enter Configure mode.
2. Negate the command that adds the peer-host to the peer-group. (If this causes the number of peer-hosts in the peer-group to drop to zero, then you must also negate the command that creates the peer group.)
3. Exit Configure mode.
4. Re-enter Configure mode.
5. Add the peer-host back to the peer-group.

If the **as-count** option is part of the startup configuration, the above steps are unnecessary.

15.2.11 Creating BGP Confederations

In a BGP autonomous system, each iBGP router has to peer with all other iBGP routers over a direct link. This is known as a "routing mesh." In a large AS, the number of peers and the number links between peers can be significant.

Creating a BGP confederation reduces the number of links between BGP peers by consolidating small autonomous systems into a larger AS. To BGP routers that are not part of the confederation, sub-AS's appear as a single AS with a single, externally-visible AS number. Each BGP confederation router uses its internal, sub-AS number to communicate with peers that are members of its confederation. Therefore, a router in a BGP confederation must be configured with both the AS number of the confederation (the externally-visible AS number) as well as the number of its sub-AS.

Note Confederation AS numbers are not exchanged in BGP ‘Open’ messages. This means that if two routers are meant to be in the same confederation but one of them is configured with an incorrect confederation AS number, BGP still establishes peering between them.

To avoid this errant behavior when configuring confederations, make sure that the correct confederation AS number is configured on all routers.

In Figure 15-2, a BGP confederation with the AS number 64801 consists of sub-AS's 100, 101, 102, and 103. BGP routers outside the confederation see only AS 64801; they cannot see the sub-AS's. For example, R2 resides in AS 1000. When R2 communicates with R1, it sees R1 as part of AS 64801; R2 does not know that R1 is a member of AS 102.

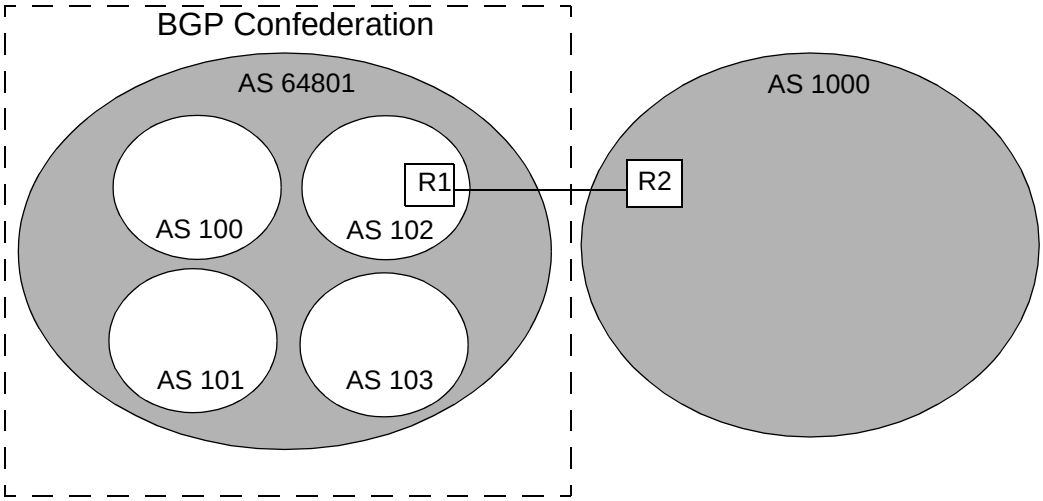


Figure 15-2 BGP confederation

BGP confederations assume that a single IGP runs across the entire confederation. BGP sessions between routers that are in the same confederation but in different sub-AS's are also known as EIBGP sessions. EIBGP sessions are similar to EBGP sessions with the following differences:

- Local preference attributes in learned routes are allowed to traverse sub-AS's instead of being ignored. For example, in Figure 15-2, R1 establishes a local preference value for a route advertised by R2. AS 102 must be allowed to advertise the local preference value to the other sub-AS's in the confederation.
- The next hop attribute is set by the first-hop router in the confederation and is then allowed to traverse sub-AS's without being changed.
- To prevent looping of routing announcements within the confederation, the AS-path attribute uses two new path segment types: as-confed-set and as-confed-sequence are similar to the as-set and as-sequence attributes, except they are only used *within* a confederation.

The confederation structure is hidden whenever an EBGP session takes place between a router in a sub-AS and a router outside the confederation. In Figure 15-2, when R1 advertises a route to R2, R1 strips any as-confed-sequence and as-confed-set path segments from the AS-path attribute and adds AS 64801 to the AS-path attribute. When R1 learns a route from R2 and advertises the route via EBGP to a router in another member AS, R1 adds the as-confed-sequence path segment to the AS-path attribute and includes its sub-AS number (102) in the new path segment.

15.2.12 Removing Private Autonomous System Numbers

Private autonomous system numbers are those in the range 64512 to 65535. They are frequently assigned by ISPs to conserve AS numbers. When private AS's are used, private AS numbers must be stripped from the AS Path of routes before those routes are exported to EBGP peers.

Configuration

You can configure the RS to strip private AS numbers from updates sent by EBGP peers.

The following example turns on private AS stripping for an EBGP peer *group*:

```
RS(config)# bgp set peer-group 20 remove-private-as
```

The following example turns on private AS stripping for EBGP peer *host* 1.1.1.1 in peer group 30:

```
RS(config)# bgp set peer-host 1.1.1.1 group 30 remove-private-as
```

Usage Notes, Rules, and Restrictions

The following notes, rules, and restrictions apply to these commands and the private AS stripping feature:

- If the option is set for the group, it applies to all group members. If set for a peer host, it only applies to that peer. When the option is set for the group, you cannot override with a different peer-host setting.
- These commands are only permitted on EBGP peers or groups. Private AS's cannot be removed for IBGP peers.
- With this feature enabled, when an outbound update contains a sequence of only private AS numbers, the sequence is dropped before sending, allowing you to hide private AS's from external, public AS BGP listeners.
- When an outbound update contains both private and public AS numbers, BGP considers this to be a configuration error and does nothing.
- Private AS numbers are only removed from the portion of the AS path that the EBGP peer receives. After stripping the private AS numbers, as usual, the EBGP peer prepends its own AS number to the AS path, regardless of whether its own AS is public or private.
- When using this feature with confederations, BGP removes the private AS numbers only if they follow the confederation portion of the AS path. AS numbers are never stripped from the confederation portion of the AS path, which is treated according to the above rules.

Example

In the following example, two EBGP peering relationships exist: R1 with R2, and R2 with R3. R1 is in private AS 64550, while R2 and R3 belong to public AS's 222 and 150.

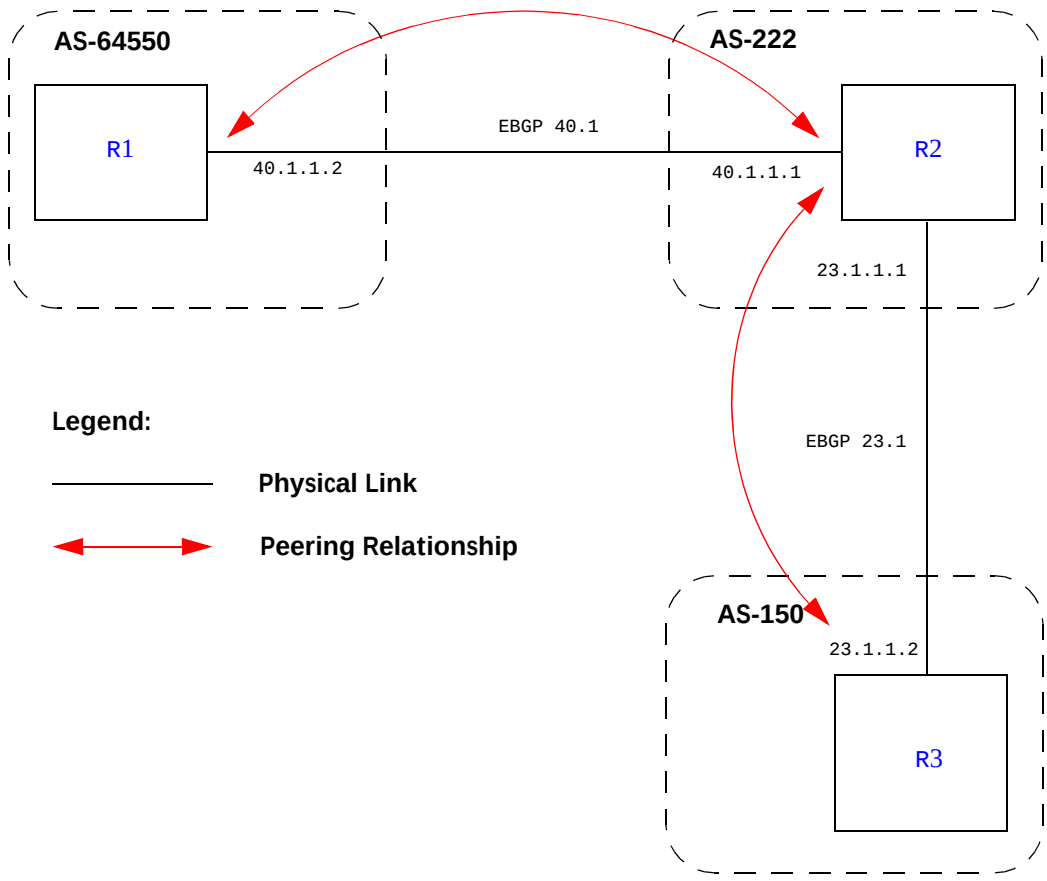


Figure 15-3 Sample BGP private AS number stripping example

To enable private AS stripping, the CLI configuration for router R2 contains the following line:

```
bgp set peer-host 23.1.1.1 group A remote-private-as
```

In this example, R1 redistributes one static route for the 182.1.1/24 network to BGP, which announces the route to R2:

```
R1# bgp show peer-host 40.1.1.1 advertised-routes
BGP table : Local router ID is 159.1.1.5
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network           Next Hop        Metric LocPrf Path
   -------           --------        ------ ------ ----
*> 182.1.1/24        40.1.1.2                      64550 ?
```

As the following two **show** commands display, R2 receives the route containing R1's private AS number and prepends its own AS, 200, to the route:

```
R2# bgp show peer-host 40.1.1.2 all-received-routes
BGP table : Local router ID is 159.1.1.15
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Path
   -------            --------        ------ ------ ----
*> 182.1.1/24         40.1.1.2                      (222) 64550 ?
```

```
R2# bgp show routes all
BGP table : Local router ID is 159.1.1.15
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Path
   -------            --------        ------ ------ ----
*> 182.1.1/24         40.1.1.2                 100 (222) 64550 ?
```

R2 then propagates this route to R3. With the private AS stripping feature disabled, R2 would forward this route to R3 with an AS path of '222 64550'. However, with private AS stripping enabled, R2 forwards this route to R3 with an AS path of '222'.

```
R2# bgp show peer-host 23.1.1.2 advertised-routes
BGP table : Local router ID is 159.1.1.15
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Path
   -------            --------        ------ ------ ----
*> 182.1.1/24         23.1.1.1                      222 ?
```

Note While R2 strips R1's AS number, it prepends its own AS to the AS path it is preparing to send. In this case, R2 belongs to a public AS. But even if R2 belonged to a private AS, the AS path it advertises would still contain its own AS number because BGP does not advertise routes with empty AS paths.

Finally, as the following two **show** commands display, the route that R3 receives from R2 does not contain R1's private AS number, only R2's.

As mentioned above, even if R2 belongs to a private AS, the route the R3 receives from R2 would still contain R2's private AS number, just not R1's.

```
R3# bgp show peer-host 23.1.1.1 all-received-routes
BGP table : Local router ID is 159.1.1.30
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Path
   -------            --------        ------ ------ ----
*> 182.1.1.1/24       23.1.1.1                      (150) 222 ?
```

```
R3# bgp show routes all
BGP table : Local router ID is 159.1.1.30
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Path
   -------            --------        ------ ------ ----
*> 182.1.1.1/24       23.1.1.1                 100 (150) 222 ?
```

15.2.13 Creating Community Lists

A community is a group of destinations that share a common property. A community is defined by the administrator of the autonomous system and can be used as a way of filtering BGP routes.

To create and define community lists on an RS, enter the following commands in Configure mode:

Create a community list.	**ip-router policy create community-list** <*identifier*> <*community-string*>
Add communities to a community list.	**ip-router policy add community-list** <*identifier*> <*community-string*>

Community lists can be specified in route maps. Communities in a BGP route can be compared to the community list. The communities in the route can either be a superset of the specified communities or they can exactly match the specified communities. Route map actions can include removing the community attribute from a route, setting the value of the community attribute, adding communities to the route, or deleting communities from the route. With route maps, you can also specify keywords for certain well-known communities, listed below.

The **bgp show routes** command shows communities associated with a BGP route.

Standard Communities

For standard communities, the <*community-string*> is in the form "<*AS-identifier*>:<*community-identifier*>," where:

<AS-identifier>

Specifies the AS number, a value in the range 1 through 65535.

<community-identifier>

Specifies the community identifier, a number in the range 0 through 65535.

Extended Communities

For extended communities, the *<community-string>* is in the form "*<type>* : {*<AS-identifier>* | *<IPaddr>*} : *<id>*," where:

<type>

Specifies the type of this extended community. You can specify one of the following:

`target` The target community identifies the destination to which a route is going.

`origin` The origin community identifies where a route originated.

<AS-identifier> | *<IPaddr>*

Specifies either an AS number or an IP address prefix.

<id>

Specifies the ID of this extended community, which identifies the local provider. This ID is two bytes long when used with IP addresses and four bytes long when used with AS numbers.

Well-Known Communities

The following lists keywords for specifying well-known communities.

Table 15-3 Keywords for well-known communities defined in RFC 1997

Keyword	Community	Description
`no_export`	65535:65281	Do not advertise to EBGP peers.
`no_advertise`	65535:65282	Do not advertise to any peer.
`no_export_subconfed`	65535:65283	Do not advertise to EBGP peers, including peers inside a BGP confederation.

15.2.14 Using Route Maps

A route map defines conditions and actions to be taken for:

- importing routes from BGP peer groups or hosts
- exporting routes to BGP peer groups or hosts
- redistributing routes from any routing protocol into BGP
- redistributing routes from BGP into any other routing protocol (only conditions are considered, actions have no effect)

A route map consists of one or more *conditions* that define BGP information and the *action* to be taken when the condition is met. Each condition tells the RS to either permit or deny route that matches the criteria specified in the route map. To be imported, exported, or redistributed, a route needs to meet the conditions of a configured route map. Note that a route can meet the conditions of a route map where the keyword **deny** is explicitly specified; in this case, the route will *not* be imported, exported, or redistributed.

Note For route maps to take effect, the RS must be selecting BGP for the route. Make sure that BGP preference is set lower than the preference of other protocols on the RS.

To create a route map, enter the following command in Configure mode:

Create a route map.	**route-map** <*number-or-string*> **permit** <*sequence-number*> <*match-criteria*> <*action*> **route-map** <*number-or-string*> **deny** <*sequence-number*> <*match-criteria*>

In the following example, when the prefix of a route matches the network address 15.4.0.0, the route is redistributed with a next hop of 12.10.4.13.

```
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-next-hop 12.10.4.13
```

You can specify the configured route map for an export, import, or redistribution policy (with the **ip-router policy export**, **ip-router policy import**, or **ip-router policy redistribute** command). You can also specify the route map when exporting routes to or importing routes from a peer group or a peer host; this is done with the **route-map-in** (import) or **route-map-out** (export) option of the **bgp set peer-group** or **bgp set peer-host** commands. For example, the following commands apply the route map with the identifier ’1’ for routes that are exported to the peer group ’pub1’:

```
bgp create peer-group pub1 type external autonomous-system 3937
bgp add peer-host 14.2.3.23 group pub1
bgp set peer-group pub1 route-map-out 1
```

For EBGP, route maps can be applied to *either* a peer group or a peer host. For IBGP, the **route-map-out** option *cannot* be used to set a value for a peer host. If you need to control the export of routes to specific IBGP peers, create a peer group for each peer and define a group-specific policy. This restriction does not apply to the **route-map-in** option.

Defining Match Criteria in Route Map Conditions

Match criteria in a route map condition describes the BGP route information that is to be filtered. The following match criteria can be specified:

- Route prefix, as specified by a previously-defined route filter or network specification
- Source protocol of the route
- Next hop for the route, as specified by a previously-defined route filter
- BGP local preference value
- BGP Multi Exit Discriminator (MED) value
- BGP origin attribute
- aspath regular expression
- Communities in route are either part of or exactly the same as previously-defined community list

When you create a route map, you specify a route map *identifier*. You can create multiple conditions with the same identifier. The sequence number in the route map definition specifies the order of a particular condition in relation to other conditions with the same route map identifier. The condition with the lowest sequence number is applied first. If the specified condition is not met, the condition with the next-lowest sequence number is applied. A route is checked against conditions in this manner until a set of route map conditions is met or there are no more conditions. If a route does not meet any configured route map conditions, the route is not imported, exported, or redistributed.

If a route matches a condition, it is imported, exported, or redistributed, or not, based on the **`permit`** or **`deny`** keyword. All subsequent conditions are ignored. Consequently, conditions that are more specific should always have lower sequence numbers than conditions that are less specific. In the following example, when the prefix of a route matches the network address 15.4.0.0, the route is redistributed with a next hop of 12.10.4.13. But when the prefix of a route matches the network address 13.0.0.0/16, the route is not imported, exported, or distributed.

```
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-next-hop 12.10.4.13
route-map 1 deny 2 match-prefix network 15.0.0.0/8
```

Defining Actions in Route Map Conditions

When a route matches a condition configured with the **`permit`** keyword, the specified action is taken. The following actions can be specified:

- Set the next hop for the route
- Set the local preference for the route
- Set the MED for the route
- Set the original for the route
- Prepend the AS number to the AS path for the route
- Remove or add communities to the route
- Set the preference for the route
- Specify the traffic bucket number for the route (see Section 15.3.11, *"BGP Accounting Examples,"* for more information)

15.2.15 Using MPLS LSPs To Resolve BGP Next Hop

Basic Functionality

The RS allows you to use MPLS LSPs to resolve BGP next hops.

Normally, MPLS LSPs are not installed in the RIB or FIB, which makes MPLS LSPs inaccessible for routing.

Using the **ip-router global set install-lsp-routes bgp** command, you can grant BGP *exclusive* access to these LSP routes, allowing BGP to use MPLS paths, *in addition to* other routes in the FIB, in resolving next hops. Under this scheme, MPLS routes are only installed in the LSP RIB and other routing protocols are not permitted to use them.

MPLS LSP routes contain the host address for each LSP's egress router. Using these tunnels, an ingress router can forward packets to the destination egress router.

Without this capability, BGP must rely on conventional routes in the FIB for transport to its next hop. With this capability, if a BGP next hop happens to be the egress point on a pre-defined MPLS tunnel, BGP can utilize this tunnel to forward to the next hop.

Configuration

By default, routing protocols must rely on conventional routes in the FIB for routing. Use the **ip-router global set install-lsp-routes on** command to install LSP routes in the Internet Unicast RIB and permit *all* routing protocols to utilize these routes for calculating IGP shortcuts. Due to their default preference, installing LSP routes in the Internet Unicast RIB usually means that they are also selected to be installed in the Unicast FIB.

```
RS(config)# ip-router global set install-lsp routes on
```

Use the **ip-router global set install-lsp-routes bgp** command to grant BGP *exclusive* access to LSP routes, allowing BGP to use MPLS paths, *in addition to* other routes in the FIB, in resolving next hops. Under this scheme, MPLS routes are only installed in the LSP RIB and other routing protocols are not permitted to use them.

```
RS(config)# ip-router global set install-lsp routes bgp
```

Usage Notes, Rules, and Restrictions

Choosing Between Conventional FIB Routes and LSP Routes

- When BGP has a choice between conventional routes and LSP routes, the route with the highest preference is chosen. You can affect this choice by using the **<igp> set preference** command to specify desired IGP preferences and the **mpls set label-switch-path preference** command to specify preferences for MPLS LSPs.

Caution Using these commands overrides default preferences and may alter the normal routing process.

- If multiple paths with identical preferences exist between conventional routes and LSP routes, BGP prefers LSP routes over conventional routes.

LSP Removed or Fails

- When BGP selects an LSP to use, it installs that LSP into its forwarding engine as the transport method of choice for the associated next hop. If the LSP is removed or fails, the path is removed from the LSP RIB and from BGP's forwarding engine. This forces BGP to select another path to the next hop from all available routes, including other LSP routes.

15.2.16 BGP QoS

Basic Functionality

The RS allows you to set the Differentiated Services Code Point (DSCP) values based on route-map matching conditions.

Used in Quality of Service (QoS), Differentiated Services is a new model where you can specify the relative priority with which traffic should be treated by intermediate systems. Defined in RFCs 2474 and 2475, Differentiated Services increases the number of priority levels you can specify by allocating 4 additional bits from the IP header for marking priority.

Eight bits comprise the expanded priority field in the IP header, but only six bits (bits 2 to 7) are used for Differentiated Services, allowing for a DSCP range of 0 to 63. The six DSCP bits and two Additional bits are summarized below:

Table 15-4 DSCP bit layout

Bit	Purpose	Usage
0	Reserved	**Other**
1	Cost	
2	Reliability	**DSCP Bits**
3	Throughput	
4	Delay	
5	Precedence	
6		
7		

Configuration

Use the **`route-map`** command to set DSCP values based on matching conditions. The following example sets the DSCP bits for all traffic from the well-known community 'no-export' to 29.

A DSCP decimal value of 29 is represented by the following binary configuration in DSCP bits

:

Table 15-5 DSCP bit example

Binary Value	0	1	1	1	0	1
Bit	**7**	**6**	**5**	**4**	**3**	**2**
Purpose	Precedence			Delay	Throughput	Reliability

```
RS(config)# route-map 1 permit 10 match-community-list no-export set-dscp 29
```

Usage Notes, Rules, and Restrictions

Note Currently, the DSCP feature only works with route-map in, not route-map out.

15.2.17 Using BGP Accounting

BGP accounting allows you to differentiate and tally IP traffic by assigning traffic indexes based on route map specifications to an input interface. Using BGP accounting, you can collect statistics (and apply billing) according to route-specific traffic. For example, domestic, international, terrestrial, satellite, and other traffic can be identified and accounted for on a per-customer basis.

You can also choose to count route-specific traffic according to Differentiated Services Code Point (DSCP) values (previously known as Type of Service values) in the packets. This allows you to collect and bill on a service level for each customer.

Enabling BGP Accounting

In the following example, BGP packets with the standard community value “11:11” are forwarded from router R1 to router R2. On router R2, a traffic index is set up to keep the counts of these packets.

On the router R1, create a standard community list for the community value “11:11.” For example, the following commands create a route-map for the community value “11:11”:

```
route-map 1 permit 1 set-community-list “11:11”
bgp set peer-group r2 route-map-out 1 out-sequence 1
```

On the router R2, do the following:

1. Create a standard community list to match the community value “11:11” and define a route-map that matches the community with a specific traffic index. For example, the following commands create a standard community list with the community value “11:11” and define a route map to match the community list with the traffic index ’1’:

```
ip-router policy create community-list list1 "11:11"
route-map 1 permit 1 match-community-list list1 set-traffic-index 1
```

2. Enable the route-map on incoming traffic from router R1. For example, the following command applies the route-map ’1’ to routes imported from the peer group ’r1’:

```
bgp set peer-group r1 route-map-in 1 in-sequence 1
```

3. Add the interface name to the BGP accounting table. For example, the following command enables BGP accounting on the interface ’customerA’:

```
ip enable bgp-actg-on customerA
```

4. Start BGP accounting. For example, to start collecting statistics for the service levels (DSCP values) of specific traffic routes:

```
ip bgp-accounting start dscp-accounting
```

To start collecting BGP traffic statistics for specific traffic routes:

```
ip bgp-accounting start accounting
```

Refer to Section 15.3.11, *"BGP Accounting Examples,"* to see detailed example configurations.

Displaying BGP Accounting Information

Use the **`bgp-actg`** option with the **`ip show interfaces`** command to display BGP accounting information on a per-interface basis. For example:

```
rs# ip show interfaces int1 bgp-actg

Interface:int1
Bucket Packets       Bytes
0      0             0
1      111           14430
```

The example output shown above displays the number of packets and bytes sent at the interface 'int1'. The user has sent 111 packets of size 130 bytes that fell into bucket 1 (traffic index 1). For example, a ping request (with a data size of 84 bytes) was sent 111 times.

Use the **`ip clear bgp-actg`** command to clear BGP accounting statistics. For example:

```
rs# ip clear bgp-actg

rs# ip show interfaces int1 bgp-actg

Interface:int1
Bucket Packets       Bytes
0      0             0
1      0             0
```

If you need to see which traffic index is assigned to a route, run the following Diagnostic mode command:

```
rs# diag
rs? ip find route 14.1.0.0
     route to: 14.1.0.0
         mask: (255) ffff ffff
    interface: toRTR2
      gateway: 12.1.1.2
  aspath info: Next Hop - 0, Origin -  0
traffic index: 1
        flags: <UP,GATEWAY>
recvpipe  sendpipe  ssthresh  rtt,msec    rttvar  hopcount      mtu
   16384     16384         0         0     e
```

Usage Notes, Rules, and Restrictions

Note Do not use BGP accounting with the hardware routing table (HRT) feature. BGP accounting only tracks usage statistics of routes in memory, not those in the HRT.

15.3 BGP CONFIGURATION EXAMPLES

This section presents sample configurations illustrating BGP features. The following features are demonstrated:

- BGP peering
- Internal BGP (IBGP)
- External BGP (EBGP) multihop
- BGP community attribute
- BGP local preference (local_pref) attribute
- BGP Multi-Exit Discriminator (MED) attribute
- EBGP aggregation
- Route reflection
- BGP confederation
- Route map

- BGP accounting

15.3.1 BGP Peering Session Example

The router process used for a specific BGP peering session is known as a *BGP speaker*. A single router can have several BGP speakers. Successful BGP peering depends on the establishment of a neighbor relationship between BGP speakers. The first step in creating a BGP neighbor relationship is the establishment of a TCP connection (using TCP port 179) between peers.

A BGP 'Open' message can then be sent between peers across the TCP connection to establish various BGP variables (BGP Version, AS number (ASN), Holdtime, BGP identifier, and optional parameters). Upon successful completion of the BGP Open negotiations, BGP Update messages containing the BGP routing table can be sent between peers.

BGP does not require a periodic refresh of the entire BGP routing table between peers. Only incremental routing changes are exchanged. Therefore, each BGP speaker is required to retain the entire BGP routing table of their peer for the duration of the peer's connection.

Note To request route database refreshes from peer-hosts, first add **`bgp set peer-host/peer-group route refresh`** to the active configuration. Then, use the **`bgp clear peer-host soft-inbound`** command. The **`soft-inbound`** option causes the peer-host to re-send it routing information without breaking and then re-establishing the connection to the peer-host.

BGP "keepalive" messages are sent between peers periodically to ensure that the peers stay connected. If one of the routers encounters a fatal error condition, a BGP notification message is sent to its BGP peer, and the TCP connection is closed.

Figure 15-4 illustrates a sample BGP peering session:

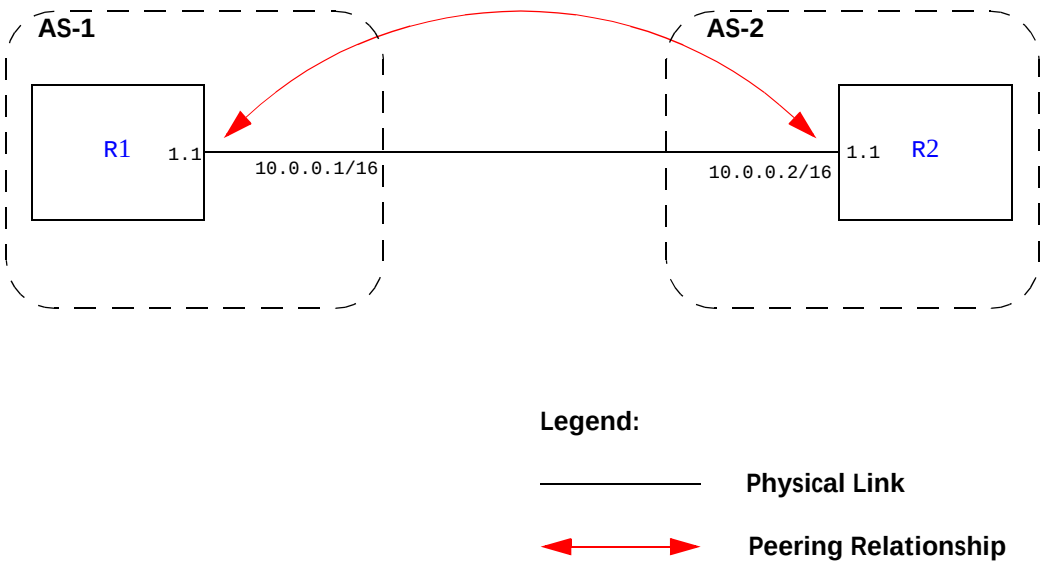


Figure 15-4 Sample BGP peering session

The CLI configuration for router R1 is as follows:

```
interface create ip et.1.1 address-netmask 10.0.0.1/16 port et.1.1
#
# Set the AS of the router
#
ip-router global set autonomous-system 1
#
# Set the router ID
#
ip-router global set router-id 10.0.0.1
#
# Create EBGP peer group pg1w2 for peering with AS 2
#
bgp create peer-group pg1w2 type external autonomous-system 2
#
# Add peer host 10.0.0.2 to group pg1w2
#
bgp add peer-host 10.0.0.2 group pg1w2
bgp start
```

The CLI configuration for router R2 is as follows:

```
interface create ip et.1.1 address-netmask 10.0.0.2/16 port et.1.1
ip-router global set autonomous-system 2
ip-router global set router-id 10.0.0.2
bgp create peer-group pg2w1 type external autonomous-system 1
bgp add peer-host 10.0.0.1 group pg2w1
bgp start
```

15.3.2 IBGP Configuration Example

Connections between BGP speakers within the same AS are referred to as internal links. A peer in the same AS is an internal peer. Internal BGP is commonly abbreviated IBGP; external BGP is EBGP.

An AS that has two or more EBGP peers is referred to as a multihomed AS. A multihomed AS can “transit” traffic between two ASs by advertising to one AS routes that it learned from the other AS. To successfully provide transit services, all EBGP speakers in the transit AS must have a consistent view of all of the routes reachable through their AS.

Multihomed transit ASs can use IBGP between EBGP-speaking routers in the AS to synchronize their routing tables. IBGP requires a full-mesh configuration; all EBGP speaking routers must have an IBGP peering session with every other EBGP speaking router in the AS.

An IGP, like OSPF, could possibly be used instead of IBGP to exchange routing information between EBGP speakers within an AS. However, injecting full Internet routes (50,000+ routes) into an IGP puts an expensive burden on the IGP routers. Additionally, IGPs cannot communicate all of the BGP attributes for a given route. It is, therefore, recommended that an IGP not be used to propagate full Internet routes between EBGP speakers. IBGP should be used instead.

IBGP Routing Group Example

An IBGP routing group uses the routes of an interior protocol to resolve forwarding addresses. An IBGP routing group will determine the immediate next hops for routes by using the next hop received with a route from a peer as a forwarding address, and using this to look up an immediate next hop in an IGP’s routes. Such groups support distant peers, but need to be informed of the IGP whose routes they are using to determine immediate next hops. This implementation comes closest to the IBGP implementation of other router vendors.

You should use the IBGP routing group as the mechanism to configure the RS for IBGP. If the peers are directly connected, then IBGP using group-type Internal can also be used. Note that for running IBGP using group-type routing you must run an IGP such as OSPF to resolve the next hops that come with external routes. You could also use protocol **any** so that all protocols are eligible to resolve the BGP forwarding address.

Figure 15-5 shows a sample BGP configuration that uses the routing group type.

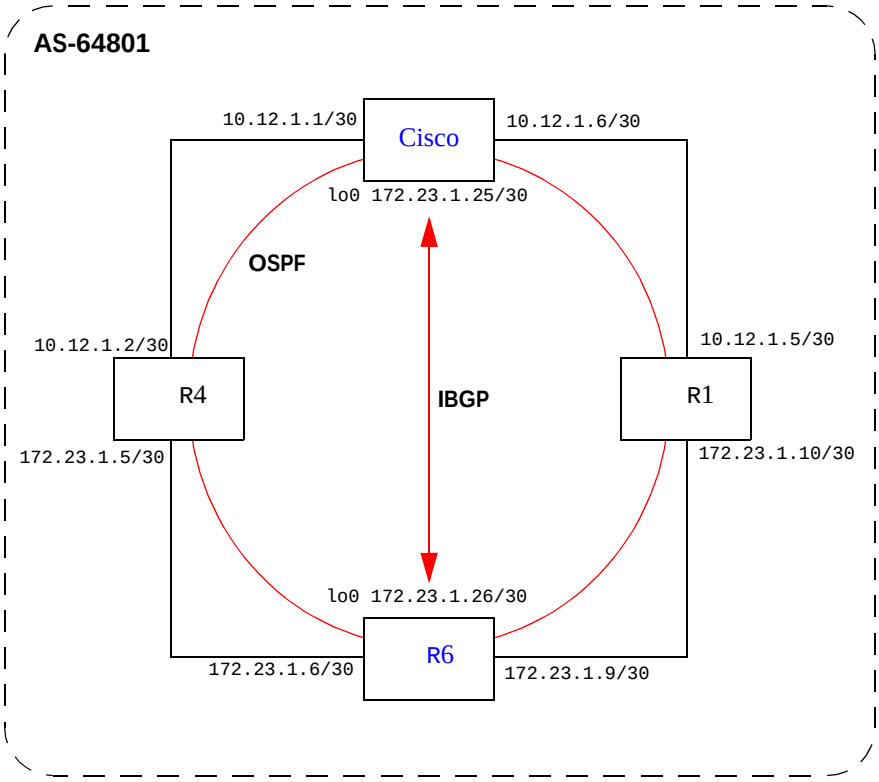


Figure 15-5 Sample IBGP configuration (routing group type)

In this example, OSPF is configured as the IGP in the autonomous system. The following lines in the router R6 configuration file configure OSPF:

```
#
# Create a secondary address for the loopback interface
#
interface add ip lo0 address-netmask 172.23.1.26/30
ospf create area backbone
ospf add interface to-R4 to-area backbone
ospf add interface to-R1 to-area backbone
#
# This line is necessary because we want CISCO to peer with our loopback
# address.This will make sure that the loopback address gets announced
# into OSPF domain
#
ospf add stub-host 172.23.1.26 to-area backbone cost 1
ospf set interface to-R4 priority 2
ospf set interface to-R1 priority 2
ospf set interface to-R4 cost 2
ospf start
```

The following lines in the Cisco router configure OSPF:

```
The following lines on the CISCO 4500 configures it for OSPF.
router ospf 1
 network 10.12.1.1 0.0.0.0 area 0
 network 10.12.1.6 0.0.0.0 area 0
 network 172.23.1.14 0.0.0.0 area 0
```

The following lines in the R6 set up peering with the Cisco router using the routing group type.

```
# Create a internal routing group.
bgp create peer-group ibgp1 type routing autonomous-system 64801 proto any
interface all
# Add CISCO to the above group
bgp add peer-host 172.23.1.25 group ibgp1
# Set our local address. This line is necessary because we want CISCO to
# peer with our loopback
bgp set peer-group ibgp1 local-address 172.23.1.26
# Start BGP
bgp start
```

The following lines on the Cisco router set up IBGP peering with router R6.

```
router bgp 64801
!
! Disable synchronization between BGP and IGP
!
 no synchronization
neighbor 172.23.1.26 remote-as 64801
!
! Allow internal BGP sessions to use any operational interface for TCP
! connections
!
 neighbor 172.23.1.26 update-source Loopback0
```

15.3.3 EBGP Multihop Configuration Example

EBGP Multihop refers to a configuration where external BGP neighbors are not connected to the same subnet. Such neighbors are logically, but not physically connected. For example, BGP can be run between external neighbors across non-BGP routers. Some additional configuration is required to indicate that the external peers are not physically attached.

This sample configuration shows External BGP peers, R1 and R4, which are not connected to the same subnet.

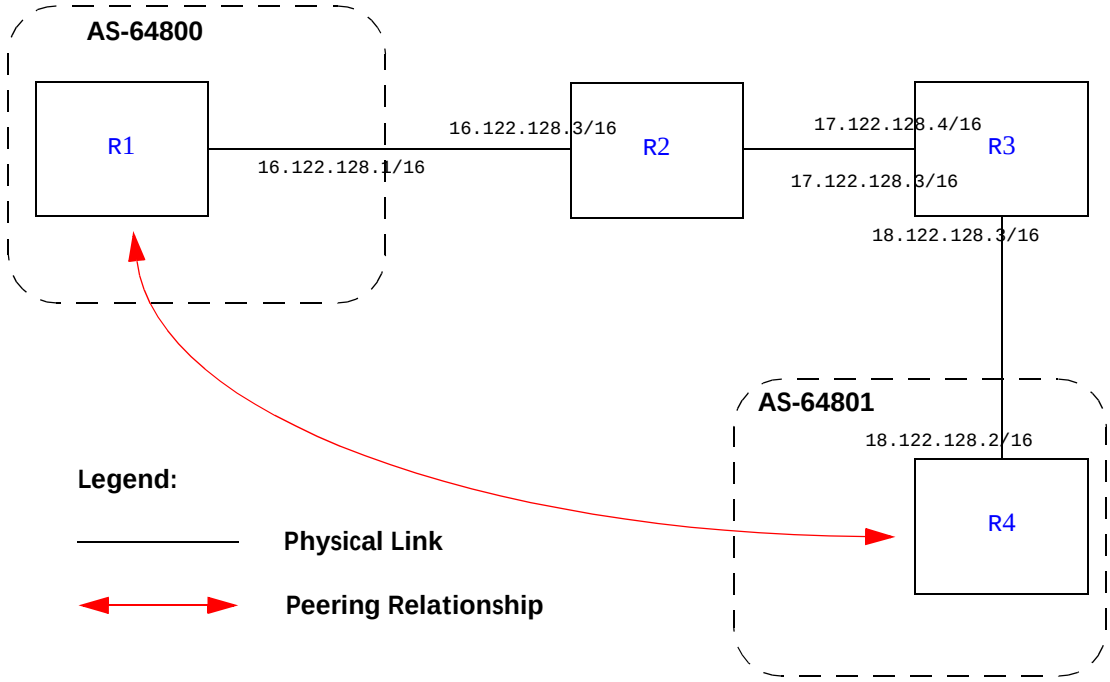


Figure 15-6 Sample EBGP configuration (multihop)

The CLI configuration for router R1 is as follows:

```
bgp create peer-group ebgp_multihop autonomous-system 64801 type external
bgp add peer-host 18.122.128.2 group ebgp_multihop
!
! Specify the multihop option, which indicates EBGP multihop.
!
bgp set peer-host 18.122.128.2 group ebgp_multihop multihop
```

The CLI configuration for router R2 is as follows:

```
interface create ip to-R1 address-netmask 16.122.128.3/16 port et.1.1
interface create ip to-R3 address-netmask 17.122.128.3/16 port et.1.2
#
# Static route needed to reach 18.122.0.0/16
#
ip add route 18.122.0.0/16 gateway 17.122.128.4
```

The CLI configuration for router R3 is as follows:

```
interface create ip to-R2 address-netmask 17.122.128.4/16 port et.4.2
interface create ip to-R4 address-netmask 18.122.128.4/16 port et.4.4
ip add route 16.122.0.0/16 gateway 17.122.128.3
```

The CLI configuration for router R4 is as follows:

```
bgp create peer-group ebgp_multihop autonomous-system 64801 type external
bgp add peer-host 18.122.128.2 group ebgp_multihop
!
! Specify the multihop option, which indicates EBGP multihop.
!
bgp set peer-host 18.122.128.2 group ebgp_multihop multihop
```

15.3.4 Community Attribute Example

The following configuration illustrates the BGP community attribute. Community is specified as one of the parameters in the **`optional attributes list`** option of the **`ip-router policy create`** command.

Figure 15-7 shows a BGP configuration where the specific community attribute is used. Figure 15-8 shows a BGP configuration where the well-known community attribute is used.

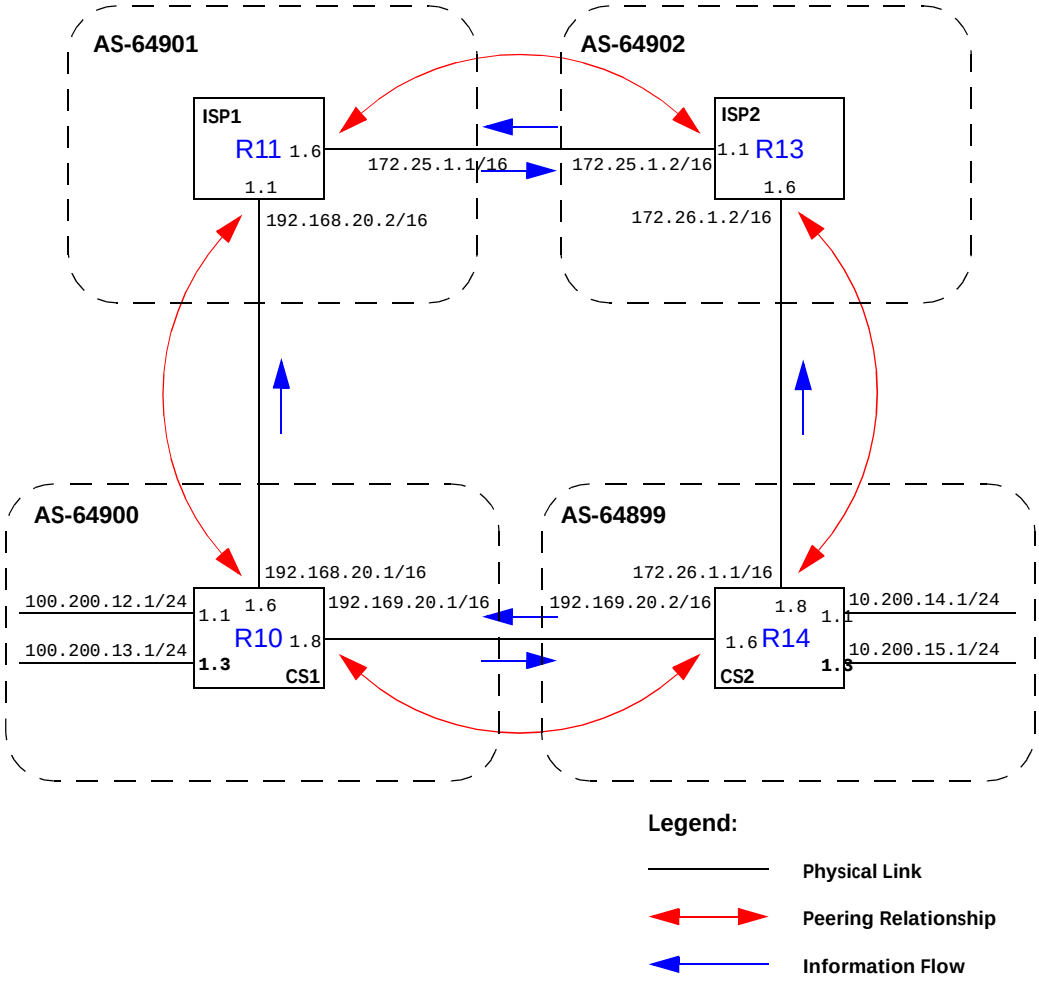


Figure 15-7 Sample BGP configuration (specific community)

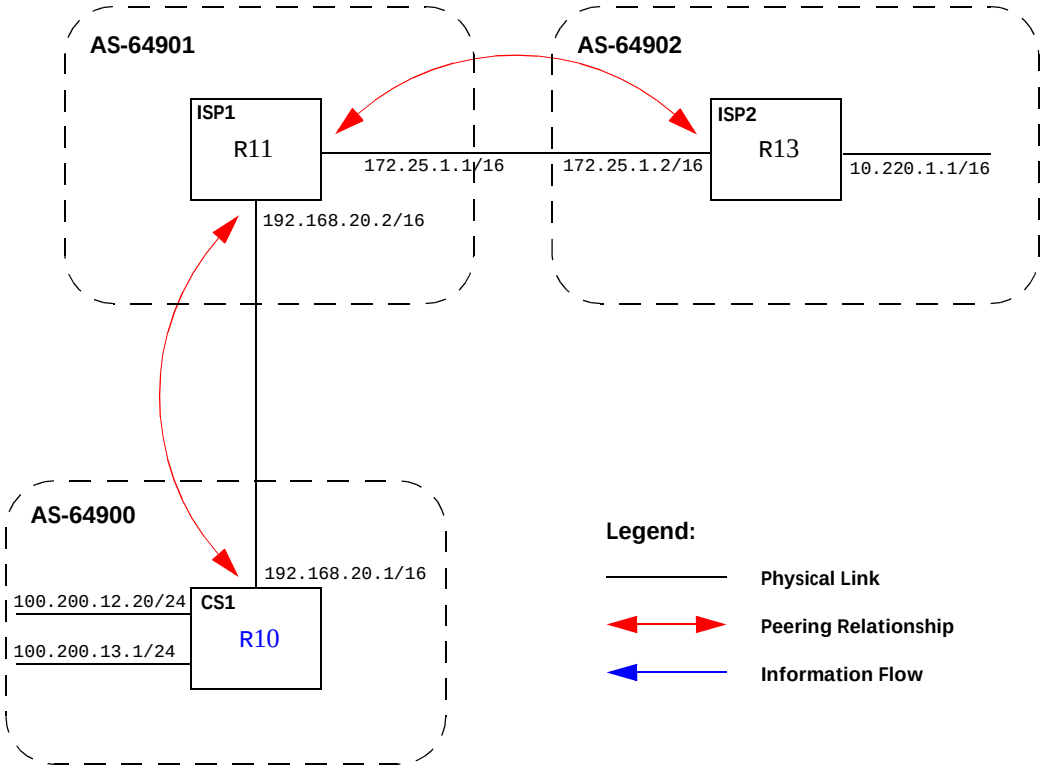


Figure 15-8 Sample BGP configuration (well-known community)

The Community attribute can be used in three ways:

1. In a BGP Group statement: Any packets sent to this group of BGP peers will have the communities attribute in the BGP packet modified to be this communities attribute value from this AS.
2. In an Import Statement: Any packets received from a BGP peer will be checked for the community attribute. The **`optional-attributes-list`** option of the **`ip-router policy create`** command allows the specification of an import policy based on optional path attributes (for instance, the community attribute) found in the BGP update. If multiple communities are specified in the **`optional-attributes-list`** option, only updates carrying all of the specified communities will be matched. If **`well-known-community none`** is specified, only updates lacking the community attribute will be matched.

   Note that it is quite possible for several BGP import clauses to match a given update. If more than one clause matches, the first matching clause will be used; all later matching clauses will be ignored. For this reason, it is generally desirable to order import clauses from most to least specific. An import clause without an **`optional-attributes-list`** option will match any update with any (or no) communities.

In Figure 15-7, router R11 has the following configuration:

```
#
# Create an optional attribute list with identifier color1 for a community
# attribute (community-id 160 AS 64901)
#
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64901
#
# Create an optional attribute list with identifier color2 for a community
# attribute (community-id 155 AS 64901)
#
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64901
#
# Create a BGP import source for importing routes from AS 64900 containing the
# community attribute (community-id 160 AS 64901). This import source is given an
# identifier 901color1 and sequence-number 1.
#
ip-router policy create bgp-import-source 901color1 optional-attributes-list
    color1 autonomous-system 64900 sequence-number 1
ip-router policy create bgp-import-source 901color2 optional-attributes-list
    color2 autonomous-system 64900 sequence-number 2
ip-router policy create bgp-import-source 901color3 optional-attributes-list
    color1 autonomous-system 64902 sequence-number 3
ip-router policy create bgp-import-source 901color4 optional-attributes-list
    color2 autonomous-system 64902 sequence-number 4
#
# Import all routes matching BGP import source 901color1 (from AS 64900 having
# community attribute with ID 160 AS 64901) with a preference of 160
#
ip-router policy import source 901color1 network all preference 160
ip-router policy import source 901color2 network all preference 155
ip-router policy import source 901color3 network all preference 160
ip-router policy import source 901color4 network all preference 155
```

In Figure 15-7, router R13 has the following configuration:

```
ip-router policy create optional-attributes-list color1 community-id 160
   autonomous-system 64902
ip-router policy create optional-attributes-list color2 community-id 155
   autonomous-system 64902
ip-router policy create bgp-import-source 902color1 optional-attributes-list
   color1 autonomous-system 64899 sequence-number 1
ip-router policy create bgp-import-source 902color2 optional-attributes-list
   color2 autonomous-system 64899 sequence-number 2
ip-router policy create bgp-import-source 902color3 optional-attributes-list
   color1 autonomous-system 64901 sequence-number 3
ip-router policy create bgp-import-source 902color4 optional-attributes-list
   color2 autonomous-system 64901 sequence-number 4
ip-router policy import source 902color1 network all preference 160
ip-router policy import source 902color2 network all preference 155
ip-router policy import source 902color3 network all preference 160
ip-router policy import source 902color4 network all preference 155
```

3. In an Export Statement: The **optional-attributes-list** option of the **ip-router policy create bgp-export-destination** command may be used to send the BGP community attribute. Any communities specified with the **optional-attributes-list** option are sent in addition to any received in the route or specified with the group.

   In Figure 15-7, router R10 has the following configuration:

```
#
# Create an optional attribute list with identifier color1 for a community
# attribute (community-id 160 AS 64902)
#
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64902
#
# Create an optional attribute list with identifier color2 for a community
# attribute (community-id 155 AS 64902)
#
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64902
#
# Create a direct export source
#
ip-router policy create direct-export-source 900toanydir metric 10
#
# Create BGP export-destination for exporting routes to AS 64899 containing the
# community attribute (community-id 160 AS 64902). This export-destination has an
# identifier 900to899dest
#
ip-router policy create bgp-export-destination 900to899dest autonomous-system
    64899 optional-attributes-list color1
ip-router policy create bgp-export-destination 900to901dest autonomous-system
    64901 optional-attributes-list color2
#
# Export routes to AS 64899 with the community attribute (community-id 160 AS
# 64902)
#
ip-router policy export destination 900to899dest source 900toanydir network all
ip-router policy export destination 900to901dest source 900toanydir network all
```

   In Figure 15-7, router R14 has the following configuration:

```
ip-router policy create bgp-export-destination 899to900dest autonomous-system
    64900 optional-attributes-list color1
ip-router policy create bgp-export-destination 899to902dest autonomous-system
    64902 optional-attributes-list color2
ip-router policy create bgp-export-source 900toany autonomous-system 64900 metric
    10
ip-router policy create optional-attributes-list color1 community-id 160
    autonomous-system 64901
ip-router policy create optional-attributes-list color2 community-id 155
    autonomous-system 64901
ip-router policy export destination 899to900dest source 899toanydir network all
ip-router policy export destination 899to902dest source 899toanydir network all
```

Any communities specified with the **optional-attributes-list** option are sent in addition to any received with the route or associated with a BGP export destination.

The community attribute may be a single community or a set of communities. A maximum of 10 communities may be specified.

The community attribute can take any of the following forms:

- Specific community

  The specific community consists of the combination of the AS-value and community ID.

- Well-known-community no-export

  Well-known-community no-export is a special community which indicates that the routes associated with this attribute must not be advertised outside a BGP confederation boundary.

  For example, router R10 in Figure 15-8 has the following configuration:

```
ip-router policy create optional-attributes-list noexport
    well-known-community no-export
ip-router policy create bgp-export-destination 900to901dest
    autonomous-system 64901 optional-attributes-list noexport
ip-router policy export destination 900to901dest source 900to901src
    network all
ip-router policy export destination 900to901dest source 900to901dir
    network all
```

- Well-known-community no-advertise

  Well-known-community no-advertise is a special community indicating that the routes associated with this attribute must not be advertised to other bgp peers. A packet can be modified to contain this attribute and passed to its neighbor. However, if a packet is received with this attribute, it cannot be transmitted to another BGP peer.

- Well-known-community no-export-subconfed

  Well-known-community no-export-subconfed is a special community indicating the routes associated with this attribute must not be advertised to external BGP peers. (This includes peers in other members' autonomous systems inside a BGP confederation.)

  A packet can be modified to contain this attribute and passed to its neighbor. However, if a packet is received with this attribute, the routes (prefix-attribute pair) cannot be advertised to an external BGP peer.

- Well-known-community none

  This is not actually a community, but rather a keyword that specifies that a received BGP update is only to be matched if no communities are present. It has no effect when originating communities.

Notes on Using Communities

When originating BGP communities, the set of communities that is actually sent is the union of the communities received with the route (if any), those specified in group policy (if any), and those specified in export policy (if any).

When receiving BGP communities, the update is only matched if all communities specified in the **optional-attributes-list** option of the **ip-router policy create** command are present in the BGP update. (If additional communities are also present in the update, it will still be matched.)

15.3.5 Local Preference Examples

There are two methods of specifying the local preference with the **`bgp set peer-group`** command:

- Setting the **`local-pref`** option. This option can only be used for the internal, routing, and IGP group types and is not designed to be sent outside of the AS.
- Setting the **`set-pref`** option, which allows the RS IP routing code (ROSRD) to set the local preference to reflect ROSRD's own internal preference for the route, as given by the global protocol preference value. Note that in this case, local preference is a function of the ROSRD preference and set-pref options.

Figure 15-9 shows a BGP configuration that uses the BGP local preference attribute in a sample BGP configuration with two autonomous systems. All traffic exits Autonomous System 64901 through the link between router R13 and router R11. This is accomplished by configuring a higher local preference on router R13 than on router S12. Because local preference is exchanged between the routers within the AS, all traffic from AS 64901 is sent to R13 as the exit point.

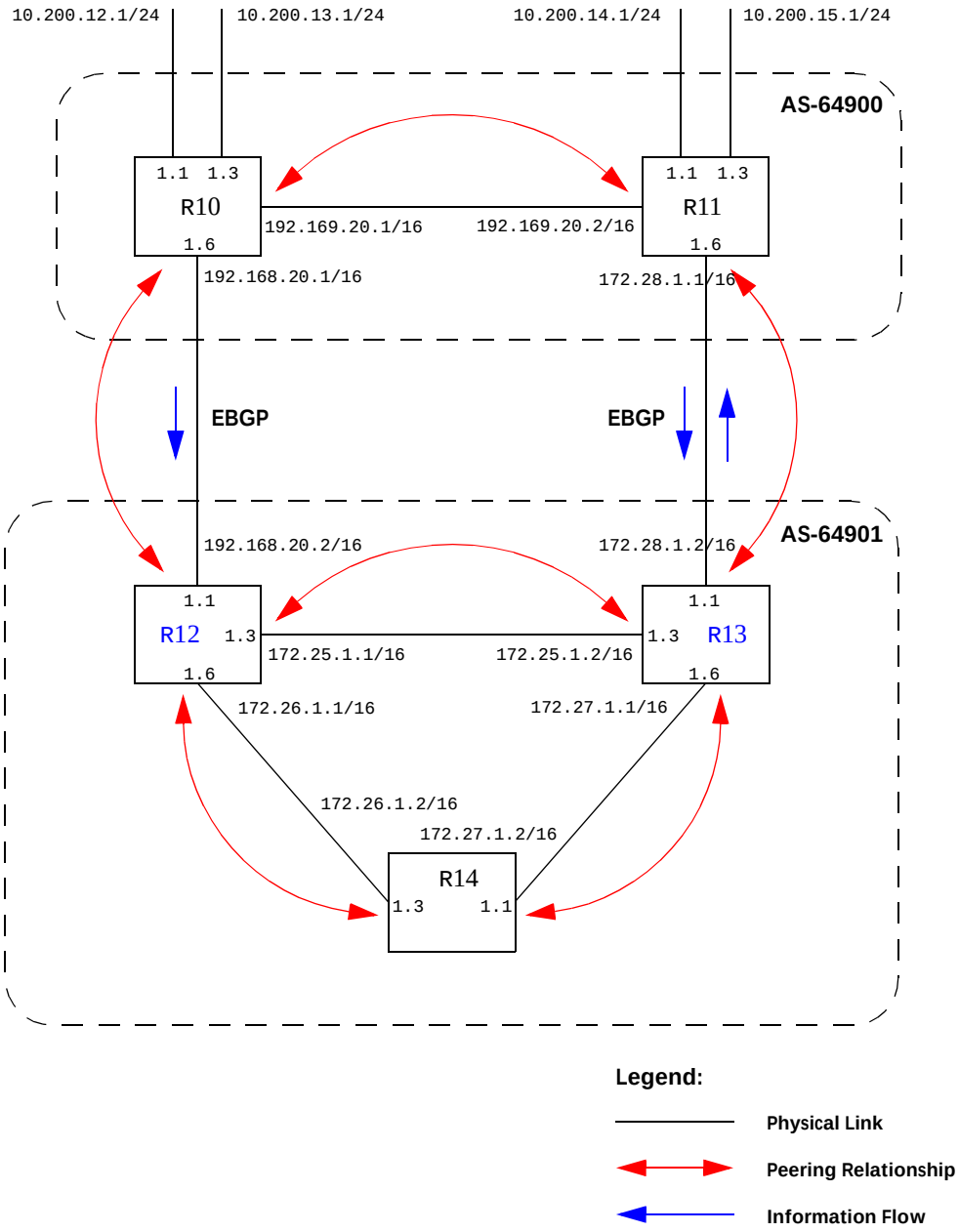


Figure 15-9 Sample BGP configuration (local preference)

The following sections explain how to configure the local preference using the **`local-pref`** and the **`set-pref`** options.

Using the local-pref Option

For router R12's CLI configuration file, **`local-pref`** is set to 194:

```
bgp set peer-group as901 local-pref 194
```

For router R13, **`local-pref`** is set to 204.

```
bgp set peer-group as901 local-pref 204
```

Using the set-pref Option

The formula used to compute the local preference is as follows:

Local_Pref = 254 – (global protocol preference for this route) + set-pref metric

Note A value greater than 254 will be reset to 254. ROSRD will only send Local_Pref values between 0 and 254.

In a mixed ROSRD and non-ROSRD (or non-GateD) network, the non-ROSRD IBGP implementation may send Local_Pref values that are greater than 254. When operating a mixed network of this type, you should make sure that all routers are restricted to sending Local_Pref values in the range metric to 254.

In router R12's CLI configuration file, the import preference is set to 160:

```
#
# Set the set-pref metric for the IBGP peer group
#
bgp set peer-group as901 set-pref 100
ip-router policy create bgp-import-source as900 autonomous-system 64900 preference
    160
```

Using the formula for local preference [Local_Pref = 254 - (global protocol preference for this route) + metric], the Local_Pref value put out by router R12 is 254 - 160+100 = 194.

For router R13, the import preference is set to 150. The Local_Pref value put out by router R13 is 254 - 150+100 = 204.

```
ip-router policy create bgp-import-source as900 autonomous-system 64900 preference
    150
```

Note the following when using the **`set-pref`** option:

- All routers in the same network that are running ROSRD and participating in IBGP should use the **`set-pref`** option, and the **`set-pref`** metric should be set to the same value.

  For example, in Figure 15-9, routers R12, R13, and R14 have the following line in their CLI configuration files:

```
bgp set peer-group as901 set-pref 100
```

- The value of the **`set-pref`** option should be consistent with the import policy in the network.

  The metric value should be set high enough to avoid conflicts between BGP routes and IGP or static routes. For example, if the import policy sets ROSRD preferences ranging from 170 to 200, a set-pref metric of 170 would make sense. You should set the metric high enough to avoid conflicts between BGP routes and IGP or static routes.

15.3.6 Multi-Exit Discriminator Attribute Example

Multi-Exit Discriminator (MED) is a BGP attribute that affects the route selection process. MED is used on external links to discriminate among multiple exit or entry points to the same neighboring AS. All other factors being equal, the exit or entry point with a lower metric should be preferred. If received over external links, the MED attribute may be propagated over internal links to other BGP speakers within the same AS. The MED attribute is never propagated to other BGP speakers in neighboring autonomous systems.

Figure 15-10 shows a sample BGP configuration where the MED attribute has been used.

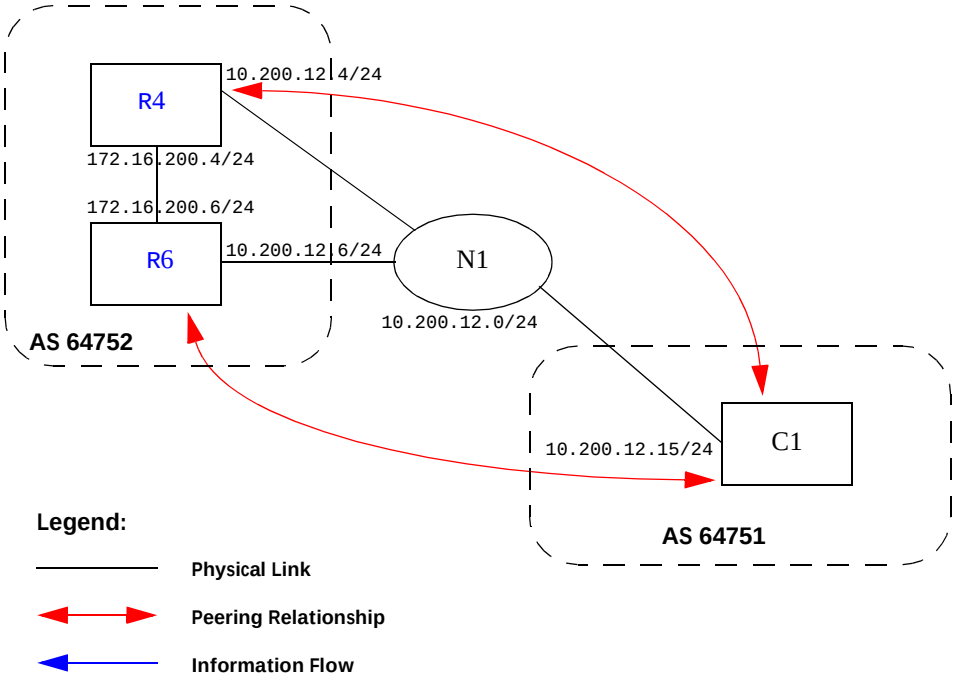


Figure 15-10Sample BGP configuration (MED attribute)

Routers R4 and R6 inform router C1 about network 172.16.200.0/24 through External BGP (EBGP). Router R6 announced the route with a MED of 10, whereas router R4 announces the route with a MED of 20. Of the two EBGP routes, router C1 chooses the one with a smaller MED. Thus router C1 prefers the route from router R6, which has a MED of 10.

Router R4 has the following CLI configuration:

```
bgp create peer-group pg752to751 type external autonomous-system 64751
bgp add peer-host 10.200.12.15 group pg752to751
#
# Set the MED to be announced to peer group pg752to751
#
bgp set peer-group pg752to751 metric-out 20
```

Router R6 has the following CLI configuration:

```
bgp create peer-group pg752to751 type external autonomous-system 64751
bgp add peer-host 10.200.12.15 group pg752to751
bgp set peer-group pg752to751 metric-out 10
```

15.3.7 EBGP Aggregation Example

Figure 15-11 shows a simple EBGP configuration in which one peer is exporting an aggregated route to its upstream peer and restricting the advertisement of contributing routes to the same peer. The aggregated route is 212.19.192.0/19.

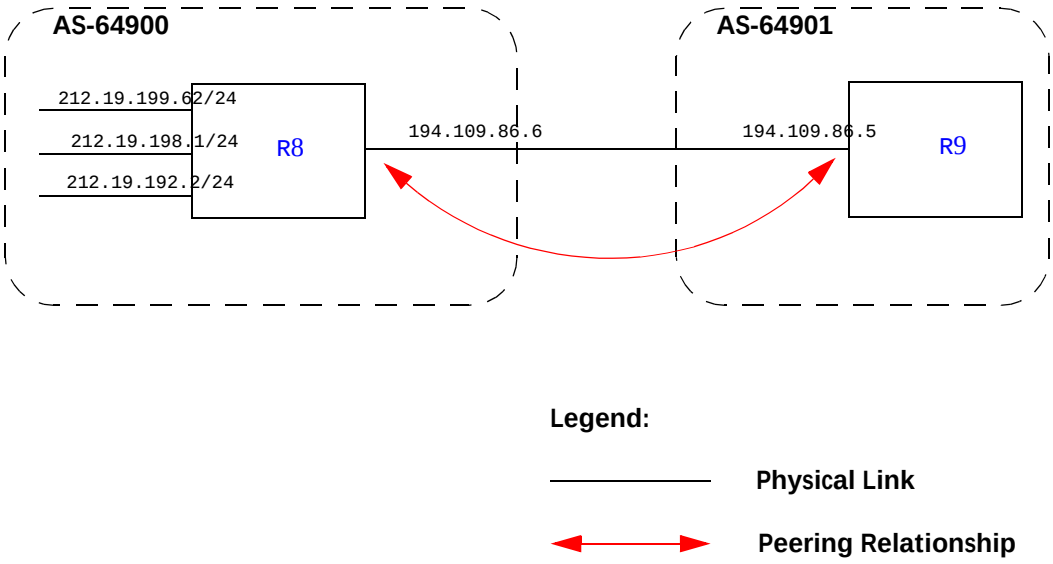


Figure 15-11Sample BGP configuration (route aggregation)

Router R8 has the following CLI configuration:

```
interface add ip xleapnl address-netmask 212.19.192.2/24
interface create ip hobbygate address-netmask 212.19.199.62/24 port
    et.1.2
interface create ip xenosite address-netmask 212.19.198.1/24 port
    et.1.7
interface add ip lo0 address-netmask 212.19.192.1/30
bgp create peer-group webnet type external autonomous system 64901
bgp add peer-host 194.109.86.5 group webnet
#
# Create an aggregate route for 212.19.192.0/19 with all its subnets as
# contributing routes
#
ip-router policy summarize route 212.19.192.0/19
ip-router policy redistribute from-proto aggregate to-proto bgp
    target-as 64901 network 212.19.192.0/19
ip-router policy redistribute from-proto direct to-proto bgp target-as
    64901 network all restrict
```

Router R9 has the following CLI configuration:

```
bgp create peer-group rtr8 type external autonomous system 64900
bgp add peer-host 194.109.86.6 group rtr8
```

15.3.8 Route Reflection Example

In some ISP networks, the internal BGP mesh becomes quite large, and the IBGP full mesh does not scale well. For such situations, route reflection provides a way to alleviate the need for a full IBGP mesh. In route reflection, the clients peer with the route reflector and exchange routing information with it. In turn, the route reflector passes on (reflects) information between clients.

The IBGP peers of the route reflector fall under two categories: clients and non-clients. A route reflector and its clients form a cluster. All peers of the route reflector that are not part of the cluster are non-clients. The RS supports client peers as well as non-client peers of a route reflector.

Figure 15-12 shows a sample configuration that uses route reflection.

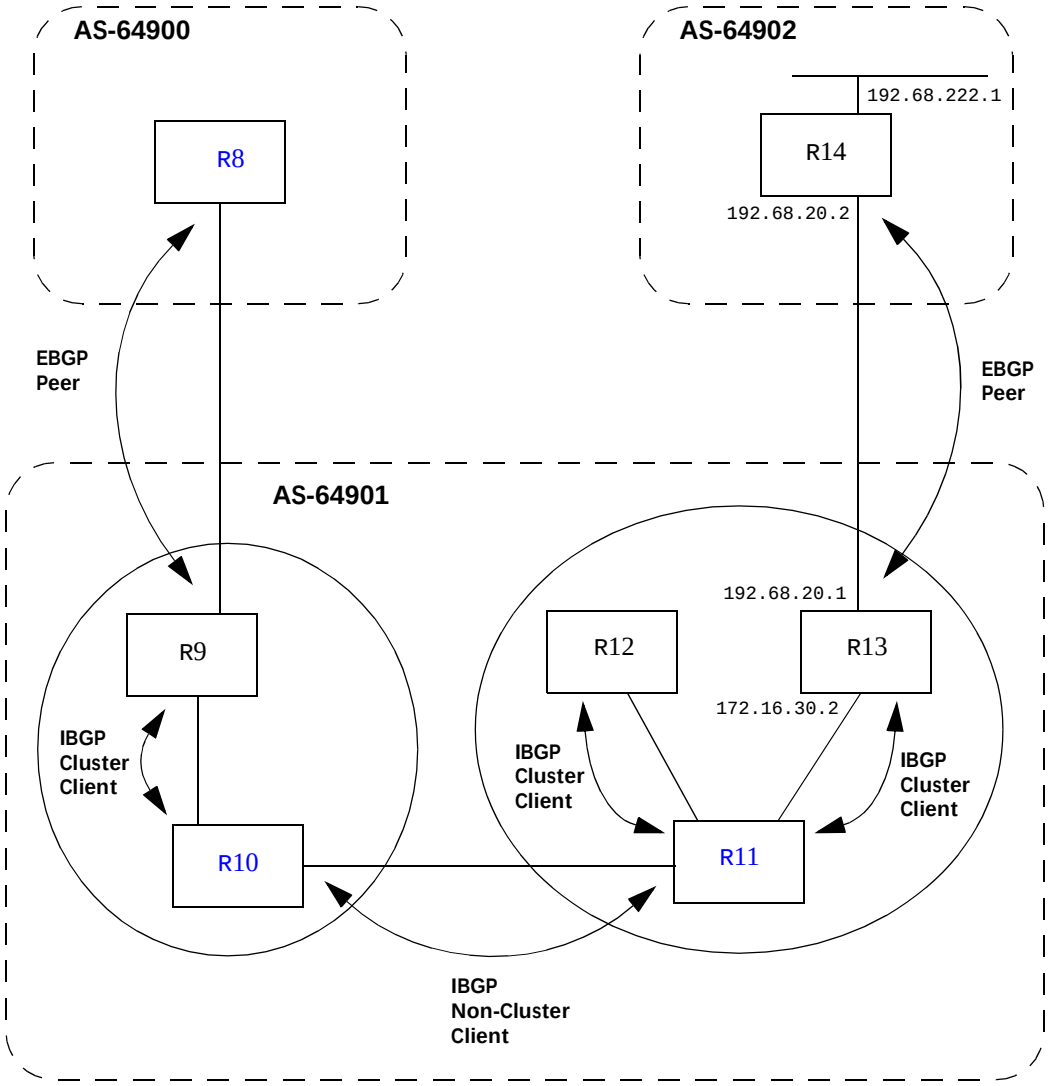


Figure 15-12Sample BGP configuration (route reflection)

In this example, there are two clusters. Router R10 is the route reflector for the first cluster and router R11 is the route reflector for the second cluster. Router R10 has router R9 as a client peer and router R11 as a non-client peer.

The following line in router R10's configuration file causes it to be a route reflector.

```
bgp set peer-group R9 reflector-client
```

Router R11 has router R12 and router R13 as client peers and router R10 as non-client peer. The following line in router R11's configuration file specifies it to be a route reflector

```
bgp set peer-group rtr11 reflector-client
```

Even though the IBGP Peers are not fully meshed in AS 64901, the direct routes of router R14, that is, 192.68.222.0/24 in AS 64902 (which are redistributed in BGP) do show up in the route table of router R8 in AS64900, as shown below:

```
*****************************************
* Route Table (FIB) of Router 8         *
*****************************************
rtr-8# ip show routes

Destination               Gateway                   Owner     Netif
-----------               -------                   -----     -----
10.50.0.0/16              directly connected        -         en
127.0.0.0/8               127.0.0.1                 Static    lo
127.0.0.1                 127.0.0.1                 -         lo
172.16.20.0/24            directly connected        -         mls1
172.16.70.0/24            172.16.20.2               BGP       mls1
172.16.220.0/24           172.16.20.2               BGP       mls1
192.68.11.0/24            directly connected        -         mls0
192.68.20.0/24            172.16.20.2               BGP       mls1
192.68.222.0/24           172.16.20.2               BGP       mls1
```

The direct routes of router R8, i.e. 192.68.11.0/24 in AS64900 (which are redistributed in BGP), do show up in the route table of router R14 in AS64902, as shown below:

```
*******************************************************
*  Route Table (FIB) of Router 14                      *
*******************************************************
rtr-14# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.50.0.0/16         directly connected   -         en0
127.0.0.0/8          127.0.0.1            Static    lo0
127.0.0.1            127.0.0.1            -         lo0
172.16.20.0/24       192.68.20.1          BGP       mls1
172.16.30.0/24       192.68.20.1          BGP       mls1
172.16.90.0/24       192.68.20.1          BGP       mls1
192.68.11.0/24       192.68.20.1          BGP       mls1
192.68.20.0/24       directly connected   -         mls1
192.68.222.0/24      directly connected   -         mls0
```

Notes on Using Route Reflection

- Two types of route reflection are supported:
  - By default, all routes received by the route reflector from a client are sent to all internal peers (including the client's group, but not the client itself).
  - If the **`no-client-reflect`** option is enabled, routes received from a route reflection client are sent only to internal peers that are not members of the client's group. In this case, the client's group must itself be fully meshed.

  In either case, all routes received from a non-client internal peer are sent to all route reflection clients.

- Typically, a single router acts as the reflector for a cluster of clients. However, for redundancy, two or more may also be configured to be reflectors for the same cluster. In this case, a cluster ID should be selected to identify all reflectors serving the cluster, using the **`clusterid`** option. Gratuitous use of multiple redundant reflectors is not advised, since it can lead to an increase in the memory required to store routes on the redundant reflectors' peers.
- No special configuration is required on the route reflection clients. From a client's perspective, a route reflector is simply a normal IBGP peer. Any BGP version 4 speaker can be a reflector client.
- If the configurations routers R10 and R11 contain export policies configured using the **`route-map-out`** option or the **`bgp advertise network`** command or an **`ip-router policy redistribute`** command, then routers R10 and R11 must have the following line in their configuration files

```
ip-router policy redistribute from-proto bgp source-as 64901 to-proto bgp target-as 64901
```

- If the cluster ID is changed, all BGP sessions with reflector clients will be dropped and restarted.

15.3.9 BGP Confederation Example

Figure 15-13 shows a BGP configuration where a single AS (AS number 64705) is split into two sub-AS's (64706 and 64707).

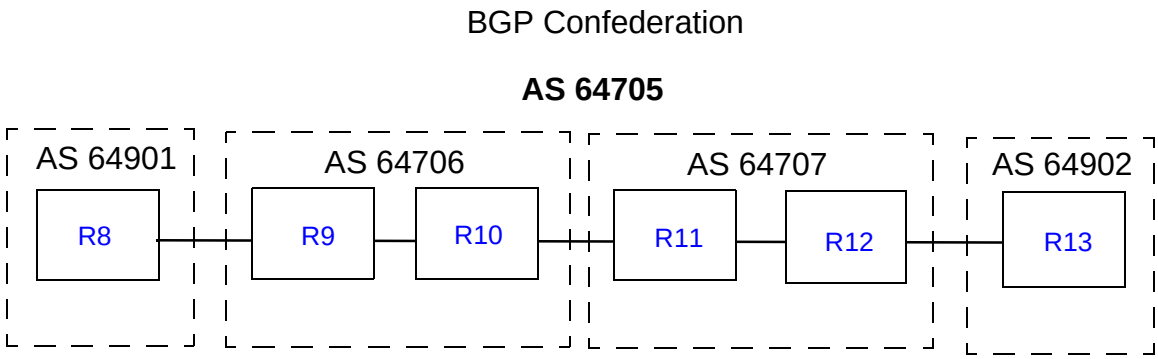


Figure 15-13Sample BGP confederation

In Figure 15-13, R9 and R10 are included in AS 64706, which is a sub-AS of the confederation with the AS number 64705. R9 has the following CLI configuration:

```
ip-router global set router-id 182.1.1.1
ip-router global set trace-state on
ip-router global set confederation-id 64705
ip-router global set autonomous-system 64706

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group ebgp type external autonomous-system 64901
bgp create peer-group rtr10 type routing autonomous-system 64706
bgp add peer-host 172.16.220.2 group ebgp
bgp add peer-host 172.16.222.2 group rtr10
bgp set peer-host 172.16.220.2 route-map-in 1 group ebgp
bgp set peer-group rtr10 confederation
bgp set peer-group ebgp
bgp start

route-map 1 permit 1 set-metric 50 set-local-preference 1000 set-community
"65000:6500 64000:6000"

ip-router policy redistribute from-proto bgp source-as 64901 to-proto bgp
target-as 64706
```

R10 has the following CLI configuration:

```
ip-router global set router-id 172.16.222.2
ip-router global set autonomous-system 64706
ip-router global set confederation-id 64705
ip-router global set trace-state on

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr9 type routing interface all proto any autonomous-system
64706
bgp create peer-group rtr11 type external autonomous-system 64707
bgp add peer-host 172.16.222.1 group rtr9
bgp add peer-host 172.16.223.2 group rtr11
bgp set peer-group rtr9 confederation
bgp set peer-group rtr11 confederation
bgp start

ip-router policy redistribute from-proto bgp source-as 64706 to-proto bgp
target-as 64707
```

In Figure 15-13, R11 and R12 are included in AS 64707, which is a sub-AS of the confederation with the AS number 64705. R11 has the following CLI configuration.

```
ip-router global set router-id 186.1.1.1
ip-router global set autonomous-system 64707
ip-router global set confederation-id 64705
ip-router global set trace-state on

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr10 type external autonomous-system 64706
bgp create peer-group rtr12 type routing autonomous-system 64707
bgp add peer-host 172.16.223.1 group rtr10
bgp add peer-host 172.16.224.2 group rtr12
bgp set peer-group rtr12 confederation
bgp set peer-group rtr10 confederation
bgp set peer-host 172.16.223.1 group rtr10 multihop
bgp set peer-group rtr10
bgp start

ip-router policy redistribute from-proto bgp source-as 64706 to-proto bgp
target-as 64707
```

R12 has the following CLI configuration:

```
ip-router global set router-id 172.16.71.2
ip-router global set autonomous-system 64707
ip-router global set confederation-id 64705

ospf create area backbone
ospf add interface all to-area backbone
ospf start

bgp create peer-group rtr11 type routing autonomous-system 64707
bgp create peer-group rtr13 type external autonomous-system 64902
bgp add peer-host 172.16.224.1 group rtr11
bgp add peer-host 172.16.225.2 group rtr13
bgp set peer-group rtr11 confederation
bgp start

ip-router policy redistribute from-proto bgp source-as 64707 to-proto bgp
target-as 64902 network 3.0.0.0/8
```

R13 has the following CLI configuration:

```
ip-router global set router-id 13.1.1.1
ip-router global set autonomous-system 64902
ip-router global set trace-state on

bgp create peer-group rtr12 type external autonomous-system 64705
bgp add peer-host 172.16.225.1 group rtr12
bgp start
```

R8 has the following CLI configuration:

```
ip-router global set autonomous-system 64901
ip-router global set router-id 134.141.178.48

ip-router policy create bgp-export-destination rtr9 autonomous-system 64705
ip-router policy create aspath-export-source abc aspath-regular-expression "(.*
701 .*)" origin any protocol all
ip-router policy redistribute from-proto bgp source-as 64751 to-proto bgp
target-as 64705 network 3.0.0.0/8

bgp create peer-group rtr9 type external autonomous-system 64705
bgp add peer-host 182.1.1.1 group rtr9
bgp add peer-host 172.16.220.1 group rtr9
bgp start
```

The following examples of the **`bgp show routes`** command show how the AS-path attribute is modified as the route is passed through the routers in the BGP confederation.

On R9, the route advertised by R8 is shown with R8's AS number (64901) prepended to the path:

```
r9# bgp show routes all
BGP table : Local router ID is 182.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8               172.16.220.2       50   1000 64901 64751 6379 1 701 80 i
  172.16.222/24      172.16.222.2              100 i
* 172.16.223/24      172.16.222.2              100 i
```

On R11, the same route is prepended with the sub-AS (64706) to which R10 belongs:

```
r11# bgp show routes all
BGP table : Local router ID is 186.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8                172.16.220.2        50   1000 {64706}64901 64751 6379 1 701
80 i
  172.16.224/24      172.16.224.2              100 i
* 172.16.225/24      172.16.224.2              100 i
```

Note that R11, while in a different sub-AS, is in the same confederation as R10. Within a confederation, routers can "see" other sub-AS's and the sub-AS numbers appear in curly braces ({}) in the path display.

On R13, which is not part of the confederation, the AS path now shows only the AS number of the confederation:

```
r13# bgp show routes all
BGP table : Local router ID is 13.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best
Origin codes: i - IGP, e - EGP, ? - incomplete

  Network            Next Hop        Metric LocPrf Path
  -------            --------        ------ ------ ----
*>3/8               172.16.225.1                  64705 64901 64751 6379 1 701 80 i
```

Note As shown in the example outputs for R9 and R11, the next hop, local pref and MED values are passed unchanged through routers in the confederation. The peer-group configuration must include the **`multihop`** parameter so that the next hop value is passed through the routers. In the above BGP confederation example, the **`multihop`** parameter should be specified for R11.

15.3.10 Route Map Example

Figure 15-14 shows a simple BGP configuration in which routes received on R2 for the networks 15.4.0.0/16 and 15.5.0.0/16 are set with community IDs 1:1 and 1:2, respectively. The routes are exported to R8 with these community IDs. On R8, BGP routes with the specified community IDs are to be monitored via BGP accounting (see Section 15.3.11, *"BGP Accounting Examples,"* for more information).

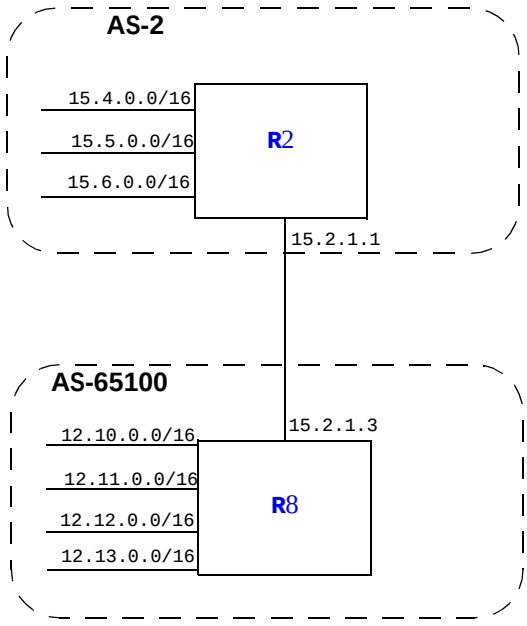


Figure 15-14Sample BGP configuration (route map)

Router R2 has the following CLI configuration:

```
ip-router global set autonomous-system 2
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-community
"1:1"
route-map 1 permit 2 match-prefix network 15.5.0.0/16 set-community
"1:2"
bgp create peer-group tored type external autonomous-system 65100
bgp add peer-host 15.2.1.3 group tored
bgp set preference 99
bgp set peer-group tored route-map-out 1
bgp start
```

Router R8 has the following CLI configuration:

```
ip-router global set autonomous-system 65100
ip-router policy create community-list 11 "1:1"
ip-router policy create community-list 12 "1:2"
route-map 11 permit 1 match-community-list 11 set-traffic-index 1
route-map 11 permit 2 match-community-list 12 set-traffic-index 2
bgp create peer-group ebgp autonomous-system 2 type external
bgp add peer-host 15.2.1.1 group ebgp
bgp set preference 9
bgp set peer-group ebgp route-map-in 11
bgp start
```

On R8, the **`bgp show routes`** command for the network interface 15.4.0.0/16 shows the following output:

```
BGP routing table entry for 15.4/16
Path: Best
Source: 15.2.1.1
Advertised to(Tasks):
None:
Local AS: 65100   Peer AS:     2   Age: 1:18:20
NextHop: 15.2.1.1          MED:  -1    Local Preference: -1
AS Path: (65100) 2 IGP (Id 38)
Community: 1:1
```

Note the standard community list for this network (1:1), as set with the **`route-map`** command on R2.

15.3.11 BGP Accounting Examples

BGP accounting allows you to collect statistics on specified IP routes. To use BGP accounting, routes must be learned through BGP and be selected routes. In other words, the routes must appear in the routing tables (displayed with the **`ip show route`** command) and BGP must be the routing protocol for the routes.

Then use the **`route-map`** command to define route-maps and set up the buckets for collecting the BGP traffic information. (If you are matching communities in the route-map definition, you will need to create the community lists.) Then apply the route-map to the BGP group or peer. Enable BGP accounting on the interface with the **`ip enable bgp-actg-on`** command, then start accounting with the **`ip bgp-accounting start`** command.

EBGP Accounting Example

The **`set-traffic-index`** option of the **`route-map`** command allows buckets to be set up in which BGP traffic information is collected. In the configuration for R8 shown in Figure 15-14, the routing updates that match the route-map configurations are set to traffic indexes 1, and 2.

To enable BGP accounting on an interface, enter CLI commands like the following:

```
ip enable bgp-actg-on int1
ip bgp-accounting start accounting
```

To see the BGP accounting information:

```
rs8# ip show interfaces all bgp-actg
Interface:gitoy
Bucket  Packets               Bytes
0       0                   0
1       33760               2160640
2       33760               2160640
```

Note For BGP accounting to take effect, the RS must be selecting BGP for the route. Make sure that the preference for BGP is set lower than the preference of other protocols on the RS.

IBGP Accounting Example

In the example below, routers R1 and R2 are running IBGP/RIP, so they exchange routes automatically. Customer traffic from 13.1.1.5 is being routed to the destination 14.1.1.1/16. The customer is connected to router R1 through the interface 'customerA.' The route to 14.1.0.0/16 is a direct route on router R2 and is learned by R1, which sets the traffic index to 1.

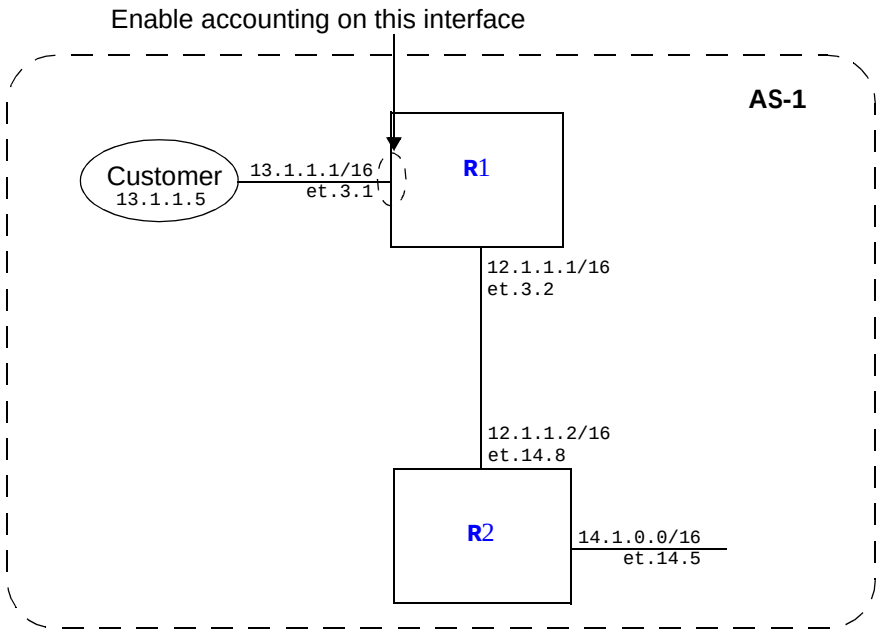


Figure 15-15Sample BGP configuration (accounting)

The following configurations enable BGP accounting on interface 'customerA' to tally the number of bytes and packets sent by the customer.

R1 has the following configuration:

```
interface create ip toR2 address-netmask 12.1.1.1/16 port et.3.2
interface create ip customerA address-netmask 13.1.1.1/16 port et.3.1

ip enable bgp-actg-on customerA,
ip bgp-accounting start accounting

ip-router global set autonomous-system 1
ip-router global set router-id 10.50.7.1

bgp create peer-group ibgp type routing autonomous-system 1
bgp add peer-host 12.1.1.2 group ibgp
bgp set peer-group ibgp route-map-in 1
bgp set preference 99
bgp start

ip-router policy create community-list list1 "11:11"

route-map 1 permit 1 match-community-list list1 set-traffic-index 1

arp add 12.1.1.2 mac-addr 001122:334455 exit-port et.3.2
arp add 13.1.1.5 mac-addr 00:00:00:00:13:01
```

R2 has the following configuration:

```
interface create ip toR1 address-netmask 12.1.1.2/16 port et.14.8
interface create ip 14.1 address-netmask 14.1.1.1/16 port et.14.5

ip-router global set autonomous-system 1
ip-router global set router-id 10.50.7.9

bgp create peer-group ibgp type routing autonomous-system 1
bgp add peer-host 12.1.1.1 group ibgp
bgp set peer-group ibgp route-map-out 1
bgp start

route-map 1 permit 1 match-prefix network 14.1.0.0/16 set-community "11:11"

arp add 14.1.1.5 mac-addr 00:00:00:00:14:01
```

Use the **bgp-actg** option with the **ip show interfaces** command to display BGP accounting information for the interface. For example:

```
rs# ip show interfaces customerA bgp-actg

Interface:customerA
Bucket Packets       Bytes
0      0             0
1      111           14430
```

BGP DSCP Accounting

You can choose to have route-specific traffic statistics broken down by DSCP values. The steps are basically the same as in the BGP accounting examples shown previously, except you use the **ip bgp-accounting start dscp-accounting** command to start the collection of statistics.

Figure 15-16 shows a simple BGP configuration in which routes received on R2 for the networks 15.4.0.0/16, 15.5.0.0/16, and 15.6.0.0/16 are exported to R8. On R8, BGP routes from these networks are to be monitored via BGP accounting, with breakout of traffic according to DSCP values.

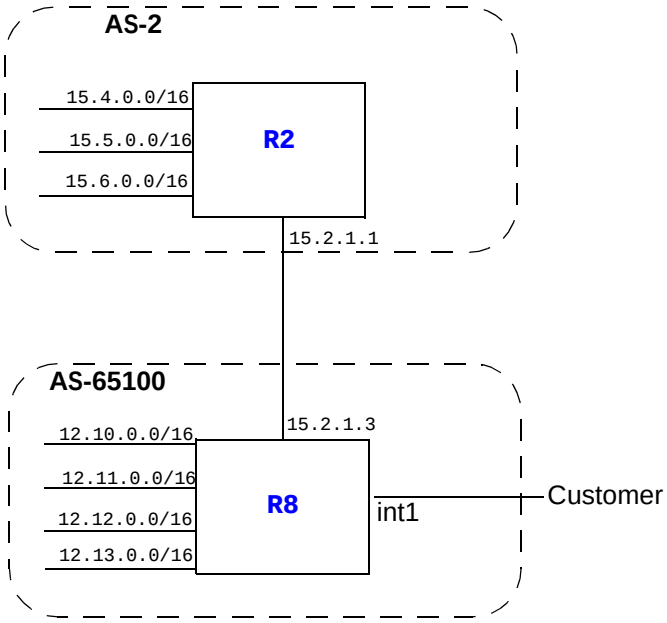


Figure 15-16Sample BGP configuration (DSCP accounting)

Router R2 has the following CLI configuration:

```
ip-router global set autonomous-system 2
bgp create peer-group tored type external autonomous-system 65100
bgp add peer-host 15.2.1.3 group tored
bgp set preference 99
bgp start
```

Router R8 has the following CLI configuration:

```
ip-router global set autonomous-system 65100
route-map 1 permit 1 match-prefix network 15.4.0.0/16 set-traffic-index
10
route-map 1 permit 2 match-prefix network 15.5.0.0/16 set-traffic-index
11
route-map 1 permit 3 match-prefix network 15.6.0.0/16 set-traffic-index
12
bgp create peer-group tor2 autonomous system 2 type external
bgp add peer-host 15.2.1.1 group tor2
bgp set preference 9
bgp set peer-group tor2 route-map-in 1 in-sequence 1
bgp start
```

To enable BGP accounting on the interface ‘int1’ on R8:

```
ip enable bgp-actg-on int1
ip bgp-accounting start dscp-accounting
```

To view the BGP accounting information collected on R8:

```
r8# ip show interfaces all bgp-actg
Interface:int1
Bucket  DSCP   Packets                Bytes
10      1       239376                15320064
10      2       239201                15308864
10      3       239001                15296064
10      4       238801                15283264
10      5       238601                15270464
10      6       238401                15257664
10      7       238597                15270208
10      8       238401                15257664
10      10      238254                15248256
10      17      238401                15257664
11      11      238189                15244096
11      15      237801                15219264
11      17      239206                15309184
11      20      239387                15320768
12      12      238176                15243264
12      14      237601                15206464
12      18      239001                15296064
```

16 LAYER-3 VPNS

Layer-3 virtual private networks (VPNs), also known as Border Gateway Protocol/Multiprotocol Label Switching Virtual Private Networks (BGP/MPLS VPNs), is a method that allows service providers to provide customers VPN services using an IP backbone.

By using MPLS for forwarding VPN traffic and BGP for distributing VPN routes, this mechanism increases scalability and flexibility for the service provider while removing the need for customers to build and run their own IP backbone. This frees customers from having to deal with inter-site connectivity issues.

By removing the restriction that customers must use globally unique IPv4 addresses, this method enhances both customer and service provider convenience. Provider routers do not have to administer a separate backbone for each customer VPN, nor do they require management access to customer routers.

Layer-3 VPNs differ significantly from Layer-2 VPNs. Layer-2 VPNs constrain customer traffic arriving on a certain port or VLAN to a set destination. Layer-3 VPNs enable PE routers to make intelligent routing decisions based on customer IP addresses.

Note Throughout this document, the terms ‘Layer-3 VPN’ and ‘BGP/MPLS VPN’ are used interchangeably.

This chapter discusses Layer-3 VPNs, provides step-by-step configuration guidelines to help you enable the feature, and presents a complete configuration example to reference in your own configurations.

We recommend that the first-time user of BGP/MPLS VPNs read this chapter straight through. Advanced users can use the following sectional abstract to seek selective instructions on enabling the feature:

- For IETF references on the standard and its components, see *Section 16.1 "RFCs and Drafts."*
- For an overview of BGP/MPLS VPN network components, see *Section 16.2 "Network Components."*
- For an overview of the Basic BGP/MPLS VPN Network, which uses OSPF and static route distribution, see *Section 16.3 "Basic BGP/MPLS VPN Network Overview."*
- To configure the Basic BGP/MPLS VPN Network, see *Section 16.4 "Basic BGP/MPLS VPN Network Configuration."*
  - To set up MPLS label-switched paths (LSPs) in the provider network, see *Section 16.4.2 "Setting Up Signaling Protocols and MPLS LSPs Between PE Routers."*
  - To configure MP-BGP between Provider Edge routers for customer route exchange, see *Section 16.4.3 "Configuring MP-BGP Between PE Routers for Customer Route Distribution."*
  - To configure multiple routing instances and VPN Routing and Forwarding tables (VRFs), see *Section 16.4.4 "Configuring Routing Instances."*

  - For information on VPN-IPv4 addresses and configuring Route Distinguishers, see Section *"Configuring Route Distinguishers and VPN-IPv4 Addresses."*
  - To add interface(s) to routing instances, see the *Section "Adding Interfaces to VRFs."*
  - To set import and export policies using BGP Extended Community Attributes, see the *Section "Configuring VRF Import and Export Policies."*
- To configure static and OSPF route distribution between Customer Edge and Provider Edge routers, see *Section 16.4.5 "Configuring Static and OSPF Route Distribution Between CE and PE Routers."*

- For an operational model of the Basic BGP/MPLS VPN Network, see *Section 16.5 "Basic BGP/MPLS VPN Network Operation."*
- To configure RIP and BGP route distribution between Customer Edge and Provider Edge routers, see *Section 16.6 "Configuring RIP and BGP Route Distribution Between CE and PE Routers."*
- To troubleshoot the Basic BGP/MPLS VPN Network, see *Section 16.7 "Troubleshooting the Basic BGP/MPLS VPN Network."*
- For an example of configuring trunk ports with multiple Customer Edge routers, see *Section 16.8 "Trunk Port With Multiple CE Routers Example."*
- For an example of configuring dual-homing Customer Edge routers, see *Section 16.9 "Dual-Homing CE Router Example."*
- For an example of configuring route reflectors in the BGP/MPLS VPN Network, see *Section 16.10 "Route Reflector Example."*
- For an example of configuring internet access in the BGP/MPLS VPN Network, see *Section 16.11 "Internet Access Example."*
  - For an example of configuring internet access using static routes, see *Section 16.11.1 "Internet Access Using Static Routes."*
  - For an example of configuring internet access using Network Address Translation (NAT), see *Section 16.11 "Internet Access Example."*
- For an example of configuring a hub-and-spoke topology in the BGP/MPLS VPN Network, see *Section 16.12 "Hub and Spoke Example."*
- For an example of the Carrier's Carrier scenario where the customer service provider supports BGP/MPLS VPNs for its customers, see *Section 16.13 "Carrier's Carrier Example."*
- For an example of configuring a BGP/MPLS VPN Network across multiple autonomous systems, see *Section 16.14 "Multiple-Autonomous System Example."*
- To use Quality of Service (QoS) with BGP/MPLS VPNs, see *Section 16.15 "QoS for BGP/MPLS VPNs."*

Timesaver Titles shown in blue represent hypertext links to the sections. Click on one of the section titles above to go immediately to that section.

16.1 RFCS AND DRAFTS

Request for Comments (RFC) 2547bis *BGP/MPLS VPNs*, by Rosen, Rekhter, et al., defines the core functionality of Layer-3 VPNs. It also defines the VPN-IPv4 address family and Route Distinguishers.

Additional components support BGP/MPLS VPNs. Refer to the following IETF RFCs and working drafts for definitions of these features:

Feature	Definition
Multiprotocol BGP (MP-BGP)	RFC 2858 *Multiprotocol Extensions for BGP4*. Bates, Chandra, Katz, and Rekhter.
Using OSPF to route between CE and PE routers	IETF draft *OSPF As the PE/CE Protocol In BGP/MPLS VPNs*. Rosen and Psenak.
BGP Extended Community Attributes	IETF draft *BGP Extended Communities Attribute*. Ramachandra, Tappan, and Rekhter.
BGP Route Refresh	RFC 2918 *Route Refresh Capability for BGP-4*. Chen.
BGP Outbound Route Filtering (ORF)	IETF draft *Cooperative Route Filtering Capability for BGP4*. Chen and Rekhter.

16.2 NETWORK COMPONENTS

Three types of devices exist in the BGP/MPLS VPN network:

- Provider Edge (PE) routers
- Provider (P) routers
- Customer Edge (CE) routers

16.2.1 PE Routers

PE routers are on the edge of the provider network. Their main function is to peer with and exchange customer routing information with CE routers.

RFC 2547bis *BGP/MPLS VPNs* by Rosen, Rekhter, et al. states the following: “a PE router is attached to a particular VPN if it is attached to a CE device which is in that VPN. Similarly, . . . a PE router is attached to a particular site if it is attached to a CE device which is in that site.”

Given this definition, a PE router only maintains routes for those VPNs to which it is directly attached. It learns these routes from CE routers and keeps them in VPN Routing and Forwarding tables (VRFs).

Customer routes are distributed across the provider network when PE routers exchange VRF routes with other PE routers. Extended Community Attribute ‘Route Targets’ define which routes a PE router advertises and which routes it receives for a particular VRF during routing updates.

PE routers use MP-BGP to distribute customer routes *only to* other PE routers, never to the provider’s internal routers (P Routers). This separation helps ensure that customer routes are kept separate from the provider’s own routes. This, along with the fact that PE routers only maintain VRFs for directly-connected sites, enhance the scalability of BGP/MPLS VPNs.

An MPLS LSP exists between any two PE routers within the same VPN. PE routers use these LSPs to forward customer traffic across the provider network.

16.2.2 P Routers

P routers are provider internal routers. They do not interface with customer routers or maintain customer routes.

P routers provide connectivity between PE routers using interior gateway protocols (IGPs). P routers also help establish and maintain MPLS LSPs between PE routers. PE routers use these LSPs to forward customer traffic across the provider network. As label switch routers (LSRs), P routers participate in this forwarding. However, they only pass MPLS traffic, and have no knowledge of the underlying customer route information.

16.2.3 CE Router

CE devices are on the edge of customer networks. They exchange routes from their local site with PE routers, who in turn exchange those routes with CE routers in other customer sites according to policies that you define.

CE routers only peer with PE routers. They do not peer with CE routers in remote sites. They learn routes for those remote sites from their local PE router.

The CE device may be a single host or a switch. In general, however, the CE device is an IP router, which we call the CE router.

Note As a network administrator, note that, as RFC 2547bis *BGP/MPLS VPNs* states, "With respect to the management of the edge devices, clear administrative boundaries are maintained between the [service provider] and its customers. Customers are not required to access the PE or P routers for management purposes, nor is the [service provider] required to access the CE devices for management purposes."

Figure 16-1 illustrates how these components make up the Basic BGP/MPLS VPN Network topology.

16.3 BASIC BGP/MPLS VPN NETWORK OVERVIEW

Figure 16-1 illustrates an example of a Basic BGP/MPLS VPN Network. In this network, a single provider supplies connectivity to two customers, A and B. The connectivity has these constraints:

- The two sites of Customer A can communicate with each other. They form VPN RED
- The two sites of Customer B can communicate with each other. They form VPN PINK
- Customer A sites *cannot* communicate with Customer B sites.

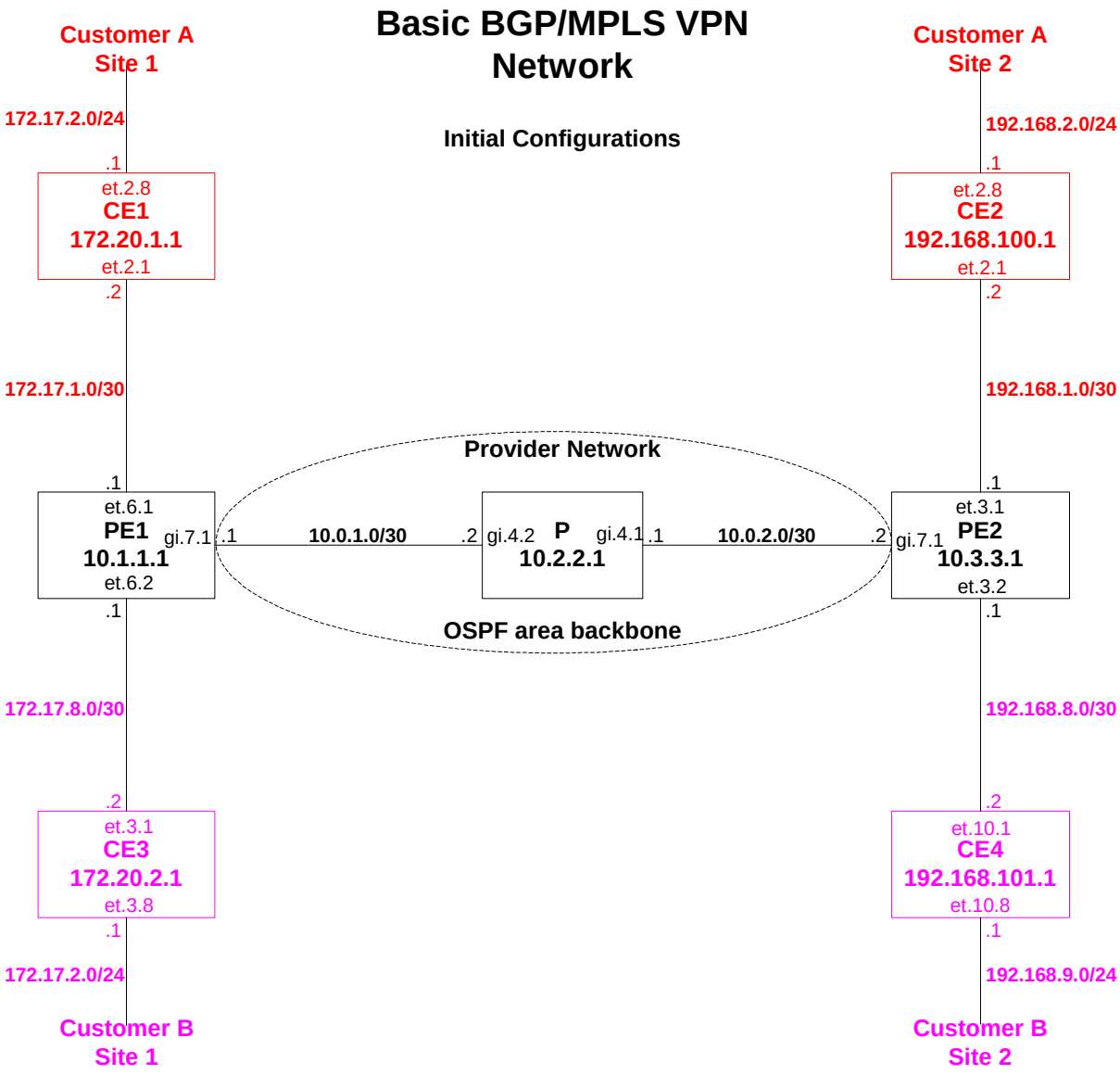


Figure 16-1 Basic BGP/MPLS VPN Network components

To achieve the desired connectivity scheme, network administrators for the customer and provider networks must perform the following configuration tasks. Subsequent sections provide detailed explanations and step-by-step instructions for each task:

In the provider network, network administrators must complete the following tasks:

- Set up the three provider routers (PE1, PE2, and P) with Interior Gateway Protocols (IGPs) for routing within the provider network. In our example, OSPF is already running in the provider network. For OSPF configuration commands, see *Section 16.4.1 "Basic BGP/MPLS VPN Network Starting Configurations."*

- Configure two MPLS LSPs between PE1 and PE2 to create bidirectional flows that allow them to transport VPN traffic. (For details and commands, see *Section 16.4.2 "Setting Up Signaling Protocols and MPLS LSPs Between PE Routers."*)
- Configure MP-BGP between PE1 and PE2. These two routers use MP-BGP to exchange learned customer routes without injecting them into the provider's IGP. Note that the P router only functions as a transit router in this exchange. It does not learn customer routes, nor does it run MP-BGP. (For details and commands, see *Section 16.4.3 "Configuring MP-BGP Between PE Routers for Customer Route Distribution."*)

Caution Keeping customer routes segregated from provider routes is extremely important. BGP/MPLS VPNs uses the following mechanisms to achieve this:

1. Separate routing instances and routing tables ensure that routes learned from customers are not injected into the provider network.

2. Using MP-BGP to exchange VPN routes and MPLS to carry VPN traffic ensures that only ingress and egress PE routers need to maintain customer routing information and interface with customer routers. P routers only need to forward MPLS traffic.

- Configure routing instances and VRFs. Separate routing instances and VRFs enable PE routers to prevent routes learned from Customer A from being leaked to Customer B. (For details and commands, see *Section 16.4.4 "Configuring Routing Instances."*) The power of BGP/MPLS VPNs lies in the following elements of routing instances:
  - Configure Route Distinguishers to create routing instances. Through the use of VPN-IPv4 addresses and Route Distinguishers, PE routers can correctly handle and route overlapping IP addresses in different VPNs. In the Basic BGP/MPLS VPN Network, PE1 can distinguish and route between the same route, 172.17.2.0/24, learned from two different connected sites (through CE1 and CE3). (For details and commands, see the *Section "Configuring Route Distinguishers and VPN-IPv4 Addresses."*)
  - Configure import and export policies that instruct each PE router on what to do with the routes it learns from its connected sites (through the CEs). Through the use of the Extended Community Attribute Route Targets, network administrators can associate each connected site on a PE with one or more import and export targets. Using these targets and routing policies, network administrators can specify which category of routes a PE router should accept for a site, and which category it should use to advertise routes learned from a site. This set of tags and policies define the VPNs. (For details and commands, see the *Section "Configuring VRF Import and Export Policies."*)

Both the customer and provider network administrators must configure CE and PE routers to exchange routes. In this example, for VPN RED, CE1 and PE1 set up static routes for the 172.17.2.0/24 network. Likewise, CE2 and PE2 using OSPF to exchange routes for the 192.168.2.0/24 network. (For details and commands, see *Section 16.4.5 "Configuring Static and OSPF Route Distribution Between CE and PE Routers."*)

16.4 BASIC BGP/MPLS VPN NETWORK CONFIGURATION

This section examines in detail how to configure each of the network components for the Basic BGP/MPLS VPN Network (The Basic BGP/MPLS VPN Network topology, connectivity scheme, and configuration tasks are outlined in *Section 16.3 "Basic BGP/MPLS VPN Network Overview."*) Although the configurations in this section are based on the example in Figure 16-1, the guidelines will enable you to achieve any connectivity scheme in your BGP/MPLS VPN network.

Progress boxes like the following list the Basic BGP/MPLS VPN Network configuration steps at the beginning of each section. The current configuration task is highlighted. In each section, you should always check that the configuration steps before the highlighted task are complete.

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
- Static and OSPF PE-CE route distribution

16.4.1 Basic BGP/MPLS VPN Network Starting Configurations

The following are the starting configurations for all the routers in the Basic BGP/MPLS VPN Network. Note that OSPF has already been configured as the IGP between the routers in the provider network (PE1, PE2, and P).

CE1 Starting Configuration

```
CE1# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-15 11:06:40
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCustomerASite1 ip id 100
 2 : vlan create ToPE1 ip id 200
 3 : vlan add ports et.2.8 to ToCustomerASite1
 4 : vlan add ports et.2.1 to ToPE1
     !
 5 : interface create ip ToCustomerASite1 address-netmask 172.17.2.1/24 vlan
     ToCustomerASite1
 6 : interface create ip ToPE1 address-netmask 172.17.1.2/30 vlan ToPE1

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 172.20.1.1/32
     !
 8 : ip-router global set router-id 172.20.1.1
     !
 // Set the system name
 9 : system set name CE1
```

CE2 Starting Configuration

```
CE2# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-15 10:32:21
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCustomerASite2 ip id 100
 2 : vlan create ToPE2 ip id 200
 3 : vlan add ports et.2.8 to ToCustomerASite2
 4 : vlan add ports et.2.1 to ToPE2
     !
 5 : interface create ip ToCustomerASite2 address-netmask 192.168.2.1/24 vlan
     ToCustomerASite2
 6 : interface create ip ToPE2 address-netmask 192.168.1.2/30 vlan ToPE2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 192.168.100.1/32
     !
 8 : ip-router global set router-id 192.168.100.1
     !
 // Set the system name
 9 : system set name CE2
```

CE3 Starting Configuration

```
CE3# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-04-16 15:29:21
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCustomerBSite1 ip id 100
 2 : vlan create ToPE1 ip id 200
 3 : vlan add ports et.3.8 to ToCustomerBSite1
 4 : vlan add ports et.3.1 to ToPE1
     !
 5 : interface create ip ToCustomerBSite1 address-netmask 172.17.2.1/24 vlan
     ToCustomerBSite1
 6 : interface create ip ToPE1 address-netmask 172.17.8.2/30 vlan ToPE1

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 172.20.2.1/32
     !
 8 : ip-router global set router-id 172.20.2.1
     !
 // Set the system name
 9 : system set name CE3
```

CE4 Starting Configuration

```
CE4# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-15 12:30:13
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCustomerBSite2 ip id 100
 2 : vlan create ToPE2 ip id 200
 3 : vlan add ports et.10.8 to ToCustomerBSite2
 4 : vlan add ports et.10.1 to ToPE2
     !
 5 : interface create ip ToCustomerBSite2 address-netmask 192.168.9.1/24 vlan
     ToCustomerBSite2
 6 : interface create ip ToPE2 address-netmask 192.168.8.2/30 vlan ToPE2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 192.168.101.1/32
     !
 8 : ip-router global set router-id 192.168.101.1
     !
 // Set the system name
 9 : system set name CE4
```

PE1 Starting Configuration

```
PE1# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-14 15:26:54
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCE1 ip id 100
 2 : vlan create ToP ip id 200
 3 : vlan create ToCE3 ip id 300
 4 : vlan add ports et.6.1 to ToCE1
 5 : vlan add ports et.6.2 to ToCE3
 6 : vlan add ports gi.4.1 to ToP
     !
 7 : interface create ip ToCE1 address-netmask 172.17.1.1/30 vlan ToCE1
 8 : interface create ip ToCE3 address-netmask 172.17.8.1/30 vlan ToCE3
 9 : interface create ip ToP address-netmask 10.0.1.1/30 vlan ToP

 // Assign the loopback address and set it as the router ID
10 : interface add ip lo0 address-netmask 10.1.1.1/32
     !
11 : ip-router global set router-id 10.1.1.1

 // Configure OSPF to route across the provider network
12 : ospf create area backbone
13 : ospf add stub-host 10.1.1.1 to-area backbone cost 1
14 : ospf add interface ToP to-area backbone
15 : ospf start
     !
 // Set the system name
16 : system set name PE1
```

Note OSPF is already configured as the IGP in the provider network. For information on configuring OSPF, see *Section 13 "OSPF Configuration Guide."*

PE2 Starting Configuration

```
PE2# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-14 12:04:16
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCE2 ip id 100
 2 : vlan create ToCE4 ip id 200
 3 : vlan create ToP ip id 300
 4 : vlan add ports et.3.1 to ToCE2
 5 : vlan add ports et.3.2 to ToCE4
 6 : vlan add ports gi.7.1 to ToP
     !
 7 : interface create ip ToCE2 address-netmask 192.168.1.1/30 vlan ToCE2
 8 : interface create ip ToCE4 address-netmask 192.168.8.1/30 vlan ToCE4
 9 : interface create ip ToP address-netmask 10.0.2.2/30 vlan ToP

 // Assign the loopback address and set it as the router ID
10 : interface add ip lo0 address-netmask 10.3.3.1/32
     !
11 : ip-router global set router-id 10.3.3.1

 // Configure OSPF to route across the provider network
12 : ospf create area backbone
13 : ospf add stub-host 10.3.3.1 to-area backbone cost 1
14 : ospf add interface ToP to-area backbone
15 : ospf start
     !
 // Set the system name
16 : system set name PE2
```

P Starting Configuration

```
P# show run
Running system configuration:
     !
     ! Last modified from Telnet (172.16.13.69) on 2002-05-11 03:04:49
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE1 ip id 100
 2 : vlan create ToPE2 ip id 200
 3 : vlan add ports gi.4.2 to ToPE1
 4 : vlan add ports gi.4.1 to ToPE2
     !
 5 : interface create ip ToPE1 address-netmask 10.0.1.2/30 vlan ToPE1
 6 : interface create ip ToPE2 address-netmask 10.0.2.1/30 vlan ToPE2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 10.2.2.1/32
     !
 8 : ip-router global set router-id 10.2.2.1
     !
 // Configure OSPF to route across the provider network
 9 : ospf create area backbone
10 : ospf add stub-host 10.2.2.1 to-area backbone cost 1
11 : ospf add interface ToPE1 to-area backbone
12 : ospf add interface ToPE2 to-area backbone
13 : ospf start
     !
 // Set the system name
14 : system set name P
```

16.4.2 Setting Up Signaling Protocols and MPLS LSPs Between PE Routers

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- **Configure MPLS LSPs in the provider network**
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
- Static and OSPF PE-CE route distribution

PE routers forward customer traffic across the provider network using MPLS. When customer traffic is encapsulated and sent through MPLS, P routers only need to swap labels and forward the traffic. If customer traffic is sent through a routing protocol instead of MPLS, P routers would need to know customer routes in order to forward them. Therefore, encapsulating and sending customer traffic via MPLS reduces core router workload and enhances overall network scalability. It requires that only ingress and egress PE routers maintain customer routing information and interface with customer routers. P routers only need to forward MPLS traffic and do not need to route customer prefixes directly.

You may use either Label Distribution Protocol (LDP) or Resource Reservation Protocol (RSVP) to establish and maintain LSPs across the provider network. Use LDP to establish *best-effort* LSPs between two PE routers. Use RSVP for bandwidth reservation or traffic engineering in selecting an LSP path.

Note Remember that LSPs are unidirectional. Two LSPs must be established (from point X to Y and Y to X) to allow bidirectional communication.

To ensure route distribution, a pair of LSPs must exist between the PE router that learns a route and the PE router that advertises the route.

For more information on LDP, RSVP, traffic engineering, and MPLS, see *Section 17 "MPLS Configuration."*

To create LSPs, first ensure that an IGP is running (for LDP) and an IGP with traffic engineering capabilities is running (for RSVP *explicit* end-to-end paths). The appropriate IGP must be running before you can configure a signaling protocol.

In our example, OSPF is already running in the provider network. For OSPF configuration commands, see *Section 16.4.1 "Basic BGP/MPLS VPN Network Starting Configurations."*

The following sections describe how to configure RSVP and LDP for signalling.

Configuring RSVP for Signaling

To implement the Basic BGP/MPLS VPN Network (Figure 16-1), RSVP is configured for signaling in the provider network and MPLS to establish bidirectional LSPs between PE1 and PE2. For more information on configuring RSVP and MPLS, see *Section 17.5 "Configuring L3 Label Switched Paths."*

Note This example builds *hop-by-hop* end-to-end paths using RSVP-TE in the provider network. Hop-by-hop paths do not take advantage of traffic-engineering capabilities and only require that an IGP is running in the provider network. In the Basic BGP/MPLS VPN Network (Figure 16-1), OSPF is already running in the provider network.

In more complex networks, you can make use of traffic engineering capabilities by omitting the **`no-cspf`** parameter in the **`mpls create label-switched-path`** command. This allows you to build *explicit* end-to-end paths in accordance with resource or hop constraints. You must turn on the appropriate IGP traffic engineering capability (ISIS-TE or OSPF-TE) in the provider network using the following command(s) for this feature:

```
ospf set traffic-engineering on
isis set traffic-engineering on
```

For more information on traffic engineering, refer to *Section 17.7 "Traffic Engineering."*

On PE1: Configure RSVP for signaling and an MPLS LSP to PE2

1. Enable RSVP on the desired interfaces. These are usually non-customer-facing interfaces on PE and P routers. On PE1, enable RSVP on one interface—ToP.
2. Start RSVP.
3. Enable MPLS on the desired interfaces. Again, these should not be customer-facing interfaces. On PE1, enable MPLS on the same interface that was added to RSVP—ToP.
4. Build LSPs between PE routers for them to use when exchanging customer routes over the provider network. You can configure LSPs between PE endpoints using the **`mpls create label-switched-path`** command. Configure a unidirectional LSP (named PE1toPE2) from PE1 to PE2 by specifying their loopback addresses as the endpoints of the LSP. The **`no-cspf`** parameter specifies that this LSP should follow the IGP (in our example, OSPF) in establishing the LSP hops and has no traffic-engineering constraints. In more complex networks where you may want to use traffic engineering, omit this parameter and turn on the appropriate IGP traffic engineering capability.

Note Remember that LSPs are unidirectional. Two LSPs must be established (from point X to Y and Y to X) to allow bidirectional communication.

To ensure route distribution, a pair of LSPs must exist between the PE router that learns a route and the PE router that advertises the route. The route-advertiser PE functions as the *ingress* LER and the route-learner PE functions as the *egress* LER for that particular LSP. When information flows in the opposite direction, these roles are reversed.

This step only establishes an LSP from PE1 to PE2. A return LSP from PE2 to PE1 also needs to be established.

5. Start MPLS.

The previous configuration steps result in the following commands:

```
PE1(config)# rsvp add interface ToP
PE1(config)# rsvp start
PE1(config)# mpls add interface ToP
PE1(config)# mpls create label-switched-path PE1toPE2 from 10.1.1.1 to 10.3.3.1
             no-cspf
PE1(config)# mpls start
```

On PE2: Configure RSVP for signaling and an MPLS LSP to PE1

On PE2, configure RSVP for signaling and an MPLS LSP to PE1 using the same steps used on PE1.

```
PE2(config)# rsvp add interface ToP
PE2(config)# rsvp start
PE2(config)# mpls add interface ToP
PE2(config)# mpls create label-switched-path PE2toPE1 from 10.3.3.1 to 10.1.1.1
             no-cspf
PE2(config)# mpls start
```

On P: Configure MPLS and RSVP for signaling

While the PE routers have similar configurations, the P router is simpler to configure. You still need to enable RSVP and MPLS, but since the P router functions purely as a transit router, an LSR, it does not need to build any LSPs of its own. Enabling RSVP and MPLS allows it to establish and maintain the LSPs between PE1 and PE2.

1. Enable RSVP on the desired interfaces. These are usually all the interfaces on the P router. On P, enable RSVP on two interfaces—ToPE1 and ToPE2.
2. Start RSVP.
3. Enable MPLS on the desired interfaces. On P, enable MPLS on the same interfaces that were added to RSVP—ToPE1 and ToPE2.
4. Start MPLS.

The previous configuration steps result in the following commands:

```
P(config)# rsvp add interface ToPE1
P(config)# rsvp add interface ToPE2
P(config)# rsvp start
P(config)# mpls add interface ToPE1
P(config)# mpls add interface ToPE2
P(config)# mpls start
```

Viewing LSPs

After configuring LSPs, use the **mpls show label-switched-path** command to verify that labels are established, up, and running.

On PE1, this command output shows that the two LSPs, PE1toPE2 and PE2toPE1, are in the up state. PE1 functions as the ingress router for the PE1toPE2 LSP and as the egress router for the PE2toPE1 LSP.

```
PE1# mpls show label-switched-path all

Ingress LSP:
LSPname                 To              From            State LabelIn LabelOut
PE1toPE2                 10.3.3.1         10.1.1.1         Up     -       4097


Transit LSP:
LSPname                 To              From            State LabelIn LabelOut


Egress LSP:
LSPname                 To              From            State LabelIn LabelOut
PE2toPE1                 10.1.1.1         10.3.3.1         Up     3       -
```

Outputs from the same command on the PE2 and P routers verify this. Notice that PE2's ingress/egress functions for these LSPs are the reverse of PE1's:

```
PE2# mpls show label-switched-path all

Ingress LSP:
LSPname                 To              From            State LabelIn LabelOut
PE2toPE1                 10.1.1.1         10.3.3.1         Up     -       4097


Transit LSP:
LSPname                 To              From            State LabelIn LabelOut


Egress LSP:
LSPname                 To              From            State LabelIn LabelOut
PE1toPE2                 10.3.3.1         10.1.1.1         Up     3       -
```

The P router acts as a transit router for both LSPs, as shown in the following output:

```
P# mpls show label-switched-path all

Ingress LSP:
LSPname                 To              From            State LabelIn LabelOut


Transit LSP:
LSPname                 To              From            State LabelIn LabelOut
PE2toPE1                 10.1.1.1         10.3.3.1          Up     4097    3
PE1toPE2                 10.3.3.1         10.1.1.1          Up     4097    3



Egress LSP:
LSPname                 To              From            State LabelIn LabelOut
```

Figure 16-2 illustrates the Basic BGP/MPLS VPN Network with the following configured:

- IGP (OSPF) in the provider network
- MPLS and RSVP in the provider network

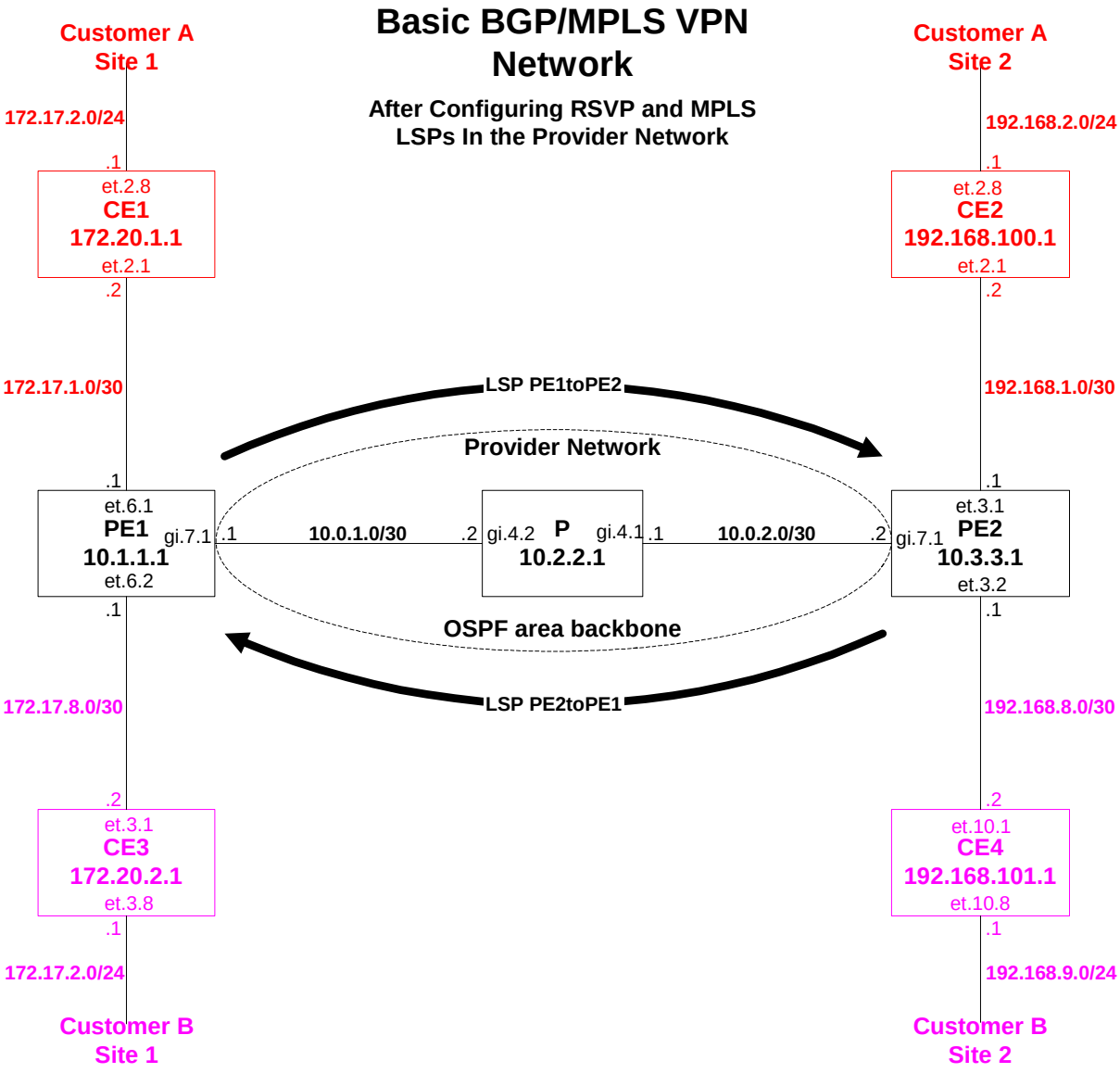


Figure 16-2 Basic BGP/MPLS VPN Network after configuring RSVP and MPLS LSPs in the provider network

Configuring LDP for Signaling

Alternatively, you can use LDP instead of RSVP to create LSPs. To use LDP, configure LDP on all the routers in the provider network. In the Basic BGP/MPLS VPN Network example, you would need to configure LDP on the PE1, PE2, and P routers. To configure LDP in your own networks, follow these steps. For more information on configuring LDP, see *Section 17.4 "LDP Configuration."*

Note LDP requires that an IGP is running.

1. Enable LDP on the desired interfaces. These are usually non-customer-facing interfaces on PE and P routers. When started, LDP discovers local peers automatically by sending Hellos on all LDP-enabled interfaces using the “all routers on this subnet” multicast address. Unlike RSVP, this exchange allows LDP to build a full mesh of bidirectional LSPs to every LDP neighbor’s loopback address. Given this capability, no additional configurations are necessary to establish PE-PE LSPs once LDP is enabled on all the provider routers. In this example, two interfaces are added to LDP—Provider-Facing-Interfaces 1 and 2.
2. Start LDP.
3. Enable MPLS on the desired interfaces. In this example, MPLS is enabled on the same interfaces that were added to RSVP—Provider-Facing-Interfaces 1 and 2.
4. Start MPLS.

The following are examples of the commands used to configure LDP on all provider routers:

```
AnyPEorP(config)# ldp add interface Provider-Facing-Interface1
AnyPEorP(config)# ldp add interface Provider-Facing-Interface2
AnyPEorP(config)# ldp start
AnyPEorP(config)# mpls add interface Provider-Facing-Interface1
AnyPEorP(config)# mpls add interface Provider-Facing Interface2
AnyPEorP(config)# mpls start
```

After configuring LDP, use the **`ldp show database`** command to verify LSP establishment. You should see an LSP to the loopback interface of every router on which LDP is enabled.

16.4.3 Configuring MP-BGP Between PE Routers for Customer Route Distribution

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- **Configure MP-IBGP between PE routers**
- RED and PINK routing instances on the PE routers
- Static and OSPF PE-CE route distribution

PE routers use multiprotocol BGP (MP-BGP) to distribute learned customer routes across the provider network. PE routers logically peer with each other in MP-BGP sessions that do not include P routers. PE routers also use LSPs for resolving next hops. These two features allow PE routers to distribute customer routes across the provider network while keeping them segregated from provider IGP routes.

When distributing VPN-IPv4 routes via MP-BGP, a PE router sets the BGP next hop as itself. Remote PE routers resolve this BGP next hop to an LSP, which it uses for transport on that route.

One of the key features of BGP/MPLS VPN is that each VPN can have its own address space. This is enormously beneficial because VPN customers may use RFC 1918 private address spaces. Therefore, two routes for the same IPv4 prefix may be to different systems. It is important that BGP does not treat the two routes as comparable and install one but not the other, resulting in one of the two systems being unreachable.

BGP4 does not have this capability. MP-BGP is a multiprotocol extension of BGP4 that can translate globally non-unique IPv4 addresses into globally unique VPN-IPv4 addresses by prepending a unique Route Distinguisher value. RFC 2858, *Multiprotocol Extensions for BGP4*, by Bates, Chandra, Katz, and Rekhter defines this standard and the address translation mechanism. The RFC explains, “If two VPNs use the same IPv4 address prefix, the PE routers translate these into unique VPN-IPv4 address prefixes. This ensures that if the same address is used in two different VPNs, it is possible to install two completely different routes to that address, one for each VPN.” For more information on VPN-IPv4 addresses and Route Distinguishers, see the RFC or the *Section "Configuring Route Distinguishers and VPN-IPv4 Addresses."*

To deploy BGP/MPLS VPNS, PE routes must support MP-BGP *in addition* to BGP4. Before exchanging VPN-IPv4 routes, BGP peers negotiate to make sure that both are capable of supporting VPN-IPv4 addresses.

MP-BGP is backward compatible with BGP4. A router that supports MP-BGP extensions can still interoperate with a router that only supports conventional BGP4.

Configuring MP-BGP Between PE Routers

MP-BGP and conventional BGP4 configurations only differ in two commands:

- **`bgp set peer-group <name> vpnv4-unicast ipv4-unicast`**
- **`ip-router global set install-lsp-routes bgp`**

The **`bgp set peer-group <name> vpnv4-unicast ipv4-unicast`** command enables the BGP process to support both conventional IPv4 and VPN-IPv4 addresses. BGP peers negotiate this capability in OPEN messages. By default, BGP supports IPv4 addresses. Unilateral support for VPN-IPv4 addresses means that these address cannot be sent in that peering session.

Note When using the **`ipv4-unicast`** option in the **`bgp set peer-group`** or **`peer-host`** commands, BGP peers must be running ROS 9.2 or later for IPv4 addresses to be exchanged.

For more information on VPN-IPv4 addresses and Route Distinguishers, see the *Section "Configuring Route Distinguishers and VPN-IPv4 Addresses."*

Note By default, BGP sends encapsulated VPN-IPv4 routes with the next hop set to 'self'.

The **`ip-router global set install-lsp-routes bgp`** command enables BGP to use MPLS LSPs for resolving next hops. Normally, MPLS LSPs are not installed in the RIB or FIB, which makes them inaccessible for routing. This command grants BGP *exclusive* access to these LSP routes, allowing BGP to use MPLS paths, *in addition to* other routes in the FIB, in resolving next hops. Under this scheme, BGP prefers MPLS paths over IGP paths. So if a pair of MPLS LSPs exist between PEs, BGP will prefer and use these LSPs for transporting customer traffic. This is desirable because when customer traffic is encapsulated and sent through MPLS, P routers only need to swap labels and forward the traffic. If customer traffic is sent through a routing protocol instead of MPLS, P routers would need to know customer routes in order to forward them. Therefore, encapsulating and sending customer traffic via MPLS is essential to reducing core router workload and enhancing overall network scalability. It requires that only ingress and egress PE routers maintain customer routing information and interface with customer routers. P routers only need to forward MPLS traffic and do not need to route customer prefixes directly.

For more information on the **`ip-router global set install-lsp-routes bgp`** command, see *Section 15.2.15 "Using MPLS LSPs To Resolve BGP Next Hop."*

For more information on configuring conventional BGP, see *Section 15 "BGP Configuration Guide."*

To implement the Basic BGP/MPLS VPN Network (Figure 16-2), MP-IBGP is configured between PE1 and PE2. IBGP is used instead of EBGP because PE1 and PE2 are within the same autonomous system, 65001.

Configuring PE1 and PE2 to route using MP-IBGP

The following examples configure PE1 and PE2 to route using MP-IBGP in AS 65001.

1. Configure both routers to be in AS 65001.
2. Create a peer group named PROVIDER on both routers for their AS 65001 peers. Since it is also in AS 65001, each router recognizes PROVIDER as an IBGP peer group and uses the 'routing' type by default.
3. Add PE1 and PE2 as peer hosts in the PROVIDER group.
   - Add PE2 as a peer host in the PROVIDER group by specifying its loopback address, 10.3.3.1, which is also its router ID.
   - Add PE1 as a peer host in the PROVIDER group by specifying its loopback address, 10.1.1.1, which is also its router ID.
4. Unlike EBGP peers, IBGP peers are not required to be directly attached. IBGP peers often peer logically but are not physically connected, as in our network example. Setting all IBGP peers to peer using their loopback addresses is a good practice.

- Configure PE1 to peer using its loopback address with all hosts in the PROVIDER group by specifying 10.1.1.1 as its local address.
- Configure PE2 to peer using its loopback address with all hosts in the PROVIDER group by specifying 10.3.3.1 as its local address.

5. **[Differs from configuring BGP4]** Specify that both routers should use MP-BGP by enabling support for both conventional IPv4 addresses and VPN-IPv4 unicast addresses. This informs the BGP process that it will be dealing with conventional IPv4 addresses from the unicast RIB and customer VPN-IPv4 addresses from Routing Instance RIB(s). By default, BGP sends all active Routing Instance routes (customer VPN-IPv4 routes) with the next hop set to itself.
6. **[Differs from configuring BGPv4]** Enable BGP on both routers to use MPLS LSPs for resolving next hops by granting BGP *exclusive* access to these LSP routes. Under this scheme, BGP prefers MPLS paths over IGP paths. So if a pair of MPLS LSPs exist between PE1 and PE2, the BGP processes on both routers will prefer these LSPs over IGP routes for transporting customer traffic. This forces PE routers to encapsulate customer traffic as MPLS packets before sending them, which relieves P routers from having to learn or route customer prefixes. Only ingress and egress PE routers maintain customer routing information and interface with customer routers. P routers only need to forward MPLS traffic. Encapsulating and sending customer traffic via MPLS is essential to reducing core router workload and enhancing overall network scalability.
7. Start BGP.

The previous configuration steps result in the following commands on PE1:

```
PE1(config)# ip-router global set autonomous-system 65001
PE1(config)# bgp create peer-group PROVIDER autonomous-system 65001
PE1(config)# bgp add peer-host 10.3.3.1 group PROVIDER
PE1(config)# bgp set peer-group PROVIDER local-address 10.1.1.1
PE1(config)# bgp set peer-group PROVIDER vpnv4-unicast ipv4-unicast
PE1(config)# ip-router global set install-lsp-routes bgp
PE1(config)# bgp start
```

The previous configuration steps result in the following commands on PE2:

```
PE2(config)# ip-router global set autonomous-system 65001
PE2(config)# bgp create peer-group PROVIDER autonomous-system 65001
PE2(config)# bgp add peer-host 10.1.1.1 group PROVIDER
PE2(config)# bgp set peer-group PROVIDER local-address 10.3.3.1
PE2(config)# bgp set peer-group PROVIDER vpnv4-unicast ipv4-unicast
PE2(config)# ip-router global set install-lsp-routes bgp
PE2(config)# bgp start
```

Viewing MP-BGP Sessions

After configuring MP-BGP, use the following commands to verify that MP-BGP is up and running between PE routers:

- **bgp show neighbor**
- **bgp show routes**
- **bgp show peer-host advertised-routes**
- **bgp show peer-host all-received routes**

On PE1, the **bgp show neighbor** command shows that it recognizes PE2 as an established neighbor. It is in a routing-type peering with PE2 in AS 65001. As configured with the **bgp set peer-group vpnv4-unicast ipv4-unicast** command, both routers support IPv4 and VPN-IPv4 addresses, as well as Route Refresh. (For more information on Route Refresh, see the *Section "Configuring VRF Import and Export Policies."*)

```
PE1# bgp show neighbor all
        Peer: 10.3.3.1+1560     Local: 10.1.1.1+179
        Type: Routing    remote AS 65001
        State: Established      Flags: <v4MP v4u>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <LocalAddress>
        Configured parameters :         Local Address: 10.1.1.1
        VRF in use  unicast VRF number 0

        Used parameters :
       Peer Version: 4 Peer ID: 10.3.3.1      Local ID: 10.1.1.1     Active Holdtime:
            180
        Group Bit: 0    Send state: in sync
        Uptime 1d20h47m39s
        Last traffic (seconds): Received 18     Sent 18 Checked 18
        Input messages :Total        18    Updates         2    Octets       396

        Output messages:Total        18    Updates         1    Octets       415

          count of sent routes                0
          count of recvd routes               0
          count of route refresh recvd        0
          count of route refresh sent         0
          count of derived routes             0
        Supported capabilities
               V4 Unicast;VPN-V4 Unicast;Route Refresh;
```

On PE2, the **bgp show neighbor** command also shows that it recognizes PE1 as an established neighbor.

```
PE2# bgp show neighbor all
        Peer: 10.1.1.1+179      Local: 10.3.3.1+1560
        Type: Routing    remote AS 65001
        State: Established      Flags: <v4MP v4u>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <LocalAddress>
        Configured parameters :         Local Address: 10.3.3.1
        VRF in use  unicast VRF number 0

        Used parameters :
       Peer Version: 4 Peer ID: 10.1.1.1      Local ID: 10.3.3.1     Active Holdtime:
            180
        Group Bit: 0    Send state: in sync
        Uptime 1d20h55m56s
        Last traffic (seconds): Received 58     Sent 58 Checked 58
        Input messages :Total        24    Updates         2    Octets       490

        Output messages:Total        25    Updates         1    Octets       548

          count of sent routes               0
          count of recvd routes              0
          count of route refresh recvd       0
          count of route refresh sent        0
          count of derived routes            0
        Supported capabilities
                V4 Unicast;VPN-V4 Unicast;Route Refresh;
```

Figure 16-3 illustrates the Basic BGP/MPLS VPN Network with the following configured:

- IGP (OSPF) in the provider network
- MPLS and RSVP in the provider network
- MP-IBGP between the PE routers

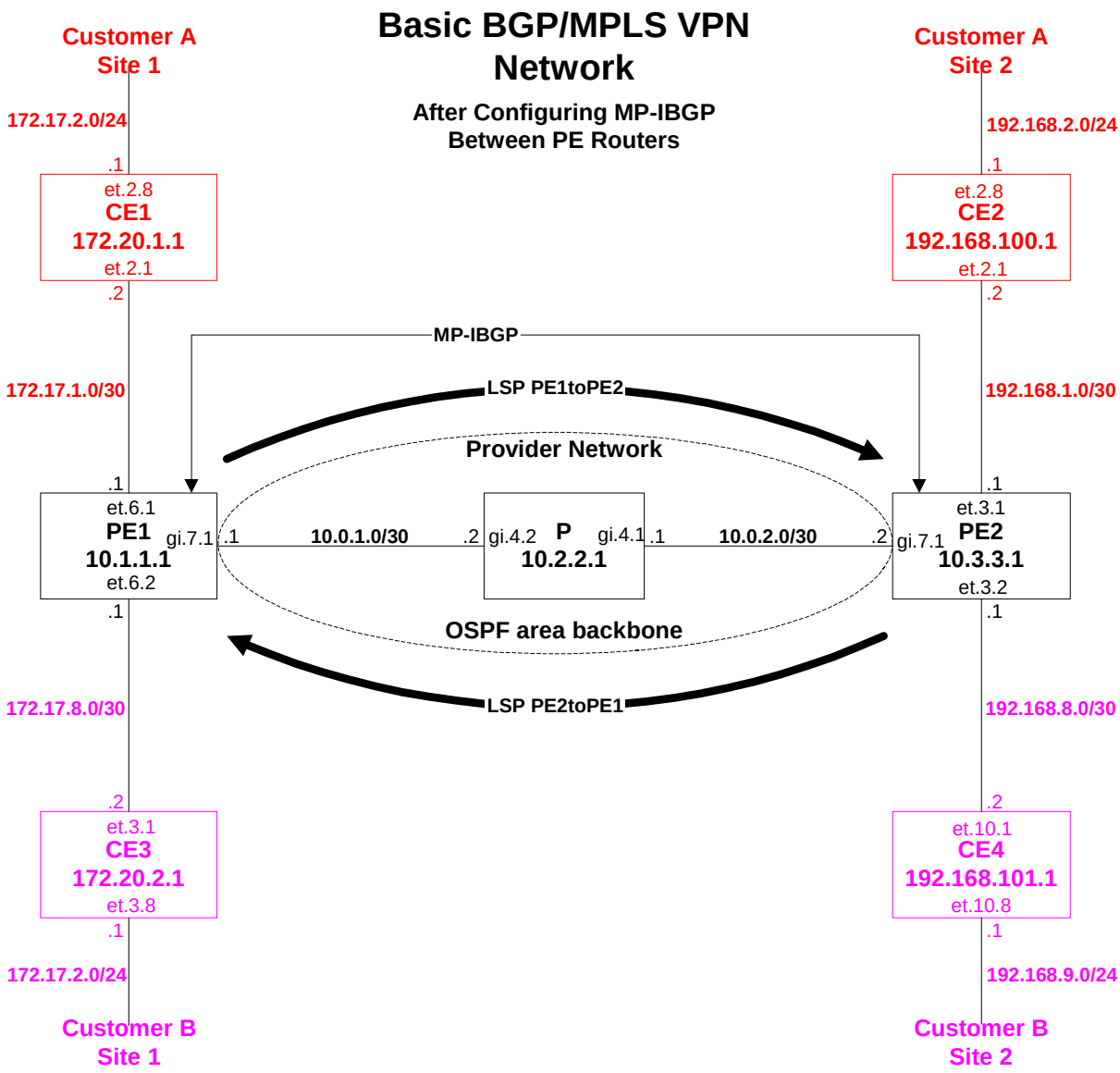


Figure 16-3 Basic BGP/MPLS VPN Network after configuring MP-IBGP between PE routers

16.4.4 Configuring Routing Instances

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- **Configure RED and PINK routing instances on the PE routers**
  - Configure Route Distinguisher—create routing instance
  - Add interface(s) to routing instance
  - Configure import and export routing policies (Route Targets) for routing instances
- Static and OSPF PE-CE route distribution

To implement BGP/MPLS VPNs, you must supply the following to PE routers:

- Which VPN(s) to support.
  - In the Basic BGP/MPLS VPN Network example, PE1 and PE2 both need to support two VPNs—RED and PINK.

- Which directly-connected customer sites belong to which VPNs.
  - In the Basic BGP/MPLS VPN Network example, PE1 needs to know that the customer router attached to port et.6.1 (CE1) belongs to the RED VPN and the customer router attached to port et.6.2 (CE3) belongs to the PINK VPN.
  - Similarly, PE2 needs to know that the customer router attached to port et.3.1 (CE2) belongs to the RED VPN and the customer router attached to port et.3.2 (CE4) belongs to the PINK VPN.

- A way to separate one customer site's routes from other customer site routes, as well as from provider internal routes. Route segregation is essential to supporting RFC 1918 private addresses for customers, which can result in overlapping addresses between VPNs and between a VPN and the provider network. It also ensures that a VPN's routes do not leak into other VPNs, or into the provider network.
  - In the Basic BGP/MPLS VPN Network example, Customer A Site 1 and Customer B Site 1 share the 172.17.2.0/24 network. PE1 learns one route from CE1 and another from CE3. PE2 learns both routes from PE1 through the MP-IBGP session between them. Both PE1 and PE2 need to distinguish between these routes when forwarding and advertising. They should only use the route learned from CE1 for the RED VPN and the route learned from CE3 for the PINK VPN.
  - The PE routers must keep RED VPN routes, PINK VPN routes, and internal provider routes separate.

VRFs and Routing Instances

RFC 2547bis, *BGP/MPLS VPNs*, in defining the BGP/MPLS VPN standard, fulfills these requirements by mandating that PE routers maintain multiple, per-site *routing and forwarding tables (VRFs)*:

> Each PE router maintains a number of separate forwarding tables. Every site to which the PE router is attached must be mapped to one of those forwarding tables. When a packet is received from a particular site, the forwarding table associated with that site is consulted in order to determine how to route the packet. The forwarding table associated with a particular site S is populated ONLY with routes that lead to other sites which have at least one VPN in common with S. This prevents communication between sites which have no VPN in common.
>
> When a PE router receives a packet from a CE device, it knows the interface or sub-interface over which the packet arrived, and this determines the forwarding table used for processing that packet. The choice of forwarding table is NOT determined by the user content of the packet.
>
> The fact that sites in different VPNs are mapped to different forwarding tables makes it possible for different VPNs to have overlapping address spaces, without creating any ambiguity.

Note While this usually means that the PE router associates one VRF for each customer-connected port, multiple ports/sites can be associated with the same VRF if they have all their VPNs in common. This allows PE routers to conserve router resources.

If sites contain hosts that are members of multiple VPNs, the VRF associated with that site contains routes for all VPNs of which that site is a member.

The PE router maintains a VRF for each directly-connected site. Multiple forwarding tables prevent sites that have no VPNs in common from communicating. This enhances scalability by not requiring PE routers to maintain a dedicated VRF for all of the VPNs supported by the provider network. Each PE router only needs to maintain VRFs for its directly-connected sites.

In addition to per-site VRFs, the PE router also maintains the default global routing and forwarding tables (RIB and FIB) for non-VPN routes.

On the RS, you do not define VRFs. You define *routing instances*, which generate VRFs. Each VRF is associated with a routing instance, which runs between PE and CE routers. The routing instance learns and manages routes for that VRF. Each VRF, like the global forwarding tables, consists of a routing information base (RIB) and a forwarding information base (FIB). The PE router first learns routes from its customer(s) and installs them in the Routing Instance RIB. Then, routing instances perform route selection and choose active routes from the Routing Instance RIB to install in the Routing Instance FIB. Using the Routing Instance FIB, routing instances forwards packets to and from customer(s). Since each VRF has its own routing instance to learn, process, and forward routes, a VRF's routes never accidentally mixes with other VRF routes.

To configure a routing instance, you must configure four required elements:

1. Create unique VPN-IPv4 addresses by configuring a Route Distinguisher
2. Specify which directly-connected customer site(s) belong to this VRF by adding interface(s)
3. Specify which categor(ies) of routes the VRF's customer site(s) should learn by configuring import polic(ies)
4. Specify which categor(ies) to use in advertising the VRF's customer site routes by configuring export polic(ies)

Configuring Route Distinguishers and VPN-IPv4 Addresses

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- **Configure RED and PINK routing instances on the PE routers**
  - **Configure Route Distinguisher—create routing instance**
  - Add interface(s) to routing instances
  - Configure import and export routing policies (Route Targets) for routing instances
- Static and OSPF PE-CE route distribution

To support overlapping customer addresses, PE routers create globally unique VPN-IPv4 addresses by prepending Route Distinguishers to globally non-unique IPv4 addresses. RFC 2547bis, *BGP/MPLS VPNs,* defines the VPN-IPv4 address family and the address translation mechanism.

Route Distinguisher and VPN-IPv4 Address Usage Notes

Note The Route Distinguisher does not, by itself, contain information about the origin of a route or the customer site(s) to which it should be distributed. It is merely used to create IPv4 addresses. Route Distinguishers are not the same as BGP Extended Community Attributes, which define a route's import and export properties.

VPN-IPv4 addresses are used only within the provider network. Customers are not aware of VPN-IPv4 addresses. PE routers convert customer IPv4 routes into VPN-IPv4 format before sending them through the provider network and out of VPN-IPv4 into IPv4 format before sending them to customers.

Prepending a unique Route Distinguisher to an IPv4 address creates a unique VPN-IPv4 address of the following format:

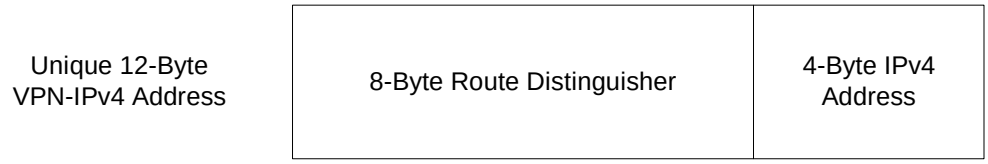


Figure 16-4 VPN-IPv4 address format

The eight-byte Route Distinguisher consists of a 2-byte Type field and a 6-byte Value field. The Value Field contains two subfields, the Administrator subfield and the Assigned Number subfield. The Administrator subfield is meant to hold a globally unique value—either the service provider's IPv4 address or autonomous system (AS) number. The Assigned Number subfield is meant to hold a provider-assigned value that is unique within the provider. Together, they create a unique string that distinguishes the customer site's IPv4 addresses from other IPv4 addresses.

Note To ensure that the Route Distinguisher is unique, use only AS numbers or IP address that you own for the Administrator subfield. Using private IPv4 addresses or AS numbers can easily result in duplicate Route Distinguishers. For this reason, the RFC strongly discourages the use of private AS numbers or IP addresses in the Route Distinguisher.

Depending on what you use in the Administrator subfield, the Route Distinguisher can take on one of two formats:

	2-Byte Type Field	2-Byte Administrator Subfield	4-Byte Assigned Number Subfield
8-Byte Route Distinguisher	*0*	*Unique AS#*	*Provider-Assigned Unique #*

Figure 16-5 Type-0 Route Distinguisher Format

	2-Byte Type Field	4-Byte Administrator Subfield	2-Byte Assigned Number Subfield
8-Byte Route Distinguisher	1	*Unique IPv4 Address*	*Provider-Assigned Unique #*

Figure 16-6 Type-1 Route Distinguisher Format

When configuring Route Distinguishers, you do not need to specify the Type field. The RS automatically detects the Route Distinguisher format based on whether your configuration uses an IPv4 address or AS number.

Note Configuring a routing instance with a Route Distinguisher creates that routing instance and should be the first step in a routing instance configuration.

Note Routing instance names are case sensitive.

To implement the Basic BGP/MPLS VPN Network (Figure 16-3), each PE router's loopback address is used for the Administrator value. All RED instances are assigned a unique identifier of '1' and all PINK instances a unique identifier of '2'. Even though this example uses RFC 1918 private addresses, you should, in general, only use publicly unique IP addresses or AS numbers in the Route Distinguisher.

Configure routing instance RED on PE1

The following example configures a RED routing instance on PE1 and specifies a Route Distinguisher using PE1's loopback address (10.1.1.1) and 1 as the provider-assigned unique identifier.

```
PE1(config)# routing-instance RED vrf set route-distinguisher "10.1.1.1:1"
```

Configure routing instance RED on PE2

The following example configures a RED routing instance on PE2 and specifies a Route Distinguisher using PE2's loopback address (10.3.3.1) and 1 as the provider-assigned unique identifier.

```
PE2(config)# routing-instance RED vrf set route-distinguisher "10.3.3.1:1"
```

Configure routing instance PINK on PE1

The following example configures a PINK routing instance on PE1 and specifies a Route Distinguisher using PE1's loopback address (10.1.1.1) and 2 as the provider-assigned unique identifier.

```
PE1(config)# routing-instance PINK vrf set route-distinguisher "10.1.1.1:2"
```

Configure routing instance PINK on PE2

The following example configures a PINK routing instance on PE2 and specifies a Route Distinguisher using PE2's loopback address (10.3.3.1) and 2 as the provider-assigned unique identifier.

```
PE2(config)# routing-instance PINK vrf set route-distinguisher "10.3.3.1:2"
```

The following section describes how to add interface(s) to a routing instance.

Adding Interfaces to VRFs

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- **Configure RED and PINK routing instances on the PE routers**
  - Configure Route Distinguisher—create routing instance
  - **Add interface(s) to routing instances**
  - Configure import and export routing policies (Route Targets) for routing instances
- Static and OSPF PE-CE route distribution

Before you can configures a routing instance to route between PE and CE routers, you must add the appropriate interfaces to it. By adding interface(s) to a routing instance, you tell the RS which directly-connected site(s) to associate with that VRF.

Note Routing instance names are case sensitive.

You can associate multiple interfaces with a VRF.

The routing protocol you use for CE-PE route distribution determines which interfaces you add to each VRF. For static routes, adding the directly-connected VRF interface to the routing instance is usually sufficient. For routing protocols that use the loopback interface, you should also add the loopback interface to the routing instance and set the loopback to be the router ID in the routing instance.

To implement the Basic BGP/MPLS VPN Network (Figure 16-3), on PE1, Customer A Site 1 is associated with the RED VRF and Customer B Site 1 is associated with the PINK VRF. On PE2, Customer A Site 2 is associated with the RED VRF and Customer B Site 2 with the PINK VRF. Customer A is using static routes with the PE routers, and only requires that directly-connected VRF interface be added to the routing instance. Customer B is using OSPF with the PE routers, which requires that the loopback be added and set as the router ID.

Associate Customer A Site 1 with the RED VRF on PE1

The following example associates Customer A Site 1 with the RED VRF on PE1 by adding the interface ‘ToCE1’ to the RED routing instance.

```
PE1(config)# routing-instance RED vrf add interface ToCE1
```

Associate Customer B Site 1 with the PINK VRF on PE1

The following example associates Customer B Site 1 with the PINK VRF on PE1 by adding the interface ‘ToCE3’ to the PINK routing instance. Since PE1 and CE3 will route using OSPF, also add PE1’s loopback as an interface and set its address as the router ID in the PINK VRF.

```
PE1(config)# routing-instance PINK vrf add interface ToCE3
PE1(config)# routing-instance PINK vrf add interface lo0
PE1(config)# routing-instance PINK vrf set router-id 10.1.1.1
```

Associate Customer A Site 2 with the RED VRF on PE2

The following example associates Customer A Site 2 with the RED VRF on PE2 by adding the interface ‘ToCE2’ to the RED routing instance.

```
PE2(config)# routing-instance RED vrf add interface ToCE2
```

Associate Customer B Site 2 with the PINK VRF on PE2

The following example associates Customer B Site 2 with the PINK VRF on PE2 by adding the interface ‘ToCE4’ to the PINK routing instance. Since PE2 and CE4 will route using OSPF, also add PE2’s loopback as an interface and set its address as the router ID in the PINK VRF.

```
PE2(config)# routing-instance PINK vrf add interface ToCE4
PE2(config)# routing-instance PINK vrf add interface lo0
PE2(config)# routing-instance PINK vrf set router-id 10.3.3.1
```

The following section describes how to configure import and export Route Targets for routing instances.

Configuring VRF Import and Export Policies

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- **Configure RED and PINK routing instances on the PE routers**
  - Configure Route Distinguisher—create routing instance
  - Add interface(s) to routing instances
  - **Configure import and export routing policies (Route Targets) for routing instances**
- Static and OSPF PE-CE route distribution

Note You must create the routing instance using the **`routing-instance vrf set route-distinguisher`** command before you can configure import and export Route Targets for it.

Through the use of the Extended Community Attribute Route Targets, you can associate each connected site on a PE router with one or more *import* and *export Route Targets*. For more information on Extended Community Attribute Route Targets, see the IETF draft *BGP Extended Communities Attribute* by Ramachandra, Tappan, and Rekhter, or the *Section "Extended Communities."*

Route Targets, defined by routing policies, allow you to specify which categor(ies) of routes a PE router should accept for a site, and which categor(ies) it should use to advertise routes learned from a site. These routing policies define VPN connectivity.

When using BGP Extended Community Attributes to define Route Targets, select from one of two forms:

`target:`<*Global autonomous system number*>**`:`**<*Identifier*>

`target:`<*Global IP address*>**`:`**<*Identifier*>

After the **`target`** keyword, specify either a global AS number or global IP address, followed by a unique identifier for this particular VRF.

Note To ensure that the Route Target is unique, use only AS numbers or IP address that you own. Using private IPv4 addresses or AS numbers can easily result in duplicate Route Targets. Even though this example uses a private AS number, you should, in general, only use publicly unique IP addresses or AS numbers.

The Basic BGP/MPLS VPN Network (Figure 16-3) uses the provider network's autonomous system number, 65001, to define the Route Targets. All RED Route Targets are assigned a unique identifier of '1' and all PINK Route Targets a unique identifier of '2'. Note that this presupposes agreement between the administration for PE1 and PE2 on the identifier assignment scheme. PE1 and PE2 must both agree that a Route Target from AS 65001 with an identifier of '1' means 'RED" and '2' means 'PINK'. Since the AS number is used, the identifier must be unique in this provider network.

If such an agreement is impossible due to preexisting routing policies or inconsistent administration, Route Targets should use PE router loopback addresses instead. Since PE routers have distinct loopback addresses, identifiers only needs to be *locally* unique in this scheme. As long as you assign different identifiers to different VRFs, other PE routers need to know what identifier you assign to 'RED', but are not constrained to making the same assignment themselves. A centrally available and up-to-date mapping of per-PE router identifier assignments can be helpful in maintaining network consistency in this case, which offers network administrators greater flexibility at the cost of higher complexity.

VRF Import and Export Policy Usage Notes

PE routers filter all routes received from remote PE routers through MP-BGP based on the Route Target(s) that you configure. It discards routes that do not match any import targets on the VRFs that it supports. It installs the remaining routes into the VPN-IPv4 RIB. The VPN-IPv4 RIB contains all routes that satisfy the import policy of at least one of the PE router's VRFs. Since this is the only table that contains all of the routes from all of the VPNs directly connected to the PE router, it is the only table that relies on Route Distinguishers to keep routes with identical IPv4 prefixes distinct.

Standard BGP route selection occurs in this table. Selected routes that match VRF import target(s) are installed into the RIB for that VRF.

Then, the routing instance associated with that VRF selects optimal and active routes from the Routing Instance RIB to install into the Routing Instance FIB.

Note When a PE router receives a route advertisement, it determines whether it should install that route into any VRFs by performing route filtering based on the route's import target. A route is only eligible to be installed in the VRF tables for a routing instance if at least one of its Route Target(s) match the import target(s) for that VRF.

Note Route Targets, which are BGP Extended Community Attributes, are not the same as Route Distinguishers. Route Distinguishers do not, by themselves, contain information about the origin of a route or the customer site(s) to which it should be distributed. They are merely used to create VPN-IPv4 addresses. A route can only have one Route Distinguisher, but it can have multiple Route Targets.

You can associate multiple import and export Route Targets on a VRF. Import and export targets need not be the same.

BGP Route Refresh

During routing exchange, BGP routers only keep routes received from peers that pass configured routing policies. When you configure a new policy or change an existing policy, the RS needs to reacquire routes that may have been previously discarded before configuration changes can take effect.

Without the Route Refresh capability, since BGP sends all routes only at the beginning of peering, clearing all established BGP peering sessions was the only way to prompt BGP peers to resend routes.

RFC 2918, *Route Refresh Capability for BGP-4* by Chen defines a mechanism whereby BGP peers can prompt for a retransmission of routes without clearing established peering sessions.

The Route Refresh mechanism is non-disruptive and turned on by default. BGP peers negotiate this capability at the beginning of peering to make sure that both are capable of supporting Route Refresh. A router that supports Route Refresh can still interoperate with a router that does not. In this case, however, you must manually clear the BGP session before configured routing policy changes can take effect. When both peers support Route Refresh, the router automatically requests routes upon a policy configuration change.

Import and Export Route Target Configuration Overview

Routing policies do not take effect until PE routers learn routes from CE routers. For more information on configuring static and OSPF route distribution between CE and PE routers, see *Section 16.4.5 "Configuring Static and OSPF Route Distribution Between CE and PE Routers."*

To implement the Basic BGP/MPLS VPN Network (Figure 16-3), import and export routing policies are configured as follows:

For Customer A, PE1 is configured to tag routes learned from CE1 as RED. It passes these routes to PE2 tagged with a RED Route Target. PE1 is also configured to only learn routes tagged RED for CE1 through a routing policy that sets the import target for this site to RED. The same holds true for routes that PE2 learns and advertises to CE2.

Similarly, for Customer B, PE1 is configured to tag routes learned from CE3 as PINK. It passes these routes to PE2 tagged with a PINK Route Target. PE1 is also configured to only learn routes tagged PINK from PE2 for CE3 through a routing policy that sets the import target for this site to PINK. The same holds true for routes that PE2 learns and advertises to CE4.

These configurations ensure that CE1 and CE2 have full connectivity. CE3 and CE4 also have full connectivity. But the Route Targets configured on PE1 and PE2 ensure that VPN RED and VPN PINK have no connectivity.

- PE1 passes Customer A Site 2 routes (learned through PE2) to Customer A Site 1 through CE1.
  PE2 passes Customer A Site 1 routes (learned through PE1) to Customer A Site 2 through CE2.
- PE1 passes Customer B Site 2 routes (learned through PE2) to Customer B Site 1 through CE3.
  PE2 passes Customer B Site 1 routes (learned through PE1) to Customer B Site 2 through CE4.
- But routes learned from Customer B sites are not passed to Customer A sites, and vice versa.

Note You must configure export targets as *routing policies* using the **`ip-router policy create`** command.

The following configuration steps define the Route Targets using the provider network's autonomous system number, 65001. It assigns all RED Route Targets a unique identifier of '1' and all PINK Route Targets a unique identifier of '2' on both PE1 and PE2. Even though this example uses a private AS number, you should, in general, only use publicly unique IP addresses or AS numbers in defining Route Targets.

Configure RED import and export Route Targets on PE1

The following example configures PE1 to only learn routes tagged with a Route Target of “target:65001:1” for the RED VRF—“target:65001:1” is the RED VRF *import* target on PE1. These routes, once learned, enter the Routing Instance RIB and FIB managed by the RED routing instance.

This example also configures PE1 to tag all routes from the RED VRF with a Route Target of “target:65001:1” before distributing them. Remote PE routers only learn these routes if they have a VRF import target of “target:65001:1” configured.

1. Configure a community list named “RED-import” that only permits routes tagged with the “target:65001:1” community string. This community list is used to define the RED VRF import route map.
2. Create a routing policy named “RED-export” that matches routes tagged with the “target:65001:1” community string. This routing policy is used to define the RED VRF export route map.

Note Community list, routing policy, and routing instance names are all case sensitive.

3. Create a route map named “RED-import” that permits all routes matching the ‘RED-import’ community list. This route map is used as the RED VRF import target.
4. Create a route map named “RED-export” that sets all routes using the ‘RED-export’ routing policy you defined. This route map is used as the RED VRF export target.
5. Apply the ‘RED-import’ route map as the RED VRF import target with a sequence number of 1. You can specify multiple VRF import targets with sequence numbers to set the order in which they should be matched.
6. Apply the ‘RED-export’ route map as the RED VRF export target with a sequence number of 1. You can specify multiple VRF export targets with sequence numbers to set the order in which they should be evaluated.

The previous configuration steps result in the following commands on PE1:

```
PE1(config)# community-list RED-import permit 10 target:65001:1
PE1(config)# ip-router policy create community-list RED-export target:65001:1
PE1(config)# route-map RED-import permit 10 match-community-list RED-import
PE1(config)# route-map RED-export permit 10 set-community-list RED-export
PE1(config)# routing-instance RED vrf set vrf-import RED-import in-sequence 1
PE1(config)# routing-instance RED vrf set vrf-export RED-export out-sequence 1
```

Configure RED import and export Route Targets on PE2

On PE2, configure RED import and export Route Targets using the same steps used on PE1.

```
PE2(config)# community-list RED-import permit 10 target:65001:1
PE2(config)# ip-router policy create community-list RED-export target:65001:1
PE2(config)# route-map RED-import permit 10 match-community-list RED-import
PE2(config)# route-map RED-export permit 10 set-community-list RED-export
PE2(config)# routing-instance RED vrf set vrf-import RED-import in-sequence 1
PE2(config)# routing-instance RED vrf set vrf-export RED-export out-sequence 1
```

Timesaver

Defining VRF import and export Route Targets using route maps, community lists, and policies allows you to match or set more than one criteria at a time. If you only want to match or set one Extended Community Attribute for the VRF import or export policy, you can apply the Extended Community Attribute string directly using the **routing-instance vrf set community** command. This command limits you to specifying only one attribute, either by using a predefined community list or by specifying the actual extended community string enclosed in quotes. By default, this command sets both the import and export Route Targets to the specified community. Use the **import** and **export** options for selective application. The **import** option has an implicit **match** and the **export** command has an implicit **set** functionality. Using this command, the above PE1 configuration can be abbreviated in the following ways:

Configure RED import and export Route Targets on PE1

```
PE1(config)# routing-instance RED vrf set community “target:65001:1”
```

```
PE1(config)# routing-instance RED vrf set community “target:65001:1” import
PE2(config)# routing-instance RED vrf set community “target:65001:1” export
```

```
PE1(config)# community-list RED permit 10 target:65001:1
PE1(config)# routing-instance RED vrf set community 10
```

```
PE1(config)# community-list RED permit 10 target:65001:1
PE1(config)# routing-instance RED vrf set community 10 import
PE1(config)# routing-instance RED vrf set community 10 export
```

Configure PINK import and export Route Targets on PE1

The following example configures PE1 to only learn routes tagged with a Route Target of “target:65001:2” for the PINK VRF—“target:65001:2” is the PINK VRF *import* target on PE1. These routes, once learned, enter the Routing Instance RIB and FIB managed by the PINK routing instance.

This example also configures PE1 to tag all routes from the PINK VRF with a Route Target of “target:65001:2” before distributing them. Remote PE routers only learn these routes if they have a VRF import target of “target:65001:2” configured.

1. First, configure a community list named “PINK-import” that only permits routes tagged with the “target:65001:2” community string. You will use this community list to define the PINK VRF import route map.
2. Second, create a routing policy named “PINK-export” that matches routes tagged with the “target:65001:2” community string. You will use this routing policy to define the PINK VRF export route map.
3. Create a route map named “PINK-import” that permits all routes matching the ‘PINK-import’ community list you defined. You will use this route map as the PINK VRF import target.
4. Create a route map named “PINK-export” that sets all routes using the ‘PINK-export’ routing policy you defined. You will use this route map as the PINK VRF export target.
5. Apply the ‘PINK-import’ route map as the PINK VRF import target with a sequence number of 1. You can specify multiple VRF import targets with sequence numbers to set the order in which they should be matched.
6. Apply the ‘PINK-export’ route map as the PINK VRF export target with a sequence number of 1. You can specify multiple VRF export targets with sequence numbers to set the order in which they should be evaluated.

The previous configuration steps result in the following commands on PE1:

```
PE1(config)# community-list PINK-import permit 10 target:65001:2
PE1(config)# ip-router policy create community-list PINK-export target:65001:2
PE1(config)# route-map PINK-import permit 10 match-community-list PINK-import
PE1(config)# route-map PINK-export permit 10 set-community-list PINK-export
PE1(config)# routing-instance PINK vrf set vrf-import PINK-import in-sequence 1
PE1(config)# routing-instance PINK vrf set vrf-export PINK-export out-sequence 1
```

Configure PINK import and export Route Targets on PE2

On PE2, configure RED import and export Route Targets using the same steps used on PE1.

```
PE2(config)# community-list PINK-import permit 10 target:65001:2
PE2(config)# ip-router policy create community-list PINK-export target:65001:2
PE2(config)# route-map PINK-import permit 10 match-community-list PINK-import
PE2(config)# route-map PINK-export permit 10 set-community-list PINK-export
PE2(config)# routing-instance PINK vrf set vrf-import PINK-import in-sequence 1
PE2(config)# routing-instance PINK vrf set vrf-export PINK-export out-sequence 1
```

Viewing import and export VRF Route Targets

Use the following commands to view configured VRF import and export targets:

- **bgp show community-list all**
- **route-map show all**

On PE1 and PE2, the **bgp show community-list** command displays the community lists you created using the **community-list** command (RED-import and PINK-import) and using the **ip-router policy create community-list** command (RED-export and PINK-export).

```
PE1# bgp show community-list all
Name           Action Sequence Count Community List
============== ====== ======== ===== ==============
PINK-export    permit 0        1     target:65001:2
RED-export     permit 0        1     target:65001:1
RED-import     permit 10       1     target:65001:1
PINK-import    permit 10       1     target:65001:2
```

```
PE2# bgp show community-list all
Name           Action Sequence Count Community List
============== ====== ======== ===== ==============
PINK-export    permit 0        1     target:65001:2
RED-export     permit 0        1     target:65001:1
RED-import     permit 10       1     target:65001:1
PINK-import    permit 10       1     target:65001:2
```

The **route-map show all** command displays the route maps you defined using the **route-map** command. Four route maps exist on both PE1 and PE2—two using match clauses (RED-import and PINK-import) and two using set clauses (RED-export and PINK-export).

```
PE1# route-map show all
route-map PINK-export, permit, sequence 10
  Match clauses
  Set clauses
    set community target:65001:2

route-map PINK-import, permit, sequence 10
  Match clauses
    community list PINK-import
        Action Sequence Count Community List
        ====== ======== ===== ==============
        permit 10       1     target:65001:2
  Set clauses

route-map RED-export, permit, sequence 10
  Match clauses
  Set clauses
    set community target:65001:1

route-map RED-import, permit, sequence 10
  Match clauses
    community list RED-import
        Action Sequence Count Community List
        ====== ======== ===== ==============
        permit 10       1     target:65001:1
  Set clauses
```

```
PE2# route-map show all
route-map PINK-export, permit, sequence 10
  Match clauses
  Set clauses
    set community target:65001:2

route-map PINK-import, permit, sequence 10
  Match clauses
    community list PINK-import
        Action Sequence Count Community List
        ====== ======== ===== ==============
        permit 10       1     target:65001:2
  Set clauses

route-map RED-export, permit, sequence 10
  Match clauses
  Set clauses
    set community target:65001:1

route-map RED-import, permit, sequence 10
  Match clauses
    community list RED-import
        Action Sequence Count Community List
        ====== ======== ===== ==============
        permit 10       1     target:65001:1
  Set clauses
```

Viewing VRFs

Use the following commands to view basic VRF configurations:

- **routing-instance show instance**
- **routing-instance show interface**

On PE1 and PE2, the **routing-instance show instance all** command displays the type, Route Distinguisher, and associated interface(s) for all configured routing instances. It also displays the import and export policies, as well as any default routes, configured for each routing instance.

```
PE1# routing-instance show instance all

PINK
Type                : vrf
Route-Distinguisher : 10.1.1.1:2
Router-ID : 10.1.1.1
Interfaces          : ToCE3 lo0
vrf-import          : PINK-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list PINK-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:2
                            Set clauses

vrf-export          : PINK-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:2

Default route        : not present
Default route active : 0

RED
Type                : vrf
Route-Distinguisher : 10.1.1.1:1
Router-ID : 172.17.1.1
Interfaces          : ToCE1
vrf-import          : RED-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list RED-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:1
                            Set clauses

vrf-export          : RED-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:1

Default route        : not present
Default route active : 0
```

```
PE2# routing-instance show instance all

PINK
Type                : vrf
Route-Distinguisher : 10.3.3.1:2
Router-ID : 10.3.3.1
Interfaces          : ToCE4 lo0
vrf-import          : PINK-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list PINK-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:2
                            Set clauses

vrf-export          : PINK-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:2

Default route        : not present
Default route active : 0

RED
Type                : vrf
Route-Distinguisher : 10.3.3.1:1
Router-ID : 192.168.1.1
Interfaces          : ToCE2
vrf-import          : RED-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list RED-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:1
                            Set clauses

vrf-export          : RED-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:1

Default route        : not present
Default route active : 0
```

The **routing-instance show interface all** command displays information about the interface(s) associated with VRF(s) on a PE router.

```
PE1# routing-instance show interface all
Interface                       IP address      Routing Instance

ToCE3                           172.17.8.1      PINK
ToCE1                           172.17.1.1      RED
```

```
PE2# routing-instance show interface all
Interface                       IP address      Routing Instance

ToCE4                           192.168.8.1     PINK
ToCE2                           192.168.1.1     RED
```

Figure 16-7 illustrates the Basic BGP/MPLS VPN Network with the following configured:

- IGP (OSPF) in the provider network
- MPLS and RSVP in the provider network
- MP-IBGP between the PE routers
- RED and PINK routing instances on the PE routers

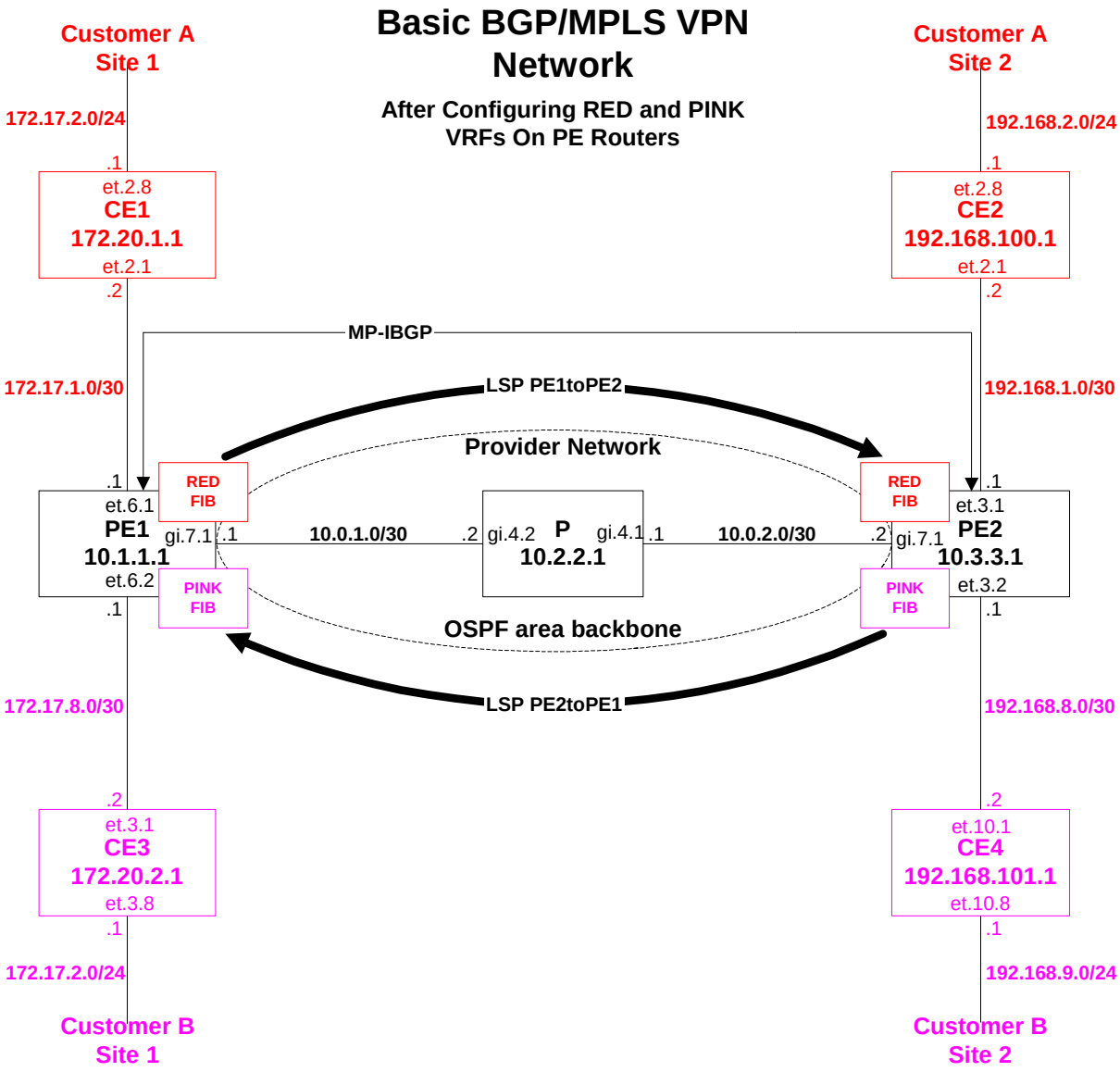


Figure 16-7 Basic BGP/MPLS VPN Network after configuring RED and PINK VRFs on PE routers

16.4.5 Configuring Static and OSPF Route Distribution Between CE and PE Routers

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
- **Configure static and OSPF PE-CE route distribution**
  - Configure Static routing between CE1 and PE1 and CE2 and PE2
  - Configure OSPF between CE3 and PE1 and CE4 and PE2

Before PE routers can forward traffic and announce customer routes, they must first learn those routes from CE routers. The customer and provider network administrators must cooperatively configure CE and PE routers to exchange routes.

In the Basic BGP/MPLS VPN Network (Figure 16-7),

- For VPN RED, CE1 and PE1 must exchange routes for the 172.17.2.0/24 network. Likewise, CE2 and PE2 must exchange routes for the 192.168.2.0/24 network.
- For VPN PINK, CE3 and PE1 must exchange routes for the 172.17.2.0/24 network. Likewise, CE4 and PE2 must exchange routes for the 192.168.9.0/24 network.

The RS supports the following routing schemes between CE and PE routers.

- Static routes
- Open Shortest Path First (OSPF)
- Routing Information Protocol (RIP)
- Border Gateway Protocol (BGP)

The following sections illustrate how to configure CE-PE route distribution using static routes and OSPF.

For instructions on configuring CE-PE route distribution using RIP and BGP, refer to the Section *"Configuring RIP and BGP Route Distribution Between CE and PE Routers."*

Configuring Static Routes Between CE and PE Routers

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
- **Configure static and OSPF PE-CE route distribution**
  - **Configure Static routing between CE1 and PE1 and CE2 and PE2**
  - Configure OSPF between CE3 and PE1 and CE4 and PE2

Configuring Static Routes On CE Routers

To use static routing between CE and PE routers, first configure static routes on the CE router pointing to the PE router. Alternatively, you may configure the CE router to use the PE router as a default gateway. This example configures the CE router to use the PE router as a default gateway. For finer routing control, configure specific static routes on CE routers.

To implement the Basic BGP/MPLS VPN Network (Figure 16-7), static routing is configured between CE1 and PE1 and between CE2 and PE2.

Configure CE1 to route statically with PE1 using a default gateway

The following example configures CE1 to use PE1 as a default gateway.

```
CE1(config)# ip add route default gateway 172.17.1.1
```

Configure CE2 to route statically with PE2 using a default gateway

The following example configures CE2 to use PE2 as a default gateway.

```
CE2(config)# ip add route default gateway 192.168.1.1
```

Configuring Static Routes On PE Routers

For a PE router to distribute VPN routes to and from CE routers, you must configure it to route within a routing instance. For more information on configuring routing instances, see *Section 16.4.4 "Configuring Routing Instances."*

In the Basic BGP/MPLS VPN Network (Figure 16-7), there are two VRFs—RED and PINK. On the PE router, each routing instance maintains the routes that it learns and advertises in its own VRF.

Use the **routing-instance *<name>* ip add route** command to configure VPN-related static routing on PE routers. This command assumes that you have already created a routing instance identified by ***<name>***.

Within a routing instance, this command functions identically to the **ip add route** command.

Note Routing instance names are case sensitive.

To implement the Basic BGP/MPLS VPN Network (Figure 16-7), PE1 is configured to route with CE1 statically and PE2 is configured to route with CE2 statically.

Configure PE1 to route statically with CE1

The following example configures the predefined RED routing instance on PE1 to route statically to the Customer A Site 1 network, 172.17.2.0/24, through CE1's directly-connected interface.

```
PE1(config)# routing-instance RED ip add route 172.17.2.0/24 gateway 172.17.1.2
```

Add CE1's loopback address, 172.20.1.1, as a static route on PE1 in the RED routing instance to provide CE3 a route to CE1's loopback address. If this is not desirable, skip this step.

```
PE1(config)# routing-instance RED ip add route 172.20.1.1/32 gateway 172.17.1.2
```

Configure PE2 to route statically with CE2

The following example configures the predefined RED static routing instance on PE2 to route statically to the Customer A Site 2 network, 172.17.2.0/24, through CE1's directly-connected interface.

```
PE2(config)# routing-instance RED ip add route 192.168.2.0/24 gateway 192.168.1.2
```

Add CE2's loopback address, 192.168.100.1, as a static route on PE2 in the RED routing instance to provide CE1 a route to CE2's loopback address. If this is not desirable, skip this step.

```
PE2(config)# routing-instance RED ip add route 192.168.100.1/32 gateway
             192.168.1.2
```

Configuring OSPF Between CE and PE Routers

Basic BGP/MPLS VPN Network configuration steps:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
- **Configure static and OSPF PE-CE route distribution**
  - Configure Static routing between CE1 and PE1 and CE2 and PE2
  - **Configure OSPF between CE3 and PE1 and CE4 and PE2**

For additional details on the implementation mechanisms of this feature, refer to the IETF draft *OSPF as the PE/CE Protocol in BGP/MPLS VPNs* by Rosen and Psenak. (The RS does not support the sham links described in section 4.2.3 of the draft.)

Configuring OSPF On CE Routers

To run OSPF between CE and PE routers, you must first configure OSPF on CE routers. CE routers need not be BGP/MPLS VPN-capable and do not need to be configured with multiple routing instances. Configure them as you would any non-BGP/MPLS VPN-capable router. For more information on configuring OSPF, see *Section 13 "OSPF Configuration Guide."*

To implement the Basic BGP/MPLS VPN Network (Figure 16-7), PE1 is configured to route with CE3 using OSPF and PE2 is configured to route with CE4 using OSPF.

Configure CE3 to route with PE1 and CE4 to route with PE2 using OSPF

1. Create the backbone area on both CE routers.

Note You do not have to use the backbone area. You may configure any OSPF area between CE and PE routers.

2. Add each CE router's loopback interface and any other interfaces that should participate in OSPF with the PE router to the backbone area. Adding interfaces to an area distributes the networks configured on those interface into that area through OSPF. For example, adding the loopback interface allows each CE router to learn the other CE router's loopback address through PE-CE route distribution. Adding a customer site-facing interface distributes OSPF routes learned on that interface to the PE router and remote CE router. If you do not want particular networks to be exchanged with remote sites, do not add the associated interfaces into OSPF.
   - On CE3, add the loopback interface, 172.20.2.1, and two other interfaces: ToCustomerBSite1 and ToPE1
   - On CE4, add the loopback interface, 192.168.101.1, and two other interfaces: ToCustomerBSite2 and ToPE2
3. Start OSPF.

The previous configuration steps result in the following commands on CE3:

```
CE3(config)# ospf create area backbone
CE3(config)# ospf add stub-host 172.20.2.1 to-area backbone cost 1
CE3(config)# ospf add interface ToCustomerBSite1 to-area backbone
CE3(config)# ospf add interface ToPE1 to-area backbone
CE3(config)# ospf start
```

The previous configuration steps result in the following commands on CE4:

```
CE4(config)# ospf create area backbone
CE4(config)# ospf add stub-host 192.168.101.1 to-area backbone cost 1
CE4(config)# ospf add interface ToCustomerBSite2 to-area backbone
CE4(config)# ospf add interface ToPE2 to-area backbone
CE4(config)# ospf start
```

Configuring OSPF On PE Routers

PE Router OSPF Routing Instance Usage Guidelines

For a PE router to distribute VPN routes to and from CE routers, you must configure it to route within a VRF routing instance. For more information on configuring routing instances, see *Section 16.4.4 "Configuring Routing Instances."*

The Basic BGP/MPLS VPN network (Figure 16-7) contains two VRFs—RED and PINK. On the PE router, each routing instance maintains the routes that it learns and advertises in its own VRF.

After a PE router learns a route, it distributes that route to other PE routers as a VPN-IPv4 route using MP-BGP. (For more information on VPN-IPv4 addresses, see the *Section "Configuring Route Distinguishers and VPN-IPv4 Addresses."* For more information on MP-BGP, see *Section 16.4.3 "Configuring MP-BGP Between PE Routers for Customer Route Distribution."*) The RS supports multiple OSPF domains within one VPN. In order for a PE router receiving a route to correctly import that route into a particular VRF, it must be able to tell whether the route comes from the same OSPF domain and area as the CE routers to which it is attached.

To accomplish this, PE routers use the user-specified OSPF Domain Identifier. The Domain Identifier is a 4-byte value specified in IP address format. It is encoded as an Extended Community Attribute in VPN-IPv4 routes, which are distributed across the PE backbone in MP-BGP advertisements. Each OSPF domain is associated with a Domain Identifier. When not specified in the configuration, the Domain Identifier is set to 0.0.0.0 by default and not carried with the VPN-IPv4 route.

Note You must ensure that all the VRFs which correspond to the same OSPF domain share the same Domain Identifier. You can either configure them to be the same or elect to use the default Domain Identifier.

Assign unique non-zero Domain Identifiers to avoid importing routes from different OSPF domains into the same VRF.

When a PE router sends OSPF routes to other PE routers, it sends them as BGP VPN-IPv4 routes. To preserve the OSPF attributes of those routes, PE routers encode them as BGP Extended Community Attributes in the VPN-IPv4 routing advertisements. The Domain Identifier is one such attribute. The RS supports both current and older encoding schemes. For interoperability purposes, select the appropriate encoding scheme using the **`routing-instance ospf set extended-community`** command.

The following is a summary of OSPF attributes and their Extended Community encoding:

OSPF Route Attribute	Encoded As
Domain Identifier	BGP Extended Community Attribute
LSA Type	OSPF-Route-Type Extended Community Attribute
OSPF Router ID (of the system identified in the BGP next hop for this route)	OSPF-Router-ID Extended Community Attribute

This encoding ensures that OSPF routes can be converted to BGP, distributed across the provider backbone, and converted back to OSPF transparently, as if BGP is not involved.

After a PE router learns a remote-site route from its PE peer, it distributes that route to its CE routers according to the policies that you configure. These policies enforce the customer connectivity scheme. (For more information on configuring import and export Route Targets, see the *Section "Configuring VRF Import and Export Policies."*) PE routers also respect the following rules when processing and announcing OSPF remote-site routes to customers:

- Routes originating from a *different* OSPF domain or from outside of the OSPF protocol
  - PE routers announce all routes received from a remote site belonging to a different OSPF domain or learned from a different protocol to directly-connected CE routers as Type-5 LSAs.
  - In this situation, the ingress PE router acts as an Autonomous System Border Router (ASBR) and sets the VPN Route Tag of these routes to a user-defined value that indicates the customer site's VPN. Setting the VPN Route Tag ensures that these Type-5 LSAs are not redistributed through the OSPF area to another PE router, possibly creating a loop within the same VPN.
  - It follows from the above that a PE router ignores received Type-5 LSAs with a VPN Route Tag set to the value you define for its customer site's VPN.

When not specified in the configuration, the PE router sets the VPN Route Tag automatically to a value based on the autonomous system to which it belongs.

Note When setting the VPN Route Tag manually, you must ensure that it is set to a distinct value for each OSPF domain.

- Routes originating from the *same* OSPF domain
  - Within the same OSPF domain, PE routers announce routes received as Type-5 LSAs as Type-5 LSAs and all others as Type-3 LSAs.
  - The IETF draft states that "[w]hen the PE/CE link is an area 0 link, the high-order bit of the LSA Options field (previously unused) is used to distinguish type 3 LSAs which report routes across the VPN backbone from other VPN sites." This is the DN bit. A PE router sets this bit when sending a Type-3 LSA to a CE router across an area 0 link.
  - It follows from the above that PE routers ignore routes received as Type-3 LSAs from CE routers which have the DN bit set. This mechanism prevents routes sent to a CE router by a PE router from being flooded through several OSPF routers and then sent to another PE router, thus avoiding a loop.

Otherwise, PE routers process remote-site routes in normal OSPF fashion and follow user-set policies in distributing routes to OSPF instances.

You can configure any OSPF area for the CE-PE link. However, as the IETF drafts states, every PE router running an OSPF routing instance must also be an area 0 router and an ABR.

Note Regardless of what OSPF area is configured for a PE-CE link, every RS that acts as a PE router in a CE-PE adjacency must have area 0 configured and *active* in that routing instance. Being active means that an area must have at least one interface added. The loopback interface can be added to area 0 as a stub host for this purpose.

Being an area 0 router and an ABR allows the PE router to distribute inter-area routes to the CE router as Type-3 LSAs. (In OSPF, all traditional ABRs must be attached to area 0. Only ABRs can generate Type-3 LSAs.) The CE router might or might not be an area 0 router, and the PE-CE link might or might not be an area 0 link.

The IETF draft further states “[i]f the OSPF network contains area 0 routers (other than the PE routers), at least one PE router must have an area 0 link to a non-PE area 0 router in that OSPF network. (The non-PE area 0 router functions as a CE router.) This ensures that inter-area routes and AS-external routes can be leaked between the PE routers and the non-PE OSPF backbone.

To configure OSPF routing instances on PE routers, use the **`routing-instance <name> ospf...`** series of commands. These commands assume that you have already created a routing instance identified by **`<name>`**. For more information on configuring routing instances, see *Section 16.4.4 "Configuring Routing Instances."*

Within a routing instance, these commands function identically to their non-routing instance counterparts. For more information on configuring OSPF, see *Section 13 "OSPF Configuration Guide."*

Note Routing instance names are case sensitive.

To implement the Basic BGP/MPLS VPN Network (Figure 16-7), PE1 is configured to route with CE3 using OSPF and PE2 is configured to route with CE4 using OSPF.

Configure PE1 to route with CE3 and PE2 to route with CE4 using OSPF

1. Create the backbone area on both PE routers in routing-instance PINK.
2. Add each PE router's loopback interface and any other interfaces that should participate in OSPF with the CE router to the backbone area.
   - On PE1, add the loopback interface, 10.1.1.1, and one other interface—ToCE3.
   - On PE2, add the loopback interface, 10.3.3.1, and one other interface—ToCE4.
3. Set the Domain Identifier for this OSPF domain to 0.0.0.0. When not specified in the configuration, all domains are assigned a Domain Identifier of 0.0.0.0 by default. Assign the same Domain Identifier to the links between PE1 and CE3 and between PE2 and CE4 because Customer B Site 1 and Site 2 are in the same VPN.
4. Set the VPN Route Tag for this customer to an arbitrary value, '1001'. The VPN Route Tag must be unique for each OSPF domain.
5. Specify which routes the PE router should learn for this VRF using a route map. The example specifies that all BGP routes should be learned. In practice, you should limit the set of routes advertised using route maps.
6. Start OSPF.

The previous configuration steps result in the following commands on PE1:

```
PE1(config)# routing-instance PINK ospf create area backbone
PE1(config)# routing-instance PINK ospf add stub-host 10.1.1.1 to-area backbone
             cost 1
PE1(config)# routing-instance PINK ospf add interface ToCE3 to-area backbone
PE1(config)# routing-instance PINK ospf set domain-id 0.0.0.0
PE1(config)# routing-instance PINK ospf set vpn-route-tag 1001
PE1(config)# route-map BGPROUTES permit 1 match-route-type bgp
PE1(config)# routing-instance PINK ospf set route-map-vpn BGPROUTES
PE1(config)# routing-instance PINK ospf start
```

The previous configuration steps result in the following commands on PE2:

```
PE2(config)# routing-instance PINK ospf create area backbone
PE2(config)# routing-instance PINK ospf add stub-host 10.3.3.1 to-area backbone
             cost 1
PE2(config)# routing-instance PINK ospf add interface ToCE4 to-area backbone
PE2(config)# routing-instance PINK ospf set domain-id 0.0.0.0
PE2(config)# routing-instance PINK ospf set vpn-route-tag 1001
PE2(config)# route-map BGPROUTES permit 1 match-route-type bgp
PE2(config)# routing-instance PINK ospf set route-map-vpn BGPROUTES
PE2(config)# routing-instance PINK ospf start
```

Viewing OSPF adjacencies between CE and PE routers

Use the following commands to view OSPF adjacencies between CE and PE routers

- **ospf show neighbor [instance]**
- **ospf show interfaces [instance]**
- **ospf show database [instance]**

To view interface-related information on the PE-CE OSPF adjacency, use these commands *without* the **instance** options on CE routers and *with* the **instance** option on PE routers.

On CE3 and CE4, the **ospf show neighbor** command displays information about the OSPF adjacency such as the adjacency area and neighboring router. On PE1 and PE2, the **ospf show neighbor instance PINK** command displays identical information about the PINK OSPF routing instance. The following output show that CE3 and PE1 recognize each other as full neighbors. CE4 and PE2 are also in a full adjacency. When troubleshooting OSPF adjacencies, watch for the **State** to be **Full** in this command output.

```
CE3# ospf show neighbor
Neighbor 10.1.1.1, interface address 172.17.8.1 [mem: 82bc2000]
    In the area 0.0.0.0 via interface address 172.17.8.2
    Neighbor priority is 1, State is Full
    Options 1
    Dead timer due in 12:35:54
    Hitless Helper: not active
```

```
PE1# ospf show neighbor instance PINK
Neighbor 172.20.2.1, interface address 172.17.8.2 [mem: 82be8000]
    In the area 0.0.0.0 via interface address 172.17.8.1
    Neighbor priority is 1, State is Full
    Options 0
    Dead timer due in 11:56:20
    Hitless Helper: not active
```

```
CE4# ospf show neighbor
Neighbor 10.3.3.1, interface address 192.168.8.1 [mem: 82bce000]
    In the area 0.0.0.0 via interface address 192.168.8.2
    Neighbor priority is 1, State is Full
    Options 1
    Dead timer due in 13:54:45
    Hitless Helper: not active
```

```
PE2# ospf show neighbor instance PINK
Neighbor 192.168.101.1, interface address 192.168.8.2 [mem: 82bc6800]
    In the area 0.0.0.0 via interface address 192.168.8.1
    Neighbor priority is 1, State is Full
    Options 0
    Dead timer due in 12:46:10
    Hitless Helper: not active
```

The **ospf show interfaces** command displays the interfaces that are participating in OSPF, with the exception of the loopback interface. Routes for directly-attached networks on these interfaces are distributed into OSPF. This command also displays the number of neighbors, designated router (DR), and backup designated router (BDR) for each network segment.

```
CE3# ospf show interfaces
Internet Address 172.17.8.2/30, Area 0.0.0.0
    Router ID 172.20.2.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State DR, Priority 1
    Designated Router (ID) 172.20.2.1, Interface address 172.17.8.2
    Backup Designated Router 10.1.1.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 12:11:53
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled

Internet Address 172.17.2.1/24, Area 0.0.0.0
    Router ID 172.20.2.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State DR, Priority 1
    Designated Router (ID) 172.20.2.1, Interface address 172.17.2.1
    No backup designated router on this network
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 12:11:53
    Neighbor Count is 0
    Authentication not enabled
    Hitless Helper Mode is disabled
```

```
PE1# ospf show interfaces instance PINK
Internet Address 172.17.8.1/30, Area 0.0.0.0
    Router ID 10.1.1.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State Back DR, Priority 1
    Designated Router (ID) 172.20.2.1, Interface address 172.17.8.1
    Backup Designated Router 10.1.1.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 13:16:27
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled
```

```
CE4# ospf show interfaces
Internet Address 192.168.8.2/30, Area 0.0.0.0
    Router ID 192.168.101.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State DR, Priority 1
    Designated Router (ID) 192.168.101.1, Interface address 192.168.8.2
    Backup Designated Router 10.3.3.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 13:26:34
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled

Internet Address 192.168.9.1/24, Area 0.0.0.0
    Router ID 192.168.101.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State DR, Priority 1
    Designated Router (ID) 192.168.101.1, Interface address 192.168.9.1
    No backup designated router on this network
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 13:26:34
    Neighbor Count is 0
    Authentication not enabled
    Hitless Helper Mode is disabled
```

```
PE2# ospf show interfaces instance PINK
Internet Address 192.168.8.1/30, Area 0.0.0.0
    Router ID 10.3.3.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State Back DR, Priority 1
    Designated Router (ID) 192.168.101.1, Interface address 192.168.8.1
    Backup Designated Router 10.3.3.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 12:26:54
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled
```

The **ospf show database** command displays the OSPF link-state database. Note that on both sides of the VPN, the remote PE-CE network is distributed as an AS external route. Although the PE router has an OSPF route to this network, it advertises the network as directly-connected, which becomes AS external when received by the remote PE.

```
CE3# ospf show database
        OSPF Router with ID (172.20.2.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
10.1.1.1        10.1.1.1        1301 800004c4  5f4f      20

172.20.2.1      172.20.2.1      1325 800003dd  c7c8      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.8.2      172.20.2.1      1325 8000002e  5b78      20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.9       10.1.1.1        1361 8000002d  2a5e      41

192.168.101.1   10.1.1.1        1361 8000002d  69d4      22


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.8       10.1.1.1        1361 8000002d  921       1
```

```
PE1# ospf show database instance PINK
        OSPF Router with ID (10.1.1.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.20.2.1      172.20.2.1      1672 800003db  cbc6      20

10.1.1.1        10.1.1.1        1645 800004c2  634d      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.8.2      172.20.2.1      1672 8000002c  5f76      20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.101.1   10.1.1.1        1705 8000002b  6dd2      22

192.168.9       10.1.1.1        1705 8000002b  2e5c      41


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.8       10.1.1.1        1705 8000002b  d1f       1
```

```
CE4# ospf show database
        OSPF Router with ID (192.168.101.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
10.3.3.1        10.3.3.1        200  80000032  d70a      20

192.168.101.1   192.168.101.1   180  80000033  ce41      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.8.2     192.168.101.1   180  80000031  603       20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.2        10.3.3.1        1700 8000002d  79bd      41

172.20.2.1      10.3.3.1        1700 8000002d  8cb9      22


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.8        10.3.3.1        1700 8000002d  bc6       1
```

```
PE2# ospf show database instance PINK
        OSPF Router with ID (10.3.3.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.101.1   192.168.101.1   411  80000033  ce41      20

10.3.3.1        10.3.3.1        429  80000032  d70a      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.8.2     192.168.101.1   411  80000031  603       20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.20.2.1      10.3.3.1        69   8000002e  8aba      22

172.17.2        10.3.3.1        69   8000002e  77be      41


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.8        10.3.3.1        69   8000002e  9c7       1
```

16.5 BASIC BGP/MPLS VPN NETWORK OPERATION

Figure 16-8 illustrates the completed Basic BGP/MPLS VPN Network. It contains the following configurations:

- IGP in the provider network (*included in initial configurations*)
- MPLS LSPs in the provider network
- MP-IBGP between PE routers
- RED and PINK routing instances on the PE routers
  - Route Distinguisher and routing instance created
  - Interface(s) added to routing instances
  - Import and export routing policies (Route Targets) for routing instances
- Static and OSPF PE-CE route distribution
  - Static routing between CE1 and PE1 and CE2 and PE2
  - OSPF between CE3 and PE1 and CE4 and PE2

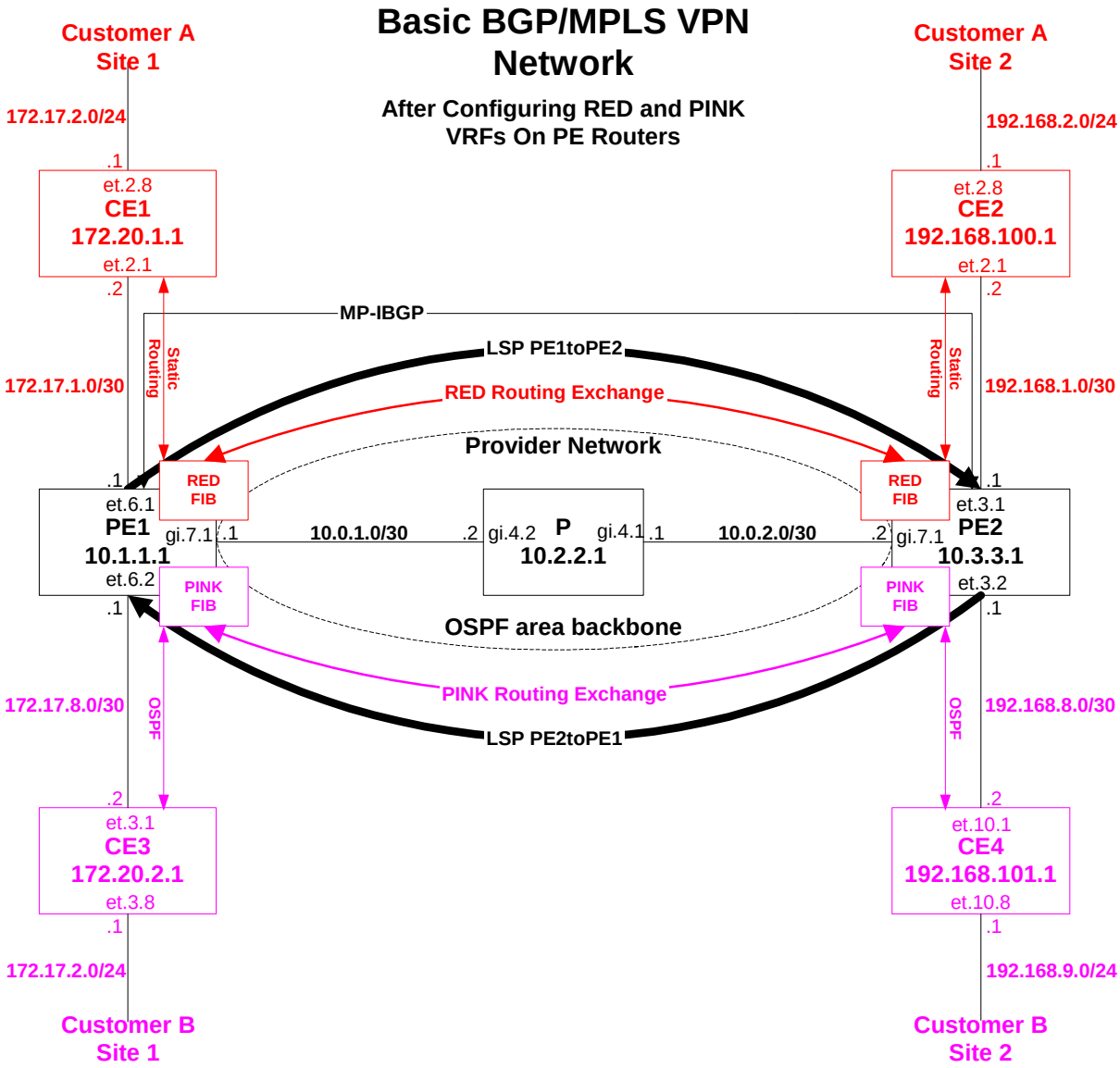


Figure 16-8 Complete Basic BGP/MPLS VPN Network

16.5.1 Routing Exchange

In BGP/MPLS VPNs, PE routers exchange customer routes through MP-BGP. You can monitor this routing exchange using the **bgp show peer-host** series of commands.

The following display output shows that on PE1 and PE2, MP-IBGP is not advertising any global routes.

```
PE1# bgp show peer-host 10.3.3.1 advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
```

```
PE2# bgp show peer-host 10.1.1.1 advertised-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
```

However, MP-IBGP is advertising routes for each routing instance. PE1 is advertising routes learned from CE1 through the RED routing instance to PE2. The example output shows that PE2 receives these routes.

```
PE1# bgp show peer-host 10.3.3.1 instance RED advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i172.17.1/30        172.17.1.1           1    100          17 i
*> i172.17.2/24        10.1.1.1                  100          19 ?
*> i172.20.1.1/32      10.1.1.1                  100          19 ?
```

```
PE2# bgp show peer-host 10.1.1.1 instance RED all-received-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i172.17.1/30        10.1.1.1                100 17    i
*> i172.17.2/24        10.1.1.1                100 19    ?
*> i172.20.1.1/32      10.1.1.1                100 19    ?
```

PE2 is also advertising routes learned from CE2 through the RED routing instance to PE1. The example output shows that PE1 receives these routes.

```
PE2# bgp show peer-host 10.1.1.1 instance RED advertised-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i192.168.1/30       192.168.1.1          1    100          17 i
*> i192.168.2/24       10.3.3.1                  100          19 ?
*> i192.168.100.1/32   10.3.3.1                  100          19 ?
```

```
PE1# bgp show peer-host 10.3.3.1 instance RED all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i192.168.1/30       10.3.3.1                100 17    i
*> i192.168.2/24       10.3.3.1                100 19    ?
*> i192.168.100.1/32   10.3.3.1                100 19    ?
```

Likewise, PE1 is advertising routes learned from CE3 through the PINK routing instance to PE2.

```
PE1# bgp show peer-host 10.3.3.1 instance PINK advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i172.17.2/24        10.1.1.1            41    100          21 i
*> i172.17.8/30        172.17.8.1           1    100          18 i
*> i172.20.2.1/32      10.1.1.1            22    100          21 i
```

```
PE2# bgp show peer-host 10.1.1.1 instance PINK all-received-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i172.17.2/24        10.1.1.1            41    100 21    i
*> i172.17.8/30        10.1.1.1                  100 18    i
*> i172.20.2.1/32      10.1.1.1            22    100 21    i
```

PE2 is advertising routes learned from CE4 through the PINK routing instance to PE1.

```
PE2# bgp show peer-host 10.1.1.1 instance PINK advertised-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i192.168.8/30       192.168.8.1          1    100          18 i
*> i192.168.9/24       10.3.3.1            41    100          21 i
*> i192.168.101.1/32   10.3.3.1            22    100          21 i
```

```
PE1# bgp show peer-host 10.3.3.1 instance PINK all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i192.168.8/30       10.3.3.1                100 18    i
*> i192.168.9/24       10.3.3.1             41 100 21    i
*> i192.168.101.1/32   10.3.3.1             22 100 21    i
```

You can also view all of the VRF routes being advertised or received by MP-BGP by specifying the **`all`** option in the **`bgp show peer-host instance`** command.

```
PE1# bgp show peer-host 10.3.3.1 instance all advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i172.17.1/30        172.17.1.1           1 100          17 i
*> i172.17.2/24        10.1.1.1                100          19 ?
*> i172.17.2/24        10.1.1.1            41 100          21 i
*> i172.17.8/30        172.17.8.1           1 100          18 i
*> i172.20.1.1/32      10.1.1.1                100          19 ?
*> i172.20.2.1/32      10.1.1.1            22 100          21 i
```

```
PE2# bgp show peer-host 10.1.1.1 instance all advertised-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i192.168.1/30       192.168.1.1          1 100          17 i
*> i192.168.2/24       10.3.3.1                100          19 ?
*> i192.168.8/30       192.168.8.1          1 100          18 i
*> i192.168.9/24       10.3.3.1            41 100          21 i
*> i192.168.100.1/32   10.3.3.1                100          19 ?
*> i192.168.101.1/32   10.3.3.1            22 100          21 i
```

The **bgp show peer-host all-received-routes** command shows all of the BGP routes received by PE1 and PE2, including VRF routes.

```
PE1# bgp show peer-host 10.3.3.1 all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i192.168.1/30       10.3.3.1             0      0 17    i
*> i192.168.8/30       10.3.3.1             0      0 18    i
*> i192.168.9/24       10.3.3.1             0      0 21    i
*> i192.168.101.1/32   10.3.3.1             0      0 21    i
*> i192.168.2/24       10.3.3.1             0      0 19    ?
*> i192.168.100.1/32   10.3.3.1             0      0 19    ?
```

```
PE2# bgp show peer-host 10.1.1.1 all-received-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i172.17.1/30        10.1.1.1             0      0 17    i
*> i172.17.2/24        10.1.1.1             0      0 21    i
*> i172.17.8/30        10.1.1.1             0      0 18    i
*> i172.20.2.1/32      10.1.1.1             0      0 21    i
*> i172.17.2/24        10.1.1.1             0      0 19    ?
*> i172.20.1.1/32      10.1.1.1             0      0 19    ?
```

Multiple Routing and Forwarding Tables

PE routers do not differentiate between VRF or other routes when receiving BGP routes. A PE router filters all BGP routes received from remote PE routers through the Route Target(s) that you configure. It discards routes that do not match any import targets on the VRFs that it supports. It installs remaining routes into the VPN-IPv4 Unicast RIB. The VPN-IPv4 Unicast RIB contains all routes that satisfy the import policy of at least one of the PE router's VRFs. Since this is the only table that contains all of the routes from all of the VPNs directly connected to the PE router, it is the only table that relies on Route Distinguishers to keep routes with identical IPv4 prefixes distinct.

BGP first installs all routes matching at least one import Route Target on the PE router in this table. From this table, routes are then installed into the Routing Instance RIB for particular VRFs based on the VRF import target(s).

Then, the routing instance associated with that VRF selects optimal and active routes from the Routing Instance RIB to install into the Routing Instance FIB. PE routers distribute these routes to directly-connected customer sites through interface(s) that have been added to the routing instance. PE routers also use Routing Instance FIBs to forward traffic for that VRF and advertise these routes to remote PE routers.

Table 16-1 summarizes the RIBs and Table 16-2 summarizes the FIBs that exist on the RS.

RIB	Purpose	Command To View
Internet Unicast	Contains global unicast routes used by the provider network.	**`ip-router show rib internet unicast-only`**
Internet Multicast	Contains global multicast routes used by the provider network.	**`ip-router show rib internet multicast-only`**
VPN/IPv4 Unicast	Contains all VPN routes received from remote PE routers via MP-BGP in VPN-IPv4 format. Since VPNs can have overlapping addresses, this RIB relies on the Route Distinguisher in the VPN-IPv4 address to disambiguate between routes to identical IPv4 addresses. Routes are listed by Route Distinguisher.	**`ip-router show rib vpn-ipv4`** To view routes for a specific Route Distinguisher: **`ip-router show rib route-distinguisher`** *<RD>* **`vpn-ipv4`**
LSP	Contains MPLS LSP routes. You can enable routing protocols to use LSP routes in resolving next hops using the **`ip-router global set install-lsp-routes`** command.	**`ip-router show rib lsp-route-only`**
Routing Instance Unicast	Contains VRF routes for a specific routing instance.	**`ip-router show rib instance`**

Table 16-1 Multiple RIBs on the RS

FIB	Purpose	Command To View
Unicast	Contains global unicast routes used by the provider network.	**ip show routes**
Routing Instance Unicast	Contains VRF routes for a specific routing instance.	**ip show routes show-vrf**

Table 16-2 Multiple FIBs on the RS

Viewing RIBs

Use the **ip-router show rib** command to view all of the RIBs on the RS. The following shows the RIBs on PE1.

```
PE1# ip-router show rib
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 3    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2
------------       - --- --------             ----- ---- ------ ------

Internet Unicast

0.0.0.6/32         *   C 10.1.1.1               lo0    7      1      0
10.0.1/30          *   C 10.0.1.1               ToP    1      1      0
10.0.1/30              O 10.0.1.1               ToP   10      2      0
10.0.2/30          *   O 10.0.1.2               ToP   10      4      0
10.1.1.1/32        *   C 10.1.1.1               lo0    1      1      0
10.1.1.1/32            O                             -10      1      0
10.2.2.1/32        *   O 10.0.1.2               ToP   10      3      0
10.2.2.1/32            O 10.0.1.2               ToP  -10      2      0
10.3.3.1/32        *   O 10.0.1.2               ToP   10      5      0
10.3.3.1/32            O 10.0.1.2               ToP  -10      4      0
127/8              *  St 127.0.0.1              lo0    1      0      0
127.0.0.1/32       *   C 127.0.0.1              lo0    1      1      0
172.17.1/30        *   C 172.17.1.1           ToCE1    1      1      0
172.17.8/30        *   C 172.17.8.1           ToCE3    1      1      0
```

```
Internet Multicast

0.0.0.6/32          *   C 10.1.1.1              lo0    7      1      0
10.0.1/30           *   C 10.0.1.1              ToP    1      1      0
10.1.1.1/32         *   C 10.1.1.1              lo0    1      1      0
127.0.0.1/32            C 127.0.0.1             lo0   -1      1      0



VPN/IPV4 Unicast

Route Distinguisher 10.3.3.1:1

192.168.1/30        *   B 0.0.0.6           PE1toPE2  170           100
192.168.2/24        *   B 0.0.0.6           PE1toPE2  170           100
192.168.100.1/32    *   B 0.0.0.6           PE1toPE2  170           100

Route Distinguisher 10.3.3.1:2

192.168.8/30        *   B 0.0.0.6           PE1toPE2  170           100
192.168.9/24        *   B 0.0.0.6           PE1toPE2  170     41    100
192.168.101.1/32    *   B 0.0.0.6           PE1toPE2  170     22    100

LSP route table

10.3.3.1/32         *   C 0.0.0.6           PE1toPE2    7      1      0

Routing-instance PINK Unicast

10.1.1.1/32             O                             -10      1      0
172.17.2/24         *   O 172.17.8.2          ToCE3    10     40      0
172.17.8/30         *   C 172.17.8.1          ToCE3     1      1      0
172.17.8/30             O 172.17.8.1          ToCE3    10     20      0
172.20.2.1/32       *   O 172.17.8.2          ToCE3    10     21      0
172.20.2.1/32           O 172.17.8.2          ToCE3   -10     20      0
192.168.8/30        *   B 0.0.0.6           PE1toPE2  170           100
192.168.9/24        *   B 0.0.0.6           PE1toPE2  170     41    100
192.168.101.1/32    *   B 0.0.0.6           PE1toPE2  170     22    100

Routing-instance RED Unicast

172.17.1/30         *   C 172.17.1.1          ToCE1     1      1      0
172.17.2/24         *  St 172.17.1.2          ToCE1     5      0      0
172.20.1.1/32       *  St 172.17.1.2          ToCE1     5      0      0
192.168.1/30        *   B 0.0.0.6           PE1toPE2  170           100
192.168.2/24        *   B 0.0.0.6           PE1toPE2  170           100
192.168.100.1/32    *   B 0.0.0.6           PE1toPE2  170           100
```

The following shows the RIBs on PE2.

```
PE2# ip-router show rib
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 2    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2
------------       - --- --------             ----- ---- ------ ------

Internet Unicast

0.0.0.6/32         *   C 10.3.3.1               lo0    7      1      0
10.0.1/30          *   O 10.0.2.1               ToP   10      4      0
10.0.2/30          *   C 10.0.2.2               ToP    1      1      0
10.0.2/30              O 10.0.2.2               ToP   10      2      0
10.1.1.1/32        *   O 10.0.2.1               ToP   10      5      0
10.1.1.1/32            O 10.0.2.1               ToP  -10      4      0
10.2.2.1/32        *   O 10.0.2.1               ToP   10      3      0
10.2.2.1/32            O 10.0.2.1               ToP  -10      2      0
10.3.3.1/32        *   C 10.3.3.1               lo0    1      1      0
10.3.3.1/32            O                             -10      1      0
127/8              *  St 127.0.0.1              lo0    1      0      0
127.0.0.1/32       *   C 127.0.0.1              lo0    1      1      0
192.168.1/30       *   C 192.168.1.1          ToCE2    1      1      0
192.168.8/30       *   C 192.168.8.1          ToCE4    1      1      0

Internet Multicast

0.0.0.6/32         *   C 10.3.3.1               lo0    7      1      0
10.0.2/30          *   C 10.0.2.2               ToP    1      1      0
10.3.3.1/32        *   C 10.3.3.1               lo0    1      1      0
127.0.0.1/32           C 127.0.0.1              lo0   -1      1      0

VPN/IPV4 Unicast
```

```
Route Distinguisher 10.1.1.1:1

172.17.1/30        *   B 0.0.0.6           PE2toPE1  170           100
172.17.2/24        *   B 0.0.0.6           PE2toPE1  170           100
172.20.1.1/32      *   B 0.0.0.6           PE2toPE1  170           100

Route Distinguisher 10.1.1.1:2

172.17.2/24        *   B 0.0.0.6           PE2toPE1  170     41    100
172.17.8/30        *   B 0.0.0.6           PE2toPE1  170           100
172.20.2.1/32      *   B 0.0.0.6           PE2toPE1  170     22    100

LSP route table

10.1.1.1/32        *   C 0.0.0.6           PE2toPE1    7      1      0

Routing-instance PINK Unicast

10.3.3.1/32            O                             -10      1      0
172.17.2/24        *   B 0.0.0.6           PE2toPE1  170     41    100
172.17.8/30        *   B 0.0.0.6           PE2toPE1  170           100
172.20.2.1/32      *   B 0.0.0.6           PE2toPE1  170     22    100
192.168.8/30       *   C 192.168.8.1          ToCE4    1      1      0
192.168.8/30           O 192.168.8.1          ToCE4   10     20      0
192.168.9/24       *   O 192.168.8.2          ToCE4   10     40      0
192.168.101.1/32   *   O 192.168.8.2          ToCE4   10     21      0
192.168.101.1/32       O 192.168.8.2          ToCE4  -10     20      0

Routing-instance RED Unicast

172.17.1/30        *   B 0.0.0.6           PE2toPE1  170           100
172.17.2/24        *   B 0.0.0.6           PE2toPE1  170           100
172.20.1.1/32      *   B 0.0.0.6           PE2toPE1  170           100
192.168.1/30       *   C 192.168.1.1          ToCE2    1      1      0
192.168.2/24       *  St 192.168.1.2          ToCE2    5      0      0
192.168.100.1/32   *  St 192.168.1.2          ToCE2    5      0      0
```

Viewing FIBs

The following show the Unicast FIBs on PE1 and PE2. The Unicast FIB does not contain any VRF routes.

```
PE1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.0.1.0/30          directly connected   -         ToP
10.0.2.0/30          10.0.1.2             OSPF      ToP
10.1.1.1             10.1.1.1             -         lo0
10.2.2.1             10.0.1.2             OSPF      ToP
10.3.3.1             10.0.1.2             OSPF      ToP
127.0.0.1            127.0.0.1            -         lo0
172.17.1.0/30        directly connected   -         ToCE1
172.17.8.0/30        directly connected   -         ToCE3
```

```
PE2# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.0.1.0/30          10.0.2.1             OSPF      ToP
10.0.2.0/30          directly connected   -         ToP
10.1.1.1             10.0.2.1             OSPF      ToP
10.2.2.1             10.0.2.1             OSPF      ToP
10.3.3.1             10.3.3.1             -         lo0
127.0.0.1            127.0.0.1            -         lo0
192.168.1.0/30       directly connected   -         ToCE2
192.168.8.0/30       directly connected   -         ToCE4
```

The following show the RED and PINK Routing Instance FIBs on PE1 and PE2.

```
PE1# ip show routes show-vrf RED

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
172.17.1.0/30        directly connected   -         ToCE1
172.17.2.0/24        172.17.1.2           Static    ToCE1
172.20.1.1           172.17.1.2           Static    ToCE1
192.168.1.0/30       10.0.1.2             BGP       PE1toPE2
192.168.2.0/24       10.0.1.2             BGP       PE1toPE2
192.168.100.1        10.0.1.2             BGP       PE1toPE2

PE1# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
172.17.2.0/24        172.17.8.2           OSPF      ToCE3
172.17.8.0/30        directly connected   -         ToCE3
172.20.2.1           172.17.8.2           OSPF      ToCE3
192.168.8.0/30       10.0.1.2             BGP       PE1toPE2
192.168.9.0/24       10.0.1.2             BGP       PE1toPE2
192.168.101.1        10.0.1.2             BGP       PE1toPE2
```

```
PE2# ip show routes show-vrf RED

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
172.17.1.0/30        10.0.2.1             BGP       PE2toPE1
172.17.2.0/24        10.0.2.1             BGP       PE2toPE1
172.20.1.1           10.0.2.1             BGP       PE2toPE1
192.168.1.0/30       directly connected   -         ToCE2
192.168.2.0/24       192.168.1.2          Static    ToCE2
192.168.100.1        192.168.1.2          Static    ToCE2

PE2# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
172.17.2.0/24        10.0.2.1             BGP       PE2toPE1
172.17.8.0/30        10.0.2.1             BGP       PE2toPE1
172.20.2.1           10.0.2.1             BGP       PE2toPE1
192.168.8.0/30       directly connected   -         ToCE4
192.168.9.0/24       192.168.8.2          OSPF      ToCE4
192.168.101.1        192.168.8.2          OSPF      ToCE4
```

The following show the configured default route in the Unicast FIBs on CE1 and CE2.

```
CE1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
default              172.17.1.1           Static    ToPE1
127.0.0.1            127.0.0.1            -         lo0
172.17.1.0/30        directly connected   -         ToPE1
172.17.2.0/24        directly connected   -         ToCustomerASite
172.20.1.1           172.20.1.1           -         lo0
```

```
CE2# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
default              192.168.1.1          Static    ToPE2
127.0.0.1            127.0.0.1            -         lo0
192.168.1.0/30       directly connected   -         ToPE2
192.168.2.0/24       directly connected   -         ToCustomerASite
192.168.100.1        192.168.100.1        -         lo0
```

Viewing the Unicast FIBs on CE3 and CE4 confirm that they are receiving remote-site routes for the PINK VRF from PE1 and PE2.

```
CE3# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.1.1.1             172.17.8.1           OSPF      ToPE1
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        directly connected   -         ToCustomerBSite
172.17.8.0/30        directly connected   -         ToPE1
172.20.2.1           172.20.2.1           -         lo0
192.168.8.0/30       172.17.8.1           OSPF_ASE  ToPE1
192.168.9.0/24       172.17.8.1           OSPF_IA   ToPE1
192.168.101.1        172.17.8.1           OSPF_IA   ToPE1
```

```
CE4# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.3.3.1             192.168.8.1          OSPF      ToPE2
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        192.168.8.1          OSPF_IA   ToPE2
172.17.8.0/30        192.168.8.1          OSPF_ASE  ToPE2
172.20.2.1           192.168.8.1          OSPF_IA   ToPE2
192.168.8.0/30       directly connected   -         ToPE2
192.168.9.0/24       directly connected   -         ToCustomerBSite
192.168.101.1        192.168.101.1        -         lo0
```

16.5.2 Case Study: Learning Routes

The following describes the operation of the Basic BGP/MPLS VPN Network when CE3 advertises the 172.17.2.0/24 network for Customer B Site 1.

On PE1

PE1 learns this IPv4 route through the PINK OSPF routing instance. It places the route into the VRF tables associated with the advertising site, PINK FIB and PINK RIB, based on the incoming interface, ToCE3.

Note PE1 also learns a different route to the same prefix (172.17.2.0/24) through CE1, but because CE1 is associated with the RED routing instance, PE1 keeps that route separate in the RED VRF and assigns a different Route Distinguisher to that route.

Next, PE1 assigns a label to this route for remote PE routers to use when sending to this route. It creates an entry in the MPLS forwarding table to specify that all MPLS packets bearing this label should be forwarded directly out the ToCE3 interface with no labels.

Then, PE1 creates a VPN-IPv4 route by prepending the Route Distinguisher for the PINK routing instance (10.1.1.1:2) to this IPv4 route.

Finally, PE1 sets the VPN-IPv4 route's Route Target to target:65001:2, assigns its own loopback address as the BGP next hop for the route, and advertises the route to PE2 using MP-IBGP.

On PE2

PE2 receives the VPN-IPv4 route into its VPN-IPv4 RIB, where the route's Route Distinguisher (10.1.1.1:2) disambiguates this route from one to an identical prefix in Customer A Site 1, which bears a different Route Distinguisher (10.1.1.1:1).

The MP-IBGP process on PE2 compares the Route Target of this route, target:65001:2, to the import targets for its configured VRFs. PE2 has two import targets, one for each configured VRF. The Route Target of this route matches the import target for the PINK VRF, target:65001:2. PE2 strips the VPN-IPv4 route of its Route Distinguisher, creating an IPv4 route, which it installs into the PINK RIB.

The PINK OSPF routing instance on PE2 performs route selection and installs the IPv4 route into the PINK FIB.

Finally, PE2 advertises the IPv4 route to CE4.

On CE4

CE4 receives the IPv4 route for the 172.17.2.0/24 network, which it places in its global RIB. The OSPF process on CE4 performs route selection, installs this route into CE4's Unicast FIB, and announces this route to Customer B Site 2.

16.5.3 Case Study: Using Routes

The following describes the operation of the Basic BGP/MPLS VPN Network when CE4 tries to send a packet to the 172.17.2.0/24 network in Customer B Site 1.

On CE4

CE4 receives a packet destined for 172.17.2.1 from Customer B Site 2. CE4 performs a longest-match lookup in its FIB and sees that the next hop for this address is PE2. CE4 sends the IPv4 packet to PE2 through its directly-connected interface.

On PE2

PE2 receives CE4's IPv4 packet and performs a longest-match lookup in the Routing Instance FIB associated with this site, PINK FIB, based on the packet's incoming interface. In the PINK FIB, the next hop for the BGP route to 172.17.2.0/24 is PE1. Since PE2 is configured to use MPLS LSPs to resolve BGP next hops, it associates the route's BGP next hop, PE1, with the MPLS LSP PE2toPE1. Two labels were also installed for this route when PE2 received PE1's MP-IBGP advertisement, the PE1-assigned label (for the 172.17.2.0/24 route) and the label associated with the MPLS LSP to PE1.

PE2 forwards the IPv4 packet as an MPLS packet with the PE1-assigned label as the bottom (or inner) label and the label associated with the MPLS LSP to PE1 as the top (or outer) label.

On P

Router P receives and switches the MPLS packet along the PE2toPE1 LSP based on the top label. If additional P routers were present along the path from PE2 to PE1, they would also switch the packet based on the top label only.

Since it is also the penultimate router to PE1, router P pops the top label, exposing the bottom label, before forwarding the packet to PE1.

Note P routers do not examine the MPLS packet contents. They merely forward packets based on the top label.

On PE1

PE1 receives the MPLS packet. Since penultimate router P already popped the top label, PE1 only sees the bottom (or inner) label, which it assigned when advertising the 172.17.2.0/24 route. PE1 does a lookup in its MPLS forwarding table based on this label. The action associated with this label is to forward the packet directly out the ToCE3 interface without attaching any labels.

Based on this, PE1 strips the bottom label from the MPLS packet, creating a native IPv4 packet, which it sends out the ToCE3 interface.

On CE3

CE3 receives the native IPv4 packet, performs a traditional longest-match lookup in its FIB, and sees that it is the packet's destination, 172.17.2.1. CE3 consumes the packet.

Note Only the outbound PE router consults the Routing Instance FIB, not the inbound PE router. The outbound PE router needs to route an IPv4 packet using the Routing Instance FIB. The inbound PE router only needs to forward an MPLS packet, and therefore, only does lookups in the MPLS forwarding table.

16.5.4 Basic BGP/MPLS VPN Network Complete Configurations

The following are complete configurations for the Basic BGP/MPLS VPN Network, as illustrated in Figure 16-8.

CE1 Complete Configuration

```
CE1# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-03 12:28:51
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE1 ip id 200
 2 : vlan create ToCustomerASite1 ip id 100
 3 : vlan add ports et.2.1 to ToPE1
 4 : vlan add ports et.2.8 to ToCustomerASite1
     !
 5 : interface create ip ToPE1 address-netmask 172.17.1.2/30 vlan ToPE1
 6 : interface create ip ToCustomerASite1 address-netmask 172.17.2.1/24 vlan
     ToCustomerASite1

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 172.20.1.1/32
     !
 8 : ip-router global set router-id 172.20.1.1
     !
 // Configure PE1 as a default gateway for static PE-CE routing
 9 : ip add route default gateway 172.17.1.1
     !
 // Set the system name
10 : system set name CE1
```

CE2 Complete Configuration

```
CE2# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-03 13:07:19
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE2 ip id 200
 2 : vlan create ToCustomerASite2 ip id 100
 3 : vlan add ports et.2.1 to ToPE2
 4 : vlan add ports et.2.8 to ToCustomerASite2
     !
 5 : interface create ip ToPE2 address-netmask 192.168.1.2/30 vlan ToPE2
 6 : interface create ip ToCustomerASite2 address-netmask 192.168.2.1/24 vlan
     ToCustomerASite2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 192.168.100.1/32
     !
 8 : ip-router global set router-id 192.168.100.1
     !
 // Configure PE1 as a default gateway for static PE-CE routing
 9 : ip add route default gateway 192.168.1.1
     !
 // Set the system name
10 : system set name CE2
```

CE3 Complete Configuration

```
CE3# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-05-06 12:11:46
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE1 ip id 200
 2 : vlan create ToCustomerBSite1 ip id 100
 3 : vlan add ports et.3.1 to ToPE1
 4 : vlan add ports et.3.8 to ToCustomerBSite1
     !
 5 : interface create ip ToPE1 address-netmask 172.17.8.2/30 vlan ToPE1
 6 : interface create ip ToCustomerBSite1 address-netmask 172.17.2.1/24 vlan
     ToCustomerBSite1

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 172.20.2.1/32
     !
 8 : ip-router global set router-id 172.20.2.1
     !
 // Configure OSPF to be the CE-PE protocol between CE1 and PE1
 9 : ospf create area backbone
10 : ospf add stub-host 172.20.2.1 to-area backbone cost 1
11 : ospf add interface ToPE1 to-area backbone
12 : ospf add interface ToCustomerBSite1 to-area backbone
13 : ospf start
     !
 // Set the system name
14 : system set name CE3
```

CE4 Complete Configuration

```
CE4# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-03 13:26:27
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE2 ip id 200
 2 : vlan create ToCustomerBSite2 ip id 100
 3 : vlan add ports et.10.1 to ToPE2
 4 : vlan add ports et.10.8 to ToCustomerBSite2
     !
 5 : interface create ip ToPE2 address-netmask 192.168.8.2/30 vlan ToPE2
 6 : interface create ip ToCustomerBSite2 address-netmask 192.168.9.1/24 vlan
     ToCustomerBSite2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 192.168.101.1/32
     !
 8 : ip-router global set router-id 192.168.101.1
     !
 // Configure OSPF to be the CE-PE protocol between CE4 and PE2
 9 : ospf create area backbone
10 : ospf add stub-host 192.168.101.1 to-area backbone cost 1
11 : ospf add interface ToPE2 to-area backbone
12 : ospf add interface ToCustomerBSite2 to-area backbone
13 : ospf start
     !
 // Set the system name
14 : system set name CE4
```

```
PE1# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-03 13:16:20
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCE1 ip id 100
 2 : vlan create ToP ip id 200
 3 : vlan create ToCE3 ip id 300
 4 : vlan add ports et.6.1 to ToCE1
 5 : vlan add ports et.6.2 to ToCE3
 6 : vlan add ports gi.4.1 to ToP
     !
 7 : interface create ip ToCE1 address-netmask 172.17.1.1/30 vlan ToCE1
 8 : interface create ip ToCE3 address-netmask 172.17.8.1/30 vlan ToCE3
 9 : interface create ip ToP address-netmask 10.0.1.1/30 vlan ToP

 // Assign the loopback address and set it as the router ID
10 : interface add ip lo0 address-netmask 10.1.1.1/32
     !
11 : ip-router global set router-id 10.1.1.1

 // Configure AS 65001 for the provider network
12 : ip-router global set autonomous-system 65001

 // Configure BGP only to use MPLS LSPs in resolving next hops
13 : ip-router global set install-lsp-routes bgp
     !
 // Create import and export target route maps using community lists and routing
    policies
14 : community-list PINK-import permit 10 target:65001:2
15 : community-list RED-import permit 10 target:65001:1
     !
16 : ip-router policy create community-list RED-export target:65001:1
17 : ip-router policy create community-list PINK-export target:65001:2
     !
18 : route-map BGPROUTES permit 1 match-route-type bgp
19 : route-map PINK-export permit 10 set-community-list PINK-export
20 : route-map PINK-import permit 10 match-community-list PINK-import
21 : route-map RED-export permit 10 set-community-list RED-export
22 : route-map RED-import permit 10 match-community-list RED-import
     !
 // Configure OSPF for routing across the provider network
23 : ospf create area backbone
24 : ospf add stub-host 10.1.1.1 to-area backbone cost 1
25 : ospf add interface ToP to-area backbone
26 : ospf start
```

```
     !
 // Configure MP-IBGP peering with PE2
27 : bgp create peer-group PROVIDER autonomous-system 65001
28 : bgp add peer-host 10.3.3.1 group PROVIDER
29 : bgp set peer-group PROVIDER local-address 10.1.1.1
30 : bgp set peer-group PROVIDER vpnv4-unicast ipv4-unicast
31 : bgp start
     !
 // Configure an MPLS LSP to PE2
32 : mpls add interface ToP
33 : mpls create label-switched-path PE1toPE2 from 10.1.1.1 to 10.3.3.1 no-cspf
34 : mpls start
     !
35 : rsvp add interface ToP
36 : rsvp start
     !
 // Set system name
37 : system set name PE1
     !
 // Configure PINK OSPF routing instance to CE3
38 : routing-instance PINK vrf set route-distinguisher "10.1.1.1:2"
39 : routing-instance PINK vrf add interface ToCE3
40 : routing-instance PINK vrf add interface lo0
41 : routing-instance PINK vrf set router-id 10.1.1.1
42 : routing-instance PINK vrf set vrf-import PINK-import in-sequence 1
43 : routing-instance PINK vrf set vrf-export PINK-export out-sequence 1
44 : routing-instance PINK ospf create area backbone
45 : routing-instance PINK ospf add stub-host 10.1.1.1 to-area backbone cost 1
46 : routing-instance PINK ospf add interface ToCE3 to-area backbone
47 : routing-instance PINK ospf set domain-id 0.0.0.0
48 : routing-instance PINK ospf set vpn-route-tag 1001
49 : routing-instance PINK ospf set route-map-vpn BGPROUTES
50 : routing-instance PINK ospf start

 // Configure RED static routing instance to CE1
51 : routing-instance RED vrf set route-distinguisher "10.1.1.1:1"
52 : routing-instance RED vrf add interface ToCE1
53 : routing-instance RED vrf set vrf-import RED-import in-sequence 1
54 : routing-instance RED vrf set vrf-export RED-export out-sequence 1
55 : routing-instance RED ip add route 172.17.2.0/24 gateway 172.17.1.2
56 : routing-instance RED ip add route 172.20.1.1/32 gateway 172.17.1.2
```

```
PE2# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-03 12:26:47
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToCE2 ip id 100
 2 : vlan create ToCE4 ip id 200
 3 : vlan create ToP ip id 300
 4 : vlan add ports et.3.1 to ToCE2
 5 : vlan add ports et.3.2 to ToCE4
 6 : vlan add ports gi.7.1 to ToP
     !
 7 : interface create ip ToCE2 address-netmask 192.168.1.1/30 vlan ToCE2
 8 : interface create ip ToCE4 address-netmask 192.168.8.1/30 vlan ToCE4
 9 : interface create ip ToP address-netmask 10.0.2.2/30 vlan ToP

 // Assign the loopback address and set it as the router ID
10 : interface add ip lo0 address-netmask 10.3.3.1/32
     !
11 : ip-router global set router-id 10.3.3.1

 // Configure AS 65001 for the provider network
12 : ip-router global set autonomous-system 65001

 // Configure BGP only to use MPLS LSPs in resolving next hops
13 : ip-router global set install-lsp-routes bgp
     !
 // Create import and export target route maps using community lists and routing
    policies
14 : community-list PINK-import permit 10 target:65001:2
15 : community-list RED-import permit 10 target:65001:1
     !
16 : ip-router policy create community-list RED-export target:65001:1
17 : ip-router policy create community-list PINK-export target:65001:2
     !
18 : route-map BGPROUTES permit 1 match-route-type bgp
19 : route-map PINK-export permit 10 set-community-list PINK-export
20 : route-map PINK-import permit 10 match-community-list PINK-import
21 : route-map RED-export permit 10 set-community-list RED-export
22 : route-map RED-import permit 10 match-community-list RED-import
     !
 // Configure OSPF for routing across the provider network
23 : ospf create area backbone
24 : ospf add stub-host 10.3.3.1 to-area backbone cost 1
25 : ospf add interface ToP to-area backbone
26 : ospf start
```

```
     !
 // Configure MP-IBGP peering with PE1
27 : bgp create peer-group PROVIDER autonomous-system 65001
28 : bgp add peer-host 10.1.1.1 group PROVIDER
29 : bgp set peer-group PROVIDER local-address 10.3.3.1
30 : bgp set peer-group PROVIDER vpnv4-unicast ipv4-unicast
31 : bgp start
     !
 // Configure an MPLS LSP to PE1
32 : mpls add interface ToP
33 : mpls create label-switched-path PE2toPE1 from 10.3.3.1 to 10.1.1.1 no-cspf
34 : mpls start
     !
35 : rsvp add interface ToP
36 : rsvp start
     !
 // Set system name
37 : system set name PE2
     !
 // Configure PINK OSPF routing instance to CE4
38 : routing-instance PINK vrf set route-distinguisher "10.3.3.1:2"
39 : routing-instance PINK vrf add interface ToCE4
40 : routing-instance PINK vrf add interface lo0
41 : routing-instance PINK vrf set router-id 10.3.3.1
42 : routing-instance PINK vrf set vrf-import PINK-import in-sequence 1
43 : routing-instance PINK vrf set vrf-export PINK-export out-sequence 1
44 : routing-instance PINK ospf create area backbone
45 : routing-instance PINK ospf add stub-host 10.3.3.1 to-area backbone cost 1
46 : routing-instance PINK ospf add interface ToCE4 to-area backbone
47 : routing-instance PINK ospf set domain-id 0.0.0.0
48 : routing-instance PINK ospf set vpn-route-tag 1001
49 : routing-instance PINK ospf set route-map-vpn BGPROUTES
50 : routing-instance PINK ospf start

 // Configure RED static routing instance to CE2
51 : routing-instance RED vrf set route-distinguisher "10.3.3.1:1"
52 : routing-instance RED vrf add interface ToCE2
53 : routing-instance RED vrf set vrf-import RED-import in-sequence 1
54 : routing-instance RED vrf set vrf-export RED-export out-sequence 1
55 : routing-instance RED ip add route 192.168.2.0/24 gateway 192.168.1.2
56 : routing-instance RED ip add route 192.168.100.1/32 gateway 192.168.1.2
```

P Complete Configuration

```
P# show run
Running system configuration:
     !
     ! Last modified from Console on 2002-06-04 02:03:52
     !
 // Create VLANs and add them to interfaces
 1 : vlan create ToPE1 ip id 100
 2 : vlan create ToPE2 ip id 200
 3 : vlan add ports gi.4.2 to ToPE1
 4 : vlan add ports gi.4.1 to ToPE2
     !
 5 : interface create ip ToPE1 address-netmask 10.0.1.2/30 vlan ToPE1
 6 : interface create ip ToPE2 address-netmask 10.0.2.1/30 vlan ToPE2

 // Assign the loopback address and set it as the router ID
 7 : interface add ip lo0 address-netmask 10.2.2.1/32
     !
 8 : ip-router global set router-id 10.2.2.1
     !
 // Configure OSPF to route across the provider network
 9 : ospf create area backbone
10 : ospf add stub-host 10.2.2.1 to-area backbone cost 1
11 : ospf add interface ToPE1 to-area backbone
12 : ospf add interface ToPE2 to-area backbone
13 : ospf start
     !
 // Configure MPLS and RSVP to support LSPs between PE1 and PE2
14 : mpls add interface ToPE1
15 : mpls add interface ToPE2
16 : mpls start
     !
17 : rsvp add interface ToPE1
18 : rsvp add interface ToPE2
19 : rsvp start
     !
 // Set the system name
20 : system set name P
```

16.6 CONFIGURING RIP AND BGP ROUTE DISTRIBUTION BETWEEN CE AND PE ROUTERS

The RS supports the following routing schemes between CE and PE routers.

- Static routes
- Open Shortest Path First (OSPF)
- Routing Information Protocol (RIP)
- Border Gateway Protocol (BGP)

For an example of configuring CE-PE route distribution using static routes and OSPF, refer to the Section *"Configuring Static and OSPF Route Distribution Between CE and PE Routers."*

Using the Basic BGP/MPLS VPN Network (Figure 16-7) example, the following sections illustrate how to configure CE-PE route distribution using RIP and BGP. In this section, the OSPF and static routes configured in the routing

16.7 TROUBLESHOOTING THE BASIC BGP/MPLS VPN NETWORK

When one customer site has no connectivity to a remote customer site in the same VRF, a problem exists in the BGP/MPLS VPN network. This section presents troubleshooting guidelines to help you step through the network and identify the problem. These steps reference the sample troubleshooting network in Figure 16-10. Progress boxes like the following appear at the beginning of each step to guide you. The current step is highlighted. In each section, you should always check that you have completed the steps before the highlighted task.

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify remote PE-PE connectivity and routing exchange by pinging between the local PE router and remote PE and CE routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

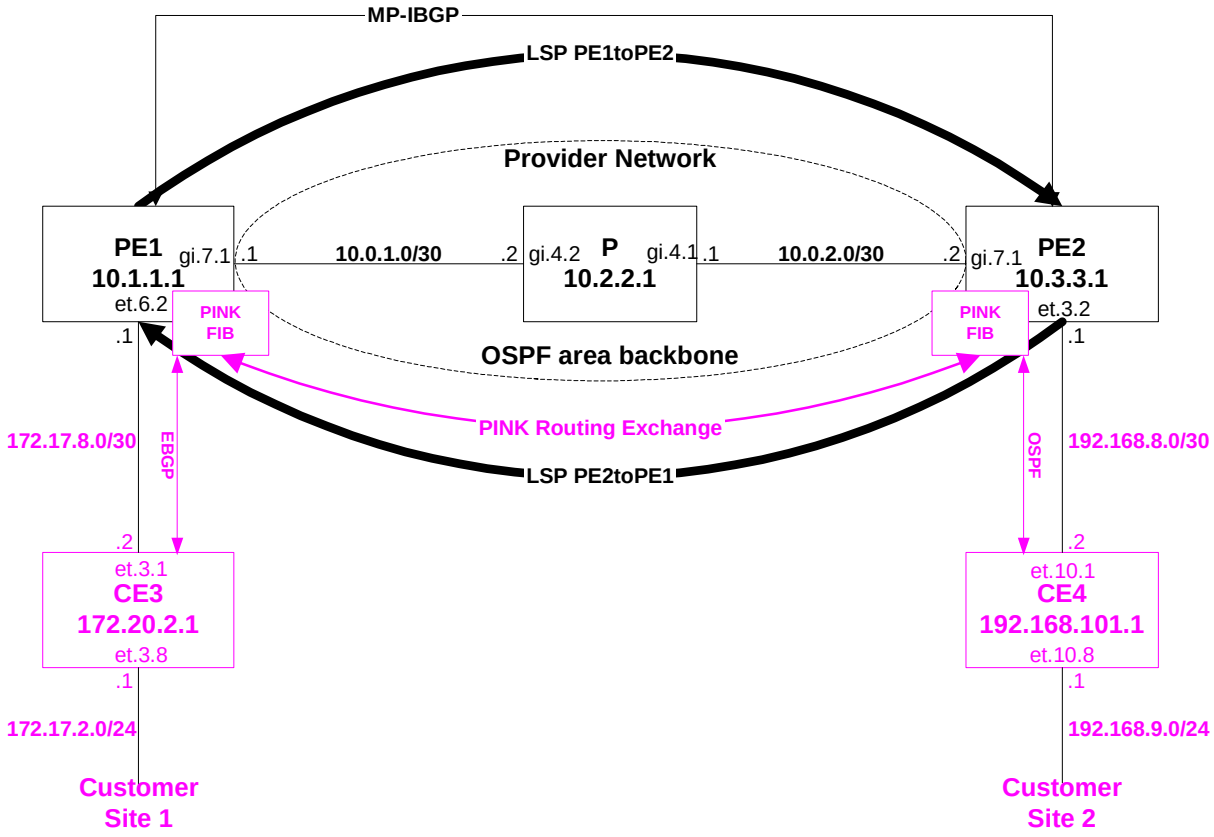


Figure 16-10 Basic BGP/MPLS VPN Troubleshooting Network

16.7.1 General Troubleshooting

When one customer site has no connectivity to a remote customer site in the same VRF, non-BGP/MPLS VPN-related problems may be the cause. Begin by performing general troubleshooting tasks, which are described in the following sections.

Basic BGP/MPLS VPN network troubleshooting steps:

- **General troubleshooting**
  - **Verify physical connectivity**
  - **Eliminate error commands from the active configuration**
  - **Verify the correct spelling of all names and references in the active configuration**
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

Verify Physical Connectivity

Verify physical connectivity on all of the network segments from one site to the other. Replace defective or incorrect wires and use LEDs to confirm that all links are up. The following troubleshooting guidelines assume that the network is free of physical-layer connectivity problems.

Eliminate Error Commands

Verify that no error commands exist in your active configuration on all CE, PE, and P routers. An error command is indicated by the letter 'E' next to the command number in the active configuration display, which you can view using the **`show run`** command in Enable mode and the **`show`** command in Configuration mode. In the following sample configuration, the command in **bold** is an error command:

```
PE# show running-configuration
...
45 : routing-instance PINK vrf set route-distinguisher "10.1.1.1:2"
46 : routing-instance PINK vrf set vrf-import PINK-import in-sequence 1
47 : routing-instance PINK vrf set vrf-export PINK-export out-sequence 1
48 : routing-instance PINK vrf add interface ToCE3
49 : routing-instance PINK ospf create area backbone
50 : routing-instance PINK ospf add stub-host 10.1.1.1 to-area backbone cost 1
51 : routing-instance PINK ospf add interface ToCE3 to-area backbone
52 : routing-instance PINK ospf start
53 : routing-instance PINK vrf add interface lo0
54 : routing-instance PINK vrf set router-id 10.1.1.1
55E: routing-instance PinK ospf set domain-id 0.0.0.0
56 : routing-instance PINK ospf set vpn-route-tag 1001
57 : routing-instance PINK ospf set route-map-vpn ALLROUTES
...
```

Figure 16-11 Error command example

Verify the Correct Spelling of all Names and References

Figure 16-11 shows a command that is in error because of a typographical error in the name of the routing instance, PINK. Typographical errors are a leading cause of misconfigurations. The RS only warns of errors when the error can be determined within the context of existing configurations. In the preceding example, the error lies in the referencing of a nonexistent routing instance. The RS cannot tell whether the *intended* routing instance exists, only that the *referenced* routing instance does not exist. Other case-sensitive names include, but are not limited to:

- Route map names
- Community list names
- Interface names
- BGP peering group names
- Routing instance names
- MPLS LSP names

Before continuing, verify that you have spelled these names correctly.

16.7.2 Verify Basic BGP/MPLS VPN Network Functionality by Pinging Between the CE Routers

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- **Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers**
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

On any router, you can test whether it has connectivity to a remote address by pinging that address. To test connectivity between two VRF sites, you can ping any device in the remote site from any device in the local site. These devices can be the CE routers themselves, or hosts beyond the CE routers. The pings succeed if CE routers are exchanging routes with their respective PE routers for the networks on which these devices reside.

The simplest way to verify VRF site connectivity is to ping from a local CE router to a remote CE router. The Basic BGP/MPLS VPN Network is not concerned with intra-site routing. It is only in charge of distributing the routes that CE routers advertise for their sites. Successful pings between CE routers confirm that PE routers are exchanging CE routes. Given this, if non-CE local-site devices cannot ping non-CE remote-site devices, then the problem most likely resides with the CE routers not distributing the necessary routes.

Typically, a CE router is configured with several networks: the site-facing network, the PE-CE network, and optionally, the loopback network. Which CE network you ping depends on which network is being advertised into the PE-CE protocol.

In static routing, for example, the CE router must be configured with a default route and the PE router must have routes specifically defined for each CE network to enable pings to that network from the remote site. For RIP, OSPF, and BGP, routes are only exchanged for those interfaces on which the protocol is applied. Given this, not being able to ping a certain loopback or physical interface is not a definitive test of whether the BGP/MPLS VPN network is working. Even in fully functional BGP/MPLS VPN networks, not all interfaces between two connected routers can be pinged. Certain interfaces may be able to ping certain other interfaces, but depending on the networks included in the routing exchange, other interfaces on the same two routers may have no connectivity. For example, a CE router should be able to ping the directly-connected interface on a PE router, but should not expect to be able to ping other interfaces, such as

- customer-facing interfaces in other VRFs
- provider-facing interfaces
- loopback interfaces (unless it has been specifically added to the CE-PE protocol)

To determine whether a ping should work, first determine whether routes for both the destination and source addresses of the ping should be exchanged. The following troubleshooting sections illustrate pings that both should and should not be successful in the Basic BGP/MPLS VPN Network.

Note A ping can succeed only if both the destination and source addresses of the ping are being exchanged. For example, for A to successfully ping B, A's routing table must have a route to B and B's routing table must have a return route to A.

In the sample troubleshooting network (Figure 16-10), CE3 is advertising the following networks to PE1 via EBGP:

- Customer-facing network: 172.17.2/24
- Provider-facing network: 172.17.8/30
- Loopback network: 172.20.2.1/32

Similarly, CE4 is advertising the following networks to PE2 via OSPF:

- Customer-facing network: 192.168.9/24
- Provider-facing network: 192.168.8/30
- Loopback network: 192.168.101.1/32

To verify basic BGP/MPLS VPN functionality, ping between the CE routers.

The following demonstrates successful pings from CE3 to the announced interfaces on CE4:

```
CE3# ping 192.168.101.1
PING 192.168.101.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.101.1: icmp_seq=0 ttl=253 time=2.786 ms

--- 192.168.101.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.786/2.786/2.786/0.000 ms

CE3# ping 192.168.9.1
PING 192.168.9.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.9.1: icmp_seq=0 ttl=253 time=2.792 ms

--- 192.168.9.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.792/2.792/2.792/0.000 ms

CE3# ping 192.168.8.2
PING 192.168.8.2: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.8.2: icmp_seq=0 ttl=253 time=2.634 ms

--- 192.168.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.634/2.634/2.634/0.000 ms
```

Figure 16-12 Ping from CE3 to CE4

The following demonstrates successful pings from CE4 to the announced interfaces on CE3:

```
CE4# ping 172.20.2.1
PING 172.20.2.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.20.2.1: icmp_seq=0 ttl=253 time=2.896 ms

--- 172.20.2.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.896/2.896/2.896/0.000 ms

CE4# ping 172.17.2.1
PING 172.17.2.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.2.1: icmp_seq=0 ttl=253 time=2.518 ms

--- 172.17.2.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.518/2.518/2.518/0.000 ms

CE4# ping 172.17.8.2
PING 172.17.8.2: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.8.2: icmp_seq=0 ttl=253 time=2.642 ms

--- 172.17.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.642/2.642/2.642/0.000 ms
```

Figure 16-13 Ping from CE4 to CE3

If you cannot ping between the CE routers, proceed to the next troubleshooting step to verify CE-PE routing.

16.7.3 Verify Local CE-PE Connectivity and Routing Exchange by Pinging Between the CE Router and the Local PE Router

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - **Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router**
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

To verify local CE-PE connectivity and routing exchange, ping between the CE router and the local PE router. Use the **`ping`** command on CE routers and the **`ping`** command with the **`vrf`** option on PE routers. You must use the **`vrf`** option because without it, the **`ping`** command resolves the destination address using routes in the Global Unicast FIB. PE and CE routers peer through a VRF, so all of the routes the CE router announces are stored in the Routing Instance Unicast FIB on the PE router, not in the Global Unicast FIB. (The exceptions are routes to networks that are directly connected to the PE router, which are stored in both the Routing Instance Unicast FIB and the Global Unicast FIB.)

The following demonstrate successful pings from CE3 to the directly-connected PE1 interface (172.17.8.1) and from PE1 to all of CE3's interfaces.

Note that CE3 cannot ping all of PE1's interfaces, such as PE1's loopback interface (10.1.1.1) and provider-facing interface (10.0.1.1). This is expected because PE1 is not configured to exchange routes for those interfaces with CE3.

```
CE3# ping 172.17.8.1
PING 172.17.8.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.8.1: icmp_seq=0 ttl=255 time=1.288 ms

--- 172.17.8.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.288/1.288/1.288/0.000 ms

CE3# ping 10.1.1.1
PING 10.1.1.1: 36 bytes of data
5 second timeout, 1 repetition
From localhost: Destination Host Unreachable

--- 10.1.1.1 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms

CE3# ping 10.0.1.1
PING 10.0.1.1: 36 bytes of data
5 second timeout, 1 repetition
From localhost: Destination Host Unreachable

--- 10.0.1.1 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms
```

Figure 16-14 Ping from CE3 to PE1

CE3 is announcing all of its interfaces to PE1.

The following demonstrates successful pings from PE1 to the announced interfaces on CE3. Note that PE1 can ping 172.17.8.2 using both the Global Unicast FIB and the Routing Instance PINK Unicast FIB. The 172.17.8.0/30 network is directly connected to PE1, so PE1 learns of it both as a direct route and through routing announcements from CE3. This causes a route to the 172.17.8.0/30 network to exist in both FIBs.

```
PE1# ping 172.17.8.2
PING 172.17.8.2: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.8.2: icmp_seq=0 ttl=255 time=1.248 ms

--- 172.17.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.248/1.248/1.248/0.000 ms

PE1# ping 172.17.8.2 vrf PINK
PING 172.17.8.2: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.8.2: icmp_seq=0 ttl=255 time=1.290 ms

--- 172.17.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.290/1.290/1.290/0.000 ms

PE1# ping 172.20.2.1 vrf PINK
PING 172.20.2.1: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.20.2.1: icmp_seq=0 ttl=255 time=2.064 ms

--- 172.20.2.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 2.064/2.064/2.064/0.000 ms

PE1# ping 172.17.2.1 vrf PINK
PING 172.17.2.1: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 172.17.2.1: icmp_seq=0 ttl=255 time=1.284 ms

--- 172.17.2.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.284/1.284/1.284/0.000 ms
```

Figure 16-15 Ping from PE1 to CE3

The following demonstrate successful pings from CE4 to two PE2 interfaces (192.168.8.1 and 10.3.3.1) and from PE2 to all of CE4's interfaces.

Note that CE4 cannot ping all of PE2's interfaces, but CE4 is able to ping PE2's loopback interface (10.3.3.1) because that interface participates in OSPF with CE4. CE4 cannot ping PE2's provider-facing interface (10.0.2.2) because PE2 is not configured to exchange routes for it with CE4.

```
CE4# ping 192.168.8.1
PING 192.168.8.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.8.1: icmp_seq=0 ttl=255 time=1.836 ms

--- 192.168.8.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.836/1.836/1.836/0.000 ms

CE4# ping 10.3.3.1
PING 10.3.3.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 10.3.3.1: icmp_seq=0 ttl=255 time=1.196 ms

--- 10.3.3.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.196/1.196/1.196/0.000 ms

CE4# ping 10.0.2.2
PING 10.0.2.2: 36 bytes of data
5 second timeout, 1 repetition
From localhost: Destination Host Unreachable

--- 10.0.2.2 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms
```

Figure 16-16 Ping from CE4 to PE2

CE4 is announcing all of its interfaces to PE1.

The following demonstrates successful pings from PE2 to the announced interfaces on CE4. Note that PE2 can ping 192.168.8.2 using both the Global Unicast FIB and the Routing Instance PINK Unicast FIB. The 192.168.8.0/30 network is directly connected to PE1, so PE1 learns of it both as a direct route and through routing announcements from CE3. This causes a route to the 192.168.8.0/30 network to exist in both FIBs.

```
PE2# ping 192.168.8.2
PING 192.168.8.2: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.8.2: icmp_seq=0 ttl=255 time=1.200 ms

--- 192.168.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.200/1.200/1.200/0.000 ms

PE2# ping 192.168.8.2 vrf PINK
PING 192.168.8.2: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.8.2: icmp_seq=0 ttl=255 time=0.990 ms

--- 192.168.8.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 0.990/0.990/0.990/0.000 ms

PE2# ping 192.168.9.1 vrf PINK
PING 192.168.9.1: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.9.1: icmp_seq=0 ttl=255 time=1.210 ms

--- 192.168.9.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.210/1.210/1.210/0.000 ms

PE2# ping 192.168.101.1 vrf PINK
PING 192.168.101.1: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.101.1: icmp_seq=0 ttl=255 time=1.218 ms

--- 192.168.101.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.218/1.218/1.218/0.000 ms
```

Figure 16-17 Ping from PE2 to CE4

If the desired pings are not successful, examine the relevant FIBs on both the CE and PE routers to determine if the appropriate VRF routes are being exchanged. Use the **ip show route** command on the CE router and the **ip show route show-vrf** <*instance*> command on the PE router. You must specify an instance on the PE router because unlike the CE router, the PE router installs the routes that it learns during CE-PE exchange in the Routing Instance Unicast FIB, not the Global Unicast FIB.

For a ping to succeed, the CE router must have a route to the PE address it is pinging, and the PE router must have a route back to the CE router. The following demonstrate this between CE3 and PE1 and between CE4 and PE2. In this step, we are only concerned with the local VRF routes, which are highlighted.

```
CE3# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        directly connected   -         ToCustomerBSite
172.17.8.0/30        directly connected   -         ToPE1
172.20.2.1           172.20.2.1           -         lo0
192.168.8.0/30       172.17.8.1           BGP       ToPE1
192.168.9.0/24       172.17.8.1           BGP       ToPE1
192.168.101.1        172.17.8.1           BGP       ToPE1
```

```
PE1# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        172.17.8.2           BGP       ToCE3
172.17.8.0/30        directly connected   -         ToCE3
172.20.2.1           172.17.8.2           BGP       ToCE3
192.168.8.0/30       10.0.1.2             BGP       PE1toPE2
192.168.9.0/24       10.0.1.2             BGP       PE1toPE2
192.168.101.1        10.0.1.2             BGP       PE1toPE2
```

Figure 16-18 Unicast FIB on CE3 and PINK Instance FIB on PE1—Verify routing exchange

```
CE4# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.3.3.1             192.168.8.1          OSPF      ToPE2
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        192.168.8.1          OSPF_ASE  ToPE2
172.17.8.0/30        192.168.8.1          OSPF_ASE  ToPE2
172.20.2.1           192.168.8.1          OSPF_ASE  ToPE2
192.168.8.0/30       directly connected   -         ToPE2
192.168.9.0/24       directly connected   -         ToCustomerBSite
192.168.101.1        192.168.101.1        -         lo0
```

```
PE2# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        10.0.2.1             BGP       PE2toPE1
172.17.8.0/30        10.0.2.1             BGP       PE2toPE1
172.20.2.1           10.0.2.1             BGP       PE2toPE1
192.168.8.0/30       directly connected   -         ToCE4
192.168.9.0/24       192.168.8.2          OSPF      ToCE4
192.168.101.1        192.168.8.2          OSPF      ToCE4
```

Figure 16-19 Unicast FIB on CE4 and PINK Instance FIB on PE2—Verify routing exchange

If the routes that you expect to see are not in the FIBs, the CE-PE routing exchange may be misconfigured.

- If you are using static routing, add the appropriate static routes and return to the beginning of this troubleshooting step.
- If you are using RIP, add the interfaces for those routes into RIP and return to the beginning of this troubleshooting step.
- If you are using OSPF or BGP for CE-PE route distribution, continue with the next troubleshooting step.

Verify Remote Connectivity Between PEs and CEs

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - **Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers**
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

The following demonstrates successful pings from PE1 to the remotely-connected PE2 interface (10.3.3.1) and from PE1 to CE4 (192.168.101.1):

```
PE2# ping 10.3.3.1 source 10.1.1.1
PING 10.3.3.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from 10.3.3.1: icmp_seq=0 ttl=255 time=1.200 ms

--- 10.3.3.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 1.200/1.200/1.200/0.000 ms

PE2# ping 192.168.101.1 vrf PINK source 10.1.1.1
PING 192.168.101.1: Using VRF PINK
36 bytes of data
5 second timeout, 1 repetition
36 bytes from 192.168.101.1: icmp_seq=0 ttl=255 time=0.990 ms

--- 192.168.101.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 0.990/0.990/0.990/0.000 ms
```

Figure 16-20 Successful Pings to Remote PE and CE

Notice that when PE1 sends pings across the MPLS Provider Network, PE1 must include its source address in the **ping** command. The source address provides the remote MPLS interface router (PE2) with the address necessary to send the reply back to the correct interface on PE1.

Troubleshoot OSPF Between CE and PE Routers

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - **Troubleshoot routing exchange between CE and PE Routers**
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

For more information on configuring OSPF between CE and PE routers, refer to the Section *"Configuring Static and OSPF Route Distribution Between CE and PE Routers."*

Troubleshoot an OSPF connection between CE and PE routers using the following **show** commands:

- **ospf show neighbor [instance]**
  - **ospf show adjacency-down-reason [instance]**
- **ospf show interface [instance]**
- **ospf show database [instance]**
  - **ospf show export-policy [instance]**
  - **ospf show import-policy [instance]**

To view instance-related information on the PE-CE OSPF adjacency, use these commands *without* the **instance** option on CE routers and *with* the **instance** option on PE routers.

On CE4, the **ospf show neighbor** command displays information about the OSPF adjacency such as the adjacency area and neighboring router. On PE2, the **ospf show neighbor instance PINK** command displays similar information about the PINK OSPF routing instance.

The following demonstrate that CE4 and PE2 recognize each other as full neighbors. When troubleshooting OSPF adjacencies, watch for the **State** to be **Full** in this command output and verify the neighbor's loopback and interface addresses. If the state is not full, use the **ospf show adjacency-down-reason [instance]** command for more information.

```
CE4# ospf show neighbor
Neighbor 10.3.3.1, interface address 192.168.8.1 [mem: 82bce000]
    In the area 0.0.0.0 via interface address 192.168.8.2
    Neighbor priority is 1, State is Full
    Options 1
    Dead timer due in 13:54:45
    Hitless Helper: not active
```

Figure 16-21 OSPF neighbors on CE4

```
PE2# ospf show neighbor instance PINK
Neighbor 192.168.101.1, interface address 192.168.8.2 [mem: 82bc6800]
    In the area 0.0.0.0 via interface address 192.168.8.1
    Neighbor priority is 1, State is Full
    Options 0
    Dead timer due in 12:46:10
    Hitless Helper: not active
```

Figure 16-22 PINK Instance OSPF neighbors on PE2

The **ospf show interfaces** command displays the interfaces that are participating in OSPF between the CE and PE routers, with the exception of the loopback interface.

The following demonstrate the interfaces participating in OSPF on CE3 and PE1. Routes for directly-attached networks on these interfaces are distributed into OSPF. When troubleshooting, verify that the interfaces for all the networks that you want to be distributed into OSPF are added to the appropriate OSPF area (and instance on PE routers).

```
CE4# ospf show interfaces
Internet Address 192.168.8.2/30, Area 0.0.0.0
    Router ID 192.168.101.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State DR, Priority 1
    Designated Router (ID) 192.168.101.1, Interface address 192.168.8.2
    Backup Designated Router 10.3.3.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 13:26:34
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled
```

Figure 16-23 PE-Facing OSPF interface on CE4

```
PE2# ospf show interfaces instance PINK
Internet Address 192.168.8.1/30, Area 0.0.0.0
    Router ID 10.3.3.1, Network Type Broadcast, Cost: 20
    Transmit Delay is 1 sec, State Back DR, Priority 1
    Designated Router (ID) 192.168.101.1, Interface address 192.168.8.1
    Backup Designated Router 10.3.3.1
    Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
        Hello due in 12:26:54
    Neighbor Count is 1
    Authentication not enabled
    Hitless Helper Mode is disabled
```

Figure 16-24 PINK Instance OSPF interfaces on PE2

The **ospf show database** command displays the OSPF link-state database. Note that on both sides of the VPN, the remote PE-CE network is distributed as an AS external route. Although the PE router has an OSPF route to this network, it advertises the network as directly-connected, which becomes AS external when received by the remote PE.

When troubleshooting, first look to see if the routes to which you have no connectivity are missing from this database. If so, use the **ospf show export-policy [instance]** and **ospf show import-policy [instance]** commands to determine if any routing policies controlling route distribution are misconfigured. (On PE routers, the VPN export route map that is applied using the **routing-instance ospf set route-map-vpn** command is not displayed as an export policy.)

If *local* PE-CE routing is misconfigured, most likely you will see indications of no local routing exchange:

- local-site routes are in the OSPF database of the CE router but are not in the local PE router
- remote-site routes are in the OSPF database of the local PE router but are not in the CE router

If *remote* PE-CE routing is misconfigured, most likely you will not see remote-site routes in the local PE and CE routers.

If the provider network is misconfigured (IGP, MP-BGP, or MPLS), you will also most likely not see remote-site routes in the local PE and CE routers.

When inspecting the OSPF database for remote-site routes, note that a route's LSA type does not positively identify it as remote. Do not assume that all remote-site routes are Type-5 LSAs. With the exception of the PE-CE network, remote-site routes of a pure OSPF origin from the same OSPF Domain are distributed as Type-3 LSAs. All other remote-site routes, including the PE-CE network, non-OSPF routes distributed into OSPF, and OSPF-originated routes from a different OSPF Domain, are distributed as Type-5 LSAs.

The following demonstrate local VRF routes in the OSPF link-state databases of CE4 and PE2.

```
CE4# ospf show database
        OSPF Router with ID (192.168.101.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
----------------------------------------------------------------
10.3.3.1        10.3.3.1        200  80000032  d70a      20

192.168.101.1   192.168.101.1   180  80000033  ce41      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
----------------------------------------------------------------
192.168.8.2     192.168.101.1   180  80000031  603       20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
----------------------------------------------------------------
172.17.2        10.3.3.1        1700 8000002d  79bd      41

172.20.2.1      10.3.3.1        1700 8000002d  8cb9      22


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
----------------------------------------------------------------
172.17.8        10.3.3.1        1700 8000002d  bc6       1
```

Figure 16-25 OSPF link-state database on CE4

```
PE2# ospf show database instance PINK
        OSPF Router with ID (10.3.3.1)


ROUTER LSA
            Router Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.101.1   192.168.101.1   411  80000033  ce41      20

10.3.3.1        10.3.3.1        429  80000032  d70a      0


NETWORK LSA
            Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
192.168.8.2     192.168.101.1   411  80000031  603       20


SUMMARY LSA
            Summary Net Link States (Area: 0.0.0.0)

Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.20.2.1      10.3.3.1        69   8000002e  8aba      22

172.17.2        10.3.3.1        69   8000002e  77be      41


ASBR SUMMARY LSA

NSSA EXTERNAL LSA

 LINK OPQ LSA

AREA OPQ LSA

AS OPQ LSA

            AS External Link States
Link ID         ADV Router      Age  Seq#      Checksum  Cost
-------------------------------------------------------------
172.17.8        10.3.3.1        69   8000002e  9c7       1
```

Figure 16-26 PINK Instance OSPF link-state database on PE2

Troubleshoot BGP Between CE and PE Routers

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - **Troubleshoot routing exchange between CE and PE Routers**
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

For more information on configuring BGP between CE and PE routers, refer to Chapter 16.6.2, *"Configuring BGP Route Distribution Between CE and PE Routers."*

Troubleshoot a BGP session between CE and PE routers using the following **`show`** commands:

- **`bgp show neighbor`**
- **`bgp show peer-host [instance] advertised-routes`**
- **`bgp show peer-host [instance] all-received-routes`**
- **`bgp show peer-host [instance] received-routes`**

To view instance-related information on the PE-CE OSPF adjacency, use these commands *without* the **`instance`** options on CE routers and *with* the **`instance`** option on PE routers.

The **`bgp show neighbor`** command displays information about the BGP peering, such as the peer's address, router ID, the state and type of peering, the BGP version, traffic statistics, and any inbound or outbound route maps in effect.

The following output show that CE4 and PE2 recognize each other as established neighbors. When troubleshooting BGP adjacencies:

- Watch for the **`State`** to be **`Established`** in this command output and verify the neighbor's router ID and interface address. If the **`State`** is not **`Established`**, execute this command several times in quick succession to determine if the BGP adjacency is cycling through certain states. If it is, refer to BGP protocol specifications for information on the possible causes of adjacency state toggling.
- Confirm that the correct autonomous system number is configured on both the PE and CE routers.
- When configuring BGP peer groups, you do not need to specify the type of peering (external or routing). The router automatically determine the type by comparing the peer group's autonomous system to its own. Type 'routing' is used for IBGP peering. Type 'external' is used for EBGP peering. A common BGP problem is misconfigured peering type. If this is the case, either select the right peering type or remove all type specifications and allow the router to use the default type.

- Check to see that the BGP peers are passing traffic.
- If expected routes are not being distributed, confirm the logic in any route maps applied.

The following demonstrate correct peering between PE1 and CE3. On PE routers, limit the **bgp show neighbor** view by specifying the appropriate CE peer. If you choose to view all neighbors, the view displays all PE and CE neighbors.

```
PE1# bgp show neighbor 172.17.8.2
Peer: 172.17.8.2+179    Local: 172.17.8.1+1033
        Type: External   remote AS 65002
        State: Established      Flags: <v4MP GenDefault>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <>
        Configured parameters : VRF in use  PINK VRF number 4

        Used parameters :
       Peer Version: 4 Peer ID: 172.20.2.1    Local ID: 10.1.1.1     Active Holdtime:
            180
        Uptime 2d23h6m44s
        Last traffic (seconds): Received 58     Sent 11 Checked 178
        Input messages :Total      4268    Updates         2    Octets     81132

        Output messages:Total      4277    Updates         8    Octets     81650

          count of sent routes                4
          count of recvd routes               3
          count of route refresh recvd        0
          count of route refresh sent         0
          count of derived routes             0
        Supported capabilities
               Route Refresh;
        Outbound policy configured :
        Routemaps for outgoing advertisements :
               Route Map               Sequence
               ================================
               ALLROUTES               1
```

Figure 16-27 PINK Instance BGP neighbor (CE3) on PE1

```
CE3# bgp show neighbor all
        Peer: 172.17.8.1+1033   Local: 172.17.8.2+179
        Type: External   remote AS 65001
        State: Established      Flags: <v4MP GenDefault>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <>
        Configured parameters : VRF in use  unicast VRF number 0

        Used parameters :
       Peer Version: 4 Peer ID: 10.1.1.1      Local ID: 172.20.2.1    Active Holdtime:
            180
        Uptime 2d23h26m57s
        Last traffic (seconds): Received 27     Sent 14 Checked 147
        Input messages :Total      4297    Updates         9    Octets     82011

        Output messages:Total      4290    Updates         1    Octets     81589

          count of sent routes                3
          count of recvd routes               4
          count of route refresh recvd        0
          count of route refresh sent         0
          count of derived routes             0
        Supported capabilities
               Route Refresh;
        Outbound policy configured :
        Routemaps for outgoing advertisements :
               Route Map              Sequence
               ==============================
               ALLROUTES              1
```

Figure 16-28 BGP neighbors on CE3

The **bgp show peer-host [instance] advertised-routes** command displays the routes that a peer is sending to a neighbor. If an expected route is missing, verify that the sending peer is announcing the route. Then verify that the receiving peer is receiving the route using the **bgp show peer-host [instance] all-received-routes** command.

If *local* PE-CE routing is misconfigured, you will not see routes being advertised or received on the CE and PE routers.

If *remote* PE-CE routing is misconfigured, most likely you will not see remote-site routes in the local PE and CE routers.

If the provider network is misconfigured (IGP, MP-BGP, or MPLS), you will also most likely not see remote-site routes in the local PE and CE routers.

The following demonstrate that CE3 is sending a route for each of its configured networks to PE1. PE1 is sending CE3 remote PINK VRF routes learned from CE4 via PE2. PE1 is also sending CE3 its directly-connected route in the PINK VRF. Both routers are receiving each other's advertised routes.

Notice that you must use the **instance** option on PE routers with the **bgp show peer-host** command to view VRF-related advertisements. It is possible for a PE router to be sending multiple VRF routes to the same peer, in which case the advertisements are sorted by instance. In the sample troubleshooting network (Figure 16-10), PE1 is only peering with CE3 via the PINK routing instance.

```
CE3# bgp show peer-host 172.17.8.1 advertised-routes
Local router ID is 172.20.2.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*>  172.17.2/24        172.17.8.2                                65002 i
*>  172.17.8/30        172.17.8.2                                65002 i
*>  172.20.2.1/32      172.17.8.2                                65002 i
```

```
PE1# bgp show peer-host 172.17.8.2 advertised-routes
%CLI-E-INCMPCMD, incomplete command - aborting
PE1# bgp show peer-host 172.17.8.2 advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----

PE1# bgp show peer-host 172.17.8.2 instance PINK advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*>  172.17.8/30        172.17.8.1                               20 65001 i
*>  192.168.8/30       172.17.8.1                               18 65001 i
*>  192.168.9/24       172.17.8.1                               21 65001 i
*>  192.168.101.1/32   172.17.8.1                               21 65001 i
```

Figure 16-29 BGP advertisements on CE3 and PE1

```
CE3# bgp show peer-host 172.17.8.1 all-received-routes
Local router ID is 172.20.2.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*   172.17.8/30        172.17.8.1                                65001 i
*>  192.168.8/30       172.17.8.1                                65001 i
*>  192.168.9/24       172.17.8.1                                65001 i
*>  192.168.101.1/32   172.17.8.1                                65001 i
```

```
PE1# bgp show peer-host 172.17.8.2 all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----

PE1# bgp show peer-host 172.17.8.2 instance PINK all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*>  172.17.2/24        172.17.8.2                    18    65002 i
*   172.17.8/30        172.17.8.2                    18    65002 i
*>  172.20.2.1/32      172.17.8.2                    18    65002 i
```

Figure 16-30 All received BGP routes on CE3 and PE1

If a route is being advertised and received, but you cannot ping to it, look for the route in the **bgp show peer-host [instance] received-routes** display output. The **bgp show peer-host received-routes** command differs from the **bgp show peer-host all-received-routes** command in that the latter displays all received routes, while the former only displays those routes that have a valid next hop and that have not been denied by a routing policy. If you see a route in the **all-received-routes** display but not in the **received-routes** display, check to make sure that no routing policies deny this route and that a route exists to its BGP next hop in the routing tables.

By comparing the **bgp show peer-host received-routes** displays to the **bgp show peer-host all-received-routes** displays, you see that the respective **received-routes** and **all-received-routes** displays are identical. This confirms that all of the PINK VRF-related received routes on both CE3 and PE1 have valid next hops.

```
PE1# bgp show peer-host 172.17.8.2 received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----

PE1# bgp show peer-host 172.17.8.2 instance PINK received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*>  172.17.2/24        172.17.8.2                     18    65002 i
*   172.17.8/30        172.17.8.2                     18    65002 i
*>  172.20.2.1/32      172.17.8.2                     18    65002 i
```

```
CE3# bgp show peer-host 172.17.8.1 received-routes
Local router ID is 172.20.2.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*   172.17.8/30        172.17.8.1                                65001 i
*>  192.168.8/30       172.17.8.1                                65001 i
*>  192.168.9/24       172.17.8.1                                65001 i
*>  192.168.101.1/32   172.17.8.1                                65001 i
```

Figure 16-31 Received BGP routes with *Valid Next Hops* on CE3 and PE1

If you are still not able to ping between the CE routers after confirming that CE-PE routing is properly configured and working, continue with the next troubleshooting step to verify the provider network configuration.

16.7.4 Troubleshoot the Provider Network

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE route
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routersr
    - Troubleshoot routing exchange between CE and PE Routers
  - **Verify provider connectivity and VRF routing exchange**
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

If you are still not able to ping between the CE routers after confirming that CE-PE routing is properly configured and working, the problem most likely exists within the provider network configuration. Within the provider network, several things can be wrong:

- IGP may be misconfigured
- MP-BGP may be misconfigured
- Routing instances may be misconfigured
- MPLS LSPs may be misconfigured

Troubleshoot the Provider Network IGP

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - **Troubleshoot provider network IGP configuration**
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

Unless PE routers are peering over directly-connected links (i.e., without any P routers in between), an IGP or static routes must be in place for MP-BGP to work. A PE router must be able to resolve MP-BGP next hops using existing IGP routes.

OSPF is the IGP running in the sample troubleshooting network (Figure 16-10). Each provider router must have a route to the following provider networks:

```
10.0.1.0/30
10.0.2.0/30
10.1.1.1/32
10.2.2.1/32
10.3.3.1/32
```

Each provider router learns the networks that are not directly connected, as well as the router IDs of other provider routers, through OSPF. Use the **`ip show routes`** command to view the FIBs on PE routers.

The following demonstrate successful OSPF route distribution within the provider network.

```
PE1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.0.1.0/30          directly connected   -         ToP
10.0.2.0/30          10.0.1.2             OSPF      ToP
10.1.1.1             10.1.1.1             -         lo0
10.2.2.1             10.0.1.2             OSPF      ToP
10.3.3.1             10.0.1.2             OSPF      ToP
127.0.0.1            127.0.0.1            -         lo0
172.17.1.0/30        directly connected   -         ToCE1
172.17.8.0/30        directly connected   -         ToCE3
```

Figure 16-32 Unicast FIB on PE1

```
P# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.0.1.0/30          directly connected   -         ToPE1
10.0.2.0/30          directly connected   -         ToPE2
10.1.1.1             10.0.1.1             OSPF      ToPE1
10.2.2.1             10.2.2.1             -         lo0
10.3.3.1             10.0.2.2             OSPF      ToPE2
127.0.0.1            127.0.0.1            -         lo0
```

Figure 16-33 Unicast FIB on P

```
PE2# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.0.1.0/30          10.0.2.1             OSPF      ToP
10.0.2.0/30          directly connected   -         ToP
10.1.1.1             10.0.2.1             OSPF      ToP
10.2.2.1             10.0.2.1             OSPF      ToP
10.3.3.1             10.3.3.1             -         lo0
127.0.0.1            127.0.0.1            -         lo0
192.168.1.0/30       directly connected   -         ToCE2
192.168.8.0/30       directly connected   -         ToCE4
```

Figure 16-34 Unicast FIB on PE2

If you do not see all of the necessary provider routes in each of the provider routers, use pings and protocol-related **show** commands to verify that the IGP is working. The provider IGP must be operational before you can verify MP-BGP.

Note that although MP-BGP is running, no BGP routes exist in the provider router FIBs. This is the case if you are running any IGP protocol that is, by default, preferred over BGP. Figure 19-1 lists the default preferences values on the RS.

If you are still not able to ping between the CE routers after confirming that the provider network IGP is properly configured and working, continue with the next troubleshooting step to verify the provider network MP-BGP configuration.

Troubleshoot the Provider Network MP-BGP

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - **Troubleshoot provider network MP-BGP configuration**
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

If you are still not able to ping between the CE routers after confirming that the provider network IGP is properly configured and working, you should troubleshoot the provider network MP-BGP configuration.

For more information on configuring MP-BGP between CE and PE routers, refer to Chapter 16.4.3, *"Configuring MP-BGP Between PE Routers for Customer Route Distribution."*

Troubleshoot a BGP connection using the following **show** commands:

- **bgp show neighbor**
- **bgp show peer-host advertised-routes**
- **bgp show peer-host all-received-routes**
- **bgp show peer-host received-routes**

The **bgp show neighbor** command displays information about the BGP peering session, such as the peer's address, router ID, the state and type of peering, the BGP version, traffic statistics, and any inbound or outbound route maps in effect.

The following demonstrate that PE1 and PE2 recognize each other as established neighbors. When troubleshooting BGP adjacencies:

- Watch for the **`State`** to be **`Established`** in this command output and verify the neighbor's router ID and interface address. If the **`State`** is not **`Established`**, execute this command several times in quick succession to determine if the BGP adjacency is cycling through certain states. If it is, refer to BGP protocol specifications for information on possible causes of adjacency state toggling.
- Confirm that the correct autonomous system number is configured on both the PE and CE routers.
- When configuring BGP peer groups, you do not need to specify the type of peering (external or routing). The router automatically determines the type by comparing the peer group's autonomous system to its own. Type 'routing' is used for IBGP peering. Type 'external' is used for EBGP peering. A common BGP problem is misconfigured peering type. If this is the case, either select the right peering type or remove all type specifications and allow the router to use the default type.
- Check to see that the BGP peers are passing traffic.
- If expected routes are not being distributed, confirm the logic in any route maps applied. Note that VRF import and export policies are not displayed as applied route maps under this command. View VRF import and export routing policies using the **`routing-instance show`** command.
- Verify that both peers show **`V4 Unicast;VPN-V4 Unicast`** under their **`Supported capabilities`**. When you configured BGP in the provider network, you specified that PE routers should use MP-BGP, as opposed to regular BGP, by enabling support for conventional IPv4 addresses and VPN-IPv4 unicast addresses. This informs the BGP process that it will be dealing with IPv4 and VPN-IPv4 addresses. By default, BGP sends all active routes from the Routing Instance RIBs (customer VPN-IPv4 routes) with the next hop set to itself if the VPN-IPv4 address capability is enabled. Unilateral support for VPN-IPv4 addresses means that these addresses cannot be sent in that peering session, which disables all VRF routing exchanges. Enabling both of these address capabilities using the **`bgp set peer-group <`*`name`*`> vpnv4-unicast ipv4-unicast`** command is integral to configuring a functional BGP/MPLS VPN network.

The following demonstrate correct peering between PE1 and PE2. Limit the **bgp show neighbor** view by specifying the appropriate PE peer. If you choose to view all neighbors, the view displays all PE and CE peers.

```
PE1# bgp show neighbor 10.3.3.1
        Peer: 10.3.3.1+179      Local: 10.1.1.1+1032
        Type: Routing    remote AS 65001
        State: Established      Flags: <v4MP v4u GenDefault>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <LocalAddress>
        Configured parameters :         Local Address: 10.1.1.1
        VRF in use  unicast VRF number 0

        Used parameters :
       Peer Version: 4 Peer ID: 10.3.3.1      Local ID: 10.1.1.1     Active Holdtime:
            180
        Group Bit: 0    Send state: in sync
        Uptime 6d3h54m35s
        Last traffic (seconds): Received 36     Sent 42 Checked 36
        Input messages :Total      8886    Updates        11    Octets    169688

        Output messages:Total      8884    Updates         8    Octets    169497

          count of sent routes                6
          count of recvd routes               6
          count of route refresh recvd        0
          count of route refresh sent         1
          count of derived routes             6
        Supported capabilities
               V4 Unicast;VPN-V4 Unicast;Route Refresh;
```

Figure 16-35 Provider network BGP neighbor (PE2) on PE1

```
PE2# bgp show neighbor 10.1.1.1
        Peer: 10.1.1.1+1032     Local: 10.3.3.1+179
        Type: Routing    remote AS 65001
        State: Established      Flags: <v4MP v4u GenDefault>
        Last State: OpenConfirm Last Event: RecvKeepAlive       Last Error: None

        Options: <LocalAddress>
        Configured parameters :         Local Address: 10.3.3.1
        VRF in use  unicast VRF number 0

        Used parameters :
       Peer Version: 4 Peer ID: 10.1.1.1      Local ID: 10.3.3.1     Active Holdtime:
            180
        Group Bit: 0    Send state: in sync
        Uptime 6d3h56m20s
        Last traffic (seconds): Received 22     Sent 15 Checked 22
        Input messages :Total      8886    Updates         9    Octets    169516

        Output messages:Total      8889    Updates        10    Octets    169790

          count of sent routes                6
          count of recvd routes               6
          count of route refresh recvd        1
          count of route refresh sent         0
          count of derived routes             6
        Supported capabilities
                V4 Unicast;VPN-V4 Unicast;Route Refresh;
```

Figure 16-36 Provider network BGP neighbor (PE1) on PE2

The **bgp show peer-host [instance] advertised-routes** command displays the routes that a peer is sending to a neighbor for a particular VRF. The **bgp show peer-host [instance] all-received-routes** command displays the routes that a peer is receiving from a neighbor for a particular VRF. Use these two commands to view the VRF routing exchange on the PE routers. If you choose not to restrict the view by specifying an instance, these commands display routes being advertised and received for other instances, as well as for the provider network, in addition to routes being exchanged for this VRF.

The following demonstrate that PE1 and PE2 are sending PINK VRF routes for their directly-connected customer sites to each other. They are also both receiving remote PINK VRF routes from each other. Both routers are receiving all of the advertised routes.

```
PE1# bgp show peer-host 10.3.3.1 instance PINK advertised-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i172.17.8/30        172.17.8.1           1    100          20 i
*> i172.17.2/24        10.1.1.1                  100          18 65002 i
*> i172.20.2.1/32      10.1.1.1                  100          18 65002 i

PE1# bgp show peer-host 10.3.3.1 instance PINK all-received-routes
Local router ID is 10.1.1.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i192.168.8/30       10.3.3.1                  100 18    i
*> i192.168.9/24       10.3.3.1             41   100 21    i
*> i192.168.101.1/32   10.3.3.1             22   100 21    i
```

Figure 16-37 Routes that PE1 is advertising to and receiving from PE2

```
PE2# bgp show peer-host 10.1.1.1 instance PINK advertised-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

    Network            Next Hop        Metric LocPrf Label       Path
    -------            --------        ------ ------ ----------- ----
*> i192.168.8/30       192.168.8.1          1    100          18 i
*> i192.168.9/24       10.3.3.1            41    100          21 i
*> i192.168.101.1/32   10.3.3.1            22    100          21 i

PE2# bgp show peer-host 10.1.1.1 instance PINK all-received-routes
Local router ID is 10.3.3.1
Status codes: > - best, * - valid, i - internal, t - stale
              s - suppressed, d - damped
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network            Next Hop        Metric LocPrf Label       Path
   -------            --------        ------ ------ ----------- ----
*> i172.17.8/30        10.1.1.1                   100 20    i
*> i172.17.2/24        10.1.1.1                   100 18    65002 i
*> i172.20.2.1/32      10.1.1.1                   100 18    65002 i
```

Figure 16-38 Routes that PE2 is advertising to and receiving from PE1

If you are still not able to ping between the CE routers after confirming that MP-BGP is properly configured and working, continue with the next troubleshooting step to verify the routing instance configurations on the PE routers.

16.7.5 Troubleshoot Routing Instances on PE Routers

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - **Troubleshoot PE router routing instance configuration**
    - Verify MPLS LSPs and MP-BGP LSP usage
  - Use traceroute to determine the last hop of connectivity

If you are still not able to ping between the CE routers after confirming that MP-BGP is properly configured and working, you should view the routing instances and BGP/MPLS VPN-related RIBs on the PE routers to verify correct routing instance configurations.

On PE routers, the **`routing-instance show instance`** command displays the properties configured on a particular instance. These include the Route Distinguisher, interfaces added to the routing instance, and route maps applied as import and export Route Targets. In the display output, verify the following:

- That the correct Route Distinguisher is configured. More importantly, check that you did not configure the same Route Distinguisher for different VRFs on the same PE router. This is especially important for PE routers that are supporting different customers with overlapping address spaces. In this situation, PE routers turn non-unique customer IPv4 addresses into unique VPN-IPv4 prefixes by prepending the Route Distinguisher. If identical Route Distinguishers are accidentally configured for different VRFs, each time the PE router sends routing advertisements, multiple routes (learned from different customers) to the same IPv4 address will repeatedly clobber each other on the receiving PE router, resulting in sporadic access to that address for the receiving PE router's customers.
- That the appropriate interfaces are added
- The logic of the import and export Route Targets applied on this routing instance. (The following section covers this in greater detail.)

The following demonstrate correctly configured Route Distinguishers on PE1 and PE2 that use their unique loopback addresses and ‘2’ as the unique identifier for the PINK VRF. The necessary interfaces are also added to both routing instances. Both routers are importing routes tagged with a Route Target of ‘target:65001:2’ for the PINK VRF.

```
PE1# routing-instance show instance PINK

PINK
Type                : vrf
Route-Distinguisher : 10.1.1.1:2
Router-ID : 10.1.1.1
Interfaces          : ToCE3 lo0
vrf-import          : PINK-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list PINK-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:2
                            Set clauses

vrf-export          : PINK-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:2

Default route        : not present
Default route active : 1
```

Figure 16-39 PINK routing instance properties on PE1

```
PE2# routing-instance show instance PINK

PINK
Type                : vrf
Route-Distinguisher : 10.3.3.1:2
Router-ID : 10.3.3.1
Interfaces          : ToCE4 lo0
vrf-import          : PINK-import, sequence 1
                          permit, sequence 10
                            Match clauses
                              community list PINK-import
                                  Action Sequence Count Community List
                                  ====== ======== ===== ==============
                                  permit 10       1     target:65001:2
                            Set clauses

vrf-export          : PINK-export, sequence 1
                          permit, sequence 10
                            Match clauses
                            Set clauses
                              set community target:65001:2

Default route        : not present
Default route active : 0
```

Figure 16-40 PINK routing instance properties on PE2

After checking the routing instance configuration properties, view the BGP/MPLS VPN-related RIBs on the PE routers to verify routing exchange.

Use the **ip-router show rib vpn-ipv4** command to view the VPN-IPv4 RIB on PE routers. A PE router filters all routes received from remote PE routers through MP-BGP based on the Route Target(s) that you configure. It discards routes that do not match any import targets on the VRFs that it supports. It installs the remaining routes into the VPN-IPv4 RIB. The VPN-IPv4 RIB contains all routes that satisfy the import policy of *at least one* of the PE router's VRFs. Since this is the only table that contains all of the routes from all of the VPNs directly connected to the PE router, it is the only table that relies on Route Distinguishers to keep routes with identical IPv4 prefixes distinct.

The following demonstrate that PE1 and PE2 are receiving all of the necessary VRF routes from each other into their VPN-IPv4 RIBs. The VPN-IPv4 RIB display lists IPv4 routes by Route Distinguisher. Two LSPs between PE1 and PE2 (PE1toPE2 and PE2toPE2) provide the method of transport for these routes.

```
PE1# ip-router show rib vpn-ipv4
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 4    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

VPN/IPV4 Unicast

Route Distinguisher 10.3.3.1:2

192.168.8/30       *   B Unnumbered        PE1toPE2  170           100 165:17:29
192.168.9/24       *   B Unnumbered        PE1toPE2  170     41    100 165:17:29
192.168.101.1/32   *   B Unnumbered        PE1toPE2  170     22    100 165:17:29
```

Figure 16-41 VPN-IPv4 RIB on PE1

```
PE2# ip-router show rib vpn-ipv4
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 2    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

VPN/IPV4 Unicast

Route Distinguisher 10.1.1.1:2

172.17.2/24        *   B Unnumbered        PE2toPE1  170           100 123:06:37
172.17.8/30        *   B Unnumbered        PE2toPE1  170           100 165:53:27
172.20.2.1/32      *   B Unnumbered        PE2toPE1  170           100 123:06:37
```

Figure 16-42 VPN-IPv4 RIB on PE2

After installing a route in the VPN-IPv4 RIB, PE routers determine whether they should import that route into any VRFs by performing route filtering based on the route's Route Target. A route is only eligible to be installed in the VRF RIB for a routing instance if *at least one* of its Route Target(s) match the import target(s) configured on that VRF. Routing instances associated with each VRF then select optimal and active routes from the VRF RIB to install in the VRF FIB.

On PE routers, use the **ip-router show rib instance** command to view VRF RIBs and the **ip show route show-vrf** command to view VRF FIBs.

Earlier, you verified the presence of local-site routes in the PE router VRF FIBs in the Section *"Verify Local CE-PE Connectivity and Routing Exchange by Pinging Between the CE Router and the Local PE Router."*

The following demonstrate that PE1 and PE2 both import all received remote-site VPN/IPv4 routes into the PINK RIB as IPv4 routes. The BGP routing instance on PE2 and the OSPF routing instance on PE1 then select these routes for import into the PINK FIB.

```
PE1# ip-router show rib instance PINK
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 4    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Netif - Next hop interface
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

Routing-instance PINK Unicast

127.0.0.1/32       *   C 127.0.0.1              lo0    1      1      0 166:52:59
172.17.2/24        *   B 172.17.8.2           ToCE3  170           100 124:06:11
172.17.8/30        *   C 172.17.8.1           ToCE3    1      1      0 166:52:59
172.17.8/30            B 172.17.8.2           ToCE3  170           100 124:06:11
172.20.2.1/32      *   B 172.17.8.2           ToCE3  170           100 124:06:11
192.168.8/30       *   B Unnumbered        PE1toPE2  170           100 166:52:59
192.168.9/24       *   B Unnumbered        PE1toPE2  170     41    100 166:52:59
192.168.101.1/32   *   B Unnumbered        PE1toPE2  170     22    100 166:52:59

PE1# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        172.17.8.2           BGP       ToCE3
172.17.8.0/30        directly connected   -         ToCE3
172.20.2.1           172.17.8.2           BGP       ToCE3
192.168.8.0/30       10.0.1.2             BGP       PE1toPE2
192.168.9.0/24       10.0.1.2             BGP       PE1toPE2
192.168.101.1        10.0.1.2             BGP       PE1toPE2
```

Figure 16-43 PINK RIB and FIB on PE1

```
PE2# ip-router show rib instance PINK
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 2    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

Routing-instance PINK Unicast

10.3.3.1/32            O                            -10      1      0 170:51:58
127.0.0.1/32       *   C 127.0.0.1                lo0    1      1      0 170:51:58
172.17.2/24        *   B Unnumbered         PE2toPE1  170           100 124:18:53
172.17.8/30        *   B Unnumbered         PE2toPE1  170           100 167:05:43
172.20.2.1/32      *   B Unnumbered         PE2toPE1  170           100 124:18:53
192.168.8/30       *   C 192.168.8.1           ToCE4    1      1      0 170:51:58
192.168.8/30           O 192.168.8.1           ToCE4   10     20      0 170:51:58
192.168.9/24       *   O 192.168.8.2           ToCE4   10     40      0 170:51:12
192.168.101.1/32   *   O 192.168.8.2           ToCE4   10     21      0 170:51:12
192.168.101.1/32       O 192.168.8.2           ToCE4  -10     20      0 170:51:12

PE2# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        10.0.2.1             BGP       PE2toPE1
172.17.8.0/30        10.0.2.1             BGP       PE2toPE1
172.20.2.1           10.0.2.1             BGP       PE2toPE1
192.168.8.0/30       directly connected   -         ToCE4
192.168.9.0/24       192.168.8.2          OSPF      ToCE4
192.168.101.1        192.168.8.2          OSPF      ToCE4
```

Figure 16-44 PINK RIB and FIB on PE2

In summary,

- for a route to be in the VPN-IPv4 RIB on a PE router, *at least one* VRF on that router must have an import target configured that is the same as the Route Target of that route.
- for a route to be in the VRF RIB on a PE router, *at least one* of its Route Target(s) must match the import target(s) for that VRF.

In troubleshooting, one typical cause of no connectivity is misconfigured Route Targets. You may encounter this situation in the following forms on the PE router:

- An expected route is in neither the VPN-IPv4 RIB nor the VRF RIB.
- A route is in the VPN-IPv4 RIB but is not being imported into the VRF RIB.

When you encounter one of these situations, use Table 16-3 to help diagnose the problem.

Is the route in the VPN-IPv4 RIB?	Is the route in the VRF RIB?	Diagnosis
Yes	Yes	Expected and correct.
Yes	No	At least one VRF configured on the PE router has an import target that is the same as the Route Target of this route. - If you do not expect any other VRFs on the PE router to import this route, verify that other VRFs have the correct import target(s) configured. - Verify that the remote PE router advertising this route is applying the correct Route Target. The VRF in which you expect to see the route does not have an import target configured that matches the Route Target of this route - Verify that this VRF has the correct import target configured. - Verify that the remote PE router advertising this route is applying the correct Route Target.
No	Yes	Impossible.
No	No	None of the Route Targets of this route match any of the import targets configured in any VRF on this PE router. - Verify that the VRF in which you expect to see the route has the correct import target configured. - Verify that the remote PE router advertising this route is applying the correct Route Target. - Verify that the BGP/MPLS VPN is properly configured.

Table 16-3 Possible causes of missing VRF routes on PE routers

The following commands may also be helpful in troubleshooting Route Targets:

- Use the **`ip-router show rib community`** command to search the entire RIB for a route configured with a particular export Route Target.
- Use the **`ip-router show rib neighbor`** command to view all routes received from a particular neighbor.
- Use the **`ip-router show rib route-distinguisher`** command to view all routes configured with a particular Route Distinguisher. Note that the Route Distinguisher is not the same as the Route Target.

If you are still not able to ping between the CE routers after confirming that the routing instances are properly configured on the PE routers, continue with the next troubleshooting step to verify MPLS LSPs and MP-BGP LSP usage between the PE routers.

Troubleshoot MPLS LSPs and MP-BGP LSP Usage in the Provider Network

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - **Verify MPLS LSPs and MP-BGP LSP usage**
  - Use traceroute to determine the last hop of connectivity

If you are still not able to ping between the CE routers after confirming that the routing instances are properly configured on the PE routers, you should verify that the MPLS LSPs between PE routers are up and running. If the CE-PE routing exchange, provider network IGP, MP-BGP, and routing instances are all configured properly, the most likely reason that routes are not being distributed to CE routers is the lack of LSP transport.

BGP/MPLS VPNs rely on MPLS LSPs for transport. This eliminates the need for PE routers to distribute customer routes into the provider network, lightens the load on P routers, and increases the BGP/MPLS VPN network scalability. For P routers to remain oblivious to customer routes, PE routers must inject customer packets into MPLS LSPs before sending them to P routers. P routers only need to swap and forward labels without having to examine packet details. In the previous section, you saw that all of the customer routes in the PE routing tables rely on MPLS LSPs for transport. You specified this when configuring MP-BGP with the **`ip-router global set install-lsp-routes bgp`** command, which permits BGP to resolve next hops using MPLS LSPs.

PE routers do not advertise to CE routers VRF routes that have no LSPs for transport across the provider network. Also, if existing MPLS LSPs are torn down, PE routers stop advertising to CE routers the VRF routes that use the torn-down LSP as a next hop. In these situations, PE routers still exchange the VRF routes themselves, but prevent these routes from being installed in the FIB by assigning them a negative preference in the RIB.

Use the **bgp show sync-tree** command to determine if routes are not being advertised because they lack an LSP for transport. The BGP synchronization tree contains all received BGP routes before they are processed for installation in the RIB. In the display output, routes that lack an LSP for transport are designated 'Orphaned routes NO LSP'.

In the sample troubleshooting network (Figure 16-10), the LSP PE1toPE2 is disabled to generate the following displays. On PE1, routes to the remote site are marked as orphan routes.

```
PE1# bgp show sync-tree all
Task BGP_Sync_4294967295_0:
        IGP Protocol: ffffffff  BGP Group: PROVIDER

        Sync Tree (* == active, + == active with alternate, - == inactive with
             alternate:
        Node 10.0.1/30 route 10.0.1/255.255.255.252 metric 1 interface
        Node 10.0.2/30 route 10.0.2/255.255.255.252 metric 4 next hop/labels:
             10.0.1.2/none
        Node 10.1.1.1/32 route 10.1.1.1/255.255.255.255 metric 1 interface
        Node 10.2.2.1/32 route 10.2.2.1/255.255.255.255 metric 3 next hop/labels:
             10.0.1.2/none
        Node 10.3.3.1/32 route 10.3.3.1/255.255.255.255 metric 5 next hop/labels:
             10.0.1.2/none
                Forwarding address 10.3.3.1
                        Routes for group PROVIDER:
                                192.168.8/255.255.255.252 peer 10.3.3.1
                                192.168.9/255.255.255 peer 10.3.3.1
                                192.168.101.1/255.255.255.255 peer 10.3.3.1
        Node 127/8 route 127/255 metric 1 interface
        Node 127.0.0.1/32 route 127.0.0.1/255.255.255.255 metric 1 interface
        Node 172.17.8/30 route 172.17.8/255.255.255.252 metric 1 interface
        Next hop hash table (2 hashed):
                References 7 Hash none Interface
                References 4 Hash 43 Next hop 10.0.1.2

Task BGP_Sync_lsp_4294967295_0:
        IGP Protocol: 10000     BGP Group: PROVIDER

        Sync Tree (* == active, + == active with alternate, - == inactive with
             alternate:
        Orphaned routes No LSP
                Forwarding address 10.3.3.1
                        Routes for group PROVIDER:
                                192.168.8/255.255.255.252- peer 10.3.3.1
                                192.168.9/255.255.255- peer 10.3.3.1
                                192.168.101.1/255.255.255.255- peer 10.3.3.1
        Next hop hash table (0 hashed):
                References 7 Hash none Interface
```

Figure 16-45 BGP synchronization tree on PE1

The following demonstrate that PE1 marks remote-site routes as invalid with a negative preference in the PINK RIB. As a result, these routes are not installed in the PINK FIB and CE3 has no knowledge of them.

```
PE1# ip-router show rib instance PINK
Routing Tables:
Generate Default: no
Destinations: 19    Routes: 24
Holddown: 0    Delete: 6    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

Routing-instance PINK Unicast

127.0.0.1/32       *   C 127.0.0.1              lo0    1      1      0  2:11:27
172.17.2/24        *   B 172.17.8.2           ToCE3  170           100  2:11:15
172.17.8/30        *   C 172.17.8.1           ToCE3    1      1      0  2:11:27
172.17.8/30            B 172.17.8.2           ToCE3  170           100  2:11:15
172.20.2.1/32      *   B 172.17.8.2           ToCE3  170           100  2:11:15
192.168.8/30           B                            -170           100  2:09:51
192.168.9/24           B                            -170     41    100  2:09:51
192.168.101.1/32       B                            -170     22    100  2:09:51

PE1# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        172.17.8.2           BGP       ToCE3
172.17.8.0/30        directly connected   -         ToCE3
172.20.2.1           172.17.8.2           BGP       ToCE3
```

Figure 16-46 PINK RIB and FIB on PE1

```
CE3# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        directly connected   -         ToCustomerBSite
172.17.8.0/30        directly connected   -         ToPE1
172.20.2.1           172.20.2.1           -         lo0
```

Figure 16-47 FIB on CE3

On PE2, however, routes learned from the remote site are *not* marked as orphan routes. This is because only one unidirectional LSP was disabled, PE1toPE2. PE2 still has an LSP to PE1, PE2toPE1. This asymmetry results in PE2 advertising remote-site VRF routes to CE4, but PE1 not advertising remote-site VRF routes to CE3.

```
PE2# bgp show sync-tree all
Task BGP_Sync_4294967295_0:
        IGP Protocol: ffffffff  BGP Group: PROVIDER

        Sync Tree (* == active, + == active with alternate, - == inactive with
            alternate:
        Node 0.0.0.7/32 route 0.0.0.7/255.255.255.255 metric 1 interface
        Node 10.0.1/30 route 10.0.1/255.255.255.252 metric 4 next hop/labels:
            10.0.2.1/none
        Node 10.0.2/30 route 10.0.2/255.255.255.252 metric 1 interface
        Node 10.1.1.1/32 route 10.1.1.1/255.255.255.255 metric 1 next hop/labels:
            0.0.0.7/none
               Forwarding address 10.1.1.1
                       Routes for group PROVIDER:
                               172.17.8/255.255.255.252 peer 10.1.1.1
                               172.17.2/255.255.255 peer 10.1.1.1
                               172.20.2.1/255.255.255.255 peer 10.1.1.1
        Node 10.2.2.1/32 route 10.2.2.1/255.255.255.255 metric 3 next hop/labels:
            10.0.2.1/none
        Node 10.3.3.1/32 route 10.3.3.1/255.255.255.255 metric 1 interface
        Node 127/8 route 127/255 metric 1 interface
        Node 127.0.0.1/32 route 127.0.0.1/255.255.255.255 metric 1 interface
        Node 192.168.1/30 route 192.168.1/255.255.255.252 metric 1 interface
        Node 192.168.8/30 route 192.168.8/255.255.255.252 metric 1 interface
        Next hop hash table (3 hashed):
               References 8 Hash none Interface
               References 2 Hash 7 Next hop 0.0.0.7
               References 2 Hash 13 Next hop 10.0.2.1

Task BGP_Sync_lsp_4294967295_0:
        IGP Protocol: 10000     BGP Group: PROVIDER

        Sync Tree (* == active, + == active with alternate, - == inactive with
            alternate:
        Node 10.1.1.1/32 route 10.1.1.1/255.255.255.255 metric 1 next hop/labels:
            0.0.0.7/none
               Forwarding address 10.1.1.1
                       Routes for group PROVIDER:
                               172.17.8/255.255.255.252 peer 10.1.1.1
                               172.17.2/255.255.255 peer 10.1.1.1
                               172.20.2.1/255.255.255.255 peer 10.1.1.1
        Next hop hash table (5 hashed):
               References 8 Hash none Interface
               References 2 Hash 7 Next hop 0.0.0.7
               References 2 Hash 7 Next hop 0.0.0.7
               References 1 Hash 7 Next hop 0.0.0.7
               References 1 Hash 7 Next hop 0.0.0.7
               References 2 Hash 7 Next hop 0.0.0.7
```

Figure 16-48 BGP synchronization tree on PE2

The following demonstrate that PE2 does not mark the routes learned from PE1 as invalid and advertises them to CE4. CE4, however, fails when using them.

```
PE2# ip-router show rib instance PINK
Routing Tables:
Generate Default: no
Destinations: 20    Routes: 25
Holddown: 0    Delete: 4    Hidden: 4
Codes: Network - Destination Network Address
       S - Status + = Best Route, - = Last Active, * = Both
       Src - Source of the route :
       Ag - Aggregate, B - BGP derived, C - Connected
       DVM - DVMRP derived, R - RIP derived, St - Static, O - OSPF derived
       OE - OSPF ASE derived, D - Default
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2
       Next hop - Gateway for the route ; Next hops in use: 4
       Netif - Next hop interface
       Prf1 - Preference of the route, Prf2 - Second Preference of the route
       Metrc1 - Metric1 of the route, Metrc2 - Metric2 of the route
       Age - Age of the route
Network/Mask       S Src Next hop             Netif Prf1 Metrc1 Metrc2      Age
------------       - --- --------             ----- ---- ------ ------      ---

Routing-instance PINK Unicast

10.3.3.1/32            O                           -10      1      0  2:15:45
127.0.0.1/32       *   C 127.0.0.1               lo0    1      1      0  2:15:45
172.17.2/24        *   B Unnumbered        PE2toPE1  170           100  2:14:23
172.17.8/30        *   B Unnumbered        PE2toPE1  170           100  2:14:23
172.20.2.1/32      *   B Unnumbered        PE2toPE1  170           100  2:14:23
192.168.8/30       *   C 192.168.8.1          ToCE4    1      1      0  2:15:45
192.168.8/30           O 192.168.8.1          ToCE4   10     20      0  2:15:45
192.168.9/24       *   O 192.168.8.2          ToCE4   10     40      0  2:15:06
192.168.101.1/32   *   O 192.168.8.2          ToCE4   10     21      0  2:15:06
192.168.101.1/32       O 192.168.8.2          ToCE4  -10     20      0  2:15:06

PE2# ip show routes show-vrf PINK

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        10.0.2.1             BGP       PE2toPE1
172.17.8.0/30        10.0.2.1             BGP       PE2toPE1
172.20.2.1           10.0.2.1             BGP       PE2toPE1
192.168.8.0/30       directly connected   -         ToCE4
192.168.9.0/24       192.168.8.2          OSPF      ToCE4
192.168.101.1        192.168.8.2          OSPF      ToCE4
```

Figure 16-49 PINK RIB and FIB on PE2

```
CE4# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.3.3.1             192.168.8.1          OSPF      ToPE2
127.0.0.1            127.0.0.1            -         lo0
172.17.2.0/24        192.168.8.1          OSPF_ASE  ToPE2
172.17.8.0/30        192.168.8.1          OSPF_ASE  ToPE2
172.20.2.1           192.168.8.1          OSPF_ASE  ToPE2
192.168.8.0/30       directly connected   -         ToPE2
192.168.9.0/24       directly connected   -         ToCustomerBSite
192.168.101.1        192.168.101.1        -         lo0

CE4# ping 172.17.8.2
PING 172.17.8.2: 36 bytes of data
5 second timeout, 1 repetition

--- 172.17.8.2 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms

CE4# ping 172.17.2.1
PING 172.17.2.1: 36 bytes of data
5 second timeout, 1 repetition

--- 172.17.2.1 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms

CE4# ping 172.20.2.1
PING 172.20.2.1: 36 bytes of data
5 second timeout, 1 repetition

--- 172.20.2.1 ping statistics ---
1 packets transmitted, 0 packets received, 100.00% packet loss
round-trip min/avg/max/dev = 0.000/0.000/0.000/0.000 ms
```

Figure 16-50 FIB on CE4

This asymmetrical problem is indicative of having an LSP configured in only one direction between PE routers. If both PE1toPE2 and PE2toPE1 are disabled, PE2 would also mark remote-site routes as orphaned and cease advertising them to CE4.

If you are still not able to ping between the CE routers after verifying that the MPLS LSPs between PE routers are up and running, continue with the next troubleshooting step to use traceroute for determining the last hop of connectivity.

16.7.6 Use Traceroute To Determine the Last Hop of Connectivity

Basic BGP/MPLS VPN network troubleshooting steps:

- General troubleshooting
  - Verify physical connectivity
  - Eliminate error commands from the active configuration
  - Verify the correct spelling of all names and references in the active configuration
- Verify basic BGP/MPLS VPN network functionality by pinging between the CE routers
  - Verify local CE-PE connectivity and routing exchange by pinging between the CE router and the local PE router
  - Verify remote connectivity and routing exchange by pinging between the local PE and remote PE and CE routers
    - Troubleshoot routing exchange between CE and PE Routers
  - Verify provider connectivity and VRF routing exchange
    - Troubleshoot provider network IGP configuration
    - Troubleshoot provider network MP-BGP configuration
    - Troubleshoot PE router routing instance configuration
    - Verify MPLS LSPs and MP-BGP LSP usage
  - **Use traceroute to determine the last hop of connectivity**

If you are still not able to ping between the CE routers after verifying that MPLS LSPs are up and running, use traceroute to determine the last hop of connectivity.

The following **traceroute** outputs demonstrate traffic being sent through the local PE router, the P router, the remote PE router, and arriving at the remote CE router. Note that each time customer traffic enters one of the ports on the P router (10.0.1.2 or 10.0.2.1), it is transported using an MPLS LSP.

```
CE3# traceroute 192.168.8.2
traceroute to 192.168.8.2 (192.168.8.2), 30 hops max, 40 byte packets
 1  172.17.8.1 (172.17.8.1) [AS 65002]  1 ms  1 ms  0 ms
 2  10.0.1.2 (10.0.1.2) [AS 65002]  2 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 3  10.3.3.1 (10.3.3.1) [AS 65002]  1 ms  1 ms  1 ms
 4  192.168.8.2 (192.168.8.2) [AS 65001]  1 ms  1 ms  1 ms

CE3# traceroute 192.168.9.1
traceroute to 192.168.9.1 (192.168.9.1), 30 hops max, 40 byte packets
 1  172.17.8.1 (172.17.8.1) [AS 65002]  1 ms  1 ms  0 ms
 2  10.0.1.2 (10.0.1.2) [AS 65002]  2 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=21 EXP2=0 TTL=1 S=1
 3  10.3.3.1 (10.3.3.1) [AS 65002]  1 ms  1 ms  1 ms
 4  192.168.9.1 (192.168.9.1) [AS 65001]  1 ms  1 ms  1 ms

CE3# traceroute 192.168.101.1
traceroute to 192.168.101.1 (192.168.101.1), 30 hops max, 40 byte packets
 1  172.17.8.1 (172.17.8.1) [AS 65002]  1 ms  1 ms  0 ms
 2  10.0.1.2 (10.0.1.2) [AS 65002]  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=21 EXP2=0 TTL=1 S=1
 3  10.3.3.1 (10.3.3.1) [AS 65002]  1 ms  1 ms  1 ms
 4  192.168.101.1 (192.168.101.1) [AS 65001]  1 ms  1 ms  1 ms
```

Figure 16-51 Traceroute from CE3 to CE4

```
CE4# traceroute 172.17.8.2
traceroute to 172.17.8.2 (172.17.8.2), 30 hops max, 40 byte packets
 1  192.168.8.1 (192.168.8.1)  1 ms  1 ms  0 ms
 2  10.0.2.1 (10.0.2.1)  2 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=19 EXP2=0 TTL=1 S=1
 3  10.1.1.1 (10.1.1.1)  2 ms  1 ms  1 ms
 4  172.17.8.2 (172.17.8.2)  2 ms  1 ms  2 ms

CE4# traceroute 172.17.2.1
traceroute to 172.17.2.1 (172.17.2.1), 30 hops max, 40 byte packets
 1  192.168.8.1 (192.168.8.1)  1 ms  1 ms  0 ms
 2  10.0.2.1 (10.0.2.1)  2 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 3  10.1.1.1 (10.1.1.1)  1 ms  1 ms  1 ms
 4  172.17.2.1 (172.17.2.1)  2 ms  2 ms  1 ms

CE4# traceroute 172.20.2.1
traceroute to 172.20.2.1 (172.20.2.1), 30 hops max, 40 byte packets
 1  192.168.8.1 (192.168.8.1)  1 ms  2 ms  0 ms
 2  10.0.2.1 (10.0.2.1)  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 3  10.1.1.1 (10.1.1.1)  1 ms  1 ms  1 ms
 4  172.20.2.1 (172.20.2.1)  2 ms  1 ms  1 ms
```

Figure 16-52 Traceroute from CE4 to CE3

Alternatively, you can perform the same traceroute from PE routers by specifying that traceroute use VRF routes to resolve the destination address. By default, traceroutes originate with the provider-facing interface on the PE router as the source address. However, the remote-site CE router does not have a route to the provider-facing interface of the PE router. Unless it is configured with a default route, the remote-site CE router only has a route to the same-VRF customer-facing interface on the PE router. Therefore, in order for the traceroute to return to the PE router, it must originate with the address of an interface added to the same VRF as the remote site.

The following demonstrate using the **traceroute** command with the **vrf** and **source** options for specifying the VRF FIB and source address to use. In the sample troubleshooting network (Figure 16-10), the default source address of a traceroute from PE1 to CE4 is 10.0.1.1, the address of PE1's provider-facing interface. Since this address is not in CE4's routing tables, CE4 cannot respond. You must specify that traceroute use the address of PE1's PINK VRF interface, 172.17.8.1, as the source address. The same applies to a traceroute from PE2 to CE3. You must specify that traceroute use 192.168.8.1 instead of 10.0.2.2 as the source address.

```
PE1# traceroute 192.168.8.2 vrf PINK source 172.17.8.1
traceroute to 192.168.8.2 (192.168.8.2) from 172.17.8.1, 30 hops max, 40 byte packets
 1  10.0.1.2 (10.0.1.2) [AS 65001]  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 2  10.3.3.1 (10.3.3.1) [AS 65001]  1 ms  1 ms  1 ms
 3  192.168.8.2 (192.168.8.2) [AS 65001]  2 ms  1 ms  2 ms

PE1# traceroute 192.168.9.1 vrf PINK source 172.17.8.1
traceroute to 192.168.9.1 (192.168.9.1) from 172.17.8.1, 30 hops max, 40 byte packets
 1  10.0.1.2 (10.0.1.2) [AS 65001]  1 ms  1 ms  2 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=21 EXP2=0 TTL=1 S=1
 2  10.3.3.1 (10.3.3.1) [AS 65001]  1 ms  1 ms  1 ms
 3  192.168.9.1 (192.168.9.1) [AS 65001]  1 ms  1 ms  1 ms

PE1# traceroute 192.168.101.1 vrf PINK source 172.17.8.1
traceroute to 192.168.101.1 (192.168.101.1) from 172.17.8.1, 30 hops max, 40 byte
            packets
 1  10.0.1.2 (10.0.1.2) [AS 65001]  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=21 EXP2=0 TTL=1 S=1
 2  10.3.3.1 (10.3.3.1) [AS 65001]  2 ms  1 ms  1 ms
 3  192.168.101.1 (192.168.101.1) [AS 65001]  1 ms  1 ms  2 ms
```

Figure 16-53 Traceroute from PE1 to CE4

```
PE2# traceroute 172.17.8.2 vrf PINK source 192.168.8.1
traceroute to 172.17.8.2 (172.17.8.2) from 192.168.8.1, 30 hops max, 40 byte packets
 1  10.0.2.1 (10.0.2.1) [AS 65001]  2 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=19 EXP2=0 TTL=1 S=1
 2  10.1.1.1 (10.1.1.1) [AS 65001]  1 ms  1 ms  1 ms
 3  172.17.8.2 (172.17.8.2) [AS 65001]  1 ms  1 ms  1 ms

PE2# traceroute 172.17.2.1 vrf PINK source 192.168.8.1
traceroute to 172.17.2.1 (172.17.2.1) from 192.168.8.1, 30 hops max, 40 byte packets
 1  10.0.2.1 (10.0.2.1) [AS 65001]  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 2  10.1.1.1 (10.1.1.1) [AS 65001]  1 ms  1 ms  1 ms
 3  172.17.2.1 (172.17.2.1) [AS 65001]  2 ms  1 ms  1 ms

PE2# traceroute 172.20.2.1 vrf PINK source 192.168.8.1
traceroute to 172.20.2.1 (172.20.2.1) from 192.168.8.1, 30 hops max, 40 byte packets
 1  10.0.2.1 (10.0.2.1) [AS 65001]  1 ms  1 ms  1 ms
    MPLS Label1=4097 EXP1=0 TTL=1 S=0
    MPLS Label2=18 EXP2=0 TTL=1 S=1
 2  10.1.1.1 (10.1.1.1) [AS 65001]  1 ms  1 ms  1 ms
 3  172.20.2.1 (172.20.2.1) [AS 65001]  2 ms  1 ms  1 ms
```

Figure 16-54 Traceroute from PE2 to CE3

Traceroute sends packets with incremental time-to-live fields (TTLs) along a routed path. Based on the replies, traceroute presents a list of routers along the path. When troubleshooting, use traceroute results to help locate the general area of configuration problems within the network.

From within the customer network, you can use the last successful traceroute hop to determine whether a configuration problem exists before the CE routers, at the CE routers, between the CE and local PE routers, or at the local PE router. Once a traceroute request enters the MPLS core, however, it is forwarded along the LSP until it arrives at an IP edge, usually at the remote PE router, before the reply can be sent. P routers must rely on PE routers because they do not have routes to the VRF addresses from which traceroutes originate. Therefore, if the remote PE router does not have a return route to the source address either, you will not see replies from any P routers along the route.

16.8 TRUNK PORT WITH MULTIPLE CE ROUTERS EXAMPLE

The following example configures a multiple CE-to-PE connection via a switch using 802.1Q Trunk ports. Figure 16-55 illustrates this topology.

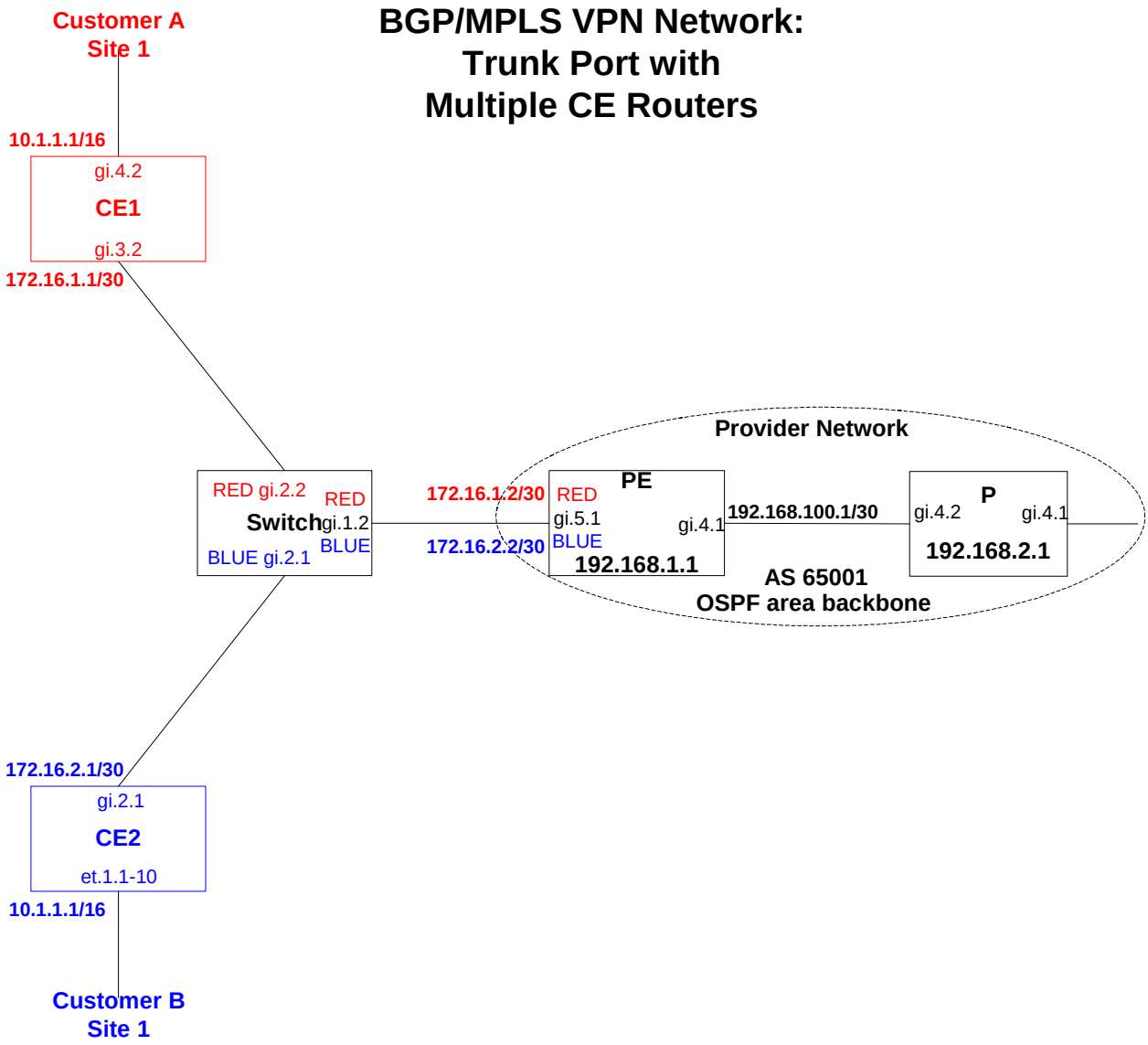


Figure 16-55 Trunk port with multiple CE routers

Trunk ports are created on both the PE router and the Switch. Traffic from two CE routers are then mapped to different VLANs, to which the trunk ports are added, enabling each trunk port to carry traffic from both CE routers. Interfaces mapped to VLANs on the PE router separate traffic coming from different CE routers.

When a single MPLS label or ATM virtual channel (VC) is shared with more than one interface over a single trunk port, the MPLS or VC label is no longer sufficient to distinguish traffic. The source VLAN ID must be used. To support this topology, you must use the **port enable multi-vrf-support** command. This command allows the RS to overwrite the source or destination socket of datagrams crossing a port with the datagram's source VLAN ID. When using this command, if either socket is in use for any purpose (for example, in an ACL), overwrite the other one.

Complete configurations for the CE routers, Switch, and PE router follow. Configurations specifically applicable to this example are highlighted.

CE1 Complete Configuration

```
vlan create VPN_RED ip id 30
vlan add ports gi.3.2 to VPN_RED

interface create ip VPN_RED address-netmask 172.16.1.1/30 vlan VPN_RED
interface create ip ip_RED address-netmask 10.1.1.1/16 port gi.4.2

rip add interface VPN_RED
rip add interface ip_RED
rip set interface all version 2
rip start
```

CE2 Complete Configuration

```
vlan create BLUE ip id 40
vlan create blue_vpn ip id 20
vlan add ports gi.2.1 to BLUE
vlan add ports et.1.1-10 to blue_vpn

interface create ip ip_BLUE address-netmask 172.16.2.1/30 vlan BLUE
interface create ip ip_blue_VPN address-netmask 10.1.1.1/16 vlan blue_vpn

rip add interface ip_BLUE
rip add interface ip_blue_VPN
rip set interface all version 2
rip start
```

Switch Complete Configuration

```
vlan make trunk-port gi.1.2 exclude-default-vlan
vlan create VPN_RED ip id 30
vlan create VPN_BLUE ip id 40
vlan create L2 port-based id 100
vlan add ports gi.1.2 to VPN_RED
vlan add ports gi.1.2 to VPN_BLUE
vlan add ports gi.1.2 to L2
vlan add ports gi.2.1 to VPN_BLUE
vlan add ports gi.2.2 to VPN_RED
```

PE Complete Configuration

```
vlan make trunk-port gi.4.1
vlan make trunk-port gi.5.1
vlan create ldp_in port-based id 110
vlan create VPN_RED ip id 30
vlan create VPN_BLUE ip id 40
vlan add ports gi.4.1 to ldp_in
vlan add ports gi.5.1 to VPN_RED
vlan add ports gi.5.1 to VPN_BLUE

port enable multi-vrf-support port gi.5.1 overwrite source-socket

interface create ip to_P address-netmask 192.168.100.1/30 vlan ldp_in
interface create ip VPN_RED address-netmask 172.16.1.2/30 vlan VPN_RED
interface create ip VPN_BLUE address-netmask 172.16.2.2/30 vlan VPN_BLUE
interface add ip lo0 address-netmask 192.168.1.1/32

ip-router global set router-id 192.168.1.1
ip-router global set autonomous-system 65001
ip-router global set install-lsp-routes bgp

ip-router policy create community-list RED "target:65001:1"
ip-router policy create community-list BLUE "target:65001:2"
route-map BLUE-Export permit 1 set-community-list BLUE
route-map BLUE-Import permit 1 match-community-list BLUE
route-map RED-Export permit 1 set-community-list RED
route-map RED-Import permit 1 match-community-list RED
route-map to-RIP-BLUE permit 1 match-routing-instance BLUE match-route-type bgp
route-map to-RIP-BLUE permit 3 match-routing-instance BLUE match-route-type rip
route-map to-RIP-BLUE permit 2 match-routing-instance BLUE match-route-type direct
route-map to-RIP-RED permit 1 match-routing-instance RED match-route-type bgp
```

```
ospf create area backbone
ospf add stub-host 192.168.1.1 to-area backbone cost 5
ospf add interface to_P to-area backbone
ospf start

bgp create peer-group PE-to-P autonomous-system 65001
bgp add peer-host 192.168.2.1 group PE-to-P
bgp set peer-group PE-to-P local-address 192.168.1.1
bgp set peer-group PE-to-P vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to_P
mpls create label-switched-path to_P_lsp from 192.168.1.1 to 192.168.2.1
mpls set label-switched-path to_P_lsp no-cspf
mpls start

rsvp add interface to_P
rsvp start

routing-instance BLUE vrf set route-distinguisher "65001:2" vrf-import BLUE-Import
    vrf-export BLUE-Export in-sequence 1 out-sequence 1
routing-instance BLUE vrf add interface VPN_BLUE
routing-instance BLUE rip add interface VPN_BLUE
routing-instance BLUE rip set interface VPN_BLUE version 2
routing-instance BLUE rip start
routing-instance BLUE rip set route-map-out to-RIP-BLUE
routing-instance RED vrf set route-distinguisher "65001:1" vrf-import RED-Import
    vrf-export RED-Export in-sequence 1 out-sequence 1
routing-instance RED vrf add interface VPN_RED
routing-instance RED rip add interface VPN_RED
routing-instance RED rip set interface VPN_RED version 2
routing-instance RED rip start
routing-instance RED rip set route-map-out to-RIP-RED
```

16.9 DUAL-HOMING CE ROUTER EXAMPLE

The following example configures a CE router to dual home to two PE routers. Figure 16-56 illustrates this topology.

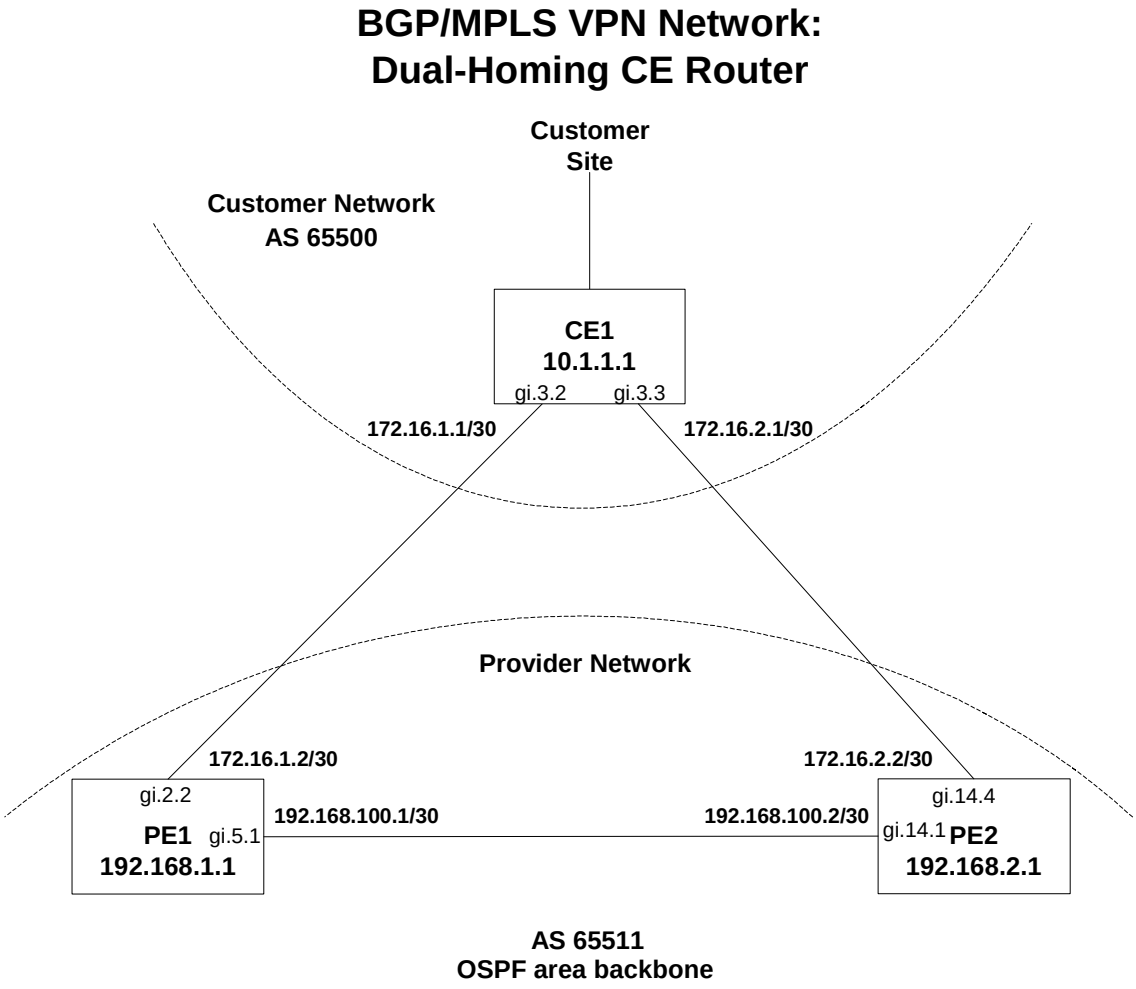


Figure 16-56 Dual-homing CE router

The RS supports dual homing for CE routers, which can result in routing loops if incorrectly configured.

In Figure 16-56, PE1 learns a customer route from the CE router and distributes it to PE2. If PE2 announces the same route back to the CE router, a routing loop can potentially occur. Whether a routing loop develops depends on the relative routing preferences of the PE-CE routing protocol and the protocol through which the CE router learns the native route. If the PE-CE routing protocol is *less preferred* than the advertising protocol of the native route, then the native route is not replaced and no routing loop results. If the PE-CE routing protocol is *more preferred* than the advertising protocol of the native route, then the native route is replaced by the PE-advertised route and a routing loop results. Figure 19-1 lists the default preferences values on the RS.

OSPF, as a PE-CE routing protocol, has built-in safeguards against routing loops. Before passing remote advertisements to a customer site, PE routers check to see that the advertisements did not originate from the same site using the DN bit in Type-3 LSAs and the VPN Route Tag in Type-5 LSAs. These safeguards are only effective, however, if OSPF is the *exclusive* PE-CE protocol. If OSPF is not used as the PE-CE protocol for any site within a VPN, the DN bit and the VPN Route Tag do not get set and routing loops can still result. Therefore, using OSPF as a PE-CE protocol does not obviate the need for further loop prevention. For more information on PE-CE OSPF routing loop prevention, see the Section *"Configuring OSPF Between CE and PE Routers."*

Note Regardless of the protocols used and whether routing loops will actually result, whenever dual homing CE routers, it is good practice to ensure routing loop prevention using the BGP Site-of-Origin Extended Community Attribute.

To prevent routing loops, associate each connected site on a PE router with a BGP Site-of-Origin Extended Community Attribute. PE routers use this attribute to check, through VRF import and export policies, that routes learned from a site are not distributed back into that site. Since this verification occurs at the MP-BGP level and not at the routing instance level, it is effective irrespective of what other routing protocols are running between the PE and CE routers. For more information on Extended Community Attribute Route Targets, see the IETF draft *BGP Extended Communities Attribute* by Ramachandra, Tappan, and Rekhter, or the Section *"Extended Communities."*

When using BGP Extended Community Attributes to define the Site of Origin, select from one of two forms:

`origin:`*<Global autonomous system number>***`:`***<Identifier>*

`origin:`*<Global IP address>***`:`***<Identifier>*

After the **`origin`** keyword, specify either a global AS number or global IP address, followed by a unique identifier for this particular site.

Note To ensure that the Site of Origin is unique, use only AS numbers or IP addresses that you own. Using private IPv4 addresses or AS numbers can easily result in duplicate Sites of Origin. Even though this example uses a private AS number, you should, in general, only use publicly unique IP addresses or AS numbers.

The following example uses the provider network's autonomous system number, 65511, to define the Site of Origin. PE1 and PE2 define a common Site of Origin, **`origin:65511:1`**, for the customer site. Note that this presupposes agreement between the administration for PE1 and PE2 on the Site of Origin assignment scheme. Since the AS number is used, the site identifier must be unique in this provider network.

In this example, both PE1 and PE2 define the Site of Origin for the customer site in the site's VRF export policy (**`trinity-export`**) and filter for it in the site's VRF import policy (**`trinity-import`**). If a route arrives at a PE router bearing **`origin:65511:1`** as the Site of Origin, it is denied by **`community-list 11`** and never advertised back to the customer site.

Complete configurations for the CE and PE routers follow. Configurations specifically applicable to this example are highlighted.

CE Complete Configuration

```
interface create ip to-PE1 address-netmask 172.16.1.1/30 port gi.3.2
interface create ip to-PE2 address-netmask 172.16.2.1/30 port gi.3.3
interface add ip lo0 address-netmask 10.1.1.1/32

ip-router global set autonomous-system 65500
ip-router global set router-id 10.1.1.1

bgp create peer-group ce-pe autonomous-system 65511
bgp add peer-host 172.16.1.1 group ce-pe
bgp add peer-host 172.16.2.1 group ce-pe
bgp start
```

PE1 Complete Configuration

```
interface create ip to-PE2 address-netmask 192.168.100.1/30 port gi.5.1
interface create ip to-CE address-netmask 172.16.1.2/30 port gi.2.2
interface add ip lo0 address-netmask 192.168.1.1/32

ip-router global set router-id 192.168.1.1
ip-router global set autonomous-system 65511
ip-router global set install-lsp-routes bgp

community-list 11 deny 5 "origin:65511:1"
community-list 11 permit 10 "target:65511:2"

ip-router policy create community-list 10 "target:65511:1 origin:65511:1"

route-map ALLROUTES permit 10
route-map trinity-export permit 10 set-community-list 10
route-map trinity-import permit 10 match-community-list 11

ospf create area backbone
ospf add interface to-PE2 to-area backbone
ospf add stub-host 192.168.1.1 to-area backbone cost 20
ospf start

bgp create peer-group pe-pe autonomous-system 65511
bgp add peer-host 192.168.2.1 group pe-pe
bgp set peer-group pe-pe local-address 192.168.1.1
bgp set peer-group pe-pe vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-PE2
mpls create label-switched-path pe1-pe2 from 192.168.1.1 to 192.168.2.1
mpls set label-switched-path pe1-pe2 no-cspf
mpls start

rsvp add interface to-PE2
rsvp start

routing-instance trinity vrf set route-distinguisher 65511:10 vrf-import
     trinity-import vrf-export trinity-export in-sequence 1 out-sequence 1
routing-instance trinity vrf add interface to-CE
routing-instance trinity bgp create peer-group pe-ce autonomous-system 65500
routing-instance trinity bgp add peer-host 172.16.1.1 group pe-ce
routing-instance trinity bgp set peer-host 172.16.1.1 route-map-out ALLROUTES
     out-sequence 1
routing-instance trinity bgp start
```

PE2 Complete Configuration

```
interface create ip to-PE1 address-netmask 192.168.100.2/30 port gi.14.1
interface create ip to-CE address-netmask 172.16.2.2/30 port gi.14.4
interface add ip lo0 address-netmask 192.168.2.1/32

ip-router global set router-id 192.168.2.1
ip-router global set install-lsp-routes bgp
ip-router global set autonomous-system 65511

community-list 10 deny 5 "origin:65511:1"
community-list 10 permit 10 "target:65511:1"

ip-router policy create community-list 20 "target:65511:2 origin:65511:1"

route-map ALLROUTES permit 10
route-map trinity-export permit 10 set-community-list 20
route-map trinity-import permit 10 match-community-list 10

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add stub-host 192.168.2.1 to-area backbone cost 20
ospf start

bgp create peer-group pe-pe autonomous-system 65511
bgp add peer-host 192.168.1.1 group pe-pe
bgp set peer-group pe-pe local-address 192.168.2.1
bgp set peer-group pe-pe vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-PE1
mpls create label-switched-path pe2-pe1 from 192.168.2.1 to 192.168.1.1
mpls set label-switched-path pe2-pe1 no-cspf
mpls start

rsvp add interface to-PE1
rsvp start

routing-instance trinity vrf set route-distinguisher 65511:20 vrf-import
     trinity-import vrf-export trinity-export in-sequence 1 out-sequence 1
routing-instance trinity vrf add interface to-CE
routing-instance trinity bgp create peer-group pe-ce autonomous-system 65500
routing-instance trinity bgp add peer-host 172.16.2.1 group pe-ce
routing-instance trinity bgp set peer-host 172.16.2.1 route-map-out ALLROUTES
     out-sequence 1
routing-instance trinity bgp start
```

16.10 ROUTE REFLECTOR EXAMPLE

MP-BGP is fully compatible with route reflectors. Route reflectors eliminate the need for a fully-meshed MP-IBGP network by requiring that PE routers only peer with the route reflector in their autonomous system. Using route reflectors, however, does *not* obviate the need for establishing MPLS LSPs between every pair of PE routers that support a common VPN.

Route reflectors are the only routers within the BGP/MPLS VPN network that must maintain routes for sites to which they are not directly connected. A route reflector is not preconfigured with a list of Route Targets. Instead, it accepts all the routes received from its clients. Based on these routes, the route reflector maintains a list of Route Targets actively configured on clients, which it uses to form the inbound route filters it applies to routes received from other route reflectors. When a route reflector no longer has any routes matching a Route Target on its list, it deletes the Route Target after two hours.

To enhance scalability and reduce router overload, deploy multiple route reflectors so that no single route reflector has to maintain all the VPN-IPv4 routes for all of the VPNs the provider network supports.

The following example configures a route reflector in the provider network and illustrates the use of different BGP signalling and forwarding paths. Figure 16-57 illustrates this topology.

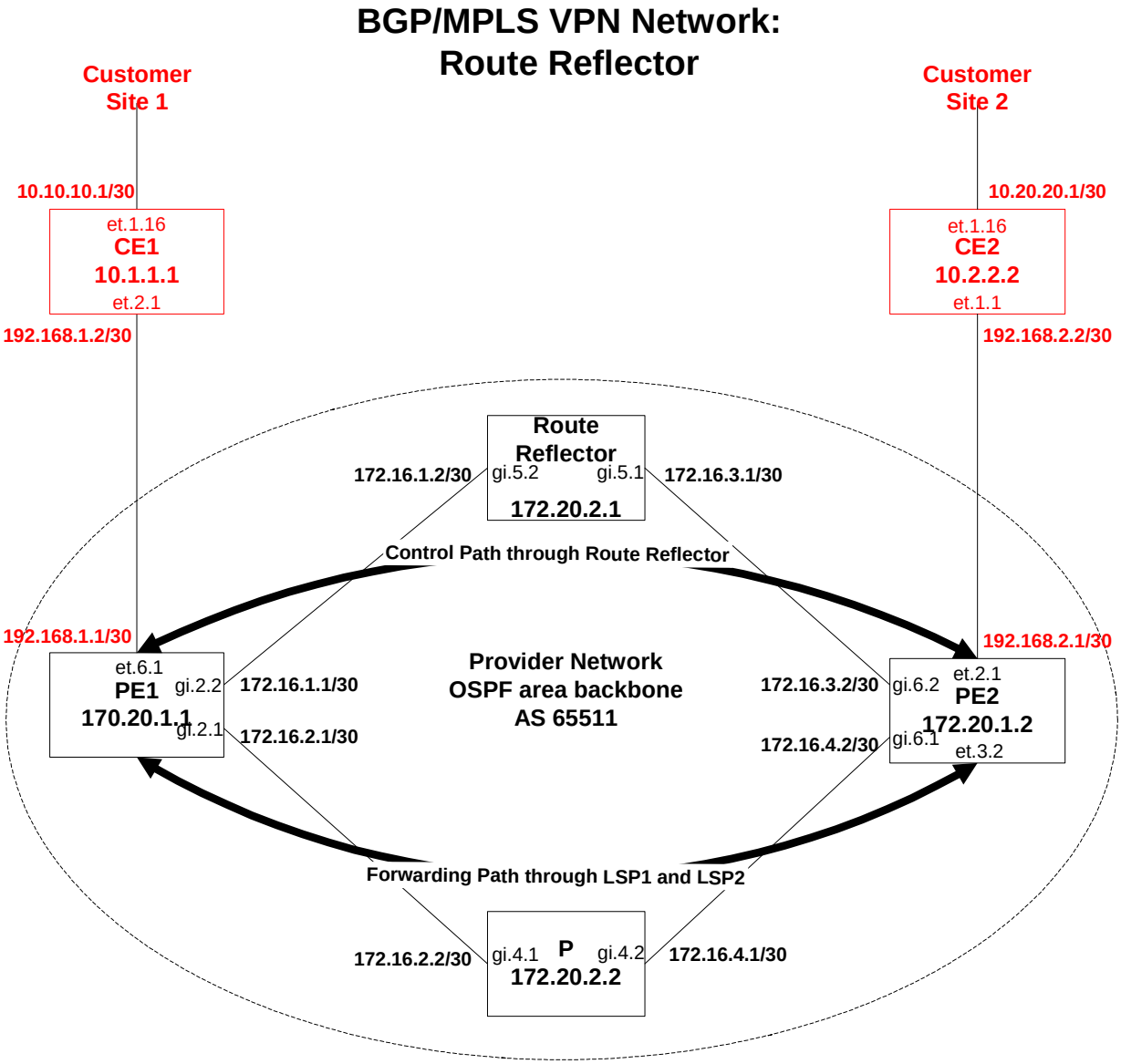


Figure 16-57 Route reflector in provider network

In this example, ROUTEREFLECTOR is the name of the router that acts as a route reflector for PE1 and PE2. MPLS and RSVP are enabled on the path PE1–P–PE2, but not on ROUTEREFLECTOR. This sets up different signalling and forwarding paths in the network. PE1 and PE2 exchange VPN routes via the path PE1–ROUTEREFLECTOR–PE2 but forward VPN traffic using the two LSPs, LSP1 and LSP2, established along the PE1–P–PE2 path.

The only configuration difference between this and a non-route reflector network is on the route reflector. One additional command is necessary to configure a route reflector: **`bgp set peer-group reflector-client`**.

Complete configurations for all routers follow. The configuration specifically applicable to this example is highlighted.

CE1 Complete Configuration

```
interface create ip to-PE1 address-netmask 192.168.1.2/30 port et.2.1
interface create ip to-Site1 address-netmask 10.10.10.1/30 port et.1.16
interface add ip lo0 address-netmask 10.1.1.1/32

ip-router global set router-id 10.1.1.1

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add interface to-Site1 to-area backbone
ospf add stub-host 10.1.1.1 to-area backbone cost 10
ospf start
```

CE2 Complete Configuration

```
interface create ip to-PE2 address-netmask 192.168.2.2/30 port et.1.1
interface create ip to-Site2 address-netmask 10.20.20.1/30 port et.1.16
interface add ip lo0 address-netmask 10.2.2.2/32

ip-router global set router-id 10.2.2.2

rip add interface to-PE2
rip add interface to-Site2
rip set interface to-PE2 version 2
rip set interface to-Site2 version 2
rip start
```

PE1 Complete Configuration

```
interface create ip to-ROUTEREFLECTOR address-netmask 172.16.1.1/30 port gi.2.2
interface create ip to-P address-netmask 172.16.2.1/30 port gi.2.1
interface create ip to-CE1 address-netmask 192.168.1.1/30 port et.1.2
interface add ip lo0 address-netmask 172.20.1.1/32

ip-router global set router-id 172.20.1.1
ip-router global set autonomous-system 65511
ip-router global set install-lsp-routes bgp

ip-router policy create community-list vpn1 "target:65511:1"
route-map BGPROUTES permit 1 match-route-type bgp
route-map vpn1-import permit 1 match-community-list vpn1
route-map vpn1-export permit 1 set-community-list vpn1

ospf create area backbone
ospf add interface to-P to-area backbone
ospf add interface to-ROUTEREFLECTOR to-area backbone
ospf add stub-host 172.20.1.1 to-area backbone cost 10
ospf start

bgp create peer-group to-ROUTEREFLECTOR autonomous-system 65511
bgp add peer-host 172.20.2.1 group to-ROUTEREFLECTOR
bgp set peer-group to-ROUTEREFLECTOR local-address 172.20.1.1
bgp set peer-group to-ROUTEREFLECTOR vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-P
mpls create label-switched-path lsp2 to 172.20.1.2
mpls set label-switched-path lsp2 no-cspf
mpls start

rsvp add interface to-P
rsvp start

routing-instance vpn1 vrf add interface to-CE1
routing-instance vpn1 vrf set vrf-import vpn1-import in-sequence 1
routing-instance vpn1 vrf set vrf-export vpn1-export out-sequence 1
routing-instance vpn1 vrf set route-distinguisher "65511:1"
routing-instance vpn1 ospf add interface to-CE1 to-area backbone
routing-instance vpn1 ospf set route-map-vpn BGPROUTES
routing-instance vpn1 ospf create area backbone
routing-instance vpn1 ospf start
```

PE2 Complete Configuration

```
interface create ip to-CE2 address-netmask 192.168.2.1/30 port et.2.1
interface create ip to-ROUTEREFLECTOR address-netmask 172.16.3.2/30 port gi.6.2
interface create ip to-P address-netmask 172.16.4.2/30 port gi.6.1
interface add ip lo0 address-netmask 172.20.1.2/32

ip-router global set router-id 172.20.1.2
ip-router global set autonomous-system 65511
ip-router global set install-lsp-routes bgp

ip-router policy create community-list vpn1 "target:65511:1"
route-map BGPROUTES permit 1 match-route-type bgp
route-map vpn1-import permit 1 match-community-list vpn1
route-map vpn1-export permit 1 set-community-list vpn1

ospf create area backbone
ospf add interface to-ROUTEREFLECTOR to-area backbone
ospf add interface to-P to-area backbone
ospf add stub-host 172.20.1.2 to-area backbone cost 10
ospf start

bgp create peer-group to-ROUTEREFLECTOR autonomous-system 65511
bgp add peer-host 172.20.2.1 group to-ROUTEREFLECTOR
bgp set peer-group to-ROUTEREFLECTOR local-address 172.20.1.2
bgp set peer-group to-ROUTEREFLECTOR vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-P
mpls create label-switched-path lsp1 to 172.20.1.1
mpls set label-switched-path lsp1 no-cspf
mpls start

rsvp add interface to-P
rsvp start

routing-instance vpn1 vrf add interface to-CE2
routing-instance vpn1 vrf set route-distinguisher "65511:2" vrf-import vpn1-import
     in-sequence 1 vrf-export vpn1-export out-sequence 1
routing-instance vpn1 rip add interface to-CE2
routing-instance vpn1 rip set interface to-CE2 version 2
routing-instance vpn1 rip set route-map-out BGPROUTES
routing-instance vpn1 rip start
```

ROUTEREFLECTOR Complete Configuration

```
interface create ip to-PE1 address-netmask 172.16.1.2/30 port gi.5.2
interface create ip to-PE2 address-netmask 172.16.3.1/30 port gi.5.1
interface add ip lo0 address-netmask 172.20.2.1/32

ip-router global set router-id 172.20.2.1
ip-router global set autonomous-system 65511

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add interface to-PE2 to-area backbone
ospf add stub-host 172.20.2.1 to-area backbone cost 10
ospf start

bgp create peer-group to-PEs autonomous-system 65511
bgp add peer-host 172.20.1.1 group to-PEs
bgp add peer-host 172.20.1.2 group to-PEs
bgp set peer-group to-PEs reflector-client
bgp set peer-group to-PEs local-address 172.20.2.1
bgp set peer-group to-PEs vpnv4-unicast ipv4-unicast
bgp start
```

P Complete Configuration

```
interface create ip to-PE1 address-netmask 172.16.2.2/30 port gi.4.1
interface create ip to-PE2 address-netmask 172.16.4.1/30 port gi.4.2
interface add ip lo0 address-netmask 172.20.2.2/32

ip-router global set router-id 172.20.2.2
ip-router global set install-lsp-routes bgp
ip-router global set autonomous-system 65511

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add interface to-PE2 to-area backbone
ospf add stub-host 172.20.2.2 to-area backbone cost 10
ospf start

mpls add interface to-PE1
mpls add interface to-PE2
mpls start

rsvp add interface to-PE1
rsvp add interface to-PE2
rsvp start
```

Using the **bgp show summary** command to verify that both PE routers are peering with the route reflector. The following command outputs show that ROUTEREFLECTOR has route reflecting capabilities enabled and is peering with both PE routers.

```
PE1# bgp show summary
Local router ID is 172.20.1.1, Local AS number 65511
BGP Route Entries 6, Unique AS Paths 3
Unique Communities 0, Unique Extended Communities 3

Neighbor        V    AS MsgRcvd MsgSent      Up/Down Prefixes Rcvd/Sent
--------        -    -- ------- -------      ------- ------------------
[Group Id: to-ROUTEREFLECTOR   VRF: unicast]
172.20.2.1         4   100      61      66   0d0h46m19s         3/3
BGP summary, 1 groups, 1 peers
```

```
PE2# bgp show summary
Local router ID is 172.20.1.2, Local AS number 65511
BGP Route Entries 6, Unique AS Paths 5
Unique Communities 0, Unique Extended Communities 2

Neighbor        V    AS MsgRcvd MsgSent      Up/Down Prefixes Rcvd/Sent
--------        -    -- ------- -------      ------- ------------------
[Group Id: to-ROUTEREFLECTOR   VRF: unicast]
172.20.2.1         4   100      58      57   0d0h50m57s         3/3
BGP summary, 1 groups, 1 peers
```

```
ROUTEREFLECTOR# bgp show summary
Local router ID is 172.20.2.1, Local AS number 65511
BGP Route Entries 6, Unique AS Paths 6
Unique Communities 0, Unique Extended Communities 2

Neighbor        V    AS MsgRcvd MsgSent      Up/Down Prefixes Rcvd/Sent
--------        -    -- ------- -------      ------- ------------------
[Group Id: to-PEs   VRF: unicast]  Route Reflector enabled, cluster id is 172.20.2.1
172.20.1.2         4   100      56      59   0d0h51m27s         3/3
172.20.1.1         4   100      52      50   0d0h46m59s         3/3
BGP summary, 1 groups, 2 peers
```

16.11 INTERNET ACCESS EXAMPLE

In the Basic BGP/MPLS VPN Network configuration, PE routers only exchange routes from the routing instance Unicast FIB with CE routers. Under this scheme, a customer site can access other customer sites that belong to the same VRF, but not provider or Internet routes.

The RS supports Internet access using static routes. The following section demonstrates this topology and configuration.

16.11.1 Internet Access Using Static Routes

The following example configures a PE router to provide Internet access for a customer site using static routes. Figure 16-58 illustrates the topology.

Enabling Internet access for customer sites using static routes requires the following:

1. Ensure that the PE router's Global Unicast FIB contains the Internet routes the customer site wishes to use.
   - In the example, PE is learning Internet routes from InternetRouter via EBGP.
2. Configure the PE router to use the Global Unicast FIB to resolve all addresses not found in the routing instance's Unicast FIB.

   When a CE packet arrives, the PE router first examines the particular routing instance Unicast FIB. In the Basic BGP/MPLS VPN example, if this lookup fails to yield a match, the packet cannot be routed. Enabling Global Unicast FIB lookup expands the set of routes accessible to customer sites from VRF routes only to VRF routes plus all provider and Internet routes. As long as a route to the requested address exists in the PE router's Global Unicast FIB, the Internet access succeeds.
   - On PE routers, use the **`routing-instance set global-unicast-lookup`** command to enable Internet access for sites belonging to the specified VRF. In the example, PE is configured to perform Global Unicast FIB lookup for the RED VRF, to which the Customer Site belongs.

Note Enabling Global Unicast FIB lookup grants customers access to Internet routes as well as the provider's internal routes. For security reasons, consider placing customer access restrictions on the PE router's customer-facing interfaces. You can do this in one of two ways using access-control lists (ACLs):
1. Prevent customers from sending to provider internal addresses on the outbound
2. Prevent provider sources from replying to customer addresses on the inbound

Before applying access restrictions, consider that customers need access to some provider internal routes in order to reach services such as DNS, NNTP, SMTP, or POP. Carefully consider any effects access restrictions may have on the customer's ability to reach these services before applying restrictions.

3. Ensure that Internet-bound traffic from customer sites originate from globally routable IP address(es). In the Basic BGP/MPLS VPN Network, customers may use RFC 1918 private addresses. Separate VRF routing tables on the PE router keep possibly overlapping customer addresses separate. To provide Internet access, PE routers must distribute to the Internet routes that the Internet relies upon for sending to customer sites (step 6). Since they are being distributed to the Internet, these routes must be globally routable. Customers may continue to use private addresses for internal VPN traffic.
   - In the example, lettered addresses like A.A.A.A/32 and B.B.B.0/24 represent globally routable IPv4 networks.
4. Configure CE routers to use PE router(s) as default gateway(s) for unknown destinations.
   - On CE routers, you can do this using the **`ip add route default gateway`** command. In the example, PE (C.C.C.1) is configured as the default gateway on CE and CE (B.B.B.1) is configured as the default gateway on CustomerRouter.
5. Configure PE routers to add routes to globally routable IP address(es) from which customer sites originate Internet packets to the Global Unicast FIB. PE routers may already contain these routes in the routing instance FIB for that customer site, but in order for PE routers to distribute these routes to the Internet (step 6), they must exist in the PE router's Global Unicast FIB. You can add these routes to the PE router's Global Unicast FIB in one of two ways:
   - Configuring global static routes to these addresses using the **`ip add route gateway`** command adds them to the global Unicast RIB. If more preferred routes to the same destinations do not already exist in the FIB, these routes become installed. In the example, PE is configured with two static routes, one to CE's loopback address (A.A.A.A/32) and another to the customer site network (B.B.B.0/24).
   - Alternatively, you may use a route map to match a particular network prefix and the **`set-import-ribs`** option to add a route to this network in the RIB(s) you specify. For example, the **`route-map ADDTORIB permit 10 match-prefix network X.X.X.X/32 set-import-ribs "unicast"`** command adds a route to host X.X.X.X/32 in the global Unicast RIB upon a match. If a more preferred route to the same destination does not already exist in the FIB, this route becomes installed. The **`set-import-ribs`** option allows you to concurrently add a route to the matched network to multiple RIBs. Multiple RIBs should be separated by a space and specified within quotes.
6. To provide Internet access, PE routers must distribute globally routable customer addresses to the Internet.
   - In the example, PE is configured to redistribute all customer-facing static routes (A.A.A.A/32 and B.B.B.0/24) to the EBGP session that it is running to the Internet using the **`ip-router policy redistribute from-proto static to-proto bgp target-as XYZ`** command. XYZ represents a global autonomous system number used on the Internet.

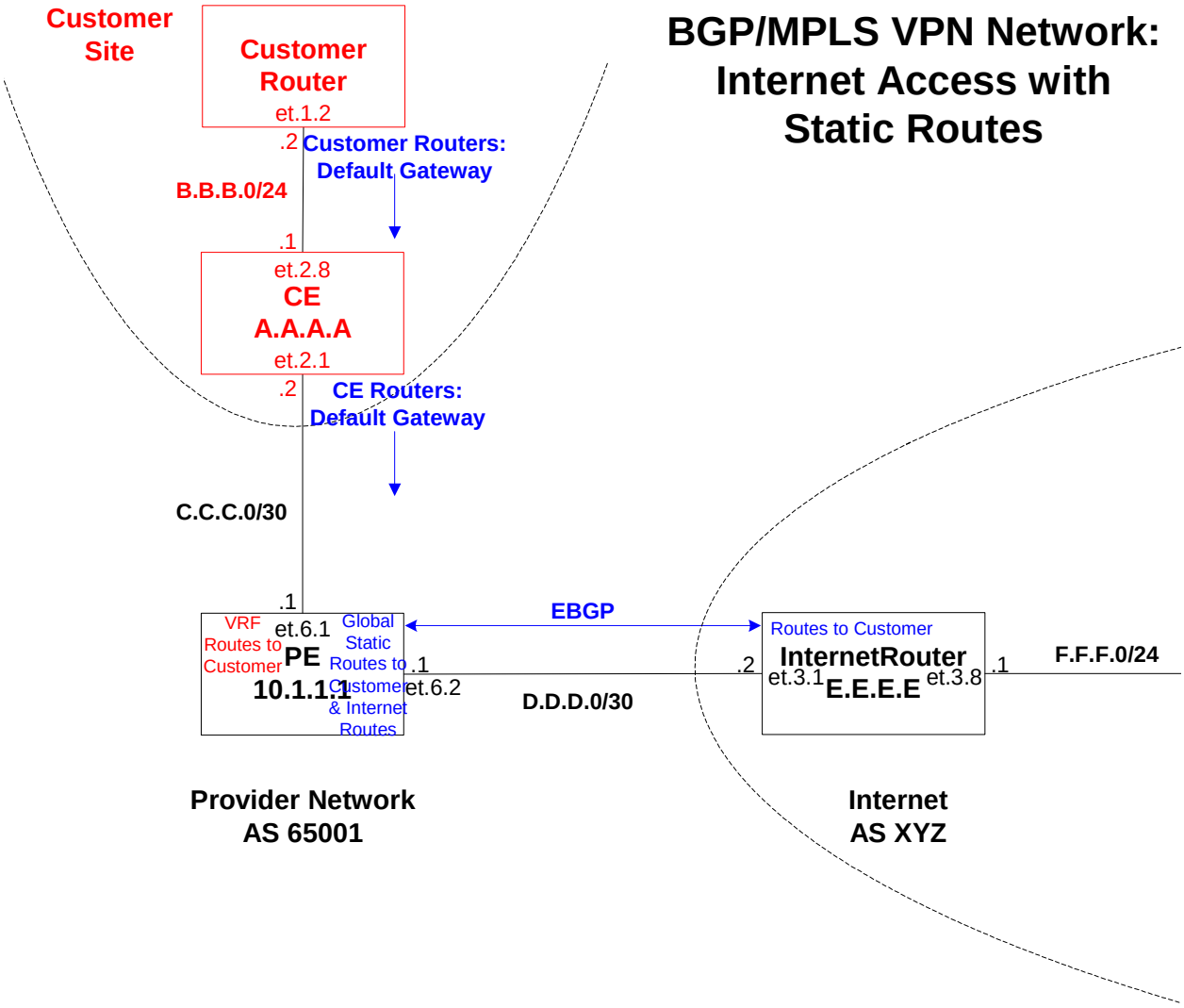


Figure 16-58 Internet access using static routes

Complete configurations for all routers follow. The configurations specifically applicable to this example are highlighted.

CustomerRouter Complete Configuration

```
interface create ip ToCE address-netmask B.B.B.2/24 port et.1.2

ip add route default gateway B.B.B.1

system set name CustomerRouter
```

CE Complete Configuration

```
vlan create ToPE ip id 200
vlan create ToCustomerSite ip id 100
vlan add ports et.2.1 to ToPE
vlan add ports et.2.8 to ToCustomerSite
interface create ip ToPE address-netmask C.C.C.2/30 vlan ToPE
interface create ip ToCustomerSite address-netmask B.B.B.1/24 vlan ToCustomerSite
interface add ip lo0 address-netmask A.A.A.A/32

ip-router global set router-id A.A.A.A
ip add route default gateway C.C.C.1

system set name CE
```

PE Complete Configuration

PE is using static routing for PE-CE route distribution, so just like in the Basic BGP/MPLS VPN Network, static routes for the customer site networks (B.B.B.0/24 and A.A.A.A) are added to the RED routing instance.

In addition, these static routes are also added on PE into the Global Unicast FIB. This is necessary for them to be distributed to the Internet.

```
vlan create ToCE ip id 100
vlan create ToInternet ip id 300
vlan add ports et.6.1 to ToCE
vlan add ports et.6.2 to ToInternet
interface create ip ToCE address-netmask C.C.C.1/30 vlan ToCE
interface create ip ToInternet address-netmask D.D.D.1/30 vlan ToInternet
interface add ip lo0 address-netmask 10.1.1.1/32

ip-router global set router-id 10.1.1.1
ip-router global set autonomous-system 65001

ip add route B.B.B.0/24 gateway C.C.C.2
ip add route A.A.A.A/32 gateway C.C.C.2

community-list RED-import permit 10 target:65001:1
ip-router policy create community-list RED-export target:65001:1
route-map RED-export permit 10 set-community-list RED-export
route-map RED-import permit 10 match-community-list RED-import

ip-router policy redistribute from-proto static to-proto bgp target-as XYZ

ospf create area backbone
ospf add stub-host 10.1.1.1 to-area backbone cost 1
ospf add interface ToInternet to-area backbone
ospf start

bgp create peer-group ToInternet autonomous-system XYZ
bgp add peer-host D.D.D.2 group ToInternet
bgp start

system set name PE

routing-instance RED vrf set route-distinguisher "10.1.1.1:1"
routing-instance RED vrf set vrf-import RED-import in-sequence 1
routing-instance RED vrf set vrf-export RED-export out-sequence 1
routing-instance RED vrf add interface ToCE
routing-instance RED ip add route B.B.B.0/24 gateway C.C.C.2
routing-instance RED ip add route A.A.A.A/32 gateway C.C.C.2
routing-instance RED vrf set global-unicast-lookup
```

InternetRouter Complete Configuration

```
vlan create ToPE ip id 200
vlan create ToInternet ip id 100
vlan add ports et.3.1 to ToPE
vlan add ports et.3.8 to ToInternet
interface create ip ToPE address-netmask D.D.D.2/30 vlan ToPE
interface create ip ToInternet address-netmask F.F.F.1/24 vlan ToInternet
interface add ip lo0 address-netmask E.E.E.E/32

ip-router global set router-id E.E.E.E
ip-router global set autonomous-system XYZ

ospf create area backbone
ospf add stub-host E.E.E.E to-area backbone cost 1
ospf add interface ToPE to-area backbone
ospf add interface ToInternet to-area backbone
ospf start

bgp create peer-group ToPE autonomous-system 65001
bgp add peer-host D.D.D.1 group ToPE
bgp start

system set name InternetRouter
```

Using the **`ip show route`** command, we confirm that PE is learning routes to the Internet (E.E.E.E/32, D.D.D.0/30, and F.F.F.0/24) from InternetRouter. We also confirm that PE's Global Unicast FIB contains the static routes configured for the customer site's globally routable IP addresses (B.B.B.0/24 and A.A.A.A).

```
PE# ip show route

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.1.1.1             10.1.1.1             -         lo0
127.0.0.1            127.0.0.1            -         lo0
C.C.C.0/30           directly connected   -         ToCE
B.B.B.0/24           C.C.C.2              Static    ToCE
D.D.D.0/30           directly connected   -         ToInternet
F.F.F.0/24           D.D.D.2              OSPF      ToInternet
A.A.A.A              C.C.C.2              Static    ToCE
E.E.E.E              D.D.D.2              OSPF      ToInternet
```

The Global Unicast FIBs on both CE and CustomerRouter show that PE is *not* distributing Internet routes to the customer site. The customer site does not need Internet routes as long as default routes send packets with unknown destinations to the PE router. The PE router then performs a Global Unicast FIB lookup for all non-VRF networks and correctly routes customer site Internet packets.

CustomerRouter has no routing protocols configured. Its Global Unicast FIB contains only directly-connected customer site routes and a default route to CE (B.B.B.1).

```
CustomerRouter# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
default              B.B.B.1              Static    ToCE
127.0.0.1            127.0.0.1            -         lo0
B.B.B.0/24           directly connected   -         ToCE
```

CE also has no routing protocols configured. Its Global Unicast FIB contains only routes for directly-connected customer and provider interfaces, as well as a default route to PE (C.C.C.1).

```
CE# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
default              C.C.C.1              Static    ToPE
127.0.0.1            127.0.0.1            -         lo0
C.C.C.0/30           directly connected   -         ToPE
B.B.B.0/24           directly connected   -         ToCustomerSite
A.A.A.A              A.A.A.A              -         lo0
```

Viewing the Global Unicast FIB on InternetRouter confirms that PE is distributing the static routes defined for the customer site's globally routable IP addresses (B.B.B.0/24 and A.A.A.A) to InternetRouter via EBGP.

```
InternetRouter# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.1.1.1             D.D.D.1              OSPF      ToPE
127.0.0.1            127.0.0.1            -         lo0
B.B.B.0/24           D.D.D.1              BGP       ToPE
D.D.D.0/30           directly connected   -         ToPE
F.F.F.0/24           directly connected   -         ToInternet
A.A.A.A              D.D.D.1              BGP       ToPE
E.E.E.E              E.E.E.E              -         lo0
```

The following demonstrates using ping to verify connectivity between CustomerRouter and the three Internet networks.

```
CustomerRouter# ping D.D.D.2
PING D.D.D.2: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from D.D.D.2: icmp_seq=0 ttl=253 time=171.852 ms

--- D.D.D.2 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 171.852/171.852/171.852/0.000 ms

CustomerRouter# ping E.E.E.E
PING E.E.E.E: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from E.E.E.E: icmp_seq=0 ttl=253 time=168.530 ms

--- E.E.E.E ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 168.530/168.530/168.530/0.000 ms

CustomerRouter# ping F.F.F.1
PING F.F.F.1: 36 bytes of data
5 second timeout, 1 repetition
36 bytes from F.F.F.1: icmp_seq=0 ttl=253 time=168.648 ms

--- F.F.F.1 ping statistics ---
1 packets transmitted, 1 packets received, 0.00% packet loss
round-trip min/avg/max/dev = 168.648/168.648/168.648/0.000 ms
```

16.11.2 Internet Access Using Network Address Translation (NAT)

The following example configures a PE router to provide Internet access for a customer site using network address translation (NAT). Figure 16-59 illustrates the topology.

Enabling Internet access for customer sites using network address translation requires the following:

1. Ensure that the PE router's Global Unicast FIB contains the Internet routes the customer site wishes to use.
   - In the example, PE is learning Internet routes from InternetRouter via EBGP.
2. Configure the PE router to use the Global Unicast FIB to resolve all addresses not found in the routing instance's Unicast FIB.

   When a CE packet arrives, the PE router first examines the particular routing instance Unicast FIB. In the Basic BGP/MPLS VPN example, if this lookup fails to yield a match, the packet cannot be routed. Enabling Global Unicast FIB lookup expands the set of routes accessible to customer sites from VRF routes only to VRF routes plus all provider and Internet routes. As long as a route to the requested address exists in the PE router's Global Unicast FIB, the Internet access succeeds.

   - On PE routers, use the **`routing-instance set global-unicast-lookup`** command to enable Internet access for sites belonging to the specified VRF. In the example, PE is configured to perform Global Unicast FIB lookup for the RED VRF, to which the Customer Site belongs.

Note Enabling Global Unicast FIB lookup grants customers access to Internet routes as well as the provider's internal routes. For security reasons, consider placing customer access restrictions on the PE router's customer-facing interfaces. You can do this in one of two ways using access-control lists (ACLs):
1. Prevent customers from sending to provider internal addresses on the outbound
2. Prevent provider sources from replying to customer addresses on the inbound

Before applying access restrictions, consider that customers need access to some provider internal routes in order to reach services such as DNS, NNTP, SMTP, or POP. Carefully consider any effects access restrictions may have on the customer's ability to reach these services before applying restrictions.

3. Use NAT to map Internet-bound traffic from customer sites to globally routable IP address(es). In the Basic BGP/MPLS VPN Network, customers may use RFC 1918 private addresses. Separate VRF routing tables on the PE router keep possibly overlapping customer addresses separate. To provide Internet access, PE routers must distribute to the Internet routes that the Internet relies upon for sending to customer sites (step 6). Since they are being distributed to the Internet, these routes must be globally routable. Customers may continue to use private addresses for internal VPN traffic.
   - The example maps internal customer addresses to globally routable addresses on the PE router in the following way:
     - NAT is enabled on on two interfaces. The customer-facing interface (toCustomerRED) is specified as the interface from which private addresses originate using the **`inside`** keyword. The Internet-facing interface (toInternet) is specified as the interface from which public addresses originate using the **`outside`** keyword.
     - A *static mapping* is created from *private address* 100.1.1.1 to *public address* 172.16.201.3. This mapping converts all IP packets originating from the private address 100.1.1.1 on the toCustomerRED interface (the inside interface) to use the public address 172.16.201.3 before it is sent to the InternetRouter. Likewise, any packet originating from the public address 172.16.201.3 on the toInternet interface (the outside interface) should be converted to use the private address 100.1.1.1 before it is sent to the CE router. The **`global-ip`** keyword specifies that this is a one-to-one mapping.
     - Using the access-control list **`to1`**, a *dynamic mapping* is created from the *private network* 100.3.1/24 to the *public address* 172.16.201.4. This mapping converts all IP packets originating from the private network 100.3.1/24 on the toCustomerRED interface (the inside interface) to use the public address 172.16.201.4 before it is sent to the InternetRouter. Likewise, any packet originating from the public address 172.16.201.4 on the toInternet interface (the outside interface) should be converted to an address within the private network 100.3.1/24 before it is sent to the CE router.

       In this example, the dynamic mapping is not a one-to-one mapping. The global-pool keyword can be used to specify that that the public address may be from a pool of addresses. (In this example, it is only a single IP address.) The enable-ip-overload keyword specifies that the number of private addresses is greater than the number of public address(es), and that each public address may be overloaded to carry more than one private address. When private addresses are overloaded, the RS relies on socket numbers to differentiate between distinct private network addresses being mapped to one public address.
4. Make sure that the PE routers can route to the private address(es)/network(s) from which customers will be originating Internet-bound traffic.
   - In the example, PE is configured with static routes to the 100.3.1/24 network and the 100.1.1.1 address in the RED VRF. The PE router mapped both of these private customer addresses to globally routable addresses with NAT. (See step 3)
5. Configure CE routers to use PE router(s) as default gateway(s) for unknown destinations.
   - On CE routers, you can do this using the **`ip add route default gateway`** command. In the example, the PE router (10.3.1.1) is configured as the default gateway on the CE router and the Customer Router (90.3.1.2) is configured as the default gateway for the private customer networks for which the PE router created NAT mappings.

6. To provide Internet access, PE routers must distribute to the Internet those globally routable addresses to which they mapped the private customer addresses.
   - In the example, the PE router adds the interface from which it borrowed the globally routable addresses (toInternet) to the EBGP session with InternetRouter, ensuring that the 172.16.201/24 network will be distributed to the Internet. Alternatively, the globally routable network may be redistributed into the EBGP session using the **`ip-router policy redistribute`** command

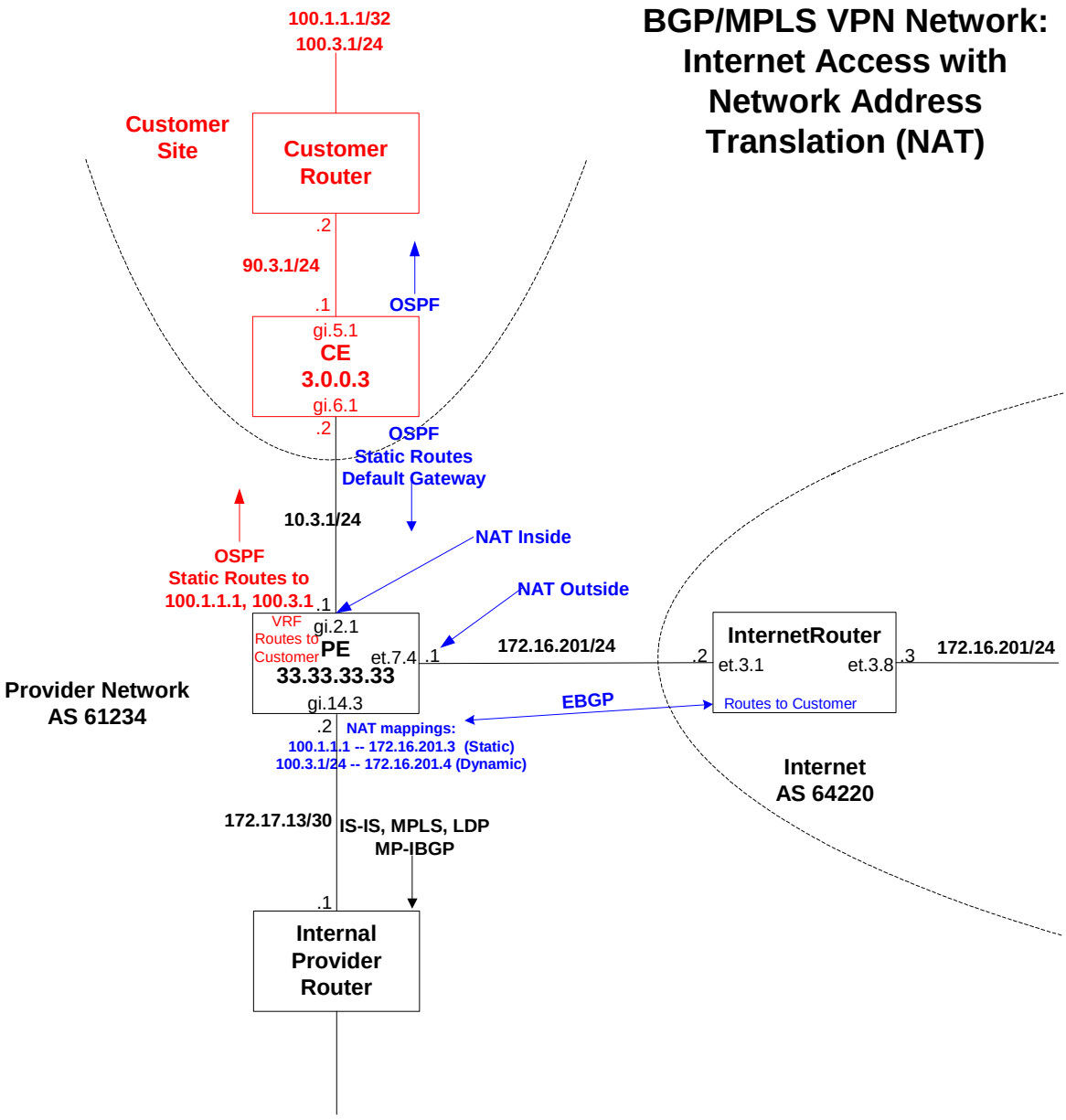


Figure 16-59 Internet access using NAT

Complete configurations for the CE and PE routers follow. The configurations specifically applicable to this example are highlighted.

PE Complete Configuration

```
interface create ip toProvider address-netmask 172.17.13.2/30 port gi.14.3
interface create ip toCustomerRED address-netmask 10.3.1.1/24 port gi.2.1
interface create ip toInternet address-netmask 172.16.201.1/24 port et.7.4
interface add ip lo0 address-netmask 33.33.33.33/32

acl to1 permit ip 100.3.1/24

ip-router global set router-id 33.33.33.33
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1 "target:61234:401"
route-map in1 permit 10 match-community-list vn1
route-map out1 permit 10 set-community-list vn1
route-map test1 permit 10 match-route-type bgp

bgp create peer-group as64220 autonomous-system 64220
bgp add peer-host 172.16.201.2 group as64220
bgp create peer-group as61234 autonomous-system 61234
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp set peer-group as61234 local-address 33.33.33.33
bgp set peer-group as61234 next-hop-self
bgp start

isis add area 27.2727.2727
isis add interface lo0
isis add interface toProvider
isis set interface toProvider level 1
isis start

mpls add interface toProvider
mpls start
ldp add interface toProvider
ldp start

routing-instance RED vrf add interface toCustomerRED
routing-instance RED ospf create area backbone
routing-instance RED ospf add interface toCustomerRED to-area backbone
routing-instance RED ospf start
routing-instance RED vrf set route-distinguisher 61234:401 vrf-import in1 in-sequence
     1 vrf-export out1 out-sequence 1
routing-instance RED ospf set route-map-vpn test1
routing-instance RED vrf set global-unicast-lookup
routing-instance RED ip add route 100.3.1/24 gateway 10.3.1.2
routing-instance RED ip add route 100.1.1.1/32 gateway 10.3.1.2
routing-instance RED vrf set router-id 10.3.1.1

nat set interface toCustomerRED inside
nat set interface toInternet outside
nat create static local-ip 100.1.1.1 global-ip 172.16.201.3 matches-in-interface
     toCustomerRED protocol ip
nat create dynamic local-acl-pool to1 global-pool 172.16.201.4 matches-in-interface
     toCustomerRED enable-ip-overload
```

CE Complete Configuration

```
interface create ip toPE address-netmask 10.3.1.2/24 port gi.6.1
interface create ip toCustomerNetwork address-netmask 90.3.1.1/24 port gi.5.1
interface add ip lo0 address-netmask 3.0.0.3/32

ip-router global set router-id 3.0.0.3

ospf create area backbone
ospf add interface toPE to-area backbone
ospf add interface toCustomerNetwork to-area backbone
ospf start

ip add route 100.3.1/24 gateway 90.3.1.2
ip add route 100.1.1.1/32 gateway 90.3.1.2
ip add route default gateway 10.3.1.1
```

16.12 HUB AND SPOKE EXAMPLE

The following example configures a hub and spoke topology separately using BGP and OSPF as the hub CE-PE protocol. Figure 16-60 illustrates this topology and highlights key configurations.

In this hub and spoke network,

- PE3 is the hub PE router
- CE3 is the hub CE router
- PE1 and PE2 are spoke PE routers
- CE1 and CE2 are spoke CE routers

PE3 is connected to CE3 through two physical links, which it uses to maintain two different VRFs: VRF spoke-to-hub for learning routes from the spokes and VRF hub-to-spoke for distributing routes to the spokes. (You may use logical links such as VLANs instead of physical links.)

In the spoke-to-hub VRF, PE3 learns routes from PE1 by importing routes with a Route Target of ‘target:65001:1’ and from PE2 by importing routes with a Route Target of ‘target:65001:2’. PE3 distributes these routes to CE3 via the to-CE3 link, which is added to this VRF. The spoke-to-hub export policy of ‘null’ prevents these routes from being advertised back to the spokes.

CE3 installs these routes in the Unicast FIB and advertises them back to PE3 *on both links*.

At this point, both the spoke-to-hub and hub-to-spoke VRFs contain spoke routes. The spoke-to-hub VRF learns these routes from the spoke PE routers. The hub-to-spoke VRF learns these routes from CE3. The spoke-to-hub VRF export policy of ‘null’ prevents these routes from being advertised back to the spokes.

The hub-to-spoke VRF exports its routes with a Route Target of ‘target:65001:3’, which both spoke PE routers are importing. Note that the hub-to-spoke import policy of ‘NULL’ prevents this VRF from learning spoke routes directly from the spokes. This limits the hub-to-spoke VRF to advertising to spoke routers only the routes learned from the hub CE router. These routes force each spoke to reach other spokes *through the hub*. So even though there is a link between PE1 and PE2 in the example, they do not exchange VRF routes. Instead, they learn routes for each other’s customer sites through the hub and traverse the hub to reach each other.

The hub and spoke topology relies on the hub CE router distributing routes learned from the hub PE router back to the hub PE router. Most routing protocols have built-in checks to prevent this type of routing loop. When implementing the hub and spoke topology using OSPF and BGP between the hub CE and PE routers, additional configurations are necessary to circumvent protocol anti-looping mechanisms. The following sections outline these configurations, which allow PE routers to distinguish a hub and spoke routing loop from a generic routing loop. Using them, PE routers can still prevent the latter but make allowances for the former.

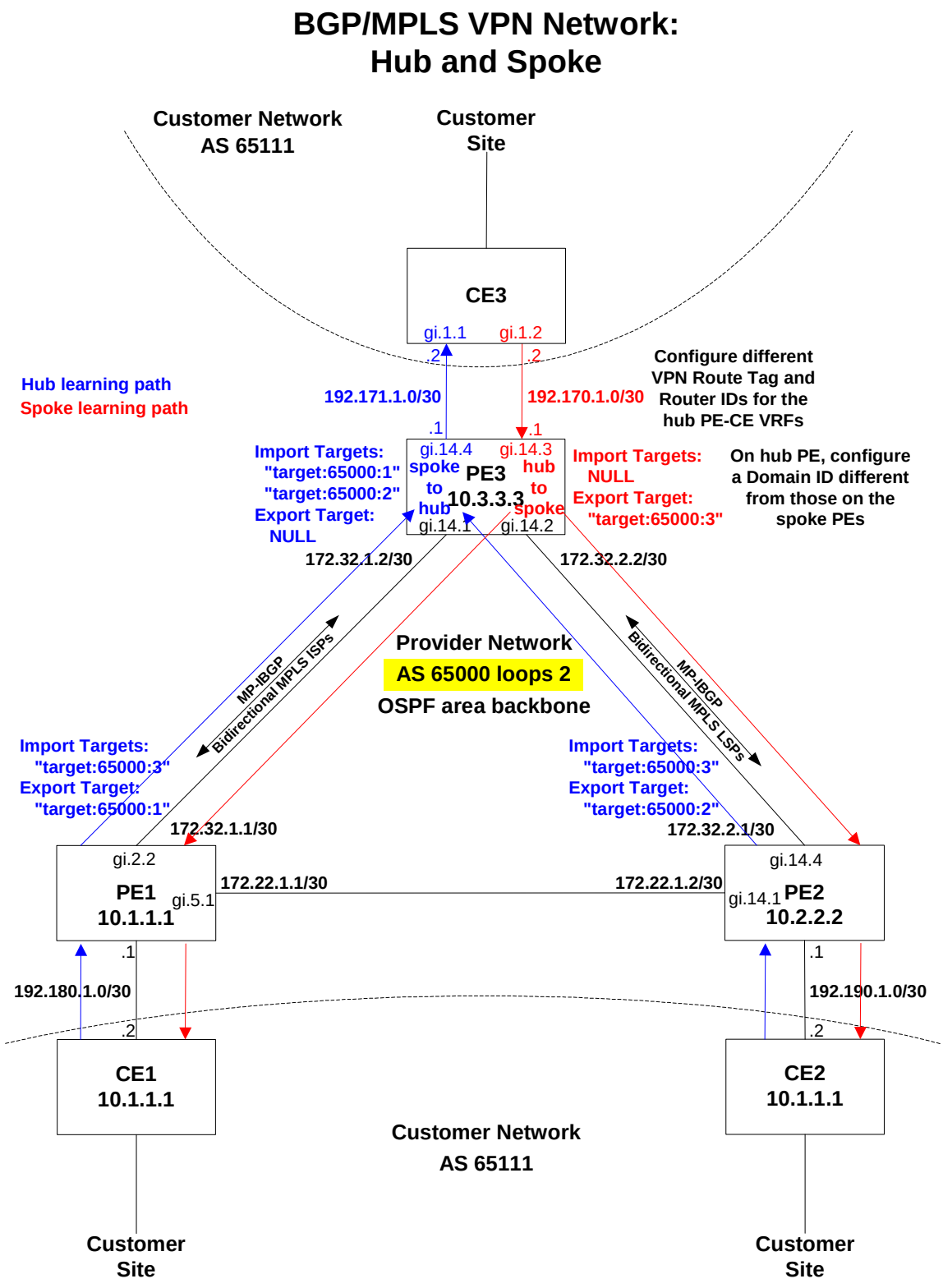


Figure 16-60 Hub and spoke

16.12.1 OSPF as the Hub CE-PE Protocol

When using OSPF as the hub CE-PE protocol, you must configure the following on the hub PE router. For more information on configuring OSPF between CE and PE routers, see the Section *"Configuring Static and OSPF Route Distribution Between CE and PE Routers."*

- Configure a different Router ID for each CE-PE VRF using the **`routing-instance vrf set router-id`** command. This prevents the hub PE router from rejecting the hub CE router's advertisements (of spoke routes) on the basis that they are self originated.
  - In the hub and spoke topology (Figure 16-60), PE3 advertises spoke routes to CE3 via the spoke-to-hub VRF with a router ID. If the hub-to-spoke VRF is configured with the same router ID, when CE3 advertises these routes back to PE3, PE3 would find the router IDs on these advertisements identical to its own and reject the advertisements because they are self originated. The solution is to configure a different router ID for each VRF between the hub CE and PE routers. You can configure multiple loopback addresses and assign them as router IDs to each VRF or use the interface address of the interface added to a VRF as the router ID for that VRF. In the example, PE3 uses the interface address on each VRF as the router ID for that VRF. PE3 originates all LSAs on the spoke-to-hub link with a router ID of 192.171.1.1 and all LSAs on the hub-to-spoke link with a router ID of 192.170.1.1.
- Configure a different VPN Route Tag for each CE-PE VRF using the **`routing-instance ospf set vpn-route-tag`** command. Before advertising VRF routes, PE routers use the VPN Route Tag to check that Type-5 LSAs are not redistributed through the OSPF area to another PE router, possibly creating a loop within the same VPN. A PE router ignores received Type-5 LSAs with a VPN Route Tag set to the value you define for its customer site's VPN.
  - If the spoke-to-hub and hub-to-spoke VRFs share one VPN Route Tag, PE3 would recognize routes that CE3 learns from the spoke-to-hub VRF and advertises to the hub-to-spoke VRF as coming from the same customer site. Based on this, PE3 would not install these LSAs. These routes would never be advertised out the hub-to-spoke VRF to the spoke PE routers. The solution is to configure a different VPN Route Tag for each VRF between the hub CE and PE routers. In the example, the OSPF instance in VRF spoke-to-hub is configured with a VPN Route Tag of '1005' and the OSPF instance in VRF hub-to-spoke is configured with a VPN Route Tag of '1010'.
- Configure a Domain ID on the hub PE router that is different from those configured on the spoke PE routers using the **`routing-instance ospf set domain-id`** command. This forces spoke routes to become Type-5 LSAs on the hub PE. Normally, PE routers treat OSPF routes originating from within the same domain as Type-3 LSAs. Type-3 LSAs rely on one bit, the DN bit, to flag loops. The DN bit is insufficient for PE routers to distinguish hub and spoke loops from generic routing loops. Type-5 LSAs do not impose this limitation. For PE routers to permit hub and spoke loops and still prevent other types of loops, they must distribute remote-site routes as Type-5 LSAs.
  - In the example, PE3 is configured with a Domain ID of 0.0.0.3 for both VRFs. Both spoke PE routers distribute routes learned via EBGP from the spoke CE routers to PE3. Since these routes originate from outside the OSPF domain, PE3 already considers them Type-5 LSAs. If the spoke PE routers learn spoke CE routes via OSPF, make sure that the Domain ID you configure on the hub PE router is distinct from the default Domain ID, 0.0.0.0, and the Domain IDs configured on the spoke PE routers. The multiple hub and spoke VRFs on the PE router, however, can share one Domain ID.

Complete OSPF-based configurations for the hub PE and CE routers follow. The configurations specifically applicable to this example are highlighted.

Hub PE (PE3) Complete Configuration—OSPF

```
interface create ip to-PE1 address-netmask 172.32.1.2/30 port gi.14.1
interface create ip to-PE2 address-netmask 172.32.2.2/30 port gi.14.2
interface create ip from-CE3 address-netmask 192.170.1.1/30 port gi.14.3
interface create ip to-CE3 address-netmask 192.171.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 10.3.3.3/32

ip-router global set router-id 10.3.3.3
ip-router global set install-lsp-routes bgp

community-list 10 permit 1 "target:65000:1"
community-list 10 permit 2 "target:65000:2"
ip-router policy create community-list 20 "target:65000:3"
route-map hub-to-spoke-export permit 1 set-community-list 20
route-map spoke-to-hub-import permit 1 match-community-list 10
route-map BGPROUTES permit 1 match-route-type bgp

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add interface to-PE2 to-area backbone
ospf add stub-host 10.3.3.3 to-area backbone cost 20
ospf start

bgp create peer-group PE1-PE3-PE2 autonomous-system 65000
bgp add peer-host 10.1.1.1 group PE1-PE3-PE2
bgp add peer-host 10.2.2.2 group PE1-PE3-PE2
bgp set peer-group PE1-PE3-PE2 local-address 10.3.3.3
bgp set peer-group PE1-PE3-PE2 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-PE2
mpls add interface to-PE1
mpls create label-switched-path pe3-pe2 from 10.3.3.3 to 10.2.2.2
mpls create label-switched-path pe3-pe1 from 10.3.3.3 to 10.1.1.1
mpls set label-switched-path pe3-pe2 no-cspf
mpls set label-switched-path pe3-pe1 no-cspf
mpls start

rsvp add interface to-PE2
rsvp add interface to-PE1
rsvp start

system set name PE-3

routing-instance hub-to-spoke vrf set route-distinguisher 65000:31 vrf-import null
vrf-export hub-to-spoke-export in-sequence 1 out-sequence 1
routing-instance hub-to-spoke vrf add interface from-CE3
```

```
routing-instance hub-to-spoke vrf set router-id 192.170.1.1
routing-instance hub-to-spoke ospf create area backbone
routing-instance hub-to-spoke ospf add interface from-CE3 to-area backbone
routing-instance hub-to-spoke ospf set vpn-route-tag 1010
routing-instance hub-to-spoke ospf set domain-id 0.0.0.3
routing-instance hub-to-spoke ospf start

routing-instance spoke-to-hub vrf set route-distinguisher 65000:30 vrf-import
spoke-to-hub-import vrf-export null in-sequence 1 out-sequence 1
routing-instance spoke-to-hub vrf add interface to-CE3
routing-instance spoke-to-hub vrf set router-id 192.171.1.1
routing-instance spoke-to-hub ospf create area backbone
routing-instance spoke-to-hub ospf add interface to-CE3 to-area backbone
routing-instance hub-to-spoke ospf set vpn-route-tag 1005
routing-instance hub-to-spoke ospf set domain-id 0.0.0.3
routing-instance hub-to-spoke ospf set route-map-vpn BGPROUTES
routing-instance spoke-to-hub ospf start
```

Hub CE (CE3) Complete Configuration—OSPF

```
interface create ip to-PE3 address-netmask 192.170.1.2/30 port gi.1.2
interface create ip from-PE3 address-netmask 192.171.1.2/30 port gi.1.1

ospf create area backbone
ospf add interface to-PE3 to-area backbone
ospf add interface from-PE3 to-area backbone
ospf start

system set name CE-3
```

16.12.2 BGP as the Hub CE-PE Protocol

When using BGP as the hub CE-PE protocol, you must configure the following on the hub PE router. For more information on configuring BGP between CE and PE routers, see the Section *"Configuring BGP Route Distribution Between CE and PE Routers."*

- Configure the hub PE router to permit one loop in a received route's aspath using the **`ip-router global set autonomous-system loops`** command with the parameter **`1`**. This command sets the test condition globally on the hub PE router and applies to all configured VRFs. Normally, BGP discards routes whose aspath lists its own autonomous system because this signals a loop. To allow the necessary hub and spoke loop, this command instructs the BGP process to permit routes that have up to one occurrences of its autonomous system. Allowing up to *one* occurrence of an AS number permits only *one* loop and still safeguards against multi-looping routes in whose aspath the current autonomous system number would occur two or more times.
  - In the hub and spoke topology (Figure 16-60), PE2 is allowed to see up to one occurrences of its own AS number, 65000, in all BGP routes, including those it receives via PE-CE route distribution from CE3.
- Configure the hub PE router to distribute active Routing Instance routes to the hub CE router using a route map. By default, in the absence of routing policies, BGP announces all routes from the Unicast FIB only. For a hub PE router to announce Routing Instance routes to the hub CE router, you must configure a route map on the hub PE router that enables it to announce the necessary VRF routes and apply this route map to the hub CE peer. For more information on configuring route maps, see *Section 15.2.14 "Using Route Maps."*
  - In the example, the route map spoke-to-hub applied to the spoke-to-hub VRF permits PE3 to advertise all active and optimal VRF routes to CE3. The route map and VRF names need not be identical.

Complete BGP-based configurations for the hub PE and CE routers follow. The configurations specifically applicable to this example are highlighted.

Hub PE (PE3) Complete Configuration—BGP

```
interface create ip to-PE1 address-netmask 172.32.1.2/30 port gi.14.1
interface create ip to-PE2 address-netmask 172.32.2.2/30 port gi.14.2
interface create ip from-CE3 address-netmask 192.170.1.1/30 port gi.14.3
interface create ip to-CE3 address-netmask 192.171.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 10.3.3.3/32

ip-router global set router-id 10.3.3.3
ip-router global set install-lsp-routes bgp
ip-router global set autonomous-system 65000 loops 1

community-list 10 permit 1 "target:65000:1"
community-list 10 permit 2 "target:65000:2"
ip-router policy create community-list 20 "target:65000:3"
route-map hub-to-spoke-export permit 1 set-community-list 20
route-map spoke-to-hub permit 10
route-map spoke-to-hub-import permit 1 match-community-list 10

ospf create area backbone
ospf add interface to-PE1 to-area backbone
ospf add interface to-PE2 to-area backbone
ospf add stub-host 10.3.3.3 to-area backbone cost 20
ospf start

bgp create peer-group PE1-PE3-PE2 autonomous-system 65000
bgp add peer-host 10.1.1.1 group PE1-PE3-PE2
bgp add peer-host 10.2.2.2 group PE1-PE3-PE2
bgp set peer-group PE1-PE3-PE2 local-address 10.3.3.3
bgp set peer-group PE1-PE3-PE2 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-PE2
mpls add interface to-PE1
mpls create label-switched-path pe3-pe2 from 10.3.3.3 to 10.2.2.2
mpls create label-switched-path pe3-pe1 from 10.3.3.3 to 10.1.1.1
mpls set label-switched-path pe3-pe2 no-cspf
mpls set label-switched-path pe3-pe1 no-cspf
mpls start

rsvp add interface to-PE2
rsvp add interface to-PE1
rsvp start

system set name PE-3

routing-instance hub-to-spoke vrf set route-distinguisher 65000:31 vrf-import null
vrf-export hub-to-spoke-export in-sequence 1 out-sequence 1
```

```
routing-instance hub-to-spoke vrf add interface from-CE3
routing-instance hub-to-spoke bgp create peer-group import-from-CE3 autonomous-system
65111
routing-instance hub-to-spoke bgp add peer-host 192.170.1.2 group import-from-CE3
routing-instance hub-to-spoke bgp start

routing-instance spoke-to-hub vrf set route-distinguisher 65000:30 vrf-import
spoke-to-hub-import vrf-export null in-sequence 1 out-sequence 1
routing-instance spoke-to-hub vrf add interface to-CE3
routing-instance spoke-to-hub bgp create peer-group export-to-CE3 autonomous-system
65111
routing-instance spoke-to-hub bgp add peer-host 192.171.1.2 group export-to-CE3
routing-instance spoke-to-hub bgp set peer-group export-to-CE3 route-map-out
spoke-to-hub out-sequence 1
routing-instance spoke-to-hub bgp start
```

Hub CE (CE3) Complete Configuration—BGP

```
interface create ip to-PE3 address-netmask 192.170.1.2/30 port gi.1.2
interface create ip from-PE3 address-netmask 192.171.1.2/30 port gi.1.1

ip-router global set autonomous-system 65111

bgp create peer-group import-from-PE3 autonomous-system 65000
bgp create peer-group export-to-PE3 autonomous-system 65000
bgp add peer-host 192.171.1.1 group import-from-PE3
bgp add peer-host 192.170.1.1 group export-to-PE3
bgp start

system set name CE-3
```

16.12.3 Configuring the Spoke PE Router

On the spoke PE router, you must configure the following:

- Just like on the hub PE router, configure the spoke PE router to permit one loop in a received route's aspath using the **`ip-router global set autonomous-system loops`** command with the parameter **`1`**. This command sets the test condition globally on the spoke PE router and applies to all configured VRFs on the spoke PE router. Normally, BGP discards routes whose aspath lists its own autonomous system because this signals a loop. To allow the necessary hub and spoke loop, this command instructs the BGP process to permit routes that have up to one occurrences of its autonomous system. Allowing up to *one* occurrences of an AS number permits only *one* loop and still safeguards against multi-looping routes in whose aspaths the current autonomous system number would occur two or more times.
  - In the hub and spoke topology (Figure 16-60), PE1 is configured to permit up to one occurrence of its own AS number, 65000, in all BGP routes, including those it receives from PE3 via the hub-to-spoke VRF.
- Do not configure the spoke PE routers to exchange routes with other spoke PE routers. This forces them to learn routes for each other's customer sites through the hub and traverse the hub to reach each other. Without routing exchange, configuring MPLS LSPs between spoke PE routers is also unnecessary.
  - In the example, PE1 only has an interface configured to PE2. It is not participating in any routing protocols with PE2, nor are there any MPLS LSPs configured between PE1 and PE2. The link between PE1 and PE2 can be disabled without affecting their connectivity through the hub.

Configure spoke CE routers as you would any CE router in the Basic BGP/MPLS VPN Network. The following complete configuration for PE1 illustrates how to configure the spoke PE router. The configurations specifically applicable to this example are highlighted.

Sample Spoke PE (PE1) Complete Configuration

```
interface create ip to-PE2 address-netmask  172.22.1.1/30 port gi.5.2
interface create ip to-PE3 address-netmask 172.32.1.1/30 port gi.5.1
interface create ip to-CE1 address-netmask 192.180.1.1/30 port gi.2.2
interface add ip lo0 address-netmask 10.1.1.1/32

ip-router global set router-id 10.1.1.1
ip-router global set install-lsp-routes bgp
ip-router global set autonomous-system 65000 loops 1

ip-router policy create community-list 10 target:65000:1
ip-router policy create community-list 11 target:65000:3
route-map bgp permit 10
route-map trinity-export permit 10 set-community-list 10
route-map trinity-import permit 10 match-community-list 11

ospf create area backbone
ospf add interface to-PE3 to-area backbone
ospf add stub-host 10.1.1.1 to-area backbone cost 20
```

```
ospf start

bgp create peer-group PE1-PE3 autonomous-system 65000
bgp add peer-host 10.3.3.3 group PE1-PE3
bgp set peer-group PE1-PE3 local-address 10.1.1.1
bgp set peer-group PE1-PE3 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface to-PE2
mpls add interface to-PE3
mpls create label-switched-path pe1-pe3 from 10.1.1.1 to 10.3.3.3
mpls set label-switched-path pe1-pe3 no-cspf
mpls start

rsvp add interface to-PE2
rsvp add interface to-PE3
rsvp start

system set name PE-1

routing-instance trinity vrf set route-distinguisher 65000:10 vrf-import
trinity-import vrf-export trinity-export in-sequence 1 out-sequence 1
routing-instance trinity vrf add interface to-CE1
routing-instance trinity bgp create peer-group PE1-CE1 autonomous-system 65111
routing-instance trinity bgp add peer-host 192.180.1.2 group PE1-CE1
routing-instance trinity bgp set peer-host 192.180.1.2 route-map-out bgp out-sequence
1
routing-instance trinity bgp start
```

16.13 CARRIER'S CARRIER EXAMPLE

The following is a complete configuration for the Carrier's Carrier example. In this scenario, the BGP/MPLS VPN customer is itself a BGP/MPLS VPN service provider to its customers, which means that:

- MPLS and LDP must extend to the customer PE router.
- The customer BGP/MPLS VPN service provider uses IGPs to exchange loopback routes and LDP to carry the labels associated with those routes.
- Once loopback addresses are propagated to customer PE routers, they establish MP-IBGP sessions to exchange end customer routes.

Figure 16-61 illustrates this topology and highlights key configurations.

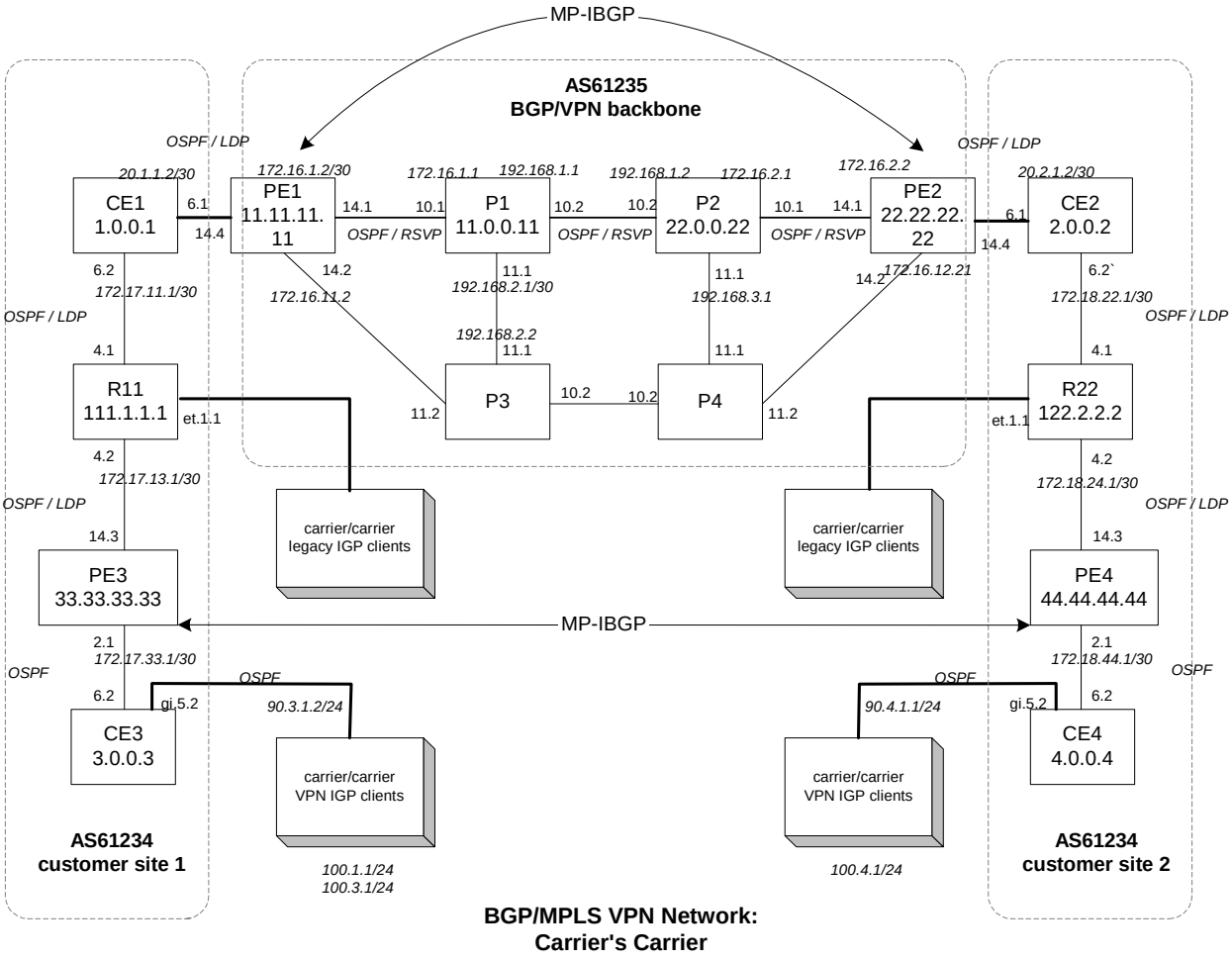


Figure 16-61 Carrier's Carrier

Complete configurations for all routers, except P3, P4, C3 and C4 follow. The configurations for P3 and P4 are identical, in spirt, to those of P1 and P2. C3 and C4 have customary non-BGP/MPLS VPN configurations.

CE1 Complete Configuration

```
interface create ip gi6.2 address-netmask 172.17.11.1/30 port gi.6.2
interface create ip v1500 address-netmask 20.1.1.2/30 port gi.6.1
interface add ip lo0 address-netmask 1.0.0.1/32

ip-router global set router-id 1.0.0.1
ip-router global set autonomous-system 61234

ospf create area backbone
ospf add interface v1500 to-area backbone
ospf add interface gi6.2 to-area backbone
ospf add stub-host 1.0.0.1 to-area backbone cost 3
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 111.1.1.1 group as61234
bgp set peer-group as61234 local-address 1.0.0.1 next-hop-self
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface v1500
mpls add interface gi6.2
mpls start

ldp add interface v1500
ldp add interface gi6.2
ldp start

system set name CE1
```

CE2 Complete Configuration

```
interface create ip gi6.2 address-netmask 172.18.22.1/30 port gi.6.2
interface create ip v1500 address-netmask 20.2.1.2/30 port gi.6.1
interface add ip lo0 address-netmask 2.0.0.2/32

ip-router global set router-id 2.0.0.2
ip-router global set autonomous-system 61234

ospf create area backbone
ospf add interface gi6.2 to-area backbone
ospf add interface v1500 to-area backbone
ospf add stub-host 2.0.0.2 to-area backbone cost 3
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 122.2.2.2 group as61234
bgp set peer-group as61234 local-address 2.0.0.2 next-hop-self
bgp set peer-group as61234 ipv4-unicast
bgp start

mpls add interface v1500
mpls add interface gi6.2
mpls start

ldp add interface v1500
ldp add interface gi6.2
ldp start

system set name CE2
```

P1 Complete Configuration

```
interface create ip gi10.1 address-netmask 172.16.1.1/30 port gi.10.1
interface create ip gi10.2 address-netmask 192.168.1.1/30 port gi.10.2
interface create ip gi11.1 address-netmask 192.168.2.1/30 port gi.11.1
interface add ip lo0 address-netmask 11.0.0.11/32

ip-router global set router-id 11.0.0.11

ospf create area backbone
ospf add stub-host 11.0.0.11 to-area backbone cost 3
ospf add interface gi10.1 to-area backbone
ospf add interface gi10.2 to-area backbone
ospf add interface gi11.1 to-area backbone
ospf set traffic-engineering on
ospf start

mpls set global point-of-local-repair-enable
mpls add interface gi10.1
mpls add interface gi10.2
mpls add interface gi11.1
mpls start

rsvp add interface gi10.1
rsvp add interface gi10.2
rsvp add interface gi11.1
rsvp set interface gi10.1 hello-enable
rsvp set interface gi10.2 hello-enable
rsvp set interface gi11.1 hello-enable
rsvp start

system set name P1
```

P2 Complete Configuration

```
interface create ip gi10.1 address-netmask 172.16.2.1/30 port gi.10.1
interface create ip gi10.2 address-netmask 192.168.1.2/30 port gi.10.2
interface create ip gi11.1 address-netmask 192.168.3.1/30 port gi.11.1

interface add ip lo0 address-netmask 22.0.0.22/32

ip-router global set router-id 22.0.0.22

ospf create area backbone
ospf add stub-host 22.0.0.22 to-area backbone cost 3
ospf add interface gi10.1 to-area backbone
ospf add interface gi10.2 to-area backbone
ospf add interface gi11.1 to-area backbone
ospf set traffic-engineering on
ospf start

mpls set global point-of-local-repair-enable
mpls add interface gi10.1
mpls add interface gi10.2
mpls add interface gi11.1
mpls start

rsvp add interface gi10.1
rsvp add interface gi10.2
rsvp add interface gi11.1
rsvp set interface gi10.1 hello-enable
rsvp set interface gi10.2 hello-enable
rsvp set interface gi11.1 hello-enable
rsvp start

system set name P2
```

PE1 Complete Configuration

```
interface create ip gi14.1 address-netmask 172.16.1.2/30 port gi.14.1
interface create ip v1500 address-netmask 20.1.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 11.11.11.11/32

ip-router global set router-id 11.11.11.11
ip-router global set install-lsp-routes on
ip-router global set autonomous-system 61235

ip-router policy create community-list vn1500 "target:61235:1500"
route-map in1500 permit 10 match-community-list vn1500
route-map out1500 permit 10 set-community-list vn1500
route-map s1500 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 11.11.11.11 to-area backbone cost 3
ospf add interface gi14.1 to-area backbone
ospf set traffic-engineering on
ospf set igp-shortcuts on
ospf start

bgp create peer-group as61235 autonomous-system 61235
bgp add peer-host 22.22.22.22 group as61235
bgp set peer-group as61235 vpnv4-unicast ipv4-unicast
bgp set peer-group as61235 local-address 11.11.11.11 next-hop-self
bgp start

mpls set global local-repair-enable node-protection
mpls add interface gi14.1
mpls add interface v1500
mpls create label-switched-path pe1-2 from 11.11.11.11 to 22.22.22.22
mpls start

rsvp add interface gi14.1
rsvp set interface gi14.1 hello-enable
rsvp start

ldp add interface v1500
ldp start

system set name PE1

routing-instance to-ce1-v1500 vrf add interface v1500
routing-instance to-ce1-v1500 vrf set route-distinguisher 61235:2999 vrf-import in1500
     in-sequence 1 vrf-export out1500 out-sequence 1
routing-instance to-ce1-v1500 ospf create area backbone
routing-instance to-ce1-v1500 ospf add interface v1500 to-area backbone
routing-instance to-ce1-v1500 ospf set route-map-vpn s1500
routing-instance to-ce1-v1500 ospf start
```

PE2 Complete Configuration

```
interface create ip gi14.1 address-netmask 172.16.2.2/30 port gi.14.1
interface create ip v1500 address-netmask 20.2.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 22.22.22.22/32

ip-router global set autonomous-system 61235
ip-router global set router-id 22.22.22.22
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1500 "target:61235:1500"
route-map in1500 permit 10 match-community-list vn1500
route-map out1500 permit 10 set-community-list vn1500
route-map s1500 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 22.22.22.22 to-area backbone cost 3
ospf add interface gi14.1 to-area backbone
ospf set traffic-engineering on
ospf set igp-shortcuts on
ospf start

bgp create peer-group as61235 autonomous-system 61235
bgp add peer-host 11.11.11.11 group as61235
bgp set peer-group as61235 local-address 22.22.22.22 next-hop-self
bgp set peer-group as61235 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface gi14.1
mpls add interface v1500
mpls create label-switched-path pe2-1 from 22.22.22.22 to 11.11.11.11
mpls start

rsvp add interface gi14.1
rsvp set interface gi14.1 hello-enable
rsvp start

ldp add interface v1500
ldp start

system set name PE2

routing-instance to-ce2-v1500 vrf add interface v1500
routing-instance to-ce2-v1500 vrf set route-distinguisher 61235:3000 vrf-import in1500
     in-sequence 1 vrf-export out1500 out-sequence 1
routing-instance to-ce2-v1500 ospf create area backbone
routing-instance to-ce2-v1500 ospf add interface v1500 to-area backbone
routing-instance to-ce2-v1500 ospf set route-map-vpn s1500
routing-instance to-ce2-v1500 ospf start
```

PE3 Complete Configuration

```
interface create ip gi14.3 address-netmask 172.17.13.2/30 port gi.14.3
interface create ip vpn1 address-netmask 10.3.1.1/24 port gi.2.1
interface add ip lo0 address-netmask 33.33.33.33/32

ip-router global set router-id 33.33.33.33
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1 "target:61234:401"
route-map in1 permit 10 match-community-list vn1
route-map out1 permit 10 set-community-list vn1
route-map test1 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 33.33.33.33 to-area backbone cost 3
ospf add interface gi14.3 to-area backbone
ospf set traffic-engineering on
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 111.1.1.1 group as61234
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp set peer-group as61234 local-address 33.33.33.33
bgp set peer-group as61234 next-hop-self
bgp start

mpls add interface gi14.3
mpls start

ldp add interface gi14.3
ldp start

system set name PE3

routing-instance to-ce3-v1 vrf add interface vpn1
routing-instance to-ce3-v1 vrf set route-distinguisher 61234:401 vrf-import in1
     in-sequence 1 vrf-export out1 out-sequence 1
routing-instance to-ce3-v1 ospf create area backbone
routing-instance to-ce3-v1 ospf add interface vpn1 to-area backbone
routing-instance to-ce3-v1 ospf set route-map-vpn test1
routing-instance to-ce3-v1 ospf start
```

PE4 Complete Configuration

```
interface create ip gi14.3 address-netmask 172.18.24.2/30 port gi.14.3
interface create ip vpn1 address-netmask 10.4.1.1/24 vlan 101
interface add ip lo0 address-netmask 44.44.44.44/32

ip-router global set router-id 44.44.44.44
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1 "target:61234:401"
route-map in1 permit 10 match-community-list vn1
route-map out1 permit 10 set-community-list vn1
route-map test1 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 44.44.44.44 to-area backbone cost 3
ospf add interface gi14.3 to-area backbone
ospf set traffic-engineering on
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 122.2.2.2 group as61234
bgp set peer-group as61234 next-hop-self
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp set peer-group as61234 local-address 44.44.44.44
bgp start

mpls add interface gi14.3
mpls start

ldp add interface gi14.3
ldp start

system set name PE4

routing-instance to-ce4-v1 vrf add interface vpn1
routing-instance to-ce4-v1 vrf set route-distinguisher 61234:402 vrf-import in1
     in-sequence 1 vrf-export out1 out-sequence 1
routing-instance to-ce4-v1 ospf create area backbone
routing-instance to-ce4-v1 ospf add interface vpn1 to-area backbone
routing-instance to-ce4-v1 ospf set route-map-vpn test1
routing-instance to-ce4-v1 ospf start
```

R11 Complete Configuration

```
interface create ip gi41 address-netmask 172.17.11.2/30 port gi.4.1
interface create ip gi42 address-netmask 172.17.13.1/30 port gi.4.2
interface create ip et11 address-netmask 93.3.1.1/24 port et.1.1

interface add ip lo0 address-netmask 111.1.1.1/32

ip-router global set install-lsp-routes on
ip-router global set router-id 111.1.1.1
ip-router global set autonomous-system 61234

ip-router policy redistribute from-proto bgp source-as 61234 to-proto bgp target-as
     61234

ospf create area backbone
ospf add interface gi42 to-area backbone
ospf add interface gi41 to-area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 3
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 1.0.0.1 group as61234
bgp add peer-host 33.33.33.33 group as61234
bgp add peer-host 122.2.2.2 group as61234
bgp set peer-group as61234 reflector-client
bgp set peer-group as61234 local-address 111.1.1.1 next-hop-self
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface gi42
mpls add interface gi41
mpls start

ldp add interface gi42
ldp add interface gi41
ldp start

system set name R11
```

R22 Complete Configuration

```
interface create ip gi41 address-netmask 172.18.22.2/30 port gi.4.1
interface create ip gi42 address-netmask 172.18.24.1/30 port gi.4.2
interface create ip et11 address-netmask 94.1.1.1/24 port et.1.1
interface add ip lo0 address-netmask 122.2.2.2/32

ip-router global set router-id 122.2.2.2
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy redistribute from-proto bgp source-as 61234 to-proto bgp target-as
     61234

ospf create area backbone
ospf add stub-host 122.2.2.2 to-area backbone cost 3
ospf add interface gi41 to-area backbone
ospf add interface gi42 to-area backbone
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 2.0.0.2 group as61234
bgp add peer-host 44.44.44.44 group as61234
bgp add peer-host 111.1.1.1 group as61234
bgp set peer-group as61234 reflector-client
bgp set peer-group as61234 local-address 122.2.2.2 next-hop-self
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp start

mpls add interface gi41
mpls add interface gi42
mpls start

ldp add interface gi41
ldp add interface gi42
ldp start

system set name R22
```

16.14 MULTIPLE-AUTONOMOUS SYSTEM EXAMPLE

The following is a complete configuration for the Multiple-Autonomous System BGP/MPLS VPN network. In this network, the BGP/MPLS VPN customer is itself a BGP/MPLS VPN service provider to its customers. The customer BGP/MPLS VPN service provider sites exist in different autonomous systems, which means that:

- MPLS and LDP must extend to the customer PE router.
- the customer BGP/MPLS VPN service provider uses MP-EBGP with Label Extensions (set using the **`bgp set peer-group`** or **`peer-host ipv4-labeledunicast`** commands) to exchange both loopback routes for remote PE routers and the MPLS labels associated with those routes.
- once loopback addresses are propagated to customer PE routers, they establish MP-EBGP sessions to exchange end customer routes. Normally, EBGP peers must be directly connected. Because they are not directly connected, customer PE routers use MP-EBGP multihop to successfully exchange routes.

Figure 16-62 illustrates this topology and highlights key configurations.

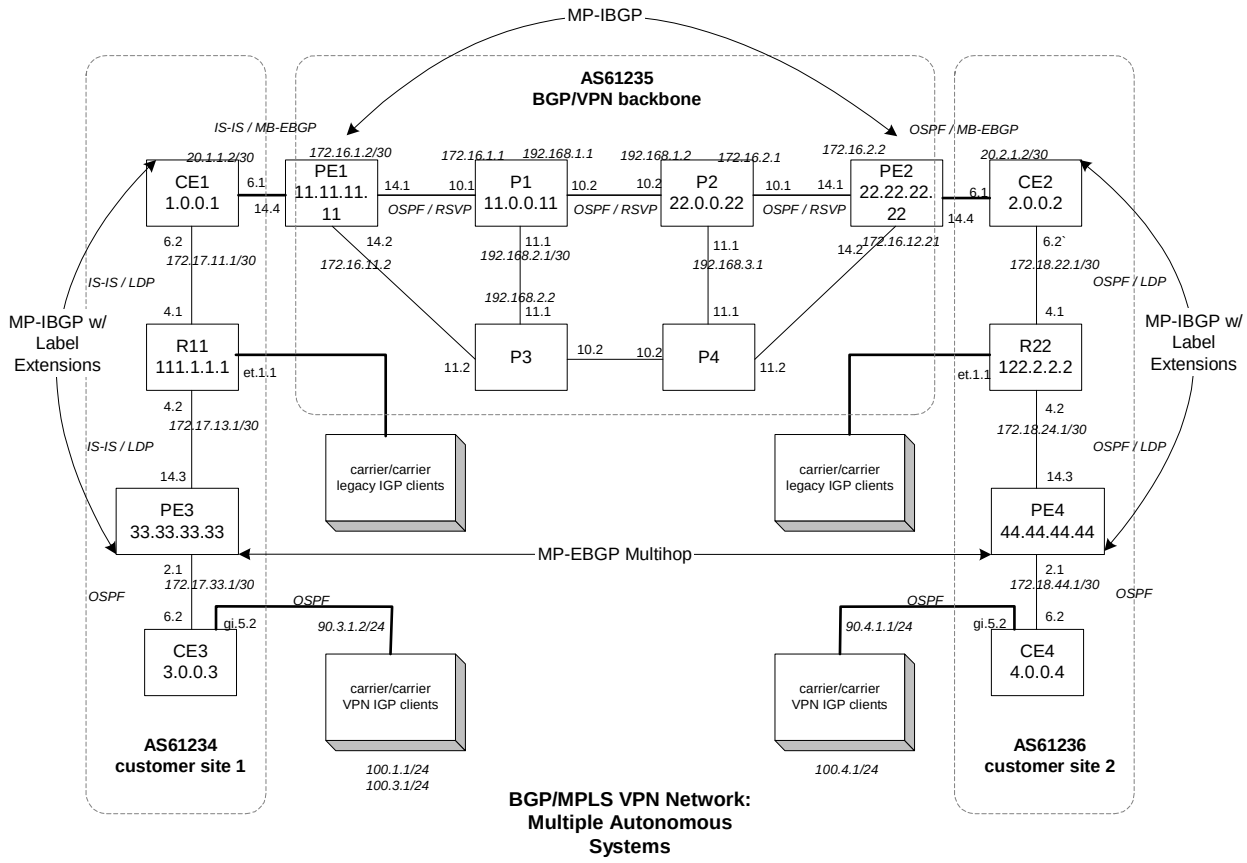


Figure 16-62 Multiple Autonomous Systems

Complete configurations for all routers (except P3 and P4) follow. The configurations for P3 and P4 are identical, in spirt, to those of P1 and P2. Additionally, the core provider network configuration illustrates the use of redundant MPLS paths and R22 illustrates route reflector usage. PE3 also illustrates the use of BGP Graceful Restart and NAT in the Multiple-Autonomous System BGP/MPLS VPN network.

CE1 Complete Configuration

```
interface create ip v1500 address-netmask 20.1.1.2/30 port gi.6.1
interface create ip gi6.2 address-netmask 172.17.11.1/30 port gi.6.2
interface add ip lo0 address-netmask 1.0.0.1/32

ip-router global set router-id 1.0.0.1
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy redistribute from-proto bgp source-as 61235 to-proto bgp target-as
     61234
ip-router policy redistribute from-proto bgp source-as 61234 target-as 61235 to-proto
     bgp
ip-router policy redistribute from-proto isis-level-1 to-proto bgp target-as 61235

bgp create peer-group as61234 autonomous-system 61234
bgp create peer-group as61235 autonomous-system 61235
bgp add peer-host 111.1.1.1 group as61234
bgp add peer-host 33.33.33.33 group as61234
bgp set peer-group as61234 local-address 1.0.0.1 next-hop-self
bgp set peer-group as61234 ipv4-labeledunicast
bgp set peer-group as61234 graceful-restart
bgp add peer-host 20.1.1.1 group as61235
bgp set peer-group as61235 ipv4-labeledunicast
bgp set peer-group as61235 ipv4-unicast
bgp start

isis add area 27.2727.2727
isis add interface lo0
isis add interface v1500
isis add interface gi6.2
isis set interface v1500 level 1
isis set interface gi6.2 level 1
isis set traffic-engineering on
isis start

mpls add interface v1500
mpls add interface gi6.2
mpls start

ldp add interface gi6.2
ldp start

system set name CE1
```

CE2 Complete Configuration

```
interface create ip v1500 address-netmask 20.2.1.2/30 port gi.6.1
interface create ip gi6.2 address-netmask 172.18.22.1/30 port gi.6.2
interface add ip lo0 address-netmask 2.0.0.2/32

ip-router global set router-id 2.0.0.2
ip-router global set autonomous-system 61236
ip-router global set install-lsp-routes on

ip-router policy redistribute from-proto ospf to-proto bgp target-as 61235
ip-router policy redistribute from-proto bgp source-as 61235 to-proto ospf
ip-router policy redistribute from-proto bgp source-as 61235 target-as 61236 to-proto
     bgp
ip-router policy redistribute from-proto bgp source-as 61236 target-as 61235 to-proto
     bgp

ospf create area backbone
ospf add interface gi6.2 to-area backbone
ospf add stub-host 2.0.0.2 to-area backbone cost 3
ospf set traffic-engineering on
ospf start

bgp create peer-group as61235 autonomous-system 61235
bgp create peer-group as61236 autonomous-system 61236
bgp add peer-host 20.2.1.1 group as61235
bgp add peer-host 44.44.44.44 group as61236
bgp set peer-group as61235 ipv4-labeledunicast
bgp set peer-group as61236 local-address 2.0.0.2 next-hop-self
bgp set peer-group as61236 ipv4-unicast vpnv4-unicast
bgp set peer-group as61236 ipv4-labeledunicast
bgp start

mpls add interface v1500
mpls add interface gi6.2
mpls create label-switched-path p2-4 to 44.44.44.44
mpls start

ldp add interface gi6.2
ldp start

system set name CE2
```

CE3 Complete Configuration

```
interface create ip vpn1 address-netmask 10.3.1.2/24 port gi.6.1
interface create ip cn1 address-netmask 90.3.1.1/24 port gi.5.1
interface add ip lo0 address-netmask 3.0.0.3/32

ip-router global set router-id 3.0.0.3

ospf create area backbone
ospf add interface vpn1 to-area backbone
ospf add interface cn1 to-area backbone
ospf add stub-host 3.0.0.3 to-area backbone cost 3
ospf start

ip add route 100.1.1/24 gateway 90.3.1.2
ip add route 100.3.1/24 gateway 90.3.1.2

system set name CE3
```

CE4 Complete Configuration

```
interface create ip vpn1 address-netmask 10.4.1.2/24 port gi.6.1
interface create ip cn1 address-netmask 90.4.1.1/24 port gi.5.1
interface add ip lo0 address-netmask 4.0.0.4/32

ip-router global set router-id 4.0.0.4

ospf create area backbone
ospf add interface vpn1 to-area backbone
ospf add interface cn1 to-area backbone
ospf add stub-host 4.0.0.4 to-area backbone cost 3
ospf start

ip add route 100.4.1/24 gateway 90.3.1.2

system set name CE4
```

P1 Complete Configuration

```
interface create ip gi10.1 address-netmask 172.16.1.1/30 port gi.10.1
interface create ip gi10.2 address-netmask 192.168.1.1/30 port gi.10.2
interface create ip gi11.1 address-netmask 192.168.2.1/30 port gi.11.1
interface add ip lo0 address-netmask 11.0.0.11/32

ip-router global set router-id 11.0.0.11

ospf create area backbone
ospf add stub-host 11.0.0.11 to-area backbone cost 3
ospf add interface gi10.1 to-area backbone
ospf add interface gi10.2 to-area backbone
ospf add interface gi11.1 to-area backbone
ospf set traffic-engineering on
ospf start

mpls set global point-of-local-repair-enable
mpls add interface gi10.1
mpls add interface gi10.2
mpls add interface gi11.1
mpls start

rsvp add interface gi10.1
rsvp add interface gi10.2
rsvp add interface gi11.1
rsvp set interface gi10.1 hello-enable
rsvp set interface gi10.2 hello-enable
rsvp set interface gi11.1 hello-enable
rsvp start

system set name P1
```

P2 Complete Configuration

```
interface create ip gi10.1 address-netmask 172.16.2.1/30 port gi.10.1
interface create ip gi10.2 address-netmask 192.168.1.2/30 port gi.10.2
interface create ip gi11.1 address-netmask 192.168.3.1/30 port gi.11.1

interface add ip lo0 address-netmask 22.0.0.22/32

ip-router global set router-id 22.0.0.22

ospf create area backbone
ospf add stub-host 22.0.0.22 to-area backbone cost 3
ospf add interface gi10.1 to-area backbone
ospf add interface gi10.2 to-area backbone
ospf add interface gi11.1 to-area backbone
ospf set traffic-engineering on
ospf start

mpls set global point-of-local-repair-enable
mpls add interface gi10.1
mpls add interface gi10.2
mpls add interface gi11.1
mpls start

rsvp add interface gi10.1
rsvp add interface gi10.2
rsvp add interface gi11.1
rsvp set interface gi10.1 hello-enable
rsvp set interface gi10.2 hello-enable
rsvp set interface gi11.1 hello-enable
rsvp start

system set name P2
```

R11 Complete Configuration

```
interface create ip gi41 address-netmask 172.17.11.2/30 port gi.4.1
interface create ip gi42 address-netmask 172.17.13.1/30 port gi.4.2
interface create ip et11 address-netmask 93.3.1.1/24 port et.1.1
interface add ip lo0 address-netmask 111.1.1.1/32

ip set port et.1.1 forwarding-mode destination-based
ip set port gi.4.1 forwarding-mode destination-based

ip-router global set install-lsp-routes on
ip-router global set router-id 111.1.1.1
ip-router global set autonomous-system 61234

ip add route 100.3.201/24 gateway 93.3.1.2

ip-router policy redistribute from-proto static to-proto bgp target-as 61234 network
     100.3.201/24
ip-router policy redistribute from-proto bgp source-as 61234 to-proto bgp target-as
     61234

bgp create peer-group as61234 autonomous-system 61234
bgp add peer-host 33.33.33.33 group as61234
bgp set peer-group as61234 reflector-client
bgp set peer-group as61234 local-address 111.1.1.1 next-hop-self
bgp set peer-group as61234 vpnv4-unicast ipv4-unicast
bgp set cluster-id 1.0.0.255
bgp start

isis add area 27.2727.2727
isis add interface lo0
isis add interface gi42
isis add interface gi41
isis set interface gi41 level 1
isis set interface gi42 level 1
isis set traffic-engineering on
isis start

mpls add interface gi42
mpls add interface gi41
mpls start

ldp add interface gi42
ldp add interface gi41
ldp start

system set name R11
```

R22 Complete Configuration

```
interface create ip gi41 address-netmask 172.18.22.2/30 port gi.4.1
interface create ip gi42 address-netmask 172.18.24.1/30 port gi.4.2
interface create ip et11 address-netmask 94.1.1.1/24 port et.1.1
interface add ip lo0 address-netmask 122.2.2.2/32

ip set port et.1.1 forwarding-mode destination-based
ip set port gi.4.1 forwarding-mode destination-based

ip-router global set router-id 122.2.2.2
ip-router global set install-lsp-routes on
ip-router global set autonomous-system 61236

ip add route 100.4.201/24 gateway 94.1.1.2

ip-router policy redistribute from-proto static to-proto bgp target-as 61234 network
     100.4.201/24
ip-router policy redistribute from-proto bgp source-as 61234 to-proto bgp target-as
     61234

ospf create area backbone
ospf add stub-host 122.2.2.2 to-area backbone cost 3
ospf add interface gi41 to-area backbone
ospf add interface gi42 to-area backbone
ospf set traffic-engineering on
ospf set igp-shortcuts on
ospf start

bgp create peer-group as61236 autonomous-system 61236
bgp set cluster-id 1.0.0.255
bgp set peer-group as61236 local-address 122.2.2.2 next-hop-self
bgp set peer-group as61236 reflector-client
bgp start

mpls add interface gi41
mpls add interface gi42
mpls start

ldp add interface gi41
ldp add interface gi42
ldp start

system set name R22
```

PE1 Complete Configuration

```
interface create ip gi14.1 address-netmask 172.16.1.2/30 port gi.14.1
interface create ip gi14.2 address-netmask 172.16.11.2/30 port gi.14.2
interface create ip v1500 address-netmask 20.1.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 11.11.11.11/32

ip-router global set router-id 11.11.11.11
ip-router global set install-lsp-routes on
ip-router global set autonomous-system 61235

ip-router policy create community-list vn1500 "target:61235:1500"
route-map in1500 permit 10 match-community-list vn1500
route-map out1500 permit 10 set-community-list vn1500
route-map s1500 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 11.11.11.11 to-area backbone cost 3
ospf add interface gi14.1 to-area backbone
ospf add interface gi14.2 to-area backbone
ospf set traffic-engineering on
ospf set igp-shortcuts on
ospf start

bgp create peer-group as61235 autonomous-system 61235
bgp add peer-host 22.22.22.22 group as61235
bgp set peer-group as61235 vpnv4-unicast ipv4-unicast
bgp set peer-group as61235 local-address 11.11.11.11 next-hop-self
bgp start

isis add area 27.2727.2727
isis add interface gi14.1
isis add interface gi14.2
isis set interface gi14.1 level 1
isis set interface gi14.2 level 1
isis set traffic-engineering on

mpls set global local-repair-enable node-protection
mpls add interface gi14.1
mpls add interface gi14.2
mpls add interface v1500
mpls create path p1 num-hops 3
mpls create path p2 num-hops 3
mpls set path p1 hop 1 ip-addr 172.16.1.2 type strict
mpls set path p1 hop 2 ip-addr 172.16.1.1 type strict
mpls set path p1 hop 3 ip-addr 172.16.2.2 type loose
mpls set path p2 hop 1 ip-addr 172.16.11.2 type strict
mpls set path p2 hop 2 ip-addr 172.16.11.1 type strict
```

```
mpls set path p2 hop 3 ip-addr 172.16.12.2 type loose
mpls create label-switched-path pp1-2 to 22.22.22.22
mpls set label-switched-path pp1-2 primary p1
mpls set label-switched-path pp1-2 secondary p2 standby
mpls start

rsvp add interface gi14.1
rsvp add interface gi14.2
rsvp set interface gi14.1 hello-enable
rsvp set interface gi14.2 hello-enable
rsvp start

system set name PE1

routing-instance to-ce1-v1500 vrf add interface v1500
routing-instance to-ce1-v1500 bgp create peer-group as61234 autonomous-system 61234
routing-instance to-ce1-v1500 bgp add peer-host 20.1.1.2 group as61234
routing-instance to-ce1-v1500 vrf set route-distinguisher 61235:2999 vrf-import in1500
in-sequence 1 vrf-export out1500 out-sequence 1
routing-instance to-ce1-v1500 bgp set peer-group as61234 route-map-out s1500
out-sequence 1
routing-instance to-ce1-v1500 bgp set peer-group as61234 ipv4-labeledunicast
routing-instance to-ce1-v1500 bgp start
```

PE2 Complete Configuration

```
interface create ip gi14.1 address-netmask 172.16.2.2/30 port gi.14.1
interface create ip gi14.2 address-netmask 172.16.12.2/30 port gi.14.2
interface create ip v1500 address-netmask 20.2.1.1/30 port gi.14.4
interface add ip lo0 address-netmask 22.22.22.22/32

ip-router global set autonomous-system 61235
ip-router global set router-id 22.22.22.22
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1500 "target:61235:1500"
route-map in1500 permit 10 match-community-list vn1500
route-map out1500 permit 10 set-community-list vn1500
route-map s1500 permit 10 match-route-type bgp

ospf create area backbone
ospf add stub-host 22.22.22.22 to-area backbone cost 3
ospf add interface gi14.1 to-area backbone
ospf add interface gi14.2 to-area backbone
ospf set traffic-engineering on
ospf start

bgp create peer-group as61235 autonomous-system 61235
bgp add peer-host 11.11.11.11 group as61235
bgp set peer-group as61235 local-address 22.22.22.22 next-hop-self
bgp set peer-group as61235 vpnv4-unicast ipv4-unicast
bgp start

isis add area 27.2727.2727
isis add interface gi14.1
isis add interface gi14.2
isis set interface gi14.1 level 1
isis set interface gi14.2 level 1

mpls set global local-repair-enable node-protection
mpls add interface gi14.1
mpls add interface gi14.2
mpls add interface v1500
mpls create label-switched-path pe2-1 from 22.22.22.22 to 11.11.11.11
mpls set label-switched-path pe2-1 fast-reroute
mpls start

rsvp add interface gi14.1
rsvp add interface gi14.2
rsvp set interface gi14.1 hello-enable
rsvp set interface gi14.2 hello-enable
rsvp start
```

```
system set name PE2

routing-instance to-ce2-v1500 vrf add interface v1500
routing-instance to-ce2-v1500 vrf set route-distinguisher 61235:3000 vrf-import in1500
in-sequence 1 vrf-export out1500 out-sequence 1
routing-instance to-ce2-v1500 bgp create peer-group as61236 autonomous-system 61236
routing-instance to-ce2-v1500 bgp add peer-host 20.2.1.2 group as61236
routing-instance to-ce2-v1500 bgp set peer-group as61236 route-map-out s1500
out-sequence 1
routing-instance to-ce2-v1500 bgp set peer-group as61236 ipv4-labeledunicast
routing-instance to-ce2-v1500 bgp start
```

PE3 Complete Configuration

```
port enable multi-vrf-support port gi.2.1 overwrite source-socket

interface create ip gi14.3 address-netmask 172.17.13.2/30 port gi.14.3
interface create ip vpn1 address-netmask 10.3.1.1/24 port gi.2.1
interface create ip et78 address-netmask 172.16.200.2/28 port et.7.8
interface create ip et74 address-netmask 172.16.201.1/24 port et.7.4
interface add ip lo0 address-netmask 33.33.33.33/32

ip-router global set router-id 33.33.33.33
ip-router global set autonomous-system 61234
ip-router global set install-lsp-routes on

ip-router policy create community-list vn1 "target:61234:401"
ip-router policy redistribute from-proto bgp source-as 61235 to-proto bgp target-as
61236 network all restrict
route-map t64220 permit 10 match-route-type direct network 172.16.201/24 match-prefix
route-map a64220 deny 15
route-map in1 permit 10 match-community-list vn1
route-map out1 permit 10 set-community-list vn1
route-map t61234 deny 10 match-aspath-regular-expression "64220 .*"
route-map test1 permit 10 match-route-type bgp

bgp create peer-group as61234 autonomous-system 61234
bgp create peer-group as61236 autonomous-system 61236
bgp create peer-group as64220 autonomous-system 64220
bgp add peer-host 44.44.44.44 group as61236
bgp set peer-group as61236 local-address 33.33.33.33 multihop
bgp set peer-group as61236 vpnv4-unicast
bgp set peer-group as61236 graceful-restart
bgp add peer-host 1.0.0.1 group as61234
bgp set peer-group as61234 local-address 33.33.33.33
bgp set peer-group as61234 next-hop-self
bgp set peer-group as61234 ipv4-labeledunicast
bgp set peer-group as61234 graceful-restart
bgp add peer-host 172.16.200.1 group as64220
bgp set peer-group as64220 route-map-out t64220 out-sequence 10
bgp set peer-host 172.16.200.1 group as64220 route-map-in a64220 in-sequence 10
bgp set resync-time 90
bgp start

isis add area 27.2727.2727
isis add interface lo0
isis add interface gi14.3
isis set interface gi14.3 level 1
isis set traffic-engineering on
isis set restart helper enable restart enable
```

```
isis start

mpls add interface gi14.3
mpls start

ldp add interface gi14.3
ldp start

system set name PE3

routing-instance to-ce3-v1 vrf add interface vpn1
routing-instance to-ce3-v1 vrf set route-distinguisher 61234:401 vrf-import in1
in-sequence 1 vrf-export out1 out-sequence 1
routing-instance to-ce3-v1 vrf set global-unicast-lookup
routing-instance to-ce3-v1 vrf set router-id 10.3.1.1
routing-instance to-ce3-v1 ospf create area backbone
routing-instance to-ce3-v1 ospf add interface vpn1 to-area backbone
routing-instance to-ce3-v1 ospf start
routing-instance to-ce3-v1 ip add route 100.3.1/24 gateway 10.3.1.2

nat set interface vpn1 inside
nat set interface et78 outside
nat create static local-ip 100.1.1.1 global-ip 172.16.201.3 matches-in-interface vpn1
protocol ip
```

PE4 Complete Configuration

```
port enable multi-vrf-support port gi.2.1 overwrite source-socket

interface create ip gi14.3 address-netmask 172.18.24.2/30 port gi.14.3
interface create ip vpn1 address-netmask 10.4.1.1/24 port gi.2.1
interface add ip lo0 address-netmask 44.44.44.44/32

ip set port gi.2.1 forwarding-mode destination-based
ip-router global set router-id 44.44.44.44
ip-router global set install-lsp-routes on
ip-router global set autonomous-system 61236

ip-router policy create community-list vn1 "target:61234:401"
route-map in1 permit 10 match-community-list vn1
route-map out1 permit 10 set-community-list vn1
route-map test1 permit 10 match-route-type bgp
ip-router policy redistribute from-proto bgp source-as 61235 to-proto bgp target-as
     61234

ospf create area backbone
ospf add stub-host 44.44.44.44 to-area backbone cost 3
ospf add interface gi14.3 to-area backbone
ospf set traffic-engineering on
ospf start

bgp create peer-group as61234 autonomous-system 61234
bgp create peer-group as61236 autonomous-system 61236
bgp add peer-host 33.33.33.33 group as61234
bgp set peer-group as61234 vpnv4-unicast
bgp set peer-group as61234 local-address 44.44.44.44 multihop
bgp set peer-group as61234 ipv4-labeledunicast
bgp add peer-host 122.2.2.2 group as61236
bgp add peer-host 2.0.0.2 group as61236
bgp set peer-group as61236 local-address 44.44.44.44 next-hop-self
bgp set peer-group as61236 ipv4-labeledunicast
bgp start

mpls add interface gi14.3
mpls start

ldp add interface gi14.3
ldp start

system set name PE4

routing-instance to-ce4-v1 vrf add interface vpn1
routing-instance to-ce4-v1 vrf set route-distinguisher 61234:402 vrf-import in1
     in-sequence 1 vrf-export out1 out-sequence 1
routing-instance to-ce4-v1 vrf set router-id 10.4.1.1
routing-instance to-ce4-v1 ospf create area backbone
routing-instance to-ce4-v1 ospf add interface vpn1 to-area backbone
routing-instance to-ce4-v1 ospf set route-map-vpn test1
routing-instance to-ce4-v1 ospf start
```

16.15 QOS FOR BGP/MPLS VPNS

The Riverstone implementation of BGP/MPLS VPNs allows Quality of Service (QoS) facilities to be applied to routing instances. Primarily, QoS is accomplished by mapping traffic characteristics, such as internal priority bits or DSCP bits, to the MPLS Experimental bits (Exp bits) on PE routers.

16.15.1 MPLS Experimental Bits

The MPLS QoS capabilities are based on the use of the three Experimental bits (Exp bits) within the MPLS label. When packets traverse the RS, they are assigned to one of four internal queues based on the value contained within the Exp bits. The priorities of these queues are *low*, *medium*, *high*, and *control*. In turn, you can configure QoS facilities, such as Weighted-Fair Queueing (WFQ), to affect the behavior of the traffic passing through each of these queues. See the QoS Configuration chapter for details on configuring the QoS facility.

16.15.2 Setting the MPLS Experimental Bits

On PE routers, you can set the MPLS Exp bits for the layer-3 traffic of any routing instance. You can either set the value of the MPLS Exp bits directly or derive it from the following sources:

- Riverstone proprietary internal priority bits – 2 bits representing the four priority queues
  - 00 = low
  - 01 = medium
  - 10 = high
  - 11 = control
- ToS precedence bits – 3 most significant bits of the ToS byte (see Figure 16-63)
- Differentiated Services Code Point (DSCP) bits – 6 most significant bits of the ToS byte (see Figure 16-63)

Note Use the **tos**, **tos-mask**, **tos-rewrite**, and **tos-precedence-rewrite** parameters of the **qos set ip** command to configure the value of the DSCP bits.

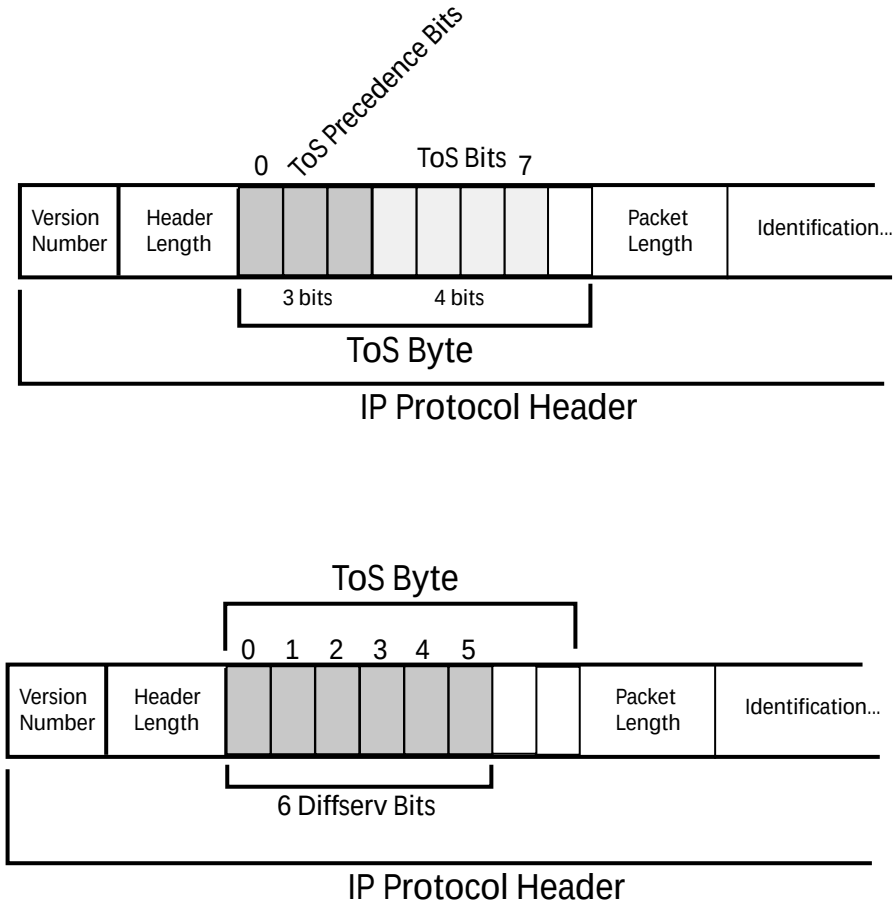


Figure 16-63 Comparison of ToS precedence bits to DSCP bits

Setingt the Exp Bit Directly

Use the **`routing-instance`** <*name*> **`vrf set exp`** <*value*> command to set the value of the MPLS Exp bits directly for a routing instance.

Deriving the MPLS Exp Bits from the Riverstone Proprietary Internal Priority Bits

Use one of the following mapping schemes to derive the MPLS Exp bits from the Riverstone proprietary internal priority bits:

Method	Command
Copy the two internal priority bits into the two least-significant Exp bits. Figure 16-64 illustrates copying bits into other bits.	**routing-instance** <*name*> **vrf set copy-intprio-to-exp**
Use a mapping table to derive the three Exp bits from the two internal priority bits. First create the mapping table, then apply it to the routing instance. Figure 16-65 illustrates setting bits using a mapping table.	**mpls create intprio-to-exp-tbl** <*name*> <*values*> **routing-instance** <*name*> **vrf set intprio-to-exp-table** <*mapping-table-name*>

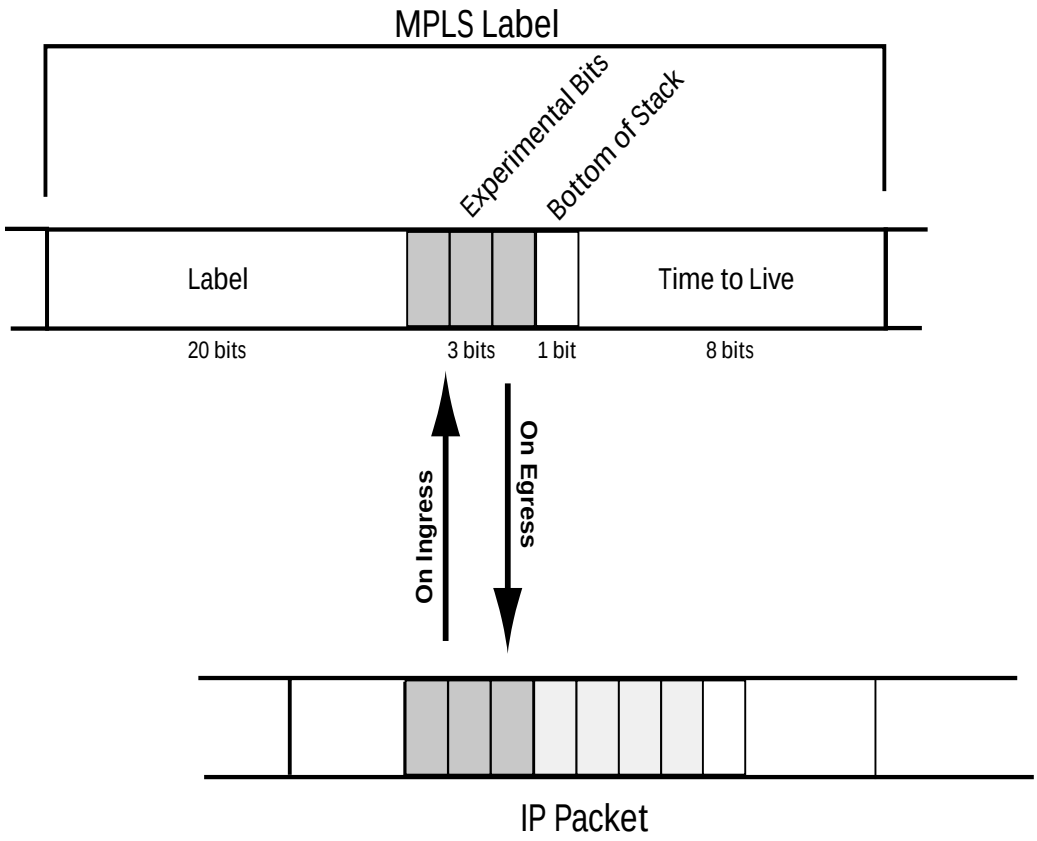


Figure 16-64 Copying bits directly to and from packets

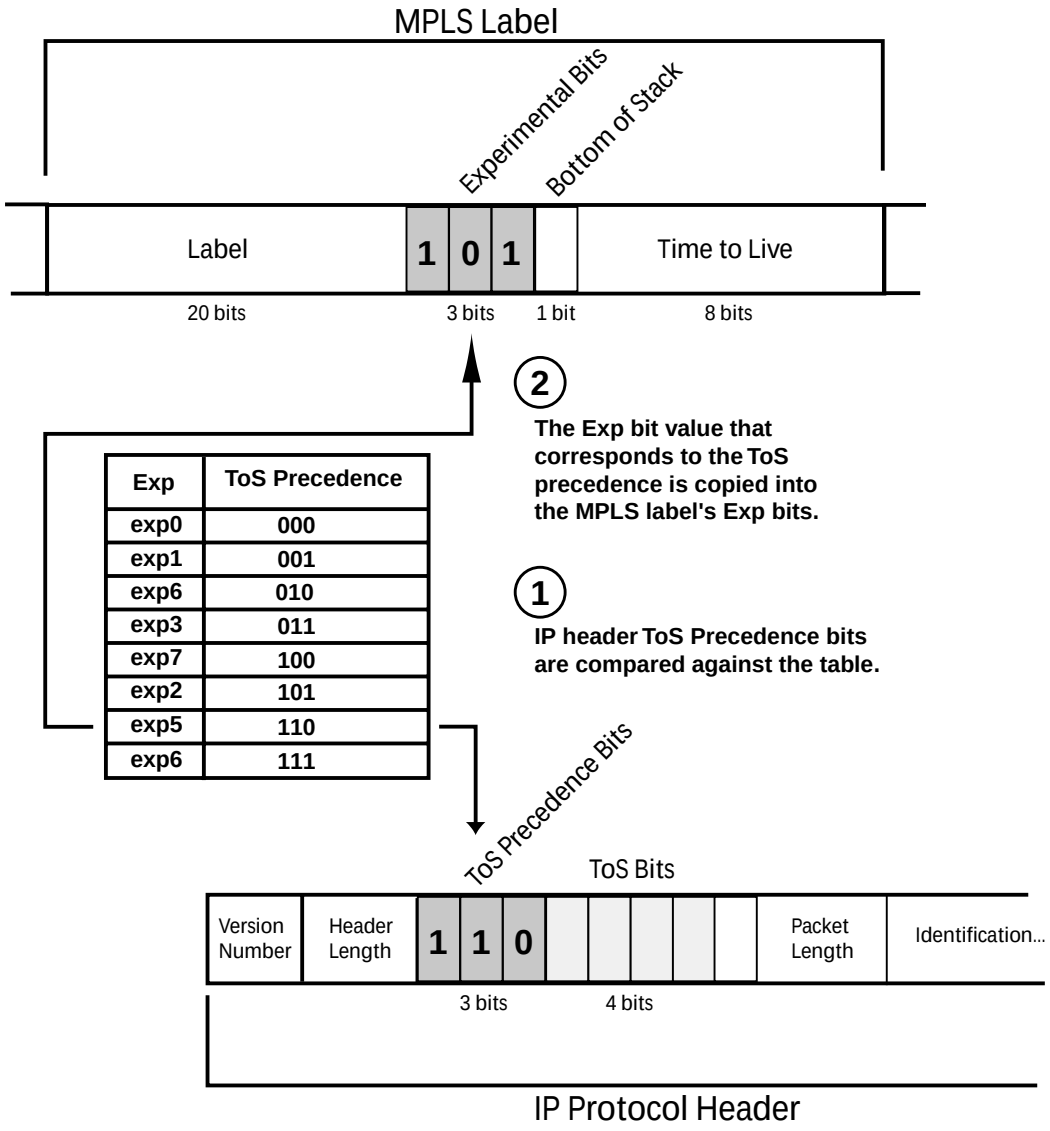


Figure 16-65 Setting the Exp bits using a mapping table

Deriving the MPLS Exp Bits from the ToS Precedence Bits

Use one of the mapping schemes to derive the MPLS Exp bits from the ToS precedence bits:

Method	Command
Copy the three ToS precedence bits directly into the three Exp bits. Figure 16-64 illustrates copying bits into other bits.	**routing-instance** <*name*> **vrf set copy-tosprec-to-exp**
Use a mapping table to derive the three Exp bits from the three ToS precedence bits. First create the mapping table, then apply it to the routing instance. Figure 16-65 illustrates setting bits using a mapping table.	**mpls create tosprec-to-exp-tbl** <*name*> <*values*> **routing-instance** <*name*> **vrf set tosprec-to-exp-table** <*mapping-table-name*>

Deriving the MPLS Exp Bits from the DSCP Bits

The DSCP bits cannot be directly copied into the Exp bits of the The MPLS label. You must define the mapping of DSCP bits to Exp bits using a table. Figure 16-65 illustrates setting bits using a mapping table.

Method	Command
Use a mapping table to derive the three Exp bits from the six ToS precedence bits. First create the mapping table, then apply it to the routing instance.	**mpls create dscp-to-exp-tbl** <*name*> <*values*> **routing-instance** <*name*> **vrf set dscp-to-exp-table** <*mapping-table-name*>

16.15.3 Creating Exp Mapping Tables

Configuring mappings using tables gives flexibility in how packet bits are mapped to Exp bits. For instance, in Figure 16-65, ToS precedence bit value 6 (110 binary) is mapped to Exp bit value 5 (101 binary).

The following lists the possible tables that you can use to map packet bits to the Exp bits.

- On ingress:
  - DSCP bits to Exp bits (**mpls create dscp-to-exp-tbl** <*name*>*)*
  - Internal priority bits to Exp bits (**mpls create intprio-to-exp-tbl** <*name*>*)*
  - ToS precedence bits to Exp bits (**mpls create tosprec-to-exp-tbl** <*name*>)

Example: Creating a Mapping Table

The following command creates the mapping table illustrated in Figure 16-65:

```
PE(config)# mpls create tosprec-to-exp-tbl <name> tosprec0 0 tosprec1 1 tosprec2 6
tosprec3 3 tosprec4 7 tosprec5 2 tosprec6 5 tosprec7 6
```

Example: Copying Internal Priority Bits to Exp Bits

The following example specifies that when a packet traverses the RED routing instance, its two internal priority bits should be copied into the least significant two bits of its three MPLS Experimental bits.

```
PE(config)# routing-instance RED vrf set copy-intprio-to-exp
```

Example: Copying ToS Precedence Bits to Exp Bits

The following example specifies that when a packet traverses the RED routing instance, its three ToS precedence bits should be copied into its three MPLS Experimental bits.

```
PE(config)# routing-instance RED vrf set copy-tosprec-to-exp
```

Example: Deriving the Exp Bits from DSCP Bits Using a Mapping Table

The following example creates a table named **dscp_tbl** that maps the DSCP bits to the Exp bits and applies this mapping to any traffic that traverses routing instance RED:

```
PE(config)# mpls create dscp-to-exp-tbl dscp_tbl dscp0 0 dscp1 1 dscp2 5 dscp7 7
PE(config)# routing-instance RED vrf set dscp-to-exp-table dscp_tbl
```

Example: Specify a Value for the Exp Bits

The following example specifies that when a packet traverses the RED routing instance, its MPLS Experimental bits should be set to the value ’3’:

```
PE(config)# routing-instance RED vrf set exp 3
```

Example: Deriving the Exp Bits from Internal Priority Bits Using a Mapping Table

The following example creates a table named **intprio_tbl** that maps the internal priority bits to the Exp bits and applies this mapping to any traffic that traverses routing instance RED:

```
PE(config)# mpls create intprio-to-exp-tbl intprio_tbl intprio0 0 intprio1 1 intprio2
5 intprio7 7
PE(config)# routing-instance RED vrf set intprio-to-exp-table intprio_tbl
```

Example: Deriving the Exp Bits from ToS Precedence Bits Using a Mapping Table

The following example creates a table named **tos_tbl** that maps the ToS precedence bits to the Exp bits and applies this mapping to any traffic that traverses routing instance RED:

```
PE(config)# mpls create tosprec-to-exp-tbl tos_tbl tosprec0 0 tosprec1 1 tosprec2 5
tosprec7 7
PE(config)# routing-instance RED vrf set tosprec-to-exp-table tos_tbl
```

When configuring mapping tables, you do not have to define all values. If a value within any table is not specified, it defaults to zero. In this example, the ToS precedence of 2 (010 binary) maps to an Exp value of 5 (101 binary). ToS precedence value 3 (011 binary), because it is not specified, defaults to an Exp value of 0.

Note If a value within any table is not specified, it defaults to zero.

Use the **mpls show diff-serv-tbls** command to display the contents of the ingress table.

```
PE# mpls show diff-serv-tbls tosprec-to-exp_tbl tos_tbl

TOS precedence to EXP table:
----------------------------
Table Name                TOSPREC --> EXP
----------                ---------------
tos-tbl                   1           1
                          2           5
                          7           7
                          *           0
```

In the display above, notice that all unspecified values for ToS precedence are wild carded to zero.

17 MPLS CONFIGURATION

Multiprotocol Label Switching (MPLS) is a technology that enables routers to forward traffic based on a simple *label* embedded into the packet header. A router can simply examine the label to determine the next hop for the packet, rather than perform a much more complex route lookup on the destination IP address.While originally designed to speed up layer 3 routing of packets, label-based switching can provide other benefits to IP networks. Riverstone's MPLS allows you to do the following:

- set the path that traffic will take through a network and set performance characteristics for a class of traffic
- add new network routing services without changing the basic forwarding paradigm
- create virtual private network (VPN) tunnels throughout the network (without the need for encryption or end-user applications)

Note The MPLS features described in this chapter are only supported on MPLS-enabled RS line cards. See your Riverstone representative for specific part numbers and applicable RS platforms.

Note 802.2 IPX encapsulation is not supported on any MPLS-capable line card.

This chapter contains the following sections:

- For an overview of MPLS concepts and terminology, and the MPLS features supported on the RS, see Section 17.1, *"MPLS Architecture Overview."*
- To enable MPLS on the RS switch router, see Section 17.2, *"Enabling and Starting MPLS on the RS."*
- To configure Resource Reservation Protocol (RSVP) signaling for MPLS, see Section 17.3, *"RSVP Configuration."*
- To configure Label Distribution Protocol (LDP) signaling for MPLS, see Section 17.4, *"LDP Configuration."*
- To configure layer 3 label switching, see Section 17.5, *"Configuring L3 Label Switched Paths."* This section includes information on configuring static and dynamic L3 paths, as well as example configurations.
- To configure layer 2 label switching, see Section 17.6, *"Configuring L2 Tunnels."* This section includes information on configuring static and dynamic L2 tunnels, as well as example configurations.
- To use MPLS traffic engineering features, see Section 17.7, *"Traffic Engineering."*

- To use QoS facilities with layer-2 and layer-3 traffic traversing an LSP, see Section 17.8, *"QoS For MPLS."*

Timesaver Titles shown in blue represent hypertext links to the sections. Click on one of the section titles above to go immediately to that section.

17.1 MPLS ARCHITECTURE OVERVIEW

A *forwarding equivalence class* (FEC) is a group of IP packets that are forwarded over the same path with the same forwarding treatment. Examples of FECs include:

- unicast packets whose destination address matches a specified IP address prefix
- unicast packets whose destination address matches a specified IP address prefix and whose type of service (ToS) bit matches a specified value
- multicast packets with the same source and destination addresses

In "traditional," non-MPLS networks, each router maps a packet to an FEC based on the destination IP address in the packet's network layer header. Each FEC is then mapped to a next hop. At each hop, the packet is examined and assigned an FEC and a next hop.

In an MPLS network, packets are forwarded in one direction across a *label switched path* (LSP), as shown in Figure 17-1. Labels are the mapping of network layer routing to data link layer switched paths. With MPLS, the assignment of a specific packet to an FEC is only done once—at the first router in the path, the *ingress label switching router* (LSR). Only the ingress LSR[1] in the path needs to analyze the layer 3 header information. If the destination address in the incoming packet matches an entry in the routing table, the appropriate label is applied to the packet and the packet is forwarded on to the next hop. At subsequent hops, intermediate or *transit* LSRs in the path need to only look at the packet label to forward the packet through the MPLS network; no further examination of the packet's network layer header is required.

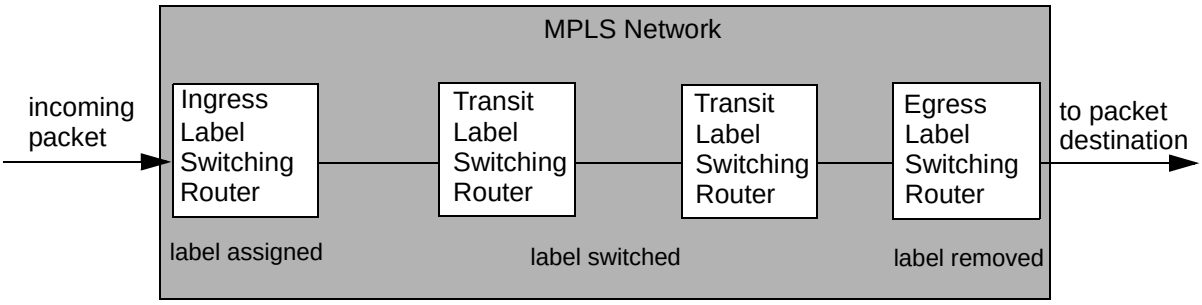


Figure 17-1 MPLS label switched path

1. Ingress and egress LSRs are sometimes also referred to as label edge routers (LERs).

At the *egress* LSR at the other edge of the path, the label is stripped off. The packet is then forwarded to its next destination using information in the IP forwarding table. There is one ingress router and one egress router for each LSP. Note that a router cannot be both an ingress and egress LSR for the *same* LSP.

Note Flow bridging mode is not supported for MPLS LSRs.

17.1.1 Labels

An MPLS label is a 20-bit integer between 0 and 1048575 that identifies a particular FEC. The label is encapsulated in the packet's layer-2 header, as shown in Figure 17-2.

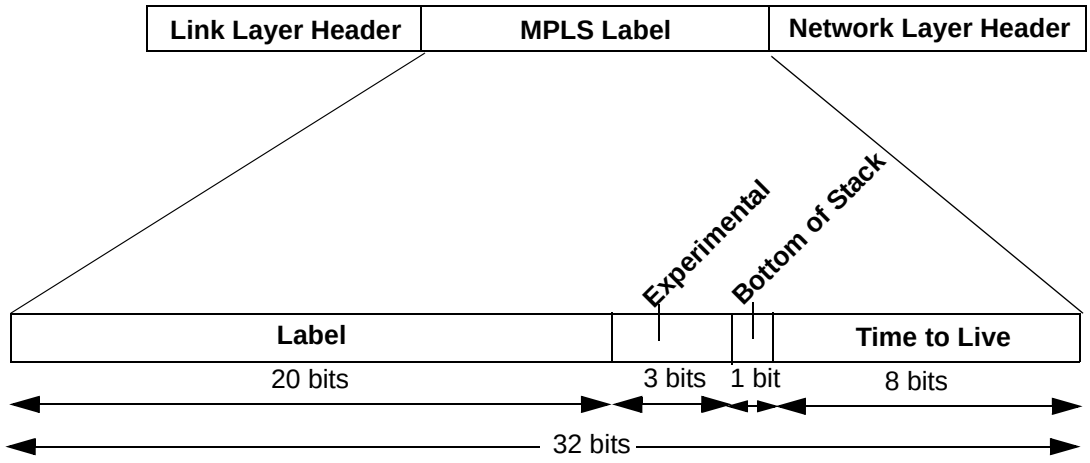


Figure 17-2 Encoding of an MPLS label

A series of two or more MPLS labels, or a *label stack*, can be encoded after the data link and before the network layer header. The top label in the label stack appears earliest in the packet and the bottom label appears last, as shown in Figure 17-3. The network layer header immediately follows the label that has the bottom of stack bit set.

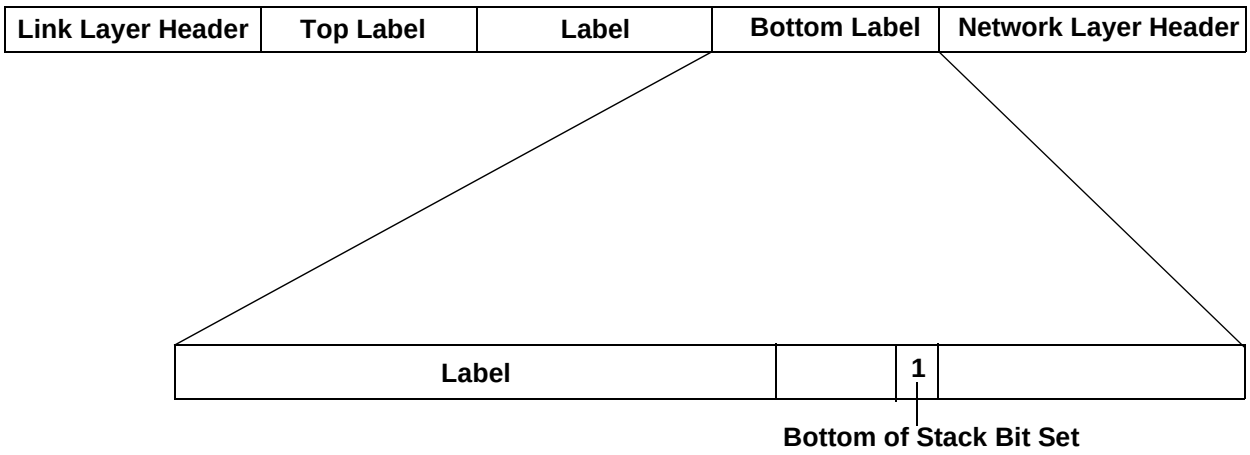


Figure 17-3 MPLS label stack

Forwarding decisions are always based on the top label in the stack. By examining the top label of an incoming packet, each LSR in the LSP determines the following:

- The next hop for the packet
- The operation to be performed on the packet's label stack. It can be one of the following:
  - replace (*swap*) the label at the top of the label stack with a new label
  - remove (*pop*) the top label in the label stack
  - swap the label at the top of the label stack with a new label, then add (*push*) a new label onto the label stack

Label stacks allow for hierarchical routing operations: for example, packets can be routed within an ISP network as well as at a higher, domain level. This allows MPLS packets to be tunneled through backbone networks. For more information about using MPLS tunneling, see Section 17.1.5, *"MPLS Tunnels."*

After a packet is labeled, the packet is forwarded through the network by switching the incoming label value with an outgoing label value at each router. A router that receives a labeled packet checks the label value to determine the next hop for the packet. A label value is relevant only to a particular hop between LSRs; in other words, a label value is significant only to two connected LSRs.

Label values 0 through 15 are reserved and have the following meanings:

Table 17-1 Reserved label values

Label Value	Meaning
0	IPv4 explicit null label. When it is the only label entry (i.e., there is no label stacking), it indicates that the label is popped upon receipt. For example, if the LSP is for IPv4 traffic only, the egress router can signal the penultimate router to use 0 as the final hop label.
1	Router alert label. Packets received with this label value are sent to the CPU for processing.

Table 17-1 Reserved label values

Label Value	Meaning
2	IPv6 explicit null label. When it is the only label entry (i.e., there is no label stacking), it indicates that the label is popped upon receipt. For example, if the LSP is for IPv6 traffic only, the egress router can signal the next to last, or penultimate, router to use 2 as the final hop label.
3	Implicit null label. Used in LDP or RSVP packets to request that the label be popped by the upstream router (penultimate hop label popping). This label should not appear in encapsulation and should not be used in a data packet.
4-15	Unassigned.

Table 17-2 is a summary of the label operations supported on the RS. These label operations are described in the following sections.

Table 17-2 MPLS label operations supported on the RS

Label bindings:	
per interface	if RSVP is used
per router	if LDP is used
Label distribution:	Downstream unsolicited—FEC-label bindings are distributed to peers when the RS is ready to forward packets in the FEC. Downstream unsolicited is supported for LDP. Downstream-on-demand is supported for RSVP.
Label retention:	Liberal—RS stores all labels learned from peers.
Label advertising:	Ordered—RS advertises FEC-to-label bindings only when it has previously received a label for the FEC from the FEC next-hop or when it is an egress router for the FEC.

17.1.2 Label Binding

As mentioned previously, in a non-MPLS network the assignment or *binding* of a packet to an FEC is based solely on the destination IP address in the packet header. In an MPLS network, packets that belong to the same FEC follow the same path, although more than one FEC can be mapped to a single LSP. At the ingress LSR, the assignment of a packet to an FEC can be influenced by external criteria and not just by the information contained in the packet header. For example, the following forwarding criteria can also be used to determine label assignment:

- destination unicast routing
- traffic engineering
- whether the packet is a multicast packet
- virtual private network (VPN) configuration

- quality of service (QoS)

The RS supports the following types of FEC-to-label bindings:

- Label bindings can be associated with interfaces. A separate pool of label values is defined for each interface on which MPLS is enabled.
- Label bindings for the router as a whole can be made from a single “global” pool of label values. Labels that are distributed on different interfaces *cannot* have the same value.

The label distribution protocol used determines whether the label bindings are assigned on a per-interface or per-router basis. See *"Label Distribution Protocols"* for more information.

17.1.3 Label Distribution and Management

Before the ingress LSR can label incoming packets for a specific FEC and forward the packets, the LSP must be set up. The binding of the label to the FEC is advertised to neighboring LSRs to establish the LSP. In Figure 17-4, packets sent from R1 to R2 for a particular FEC use the same label binding. In this relationship, R1 is the *upstream* LSR, while R2 is the *downstream* LSR. The downstream LSR determines the binding of a label to an FEC and informs the upstream LSR of the binding through a *label distribution protocol* (discussed later in this section).

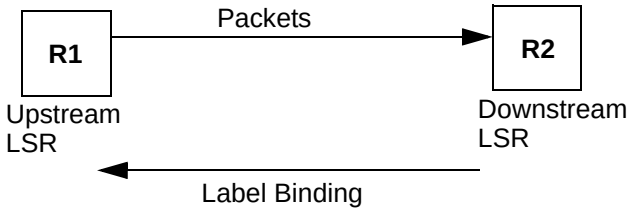


Figure 17-4 Label binding distribution

There are two ways an LSR can *distribute* label bindings:

- An LSR can explicitly request a label binding for a particular FEC from its next hop—this is called *downstream on demand* label distribution.
- An LSR can also distribute label bindings to other LSRs even if it has not been explicitly requested to do so—this is called *downstream unsolicited* label distribution. In *downstream unsolicited* mode, FEC-label bindings are distributed to peers when an LSR is ready to forward packets in the FEC.

Label Distribution Protocols

An LSP is defined by the set of labels from the ingress LSR to the egress LSR. When an LSR assigns a label to an FEC, it must let other LSRs in the path know about the label and its meaning. Label distribution protocols help to establish the LSP by providing a set of procedures that LSRs can use to distribute labels. Specifically, label distribution protocols allow an LSR to request a label from a downstream LSR so that it can bind the label to a specific FEC. The downstream LSR responds to the request from the upstream LSR by sending the requested label.

The RS supports the following protocols for label distribution:

- *Label distribution protocol* (LDP) is an IETF-defined protocol for LSRs to distribute labels and their meanings to LDP peers. LDP assigns labels from a single pool of labels on a router. To establish an LSP, LDP does not need to rely on routing protocols at every hop along the LSP. LDP allows the establishment of “best effort” LSPs; it does not provide traffic engineering mechanisms. LDP is required for tunneling of layer-2 frames across MPLS networks, as described in Section 17.6, *"Configuring L2 Tunnels."* For more information about configuring LDP on the RS, see Section 17.4, *"LDP Configuration."*
- *Resource reservation protocol* (RSVP) is a protocol that allows channels or paths to be reserved for high bandwidth transmissions. RSVP assigns labels on a per-interface basis. RSVP is used for traffic engineering, which is often required in core or backbone networks where resources are not always available; see Section 17.7, *"Traffic Engineering."* For more information about configuring RSVP on the RS, see Section 17.3, *"RSVP Configuration."*

The LSP must be set up before packets can be forwarded through the MPLS network. Figure 17-5 shows how labels are created and distributed to create an LSP.

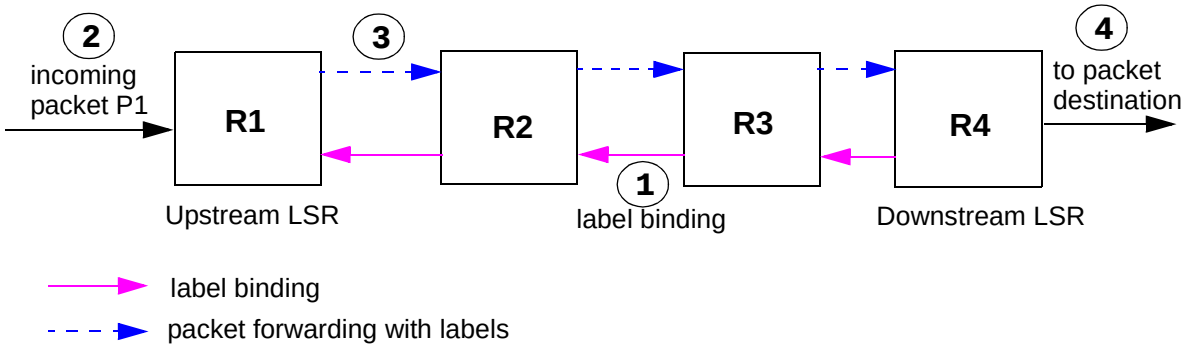


Figure 17-5 LSP creation and packet forwarding

1. Downstream routers distribute label bindings to upstream neighbors.
2. Packet P1 is received at router R1.
3. Router R1 inserts the appropriate label into the packet and forwards it to the next hop. The packet label is examined, replaced and forwarded through the MPLS network. (If R1 does not find a match for this FEC, the packet is forwarded using IP forwarding table information.)
4. The label is removed and forwarded using information in the IP forwarding table at R4.

Label Advertising Mode

An LSR can advertise label bindings to its peers in one of two modes:

- It can make an independent decision to bind a label to an FEC and distribute that binding to its peers—this is called *independent* mode.
- It can bind a label to a particular FEC if it is the egress LSR for that route or if it has already received a label binding for that FEC from its next hop for the route—this is called *ordered* mode.

The RS supports only ordered label advertising.

Label Retention Mode

An LSR can *store* the label bindings in one of two modes:

- Only label bindings received from next hop downstream LSR peers are stored—this is called *conservative* label retention.
- All label bindings received from peer LSRs are stored, even if the peer is *not* the next hop for a route—this is called *liberal* label retention.

The RS supports only liberal label retention.

17.1.4 Penultimate Hop Popping

The next-to-last LSR in an LSP, or the *penultimate* LSR, can pop the label stack. This process, called penultimate hop popping (PHP), has the following advantage: If the penultimate LSR does not pop the label stack, the egress LSR must do two table lookups to process the packet: first, it must look at the top label in the stack and pop the stack. Then it must either look at the next label in the stack, or if there is no other label in the stack, look up the packet's destination address to forward it. By having the penultimate LSR pop the label stack, there is only a single table lookup performed at each of the egress and penultimate LSRs. By default, RS routers that are PHP LSRs pop the label stack. You can configure the RS egress router to notify the PHP router to *not* pop the label stack.

17.1.5 MPLS Tunnels

You can use MPLS label stacks, instead of network layer encapsulation, to tunnel packets across a backbone MPLS network. Tunneling allows shared resources, such as public networks, to be used to carry private communications. For example, companies can use VPN tunnels to send intranet traffic over the Internet. The advantage that MPLS offers is that the contents of the tunneled data packets do not need to be examined as they proceed through an LSP, as the forwarding of the packets is based only on the attached labels.

Multiple LSPs traveling between the same LSRs across a network can be sent together on a higher-level tunnel LSP. The packets to be sent through the tunnel LSP are considered to be a single FEC by the LSR at the tunnel entrance. This LSR pushes an additional label onto the packets that enter the tunnel LSP before sending the labeled packets to the next hop in the tunnel. When the packets emerge from the tunnel LSP, the top label is popped.

In Figure 17-6, R1 is the ingress LSR for an LSP to the egress LSR, R4. R2 is the entry point for the tunnel LSP and R3 is the exit point for the tunnel LSP.

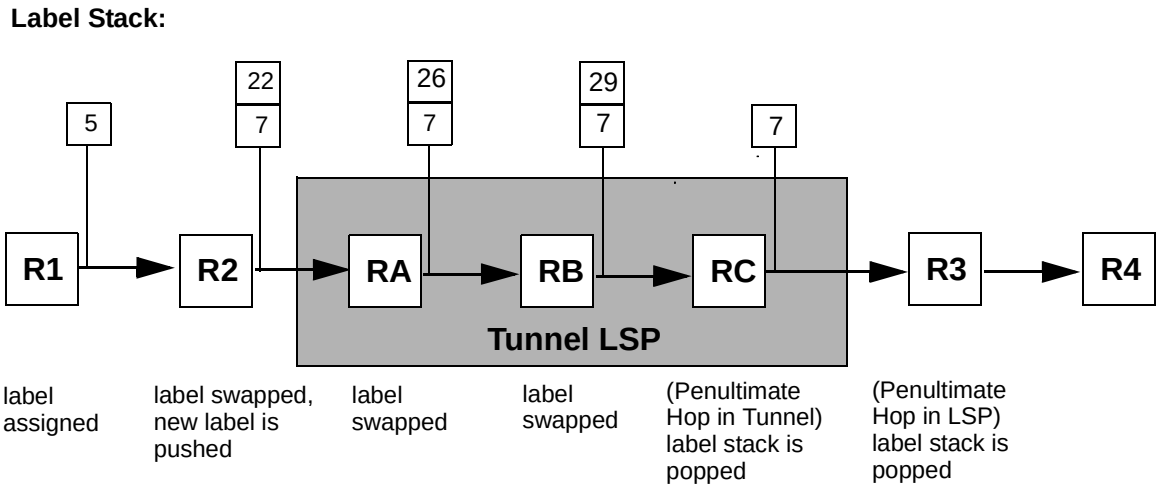


Figure 17-6 LSP tunneling

R1 assigns the label “5” to packets for the LSP to R4. At R2, the label value is swapped from “5” to “7.” R2 also determines that the packet destined for R3 must pass through the tunnel. It pushes onto the label stack for the packet a new label “22,” a label that is meaningful to the router RA, before forwarding the packet to RA. At the tunnel routers, RA, RB, and RC, label switching is done on the level 2 label. Note that the bottom label in the label stack retains its value as the packet is forwarded through the tunnel LSP; only the top label in the stack is switched.

At RC, the penultimate hop in the tunnel LSP, the label stack is popped before the packet is forwarded out of the tunnel to R3. At R3, the penultimate hop in the LSP, the label stack is popped once again before the unlabeled packet is forwarded to R4.

Note that each LSP is unidirectional. In most cases, it is desirable to have two MPLS LSPs, one going in each direction, to form a logical pipe for the flow of data.

17.1.6 Using SmartTRUNKS with MPLS

SmartTRUNKs can be used as MPLS links (see Figure 17-7). When MPLS commands require a port be specified, the SmartTRUNK number is supplied, instead. For example, consider the following command line actions:

```
rs(config)# mpls connect customer-profile Cust1 out-port ?
[out-port] requires a value of this type:
        (A single instance, no lists allowed)
   SmartTRUNK             - example: st.1
   Gigabit                - example: gi.5.1
   Ethernet               - example: et.2.1

rs(config)# mpls connect customer-profile Cust1 out-port st.3 remote-peer 3.3.3.3
rs(config)# save active
```

Notice that the question mark after the parameter **`out-port`** displays a list of valid port types, among which, the syntax for specifying a SmartTRUNK is displayed (`st.1`). In the next action, a predefine SmartTRUNK (**`st.3`**) is specified as the **`out-port`**.

When using SmartTRUNKS as MPLS links, it’s important to remember the following:

- When MPLS is set up over a SmartTRUNK, one of the SmartTRUNK's links is elected to carry all signaling traffic. This link will continue to carry all signaling traffic for the life of the MPLS link.
- Load balancing (the way traffic is shared among the links making up the SmartTRUNK) is performed on a per-LSP basis. In other words, load balancing across the SmartTRUNK does not consider what is inside the LSP – for example, no load balancing is performed on a set of layer-2 tunnels that exist within an LSP.
- If a fault occurs with one of the links that make up the SmartTRUNK, the LSPs assigned to the faulty link are redistributed to the remaining SmartTRUNK links.

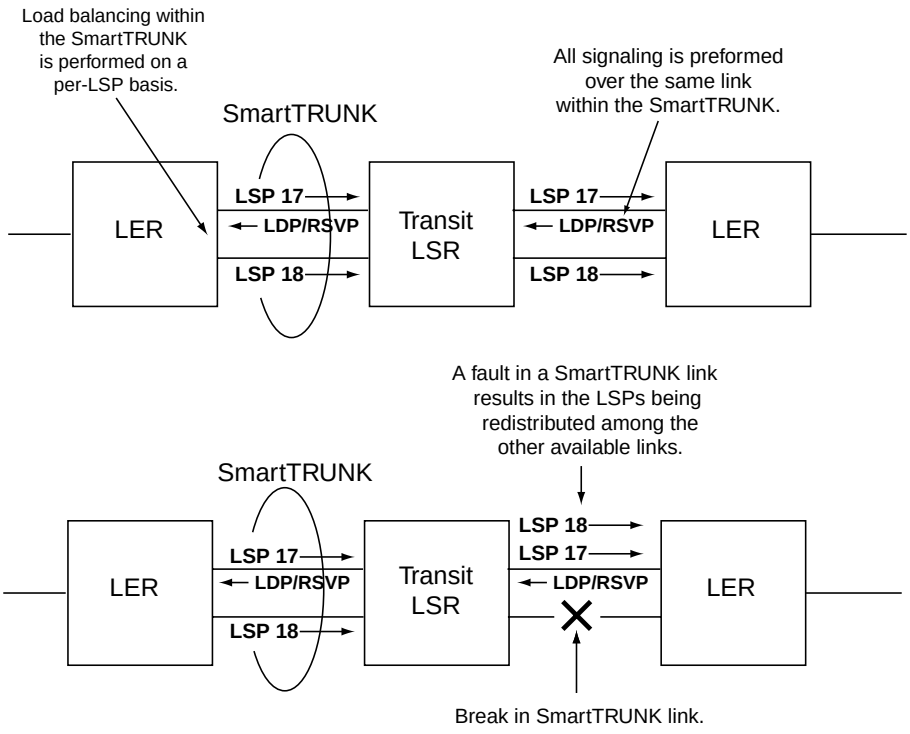


Figure 17-7 LSPs over SmartTRUNKs

17.1.7 MPLS Table Information

This section describes the various tables that are used to process MPLS packets on the RS.

Output Tag Table (OTT)

The OTT contains information about labels that are to be pushed onto or popped off the MPLS label stack. The OTT entry can also indicate that all labels should be popped off the packet's label stack (Penultimate Hop Popping). Use the **`mpls show hw-ott-tbl`** command to display entries in the hardware OTT by port and index number. OTT information is also maintained in the software; use the **`mpls show ott-table`** command to display OTT information by interface name or IP address or for all interfaces. The **`mpls show ott-table`** command also displays the index number for the entry in the hardware OTT.

Incoming Label Map (ILM)

The ILM contains mappings of labels to output channels and ports. Each entry in the ILM provides an index into the OTT. When an MPLS labeled packet arrives at the RS, the router uses the top label to perform a lookup in the ILM table. From the ILM table entry, the RS determines the proper channel and port on which to forward the packet onto the LSP. (If there is no matching ILM table entry for a label value in an incoming packet, the packet is dropped.)

Use the **`mpls show hw-ilm-tbl`** command to display entries in the hardware ILM by port and index number. ILM information is also maintained in the software; use the **`mpls show ilm-table`** command to display ILM information by interface name or IP address or for all interfaces.

Content Address Memory (CAM)

The CAM is used to map L2 packets to FECs and VC LSPs to the OTT entries. The RS performs a CAM lookup only if it is the ingress LSR for an LSP. An entry in the CAM table contains the destination and source MAC address, ethertype, VLAN, port of entry (POE), and 802.1q priority. If a CAM entry exists for an L2 packet, the RS retrieves the appropriate OTT index. The OTT entry identified by the OTT index provides the label to be pushed onto the label stack of the MPLS packet. Use the **`mpls show hw-cam-tbl`** command to display entries in the CAM by port and index number.

Table Lookups at Ingress LSRs

On ingress LSRs, incoming packets must be classified into FECs in order to put MPLS labels on the packets. The RS performs OTT lookups to transform packets into MPLS labeled packets. For MPLS labeling of *routed* packets, the OTT lookup is based on the L3 table entry. For MPLS labeling of *bridged* packets, a CAM lookup is first performed using the L2 header information. If there is a matching CAM entry, there is an FEC for these bridged packets and the corresponding OTT index is returned. The OTT entry identified by the OTT index provides the label to be pushed onto the label stack of the MPLS packet.

Table Lookups at Transit LSRs

On transit LSRs, MPLS packets are switched from the input port to the output port of the LSR using only the information in the top label of the MPLS packet. When a labeled packet arrives at the transit LSR, the router looks up the top label in the ILM table to determine the exit port on the LSR for the packet and the corresponding OTT entry. Before the packet leaves the LSR, the top label must be replaced with another label, since labels only have significance between two LSRs that are connected together. The OTT entry determines the new label for the top of the stack. Before the MPLS packet leaves the LSR, the MPLS time to live (TTL) for the top label is decremented, the top label is discarded, and the new label value from the OTT entry is put in its place.

Table Lookups at Egress LSRs

On egress LSRs, the processing of MPLS packets is similar to that done on transit LSRs. The LSR looks up the top label in the ILM table. For any of the following conditions, the MPLS packet is decapsulated and forwarded as a routed or bridged packet:

- the ILM entry indicates that this is the end of an L2 tunnel
- the END_OF_TUNNEL label is the only label on the label stack
- the ILM entry indicates that this node is at the end of the outermost MPLS domain

- the explicit null label (label value 0) is the only label on the stack

LSP-Ping

The LSP-Ping facility allows one to determine connectivity between two Label Edge Routers (LERs) running MPLS. If the Label Switched Path (LSP) was set up using LDP, connectivity is determined by pinging using the IP address and subnet mask of the interface on which the LSP resides. If RSVP was used to set up the LSP, connectivity is determined by pinging the name of the interface on which the LSP resides.

To use the **lsp-ping** command, first enable the LSP ping task from within Configure mode, using the **lsp-ping enable task** command. Once this is done, connectivity between two LERs can be tested by performing a ping

For example, the following uses the IP address/mask of the LER interface on which the LSP resides:

```
rs# lsp-ping ldp 111.1.1.1/32
```

The following example uses the interface name (**lsp1**) of the LSP created by RSVP:

```
rs# lsp-ping rsvp lsp1
```

See the *LSP-Ping* chapter of the *Riverstone Networks Command Line Interface Manual* for more details regarding the use of the **lsp-ping** command.

Note LSP-ping works only between LERs. It cannot be used to ping individual Transit Routers.

17.2 ENABLING AND STARTING MPLS ON THE RS

You must enable and start MPLS on all routers and all router interfaces that may become part of an LSP. You must also enable and start either RSVP or LDP on the same routers and router interfaces[2]. When you enable MPLS and either RSVP or LDP on the RS, MPLS uses RSVP or LDP to set up the configured LSPs. For example, when you configure an LSP on the RS with both MPLS and RSVP running, RSVP initiates a session for the LSP. RSVP uses the local router as the RSVP session sender and the LSP destination as the RSVP session receiver. When the RSVP session is created, the LSP is set up on the path created by the session. If the session is not successfully created, RSVP notifies MPLS; MPLS can then either initiate backup paths or retry the initial path.

Note For both RSVP and LDP, you must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

The following CLI commands allow the RS to send and receive labeled packets:

```
! Enable MPLS on router interfaces
mpls add interface int1
mpls add interface int2
! Start MPLS on the router
mpls start
```

In the above example, MPLS is enabled on the interfaces ‘int1’ and ‘int2’. Note that no MPLS processing occurs on the router until MPLS is started with the **`mpls start`** command. This allows you to configure MPLS path information, using other **`mpls`** commands, before starting MPLS.

LSRs can use RSVP to establish and maintain LSPs. As mentioned previously, RSVP is a protocol that allows channels or paths to be reserved for specified transmissions. The following CLI commands enable RSVP on the RS:

```
! Enable RSVP on router interfaces
rsvp add interface int1
! Start RSVP on the router
rsvp start
```

In the above example, RSVP is enabled on the interface ‘int1’. No RSVP processing occurs on the router until RSVP is started with the **`rsvp start`** command and no LSP creation occurs until MPLS is enabled and started. You can optionally configure RSVP, using the **`rsvp set`** commands, before starting RSVP. For more information about configuring RSVP, see Section 17.3, *"RSVP Configuration."*

2. You do not need to enable RSVP or LDP if you are configuring *static* LSPs. See Section 17.5.1, *"Configuring L3 Static LSPs."*

LSRs can also use LDP to distribute labels and their meanings to LDP peers. LDP enables LSR peers to find each other and establish communications. The following CLI commands enable LDP on the RS:

```
! Enable LDP on router interfaces
ldp add interface int2
! Start LDP on the router
ldp start
```

In the above example, LDP is enabled on the interfaces ‘int2’. No LDP processing occurs on the router until LDP is started with the **ldp start** command and no LSP creation occurs until MPLS is enabled and started. You can optionally configure LDP, using other **ldp** commands, before starting LDP. For more information about configuring LDP, see Section 17.4, *"LDP Configuration."*

LDP and RSVP each generate signaling traffic to establish and maintain LSPs. In general, you should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used. For example, issuing the **rsvp add interface all** and **mpls add interface all** commands is an expedient way to enable RSVP and MPLS on all router interfaces. However, if you are using MPLS on a handful of interfaces only, this creates an unnecessary amount of processing overhead and signaling traffic.

17.3 RSVP CONFIGURATION

Network hosts use the Resource Reservation Protocol (RSVP) to request certain qualities of service from the network for application data flows. Routers also use RSVP to deliver quality of service (QoS) requests to all nodes on the path of a data flow, and to establish and maintain refresh states to provide the requested service. Resources, such as link bandwidth, are reserved on each node along a data path as a result of RSVP requests.

RSVP makes reservations for *unidirectional* data flows, that is, resource requests are made in only one direction. RSVP senders are distinct from receivers, although an application can be both an RSVP sender and receiver at the same time. RSVP operates on top of IP, however it does not transport application data and is only concerned with the QoS of the packets that are forwarded. RSVP is designed to operate with unicast and multicast routing protocols: the routing protocols determine where packets are forwarded, while the RSVP process consults local routing tables to obtain routes.

Note RSVP on the RS supports dynamic signaling for MPLS LSPs only. It does *not* support IP multicast sessions, or resource reservations for real-time audio or video flows.

Note You must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

You must enable both RSVP and MPLS on each router interface on which you want RSVP to run. You also need to enable a unicast routing protocol (for example, OSPF) on the same interface; otherwise, LSPs may not be established between an egress router and all ingress routers. RSVP can be enabled on all router interfaces or on specific router interfaces, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."* The following configuration commands enable and start RSVP and MPLS on the router interface **`to_r1`** on the RS:

```
rsvp add interface to_r1
rsvp start
mpls add interface to_r1
mpls start
```

Note You should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used, as this creates an unnecessary amount of processing overhead and signaling traffic.

17.3.1 Establishing RSVP Sessions

RSVP includes the following types of messages:

- *Path* messages travel from the potential sender of the data flow to the receiver and include traffic specifications and QoS requirements provided by the sender. Path messages establish the RSVP path between the sender and the path flow destination, storing a *path state* in each router along the way. The path state includes the unicast IP address of the previous hop.
- *Resv* messages travel from the intended receiver of the data flow to the sender and identify the session for which the reservation is being made, the level of QoS required by the receiver, and the label binding for the session. Resv messages use the path state information in each router to follow exactly the reverse path (or paths) that the data packets will use, creating and maintaining a *reservation state* in each router along the path(s).
- *Teardown* messages delete the reservation. Although RSVP uses session timeouts, teardown messages are a more efficient way to release network resources. Either the sender or receiver of a data flow can initiate a teardown request: *PathTear* messages are sent by the sender of the data flow, and *ResvTear* messages are sent by the data flow receiver.

Figure 17-8 illustrates the flow of RSVP Path and Resv messages.

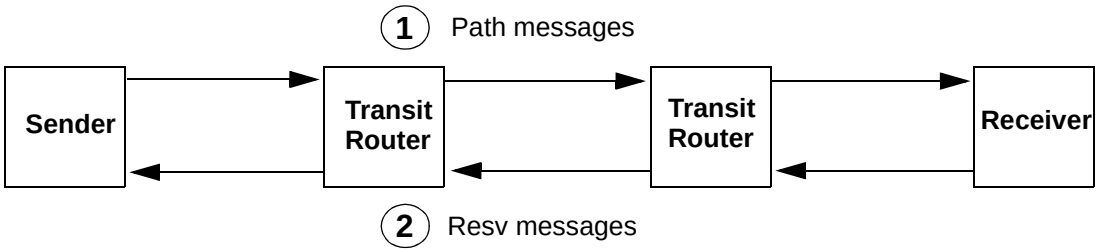


Figure 17-8 RSVP Path and Resv messages

With RSVP, the potential *receiver* of a data flow is responsible for initiating and maintaining the resource reservation for that flow. The receiver passes a QoS request to the local RSVP process. The RSVP protocol then carries the request to all routers upstream to the data sender(s).

During reservation setup, RSVP determines:

- whether the router has sufficient available resources to supply the requested QoS, and
- whether the requestor has the administrative permission required to make the reservation

If either of the above checks fail, RSVP returns an error notification to the requestor. Otherwise, if both checks succeed, the reservation is made at the link layer and the request is propagated upstream toward the appropriate sender.

RSVP uses a *soft state* approach to managing the reservation state in routers, that is, the state is created and periodically refreshed by Path and Resv messages. When a path or reservation state times out, the reservation is deleted or torn down. An explicit teardown message, either PathTear or ResvTear, can also delete the reservation.

Table 17-3 is a summary of the RSVP parameters on the RS and their default values. The commands that you use to enable an RSVP operation or change a default value are also listed.

Table 17-3 RSVP parameters on the RS

Parameter	Default Value	Command to Change Default Value
Path refresh:		
path refresh interval	30 seconds	**rsvp set global path-refresh-interval**
path multiplier	3	**rsvp set global path-multiplier**
Reservation refresh:		
reservation refresh interval	30 seconds	**rsvp set global resv-refresh-interval**
reservation multiplier	3	**rsvp set global resv-multiplier**
Hello packets:	(Disabled)	**rsvp set interface** <*interface*> **hello-enable**
hello interval	3 seconds	**rsvp set global hello-interval**
hello multiplier	3	**rsvp set global hello-multiplier**
Authentication:	(Disabled)	
MD5 signature		**rsvp set interface** <*interface*> **auth-method md5**
Blockade aging:		
interval	60 seconds	**rsvp set global blockade-aging-interval**
Message aggregation:	(Disabled)	**rsvp set interface** <*interface*> **aggregate-enable**
bundle interval	5 seconds	**rsvp set global bundle-interval**
Message ID extensions:	(Disabled)	**rsvp set interface** <*interface*> **msgid-extensions-enable**
summary refresh interval	3 seconds	**rsvp set global msgid-list-interval**
acknowledgement interval	1 second	**rsvp set global msgack-interval**
LSP preemption:	(Disabled)	**rsvp set global preemption**

The following sections describe the RSVP parameters in more detail.

17.3.2 RSVP Refresh Intervals

As mentioned previously, RSVP soft state management depends upon periodic refreshes of the Path and Resv messages. RSVP Path and Resv refresh messages are sent periodically to refresh the states in neighbor routers and ensure that these states do not time out.

In the following formulas, *lifetime* is how long an RSVP router keeps a path or reservation state as a valid state:

*path-lifetime = path-multiplier * path-refresh-interval*

*resv-lifetime = resv-multiplier * resv-refresh-interval*

The *path-refresh-interval* and *resv-refresh-interval* are the periods of time between the generation of successive refresh messages by an RSVP neighbor. The *path-refresh-interval* or *resv-refresh-interval* is set locally at each RSVP router; this value is sent to neighbor routers in Path and Resv messages, respectively. The receiving RSVP node uses the values contained in the messages to calculate the *path-lifetime* or *resv-lifetime* for the path or reservation state. On the RS, the default interval for both Path and Resv refreshes is 30 seconds.

The *path-multiplier* and *resv-multiplier* are integers between 1 and 255 that are configured on the local router. On the RS, the default for both multipliers is 3.

For example, if the *path-multiplier* is set locally at 3 and the *path-refresh-interval* received from an RSVP neighbor is 30 seconds, then:

path-lifetime = 3 * 30 = 90 seconds

[*path-multiplier* minus 1] successive Path refresh messages may be lost without the path state timing out. For example, the *path-multiplier* default value on the RS is 3; 2 successive Path refresh messages can be lost without the path state timing out.

On the RS, you can use the **`rsvp set global`** command to set the values for the Path and Resv refresh intervals and multipliers:

- The **`path-refresh-interval`** parameter specifies the interval at which RSVP sends out Path messages to the downstream neighbor. The default value is 30 seconds.
- The **`resv-refresh-interval`** parameter specifies the interval at which RSVP sends out Resv messages to the upstream neighbor. The default value is 30 seconds.
- You can specify a **`path-multiplier`** parameter value between 1 and 255. The default value is 3.
- You can specify a **`resv-multiplier`** parameter value between 1 and 255. The default value is 3.

17.3.3 RSVP Hello Packets

The RS supports the sending of RSVP hello packets on a per-interface basis. Sending hello packets allows RSVP routers to detect the loss of RSVP state information of a neighbor node, for example, when a link fails or the neighbor router restarts. RSVP hello packets can detect the state change of a neighbor node more quickly than simply relying on RSVP soft state timeouts. For example, if a link fails, RSVP hello packets can detect the state change in about 9 seconds, compared to 90 seconds for an RSVP soft state timeout.

When hello packets are enabled on an interface, RSVP sends unicast hello packets to the RSVP neighbor on that interface. On an RS interface, hello packets are sent by default at 3-second intervals. RSVP sessions with a neighbor node are considered to be “down” if hello packets are not received within the following time period:

*hello-interval * hello-multiplier*

On the RS, the default for the *hello-multiplier* is 3. Thus, if hello packets are not received from a neighbor within 9 seconds, that neighbor and its RSVP session are considered to be down.

Sending RSVP hello packets is disabled by default on the RS. You can enable RSVP hello packets on an interface with the **`hello-enable`** parameter of the **`rsvp set interface`** command. For example, the following command enables RSVP hello packets on the interface ‘int2’:

```
rsvp set interface int2 hello-enable
```

If an RSVP neighbor on the interface does not support hello packets, soft state timeouts are used to detect loss of state information.

By default, RSVP hello packets are sent at 3-second intervals. You can change this interval with the **rsvp set global hello-interval** command. For example, the following command sets the sending of RSVP hello packets to 5-second intervals:

```
rsvp set global hello-interval 5
```

By default, the RSVP hello multiplier is 3. You can change this variable with the **rsvp set global hello-multiplier** command. For example, the following command sets the RSVP hello multiplier to 5:

```
rsvp set global hello-multiplier 5
```

If RSVP hello packets are supported on all neighbor nodes, you can increase RSVP refresh intervals and thereby reduce the refresh overhead. (See Section 17.3.2, *"RSVP Refresh Intervals."*) Refresh operations will consume less CPU and bandwidth, allowing scaling for a larger number of sessions. The time needed for node or link failure detection is not adversely impacted.

17.3.4 Authentication

RSVP messages can be authenticated to prevent unauthorized nodes from setting up reservations. On the RS, RSVP authentication is enabled on a per-interface basis; RSVP authentication is disabled by default. If RSVP authentication is used, all routers connected to the same IP subnet must use authentication. Authentication is performed on all RSVP messages that are sent or received on an interface where RSVP authentication is enabled.

RSVP on the RS supports the IETF standard MD5 signature authentication. To set RSVP authentication for an interface on the RS, use the **rsvp set interface** command. Use the **auth-key** parameter to specify the password.

For example, the following command sets the MD5 password ‘p55717’ for RSVP sessions on the interface ‘int2’:

```
rsvp set interface int2 auth-key p55717
```

In the above example, if you specify **interface all,** the MD5 password is applied to *all* RSVP sessions on the router.

17.3.5 Blockade Aging Interval

A “killer reservation” situation occurs when an RSVP reservation request effectively denies service to any other request. For example, an RSVP node attempting (and failing) to make a large reservation can prevent smaller reservation requests from being forwarded and established. On the RS, when there is a reservation error, the offending request enters a *blockade state* for a predetermined amount of time. While a reservation request is *blockaded*, smaller requests can be forwarded and established.

On the RS, the default time that a request can be blockaded is 60 seconds. You can change this interval with the **rsvp set global blockade-aging-interval** command. For example, the following command sets the blockade interval to 50 seconds:

```
rsvp set global blockade-aging-interval 50
```

17.3.6 RSVP Refresh Reduction

As described previously, RSVP uses Path and Resv refresh messages to maintain states between RSVP neighbors. Each RSVP session requires that refresh messages be generated, transmitted, received, and processed for each refresh period. Supporting a large number of RSVP sessions presents a scaling problem as the resources required for processing these messages increase proportionally with the number of RSVP sessions.

The RS supports the following features that can reduce the overhead required to process refresh messages on a per-interface basis:

- Message aggregation
- Message ID extensions

The following sections describe how to configure and use these features.

RSVP Message Aggregation

The RS supports the aggregation, or bundling, of multiple RSVP messages on a per-interface basis. Message aggregation helps to scale RSVP by reducing processing overhead and bandwidth consumption. Aggregated RSVP messages can only be sent to RSVP neighbors that support message aggregation. Aggregated RSVP messages must *not* be used if the RSVP neighbor does not support message aggregation.

RSVP message aggregation is disabled by default on the RS. You can enable message aggregation on an interface with the **aggregate-enable** parameter of the **rsvp set interface** command. For example, the following command enables RSVP message aggregation on the interface 'int2':

```
rsvp set interface int2 aggregate-enable
```

If message aggregation is enabled on an interface, traffic headed to a specific destination is aggregated at 5-second intervals. You can change this interval with the **rsvp set global bundle-interval** command. For example, the following command sets RSVP message aggregation to 7-second intervals:

```
rsvp set global bundle-interval 7
```

Message ID Extensions

The RS supports message ID extensions, as defined by RFC 2961. These message IDs are generated and processed over a single hop between RSVP neighbors. Enabling message ID extensions provides the following functions:

- *Summary refresh* allows RSVP neighbors to readily identify unchanged messages, thereby reducing refresh message processing. An unchanged message is a message that represents a previously-advertised state, contains the same information as a previously-transmitted message, and is sent over the same path.
- Use of *acknowledgements* between RSVP neighbors to detect message loss and to support reliable RSVP message delivery.

RSVP message ID extensions are disabled by default on the RS. You can enable message ID extensions on an interface with the **msgid-extensions-enable** parameter of the **rsvp set interface** command. For example, the following command enables RSVP message ID extensions on the interface 'int2':

```
rsvp set interface int2 msgid-extensions-enable
```

Summary refresh is used to refresh Path and Resv states without transmitting standard Path or Resv messages. Summary refresh is the periodic transmittal of a list of the message IDs associated with states that were previously advertised in Path or Resv messages. The message ID list reduces the amount of information that must be transmitted and processed in order to maintain RSVP state synchronization. By default, the message ID list is sent at 3-second intervals if message ID extensions are enabled for an interface. You can change this interval with the **`rsvp set global msgid-list-interval`** command. For example, the following command sets the transmission of the message ID list to 5-second intervals:

```
rsvp set global msgid-list-interval 5
```

Acknowledgements are sent between RSVP neighbors that support message ID extensions. When message ID extensions are enabled, acknowledgements are sent for RSVP messages that advertise state or any other information that was not previously transmitted. Message acknowledgements can be sent in any RSVP message that has an IP destination address that matches the original message generator. Or, the acknowledgement can be sent in a separate acknowledgement message, if no appropriate RSVP message is available. If an acknowledgement is delayed, the corresponding message is retransmitted. To avoid retransmission, the acknowledgement should be sent at minimal intervals. On the RS, the default interval for sending message acknowledgements is 1 second. You can change this interval with the **`rsvp set global msgack-interval`** command. For example, the following command sets the transmission of message acknowledgements to 3-second intervals:

```
rsvp set global msgack-interval 3
```

17.3.7 LSP Preemption

When there is not enough bandwidth to establish new LSPs, it may be desirable to *preempt* an already-established LSP to allow a higher-priority LSP to be established. The priority of an LSP depends upon its **`setup-priority`** and **`hold-priority`** values, as configured with the **`mpls create|set label-switched-path`** commands. (See *"Setup and Hold Priority"* for information about configuring the **`setup-priority`** and **`hold-priority`** parameters for an LSP.)

By default, preemption of LSPs is not enabled on the RS. The following command enables LSP preemption for RSVP-signaled LSPs:

```
rsvp set global preemption
```

If preemption is enabled, a new LSP can preempt an already-established LSP under the following conditions:

- The **`setup-priority`** value of the new LSP must be greater than the **`hold-priority`** value of the already-established LSP. For example, an LSP with a **`setup-priority`** value of 0 (highest priority) can preempt an LSP with a **`hold-priority`** value of 7 (lowest priority).
- There must be enough bandwidth created by preempting the existing LSP to establish the new LSP. If preempting the existing LSP would not create enough bandwidth to support the new LSP, then preemption will not take place.
- If multiple LSPs qualify for preemption, the LSP with the most bandwidth would be preempted.
- The **`hold-priority`** value of the existing LSP must be relatively low so that it can be preempted by the new LSP. For example, if the **`hold-priority`** value of the existing LSP is 0 (highest priority), other LSPs cannot preempt it.

To avoid preemption loops, you must not configure an LSP with both a high **setup-priority** value and a low **hold-priority** value. The **hold-priority** value of the LSP must be equal to or higher than the **setup-priority** value.

Note If link bandwidth has to be changed for active LSPs on a link interface, first bring down all LSPs that use this link interfaces, change their bandwidths, and then reestablish the LSPs.

17.3.8 Displaying RSVP Information

Table 17-4 is a summary of the RSVP session information that you can display on the RS and the CLI commands that you use to display the information.

Table 17-4 RSVP session information

To see this information:	Use this command:
RSVP global, path state block, reservation state block, traffic control state block, session, and neighbor information.	**rsvp show all**
RSVP global parameters	**rsvp show global**
RSVP interface parameters	**rsvp show interface**
RSVP neighbors, next-hop, and number of sessions	**rsvp show neighbors**
RSVP path state block information	**rsvp show psb**
RSVP reservation state block information	**rsvp show rsb**
RSVP session information	**rsvp show session**
RSVP traffic control state block information	**rsvp show tcsb**

17.4 LDP CONFIGURATION

LDP is a set of procedures and messages that allow LSRs to establish an LSP through a network by mapping network-layer routing information to data-link layer switched paths. The LSP can have an endpoint at a directly attached neighbor or it may have an endpoint at an egress LSR with switching enabled via transit LSRs. LDP supports label distribution for MPLS forwarding along normally-routed paths (as determined by destination-based routing protocols); this is also called MPLS *hop-by-hop forwarding*.

LDP allows the establishment of *best-effort* LSPs and is generally used where traffic engineering is *not* required. In contrast, RSVP is generally used for label distribution and LSP setup where traffic engineering is necessary, primarily in backbone networks. LDP is also used for signaling layer 2 FEC-to-label mappings to tunnel L2 frames across an MPLS network, as discussed in Section 17.6.1, *"Configuring Dynamic L2 Labels."*

You must enable both LDP and MPLS on each router interface on which you want LDP to run. You also need to enable a unicast routing protocol (for example, OSPF) on the same interface; otherwise, LSPs may not be established between an egress router and all ingress routers. LDP can be enabled on all router interfaces or on specific router interfaces, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."* The following configuration commands enable and start LDP and MPLS on the router interface **`to_r1`** on the RS:

```
ldp add interface to_r1
ldp start
mpls add interface to_r1
mpls start
```

Note You must configure the router identifier on the LSR with the **`ip-router global set router-id`** command.

Note You should not enable LDP, RSVP, or MPLS on interfaces where they will *not* be used, as this creates an unnecessary amount of processing overhead and signaling traffic.

17.4.1 Establishing LDP Sessions

LSRs that use LDP to exchange FEC-label binding information are called LDP *peers*. LDP allows LSRs to automatically discover potential LDP peers. When LDP is started on the RS, the router attempts to discover other LDP peers by sending LDP hello packets out on its LDP-enabled interfaces. LDP hello packets are sent as multicast UDP packets. If multiple LDP-enabled interfaces exist between two adjacent routers, only one LDP session is established between the routers.

An LDP session using a TCP connection is established between LDP peers to exchange the binding information. When an LDP peer is discovered, the LSR attempts to establish an LDP session through the well-known port 646. After session parameters are successfully negotiated between the peers, the session is used for label distribution.

17.4.2 Monitoring LDP Sessions

In addition to discovering LDP peers, sending hello packets also allows LDP nodes to detect link or peer node failures. When LDP is started, the RS sends out LDP hello packets every 5 seconds by default. The hello message includes a hold time value that tells the router's peers how long to wait for a hello message. Since the hold time is set by each LDP router, its neighbors can assume that a router or link is down if they do not receive a hello packet from the router within the specified hold time. The default hello hold time used by LDP on the RS is 15 seconds. You can use the **`ldp set interface`** command to specify a different hello hold time for LDP peers on a specific interface or on all router interfaces. For example, the following command sets the LDP hello hold time to 20 seconds on the interface 'int1':

```
ldp set interface int1 hold-time 20
```

LDP neighbors do not have to set the *same* hold time value. For example, router R1 can set a hold time of 15 seconds, while its neighbor R2 can set a hold time of 20 seconds.

Once an LDP session is established, LDP keepalive packets are used to monitor the status of the session. On the RS, keepalive packets are sent at 10 second intervals and if the LDP peer does not respond in 30 seconds, the session is considered down. The default session timeout on the RS is 30 seconds. You can use the **`ldp set interface`** command to specify a different LDP session timeout for LDP peers on a specific interface or on all router interfaces. For example, the following command sets the LDP session timeout to 40 seconds on the interface 'int1':

```
ldp set interface int1 keepalive-timeout 40
```

Table 17-5 shows the default times used by the RS to monitor LDP sessions on both directly-connected LDP peers and remote LDP peers. (For more information about remote LDP peers, see Section 17.4.3, *"Remote Peers."*)

Table 17-5 Default LDP session monitoring parameters

Session monitoring parameters	LDP peer (direct-connect or remote)
Hello Messages:	
Send interval (not configurable - 1/3 of hold time)	5 seconds
Hold time	15 seconds
Session Keepalive Messages:	
Send interval (not configurable - 1/3 of timeout)	10 seconds
Timeout	30 seconds

17.4.3 Remote Peers

Note that only directly-connected peers are automatically discovered when LDP is started on the RS. If you need the router to establish LDP communications with an LSR that is *not* directly connected, enable LDP on the loopback interface lo0, and use the **ldp add remote-peer** command to specify the router ID of the remote LSR. For example:

```
ldp add interface lo0
ldp add remote-peer 100.100.100.102
```

Note The router ID of the remote LDP peer must be the loopback address of the remote router.

You can use the **ldp set remote-peer** command to specify the hold time for hello messages and the timeout for session keepalive messages for remote LDP peers. You can also use the **ldp set interface** command to specify the hello hold time for remote LDP peers and LDP neighbors.

For example, the following command sets a hold time of 60 seconds and a keepalive timeout of 45 seconds for the remote peer 100.100.100.102:

```
ldp set remote-peer 100.100.100.102 hello-hold-time 60 keepalive-timeout 45
```

You can use the **hold-time** parameter of the **ldp set interface** command to specify a different hello hold time for all LDP peers, including remote peers. Setting the hello hold time for a *specific* remote LDP peer (with the **ldp set remote-peer** command) takes precedence. The **ldp set interface all keepalive-timeout** command sets the keepalive timeout for all LDP peers, including remote peers. Setting the keepalive timeout for a specific remote LDP peer (with the **ldp set remote-peer** command) takes precedence.

17.4.4 Loop Detection

With conventional IP forwarding, packets carry a “Time to Live” (TTL) value in their headers. TTL protects against forwarding loops in the network. When a packet passes through a router, its TTL is decremented by 1. If the TTL reaches 0 before the packet reaches its destination, the packet is discarded. Certain LSP segments may not use TTL. To prevent label request messages from looping in LSPs that traverse non-TTL MPLS networks, you can enable loop detection on the RS. When enabling loop detection, you also specify the maximum path vector length (the path vector contains a list of LSRs traversed by the label request or label mapping message). When an LSR encounters a path vector length that reaches the specified limit, a loop is assumed.

For example, the following command enables path vector loop detection on the RS and sets the path vector limit to 100:

```
ldp set global path-vector-loop-detection-enable path-vector-limit 100
```

By default, the TCP session address used by LDP is the primary address of the interface on which LDP is enabled. You can specify that the TCP session address used by LDP is the address of the loopback interface with the following command:

```
ldp set global transport-address-loopback
```

17.4.5 MD5 Password Protection

Since LDP uses TCP as its transport, you can use the IETF standard MD5 signature option to protect LDP session connections. Use the **ldp set md5-password** command to set an MD5 password on a per-router, per-interface, or per-peer basis.

For example, the following command sets the MD5 password 'p55717' for LDP sessions with the peer 100.100.100.102:

```
ldp set md5-password p55717 peer 100.100.100.102
```

In the above example, if you omit the **peer** keyword and IP address, the MD5 password is applied to *all* LDP sessions on the router.

17.4.6 Using LDP Filters

With MPLS, there is no way to restrict which FECs are or are not bound to labels. You can, however, create and apply LDP filters that restrict the label *bindings* that are sent from downstream LSRs to upstream LSRs. You can also create and apply LDP filters that restrict the label *requests* that an upstream LSR can send to a downstream LSR.

If an upstream LSR does not have label binding information for a specific FEC, it will route packets based on information in the IP routing table. However, if there are several paths of equal cost to the same destination, LDP filters can exclude next-hops from considerations.

On the RS, you can define an LDP filter for:

- outgoing label requests—use the **ldp add export-filter request** command.
- incoming label requests—use the **ldp add import-filter request** command.
- outgoing label bindings—use the **ldp add export-filter mapping** command.
- incoming label bindings—use the **ldp add import-filter mapping** command.

Note A filtered *incoming* label binding will still appear in the LDP input label database (displayed with the **ldp show database verbose** command) on the local router, but will not be considered for LSP establishment. A filtered *outgoing* label binding is not advertised to the specified neighbor LSR, although it will still be advertised to other LDP neighbors and considered by the local router for LSP establishment.

The following shows LDP filter commands configured on the router rs1. The first command specifies that bindings for 6.6.6.6/32 from the neighbor router 6.6.6.6 are *not* to be used for LSP establishment. The second command allows all other bindings from the same neighbor router to be accepted and used for LSP establishment. Note that the more restrictive filter command has the lower sequence number and will be executed first.

```
rs1(config)# ldp add import-filter mapping network 6.6.6.6/32 restrict neighbor
6.6.6.6 sequence 1
rs1(config)# ldp add import-filter mapping network all neighbor 6.6.6.6 sequence 2
```

Note that if you run the **ldp show database verbose** command on rs1 (see the following example), the label binding for 6.6.6.6/32 appears in router rs1's LDP database, but it is marked as "Filtered" (shown in boldface in the example) and is therefore not considered on rs1 for LSP establishment.

```
rs1# ldp show database verbose

Input label database, 1.1.1.1:0-6.6.6.6:0
  Label     Prefix
   2051     1.1.1.1/32
            State:Active
   2052     3.3.3.3/32
            State:Active
     16     6.6.6.6/32
            State:Active, Filtered

Output label database, 1.1.1.1:0-6.6.6.6:0
  Label     Prefix
   2049     3.3.3.3/32
            State:Active
     16     1.1.1.1/32
            State:Active


Input label database, 1.1.1.1:0-3.3.3.3:0
  Label     Prefix
   2050     1.1.1.1/32
            State:Active
     16     3.3.3.3/32
            State:Active

Output label database, 1.1.1.1:0-3.3.3.3:0
  Label     Prefix
   2049     3.3.3.3/32
            State:Active
     16     1.1.1.1/32
            State:Active
```

You can also define an LDP prefix filter with the **ldp add prefix-filter** command. Once defined, the prefix filter can be used in multiple LDP filter commands. For example, if you want to restrict both outgoing and incoming label requests for certain IP addresses, define an LDP prefix filter first.

In the following example, the **ldp add prefix-filter** command defines a prefix filter for the host node 10.10.10.101. The subsequent commands use the prefix filter to prevent requests or bindings for 10.10.10.101 from being sent to other LDP routers.

```
rs(config)# ldp add prefix-filter 101serv network 10.10.10.101/32 host-net
rs(config)# ldp add export-filter request restrict prefix-filter 101serv neighbor
1.1.1.1 sequence 1
rs(config)# ldp add export-filter mapping restrict prefix-filter 101serv neighbor
1.1.1.1 sequence 1
```

17.4.7 Displaying LDP Information

Table 17-6 is a summary of the LDP session information that you can display on the RS and the CLI commands that you use to display the information.

Table 17-6 LDP peer and session information

To see this information:	Use this command:
LDP global, interface, neighbor, and session parameters, and input and output labels for each LDP session	**ldp show all**
Input and output labels that are exchanged for each LDP session	**ldp show database**
LDP global parameters	**ldp show global**
LDP interface parameters, LDP neighbors on interface, and label space identifier being advertised on interface	**ldp show interface**
Interface on which LDP neighbor was discovered and label space identifier advertised by neighbor	**ldp show neighbor**
LDP session state information. Verbose option shows session connection parameters as well as list of next-hop addresses received on the session.	**ldp show session**

17.5 CONFIGURING L3 LABEL SWITCHED PATHS

The RS supports two basic types of LSPs:

- *Static* LSPs require that you configure all routers and assign all labels in the path. This is similar to configuring static routes on the router, and there is no reporting of errors or statistics. MPLS must be enabled. No signaling protocol is used, so you do not need to enable RSVP or LDP.
- *Dynamic* LSPs (also called signaled LSPs) use RSVP to set up the path and dynamically assign labels. On the ingress LSR, you configure the LSP as well as enable MPLS and RSVP. On all other LSRs in the dynamic LSP, you only need to enable MPLS and RSVP.

17.5.1 Configuring L3 Static LSPs

In a static LSP, *each* router in the path must be configured with static forwarding information. You can specify label values between 16 and 1024. No signaling protocol is used. MPLS must be enabled on all routers, as described in Section 17.2, *"Enabling and Starting MPLS on the RS."*

This section describes how to configure the ingress, transit, and PHP LSRs for a static LSP. (For a detailed example of how to configure a static path on an RS router, see Section , *"L3 Static Path Configuration Example."*)

Ingress LSR Configuration

Use the **`mpls create static-path`** and **`mpls set static-path`** commands to configure a static LSP on the ingress RS. When configuring the static LSP on the ingress LSR, you specify:

- destination IP address for the static path
- Non-global label value to be pushed onto the top of the label stack – See note below
- next-hop IP address (gateway) for the path

Note These labels must not fall within *global label space*. By default, non-global label space is the same as RSVP label space (from 3584 to 7167). If necessary, the start of global label space can be moved lower or higher using the **`mpls set global max-global-label`** command.

For example, the following command creates the static path SP1 on the ingress LSR. Packets to the destination 50.1.1.1 are assigned the label value 4000 and are sent out on the next-hop 10.1.1.5.

```
mpls create static-path SP1 to 50.1.1.1 push 4000 gateway 10.1.1.5
```

Transit LSR Configuration

In a static LSP, transit LSRs can change (*swap*) the label value at the top of the label stack. Use the **`mpls set interface`** command to configure the static LSP on the transit RS. When configuring the static LSP on the transit LSR, you specify:

- the incoming interface or IP address for the path

- the next-hop interface or IP address for the path
- the incoming label value and one of the following actions to be taken on the label (the *label map*):
  - swap the incoming label with a specified outgoing label value
  - pop the top value on the label stack
  - push a new label value on the top of the label stack

For example, the following command on a transit LSR looks at packets arriving on the interface MPLS-R2IN. Packets that have a label value of ‘4000’ have their labels replaced by the value ‘4001’ before they are sent to the next-hop IP address 20.1.1.2.

```
mpls set interface MPLS-R2IN label-map 4000 swap 4001 next-hop 20.1.1.2
```

PHP LSR Configuration

In a static LSP, the PHP LSR removes (pops) the label stack and then forwards the packet to the egress LSR. Use the **`mpls set interface`** command to configure the static LSP on the PHP RS. When configuring the static LSP on the PHP LSR, you specify:

- the incoming interface or IP address for the path
- the next-hop interface or IP address for the path
- the incoming label value to be popped from the label stack (normally, this would be the *only* label in the stack)

For example, the following command on a PHP LSR looks at packets arriving on the interface MPLS-R3IN. Packets that have a label value of ‘4001’ have their label popped before they are sent to the next-hop IP address 30.1.1.2.

```
mpls set interface MPLS-R3IN label-map 4001 pop next-hop 30.1.1.2
```

L3 Static Path Configuration Example

In the example shown in Figure 17-9, the RS router R1 is an ingress LSR for a static path. For incoming traffic, the RS looks up the destination IP address in its routing table. If a path has been configured for the destination address, the appropriate label is pushed on the packet and the packet is forwarded on to the next hop. For traffic destined for the 50.1/16 network, the label ‘4000’ is assigned by R1 before forwarding to the next-hop LSR at 10.1.1.2, in this case, another RS router, R2, which is also the PHP LSR.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

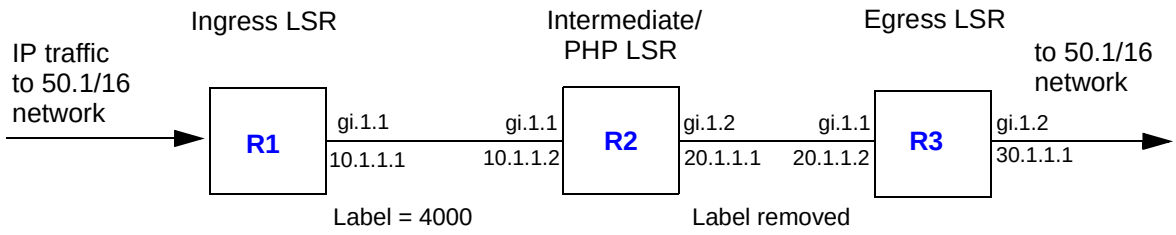


Figure 17-9 L3 static label switched path

Router R1 has the CLI configuration shown below. Note the **push** parameter in the **mpls create static-path** command, which assigns the label '4000' to packets destined for 50.1/16.

```
! Create the MPLS interface on this router
interface create ip MPLS-R1OUT address-netmask 10.1.1.1/16 port gi.1.1
! Enable MPLS on the router interfaces
mpls add interface MPLS-R1OUT
! Create a policy to filter traffic to 50.1.0.0/16
mpls create policy POL1 dst-ipaddr-mask 50.1.0.0/16
! Create the static path and assign the label 4000 to packets that will travel this path
mpls create static-path SP1 to 50.1.1.1 push 4000 gateway 10.1.1.2
! Apply the policy POL1 to this static path
mpls set static-path SP1 policy POL1
! Enable MPLS on this router
mpls start
```

At router R2, packets arriving on interface MPLS-R2IN that are labeled “4000” are stripped of their label and forwarded to the next-hop router (R3) at 20.1.1.2. Note the **`mpls set interface`** command in the following configuration for R2:

```
! Create the MPLS interfaces on this router
interface create ip MPLS-R2IN address-netmask 10.1.1.2/16 port. gi.1.1
interface create ip MPLS-R2OUT address-netmask 20.1.1.1/16 port gi.1.2
! Enable MPLS on the router interfaces
mpls add interface MPLS-R2IN
mpls add interface MPLS-R2OUT
! Configure swapping of labels and next-hop
mpls set interface MPLS-R2IN label-map 4000 pop next-hop 20.1.1.2
! Enable MPLS on this router
mpls start
```

Router R3 is the egress label edge router in the path. Router R3 has the following configuration:

```
! Create the MPLS interfaces on this router
interface create ip MPLS-R3IN address-netmask 20.1.1.2/16 port. gi.1.1
interface create ip MPLS-R3OUT address-netmask 30.1.1.1/16 port gi.1.2
! Enable MPLS on the router interfaces
mpls add interface MPLS-R3IN
mpls add interface MPLS-R3OUT
! Enable MPLS on this router
mpls start
```

In the above example, a policy is defined at the ingress router (R1) to filter traffic that is directed onto the static path. There are other ways that you can send traffic on a path, including IGP shortcuts. (See Section 17.7.3, *"IGP Shortcuts."*)

You can use the **`mpls show static-paths`** command to display the MPLS static path information. On router R1, the following is displayed for the configured static path:

```
R1# mpls show static-paths all

Ingress LSP:
LSPname                  To               From             State LabelIn  LabelOut
SP1                      50.1.1.1         7.7.7.7          Up    -        4000
```

You can use the **`mpls show policy`** command to display information on MPLS policies. All configured policies are shown; policies that are applied to LSPs are shown to be “INUSE.” The following shows an example of the output from router R1; note that the policy ‘POL1’ is shown to be “INUSE.”

```
R1# mpls show policy all
Name        Type Destination     Port   Source        Port   TOS Prot  Use
----------- ---- --------------- ------ ------------- ------ --- ----- -----
POL1        L3   50.1.0.0        any    50.1.0.0      any    any IP    INUSE
```

You can also use the **ip-policy show** command to display information on IP policies, including MPLS policies. Only active policies (MPLS policies that are applied to LSPs) are shown.The following is an example of the output on router R1:

```
R1# ip-policy show all

--------------------------------------------------------------------------------
IP Policy name     : MPLS_PBR_SP1
Applied Interfaces : all-IP-interfaces local-policy
Load Policy        : first available
Health Check       : disabled

ACL          Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK Prot ORIG AS
---          --------------     -------------      -------   -------   --- -------- ---- -------
MPLS_ACL_POL1anywhere           50.1.0.0/16         any       any       any  None     IP

                                                        Next Hop Information
                                                        --------------------
 Seq   Rule   ACL          Cnt      Action       Next Hop        Cnt      Last
 ---   ----   --------     ---      -----------  --------        ---      ----
 10    permit MPLS_ACL_POL1 0        Policy First 10.1.1.1         0        Dwn
```

Note that in the above output ‘MPLS_PBR_SP1’ refers to the name of the LSP, which in this configuration example is ‘SP1.’ Similarly, the ACL ‘MPLS_ACL_POL1’ refers to the name of the policy, which in this configuration example is ‘POL1.’

17.5.2 Configuring L3 Dynamic LSPs

With dynamic LSPs, you configure the LSP on the ingress router only. The ingress router sends RSVP signaling information to other LSRs in the path in order to establish and maintain the LSP. Labels are dynamically assigned on the LSRs.

Note Configuring LSPs are only required for RSVP-signaled LSPs. LSPs that use LDP do not need to be configured with the **mpls** commands described in this section.

There are two types of dynamic LSPs:

- *Explicit*: You configure the LSP on the ingress router. The sequence of other routers in the path can be specified. The path can be *strict* (the path must go through the specified routers and must not include other routers) or *loose* (the path can include other routers or interfaces). On the RS, strict is the default when configuring an explicit path. The ingress router uses signaling to pass forwarding information to each router in the LSP. In non-MPLS networks, explicit routing of packets requires the packet to carry the identity of the explicit route. With MPLS, it is possible to have packets follow an explicit route by having the label represent the route.

  With an explicit LSP, each LSR in the path does *not* independently choose the next hop. Explicit LSPs are useful for policy routing or traffic engineering.
- *Constraint-based*: You configure the LSP path constraints on the ingress router. The ingress router calculates the entire path or part of the LSP. RSVP is then used to establish the LSP. All routers must be running either the IS-IS or OSPF routing protocol with traffic engineering extensions enabled.

  For information on configuring constraint-based LSPs, see Section 17.7, *"Traffic Engineering."*

17.5.3 Configuring an Explicit LSP

As mentioned previously, all LSRs in a dynamic LSP use RSVP to establish and maintain the LSP. Therefore, all LSRs must enable RSVP in addition to MPLS. See Section 17.2, *"Enabling and Starting MPLS on the RS."*

You configure an explicit LSP only on the ingress router. Configuring an explicit LSP on the ingress router is a two-step process:

1. Create one or more explicit paths. You can specify some or all transit LSRs in the path. For each transit LSR you specified, you designate whether the route from the previous router to this router is direct and cannot include other routers (*strict* route) or whether the route from the previous router to this router can include other routers (*loose* route).
2. Create the LSP, specifying the previously created explicit paths as either the *primary* or *secondary* path. The secondary path is the alternate path to the destination and is used if the primary path can no longer reach the destination. If the LSP switches from the primary to the secondary path, the LSP will revert back to the primary path when it becomes available.

Configuring an Explicit Path

Use the **`mpls create path`** and **`mpls set path`** commands to configure an explicit path. When configuring an explicit path, you specify the following:

- maximum number of hops for the path
- hop number and IP address of transit routers in the path
- whether the route to the transit router is strict or loose

The following is an example of configuring an explicit path on the RS:

```
mpls create path 567 num-hops 3
mpls set path 567 hop-num 1 ip-addr 30.1.1.1
mpls set path 567 hop-num 2 ip-addr 30.1.1.2
mpls set path 567 hop-num 3 ip-addr 31.1.1.2
```

The **`mpls create path`** command shown above creates an explicit path 567 with a total of 3 hops. The **`mpls set path`** commands identify each of the three hops in the explicit path. By default, the path is *strict*—the path *must* go through the specified hop addresses. (To specify a loose route, include the option **`type loose`**.)

Configuring the LSP

You can then specify the explicit path as the primary or secondary path for the LSP by specifying the parameter **`primary`** or **`secondary`** with the **`mpls set label-switched-path`** commands. For example, the **`mpls create label-switched-path`** command shown below creates an LSP L1 to the destination address 100.1.1.1. The **`mpls set label-switched-path`** command specifies the explicit path 567 as the primary path for the LSP:

```
mpls create label-switched-path L1 to 100.1.1.1 no-cspf
mpls set label-switched-path L1 primary 567 adaptive
```

Note When configuring an explicit LSP, specify the **no-cspf** parameter. Otherwise, the LSP waits indefinitely for a valid constrained shortest path first (CSPF) response.

You can configure the same parameters for the LSP or for the explicit path. You configure parameters for an LSP with the **mpls create label-switched-path** or **mpls set label-switched-path** commands; the parameters you configure at this level apply to *all* paths in the LSP. You configure parameters for an explicit path by specifying the **primary** or **secondary** path with the **mpls set label-switched-path** command; the parameters you configure at the explicit path level apply only to that path. If you configure the same parameter at both the LSP and the explicit path level, the explicit path configuration takes precedence.

Table 17-7 shows the parameters that you can configure for an LSP or for each explicit path (primary or secondary). Some of the parameters are described in more detail following the table. Remember that if you configure the same parameter for both an LSP and an explicit path, the explicit path configuration takes precedence. Also note that certain parameters are only configurable for the LSP.

Table 17-7 LSP and explicit path parameters

Parameter	Description	LSP	Path
adaptive	LSP waits for a recalculated route to be set up before tearing down the old LSP. Disabled by default. (See *"Policies"*.)	X	X
admin-group	Specifies whether administrative groups are included or excluded on LSP (see **exclude** and **include** parameters). All administrative groups are included by default. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X
bps	Bandwidth, in bits, to be reserved with RSVP. (See *"Bandwidth"*.)	X	X
class-of-service	Sets a fixed CoS value for all packets entering the LSP. (See *"CoS Value"*.)	X	X
disable	Disables the LSP or path.	X	X
exclude	Exclude specified administrative groups. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X
fast-reroute	Enables fast rerouting to be used with this LSP. (See *"Fast Reroute"*.)	X	
from	Address of the local router (default is the local router ID).	X	
hold-priority	Priority for this LSP to reserve bandwidth for established session. Default value is 0—other LSPs cannot preempt this LSP. (See *"Standby"*.)	X	
hop-limit	The maximum number of hops, including the ingress and egress LSR, allowed in this LSP. (See *"Hop Limit"*.)	X	X
include	Include specified administrative groups. (For more detailed explanations of administrative groups and example configurations, see Section 17.7.1, *"Administrative Groups."*)	X	X

Table 17-7 LSP and explicit path parameters

Parameter	Description	LSP	Path
ldp-tunneling	Enables this LSP to use LDP over RSVP label stacking. (See *"LDP over RSVP LSPs"*.)	X	
metric	Assigns a metric to this LSP. (See *"LSP Metric"*.)	X	
mtu	Maximum transmission unit (MTU) for the path.	X	X
no-cspf	LSP does *not* use constrained shortest path first (CSPF) algorithm. This parameter *must* be specified for explicit path LSPs. (See *"Disabling CSPF"*.)	X	X
no-decrement-ttl	TTL field of IP packet is decremented only when exiting LSP. The entire LSP appears as a single hop to IP traffic. (See *"Disabling TTL Decrementing"*.)	X	X
no-record-route	Disables recording of path route information by LSP. (See *"Disabling Path Route Recording"*.)	X	X
policy	Specifies the MPLS policy to be applied. (See *"Policies"*.)	X	X
preference	Assigns a preference value to this LSP. (See *"Preference"*.)	X	X
primary	Specifies the name of the primary explicit path.	X	
retry-interval	Number of seconds the ingress LSR waits to try to connect to the egress LSR over the primary path. Default is 15 seconds. (See *"Connection Retries"*.)	X	X
retry-limit	Number of times the ingress LSR tries to connect to the egress LSR over the primary path. Default is 5000 times. (See *"Connection Retries"*.)	X	X
secondary	Specifies the name of the secondary explicit path.	X	
setup-priority	Priority for this LSP to reserve bandwidth for session setup. Default value is 7—this LSP cannot preempt other LSPs. (See *"Standby"*.)	X	
standby	Sets the secondary path in standby state. Disabled by default. (See *"Standby"*.)	X	X
to	Address of the egress router.	X	

Refer to the **mpls create label-switched-path** and **mpls set label-switched-path** commands in the *Riverstone RS Switch Router Command Line Interface Reference Manual* for more information on the above parameters.

See *"Dynamic L3 LSP Configuration Example"* for details on how to configure a dynamic LSP on the RS.

Adaptive LSP

An LSP can be rerouted if the explicit path is reconfigured or unable to connect. When an LSP is rerouting, the existing path is torn down even if the new optimized route is not yet set up for traffic. Also, transit LSRs can allocate the same amounts of bandwidth to both the old and new paths for the same LSP; this can cause over-allocation of available bandwidth on some links.

To counter these problems, you can configure an LSP or an explicit path to be **`adaptive`**. An adaptive LSP or explicit path retains its resources and continues to carry traffic until the new LSP or path is established. An adaptive LSP or explicit path is torn down only when the new route is successfully set up for traffic. Note that if you specify an LSP to be adaptive, all primary and secondary paths of the LSP are adaptive; the primary and secondary paths share bandwidth on common links. If you specify a primary or secondary path to be adaptive, only that path will be adaptive.

Bandwidth

You can use the **`bps`** parameter to specify the bandwidth, in bits, to be reserved with RSVP for this LSP. (The default bandwidth value is 0.) If you specify a bandwidth, transit routers will reserve outbound link capacity for the LSP. LSP setup may fail if there is a failure in bandwidth reservation.

CoS Value

A class of service (CoS) value places traffic into a transmission priority queue. For packets entering an LSP, the ingress LSR can place a specific CoS value into the MPLS header. This CoS value enables all packets that enter the LSP to receive the same class of service, as all LSRs in the LSP will use the CoS set by the ingress LSR. The MPLS header and the CoS value are removed at the egress LSR.

You can assign the CoS value to be set by the ingress LSR by specifying the **`class-of-service`** parameter when configuring the LSP. If you do not specify this parameter, the CoS value placed in the MPLS header is the value that corresponds to the internal priority queue used to buffer the packet on the ingress LSR.

Hop Limit

The hop limit is the maximum number of hops, including the ingress and egress routers, allowed in the LSP. A hop limit of 2 includes only the ingress and egress routers. The default hop limit is 255, which you can change with the **`hop-limit`** parameter.

LSP Metric

Assigning a metric to LSPs forces traffic to prefer certain LSPs over other LSPs, to prefer LSPs over IGP paths, or to load share among LSPs or among LSPs and IGP paths. For example, if there are two or more LSPs to the same egress router, the LSP with the lowest metric value is the preferred path. If the metric value is the same for multiple LSPs to the same egress router, the traffic load is shared among the LSPs.

If you are using IGP shortcuts, the LSP metric value can be added to other IGP metrics to determine the total cost of the path. IGP path and LSP metric values can be compared to determine the preferred path. For more information about using LSPs as IGP shortcuts, see Section 17.7.3, *"IGP Shortcuts."*

If an LSP exists between two BGP peers, the LSP metric represents to downstream BGP neighbors a cost value that does not change even if the LSP is rerouted.

Disabling CSPF

The **no-cspf** parameter disables constrained path LSP computations by the ingress LSR and must be specified when configuring an explicit path LSP. This parameter must not be specified with constrained shortest path first (CSPF) configurations; for an explanation of CSPF and configuration examples, see Section 17.7, *"Traffic Engineering."*

Disabling TTL Decrementing

With normal decrementing, the (time-to-live) TTL field in an IP packet header is decremented by 1 on each LSR in the LSP. With the **no-decrement-ttl** parameter, the IP packet's TTL field is only decremented by 1 at the egress router when the entire LSP is traversed, thus making the whole LSP appear as one hop. The **no-decrement-ttl** parameter can be applied to RSVP-signaled LSPs only. Note that the MPLS label has its own TTL that is decremented by 1 for each hop in the LSP. When the label is popped at the PHP router, the label's TTL value is not written to the IP packet's TTL and the IP packet's TTL is decremented by 1 at the egress LSR.

Disabling Path Route Recording

By default, RSVP-signaled LSPs on RS routers record path route information. While this information may be useful for troubleshooting, this function must be supported on all transit routers. Specify the **no-record-route** option to disable the recording.

Preference

The default preference value for an LSP is 7, which, with the exception of direct routes, is more preferred than all learned routes. Where there are multiple LSPs between the same source and destination, you can assign a different preference value to an LSP. A smaller value signifies a more desirable path.

Connection Retries

The ingress LSR tries to connect to the egress router over the primary path at 15-second intervals for up to 5000 attempts. You can change the intervals at which connections are attempted with the **retry-interval** parameter or change the maximum number of attempts with the **retry-limit** parameter. If the number of attempts by the ingress LSR to connect to the egress router exceeds the **retry-limit** parameter, you will need to restart the primary path.

Setup and Hold Priority

The **setup-priority** and **hold-priority** parameters in LSP configuration determine whether an LSP can be preempted by another LSP. This is important when there is not enough bandwidth to establish new LSPs. If a new LSP has a higher **setup-priority** value than the **hold-priority** value of an existing LSP, the new LSP can preempt the existing LSP. LSPs with higher **setup-priority** values are usually established before those with lower values. By default, an LSP has a **setup-priority** of 7, the lowest value, which means that it cannot preempt other LSPs.

If a new LSP has a higher **hold-priority** value than an existing LSP, the new LSP can preempt the existing LSP. By default, an LSP has a **hold-priority** of 0, the highest value, which means that it cannot be preempted by other LSPs. You must configure the **hold-priority** value to be higher (0 is the highest) than or equal to the **setup-priority** value.

Note In order for an LSP to preempt an already-established LSP of lower priority, you must enable preemption on the RS with the **`rsvp set global preemption`** command. (See Section 17.3.7, *"LSP Preemption."*)

Standby

The secondary path is an alternate path to a destination and is only used if the primary path can no longer reach the destination. If the LSP switches from the primary to the secondary path, it will revert back to the primary when it becomes available. The switch from the primary to the secondary path can take awhile as timeouts and retries need to be exhausted. You can specify that the secondary path be placed into a "hot" standby state to allow faster cutover from the primary to the secondary path in the event of problems with link connectivity. Specify the **`standby`** parameter when configuring the secondary path. Note that if paths are placed into hot standby state, all LSRs in the LSP must maintain this state information.

Primary/Secondary Fate Sharing

Sometimes it's desirable for the primary and secondary paths to have nothing in common (this is what is meant by *no fate sharing*). The ingress LSR can be configured so that if primary and secondary paths are created, the secondary path will contain none of the hops contained within the primary's path. Using the **`no-primary-hops`** option with the **`mpls set label-switched-path`** command specifies that if the LSP fails over to the secondary path, no hop in the secondary path will be a hop within the primary path.

Path Flapping

If a primary path is in a state of continually coming up and then going down, the LSP will *flap*, first using the primary path, then the secondary path, then reverting to the primary path, and so on.

If path flapping is an issue with a link on the LSP, use the **`path-damping-interval`** option of the **`mpls set label-switched-path`** command to create a dampening behavior that checks whether the primary path has settled down and is stable before switching back to the primary path.

The value set for the **`path-damping-interval`** is used to exponentially dampen path flapping if a link with a backup link is repeatedly going up and down. The degree to which damping is performed is computed by the following equation:

Next-interval = current interval + current interval / path-flap-interval. The default is zero (disabled).

Policies

On the RS, you can optionally create and apply a *policy* to specify the type of traffic allowed on the path. On the RS, a policy is a definition of the type of traffic to which a particular router feature is applied. For example, you can create policies that define traffic from a particular source address to a particular destination address, or traffic of a certain protocol type.

For MPLS, you can create a policy that defines traffic characteristics such as source/destination IP addresses and netmask values, source/destination MAC addresses, VLAN ID, 802.1p priority, and protocol type. You can then apply the policy to an LSP. Only the labeled packets that meet the requirements of the policy are allowed to travel on that LSP. For example, you can define a policy that allows only labeled packets with source IP addresses in the 100.1.1.0/24 network to traverse an LSP.

On the RS, use the **`mpls create policy`** command to create policies that you can apply to LSPs. For example, the following command creates a policy that will allow only labeled traffic with the source IP address 100.1.1.0/24:

```
mpls create policy allow_subnet_100 src-ipaddr-mask 100.1.1.0/24
```

You can then use the **`mpls set static-path`** or **`mpls set label-switched-path`** commands to apply the policy to a previously-created LSP.

```
mpls set static-path to_SanJose policy allow_subnet_100
```

Note that an MPLS policy affects the traffic that is forwarded on an LSP. If you want to restrict the *establishment* of LSPs by restricting the label requests and label bindings that are distributed, use LDP filters. For more information, see Section 17.4.6, *"Using LDP Filters."*

LDP over RSVP LSPs

You can tunnel L3 LDP-signaled LSPs over RSVP-signaled LSPs with the **`ldp-tunneling`** parameter. For example, LDP LSPs can be tunneled through a backbone network where LSPs have been established via RSVP for traffic engineering. LDP treats the RSVP-signaled LSP as a single hop.

Note To tunnel LDP LSPs over RSVP LSP, you must enable LDP on the lo0 loopback interface. Also, all routers in the LSP must be in the same OSPF area or in the same IS-IS level.

Fast Reroute

The RS supports fast rerouting of RSVP-signaled LSPs. Fast reroute provides a way to automatically establish backup LSP tunnels, or detour paths, in order to reduce packet loss on the LSP. If there is a link or node failure, an LSP that employs fast reroute is able to redirect user traffic to previously-computed and established detours around the failed link or node.

Note If your network consists of RS switch routers running both Release 9.4 (or later) and Release 9.3, use the **`rsvp set global fast-reroute-old-ctype`** command on the 9.4 RSs to make fast reroute compatible with the 9.3 RSs.

Release 9.3 generates objects of ctype 7, while Release 9.4 generates objects of ctype 1. The command above forces Release 9.4 to generate objects of ctype 7.

A detour is an alternate path established by an upstream LSR on an LSP to a downstream node that is more than one hop away. The detour path does not traverse the immediate downstream node or the outgoing link to the immediate downstream node. No detour path can be established for the egress LSR, since the egress LSR has no downstream link or node. If there is a link or node failure on the LSP, the upstream LSR redirects traffic onto the detour and notifies the ingress LSR of the failure.

Figure 17-10 shows an LSP from the ingress LSR R1 to the egress LSR R4. To protect against a potential failure of the R2 LSR and failure of the links between R1 and R2 and R2 and R3, a detour path is established between R1 and R3. A detour path between R2 and R4 protects against the failure of R3 and link failures between R2 and R3 and R3 and R4. A detour path between R3 and R4 protects only against the failure of the local link between R3 and R4.

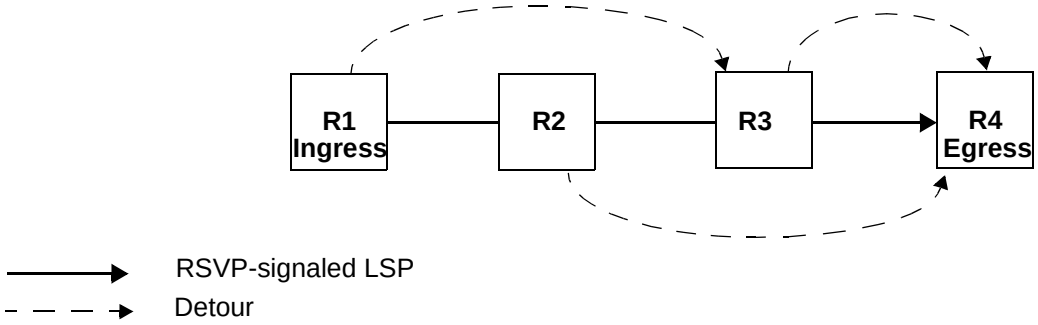


Figure 17-10Detour paths for an LSP

Note Detours represented by dotted lines actually consist of a number of LSRs.

Note that a detour path can be allowed to traverse a number of transit routers, as long as it does not traverse the immediate downstream link and node. Each LSR establishes a maximum of one detour path for each fast reroute LSP.

To achieve timely redirection of traffic onto a detour, it is essential that the detour paths be computed and established in advance of the failure. You enable fast reroute on an LSP at the *ingress* LSR only; no configuration is necessary on transit and egress LSRs. The ingress LSR uses RSVP to notify downstream routers that fast reroute is configured for the LSP.

Detour paths are established only between routers on the main LSP that support fast reroute. If a router does not support fast reroute, then it will not set up any detours but it will continue to support the LSP. For example, in Figure 17-11, router R2 does not support fast reroute. In this case, detours are only established between routers R1 and R3 and R3 and R4. There is no protection against the failure of R3 and link failures between R2 and R3 and between R3 and R4.

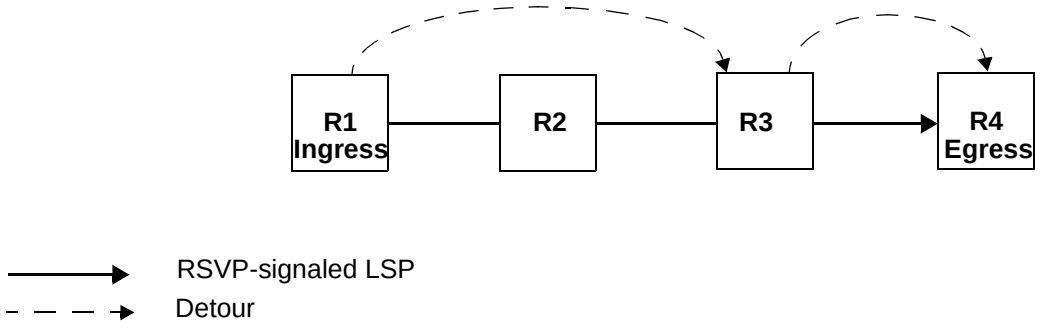


Figure 17-11Detour paths for an LSP when router does not support fast reroute

Link and Node Protection

The RS provides for a way to specify whether a link or a node should be avoided during a fast reroute. Use the **`mpls set global local-repair-enable`** command to specify whether a link or a node should be avoided during the reroute. Consider Figure 17-12. R1 is configured to find an alternate link to R2 – **`mpls set global local-repair-enable link-protection`**. In this case (although other paths could be chosen by fast reroute), R1 fast reroutes the LSP to R3 and then to R2 through an alternate link.

Note that R1 senses the cause of the LSP failure as a downed link by receiving a *link-down* signal.

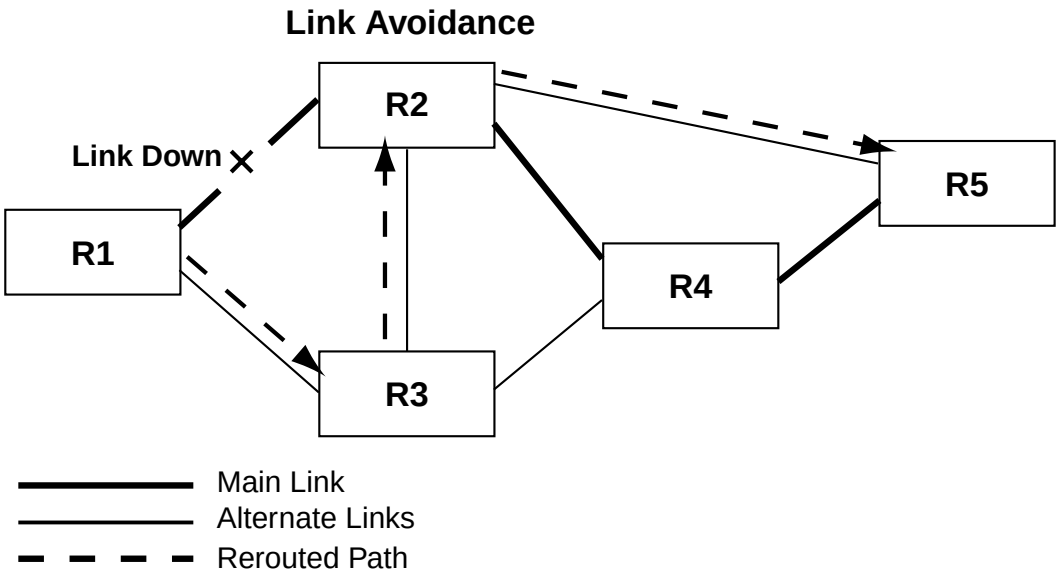


Figure 17-12 Link protection diagram

Fast reroute can be set to protect against the failure of the LSP because of a down node. Use the **mpls set global local-repair-enable** command, specifying the **node-protection** option. Doing so, instructs fast reroute to bypass the downed node (see Figure 17-13). Actually, the option **node-protection** enables both node and link protection at the same time. However, notice the difference in the LSP fast reroute paths shown in Figure 17-12 and Figure 17-13. When node-protection is enabled, the fast reroute path bypasses R2 to complete the LSP.

In Figure 17-13 R1 learns that R2 is down by the elapsing of the hello-packet timer.

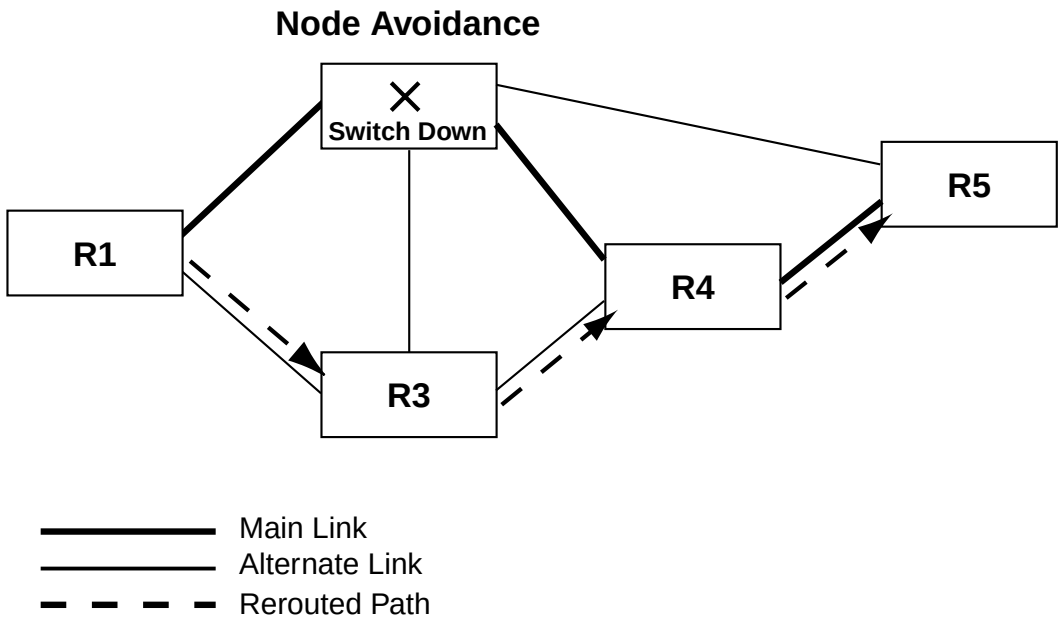


Figure 17-13 Node protection diagram

In addition to either link or node protection, a dynamic choice capability can be implemented by specifying the option **node-prefer-protection**. This option invokes the following behavior: “All detour LSPs starting from this router will use link protection, but if there is a node protection path available, that path is used.”

Enabling Fast Reroute

To enable fast reroute on an LSP, specify the **fast-reroute** parameter with the **mpls set label-switched-path** command on the ingress LSR. You can optionally configure the following constraints for the detour path(s):

- **detour-setup-pri** and **detour-hold-pri** set the priority of the detour in taking and holding resources.
- **detour-hop-limit** is the maximum number of extra hops the detour is allowed to take from the current node to the downstream merging node. A hop limit of 0 means that only direct links between the current and merging nodes can be considered.
- **detour-bps** is the allocated bandwidth for the detour. No bandwidth is allocated for the detour.
- **detour-exclude** and **detour-include** are the administrative groups that are to be excluded or included for the detour.

Note Detour paths must be within the same OSPF area or the same IS-IS level.

In order for an RS MPLS LSR to act as a *detour-node* the command **`mpls set global point-of-local-repair-enable`** is required in the detour-node's configuration. By default, an RS MPLS LSR along the main path will not attempt to establish a detour path. Only possible detour nodes need to be configured with the **`mpls set global point-of-local-repair-enable`** command. The MPLS LSRs on the detour path and the merge node will react automatically to detour messaging. The ingress router, edge of the MPLS cloud, just requires fast reroute to be enabled on the LSP.

Dynamic L3 LSP Configuration Example

Figure 17-14 shows a network where RS router R5 is the ingress router for a dynamic LSP to the egress router R7. The LSP configuration consists of two different path designations: the primary path is an explicit path from R5 to R7, while the secondary path is an explicit path that follows specific hops from R5 to R6 and then to R7. The secondary path also operates in standby mode. Both paths are configured to be adaptive; that is, during route recalculation, the LSP waits until the new optimized route is set up before tearing down the previous LSP. In this example, RSVP is the signaling protocol used (LDP can also be used, as traffic engineering is not being utilized).

Additionally, a dynamic LSP will be configured from RS router R5 to the router JN1 and another from R6 to R7. These LSPs are also configured to be adaptive.

OSPF is the routing protocol that is used on all RS routers.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

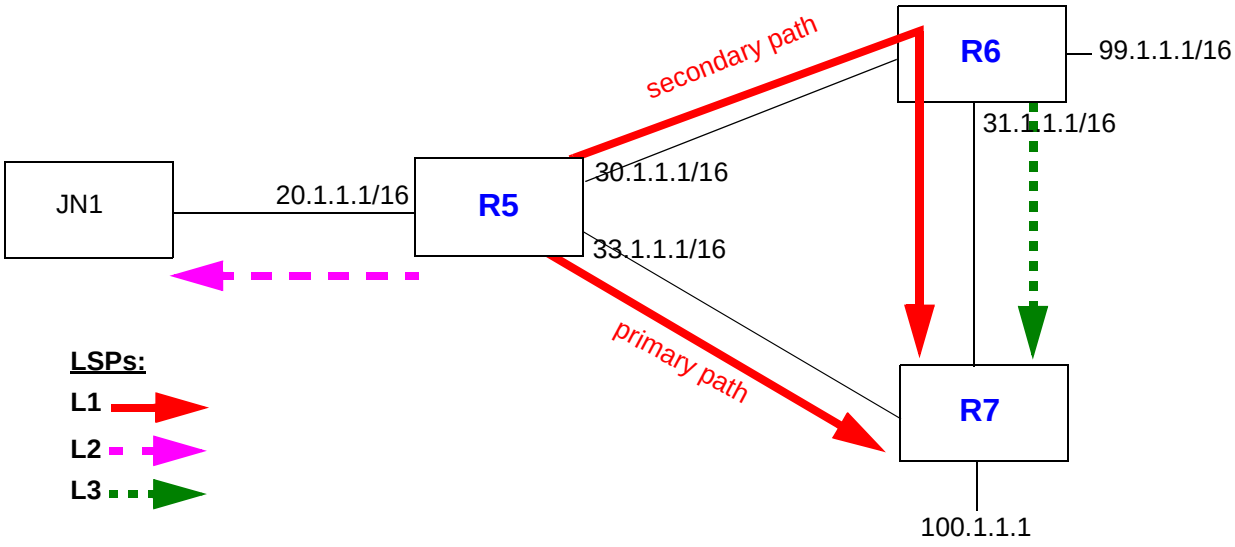


Figure 17-14Dynamic L3 LSP paths

The following is the configuration for router R5:

```
! Create interfaces
interface create ip 30net address-netmask 30.1.1.1/16 port et.1.2
interface create ip 33net address-netmask 33.1.1.1/16 port et.1.5
interface create ip 20net address-netmask 20.1.1.1/16 port et.5.1
interface add ip lo0 address-netmask 98.1.1.1/16

! Configure router
ip-router global set autonomous-system 64977
ip-router global set router-id 98.1.1.1

! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start

! Enable MPLS on all interfaces
mpls add interface all

! Create explicit path 57 (primary path to 100.1.1.1)
mpls create path 57

! Create explicit path 567 with 3 hops (secondary path to 100.1.1.1)
mpls create path 567 num-hops 3
mpls set path 567 hop-num 1 ip-addr 30.1.1.1
mpls set path 567 hop-num 2 ip-addr 30.1.1.2
mpls set path 567 hop-num 3 ip-addr 31.1.1.2

! Create dynamic LSP L1 to egress router 100.1.1.1 w/ primary, secondary paths
mpls create label-switched-path L1 to 100.1.1.1 no-cspf
mpls set label-switched-path L1 primary 57 adaptive
mpls set label-switched-path L1 secondary 567 adaptive standby

! Create dynamic LSP L2 to egress router 20.1.1.2
mpls create label-switched-path L2 to 20.1.1.2 adaptive no-cspf

! Start MPLS on router R5
mpls start

! Configure RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for router R6:

```
! Create interfaces
interface create ip 30net address-netmask 30.1.1.2/16 port et.1.2
interface create ip 31net address-netmask 31.1.1.1/16 port et.1.3
interface create ip 99net address-netmask 99.1.1.1/16 port et.1.1
! Configure router
ip-router global set router-id 99.1.1.1
! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start
! Enable MPLS on all interfaces
mpls add interface all
! Create dynamic LSP L3 to egress router 100.1.1.1
mpls create label-switched-path L3 to 100.1.1.1 adaptive no-cspf
! Start MPLS on router R6
mpls start
! Configure RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for router R7:

```
! Create interfaces
interface create ip 33net address-netmask 33.1.1.2/16 port et.1.5
interface create ip 31net address-netmask 31.1.1.2/16 port et.1.3
interface create ip 100net address-netmask 100.1.1.1/16 port et.1.1
! Configure router
ip-router global set router-id 100.1.1.1
! Configure OSPF
ospf create area backbone
ospf add interface all to-area backbone
ospf start
! Start MPLS on router R7
mpls start
! Configure RSVP
rsvp add interface all
rsvp start
```

Dynamic and Static L3 LSP Configuration Example

In Figure 17-15, R1 is the ingress LSR for both a dynamic LSP and a static LSP. The dynamic LSP has a primary path and one secondary path. Only traffic to the 150.10.0.0/16 network is forwarded on the dynamic LSP, while only traffic to the 160.10.0.0/16 network is forwarded on the static LSP; traffic filtering is performed by defining and applying different policies to the LSPs.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

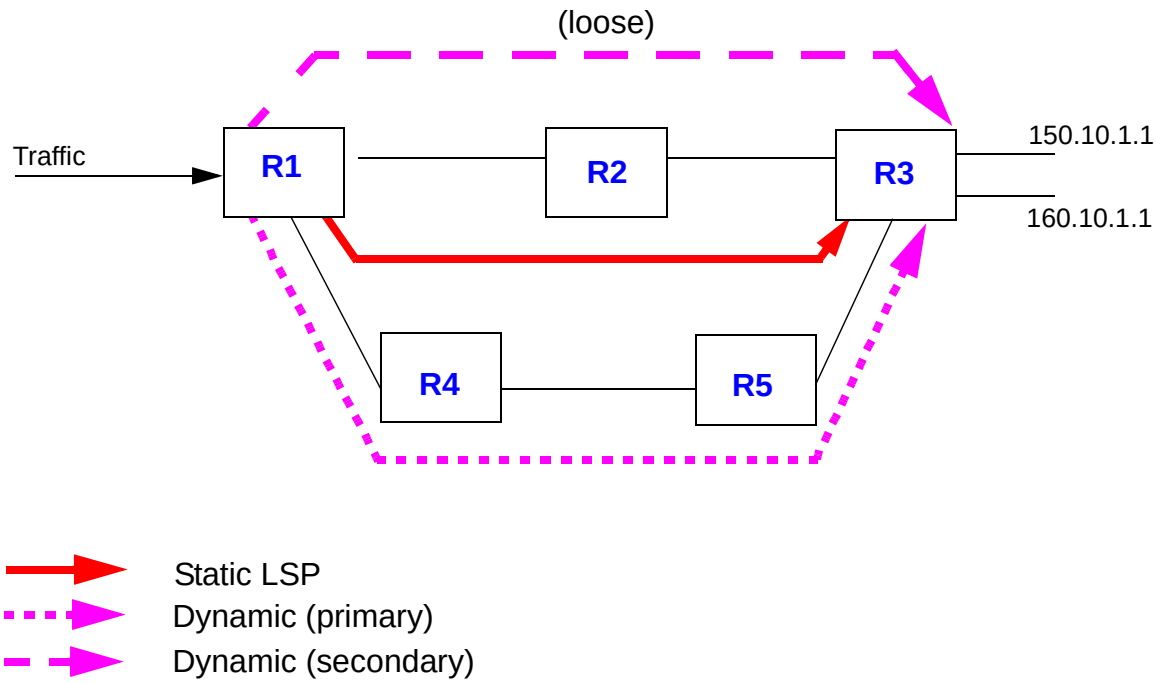


Figure 17-15 Static and dynamic L3 LSP example

In this example, RSVP is the signaling protocol used (LDP can also be used, as traffic engineering is not being utilized). OSPF is the routing protocol that is used on all RS routers.

R1 has the following configuration:

```
! Configure interfaces
interface create ip R1R4 address-netmask 200.135.89.73/26 port gi.2.1
interface create ip R1R2 address-netmask 200.135.89.4/28 port gi.2.2
interface add ip lo0 address-netmask 1.1.1.1/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add interface R1R4 to-area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface R1R2 to-area backbone
ospf start
```

```
! Create policies
mpls create policy p1 dst-ipaddr-mask 150.10.0.0/16
mpls create policy p2 dst-ipaddr-mask 160.10.0.0/16

! Create dynamic LSP:
! Create primary path dp1
mpls create path dp1 num-hops 4
mpls set path dp1 hop 1 ip-addr 200.135.89.73 type strict
mpls set path dp1 hop 2 ip-addr 201.135.89.76 type strict
mpls set path dp1 hop 3 ip-addr 201.135.89.130 type strict
mpls set path dp1 hop 4 ip-addr 201.135.89.197 type strict
! Create secondary path dp2l (loose)
mpls create path dp2l num-hops 2
mpls set path dp2l hop 1 ip-addr 200.135.89.4 type loose
mpls set path dp2l hop 2 ip-addr 16.128.11.7 type loose
! Configure dynamic LSP d1
mpls create label-switched-path d1 to 3.3.3.3 no-cspf
mpls set label-switched-path d1 policy p1
mpls set label-switched-path d1 primary dp1 standby no-cspf
mpls set label-switched-path d1 secondary dp2l no-cspf adaptive standby

! Create static LSP s1
mpls create static-path s1 push 70,60,50 gateway 200.135.89.76 to 3.3.3.3
mpls set static-path s1 policy p2

! Start MPLS and RSVP
mpls start
rsvp start
```

R2 has the following configuration:

```
! Configure interfaces
interface create ip R2R1 address-netmask 200.135.89.5/28 port gi.4.2
interface create ip R2R3 address-netmask 16.128.11.10/24 port gi.4.1
interface add ip lo0 address-netmask 2.2.2.2/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 2.2.2.2
ospf create area backbone
ospf add interface R2R1 to-area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface R2R3 to-area backbone
ospf start
```

```
! Configure static LSP
mpls set interface R2R1 label-map 70 pop pop-count 3 next-hop 16.128.11.7

! Start MPLS and RSVP
mpls start
rsvp start
```

R3 has the following configuration:

```
! Configure interfaces
interface create ip Net1 address-netmask 150.10.1.1/16 port et.2.8
interface create ip R3R5 address-netmask 201.135.89.197/26 port gi.6.1
interface create ip R3R2 address-netmask 16.128.11.7/24 port gi.6.2
interface add ip lo0 address-netmask 3.3.3.3/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 3.3.3.3
ospf create area backbone
ospf add interface R3R5 to-area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface R3R2 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```

R4 has the following configuration:

```
! Configure interfaces
interface create ip R4R1 address-netmask 200.135.89.76/26 port gi.4.1
interface create ip R4R5 address-netmask 201.135.89.131/26 port gi.4.2
interface add ip lo0 address-netmask 4.4.4.4/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 4.4.4.4
ospf create area backbone
ospf add interface R4R1 to-area backbone
ospf add stub-host 4.4.4.4 to-area backbone cost 10
ospf add interface R4R5 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```

R5 has the following configuration:

```
! Configure interfaces
interface create ip R5R4 address-netmask 201.135.89.130/26 port gi.1.1
interface create ip R5R3 address-netmask 201.135.89.195/26 port gi.1.2
interface add ip lo0 address-netmask 5.5.5.5/16

mpls add interface all
rsvp add interface all

! Configure OSPF
ip-router global set router-id 5.5.5.5
ospf create area backbone
ospf add interface R5R4 to-area backbone
ospf add stub-host 5.5.5.5 to-area backbone cost 10
ospf add interface R5R3 to-area backbone
ospf start

! Start MPLS and RSVP
mpls start
rsvp start
```

The following is an example of the output of the **`mpls show label-switched-paths d1`** command issued at R1. Note that the state of LSP ‘d1’ is “Up” and the label value 17 is assigned to outgoing packets on this LSP.

```
R1# mpls show label-switched-paths d1
Ingress LSP:
LSPname                  To               From             State LabelIn LabelOut
d1                       3.3.3.3          1.1.1.1          Up    -       17
```

The following is an example of the output of the **`mpls show label-switched-paths d1 verbose`** command issued at R1. Note the lines that are shown in bold: the explicit path ‘dp1’ is the primary path for LSP ‘d1’ and is currently up and active, while the explicit path ‘dp21’ is the secondary path and is up but not active.

```
R1# mpls show label-switched-paths d1 verbose

    Label-Switched-Path: d1
        to: 3.3.3.32             from: 1.1.1.1
        state: Up               lsp-id: 0x9
        proto: <rsvp>           protection: primary
        setup-pri: 7            hold-pri: 0
        attributes: <POLICY PRI SEC>

        Protection-Path "dp1": <Active, Primary>
            State: Up   lsp-id: 0x1000001
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 3            ref-count: 1
            mtu: 0
            explicit-path: dp1      num-hops: 4
                200.135.89.73       - strict
                200.135.89.76       - strict
                201.135.89.130      - strict
                201.135.89.197      - strict

        Protection-Path "dp2l": <Secondary>
            State: Up   lsp-id: 0x1000002
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY ADAPTIVE NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 1            ref-count: 1
            explicit-path: dp2l     num-hops: 2
```

```
                200.135.89.4        - loose
                16.128.11.7         - loose
```

If the link between R1 and R4 becomes unavailable, the configured primary path for the dynamic LSP cannot be used. The configured secondary path is then used for the LSP. A message like the following is displayed:

```
2001-04-06 16:13:24 %MPLS-I-LSPPATHSWITCH, LSP "d1" switching to Secondary Path "dp2l".
```

The secondary path ‘dp2l’ is now used for the LSP, as shown by the **`mpls show label-switched-paths d1 verbose`** command at R1. Note that the explicit path ‘dp1,’ the configured primary path, is now down and the configured secondary path ‘dp2l’ is now both up and active.

```
R1# mpls show label-switched-paths d1 verbose

    Label-Switched-Path: d1
        to: 3.3.3.3             from: 1.1.1.1
        state: Up               lsp-id: 0x9
        proto: <rsvp>           protection: secondary
        setup-pri: 7            hold-pri: 0
        attributes: <POLICY PRI SEC>

        Protection-Path "dp1": <Primary>
            State: Down         lsp-id: 0x1000001
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY RETRYING NO-CSPF>
            inherited-attributes: <>
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 0 sec.
            ott-index:              ref-count: 1
            mtu: 0
            explicit-path: dp1      num-hops: 4
                hop: 200.135.89.73 - strict
                hop: 200.135.89.76 - strict
                hop: 201.135.89.130 - strict
                hop: 201.135.89.197 - strict

        Protection-Path "dp2l": <Active, Secondary>
            State: Up           lsp-id: 0x1000002
            attributes: <>
        Path-Signalling-Parameters:
            attributes: <STANDBY ADAPTIVE NO-CSPF>
            inherited-attributes:
            retry-limit: 5000       retry-int: 3 sec.
            retry-count: 5000       next_retry_int: 600 sec.
            bps: 20000000           preference: 7
```

```
            hop-limit: 255          opt-int: 0 sec.
            ott-index: 1            ref-count: 1
            explicit-path: dp2l     num-hops: 2
                200.135.89.4        - loose
                16.128.11.7         - loose
```

BGP Traffic over an LSP Configuration Example

In traditional BGP networks, BGP must be run on every router in order to provide packet forwarding. If BGP routing information is not propagated to all routers, including backbone routers, packets may not be able to be routed to their BGP destinations. You can run MPLS in a BGP network to remove BGP routing from backbone routers. Removing BGP from the backbone network provides the following benefits:

- Memory requirements for backbone routers is reduced, as they do not have to store extensive routing information
- Backbone routers do not have to perform BGP update processing, thus saving CPU utilization
- Routing tables are more stable, because backbone routers do not have to process route flaps

In Figure 17-16, R7 in AS 63498 and R9 in AS 65498 are running BGP. BGP traffic between R7 and R9 is routed through AS 64498 where OSPF is running as the IGP. Routers R3 and R6 are LSRs running MPLS and LDP, in addition to BGP.

R3 and R6 are ingress and egress LSRs for bidirectional LSPs. R1 is a transit LSR. On the LSPs, the BGP traffic is label switched, with LDP as the label signaling protocol. (RSVP can be used in MPLS networks where traffic engineering is needed.) R3 and R6 use labels that are generated for the next-hop addresses of advertised BGP routes. Packets with BGP destinations are sent across the LSPs with labels that correspond to the egress LSR that advertised the external route. Note that R1 and any other transit LSRs on the LSPs do not need to perform IP lookups nor do they need to learn BGP routing information to forward packets.

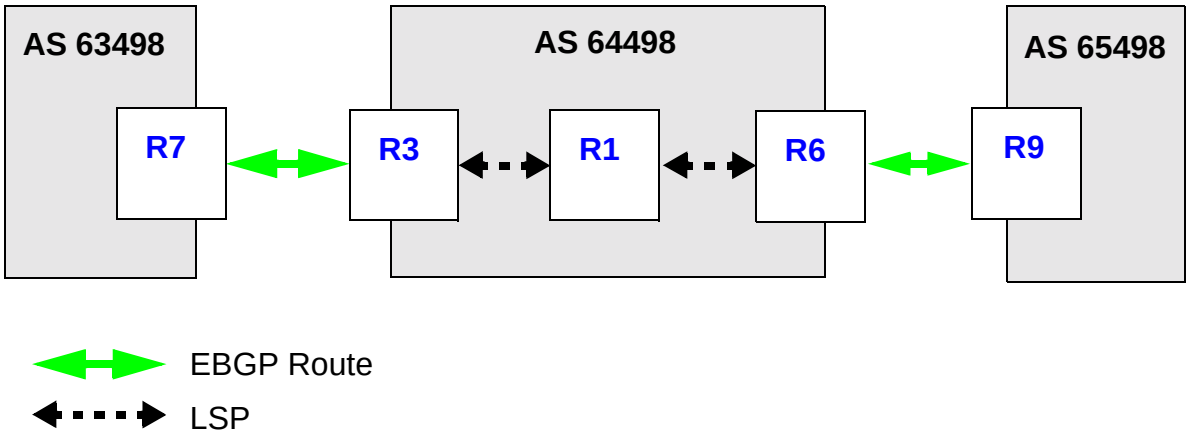


Figure 17-16 BGP traffic over an MPLS LSP

Timesaver Click on the router name (in blue) to see the corresponding configuration.

Note By default, routes are automatically advertised between EBGP peers. However, routes are not automatically advertised between IBGP multi-hop peers. Therefore, in the example configuration, you need to configure routes from AS63498 and AS 65498 to be redistributed to the IBGP peers in AS 64498.

The following is the configuration for R7:

```
! Configure interfaces
interface create ip rt7-rt3 address-netmask 137.1.1.7/24 port et.1.1
interface create ip rt7-rt3.mp address-netmask 137.2.2.7/24 port et.2.7
interface add ip lo0 address-netmask 7.7.7.7/32

! Configure BGP
ip-router global set router-id 7.7.7.7
ip-router global set autonomous-system 63498
ip add route default gateway 137.2.2.3
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group to-rt3 type external autonomous-system 64498
bgp add peer-host 137.2.2.3 group to-rt3
bgp start
```

R3 is the both the ingress LSR for the LSP to R6 and the egress LSR for the LSP from R6. The following is the configuration for R3:

```
! Configure interfaces
interface create ip rt3-rt7.mp address-netmask 137.2.2.3/24 port et.7.8
interface create ip rt3-rt1.mp address-netmask 113.2.2.3/24 port gi.3.1
interface add ip lo0 address-netmask 3.3.3.3/32

! Configure BGP
ip-router global set router-id 3.3.3.3
ip-router global set autonomous-system 64498
ip-router policy redistribute from-proto bgp source-as 63498 to-proto bgp target-as 64498
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group to-rt6 type routing autonomous-system 64498
bgp create peer-group to-rt7 type external autonomous-system 63498
bgp add peer-host 6.6.6.6 group to-rt6
bgp add peer-host 137.2.2.7 group to-rt7
bgp set peer-group to-rt6 local-address 3.3.3.3
bgp set peer-group to-rt6 next-hop-self Sets R3's address as next-hop in BGP route advertisements
bgp start

! Configure OSPF
ospf create area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface rt3-rt1.mp to-area backbone
ospf start

! Enable and start MPLS and LDP on interface to R1
mpls add interface rt3-rt1.mp
mpls start
ldp add interface rt3-rt1.mp
ldp start
```

R1 is the transit LSR for the LSPs from R3 to R6 and from R6 to R3. The following is the configuration for R1:

```
! Configure interfaces
interface create ip rt1-rt3.mp address-netmask 113.2.2.1/24 port gi.3.2
interface create ip rt1-rt6.mp2 address-netmask 116.3.3.1/24 port gi.3.1
interface add ip lo0 address-netmask 1.1.1.1/32

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface rt1-rt3.mp to-area backbone
ospf add interface rt1-rt6.mp2 to-area backbone
ospf start

! Enable and start MPLS and LDP on interfaces to R3 and R6
mpls add interface rt1-rt6.mp2
mpls add interface rt1-rt3.mp
mpls start
ldp add interface rt1-rt3.mp
ldp add interface rt1-rt6.mp2
ldp start
```

R6 is the both the ingress LSR for the LSP to R3 and the egress LSR for the LSP from R3.The following is the configuration for R6:

```
! Configure interfaces
interface create ip rt6-rt9 address-netmask 169.1.1.6/24 port et.7.2
interface create ip rt6-rt1.mp2 address-netmask 116.3.3.6/24 port gi.4.2

! Configure BGP
interface add ip lo0 address-netmask 6.6.6.6/32
ip-router global set router-id 6.6.6.6
ip-router global set autonomous-system 64498
ip-router policy redistribute from-proto bgp source-as 65498 to-proto bgp target-as 64498
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group bgp-to-rt9 type external autonomous-system 65498
bgp create peer-group to-rt3 type routing autonomous-system 64498
bgp add peer-host 169.1.1.9 group bgp-to-rt9
bgp add peer-host 3.3.3.3 group to-rt3
bgp set peer-group to-rt3 local-address 6.6.6.6
bgp set peer-group to-rt3 next-hop-self Sets R6's address as next-hop in BGP route advertisements
bgp start

! Configure OSPF
ospf create area backbone
ospf add stub-host 6.6.6.6 to-area backbone cost 10
ospf add interface rt6-rt1.mp2 to-area backbone
ospf start

! Enable and start MPLS and LDP on the interface to R1
mpls add interface rt6-rt1.mp2
mpls start
ldp add interface rt6-rt1.mp2
ldp start
```

The following is the configuration for R9:

```
! Configure interfaces
interface create ip rt9-rt6 address-netmask 169.1.1.9/24 port et.1.1
interface create ip rt9-32 address-netmask 92.1.1.9/24 port et.3.2
interface create ip rt9-33 address-netmask 93.1.1.9/24 port et.3.3
interface create ip rt9-34 address-netmask 94.1.1.9/24 port et.3.4
interface create ip rt9-35 address-netmask 95.1.1.9/24 port et.3.5
interface create ip rt9-36 address-netmask 96.1.1.9/24 port et.3.6
interface create ip rt9-37 address-netmask 97.1.1.9/24 port et.3.7
interface create ip rt9-38 address-netmask 98.1.1.9/24 port et.3.8
interface add ip lo0 address-netmask 9.9.9.9/32

! Configure BGP
ip-router global set router-id 9.9.9.9
ip-router global set autonomous-system 65498
ip add route default gateway 169.1.1.6
ip-router policy redistribute from-proto direct to-proto bgp target-as 64498
bgp create peer-group bgp-to-nil6 type external autonomous-system 64498
bgp add peer-host 169.1.1.6 group bgp-to-nil6
bgp start
```

17.6 CONFIGURING L2 TUNNELS

Riverstone's layer-2 (L2) MPLS implementation supports the encapsulation and transport of L2 Protocol Data Units (PDUs) across an MPLS network, by using both Martini Internet-Draft tunnels and Transparent LAN Services (TLS) tunnels. These features allow you to use MPLS labels, instead of network layer encapsulation, to tunnel L2 frames across a backbone MPLS network. For metro service providers, this has many important benefits:

- Scalability of 802.1q and IP VPN services. With 802.1q VLANs, the total number of VLANs in the entire network is limited to 4,096. With IP VPNs, layer-2 tunnel protocol (L2TP) tunnels that carry traffic across the MPLS network must be manually configured with a pair of IP addresses assigned to each tunnel. With MPLS, packets to be sent through the L2 tunnel can be considered as a single FEC. Transit LSRs only need to look at the top label to switch the labeled packet across the MPLS network.
- L2 tunnels across backbone networks can be added as virtual interfaces to VLANs, allowing transparent bridging across the backbone. Customer network information, such as MAC addresses and VLAN IDs, is not exposed to the backbone network since only the outer MPLS label is examined by each router in the tunnel.
- Many end-to-end customer-specific or VLAN-specific *virtual circuits* can be bundled into a small number of L2 tunnels that run through the backbone. Traffic on each virtual circuit is isolated from each other, with the same level of security as a frame relay or ATM virtual circuit.

The RS supports two methods of transporting L2 VPN frames over MPLS:

- Point-to-point LSPs for Virtual Leased Line (VLL) services. (See Section 17.6.2, *"Configuring Point-to-Point L2 LSPs."*)
- Point-to-multipoint LSPs for Transparent LAN services (TLS). TLS allows transport of Ethernet and VLAN traffic for multiple sites that belong to the same L2 broadcast domain. (See Section 17.6.3, *"Configuring Point-to-Multipoint L2 LSPs (TLS)."*)

The RS supports two basic types of virtual circuit labels:

- *Static* labels require that you configure all routers and all labels in the path. MPLS must be enabled. No signaling protocol is used, so you do not need to enable RSVP or LDP.
- *Dynamic* labels use LDP signaling on the ingress and egress LSRs to specify the FEC-to-label mapping for the virtual circuit. You can use either RSVP or LDP signaling within the tunnel LSP.

Note The RS supports the transport of Ethernet frames only with MPLS labels.

17.6.1 Configuring Dynamic L2 Labels

In Figure 17-17, layer-2 frames are received at the ingress LSR R1, then transmitted to the egress LSR R2 across an MPLS network through a *tunnel LSP*. At the ingress LSR, a *virtual circuit* (*VC*) *label* is added to the L2 frame. The VC label is used to inform the egress LSR how to treat the received packet and the interface on which the frame is to be output. When R1 sends the L2 frame to R2, a *tunnel label* is pushed onto the MPLS label stack. As the packet traverses through the MPLS network, additional labels can be pushed onto and popped off the label stack. A number of L2 VCs can be carried in this way across a single tunnel LSP.

Note that the process of transporting L2 frames across an MPLS network is unidirectional; you will need to repeat the configuration in the reverse direction to provide bidirectional operation. You must configure the same VC identifiers (for example, VLAN IDs) for each direction of a virtual circuit.

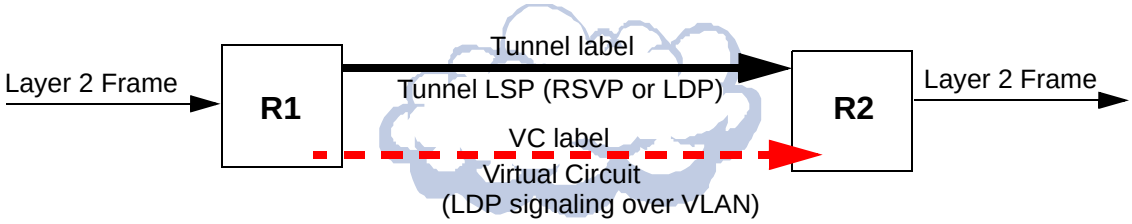


Figure 17-17 Transport of layer 2 frames across an MPLS network

Virtual Circuit Signaling

For dynamic label assignments, the VC label is distributed using LDP in downstream unsolicited mode. A remote LDP connection must be established between the ingress and egress LSRs. You configure VLANs to carry the signaling necessary to establish the LDP connection. In this section, these VLANs are referred to as *LDP-signaling VLANs*.

Tunnel LSP Signaling

Either RSVP or LDP can be used to assign and distribute the tunnel labels used within the tunnel LSP. If you use RSVP for signaling in the tunnel LSP, you need to configure LSPs with the **`mpls create`** and/or **`mpls set`** commands. If you use LDP for signaling in the tunnel LSP, you do not need to configure LSPs with the **`mpls`** commands; however, you need to enable and start MPLS on tunnel LSRs.

Note The MTU size for MPLS ports must be at least 22 bytes more than the MTU size of incoming non-MPLS traffic; additional bytes are required for multiple labels. The default maximum transmission unit (MTU) size for non-MPLS ports on the RS is 1522 bytes. The default MTU size for ports on MPLS-enabled line cards on the RS is 1568 bytes, which allows for multiple MPLS labels).

The MPLS network must be configured with an MTU that is large enough to transport the maximum size frame that will be transported in the tunnel LSP (this can be at least 12 bytes more than the largest frame size). If an MPLS packet exceeds the tunnel MTU, it will be dropped. If an egress LSR receives a packet that exceeds the MTU of the destination L2 interface, the packet will be dropped.

17.6.2 Configuring Point-to-Point L2 LSPs

FEC-Label Bindings

On the RS, the following can be used to identify the FEC-to-label binding for a point-to-point virtual circuit LSP:

- VLAN ID assigned to a customer by a service provider
- incoming port
- incoming port and the customer-specific VLAN ID assigned by the customer

This section includes example configurations for each type of FEC-to-label binding.

Ingress and Egress LSR Configuration for Point-to-Point L2 LSPs

On the ingress and egress LSRs, configure the following:

1. Configure the L2 FEC.
   - If you are using the VLAN ID as the FEC, create the VLAN with the **`vlan create`** and **`vlan add ports`** commands.
   - If you are using the incoming port as the FEC, use the **`ldp map ports`** command to map the port to a logical customer ID number.

Note The ports that are mapped to a single customer ID number must be either all trunk ports or all access ports.

A port cannot be mapped to more than one customer ID number.

   - If you are using a combination of customer VLAN ID and incoming port as the FEC, create the VLAN with the **`vlan create`** and **`vlan add ports`** commands and use the **`ldp map ports`** command to map the port to a logical customer ID number.
2. Advertise the FEC-to-label mapping via LDP to the remote peers. Enable and start LDP.

- Specify the remote LDP peer with the **ldp add remote-peer** command. Specify the router ID of the remote LDP peer, which must be one of the loopback addresses of the remote router.
- If you are using the VLAN ID as the FEC, specify the **vlan** option with the **ldp add l2-fec** command.
- If you are using the incoming port as the FEC, specify the **customer-id** option with the **ldp add l2-fec** command.
- If you are using a combination of VLAN ID and incoming port as the FEC, specify both the **vlan** and **customer-id** options with the **ldp add l2-fec** command.

3. Configure the LDP-signaling VLAN and interface. The ports at both ends of a link between two LSRs must belong to the same VLAN, i.e., the VLAN ID must be the same on both routers.
4. Configure the tunnel LSP. If you are using RSVP for signaling in the tunnel LSP, use **mpls** commands, as described in Section 17.5, *"Configuring L3 Label Switched Paths."* If you configure more than one tunnel LSP to the same destination, you can specify the preferred LSP to be used with the **transport-lsp** option of the **ldp set l2-fec** command. You can also specify if an alternate LSP can be used. Enable and start MPLS and the signaling protocol (either LDP or RSVP) for the tunnel LSP.

Note The **transport-lsp** option of the **ldp set l2-fec** command allows you to assign a specific LSP to specific customer traffic. This provides a way to offer different LSP services to different customers.

5. Configure the IGP routing protocol, either OSPF or IS-IS.

Transit LSR Configuration for Point-to-Point L2 LSPs

On the transit LSRs, configure the following:

1. Configure the LDP- or RSVP-signaling VLAN and interface.
2. Enable and start MPLS and the signaling protocol (either LDP or RSVP) for the tunnel LSP.
3. Configure the IGP routing protocol, either OSPF or IS-IS.

L2 Tunneling Based on VLAN ID Configuration Examples (Point-to-Point)

The FEC-to-label binding for a virtual circuit can be based on the VLAN ID assigned to a customer by a service provider. Figure 17-18 shows a customer VLAN with an ID of 100, and another customer VLAN with an ID of 200. The VLANs are mapped to VC labels that are distributed via LDP. LDP-signaling VLANs carry the signaling necessary to establish the LDP connection. For example, the ports at each end of the link between R1 and R2 are configured with VLAN ID 110, while the ports at each end of the link between R2 and R3 are configured with VLAN ID 120. The tunnel LSP can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

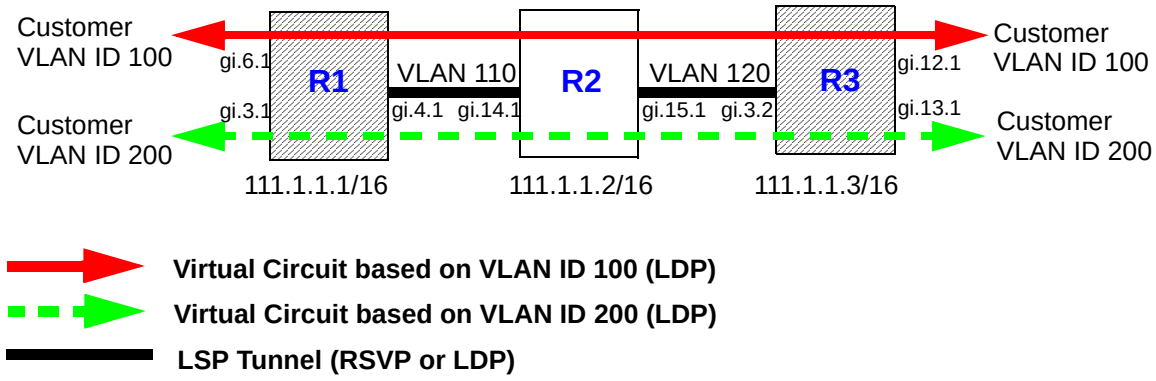


Figure 17-18 Tunneling of multiple virtual circuits based on VLAN ID

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 a trunk port
vlan make trunk-port gi.4.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.6.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.3.1 to cust2
```

```
! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 sends label mapping for VLAN ID 100 to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 sends label mapping for VLAN ID 200 to R3
ldp start

! Create the LDP-signaled VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls create label-switched-path lsp1 to 111.1.1.3
mpls set label-switched-path lsp1 no-cspf
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure LDP-signaling VLANs and interfaces:
vlan make trunk-port gi.14.1
vlan make trunk-port gi.15.1
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 220.1.1.1/16 vlan ldp_in3
```

```
! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 a trunk port
vlan make trunk-port gi.3.2

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.12.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.13.1 to cust2

! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.1 sends label mapping for VLAN ID 100 to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 sends label mapping for VLAN ID 200 to R1
ldp start
```

```
! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP  (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start
```

Figure 17-19 shows two VLANs, with sites that are connected to routers R1, R3, and R5. The VLANs are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

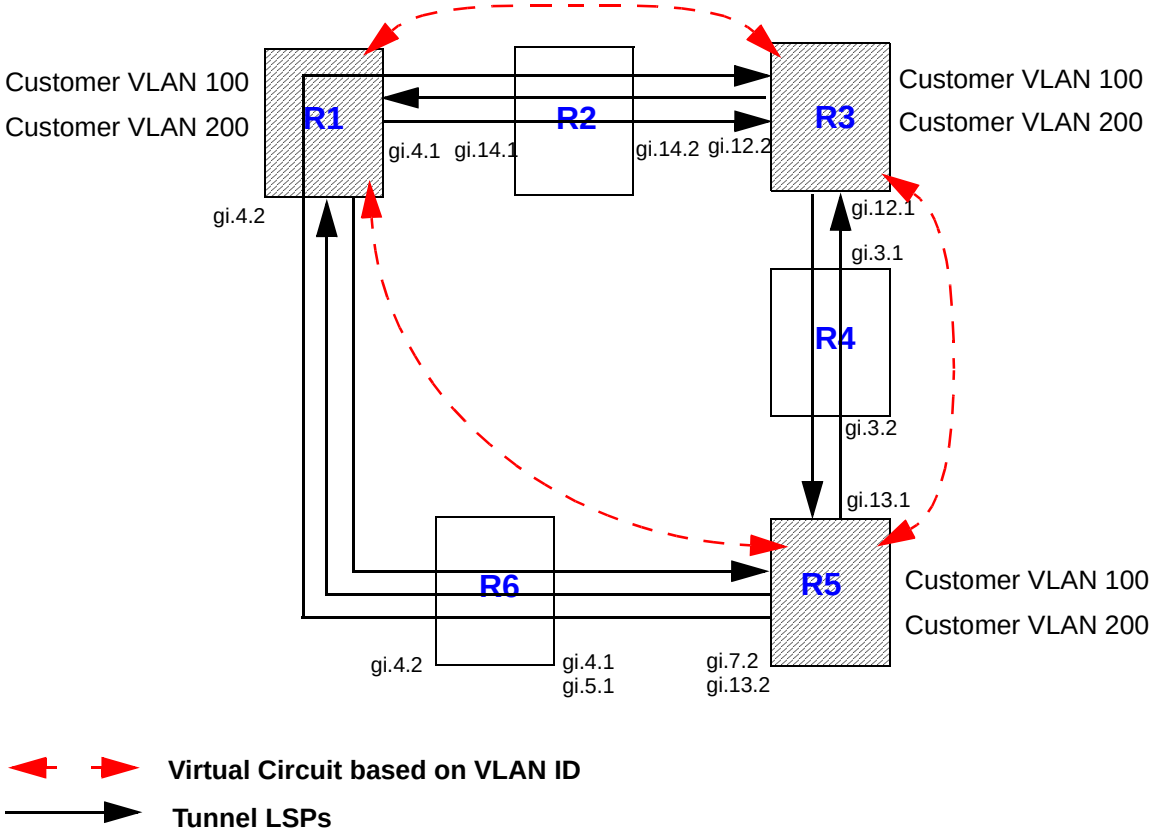


Figure 17-19 Tunneling of virtual circuits based on VLAN ID (RSVP tunnel)

Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops.

Note If you configure more than one tunnel LSP to the same destination, you can specify the preferred LSP to be used with the **transport-lsp** option of the **ldp set l2-fec** command. You can also specify if an alternate LSP can be used. The **transport-lsp** option of the **ldp set l2-fec** command allows you to assign a specific LSP to specific customer traffic. This provides a way to offer different LSP services to different customers.

The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan create cust1 port-based id 100
vlan create cust2 port-based id 200
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based id 120
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.1 to ldp_in
vlan add ports gi.6.1,gi.2.2 to cust1
vlan add ports gi.3.1 to cust2
interface create ip to_rs2 address-netmask 200.1.1.1/16 vlan ldp_in  LDP-signaling VLAN to R2
interface create ip to_rs6 address-netmask 201.1.1.1/16 vlan ldp_in2  LDP-signaling VLAN to R6
interface create ip ip_32 address-netmask 124.2.1.1/16 port gi.3.2
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs6

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3
```

```
! Configure tunnel LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure tunnel LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs6
rsvp start

! Configure LDP
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 send VLAN 100 mapping to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 send VLAN 100 mapping to R5
ldp add l2-fec vlan 200 to-peer 111.1.1.5 send VLAN 200 mapping to R3
ldp add l2-fec vlan 100 to-peer 111.1.1.5 send VLAN 200 mapping to R5
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_rs1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_rs3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

```
! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs3
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs3
rsvp start
```

Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and restricted to traffic destined for the 124.2.0.0/16 subnet. The following is the configuration for R3:

```
! Configure VLANs and interfaces
vlan make trunk-port gi.12.2
vlan make trunk-port gi.12.1
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan create cust1 port-based id 100
vlan create cust2 ip id 200
vlan create to_rs1_only ip id 50
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.14.1,gi.12.2 to cust1
vlan add ports gi.12.1 to ldp_if1
vlan add ports gi.12.1 to cust1
vlan add ports gi.12.2,at.3.1.0.100 to cust2
vlan add ports gi.13.2 to cust2
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
```

```
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1

! Create tunnel LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp add l2-fec vlan 100 to-peer 111.1.1.1 send VLAN 100 mapping to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 send VLAN 200 mapping to R1
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.5 send VLAN 100 mapping to R5
ldp add l2-fec vlan 200 to-peer 111.1.1.5 send VLAN 200 mapping to R5
ldp start
```

R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Configure interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs3
```

```
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces to R4 and R6
vlan make trunk-port gi.13.1
vlan make trunk-port gi.7.2
vlan create cust1 port-based id 100
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan create cust2 ip id 200
vlan add ports gi.12.1,gi.13.2 to cust1
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
vlan add ports gi.13.1 to cust1
vlan add ports gi.6.1 to cust2
vlan add ports gi.7.2 to cust1
vlan add ports gi.7.2 to ldp_in1
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32

! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
```

```
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start
```

```
! Configure LDP
ldp add interface lo0
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec vlan 100 to-peer 111.1.1.3 send VLAN 100 mapping to R3
ldp add l2-fec vlan 200 to-peer 111.1.1.3 send VLAN 200 mapping to R3
ldp add l2-fec vlan 100 to-peer 111.1.1.1 send VLAN 100 mapping to R1
ldp add l2-fec vlan 200 to-peer 111.1.1.1 send VLAN 200 mapping to R1
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure interfaces to R1 and R5
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```

L2 Tunneling Based on Ports Configuration Examples (Point-to-Point)

The FEC-to-label binding for a virtual circuit can be based on the port on which traffic arrives. One or more incoming ports are mapped to a logical customer ID number, which is then mapped to an FEC.

In Figure 17-20, ports gi.6.1 on R1 and gi.12.1 on R3 are mapped to customer ID 1. Ports gi.3.1 on R1 and gi.13.1 on R3 are mapped to customer ID 2. The customer IDs are mapped to VC labels that are distributed via LDP. You can choose to have either untagged or 802.1q tagged frames transported across the tunnel LSP; the configuration for transporting untagged packets is shown. The tunnel LSP can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP tunnel signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

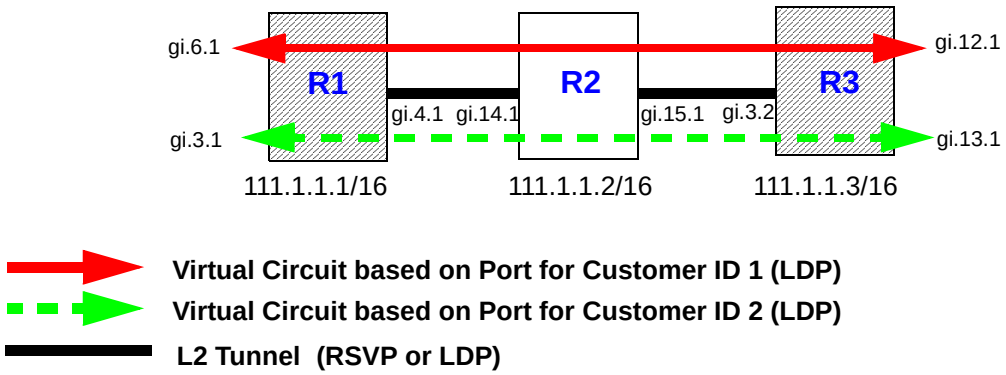


Figure 17-20 Tunneling of multiple virtual circuits based on ports (untagged frames)

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 a trunk port that does not send out 802.1q tagged frames
vlan make trunk-port gi.4.1 untagged

! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp map ports gi.6.1 customer-id 1 maps port gi.6.1 to customer-id 1
ldp map ports gi.3.1 customer-id 2 maps port gi.3.1 to customer-id 2
ldp add l2-fec customer-id 1 to-peer 111.1.1.3 sends label mapping for customer-id 1 to R3
ldp add l2-fec customer-id 2 to-peer 111.1.1.3 sends label mapping for customer-id 2 to R3
ldp start
```

```
! Create the LDP-signaling VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure VLANs and interfaces:
vlan make trunk-port gi.14.1 untagged  configure trunk port that does not send out 802.1q tagged frames
vlan make trunk-port gi.15.1 untagged  configure trunk port that does not send out 802.1q tagged frames
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 210.1.1.1/16 vlan ldp_in3

! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start
```

```
! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 a trunk port  that does not send out 802.1q tagged frames
vlan make trunk-port gi.3.2 untagged

! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp map ports gi.12.1 customer-id 1 maps port gi.12.1 to customer-id 1
ldp map ports gi.13.1 customer-id 2 maps port gi.13.1 to customer-id 2
ldp add l2-fec customer-id 1 to-peer 111.1.1.1  sends label mapping for customer-id 1 to R1
ldp add l2-fec customer-id 2 to-peer 111.1.1.1  sends label mapping for customer-id 2 to R1
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start
```

```
! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP  (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start
```

In Figure 17-21, ports gi.6.2, gi.2.1, and gi.5.1 on R1, port gi.15.1 on R3, and port gi.12.2 on R5 are mapped to customer ID 10. The customer IDs are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Note The ports that are mapped to a single customer ID number must be either all trunk ports or all access ports. The example shows configurations for transporting 802.1q traffic.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

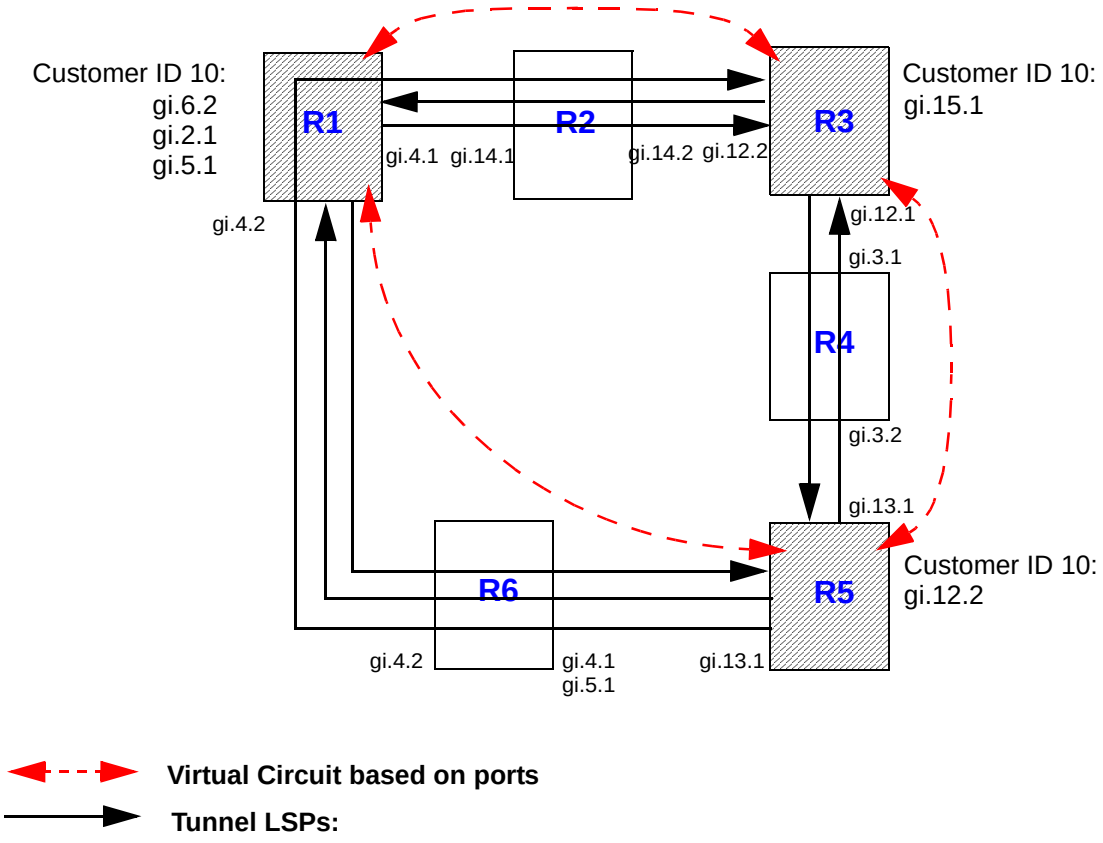


Figure 17-21 Tunneling of virtual circuits based on ports (RSVP tunnel)

Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, and R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops. The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan make trunk-port gi.2.1 customer ports must be trunk ports for 802.1q packets
vlan make trunk-port gi.6.2  customer ports must be trunk ports for 802.1q packets
vlan make trunk-port gi.5.1  customer ports must be trunk ports for 802.1q packets
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based id 120
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.1 to ldp_in
interface create ip to_rs2_1 address-netmask 200.1.1.1/16 vlan ldp_in  LDP-signaling VLAN interface
interface create ip to_rs2_second address-netmask 201.1.1.1/16 vlan ldp_in2  LDP-signaling VLAN
interface
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2_1 to-area backbone
ospf add interface to_rs2_second to-area backbone
ospf add interface ip_to_rs3000 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2_1
mpls add interface to_rs2_second

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3

! Configure LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
```

```
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2_1
rsvp add interface to_rs2_second
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.6.2 customer-id 10 map ports to customer-id 10
ldp map ports gi.2.1 customer-id 10
ldp map ports gi.5.1 customer-id 10
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.3 send customer-id 10 to R3
ldp add l2-fec customer-id 10 to-peer 111.1.1.5 send customer-id 10 to R5
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_RS1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_RS3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_RS1
mpls add interface to_RS3
mpls start

! Configure RSVP
rsvp add interface to_RS1
```

```
rsvp add interface to_RS3
rsvp start
```

Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and is restricted to traffic destined for the 124.2.0.0/16 subnet. The following is the configuration for R3:

```
! Configures VLANs and interfaces
vlan make trunk-port gi.15.1  customer ports must be trunk ports for 802.1q packets
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.12.1 to ldp_if1
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf add interface ip_local_123 to-area backbone
ospf add interface to_rs38000_internet to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.15.1 customer-id 10  map port gi.15.1 to customer-id 10
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.1  send customer-id mapping to R1
ldp add remote-peer 111.1.1.5  adds R5 as LDP peer
```

```
ldp add l2-fec customer-id 10 to-peer 111.1.1.5 send customer-id mapping to R5
ldp start
```

R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Configure VLANs and interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs3
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces to R4 and R6
vlan make trunk-port gi.12.2  customer ports must be trunk ports for 802.1q packets
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32
```

```
! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
```

```
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.12.2 customer-id 10  map port gi.12.2 to customer-id 10
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.1  send customer-id mapping to R1
ldp add remote-peer 111.1.1.3  adds R3 as LDP peer
ldp add l2-fec customer-id 10 to-peer 111.1.1.3  send customer-id mapping to R3
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure interfaces to R1 and R5
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```

L2 Tunneling Based on VLAN ID and Port Configuration Examples (Point-to-Point)

The FEC-to-label binding for a virtual circuit can be based on both a customer-specified VLAN ID and the port on which the traffic arrives. Each combination of VLAN ID and logical customer ID (which represents the incoming port) is mapped to a single FEC.

Figure 17-22 shows two VLANs with sites that are connected to routers R1 and R3. Port gi.6.1 on R1 and gi.12.1 on R3 provide access for the VLANs. Each VLAN ID/port combination is mapped to a VC label that is distributed via LDP. The LSP tunnel can use either LDP or RSVP as the signaling protocol; configuration commands for both LDP and RSVP tunnel signaling are shown.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

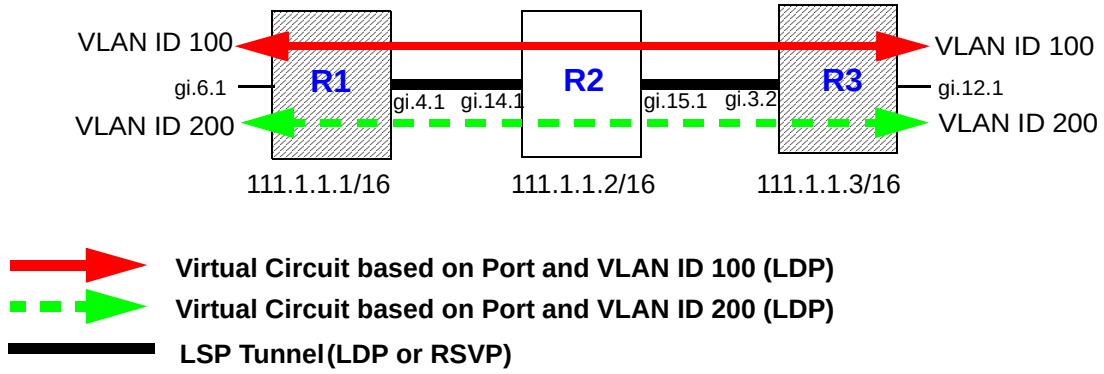


Figure 17-22 Tunneling of multiple virtual circuits based on port and VLAN ID

The following is the configuration for R1:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.1/32

! Make gi.4.1 and gi.6.1 trunk ports
vlan make trunk-port gi.4.1
vlan make trunk-port gi.6.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.6.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.6.1 to cust2
```

```
! Configure the LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp map ports gi.6.1 customer-id 10 maps port gi.6.1 to customer-id 50
ldp add l2-fec customer-id 10 vlan 100 to-peer 111.1.1.3 sends label mapping for customer-id 10/VLAN ID 100 to R3
ldp add l2-fec customer-id 10 vlan 200 to-peer 111.1.1.3 sends label mapping for customer-id 10/VLAN ID 200 to R3
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in port-based id 110
vlan add ports gi.4.1 to ldp_in
interface create ip to_r2_1 address-netmask 200.1.1.1/16 vlan ldp_in

! If tunnel LSP uses RSVP:
mpls add interface to_r2_1
mpls start
rsvp add interface to_r2_1
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2_1
mpls start
ldp add interface to_r2_1
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_r2_1 to-area backbone
ospf start
```

The following is the configuration for R2:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure VLANs and interfaces:
vlan make trunk-port gi.14.1
vlan make trunk-port gi.15.1
vlan create ldp_in1 port-based id 110
vlan create ldp_in3 port-based id 120
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.15.1 to ldp_in3
interface create ip to_r1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_r3 address-netmask 210.1.1.1/16 vlan ldp_in3
```

```
! If tunnel LSP uses RSVP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
rsvp add interface to_r1
rsvp add interface to_r3
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r1
mpls add interface to_r3
mpls start
ldp add interface to_r1
ldp add interface to_r3
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start
```

The following is the configuration for R3:

```
! Configure router loopback
interface add ip lo0 address-netmask 111.1.1.3/32

! Make gi.3.2 and gi.12.1 trunk ports
vlan make trunk-port gi.3.2
vlan make trunk-port gi.12.1

! Configure the VLAN cust1 with a VLAN ID of 100
vlan create cust1 port-based id 100
vlan add ports gi.12.1 to cust1

! Configure the VLAN cust2 with a VLAN ID of 200
vlan create cust2 port-based id 200
vlan add ports gi.12.1 to cust2
```

! Configure LDP peers and label bindings
ldp add interface lo0
ldp add remote-peer 111.1.1.1 *adds R1 as LDP peer*
ldp map ports gi.12.1 customer-id 10 *maps port gi.12.1 to customer-id 10*
ldp add l2-fec customer-id 10 vlan 100 to-peer 111.1.1.1 *sends label mapping for customer-id 10/VLAN 100 to R1*
ldp add l2-fec customer-id 10 vlan 200 to-peer 111.1.1.1 *sends label mapping for customer-id 10/VLAN 200 to R1*
ldp start

! Create the LDP-signaling VLAN and interface
vlan create ldp_in1 port-based id 120
vlan add ports gi.3.2 to ldp_in1
interface create ip to_r2 address-netmask 220.1.1.2/16 vlan ldp_in1

! If tunnel LSP uses RSVP:
mpls add interface to_r2
mpls start
rsvp add interface to_r2
rsvp start

! If tunnel LSP uses LDP:
mpls add interface to_r2
mpls start
ldp add interface to_r2
ldp start

! Configure IGP (in this example, OSPF is the IGP)
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add interface to_r2 to-area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf start

Figure 17-23 shows two VLANs (with IDs 50 and 60) that enter R1 on port gi.2.2. VLAN 50 traffic enters R3 on port gi.15.1, while VLAN 60 traffic enters R5 on port gi.6.2. The VLAN ID/port combinations are mapped to VC labels that are distributed via LDP. The tunnel LSPs can use either LDP or RSVP as the signaling protocol; configuration commands for RSVP tunnel signaling are shown for this example.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

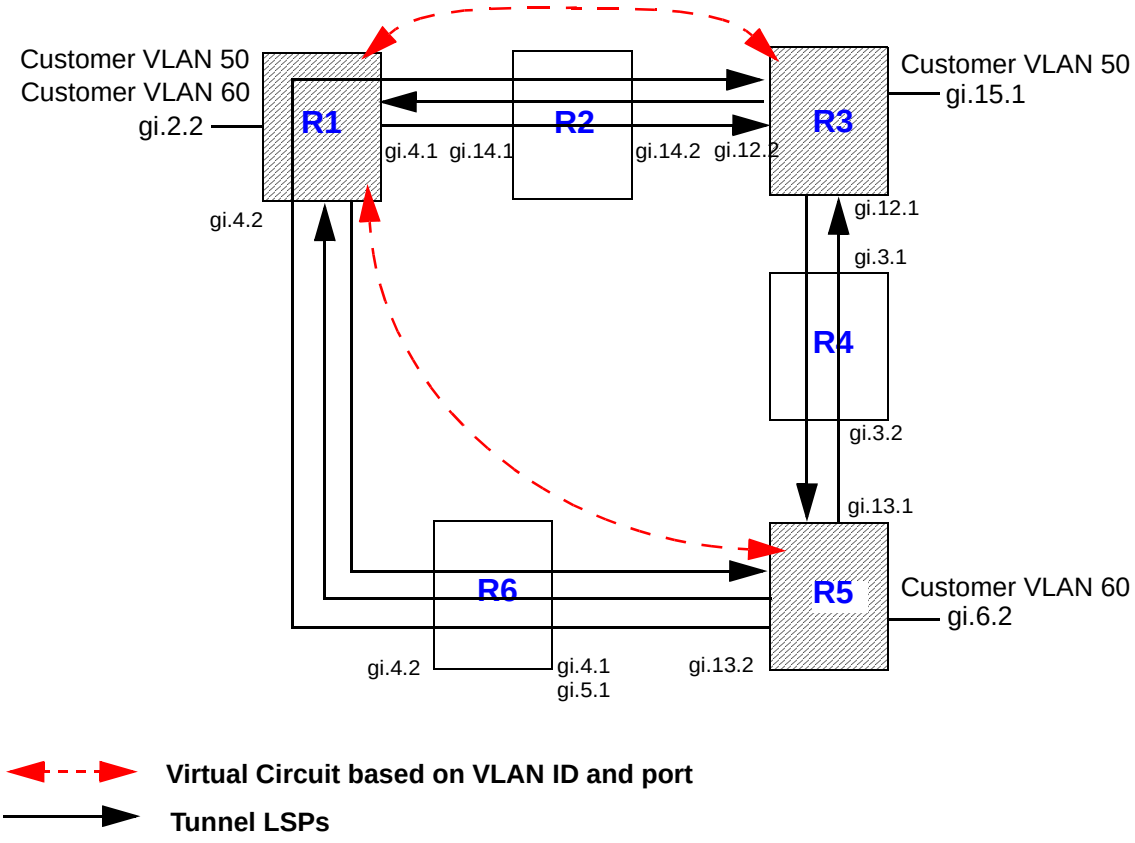


Figure 17-23 Tunneling of virtual circuits based on VLAN ID and port (RSVP tunnel)

Two LSPs are configured on R1. The LSP from R1 to R5 is configured with a strict explicit path of 3 hops (R1, R6, R5) and is restricted to traffic destined for the 152.1.0.0/16 subnet. The LSP from R1 to R3 is configured with a loose explicit path of 2 hops. The following is the configuration for R1:

```
! Configure VLANs and interfaces
vlan create ldp_in port-based id 110
vlan create ldp_in2 port-based 120
vlan create to_rs3_only port-based id 50
vlan create to_rs5_only port-based id 60
```

```
vlan add ports gi.4.2 to ldp_in2
vlan add ports gi.4.1 to ldp_in
vlan add ports gi.2.2 to to_rs3_only
vlan add ports gi.2.2 to to_rs5_only
interface create ip to_rs2 address-netmask 200.1.1.1/16 vlan ldp_in   LDP-signaling VLAN interface
interface create ip to_rs6 address-netmask 201.1.1.1/16 vlan ldp_in2   LDP-signaling VLAN interface
interface add ip lo0 address-netmask 111.1.1.1/32

! Configure OSPF
ip-router global set router-id 111.1.1.1
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs6 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs6

! Configure explicit path p1 to R3
mpls create path p1 num-hops 2
mpls set path p1 ip-addr 200.1.1.1 type loose hop 1
mpls set path p1 ip-addr 210.1.1.2 type loose hop 2

! Configure explicit path to R5
mpls create path to_rs5_primary num-hops 3
mpls set path to_rs5_primary ip-addr 201.1.1.1 type strict hop 1
mpls set path to_rs5_primary ip-addr 201.1.1.2 type strict hop 2
mpls set path to_rs5_primary ip-addr 220.1.1.2 type strict hop 3

! Configure LSP to R3 with explicit path p1
mpls create label-switched-path to_rs3_rsvp to 111.1.1.3 no-cspf preference 10
mpls set label-switched-path to_rs3_rsvp primary p1 no-cspf retry-interval 5 mtu 1000

! Configure LSP to R5
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs5 dst-ipaddr-mask 152.1.0.0/16
mpls set label-switched-path to_rs5_rsvp policy dip_to_rs5
mpls set label-switched-path to_rs5_rsvp primary to_rs5_primary no-cspf retry-interval 5
preference 30

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs6
```

```
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.2.2 customer-id 20 maps port gi.2.2 to customer-id 20
ldp add remote-peer 111.1.1.3 adds R3 as LDP peer
ldp add remote-peer 111.1.1.5 adds R5 as LDP peer
ldp add l2-fec customer-id 20 vlan 50 to-peer 111.1.1.3 sends label mapping for customer-id 20/VLAN 50 to R3
ldp add l2-fec customer-id 20 vlan 60 to-peer 111.1.1.5 sends label mapping for customer-id 20/VLAN 60 to R5
ldp start
```

R2 is a transit LSR with interfaces to R1 and R3. The following is the configuration for R2:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 110
vlan create ip_ldp ip id 175
vlan add ports gi.14.1 to ldp_in1
vlan add ports gi.14.2 to ip_ldp
interface create ip to_RS1 address-netmask 200.1.1.2/16 vlan ldp_in1
interface create ip to_RS3 address-netmask 210.1.1.1/16 vlan ip_ldp
interface add ip lo0 address-netmask 111.1.1.2/32

! Configure OSPF
ip-router global set router-id 111.1.1.2
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_RS1
mpls add interface to_RS3
mpls start

! Configure RSVP
rsvp add interface to_RS1
rsvp add interface to_RS3
rsvp start
```

Two LSPs are configured on R3: one is from R3 to R5, while the other is from R3 to R1 and restricted to traffic destined for the 124.2.0.0.16 subnet. The following is the configuration for R3:

```
! Create VLANs and interfaces
vlan create ldp_if1 id 120
vlan create ip_ldp port-based id 175
vlan create to_rs1_only ip id 50
vlan add ports gi.12.2 to ip_ldp
vlan add ports gi.12.1 to ldp_if1
vlan add ports gi.15.1 to to_rs1_only
interface create ip to_rs2 address-netmask 210.1.1.2/16 vlan ip_ldp
interface create ip to_rs4 address-netmask 110.1.1.1/16 vlan ldp_if1
interface add ip lo0 address-netmask 111.1.1.3/32

! Configure OSPF
ip-router global set router-id 111.1.1.3
ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to_rs2 to-area backbone
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs2
mpls add interface to_rs4
mpls create label-switched-path to_rs1_rsvp to 111.1.1.1 no-cspf
mpls create label-switched-path to_rs5_rsvp to 111.1.1.5 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_rsvp policy dip_to_rs1
mpls start

! Configure RSVP
rsvp add interface to_rs2
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
ldp map ports gi.15.1 customer-id 20  maps port gi.15.1 to customer-id 20
ldp add l2-fec customer-id 20 vlan 50 to-peer 111.1.1.1  sends label mapping for customer-id 20/VLAN 50 to R1
ldp add remote-peer 111.1.1.1  adds R1 as LDP peer
ldp start
```

R4 is a transit LSR with interfaces to R3 and R5. The following is the configuration for R4:

```
! Create VLANs and interfaces
vlan create rsvp_vlan1 ip id 140
vlan add ports gi.3.2 to rsvp_vlan1
interface create ip to_rs3 address-netmask 110.1.1.2/16 port gi.3.1
interface create ip to_rs5 address-netmask 100.1.1.2/16 vlan rsvp_vlan1
interface add ip lo0 address-netmask 111.1.1.4/32

! Configure OSPF
ip-router global set router-id 111.1.1.4
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs3
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs3
rsvp add interface to_rs5
rsvp start
```

Two LSPs are configured on R5. The LSP from R5 to R1 is configured with a loose explicit path of 2 hops and is restricted to traffic destined for the 124.2.0.0/16 subnet. The LSP from R5 to R3 is configured with a primary and secondary path. The primary path is a strict explicit path of 3 hops (R5, R4, R3) and the secondary path is a strict explicit path of 5 hops (R5, R6, R1, R2, R3). The following is the configuration for R5:

```
! Configure VLANs and interfaces
vlan create ldp_in1 port-based id 130
vlan create to_rs4_vlan port-based id 140
vlan create to_rs1_only port-based id 60
vlan add ports gi.13.2 to ldp_in1
vlan add ports gi.13.1 to to_rs4_vlan
vlan add ports gi.6.2 to to_rs1_only
interface create ip to_rs6 address-netmask 220.1.1.2/16 vlan ldp_in1
interface create ip to_rs4 address-netmask 100.1.1.1/16 vlan to_rs4_vlan
interface add ip lo0 address-netmask 111.1.1.5/32

! Configure OSPF
ip-router global set router-id 111.1.1.5
ospf create area backbone
ospf add interface lo0 to-area backbone
ospf add interface to_rs6 to-area backbone
```

```
ospf add stub-host 111.1.1.5 to-area backbone cost 5
ospf add interface to_rs4 to-area backbone
ospf start

! Configure MPLS
mpls add interface to_rs6
mpls add interface to_rs4

! Create explicit path to_rs3_primary to R3
mpls create path to_rs3_primary num-hops 3
mpls set path to_rs3_primary ip-addr 100.1.1.1 type strict hop 1
mpls set path to_rs3_primary ip-addr 100.1.1.2 type strict hop 2
mpls set path to_rs3_primary ip-addr 110.1.1.1 type strict hop 3

! Create explicit path to_rs3_secondary to R3
mpls create path to_rs3_secondary num-hops 5
mpls set path to_rs3_secondary ip-addr 220.1.1.2 type strict hop 1
mpls set path to_rs3_secondary ip-addr 220.1.1.1 type strict hop 2
mpls set path to_rs3_secondary ip-addr 201.1.1.1 type strict hop 3
mpls set path to_rs3_secondary ip-addr 200.1.1.2 type strict hop 4
mpls set path to_rs3_secondary ip-addr 210.1.1.2 type strict hop 5

! Create explicit path to_rs1_primary to R1
mpls create path to_rs1_primary num-hops 2
mpls set path to_rs1_primary ip-addr 220.1.1.2 type loose hop 1
mpls set path to_rs1_primary ip-addr 201.1.1.1 type loose hop 2

! Create tunnel LSP to R1
mpls create label-switched-path to_rs1_1 to 111.1.1.1 no-cspf
mpls create policy dip_to_rs1 dst-ipaddr-mask 124.2.0.0/16
mpls set label-switched-path to_rs1_1 primary to_rs1_primary retry-interval 10 mtu 1300 no-cspf
mpls set label-switched-path to_rs1_1 policy dip_to_rs1

! Create tunnel LSP to R3
mpls create label-switched-path to_rs3_1 to 111.1.1.3 no-cspf
mpls set label-switched-path to_rs3_1 secondary to_rs3_secondary no-cspf standby
mpls set label-switched-path to_rs3_1 primary to_rs3_primary no-cspf retry-interval 5 mtu 1200

! Start MPLS
mpls start

! Configure RSVP
rsvp add interface to_rs6
rsvp add interface to_rs4
rsvp start

! Configure LDP
ldp add interface lo0
```

```
ldp map ports gi.6.2 customer-id 20 map port gi.6.2 to customer-id 20
ldp add remote-peer 111.1.1.1 adds R1 as LDP peer
ldp add l2-fec customer-id 20 vlan 60 to-peer 111.1.1.1 sends label mapping for customer-id 20/VLAN 60 to R1
ldp start
```

R6 is a transit LSR with interfaces to R1 and R5. The following is the configuration for R6:

```
! Configure VLANs and interfaces
vlan create ip_signal ip id 12
vlan add ports gi.4.1,gi.5.1 to ip_signal
interface create ip to_rs1 address-netmask 201.1.1.2/16 port gi.4.2
interface create ip to_rs5 address-netmask 220.1.1.1/16 vlan ip_signal
interface add ip lo0 address-netmask 111.1.1.6/32

! Configure OSPF
ip-router global set router-id 111.1.1.6
ospf create area backbone
ospf add interface all to-area backbone
ospf add stub-host 111.1.1.6 to-area backbone cost 5
ospf start

! Configure MPLS
mpls add interface to_rs1
mpls add interface to_rs5
mpls start

! Configure RSVP
rsvp add interface to_rs1
rsvp add interface to_rs5
rsvp start
```

Re-mapping a VLAN in a Point-to-Point Tunnel

The ingress LSR can be configured to re-map a VLAN to a different VLAN at the end of the tunnel. For example, you can configure a re-mapping on the ingress LSR such that VLAN 50's traffic winds up on VLAN 60 on the egress LSR. To accomplish this re-mapping, use the **`ldp add l2-fec`** command, and specify the ingress VLAN id and the VLAN id to which the ingress VLAN traffic should be re-mapped.

The following is an example of re-mapping traffic from VLAN 50 to VLAN 60 on the egress router:

```
rs(config)# ldp add l2-fec to-peer 3.3.3.3 vlan 50 vc-id 60 vc-type ethernet-vlan
```

Notice in the example above that VLAN traffic from the VLAN with id of 50 (**`vlan 50`**) is re-mapped to VLAN 60 (**`vc-id 60`**) on the egress LSR. When using the l**`dp add l2-fec`** command you also must set the **`remote-peer`** address, and the **`vc-type`** must be specified as **`ethernet-vlan`**.

Sending a Group of VLANs Across a Martini Connection Using a Single VLAN ID

A number of ingress LSR VLANs can be mapped to a single transit VLAN and then re-mapped to their original VLANs on the egress LSR. VLAN ids are specified on the ingress LSR using the **`vlan`** option. The transit VLAN to which the range of VLANs is mapped is specified using the **`vc-id`** option of the **`ldp add l2=fec`** command.

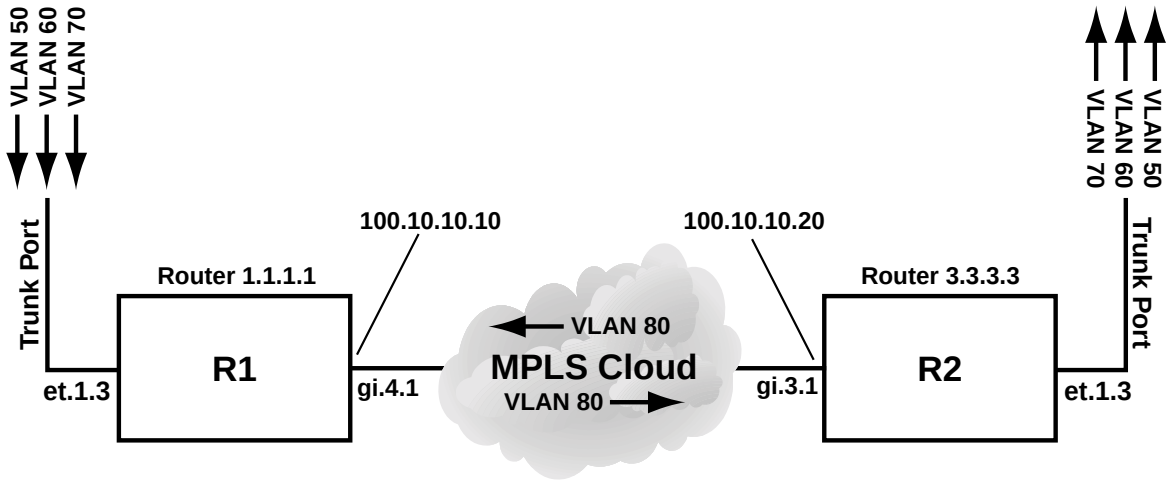


Figure 17-24 Mapping multiple ingress VLANs to different egress VLAN

The following example shows the configuration steps for sending three VLANs (**50**, **60**, **70**) on the transit VLAN **80** (see Figure 17-24):

```
vlan make trunk-port et.1.3

vlan create V1 port-based id 50
vlan create V2 port-based id 60
vlan create V3 port-based id 70

vlan add ports et.1.3 to V1
vlan add ports et.1.3 to V2
vlan add ports et.1.3 to V3

interface create ip mpls1 address-netmask 100.10.10.10/24 port gi.4.1
interface add ip lo0 address-netmask 1.1.1.1/32

ip-router global set router-id 1.1.1.1

ospf create area backbone
ospf add interface mpls1 to-area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf start

mpls add interface mpls1
mpls start

ldp add remote-peer 3.3.3.3
ldp add l2-fec to-peer 3.3.3.3 vlan 50,60,70 vc-id 80 vc-type ethernet-vlan
ldp add interface mpls1
ldp add interface lo0
ldp start
```

This example assumes that the configuration on egress LSR R2 is very similar to R1's configuration. For instance, the same number of trunk ports and VLANs must exist on both the ingress and egress LSRs. Furthermore, the VLAN ids must be identical on R1 and R2.

Using Figure 17-24 as a guide, the following is the configuration that must exist on R2 in order for the group sending of VLANs using a single transit VLAN to be possible:

```
vlan make trunk-port et.1.3

vlan create V1 port-based id 50
vlan create V2 port-based id 60
vlan create V3 port-based id 70

vlan add ports et.1.3 to V1
vlan add ports et.1.3 to V2
vlan add ports et.1.3 to V3

interface create ip mpls2 address-netmask 100.10.10.20/24 port gi.3.1
interface add ip lo0 address-netmask 3.3.3.3/32

ip-router global set router-id 3.3.3.3

ospf create area backbone
ospf add interface mpls2 to-area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf start

mpls add interface mpls2
mpls start

ldp add remote-peer 1.1.1.1
ldp add l2-fec to-peer 1.1.1.1 vlan 50,60,70 vc-id 80 vc-type ethernet-vlan
ldp add interface mpls2
ldp add interface lo0
ldp start
```

Notice in R2's configuration that the trunk ports and VLAN ids are identical to R1's configuration.

In the example above, the traffic for the VLANs with ids of **50**, **60**, and **70** use VLAN **80** as a transit VLAN. Once the transit VLAN reaches the egress LSR (R2), the 802.1Q VLAN tags are checked and the VLAN packets are each sent out through the appropriate port.

17.6.3 Configuring Point-to-Multipoint L2 LSPs (TLS)

This document presents some introductory concepts needed for implementing Virtual Private LAN Services (VPLS) over MPLS on Riverstone Networks switch routers. Four VPLS example configurations for the PEs (edge LSRs) are provided. Each example uses a different VPN type. These examples also illustrate the use of LDP and RSVP for the signaling protocol.

Introduction – Why VPLS Over MPLS

The RS family of switch routers supports the deployment of Virtual Private LAN Services (VPLS) over MPLS layer-2 Transparent LAN Service (TLS). MPLS-based TLS allow MSPs to create LSP tunnels through an MPLS backbone network for each customer, with each LSP provisioned for customer-specific service. To each customer site, the entire

MPLS network appears as a logical L2 switch. Thus, VPLS over MPLS allows business customers to integrate their LAN sites with a metro service provider's MAN. To the business customer, geographically separate networks appear as a single logical VLAN – the MSP's MAN appears transparent to the customer.

MPLS Tunnels

With MPLS tunnels, MPLS label stacks are used instead of network layer encapsulation to tunnel packets across a backbone MPLS network. Tunneling allows shared resources such as public networks to be used to carry private communications. For example, companies can use VPN tunnels to send intranet traffic over the Internet. The advantage that MPLS offers is that the contents of the tunneled data packets do not need to be examined as they proceed through an LSP, because forwarding of the packets is based only on the attached labels (See Section 17.1.5, *"MPLS Tunnels."*).

For example, a customer with three geographically distinct sites can be connected using end-to-end virtual circuit LSPs that are carried over tunnel LSPs. The tunnel label (the label at the top of the MPLS label stack) is used to route traffic over the MPLS backbone, while the VC label (the label at the bottom of the MPLS label stack) is used to determine the egress PE (See Section 17.6.1, *"Configuring Dynamic L2 Labels."*).

Basic PE Configuration for L2 VPLS

The configuration of the PE routers is covered in detail in *VPLS Configuration Examples* sections. However, the basic process for configuring ingress and egress PEs is explained in the following seven steps:

1. Configure the L2 FEC for each customer in a *customer profile* with the **`mpls set customer-profile`** command. The customer profile must include the following:
2. A unique identifier number for each customer
   - One or more physical customer-facing ports on the PE, which are assigned to the customer
   - The VPN type used with this customer profile – The VPN type specifies the source of traffic to be forward through the LSP. Table 17-8 lists the various VPN types and explains their function.

Table 17-8 VPN types and their descriptons

VPN TYPE	Description
Port	Specifies a port-to-port VPN. The port is the customer side port – all traffic arriving on this port(s) is identified as belonging to this customer and is forwarded through the LSP.
Port-VLAN	Specifies a port-to-VLAN VPN. The port is the customer side port – all traffic arriving on this port(s) that belongs to the specified VLAN is identified as belonging to this customer and is forwarded through the LSP.
VLAN	Specifies a VLAN-to-VLAN VPN. All traffic from this VLAN is identified as belonging to this customer and is forwarded through the LSP. Ports are added to the VLAN using the **`vlan add port`** command.

Table 17-8 VPN types and their descriptons (Continued)

Port-VLAN-Range	Specifies a port/VLAN range VPN. The port is the customer side port – all traffic arriving on this port(s) that belongs to the specified range of VLANs is identified as belonging to this customer and is forwarded through the LSP. .
VLAN-Range	Specifies a VLAN range to VLAN range VPN. All traffic from any of the specified VLANs is identified as belonging to this customer and is forwarded through the LSP. Ports are added to the VLAN using the **`vlan add port`** command.

3. Advertise the FEC-to-label mapping via LDP to the remote peers. Enable and start LDP.
   - Specify the remote LDP peer with the **`ldp add remote-peer`** command. Specify the loopback addresses of the remote router. This is typically the router ID of the remote LDP peer, which is applied to the loopback interface using the **`interface add ip lo0`** <*router ID*> command.
   - Send the label mapping for each customer profile to the appropriate remote peer with the **`ldp connect customer-profile`** command.
4. Configure the signaling VLAN (or tunnel LSP) and interface. The ports at both ends of a link between two PEs must belong to the same VLAN, i.e., the VLAN ID must be the same on both routers.
5. Configure the tunnel (or signaling) LSP. Either LDP or RSVP can be used for signaling in the tunnel LSP.
6. Start MPLS and the signaling protocol (either LDP or RSVP) for the tunnel LSP.
7. Configure the IGP routing protocol, either OSPF or IS-IS.

Transit LSR Configuration for VPLS

The configuration of the transit LSRs depends on many factors. Among these factors are the number of transit LSRs, the signaling protocol, and the type of equipment used. Because of these factors, a complete discussion of transit LSR configurations is beyond the scope of this document. Instead, this document represents the MPLS transit network as an MPLS cloud. This cloud does not specify either the topology or configurations of the transit LSRs within.

In general, LSRs within the MPLS cloud usually require the following components to be configured.

- The LDP or RSVP signaling VLAN and interface is created
- MPLS and the signaling protocol (either LDP or RSVP) are enabled for the tunnel LSP
- An IGP routing protocol, either OSPF or IS-IS is configured on the LSRs

For completeness and purposes of education, however, a configuration for a single transit LSR, is presented as an example at the end of this document (see *example five*). This transit LSR configuration is compatible with all four VPLS example configurations.

When 802.1Q Tagging is used

Table 17-9 describes when 802.1Q tagging is used for a particular VPN type:

Table 17-9 When 802.1Q tag is used by VPLS

VPN Type	Customer Port Type	.1Q header in VPLS Frame	Comment
Port-Only	Access	Yes	If the customer port is an access port, the creation of the customer profile does not define the VLAN(s) being used, so the VPLS VPN is propagated across the link. In the case where the customer port is a trunk port, the VLANs being used are unknown.
	Trunk	Yes	
VLAN-Only	Access	No	When a VLAN-only L2-FEC is created, the one VLAN concerned is explicitly configured. It is unnecessary to propagate the VLAN info across the VPLS.
	Trunk	No	
Port-VLAN	Access	No	When a port-VLAN L2-FEC is created, the one vlan concerned is explicitly configured. It is unnecessary to propagate the VLAN info across the VPLS
	Trunk	No	
VLAN-Range	Trunk	Yes	When sending multiple VLANs down one L2-FEC, the .1q tag must be kept in order to differentiate the traffic at the remote end.
Port-VLAN-Range	Trunk	Yes	

VPLS Configuration Examples

All configuration examples presented here are based on the topology shown in Figure 17-25.

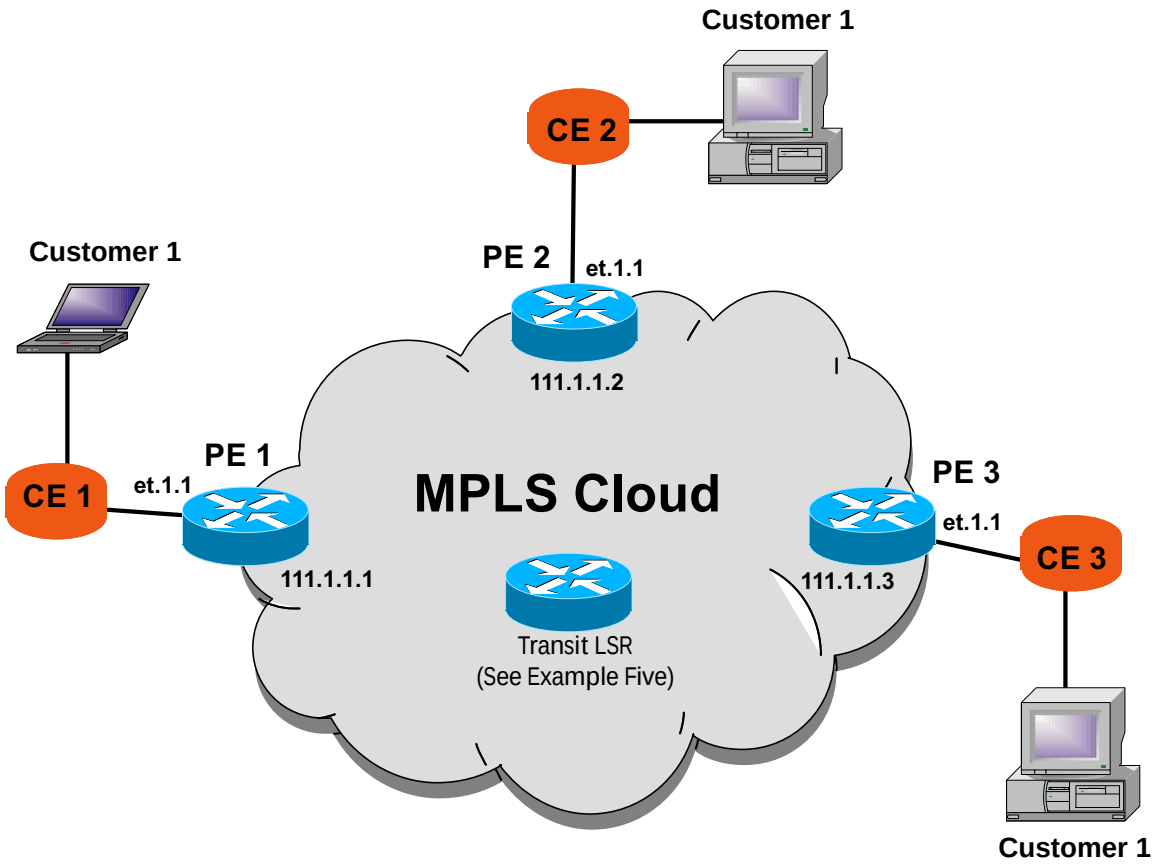


Figure 17-25 VPLS topology for configuration examples

Notice in the figure that each CE is attached to its PE through an Ethernet port (customer facing port). Also, notice the router IDs used by each PE (111.1.1.1 for PE 1, 111.1.1.2 for PE 2, and so on). These router IDs also are used as the loopback interface addresses that identify each PE as a remote peer.

Example One – Port-based VPLS Using LDP Over RSVP

The following example creates a Virtual Private LAN Service for customer 1 that resides on CE 1 through CE 3. Notice that with few exceptions the configurations for PE 1 through PE 3 are essentially the same. For this reason, the first configuration (for PE 1) is annotated in detail, while the configurations for PE 2 and PE 3 are annotated only where there are difference.

In this example, the VPN is tunneled using LDP, while TLS signaling is performed using RSVP.

Configuration for PE 1:

Create Customer 1's VLAN on PE 1, give it the ID of 110, and add the port gi.2.1 to the VLAN:

```
vlan create cust1 port-based id 110
vlan add ports gi.2.1 to cust1
```

Create an interface for the VLAN and assign it an IP address and netmask – This is the interface that faces the core LSRs:

```
interface create ip to-core1 address-netmask 200.1.1.1/16 vlan cust1
```

Add an additional IP address (other than 127.0.0.1) to the loopback interface (use subnet mask 32) – This IP address is the PE's remote peer identity:

```
interface add ip lo0 address-netmask 111.1.1.1/32
```

Set the router ID for OSPF – This can be the same as the new loopback address:

```
ip-router global set router-id 111.1.1.1
```

Create the OSPF backbone area (used for signaling), add the VLAN interface to the backbone, then start OSPF:

```
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to-core1 to-area backbone
ospf start
```

Add the signaling VLAN interface to MPLS:

```
mpls add interface to-core1
```

Create the label switch paths to the other PEs, identified by their loopback addresses:

```
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls create label-switched-path to-PE3 to 111.1.1.3
```

Turn off CSPF (`no-cspf`) for each label switch path:

```
mpls set label-switched-path to-PE2 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Create the customer profile, assign a customer ID number, specify the customer facing port (`et.1.1`), the customer profile type (L2-FEC type), then start MPLS:

```
mpls set customer-profile 1-2-3 customer_id 10 in-port-list et.1.1 type port
mpls start
```

Add the VLAN interface to RSVP, and then start RSVP – Signaling for the VPN is performed by RSVP:

```
rsvp add interface to-core
rsvp start
```

Add the VLAN interface and the remote peer IP addresses (address for PE 2 and PE 3) to LDP:

```
ldp add interface lo0
ldp add remote-peer 111.1.1.2
ldp add remote-peer 111.1.1.3
```

Make the VPN connections between this PE (PE 1) and the remote PEs (PE 2 and PE 3) – Here, both the customer profile and the remote peer IP address are specified:

```
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
```

Start LDP:

```
ldp start
```

Configuration for PE 2:

Create Customer 1's VLAN on PE 2, give it the ID of 120, and add the port gi.4.1 to the VLAN:

```
vlan create cust1 port-based id 120
vlan add ports gi.4.1 to cust1
```

The IP address for PE 2 is in a different broadcast domain from PE 1 and PE 3:

```
interface create ip to-core2 address-netmask 201.1.1.1/16 vlan cust1
```

The IP address for PE 2's loopback interface ends in a 2:

```
interface add ip lo0 address-netmask 111.1.1.2/32

ip-router global set router-id 111.1.1.2

ospf create area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf add interface to-core2 to-area backbone
ospf start

mpls add interface to-core
```

Notice that the label switched paths are going to PE 1 and PE 3:

```
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE3 no-cspf
mpls set customer-profile 1-2-3 customer_id 10 in-port-list et.1.1 type port
mpls start

rsvp add interface to-core2
rsvp start

ldp add interface lo0
```

Notice that for PE 2, the remote peers are PE 1 and PE 3:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 3:

Create Customer 1's VLAN on PE 3, give it the ID of 130, and add the port gi.4.1 to the VLAN:

```
vlan create cust1 port-based id 130
vlan add ports gi.4.1 to cust1
```

The IP address for PE 3 is in a different broadcast domain from PE 1 and PE 2:

```
interface create ip to-core3 address-netmask 202.1.1.1/16 vlan cust1
```

The IP address for PE 3's loopback interface ends in a 3:

```
interface add ip lo0 address-netmask 111.1.1.3/32

ip-router global set router-id 111.1.1.3

ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to-core3 to-area backbone
ospf start

mpls add interface to-core
```

Notice that the label switched paths are going to PE 1 and PE 2:

```
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE2 no-cspf
mpls set customer-profile 1-2-3 customer_id 10 in-port-list et.1.1 type port
mpls start

rsvp add interface to-core3
rsvp start

ldp add interface lo0
```

Notice that for PE 3, the remote peers are PE 1 and PE 2:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp start
```

Example Two – Port-VLAN VPLS Using LDP Over LDP

In the following example, the VPN type is *Port-VLAN*, where the port is the customer side port – All traffic arriving on this port that belongs to the specified VLAN is identified as belonging to this customer and is forwarded through the LSP. Notice in this example that both VPN tunneling and TLS signaling use LDP.

Configuration for PE 1:

Create the customer VLAN for carrying the VPN:

```
vlan create cust1 port-based id 100
```

Create the VLAN used for signaling:

```
vlan create signal1 based id 110
```

Add the customer-facing port to VLAN cust1:

```
vlan add ports et.1.1 to cust1
```

Add the MPLS facing port to VALN signal1:

```
vlan add ports gi.2.1 to signal1
```

Create an interface for the signaling VLAN and assign it an IP address and netmask – This is the interface that faces the core LSRs:

```
interface create ip to-core1 address-netmask 200.1.1.1/16 vlan signal1
```

Add an additional IP address (other than 127.0.0.1) to the loopback interface (use subnet mask 32) – This IP address is the PE's remote peer identity:

```
interface add ip lo0 address-netmask 111.1.1.1/32
```

Set the router ID for OSPF – This can be the same as the new loopback address:

```
ip-router global set router-id 111.1.1.1
```

Create the OSPF backbone area (used for signaling), add the signaling VLAN interface to the backbone, then start OSPF:

```
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to-core1 to-area backbone
ospf start
```

Add the signaling VLAN interface to MPLS:

```
mpls add interface to-core
```

Create the label switch paths to the other PEs, identified by their loopback addresses:

```
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls create label-switched-path to-PE3 to 111.1.1.3
```

Turn off CSPF (`no-cspf`) for each label switch path:

```
mpls set label-switched-path to-PE2 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Create the customer profile, assign a customer ID number, specify the customer facing port (`et.1.1`), the customer profile type (L2-FEC type), then start MPLS:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
```

```
port-vlan
mpls start
```

Add the VLAN interface and the remote peer IP addresses (address for PE 2 and PE 3) to LDP:

```
ldp add interface lo0
ldp add interface to-core1
ldp add remote-peer 111.1.1.2
ldp add remote-peer 111.1.1.3
```

Make the VPN connections between this PE (PE 1) and the remote PEs (PE 2 and PE 3) – Here, both the customer profile and the remote peer IP address are specified:

```
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
```

Start LDP:

```
ldp start
```

Configuration for PE 2:

Create Customer 1's VLAN on PE 2, give it the ID of 120, and add the port gi.4.1 to the VLAN:

```
vlan create cust1 port-based id 100
vlan create signal2 port-based id 120
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 to signal2
```

The IP address for PE 2 is in a different broadcast domain from PE 1 and PE 3:

```
interface create ip to-core2 address-netmask 201.1.1.1/16 vlan signal2
```

The IP address for PE 2's loopback interface ends in a 2:

```
interface add ip lo0 address-netmask 111.1.1.2/32

ip-router global set router-id 111.1.1.2

ospf create area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf add interface to-core2 to-area backbone
ospf start

mpls add interface to-core2
```

Notice that the label switched paths are going to PE 1 and PE 3:

```
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE3 no-cspf
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
port-vlan
mpls start

ldp add interface lo0
```

```
ldp add interface to-core2
```

Notice that for PE 2, the remote peers are PE 1 and PE 3:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 3:

Create Customer 1's VLAN on PE 3, give it the ID of 130, and add the port gi.4.1 to the VLAN:

```
vlan create cust1 port-based id 100
vlan create signal1 port-based id 130
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 to signal3
```

The IP address for PE 3 is in a different broadcast domain from PE 1 and PE 2:

```
interface create ip to-core3 address-netmask 202.1.1.1/16 vlan signal3
```

The IP address for PE 3's loopback interface ends in a 3:

```
interface add ip lo0 address-netmask 111.1.1.3/32

ip-router global set router-id 111.1.1.3

ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to-core3 to-area backbone
ospf start

mpls add interface to-core
```

Notice that the label switched paths are going to PE 1 and PE 2:

```
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE2 no-cspf
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
port-vlan
mpls start

ldp add interface lo0
ldp add interface to-core3
```

Notice that for PE 3, the remote peers are PE 1 and PE 2:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp start
```

Example Three – Port-VLAN VPLS Using LDP Over RSVP

The following example is essentially identical to the one above (Port-VLAN using LDP over LDP), with the exception that RSVP is used as the signaling protocol.

Configuration for PE 1

```
vlan create cust1 port-based id 100
vlan create signal1 port-based id 110
vlan add ports et.1.1 to cust1
vlan add ports gi.2.1 to signal1

interface create ip to-core1 address-netmask 200.1.1.1/16 vlan signal1
interface add ip lo0 address-netmask 111.1.1.1/32

ip-router global set router-id 111.1.1.1

ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to-core1 to-area backbone
ospf start

mpls add interface to-core1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE2 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Notice that the type is Port-VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
port-vlan
mpls start
```

In this configuration, RSVP is used for signaling – The interface must be added and RSVP must be started:

```
rsvp add interface to-core1
rsvp start
```

Notice that the interface (to-core) is not added to LDP:

```
ldp add interface lo0
```

Remote peers for PE 1 are PE 2 and PE 3:

```
ldp add remote-peer 111.1.1.2
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 2

```
vlan create cust1 port-based id 100
vlan create signal2 port-based id 120
```

```
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 signal2

interface create ip to-core2 address-netmask 201.1.1.1/16 signal2
interface add ip lo0 address-netmask 111.1.1.2/32

ip-router global set router-id 111.1.1.2

ospf create area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf add interface to-core2 to-area backbone
ospf start

mpls add interface to-core2
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Notice that the type is Port-VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
port-vlan
mpls start
```

In this configuration, RSVP is used for signaling – The interface must be added and RSVP must be started:

```
rsvp add interface to-core2
rsvp start
```

Notice that the interface (to-core) is not added to LDP:

```
ldp add interface lo0
```

Remote peers for PE 2 are PE 1 and PE 3:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 3

```
vlan create cust1 port-based id 100
vlan create signal3 port-based id 130
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 to signal3

interface create ip to-core3 address-netmask 202.1.1.1/16 vlan signal3
interface add ip lo0 address-netmask 111.1.1.3/32

ip-router global set router-id 111.1.1.3

ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
```

```
ospf add interface to-core3 to-area backbone
ospf start

mpls add interface to-core3
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE2 no-cspf
```

Notice that the type is Port-VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 in-port-list et.1.1 type
port-vlan
mpls start
```

In this configuration, RSVP is used for signaling – The interface must be added and RSVP must be started:

```
rsvp add interface to-core3
rsvp start
```

Notice that the interface (to-core) is not added to LDP:

```
ldp add interface lo0
```

Remote peers for PE 3 are PE 1 and PE 2:

```
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp start
```

Example Four – VLAN-Based VPLS Using LDP over RSVP

This example illustrates the configuration for a VLAN-to-VLAN VPN, which specifies that all traffic from a particular VLAN is identified as belonging to the specified customer and is forwarded through the LSP. Notice that in this example RSVP is used as the signaling protocol.

Notice also that the configuration for the three PE (edge) routers is almost identical to the configurations in example three (Port-VLAN Using LDP over RSVP). The VPN type is the only difference between example three and four.

Configuration for PE 1

```
vlan create cust1 port-based id 100
vlan create signal1 port-based id 110
vlan add ports et.1.1 to cust1
vlan add ports gi.2.1 signal1

interface create ip to-core1 address-netmask 200.1.1.1/16 signal1
interface add ip lo0 address-netmask 111.1.1.1/32

ip-router global set router-id 111.1.1.1
```

```
ospf create area backbone
ospf add stub-host 111.1.1.1 to-area backbone cost 5
ospf add interface to-core1 to-area backbone
ospf start

mpls add interface to-core1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE2 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Notice that the VPN type is VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 type vlan
mpls start

rsvp add interface to-core1
rsvp start

ldp add interface lo0
ldp add remote-peer 111.1.1.2
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 2

```
vlan create cust1 port-based id 100
vlan create signal2 port-based id 120
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 signal2

interface create ip to-core2 address-netmask 201.1.1.1/16 signal2
interface add ip lo0 address-netmask 111.1.1.2/32

ip-router global set router-id 111.1.1.2

ospf create area backbone
ospf add stub-host 111.1.1.2 to-area backbone cost 5
ospf add interface to-core2 to-area backbone
ospf start

mpls add interface to-core2
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE3 to 111.1.1.3
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE3 no-cspf
```

Notice that the VPN type is VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 type vlan
mpls start

rsvp add interface to-core2
rsvp start
```

```
ldp add interface lo0
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.3
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.3
ldp start
```

Configuration for PE 3

```
vlan create cust1 port-based id 100
vlan create signal3 port-based id 130
vlan add ports et.1.1 to cust1
vlan add ports gi.4.1 to signal3

interface create ip to-core3 address-netmask 202.1.1.1/16 signal3
interface add ip lo0 address-netmask 111.1.1.3/32

ip-router global set router-id 111.1.1.3

ospf create area backbone
ospf add stub-host 111.1.1.3 to-area backbone cost 5
ospf add interface to-core3 to-area backbone
ospf start

mpls add interface to-core3
mpls create label-switched-path to-PE1 to 111.1.1.1
mpls create label-switched-path to-PE2 to 111.1.1.2
mpls set label-switched-path to-PE1 no-cspf
mpls set label-switched-path to-PE2 no-cspf
```

Notice that the VPN type is VLAN:

```
mpls set customer-profile 1-2-3 customer_id 10 vlans 100 type vlan
mpls start

rsvp add interface to-core3
rsvp start

ldp add interface lo0
ldp add remote-peer 111.1.1.1
ldp add remote-peer 111.1.1.2
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.1
ldp connect customer-profile 1-2-3 remote-peer 111.1.1.2
ldp start
```

Example Five – Core Configuration for Examples One through Four

The following is a configuration example for an MPLS cloud (transit router cloud). For simplicity, this MPLS cloud consists of a single transit router, whose configuration will work with any of the four VPLS examples. Note that this configuration is provided for completeness and educational purposes only.

Transit Router Configuration (Core of MPLS Cloud)

```
vlan create signal1 port-based id 110
vlan create signal2 port-based id 120
vlan create signal3 port-based id 130
vlan add ports gi.3.1 to signal1
vlan add ports gi.3.2 to signal2
vlan add ports gi.4.1 to signal3

interface create ip to-core1 address-netmask 200.1.1.2/16 vlan signal1
interface create ip to-core2 address-netmask 201.1.1.2/16 vlan signal2
interface create ip to-core3 address-netmask 202.1.1.2/16 vlan signal3
interface add ip lo0 address-netmask 111.1.1.4/32

ip-router global set router-id 111.1.1.4

ospf create area backbone
ospf add stub-host 111.1.1.4 to-area backbone cost 5
ospf add interface all to-area backbone
ospf start

mpls add interface to-core1
mpls add interface to-core2
mpls add interface to-core3
mpls start

rsvp add interface to-core1
rsvp add interface to-core2
rsvp add interface to-core3
rsvp start
```

Note that if the VPN is signaled using LDP the following lines should replace the above four RSVP lines:

```
ldp add interface to-core1
ldp add interface to-core2
ldp add interface to-core3
ldp start
```

Re-mapping a VLAN in a Point-to-Multipoint Tunnel

The ingress LSR can be configured to re-map a VLAN to a different VLAN at the egress LSR. For example, you can configure a mapping on the ingress LSR such that VLAN 50's traffic winds up on VLAN 60 on the egress LSR. To re-map, two commands are used. First, use the **`mpls set customer-profile`** to create a customer profile and to specify the ingress VLAN id. Next, use the **`ldp connect customer-profile`** command to specify the ingress VLAN id and the VLAN id to which VLAN traffic should be mapped on the egress LSR:

The following is an example of VLAN re-mapping:

```
rs(config)# mpls set customer-profile prof-1 customer_id 111 vlans 50 type vlan

rs(config)# ldp connect customer-profile prof-1 remote-peer 3.3.3.3 vc-id 60 vc-type
ethernet-vlan
```

Notice in the example above that VLAN traffic from the VLAN with id of **50** (in **mpls set customer-profile**) is re-mapped to VLAN **60** (in **ldp connect customer-profile**) on the egress LSR. When using the l**dp connect customer-profile** command you also must set the **remote-peer** address, and the **vc-type** must be specified as **ethernet-vlan**.

Sending a Group of VLANs Across a TLS Connection Using a Single VLAN ID

To send a number of ingress VLANs using a single transport VLAN, use the **mpls set customer-profile** option, **type**, to set the VPN type to **vlan-range**. Also, use the **ldp connect customer-profile** option, **vc-id**, to specify the VLAN id of the transit VLAN (see Figure 17-26).

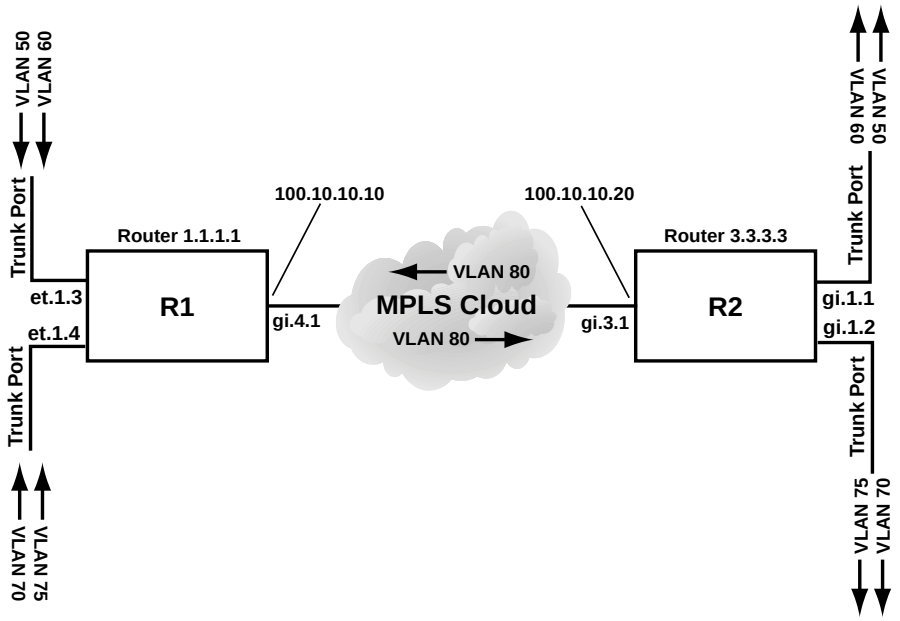


Figure 17-26 VLAN re-mapping on a TLS connection

Notice that in Figure 17-26 when the VLANs reach the egress LSR (R2), VLANs **50** and **60** are trunked through port **gi.1.1**, while VLANs **70** and **75** are trunked through port **gi.1.2**. This occurs because the egress LSR looks at the VLAN traffic's 802.1Q tags. As a result, the traffic from each VLAN exits the appropriate port.

The following is an example of configuration for ingress LSR (R1) that sends VLANs **50**, **60**, **70**, and **75** across the MPLS cloud using a single transit VLAN with id **80**

```
vlan make trunk-port et.1.3
vlan make trunk-port et.1.4

vlan create V1 port-based id 50
vlan create V2 port-based id 60
vlan create V3 port-based id 70
vlan create V4 port-based id 75

vlan add ports et.1.3 to V1
vlan add ports et.1.3 to V2
vlan add ports et.1.4 to V3
vlan add ports et.1.4 to V4

interface create ip mpls1 address-netmask 100.10.10.10/24 port gi.4.1
interface add ip lo0 address-netmask 1.1.1.1/32

ip-router global set router-id 1.1.1.1

ospf create area backbone
ospf add interface mpls1 to-area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf start

mpls set customer-profile prof-1 customer_id 111 in-port-list et.1.3-4 type vlan-range vlans
50,60,70,75
mpls add interface mpls1
mpls start

ldp add remote-peer 3.3.3.3
ldp connect customer-profile prof-1 remote-peer 3.3.3.3 vc-type ethernet-vlan vc-id 80
ldp add interface mpls1
ldp start
```

This example assumes that the configuration on egress LSR R2 is very similar to R1's configuration. For instance, the same number of trunk ports and VLANs must exist on both the ingress and egress LSRs. Furthermore, the VLAN ids must be identical on RS1 and RS2.

Using Figure 17-26 as a guide, the following the configuration that must exist on R2 in order for the group sending of VLANs using a single transit VLAN to be possible:

```
vlan make trunk-port gi.1.1
vlan make trunk-port gi.1.2

vlan create V1 port-based id 50
vlan create V2 port-based id 60
vlan create V3 port-based id 70
vlan create V4 port-based id 75

vlan add ports gi.1.1 to V1
vlan add ports gi.1.1 to V2
vlan add ports gi.1.1 to V3
vlan add ports gi.1.1 to V4

interface create ip mpls2 address-netmask 100.10.10.20/24 port gi.3.1
interface add ip lo0 address-netmask 3.3.3.3/32

ip-router global set router-id 3.3.3.3

ospf create area backbone
ospf add interface mpls2 to-area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf start

mpls set customer-profile prof-2 customer_id 112 in-port-list gi.1.1-2 type vlan-range vlans
50,60,70,75
mpls add interface mpls2
mpls start

ldp add remote-peer 1.1.1.1
ldp connect customer-profile prof-2 remote-peer 1.1.1.1 vc-type ethernet-vlan vc-id 80
ldp add interface mpls2
ldp start
```

Notice in R2's configuration that the trunk ports are Gigabit Ethernet ports. This is acceptable, as long as they are made trunk ports and VLANs with ids that are identical to R1's configuration are assigned to these ports.

17.7 TRAFFIC ENGINEERING

One of the most important applications of MPLS is *traffic engineering*. Traffic engineering allows you to optimize the utilization of network resources and traffic performance throughout a network. Traffic engineering does not mean that the shortest path is always selected—traditional shortest path routing, as determined by interior gateway protocols (IGPs), can cause both network congestion and the overuse of certain network paths, while longer paths are under-utilized. Traffic engineering allows more efficient use of available bandwidth while avoiding congestion. Packets with the same source and destination addresses can travel completely different paths in the network.

With MPLS, explicit LSPs can provide traffic engineering. For example, you can configure two explicit paths to the same destination, with one the primary and the other the secondary path. However, explicit LSPs require you to configure the paths on the ingress router. More dynamic traffic engineering can be performed with constraint-based LSPs.

Traffic engineering requires extensions to the IGP. The RS provides extensions to OSPF and IS-IS IGPs to support traffic engineering with MPLS. Traffic engineering is disabled by default for OSPF and IS-IS on RS routers.

This section discusses some of the features of traffic engineering and provides example configurations.

17.7.1 Administrative Groups

An MPLS *administrative group*[3] designates certain link attributes that can be used to impose additional path constraints. Administrative groups can be used to contain certain traffic trunks within specific topological regions of an MPLS network. You can employ administrative groups for path setup and selection for constrained path LSPs. You can use administrative groups to:

- Apply the same policies to a set of resources that are not necessarily in the same topological area.
- Specify the relative preference of a set of resources for placement of traffic trunks.
- Restrict the placement of traffic trunks to specific sets of resources.
- Implement general include/exclude policies.
- Enforce policies that contain local traffic within specific regions of the network.
- Identify a particular set of resources.

For example, all OC-48 links in a network may be assigned to a particular administrative group. You can also assign subsets of the OC-48 links to other administrative groups.

If you use administrative groups, the names of the groups and their corresponding decimal values must be the same on all routers within the domain. You can configure up to 32 administrative groups in an MPLS domain.

You can specify one or more administrative groups to be included or excluded from an LSP computation. If you *include* any administrative groups in an LSP computation, each selected link will have at least one included group. If you *exclude* specific administrative groups in an LSP computation, each selected link cannot have any excluded groups. If you include or exclude administrative groups in an LSP computation, links that do not have an associated group are not considered. You can configure administrative group constraints for an LSP, or for a primary or secondary LSP. You can include or exclude a maximum of 16 administrative groups for an LSP, or for a primary or secondary path.

You can assign one or more administrative groups to a router interface. IGPs use administrative groups to provide information, such as IGP topology, to all routers in the domain.

If you change the administrative group for an *LSP*, the route is recalculated and the LSP may be rerouted. If you change the administrative group for an *interface*, the change affects only *new* LSPs on the interface.

3. Administrative groups are referred to as *resource classes* or *link colors* in some implementations.

To set up administrative groups, do the following:

1. Create the administrative groups with the **mpls create admin-group** command. Assign each group a decimal value between 1-32. You must create identical group names and assign the same value to each group on all routers in the MPLS domain. For example:

```
mpls create admin-group sector1 group-value 1
```

2. Assign one or more groups to an interface with the **mpls set interface** command. This identifies the administrative groups to which the interface belongs. For example:

```
mpls set interface RS1IN admin-group sector1
```

3. Specify administrative groups to be included or excluded from an LSP computation. To include or exclude groups for an LSP, use the **mpls create label-switched-path** command. For example:

```
mpls create label-switched-path LSP1 include sector1
```

   To include or exclude groups for a primary or secondary LSP path, use the **mpls set label-switched-path** command. For example:

```
mpls set label-switched-path LSP1 primary PA include sector1
```

An example of using administrative groups is shown in Section 17.7.2, *"Constrained Shortest Path First."*

Use the **mpls show admin-groups** command to see the administrative groups configured on an RS. For example:

```
rs# mpls show admin-groups

       Group               Bit index
       -----               ---------
       sector1             1
```

The **mpls show interface** command shows the interfaces configured on an RS and the administrative group, if any, that is applied to an interface. For example, in the following output the administrative group sector1 is applied to the interfaces R2R3 and R2R1b:

```
rs# mpls show interface all
Interface        State       Administrative groups
lo               Up          <none>
lo               Up          <none>
R2R3             Up          sector1
R2R1             Up          <none>
R2R1b            Up          sector1
```

17.7.2 Constrained Shortest Path First

An ingress LSR uses the information in the traffic engineering database (TED) to calculate its LSPs across the network. The constrained shortest path first (CSPF) algorithm is a modification of the OSPF and IS-IS shortest path first calculation. With CSPF, nodes and links for an LSP are accepted or rejected based on resource availability or on whether administrative group or policy constraints are met. The result is an explicit route that provides the shortest path through the network that meets certain constraints. The explicit route, comprised of a sequence of LSR addresses, is passed to the signaling protocol to deliver the path information to each LSR in the LSP.

The CSPF algorithm takes into account link-state and network state information from the TED, as well as the following LSP attributes:

- bandwidth
- hops
- administrative group
- setup and hold priority
- strict or loose explicit route

When choosing between multiple equal-cost paths to a destination, CSPF applies the following tie-breaking algorithm:

1. Select the path whose last hop address is the same as the LSP's destination address
2. Select the path with the fewest number of hops
3. Select the path that is least loaded (i.e., with the largest available bandwidth). The least-loaded selection mechanism aims to equalize the reservations on each link.

To enable CSPF on RS routers:

1. If OSPF is the IGP, enable traffic engineering extensions for OSPF with the **ospf set traffic-engineering on** command. If IS-IS is the IGP, enable traffic engineering extensions for IS-IS with the **isis set traffic-engineering enable** command.

Note Traffic engineering with OSPF as the IGP requires support for opaque LSAs (defined by RFC 2370). This support is enabled by default on the RS, but can be disabled with the **ospf set opaque-capability off** CLI command. If you are enabling traffic engineering extensions for OSPF, make sure that opaque LSA support has not been *disabled*.

2. Configure the dynamic LSP, as described in Section 17.5.3, *"Configuring an Explicit LSP."* Do *not* specify the **no-cspf** parameter with the **mpls create label-switched-path** or **mpls set label-switched-path** commands.

Constrained Path Selection Configuration Example for OSPF Traffic Engineering

The following example illustrates constrained path selection based on an administrative group with OSPF as the IGP. The same administrative group must be configured on all routers in the LSP. In the example shown in Figure 17-27, the administrative group 'SKY' with a value of 7 is created on all LSRs and applied to the following interfaces: R1R2b on R1, R2R1b and R2R3 on R2, and R3R2 on R3. An LSP 'LSP1' is configured on R1 with R3 as the LSP destination and SKY as the administrative group. That means that even though there are two possible paths from R1 to R3, CSPF selects the path that traverses through the interfaces where the administrative group SKY is applied.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

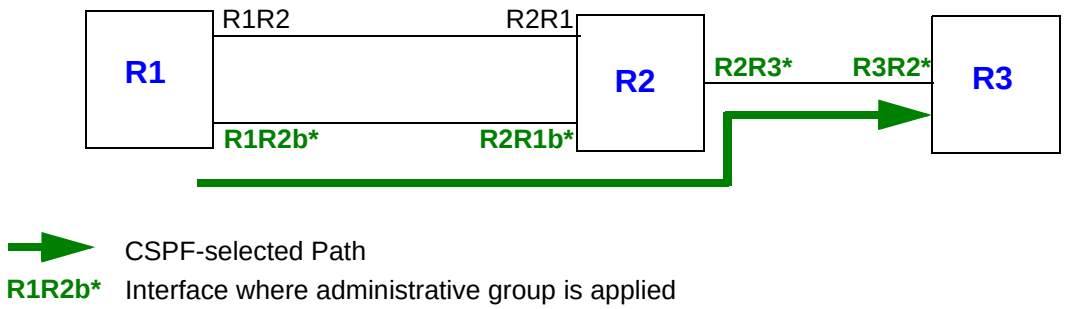


Figure 17-27 Constrained path selection by administrative group

The following is the configuration for R1:

```
! Create interfaces
interface create ip R1R2 address-netmask 16.128.11.10/24 port gi.4.1
interface create ip R1R2b address-netmask 94.9.9.10/24 port gi.3.1
interface add ip lo0 address-netmask 1.1.1.1/16

! Configure OSPF
ip-router global set router-id 1.1.1.1
ospf create area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface R1R2 to-area backbone
ospf add interface R1R2b to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start
```

```
! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R1R2b
mpls set interface R1R2b admin-group sky

! Configure LSP with admin-group constraint (do not specify no-cspf parameter)
mpls create label-switched-path LSP1 to 3.3.3.3 include sky

!Enable and start MPLS and RSVP
mpls add interface R1R2
mpls start
rsvp add interface R1R2
rsvp add interface R1R2b
rsvp start
```

The following is the configuration for R2:

```
! Create interfaces
interface create ip R2R1 address-netmask 16.128.11.7/24 port gi.6.2
interface create ip R2R1b address-netmask 94.9.9.11/24 port gi.5.1
interface create ip R2R3 address-netmask 201.135.89.197/26 port gi.4.1
interface add ip lo0 address-netmask 2.2.2.2/16

! Configure OSPF
ip-router global set router-id 2.2.2.2
ospf create area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface R2R1 to-area backbone
ospf add interface R2R1b to-area backbone
ospf add interface R2R3 to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start

! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R2R1
mpls add interface R2R1b
mpls add interface R2R3
mpls set interface R2R1b admin-group sky
mpls set interface R2R3 admin-group sky

! Enable and start MPLS and RSVP
mpls start
rsvp add interface R2R1
rsvp add interface R2R1b
rsvp add interface R2R3
rsvp start
```

The following is the configuration for R3:

```
! Create interfaces
interface create ip R3R2 address-netmask 201.135.89.195/26 port gi.1.2
interface add ip lo0 address-netmask 3.3.3.3/16

! Configure OSPF
ip-router global set router-id 3.3.3.3
ospf create area backbone
ospf add stub-host 3.3.3.3 to-area backbone cost 10
ospf add interface R3R2 to-area backbone
ospf set traffic-engineering on  Enable traffic engineering extensions for OSPF
ospf start

! Create and apply admin-group
mpls create admin-group sky group-value 7
mpls add interface R3R2
mpls set interface R3R2 admin-group sky

! Enable and start MPLS and RSVP
mpls start
rsvp add interface R3R2
rsvp start
```

On R1, the **mpls show label-switched-paths** command with the **verbose** option displays the selected path in the **cspf-path** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group SKY is applied on the routers:

```
R1# mpls show label-switched-paths LSP1 verbose

    Label-Switched-Path: LSP1

        to: 3.3.3.3             from: 1.1.1.1
        state: Up               lsp-id: 0x8
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <>

        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 1000       retry-int: 30 sec.
            retry-count: 1000       next_retry_int: 60 sec.
            bps: 0                  preference: 7
            hop-limit: 255          opt-int: 600 sec.
            ott-index: 0            ref-count: 0
            mtu: 0
            cspf-path:   num-hops: 3
                hop: 94.9.9.10       - strict
                hop: 94.9.9.11       - strict
                hop: 201.135.89.195  - strict
           include:                  sky
           record-route:
                94.9.9.10
                94.9.9.11
                201.135.89.195
```

Constrained Path Selection Configuration Example for IS-IS Traffic Engineering

The following examples shows the configuration of two constrained path LSPs from R1 to R4:

- LSP1 includes the administrative group ‘red’
- LSP2 includes the administrative group ‘green’ and the bandwidth constraint of 8 megabits per second

IS-IS is the IGP running on all routers in the network. IS-IS MD5 authentication is also configured.

Timesaver Click on the router name (in blue) to see the corresponding configuration.

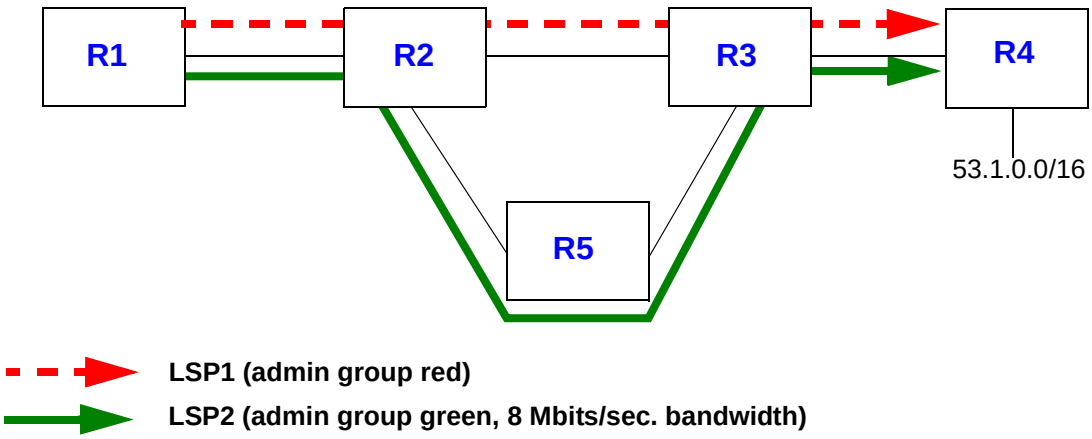


Figure 17-28 Traffic engineering with IS-IS

Note For simplicity, the configurations shown in this section are for *unidirectional* LSPs from R1 to R4. In most cases, you would also need to configure LSPs in the reverse direction, from R4 to R1.

The following is the configuration for R1:

```
! Create interfaces
interface create ip to-R2 address-netmask 153.1.1.13/16 port gi.2.1
interface add ip lo0 address-netmask 113.113.113.113/32

! Configure IS-IS
ip-router global set router-id 113.113.113.113
ip-router policy redistribute from-proto direct to-proto isis-level-1
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
```

```
isis add interface lo0
isis add interface to-R2
isis set system-id 13.1313.1313.13
isis set interface to-R2 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis set level 1
isis set interface lo0 level 1
isis start

! Configure MPLS
mpls add interface to-R2
mpls set interface to-R2 admin-group red,green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls create label-switched-path LSP1 from 113.113.113.113 to 124.124.124.124
mpls create label-switched-path LSP2 from 113.113.113.113 to 124.124.124.124
mpls set label-switched-path LSP1 include red
mpls set label-switched-path LSP2 include green bps 8000000
mpls create policy to-53-net dst-ipaddr-mask 53.0.0/16 proto ip
mpls set label-switched-path LSP1 policy to-53-net
mpls start

! Enable and start RSVP
rsvp add interface to-R2
rsvp start
```

The following is the configuration for R2:

```
! Configure VLANs
smarttrunk create st.1 protocol no-protocol
smarttrunk add ports et.3.3 to st.1
smarttrunk add ports et.3.4 to st.1
vlan create to-R3 ip
vlan add ports st.1 to to-R3
vlan create to-R5 ip
vlan add ports et.3.5 to to-R5

! Create interfaces
interface create ip to-R1 address-netmask 153.1.1.12/16 port gi.6.1
interface create ip to-R3 address-netmask 192.1.1.12/24 vlan to-R3
interface create ip to-R5 address-netmask 186.1.1.12/8 vlan to-R5
interface add ip lo0 address-netmask 12.12.12.12/32

! Configure IS-IS
ip-router global set router-id 12.12.12.12
```

```
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R3
isis add interface to-R5
isis add interface to-R1
isis set system-id 12.1212.1212.12
isis set level 1-and-2
isis set interface to-R3 level 1
isis set interface to-R1 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set interface to-R3 key-chain test1 authentication-method md5
isis set interface to-R5 level 1
isis set interface to-R5 key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis set interface to-R1 level 1
isis start

! Configure MPLS
mpls add interface all
mpls add interface lo0
mpls set interface to-R5 bandwidth 20000000
mpls set interface to-R3 admin-group red
mpls set interface to-R1 admin-group red,green
mpls set interface to-R5 admin-group green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for R3:

```
! Configure VLANs
smarttrunk create st.1 protocol no-protocol
smarttrunk add ports et.13.3 to st.1
smarttrunk add ports et.13.4 to st.1
vlan make trunk-port et.13.8
vlan create to-R2 ip
vlan add ports st.1 to to-R2
vlan create to-R5 ip
vlan add ports et.6.8 to to-R5
vlan create to-R4 ip id 22
vlan add ports et.13.8 to to-R4
```

```
! Create interfaces
interface add ip lo0 address-netmask 15.15.15.15/32
interface create ip to-R2 address-netmask 192.1.1.15/24 vlan to-R2
interface create ip to-R5 address-netmask 187.1.1.15/16 vlan to-R5
interface create ip to-R4 address-netmask 185.1.1.15/16 vlan to-R4

! Configure IS-IS
ip-router global set router-id 15.15.15.15
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 id 255 type primary (key is encrypted)
isis add area 53.da05
isis add interface to-R5
isis add interface to-R4
isis add interface to-R2
isis add interface lo0
isis set system-id 15.1515.1515.15
isis set interface to-R4 level 1
isis set level 1-and-2
isis set interface to-R5 level 1
isis set interface to-R2 level 1
isis set area-key-chain test1 authentication-method md5
isis set interface to-R2 key-chain test1 authentication-method md5
isis set interface to-R4 key-chain test1 authentication-method md5
isis set interface to-R5 key-chain test1 authentication-method md5
isis set traffic-enghneering enable
isis set interface lo0 level 1
isis start

! Configure MPLS
mpls add interface all
mpls set interface to-R5 bandwidth 20000000
mpls set interface to-R5 admin-group green
mpls set interface to-R4 admin-group red,green
mpls set interface to-R2 admin-group red
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the configuration for R4:

```
! Configure VLANs
vlan create to-R3 ip id 22
vlan add ports et.16.23 to to-R3
```

```
vlan create 53net ip
vlan add ports et.13.22 to 53net
vlan make trunk-port et.14.23

! Create interfaces
interface create ip to-R3 address-netmask 185.1.1.24/16 vlan to-R3
interface create ip to-R3 address-netmask 185.1.1.24/16 port et.16.23
interface create ip 53net address-netmask 53.1.1.22/16 vlan 53net

! Configure IS-IS
ip-router global set router-id 124.124.124.124
ip-router policy redistribute from-proto direct to-proto isis-level-1
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R3
isis set system-id 24.2424.2424.24
isis set level 1
isis set interface to-R3 level 1
isis set interface lo0 level 1
isis set interface to-R3 key-chain test1 authentication-method md5
isis set area-key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis start

! Configure MPLS
mpls add interface to-R3
mpls set interface to-R3 admin-group red,green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Configure RSVP
rsvp add interface to-R3
rsvp start
```

The following is the configuration for R5:

```
! Configure VLANs
vlan create to-R2 ip
vlan add ports et.2.15 to to-R2
vlan create to-R3 ip
vlan add ports et.1.15 to to-R3
```

```
! Create interfaces
interface create ip to-R2 address-netmask 186.1.1.26/8 vlan to-R2
interface create ip to-R3 address-netmask 187.1.1.26/16 vlan to-R3

! Configure IS-IS
ip-router global set router-id 126.126.126.126
ip-router authentication create key-chain test1 key ed301c4c0a9b1171 type primary id 255 (key is encrypted)
isis add area 53.da05
isis add interface lo0
isis add interface to-R2
isis add interface to-R3
isis set level 1
isis set system-id 26.2626.2626.26
isis set interface to-R2 level 1
isis set interface to-R3 level 1
isis set area-key-chain test1 authentication-method md5
isis set interface to-R2 key-chain test1 authentication-method md5
isis set interface to-R3 key-chain test1 authentication-method md5
isis set traffic-engineering enable
isis start

! Configure MPLS
mpls add interface all
mpls set interface to-R2 admin-group green
mpls set interface to-R3 bandwidth 20000000
mpls set interface to-R2 bandwidth 20000000
mpls set interface to-R3 admin-group green
mpls create admin-group red group-value 1
mpls create admin-group green group-value 3
mpls start

! Enable and start RSVP
rsvp add interface all
rsvp start
```

The following is the **`mpls show label-switched-path LSP1 verbose`** command on R1 that shows the selected path for LSP1 in the **`cspf-path`** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group 'red' is applied on the routers.

```
R1# mpls show label-switched-paths LSP1 verbose

    Label-Switched-Path: "LSP1"
        to: 124.124.124.124             from: 113.113.113.113
        state: Up               lsp-id: 0xf
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <FROM_ADDR>
```

```
        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 5000   retry-int: 3 sec.
            retry-count: 5000   next_retry_int: 0.000000 sec.
            bps: 0              preference: 7
            hop-limit: 255      opt-int: 600 sec.
            ott-index: 3        ref-count: 1
            mtu: 0
            cspf-path:  num-hops: 4
                153.1.1.13      - strict
                153.1.1.12      - strict
                192.1.1.15      - strict
                185.1.1.24      - strict
            include:            red
            record-route:
                153.1.1.12
                192.1.1.15
                185.1.1.24
```

The following is the **`mpls show label-switched-path LSP2 verbose`** command on R1 that shows the selected path for LSP2 in the **`cspf-path`** section (shown in **bold** in the example output below). Note that the hops are the interfaces where the administrative group 'green' is applied on the routers. This LSP also has a bandwidth of 8 Mbps reserved on the path.

```
R1# mpls show label-switched-paths LSP2 verbose

    Label-Switched-Path: "LSP2"
        to: 124.124.124.124             from: 113.113.113.113
        state: Up               lsp-id: 0x12
        proto: <rsvp>           protection: none
        setup-pri: 7            hold-pri: 0
        attributes: <FROM_ADDR BPS>

        Path-Signalling-Parameters:
            attributes: <>
            inherited-attributes: <>
            retry-limit: 5000   retry-int: 3 sec.
            retry-count: 5000   next_retry_int: 0.000000 sec.
            bps: 8000000        preference: 7
            hop-limit: 255      opt-int: 600 sec.
            ott-index: 6        ref-count: 1
            mtu: 0
            cspf-path:  num-hops: 5
                153.1.1.13      - strict
                153.1.1.12      - strict
                186.1.1.26      - strict
                187.1.1.15      - strict
```

```
                185.1.1.24      - strict
            include:            green
            record-route:
                153.1.1.12
                186.1.1.26
                187.1.1.15
                185.1.1.24
```

The following command shows the IS-IS adjacencies on R1:

```
R1#  isis show adjacencies

Adjacencies

Interface   System         State  Level Hold(s) SNPA                   Priority
to-R2       R2             up     L1     9      802.2 0:0:0:a3:62:61    100
```

The following command shows the IS-IS traffic engineering database on R1:

```
R1# isis show ted
  TED database:
  NodeID:  R2(12.12.12.12)  Age: 1099 secs
  Protocol: IS-IS(1)
    To:  1212.1212.1212.0e, Local: 186.1.1.12
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
[0]             12 Mbps [1]             12 Mbps
[2]             12 Mbps [3]             12 Mbps
[4]             12 Mbps [5]             12 Mbps
[6]             12 Mbps [7]             12 Mbps

    To:  1212.1212.1212.0b, Local: 153.1.1.12
    Color:  0xe
    Static BW:              1 Gbps
    Reservable BW:              1 Gbps
    Available BW [priority]:
[0]              1 Gbps [1]              1 Gbps
[2]              1 Gbps [3]              1 Gbps
[4]              1 Gbps [5]              1 Gbps
[6]              1 Gbps [7]              1 Gbps

    To:  1212.1212.1212.0d, Local: 192.1.1.12
```

```
    Color:  0x2
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]            100 Mbps [1]            100 Mbps
[2]            100 Mbps [3]            100 Mbps
[4]            100 Mbps [5]            100 Mbps
[6]            100 Mbps [7]            100 Mbps


  NodeID: 1212.1212.1212.0b00  Age: 1081 secs
  Protocol: IS-IS(1)
    To:  1313.1313.1313.00
    To:  1212.1212.1212.00

  NodeID: 1212.1212.1212.0d00  Age: 1076 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.00
    To:  1212.1212.1212.00

  NodeID: 1212.1212.1212.0e00  Age: 1076 secs
  Protocol: IS-IS(1)
    To:  2626.2626.2626.00
    To:  1212.1212.1212.00

  NodeID:  R1(113.113.113.113)  Age: 1092 secs
  Protocol: IS-IS(1)
    To:  0000.1717.1717.0a
    To:  1212.1212.1212.0b, Local: 153.1.1.13, Remote: 153.1.1.12
    Color:  0xa
    Static BW:              1 Gbps
    Reservable BW:              1 Gbps
    Available BW [priority]:
[0]            992 Mbps [1]            992 Mbps
[2]            992 Mbps [3]            992 Mbps
[4]            992 Mbps [5]            992 Mbps
[6]            992 Mbps [7]            992 Mbps


  NodeID:  R3(15.15.15.15)  Age: 1088 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.08, Local: 185.1.1.15
    Color:  0xa
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]             92 Mbps [1]             92 Mbps
[2]             92 Mbps [3]             92 Mbps
[4]             92 Mbps [5]             92 Mbps
[6]             92 Mbps [7]             92 Mbps
```

```
    To:  1515.1515.1515.06, Local: 187.1.1.15
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
[0]             20 Mbps [1]             20 Mbps
[2]             20 Mbps [3]             20 Mbps
[4]             20 Mbps [5]             20 Mbps
[6]             20 Mbps [7]             20 Mbps

    To:  1212.1212.1212.0d, Local: 192.1.1.15, Remote: 192.1.1.12
    Color:  0x2
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
[0]            100 Mbps [1]            100 Mbps
[2]            100 Mbps [3]            100 Mbps
[4]            100 Mbps [5]            100 Mbps
        [6]            100 Mbps [7]            100 Mbps


  NodeID: 1515.1515.1515.0600  Age: 1074 secs
  Protocol: IS-IS(1)
    To:  2626.2626.2626.00
    To:  1515.1515.1515.00

  NodeID: 1515.1515.1515.0800  Age: 1070 secs
  Protocol: IS-IS(1)
    To:  2424.2424.2424.00
    To:  1515.1515.1515.00

  NodeID:  R4(124.124.124.124)  Age: 1065 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.08, Local: 185.1.1.24, Remote: 185.1.1.15
    Color:  0xa
    Static BW:            100 Mbps
    Reservable BW:            100 Mbps
    Available BW [priority]:
        [0]            100 Mbps [1]            100 Mbps
        [2]            100 Mbps [3]            100 Mbps
        [4]            100 Mbps [5]            100 Mbps
        [6]            100 Mbps [7]            100 Mbps

  NodeID:  R5(126.126.126.126)  Age: 1093 secs
  Protocol: IS-IS(1)
    To:  1515.1515.1515.06, Local: 187.1.1.26, Remote: 187.1.1.15
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
```

```
    Available BW [priority]:
        [0]             12 Mbps [1]             12 Mbps
        [2]             12 Mbps [3]             12 Mbps
        [4]             12 Mbps [5]             12 Mbps
        [6]             12 Mbps [7]             12 Mbps

    To:  1212.1212.1212.0e, Local: 186.1.1.26, Remote: 186.1.1.12
    Color:  0x8
    Static BW:             20 Mbps
    Reservable BW:             20 Mbps
    Available BW [priority]:
        [0]             20 Mbps [1]             20 Mbps
        [2]             20 Mbps [3]             20 Mbps
        [4]             20 Mbps [5]             20 Mbps
        [6]             20 Mbps [7]             20 Mbps
```

17.7.3 IGP Shortcuts

Link-state IGPs, such as IS-IS and OSPF, use shortest path calculations to produce destination-first hop entries in the routing table. With normal hop-by-hop routing, the first hop is a *physical* interface on the router. A *logical* interface, which represents an explicit path LSP, can also be installed in the routing table to be used by the IGP as the first hop to a specified destination. Thus, the LSP is used as a "shortcut" to a specific destination in the network.

Using IGP shortcuts provides the following benefits:

- control of traffic to destinations that do not support MPLS LSPs
- allows LSPs to be deployed on a regional basis

IGP shortcuts can be enabled on a per-router basis (it is disabled by default). When IGP shortcuts are enabled, each router maintains a list of IGP shortcuts that originate at the local router and the ID of the router at the opposite end of the shortcut. Traffic to nodes that are at the tail end of a shortcut and to nodes that are downstream from the end of a shortcut will flow over the shortcut.

Note To use IGP shortcuts, all routers in the LSP must be in the same OSPF area or in the same IS-IS level.

To enable IGP shortcuts on RS routers that use OSPF as the IGP:

```
ip-router global set install-lsp-routes on
ospf set igp-shortcuts on
```

To enable IGP shortcuts on RS routers that use IS-IS as the IGP:

```
ip-router global set install-lsp-routes on
isis set igp-shortcuts enable
```

IS-IS IGP Shortcuts Example

Refer to the example routing network shown in Figure 17-28. On R1, packets for the destination 53.1.0.0/16 (on R4) use the gateway IP address 153.1.1.12 as the immediate next-hop. In the routing table display on R1 shown below, the entry for destination 53.1.0.0/16 is shown in **bold**:

```
R1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.61.0.0/16         directly connected   -         en0
12.12.12.12          153.1.1.12           ISIS_L1   to-R2
15.15.15.15          153.1.1.12           ISIS_L1   to-R2
26.26.26.26          153.1.1.12           ISIS_L1   to-R2
27.0.0.0/8           153.1.1.12           ISIS_L1   to-R2
53.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
55.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
92.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
95.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
96.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
97.1.0.0/16          153.1.1.12           ISIS_L1   to-R2
101.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
102.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
103.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
104.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
113.113.113.113      113.113.113.113      -         lo0
124.124.124.124      Unnumbered           -         LSP1
126.126.126.126      153.1.1.12           ISIS_L1   to-R2
127.0.0.1            127.0.0.1            -         lo0
134.141.0.0/16       10.61.1.1            Static    en0
153.1.0.0/16         directly connected   -         to-R2
185.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
186.0.0.0/8          153.1.1.12           ISIS_L1   to-R2
187.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
192.1.1.0/24         153.1.1.12           ISIS_L1   to-R2
195.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
```

To enable IGP shortcuts on the router R1, enter the following command:

```
R1(config)# ip-router global set install-lsp-routes on
R1(config)# isis set igp-shortcuts enable
```

Now, the routing table on R1 includes the constrained path LSPs configured in *"Constrained Path Selection Configuration Example for IS-IS Traffic Engineering"*. Packets to the destination 53.1.0.0/16, as well as other destinations, can be forwarded using the LSPs LSP1 or LSP2, as shown in the routing table display below:

```
R1# ip show routes

Destination          Gateway              Owner     Netif
-----------          -------              -----     -----
10.61.0.0/16         directly connected   -         en0
12.12.12.12          153.1.1.12           ISIS_L1   to-R2
15.15.15.15          153.1.1.12           ISIS_L1   to-R2
27.0.0.0/8           Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
                     Unnumbered           ISIS_L1   LSP2
53.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
55.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
78.1.0.0/16          directly connected   -         78net
92.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
95.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
96.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
97.1.0.0/16          Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
101.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
102.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
103.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
104.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
113.113.113.113      113.113.113.113      -         lo0
124.124.124.124      Unnumbered           -         LSP1
126.126.126.126      153.1.1.12           ISIS_L1   to-R2
127.0.0.1            127.0.0.1            -         lo0
134.141.0.0/16       10.61.1.1            Static    en0
142.1.1.0/24         directly connected   -         142net
143.1.0.0/16         directly connected   -         143net
153.1.0.0/16         directly connected   -         to-R2
185.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
186.0.0.0/8          153.1.1.12           ISIS_L1   to-R2
187.1.0.0/16         153.1.1.12           ISIS_L1   to-R2
192.1.1.0/24         153.1.1.12           ISIS_L1   to-R2
195.1.0.0/16         Unnumbered           ISIS_L1   LSP1
                     Unnumbered           ISIS_L1   LSP2
```

Advertising IGP Shortcuts

IGP shortcuts need to be advertised so that other routers in the autonomous system can calculate paths that use the LSP. You advertise these shortcuts with the **`isis add label-switched-path`** command for IS-IS networks and with the **`ospf add label-switched-path`** command for OSPF networks.

Note Each LSP is advertised as a unidirectional, point-to-point link. OSPF and IS-IS both verify that there is a bidirectional connection between nodes before using an advertised link. Therefore, you need to configure two LSPs, one in each direction, for paths between two LSRs that will be advertised in IS-IS or OSPF autonomous systems.

The LSP is advertised as a unidirectional, point-to-point link. The advertisement contains:

- the source address of the LSP (usually the address of the local router)
- the destination address of the LSP (usually the address of the egress router)
- a metric value

The metric value is an optional parameter configured for the LSP with the **`mpls create|set label-switched-path`** command. If no metric value is configured for the LSP with the **`isis`**, **`ospf`**, or **`mpls`** commands, then a metric value of 1 is used.

17.8 QOS FOR MPLS

The Riverstone implementation of MPLS allows Quality of Service (QoS) facilities to be applied to layer-2 tunneled frames and layer-3 packets traversing an LSP. These QoS facilities can be applied to both input and output ports of the LSRs. Primarily, QoS is accomplished by mapping traffic characteristics such as internal priority bits or 802.1P bits to the MPLS Experimental bits (Exp bits).

17.8.1 MPLS Experimental Bits

The MPLS QoS capabilities are based on the use of the three Experimental bits (Exp bits) contained within the MPLS label. The value contained within the Exp bits is used to assign a packets to one of four internal queues when the packets traverse the RS. The priorities of these queues are *low*, *medium*, *high*, and *control*. In turn, QoS facilities, such as WFQ, are configured to affect the behavior of the traffic passing through each of these queues.

Note .See the QoS Configuration chapter for details on how to configure the QoS facilities.

For layer-2 frames (both Martini tunnels and TLS), the Exp bit values are derived from the following:

- 802.1p priority bits – 3 bits
- Riverstone proprietary internal priority bits – 2 bits representing the four priority queues
  - 00 = low
  - 01 = medium
  - 10 = high
  - 11 = control

For layer-3 packets, the Exp bit values are derived from the following:

- Riverstone proprietary internal priority bits – 2 bits representing the four priority queues
  - 00 = low
  - 01 = medium
  - 10 = high
  - 11 = control
- ToS precedence bits – 3 most significant bits of the ToS byte (see Figure 17-29)
- Differentiated Services Code Point (DSCP) bits – 6 most significant bits of the ToS byte (see Figure 17-29)

Note Use the **`tos`**, **`tos-mask`**, **`tos-rewrite`**, and **`tos-precedence-rewrite`** parameters of the **`qos set ip`** command to configure the value of the DSCP bits.

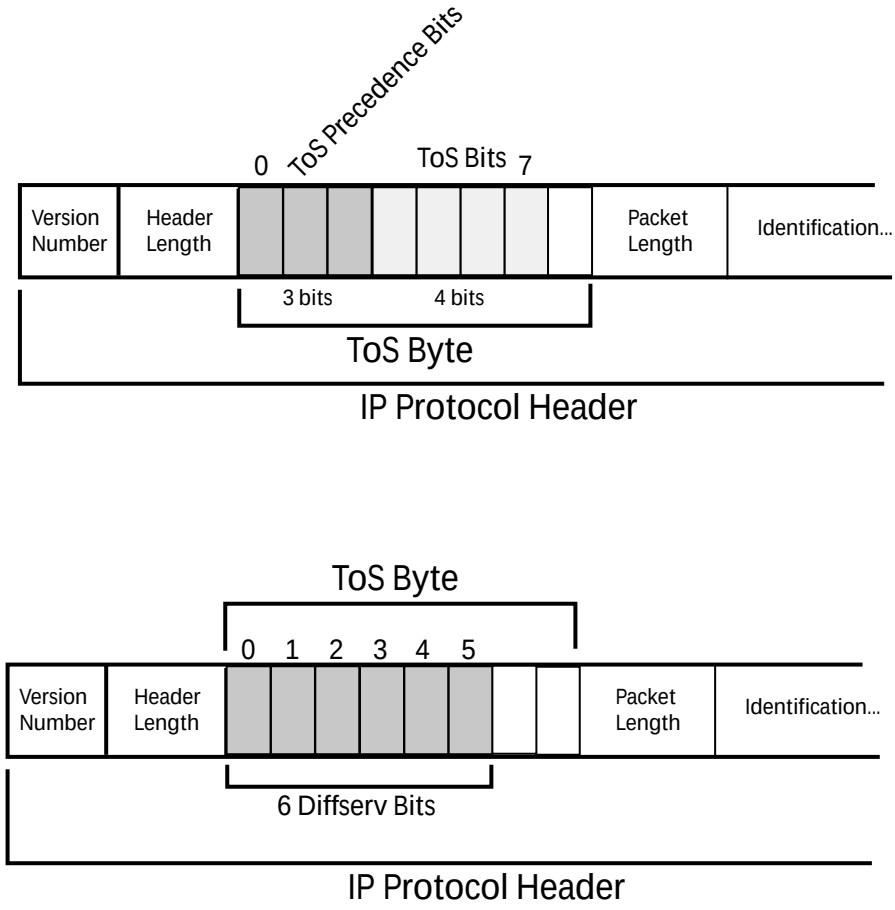


Figure 17-29 Comparison of ToS precedence bits to DSCP bits

Setting the Exp Bits

The Exp bits are set by creating an *ingress policy* on the ingress LSR. This ingress policy sets the Exp bits in relation to values associated with the frames and packets traversing the LSP. For example, if a VLAN trunk port is tunneled through the LSP, the EXP bits can be set by directly copying the values contained within the three 802.1p priority bits of the 802.1Q headers. Once packets/frames have reached the egress LSR, an *egress policy* can be created on the egress LSR that maps the Exp bits back into the bit values of the packets or frames.

Figure 17-30 shows an example of bits being copied on ingress into the Exp bits, and then copied back to the packet on egress.

Alternately, tables can be configured (using the **`mpls create`** command) that map the ingress packet/frame bits to the Exp bits – while other tables can be created that map the Exp bits back to packet/frame bits on the egress. The table method has the advantage of allowing flexibility on how packet/frame bits are mapped to the Exp bits.

For example, in Figure 17-31, an ingress table has been created (using the **`mpls create tosprec-to-exp-tbl`** command) that maps incoming ToS precedence bits to the Exp bits. In this example, the ToS precedence bits are read from incoming packets then compared against the table to determine how to set the Exp bits. Within the table, any ToS precedence value can be mapped to any Exp bit value – for instance, in Figure 17-31, ToS precedence bit value 6 (110 binary) is mapped to Exp bit value 5 (101 binary).

The following is the command that creates the ingress table mapping in Figure 17-31:

```
rs(config)# mpls create tosprec-to-exp-tbl <name> tosprec0 0 tosprec1 1 tosprec2 6
tosprec3 3 tosprec4 7 tosprec5 2 tosprec6 5 tosprec7 6
```

A second table can be created on the egress LSR that maps the Exp bits back to bit fields within packets or frames.

Note The DSCP bits cannot be directly copied into the Exp bits of the The MPLS label. The mapping of DSCP bits to Exp bits must always be done using a table.

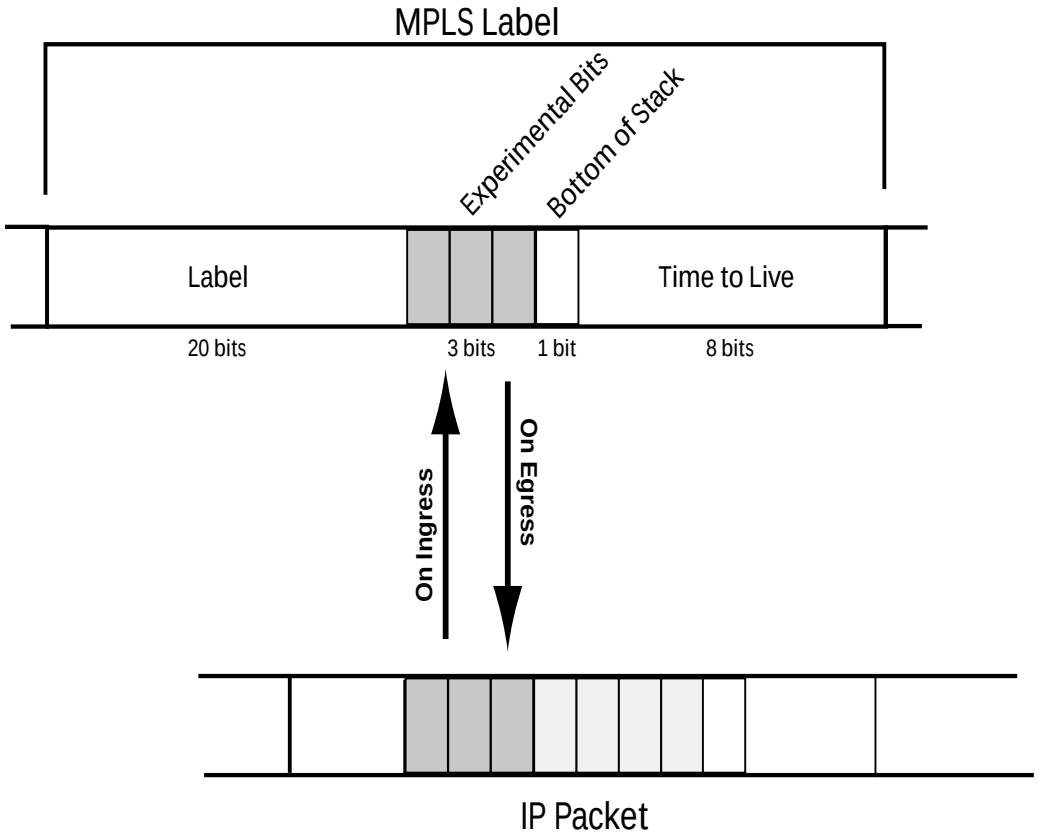


Figure 17-30 Copying bits directly to and from packets traversing the LSP

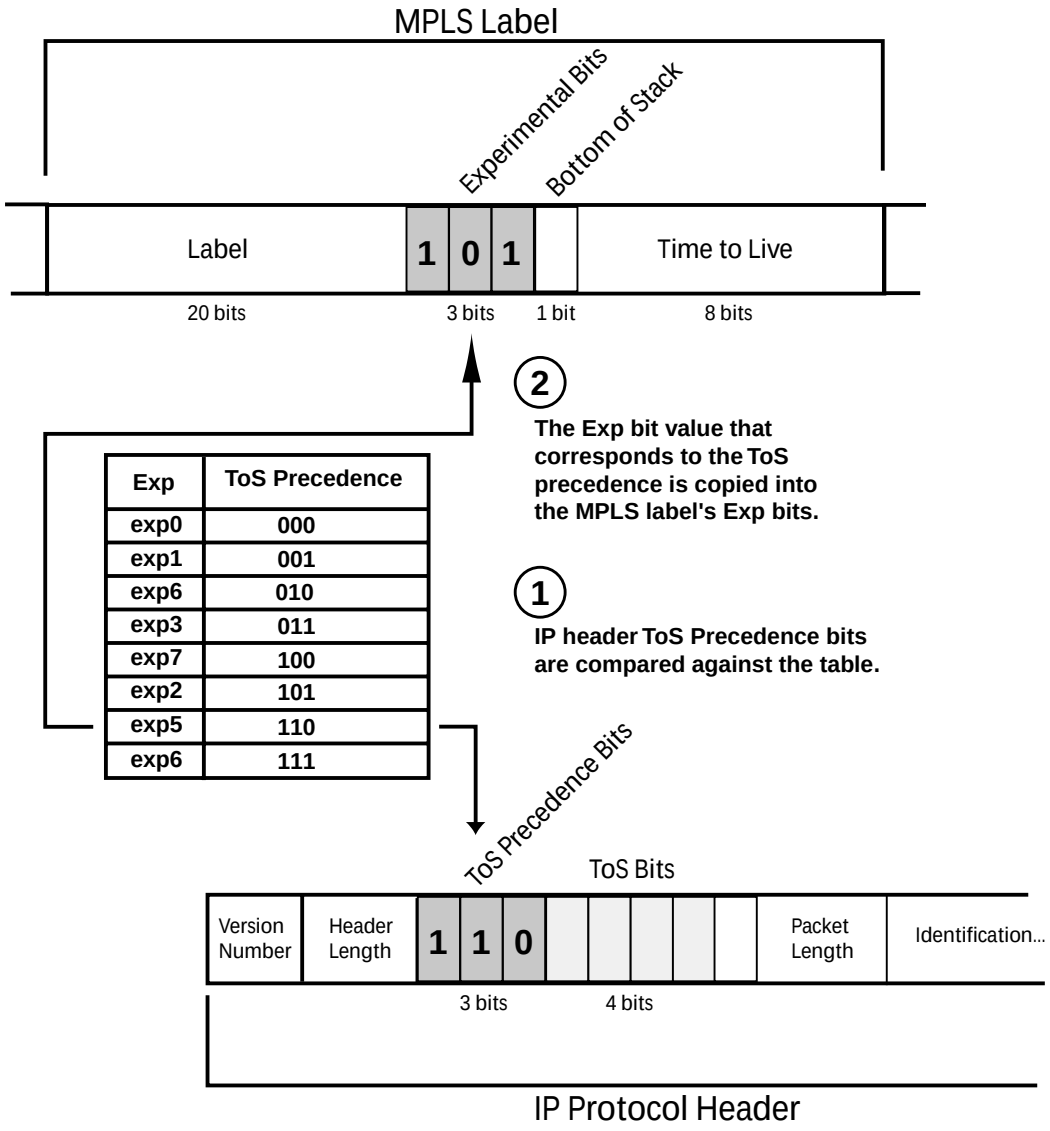


Figure 17-31 Setting the Exp bits using a mapping table

In the following example, a layer-2, a Transparent LAN Service (TLS) customer profile is defined, and then a table is created (**`Tabl1`**) that maps the 802.1P priority bits to the Exp bits. Finally, the table is applied to the TLS path using the **`ldp set l2-tls`** command:

```
rs(config)# mpls set customer-profile CUS1 customer_id 200 in-port-list gi.4.1 type
port
rs(config)# mpls create 1p-to-exp-tbl Tabl1 1p0 0 1p1 3 1p2 7 1p3 7
rs(config)# ldp connect customer-profile CUS1 remote-peer 3.3.3.3
rs(config)# ldp set l2-tls 1p-to-exp-table Tabl1 customer-id 200 to-peer 3.3.3.3
```

The following lists the possible tables that can be used to map packet/frame bits to the Exp bits.

- On ingress:
  - 802.1P bits to Exp bits (**`mpls create 1p-to-exp-tbl`** <*name*>)
  - DSCP bits to Exp bits (**`mpls create dscp-to-exp-tbl`** <*name*>)
  - Internal priority bits to Exp bits (**`mpls create intprio-to-exp-tbl`** <*name*>)
  - ToS precedence bits to Exp bits (**`mpls create tosprec-to-exp-tbl`** <*name*>)
- On Egress:
  - Exp bits to 802.1P bits (**`mpls create exp-to-1p-tbl`** <*name*>)
  - Exp bits to DSCP bits (**`mpls create exp-to-dscp-tbl`** <*name*>)
  - Exp bits to ToS precedence bits (**`mpls create exp-to-tosprec-tbl`** <*name*>)

Note There is no facility for mapping Exp bits to internal priority bits on egress. However, Exp bits that were set on ingress using the internal priority bits can be mapped to other packet/frame bits on egress (DSCP, 802.1P, and so on).

Creating and using tables is covered in more detail within the following sections.

17.8.2 Creating Ingress and Egress Policies

This section illustrates the basic steps for creating both an ingress and egress policy for mapping packet and frame bits to and from the Exp bits. Configuration examples for both layer-2 and layer-3 traffic are presented at the end of this section.

Layer-2 Ingress and Egress Policies

The following steps outline the process for creating a layer-2 ingress policy on the ingress LSR.

1. If using table matching to map frame bits to the Exp bits, use the **`mpls create`** command to specify the type of table, the table's name, and its contents.
2. Use the **`ldp set l2-fec`** command to apply the ingress policy to layer-2 Martini tunnel traffic.
3. Use the **`ldp set l2-tls`** command to apply the ingress policy to layer-2 TLS tunnel traffic.

The following steps outline the process for creating a layer-2 egress policy on the egress LSR.

1. If using table matching to map Exp bits to frame bits, use the **`mpls create`** command to specify the type of table, the table's name, and its contents.
2. Use the **`mpls set egress-l2-diffserv-policy`** command to apply the egress policy to layer-2 traffic. Note that the egress policy is applied globally to all layer-2 traffic traversing the LSP.

Layer-3 Ingress and Egress Policies

The following steps outline the process for creating a layer-3 ingress policy on the ingress LSR.

1. If using table matching to map packet bits to the Exp bits, use the **`mpls create`** command to specify the type of table, the table's name, and its contents.

2. Use the **mpls set ingress-diffserv-policy** command to apply the ingress policy to layer-3 traffic.

The following steps outline the process for creating a layer-3 egress policy on the egress LSR.

1. If using table matching to map Exp bits to packet bits, use the **mpls create** command to specify the type of table, the table's name, and its contents.
2. Use the **mpls set egress-l3-diffserv-policy** command to apply the egress policy to layer-3 traffic. Note that the egress policy is applied globally to all layer-3 traffic traversing the LSP

Layer-2 Example

The following example creates an ingress policy that copies the 802.1p bits to the Exp bits, and an egress policy that copies the Exp bits back to the 802.1p bits. It is assumed that all other MPLS parameters have been previously set to create an LSP over which layer-2 traffic is being tunneled.

One the ingress LSR of the LSP with VLAN id **200** and remote peer **100.10.10.11,** do the following:

```
rs(config)# ldp set l2-fec copy-1p-to-exp vlan 200 to-peer 100.10.10.11
```

On the egress LSR:

```
rs(config)# mpls set egress-l2-diffserv-policy copy-exp-to-1p
```

As VLAN traffic traverses the LSP, the Exp bits in the MPLS label carry the values of the 802.1p bits. When leaving the LSP (at egress), the Exp bits in the MPLS label are copied back to the 802.1p bits in the 802.1Q headers.

Layer-3 Example

The following example creates an ingress policy that maps ToS precedence bits to Exp bits through the use of a table, and an egress policy that maps the Exp bits back to the ToS precedence bits with another table. It is assumed in this example that the LSP already exists and is fully configured.

On the ingress LSR, create a table named **tos_tbl** that maps the ToS precedence bits to the Exp bits:

```
rs(config)# mpls create tosprec-to-exp-tbl tos_tbl tosprec0 0 tosprec1 1 tosprec2 5
tosprec7 7
```

Notice that not all ToS precedence vales are defined, and that a ToS precedence of 2 (010 binary) maps to an Exp value of 5 (101 binary).

Note If a value within any table is not specified, it defaults to zero.

Use the **mpls show diff-serv-tbls** command to display the contents of the ingress table.

```
rs# mpls show diff-serv-tbls tosprec-to-exp_tbl tos_tbl

TOS precedence to EXP table:
----------------------------
Table Name                TOSPREC --> EXP
----------                ---------------
tos-tbl                   1           1
                          2           5
                          7           7
                          *           0
```

In the display above, notice that all unspecified values for ToS precedence are wild carded to zero.

On the ingress LSR, use the **mpls set** command to create an ingress policy for LSP **path1** that uses the table **tos_tbl**:

```
rs(config)# mpls set ingress-diffserv-policy tosprec-to-exp-table tos_tbl
label-switched-path path1
```

On the egress LSR, create a table named **exp_tbl** that maps the Exp bits back to the ToS precedence bits:

```
rs(config)# mpls create exp-to-tosprec-tbl exp_tbl exp0 0 exp1 1 exp5 2 exp7 7
```

Notice that not all Exp values are defined, and that the Exp value of 2 (010 binary) is mapped back to a ToS precedence of 2 (**tosprec2** was mapped to 5 on the ingress).

Use the **mpls show diff-serv-tbls exp-to-tosprec_tbl** command to view the contents of table **exp_tbl**:

```
rs# mpls show diff-serv-tbls exp-to-tosprec_tbl exp_tbl

EXP to TOS precedence table:
----------------------------
Table Name                EXP --> TOSPREC
----------                ---------------
exp_tbl                   1       1
                          5       2
                          7       7
                          *       0
```

On the egress LSR, use the **mpls set** command to create an egress policy that uses the table **exp_tbl**:

```
rs(config)# mpls set egress-l3-diffserv-policy exp-to-tosprec-table exp_tbl
```

As layer-3 traffic enters the ingress LSR, the ToS precedence bits in the IP header are compared to the values in **tos_tbl**, and the Exp bits in the MPLS label are set accordingly. At the egress LSR, **exp_tbl** is used to map the Exp bits back to the ToS precedence bits.

18 MSDP CONFIGURATION GUIDE

The RS supports the Multicast Source Discovery Protocol (MSDP) as specified in the `draft-ietf-msdp-spec-11.txt` file.

Use MSDP, in conjunction with the Protocol Independent Multicast - Sparse Mode (PIM-SM) protocol, to implement both intra- and inter-domain multicast routing. Use PIM-SM for multicast routing within a network, then run MSDP for multicast routing between PIM domains.

This chapter contains information about running MSDP on the RS. It provides:

- an overview of MSDP in Section 18.1, *"MSDP Overview."*
- a description of how to configure MSDP on the RS in Section 18.2, *"Configuring MSDP."*

This chapter also describes the following optional tasks:

- to configure a default or static peer, refer to Section 18.3, *"Defining Peers."*
- to configure a mesh group, refer to Section 18.4, *"Configuring an MSDP Mesh Group."*
- to modify MSDP default timer values, refer to Section 18.5, *"Setting MSDP Timers."*
- to filter MSDP Source-Active (SA) messages, refer to 18.6, *"Filtering SA-Messages."*

Note MSDP runs with PIM-SM. To run MSDP on the RS, you must first configure PIM-SM. For information on running PIM-SM on the RS, refer to Chapter 22, *"PIM-SM Routing Configuration."*

18.1 MSDP OVERVIEW

MSDP connects multiple PIM-SM domains. It provides a mechanism for PIM-SM Rendezvous Points (RPs) to discover active sources in other domains. If a domain has receivers for a multicast source in another domain, then PIM-SM is used to build an inter-domain source distribution tree to transmit multicast data from one domain to another. MSDP uses TCP as its transport protocol.

The following sections describe how MSDP operates in conjunction with PIM-SM to provide both intra- and inter-domain multicast routing.

18.1.1 Flooding SA-Messages

A source or a first-hop router (a router directly connected to the source) sends data packets encapsulated in Register messages to its RP. When the RP receives the Register message, the RP decapsulates the Register message and forwards the data packet downstream on the shared distribution tree. The RP that has also been configured as an MSDP peer generates and floods a Source-Active message (SA-message) to its MSDP peers in the different PIM-SM domains. The SA-message alerts the MSDP peers to the new source; it contains information about the source, the multicast group, and the RP that originated the SA message.

18.1.2 Peer RPF Check

Each MSDP peer that receives the SA-message performs a Reverse Path Forwarding (RPF) check based on the RP address in the SA message. If the message passes the RPF check, the MSDP peer caches the SA-message and forwards it to its downstream neighbor away from the source RP. If the message doesn't pass the RPF check, the MSDP peer drops the message.

18.1.3 Joining the Distribution Tree

When an MSDP peer which is also the RP for its domain receives an SA message, the MSDP peer checks whether there are interested receivers in its domain. If the RP determines that it has receivers for that particular multicast group, the RP triggers an (S,G) join event towards the source. Subsequent packets are then forwarded to the RP and down the shared distribution tree in the domain. Once the distribution tree is built from the RP to the source, then regular PIM-SM processing takes over wherein the designated router or the last hop router of a receiver can join the source tree directly.

Note For information on Reverse Path Forwarding (RPF) and other multicast concepts, refer to Chapter 20, *"Multicast Routing Configuration."*

18.1.4 Sending SA-Requests

An RP in a group can send an SA request to an MSDP peer when it wants to know all the active sources for a group. When an MSDP peer receives an SA request, it responds with an SA-Response message which lists all active sources in its SA cache sending to the group specified in the SA request. The peer that sent the request does not flood the SA response to all the other peers.

18.2 CONFIGURING MSDP

To run MSDP on the RS, you must do the following:

- specify the **`msdp start`** command
- specify the **`msdp add peer`** command to configure at least one MSDP peer
- configure BGP (For information on configuring BGP, refer to Chapter 15, *"BGP Configuration Guide."*)

18.2.1 Running BGP with MSDP

MSDP relies on BGP for the inter-domain routing information it needs to perform its RPF checks. When you run BGP, the BGP routes that are exchanged between BGP peers are installed in their unicast RIBs only. To install the BGP routes in both the unicast and multicast RIBs, specify the **`multicast-rib`** option of the **`bgp set peer-group`** command and configure the BGP peer as an MSDP peer.

In a stub network, you can choose *not* to configure BGP and instead, configure static or default peers. For additional information on configuring static or default peers, refer to Section 18.3, *"Defining Peers."*

18.2.2 MSDP Configuration Example

MSDP relies on BGP for the inter-domain routing information it uses to perform RPF checks.The following diagram illustrates a basic configuration where MSDP connects two PIM domains.

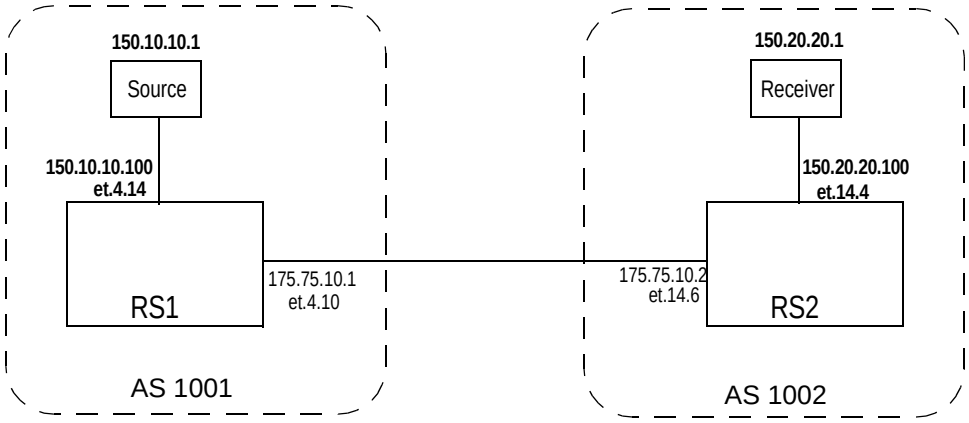


Figure 18-1 MSDP Configuration Example

In Figure 18-1, each network is running PIM-SM. RS1 is the RP of its domain and RS2 is the RP of its domain. To exchange information about the active sources in each other's domains, the two RPs must run MSDP and establish an MSDP peering relationship with each other.

Following are the steps and commands that were used to configure RS1:

```
! Configure the interfaces
interface create ip to-32k address-netmask 175.75.10.1/24 port et.4.10
interface create ip to-pc10 address-netmask 150.10.10.100 port et.4.14
interface add ip lo0 address-netmask 1.1.1.1/32
! Set the router ID and autonomous system
ip-router global set router-id 1.1.1.1
ip-router global set autonomous-system 1001
! Configure OSPF
ospf create area backbone
ospf add stub-host 1.1.1.1 to-area backbone cost 10
ospf add interface to-pc10 to-area backbone
ospf set rib multicast
ospf start
! Configure BGP
bgp create peer-group domain-2 autonomous-system 1002 type external
bgp add peer-host 175.75.10.2 group domain-2
bgp set peer-group domain-2 multicast-rib
bgp start
! Redistribute the directly connected route to BGP
ip-router policy redistribute from-proto direct to-proto bgp target-as all
! Configure IGMP on the interface connected to the host
igmp add interface to-pc10
igmp start
! Configure PIM-SM
pim sparse add interface 1.1.1.1
pim sparse add interface 175.75.10.1
pim sparse add interface to-pc10
pim sparse static-rp address 1.1.1.1
pim sparse start
! Configure MSDP
msdp add peer local-addr 175.75.10.1 remote-addr 175.75.10.2
msdp start
```

Following are the steps and commands that were used to configure RS2:

```
! Configure the interfaces
interface create ip to-8k1 address-netmask 175.75.10.2/24 port et.14.6
interface create ip to-pc20 address-netmask 150.20.20.100 port et.14.4
interface add ip lo0 address-netmask 2.2.2.2/32
! Set the router ID and autonomous system
ip-router global set router-id 2.2.2.2
ip-router global set autonomous-system 1002
! Configure OSPF
ospf create area backbone
ospf add stub-host 2.2.2.2 to-area backbone cost 10
ospf add interface to-pc20 to-area backbone
ospf set rib multicast
ospf start
! Configure BGP
bgp create peer-group domain-1 autonomous-system 1001 type external
bgp add peer-host 175.75.10.1 group domain-1
bgp set peer-group domain-1 multicast-rib
bgp start
! Redistribute the directly connected route to BGP
ip-router policy redistribute from-proto direct to-proto bgp target-as all
! Configure IGMP on the interface connected to the host
igmp add interface to-pc20
igmp start
! Configure PIM-SM
pim sparse add interface to-8k1 boundary
pim sparse add interface 2.2.2.2
pim sparse add interface to-pc20
pim sparse static-rp address 2.2.2.2
pim sparse start
! Configure MSDP
msdp add peer local-addr 175.75.10.2 remote-addr 175.75.10.1
msdp start
```

To verify that the MSDP peering relationship was established between the two routers, you can specify the **`msdp show peers`** command as shown in the following examples:

```
rs1# msdp show peers
Comp      Lcl             Rmt             State MeshID Flags  HoldTime
msdp0     175.75.10.1     175.75.10.2     ESTB       0 (none) 46
```

:

```
rs2# msdp show peers
Comp      Lcl             Rmt             State MeshID Flags  HoldTime
msdp0     175.75.10.2     175.75.10.1     ESTB       0 (none) 19
```

Figure 18-1 shows that RS1 is connected to a source. When this source sends a Register message to RS1, it generates an SA message and sends it to RS2. To view the SA messages that were sent by RS1 to RS2, use the **msdp show sa-cache** command, as shown in the following example:

```
rs2# msdp show sa-cache
Comp: msdp0
        1.1.1.1 (150.10.10.1/32, 224.1.2.1/32)
```

As shown in the example, the SA message contains the source (150.10.10.1/32), the multicast group (224.1.2.1/32), and the RP that originated the SA message (1.1.1.1).

18.3 DEFINING PEERS

You can optionally define a previously configured peer as either a default peer or a static peer. MSDP does not perform an RPF check when the router receives SA messages from a static or a default peer. Therefore, if you are configuring a static or default peer for a stub network, you don't need to run BGP between the router and its static or default peer.

18.3.1 Defining a Default Peer

If you want the RS to accept all SA-messages from a particular peer, define it as the default peer. In the following example, the remote peer, `175.75.10.1`, is defined as the default peer. You can define only one default peer.

```
rs (config)# msdp add peer local-addr 175.75.10.2 remote-addr 175.75.10.1
rs (config)# msdp add default-rpf-peer 175.75.10.1
```

Use the **`msdp show default-peers`** command to verify the default peer as shown in the following example:

```
rs# msdp show default-peers
Comp: msdp0 Default-Peer: 175.75.10.1
```

18.3.2 Defining a Static Peer

If you want the RS to accept SA messages from a particular remote peer for a specific RP, you can map the RP address to that remote peer. In the following example, the RS will accept any SA-message from the remote peer (10.1.1.1) if the IP address of the RP (192.168.2.1) is in the SA-message.

```
rs (config)# msdp add peer local-addr 175.75.10.2 remote-addr 10.1.1.1
rs (config)# msdp add static-rpf-peer peer-addr 10.1.1.1 rp-addr 192.168.2.1
```

Use the **`msdp show static-peers`** command to verify your configuration as shown in the following example:

```
rs# msdp show static-peers
Comp: msdp0
        RP: 192.168.2.1 Static-Peer: 10.1.1.1
```

18.4 CONFIGURING AN MSDP MESH GROUP

A mesh group is a group of MSDP peers in one PIM-SM domain. You can configure a mesh group to reduce SA flooding when there are multiple RPs in one domain.

In a mesh group, only the SA-originator forwards the SA message to the members of the mesh group. Mesh group members *do not* forward SA messages to other members. Instead, the members forward SA messages only to non-mesh group peers and to members of other mesh groups.

For the originator to forward SA messages to all members, each member in the group must have a peer connection with every other member of the mesh group. A peer can be a member of more than one mesh group.

The following diagram illustrates how SA messages are flooded within mesh groups and outside of mesh groups.

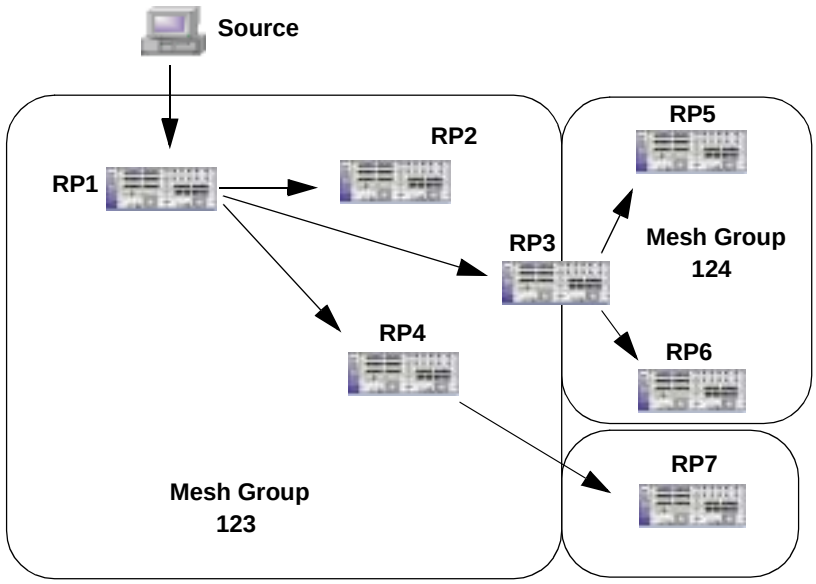


Figure 18-2 Flooding SA messages in mesh groups

The source sends a Register message to its RP, *RP1*. *RP1* creates an SA message and floods it to the members of its mesh group, *123*.

In addition to mesh group *123*, *RP3* also belongs to mesh group *124*. Therefore, *RP3* floods the SA message to the RPs in mesh group *124*, but not to mesh group *123*.

The RPF neighbor of *RP4* is *RP7*. Therefore, *RP4* sends the SA message to *RP7*, which belongs to another PIM-SM domain.

To specify that an MSDP peer is in a mesh group, use the **mesh** option as shown in the following example:

```
rs (config)# msdp add peer local-addr 10.1.1.1 remote-addr 100.10.10.1 mesh 123
rs (config)# msdp start
```

18.5 SETTING MSDP TIMERS

MSDP has a number of timers with default values. The RS provides commands for changing these default values as described in this section.

- **Connect Retry**

  An MSDP speaker tries to open a TCP connection to its peer at 30 second intervals. You can change this interval as shown in the following example:

```
rs (config)# msdp set connect-retry-period 40
```

- **Peer Holdtime**

  MSDP peers exchange messages at a specified interval. If an MSDP peer does not receive an MSDP message within a specified period, it sends a Notification message and closes the MSDP connection. On the RS, the default is 90 seconds. You can change this interval as shown in the following example:

```
rs (config)# msdp set peer-holdtime 100
```

- **Keep Alive**

  Once a connection is established, the MSDP peers exchange keepalive messages every 75 seconds.You can change this interval as shown in the following example, which sets the keepalive period to 60 seconds:

```
rs (config)# msdp set keepalive-period 60
```

- **Cache Timeout**

  The source-active (SA) messages also have timers associated with them. MSDP routers must cache SA messages. By default, the RS caches SA messages for 60 seconds. You can change this default value, as shown in the following example, which sets the cache time interval to 100 seconds:

```
rs (config)# msdp set sa-cache timeout 100
```

- **Holddown**

  In addition, there is a time for the interval between SA-advertisement messages from an (S,G) pair. The default is 30 seconds. You can change this default as shown in the following example, which sets the interval to 45 seconds:

```
rs (config)# msdp set sa-cache holddown 45
```

18.6 FILTERING SA-MESSAGES

By default, all SA messages are forwarded to and from the RS's MSDP peers and the RS's local PIM domain. However, you can configure MSDP filters to control the receiving and forwarding of SA messages. This section describes the three types of filters that are available on the RS:

- PIM filters
- incoming SA-message filters
- outgoing SA-message filters

Only the RP in the same domain as the source can restrict SA messages. MSDP peers in transit domains should not filter SA messages.

18.6.1 Using PIM Filters

By default, the RP advertises all its registered sources to its peers. You can restrict which sources are advertised by configuring a PIM filter. A PIM filter specifies which (S,G) pairs learned from the local PIM domain should be excluded from the outgoing-SA messages.

To filter local (S,G) pairs from outgoing messages, use the **`msdp filter pim`** command as shown in the following example:

```
rs (config)# msdp filter pim grp-addr 234.132.145.100 src-addr 132.131.12.1
```

18.6.2 Using Incoming SA-Message Filters

When an MSDP peer which is also the RP for its domain receives an SA message, the MSDP peer checks whether there are interested receivers in its domain. You can restrict which (S,G) groups are advertised in the RP's PIM domain by configuring an incoming SA-message filter. This type of filter specifies which (S,G) group should not be advertised in the PIM domain. (Note though that the RP will continue to propagate the SA-message to its other MSDP peers. It just won't advertise it in its own domain.)

To filter (S,G) pairs from incoming messages, use the **`msdp filter incoming-sa-msg`** command as shown in the following example:

```
rs (config)# msdp filter incoming-sa-msg grp-addr 234.132.145.100 src-addr
132.131.12.1
```

18.6.3 Using Outgoing SA-Message Filters

By default, the RS forwards all the SA-messages that it receives to all its MSDP peers. You can prevent SA-messages for certain (S,G) pairs from being sent out by configuring an outgoing SA-message filter. When the RS receives an SA-message which contains an (S,G) pair specified in the filter, it will not forward the SA-message.

To filter (S,G) pairs from outgoing SA messages, use the **`msdp filter outgoing-sa-msg`** command as shown in the following example:

```
rs (config)# msdp filter outgoing-sa-msg grp-addr 234.132.145.100 src-addr
132.131.12.1
```

19 ROUTING POLICY CONFIGURATION

The RS family of routers supports extremely flexible routing policies. The RS allows the network administrator to control import and export of routing information based on criteria including:

- Individual protocol
- Source and destination autonomous system
- Source and destination interface
- Previous hop router
- Autonomous system path
- Tag associated with routes
- Specific destination address

The network administrator can specify a preference level for each combination of routing information being imported by using a flexible masking capability.

The RS also provides the ability to create advanced and simple routing policies. Simple routing policies provide a quick route redistribution between various routing protocols (RIP, OSPF, IS-IS and BGP). Advanced routing policies provide more control over route redistribution.

19.1 PREFERENCE

Preference is the value the RS routing process uses to order preference of routes from one protocol or peer over another. Preference can be set using several different configuration commands. Preference can be set based on one network interface over another, from one protocol over another, or from one remote gateway over another. Preference may not be used to control the selection of routes within an Interior Gateway Protocol (IGP). This is accomplished automatically by the protocol based on metric.

Preference may be used to select routes from the same Exterior Gateway Protocol (EGP) learned from different peers or autonomous systems. Each route has only one preference value associated with it, even though the preference can be set at many places using configuration commands. The last or most specific preference value set for a route is the value used. A preference value is an arbitrarily assigned value used to determine the order of routes to the same destination in a single routing database. The active route is chosen by the lowest preference value.

A default preference is assigned to each source from which the RS routing process receives routes. Preference values range from 0 to 255 with the lowest number indicating the most preferred route.

The following table summarizes the default preference values for routes learned in various ways. The table lists the CLI commands that set preference, and shows the types of routes to which each CLI command applies. A default preference for each type of route is listed, and the table notes preference precedence between protocols. The narrower the scope of the statement, the higher precedence its preference value is given, but the smaller the set of routes it affects.

Table 19-1 Default preference values

Preference	Defined by CLI Command	Default
Direct connected networks	**ip-router global set interface**	0
OSPF routes	**ospf**	10
Static routes from config	**ip add route**	5
RIP routes	**rip set preference**	100
Point-to-point interface		110
Routes to interfaces that are down	**ip-router global set interface down-preference**	120
Aggregate/generate routes	**aggr-gen**	130
OSPF AS external routes	**ospf set ase-defaults preference**	150
BGP routes	**bgp set preference**	170
IS-IS routes	**isis set preference**	

19.1.1 Import Policies

Import policies control the importation of routes from routing protocols and their installation in the routing databases (Routing Information Base and Forwarding Information Base). Import Policies determine which routes received from other systems are used by the RS routing process. Every import policy can have up to two components:

- Import-Source
- Route-Filter

Import-Source

This component specifies the source of the imported routes. It can also specify the preference to be associated with the routes imported from this source.

The routes to be imported can be identified by their associated attributes:

- Type of the source protocol (RIP, OSPF, BGP).
- Source interface or gateway from which the route was received.
- Source autonomous system from which the route was learned.
- AS path associated with a route. Besides autonomous system, BGP also supports importation of routes using AS path regular expressions and AS path options.
- If multiple communities are specified using the optional-attributes-list, only updates carrying all of the specified communities will be matched. If the specified optional-attributes-list has the value **none** for the **well-known-community** option, then only updates lacking the community attribute will be matched.

In some cases, a combination of the associated attributes can be specified to identify the routes to be imported.

Note It is quite possible for several BGP import policies to match a given update. If more than one policy matches, the first matching policy will be used. All later matching policies will be ignored. For this reason, it is generally desirable to order import policies from most to least specific. An import policy with an optional-attributes-list will match any update with any (or no) communities.

The importation of RIP routes may be controlled by source interface and source gateway. RIP does not support the use of preference to choose between RIP routes. That is left to the protocol metrics.

Due to the nature of OSPF, only the importation of ASE routes may be controlled. OSPF intra-and inter-area routes are always imported into the routing table with a preference of 10. If a tag is specified with the import policy, routes with the specified tag will only be imported. It is only possible to restrict the importation of OSPF ASE routes when functioning as an AS border router.

Like the other interior protocols, preference cannot be used to choose between OSPF ASE routes. That is done by the OSPF costs.

Route-Filter

This component specifies the individual routes which are to be imported or restricted. The preference to be associated with these routes can also be explicitly specified using this component.

The preference associated with the imported routes are inherited unless explicitly specified. If there is no preference specified with a route-filter, then the preference is inherited from the one specified with the import-source.

Every protocol (RIP, OSPF, and BGP) has a configurable parameter that specifies the default-preference associated with routes imported to that protocol. If a preference is not explicitly specified with the route-filter, as well as the import-source, then it is inherited from the default-preference associated with the protocol for which the routes are being imported.

19.1.2 Export Policies

Export policies control the redistribution of routes to other systems. They determine which routes are advertised by the Unicast Routing Process to other systems. Every export policy can have up to three components:

- Export-Destination
- Export-Source
- Route-Filter

Export-Destination

This component specifies the destination where the routes are to be exported. It also specifies the attributes associated with the exported routes. The interface, gateway, or the autonomous system to which the routes are to be redistributed are a few examples of export-destinations. The metric, type, tag, and AS-Path are a few examples of attributes associated with the exported routes.

Export-Source

This component specifies the source of the exported routes. It can also specify the metric to be associated with the routes exported from this source.

The routes to be exported can be identified by their associated attributes:

- Their protocol type (RIP, OSPF, BGP, Static, Direct, Aggregate, IS-IS).
- Interface or the gateway from which the route was received.
- Autonomous system from which the route was learned.
- AS path associated with a route. When BGP is configured, all routes are assigned an AS path when they are added to the routing table. For interior routes, this AS path specifies IGP as the origin and no ASs in the AS path (the current AS is added when the route is exported). For BGP routes, the AS path is stored as learned from BGP.
- Tag associated with a route. Both OSPF and RIP version 2 currently support tags. All other protocols have a tag of zero.

In some cases, a combination of the associated attributes can be specified to identify the routes to be exported.

Route-Filter

This component specifies the individual routes which are to exported or restricted. The metric to be associated with these routes can also be explicitly specified using this component.

The metric associated with the exported routes are inherited unless explicitly specified. If there is no metric specified with a route-filter, then the metric is inherited from the one specified with the export-source.

If a metric was not explicitly specified with both the route-filter and the export-source, then it is inherited from the one specified with the export-destination.

Every protocol (RIP, OSPF, BGP, and IS-IS) has a configurable parameter that specifies the default-metric associated with routes exported to that protocol. If a metric is not explicitly specified with the route-filter, export-source as well as export-destination, then it is inherited from the default-metric associated with the protocol to which the routes are being exported.

19.1.3 Specifying a Route Filter

Routes are filtered by specifying a route-filter that will match a certain set of routes by destination, or by destination and mask. Among other places, route filters are used with martians and in import and export policies.

The action taken when no match is found is dependent on the context. For instance, a route that does match any of the route-filters associated with the specified import or export policies is rejected.

A route will match the most specific filter that applies. Specifying more than one filter with the same destination, mask, and modifiers generates an error.

There are three possible formats for a route filter. Not all of these formats are available in all places. In most cases, it is possible to associate additional options with a filter. For example, while creating a martian, it is possible to specify the **`allow`** option, while creating an import policy, one can specify a **`preference`**, and while creating an export policy one can specify a **`metric`**.

The three forms of a route-filter are:

Network	[exact | refines | between number,number]
Network/mask	[exact | refines | between number,number]
Network/masklen	[exact | refines | between number,number]

Matching usually requires both an address and a mask, although the mask is implied in the shorthand forms listed below. These three forms vary in how the mask is specified. In the first form, the mask is implied to be the natural mask of the network. In the second, the mask is explicitly specified. In the third, the mask is specified by the number of contiguous one bits.

If no optional parameters (exact, refines, or between) are specified, any destination that falls in the range given by the network and mask is matched, so the mask of the destination is ignored. If a natural network is specified, the network, any subnets, and any hosts will be matched. Three optional parameters that cause the mask of the destination to also be considered are:

Exact	Specifies that the mask of the destination must match the supplied mask exactly. This is used to match a network, but no subnets or hosts of that network.
Refines	Specifies that the mask of the destination must be more specified (i.e., longer) than the filter mask. This is used to match subnets and/or hosts of a network, but not the network.
Between number, number	Specifies that the mask of the destination must be as or more specific (i.e., as long as or longer) than the lower limit (the first number parameter) and no more specific (i.e., as long as or shorter) than the upper limit (the second number). Note that exact and refines are both special cases of between.

19.1.4 Aggregates and Generates

Route aggregation is a method of generating a more general route, given the presence of a specific route. It is used, for example, at an autonomous system border to generate a route to a network to be advertised via BGP given the presence of one or more subnets of that network learned via OSPF. The routing process does not perform any aggregation unless explicitly requested.

Route aggregation is also used by regional and national networks to reduce the amount of routing information passed around. With careful allocation of network addresses to clients, regional networks can just announce one route to regional networks instead of hundreds.

Aggregate routes are not actually used for packet forwarding by the originator of the aggregate route, but only by the receiver (if it wishes). Instead of requiring a route-peer to know about individual subnets which would increase the size of its routing table, the peer is only informed about an aggregate-route which contains all the subnets.

Like export policies, aggregate-routes can have up to three components:

- Aggregate-Destination
- Aggregate-Source

- Route-Filter

Aggregate-Destination

This component specifies the aggregate/summarized route. It also specifies the attributes associated with the aggregate route. The preference to be associated with an aggregate route can be specified using this component.

Aggregate-Source

This component specifies the source of the routes contributing to an aggregate/summarized route. It can also specify the preference to be associated with the contributing routes from this source. This preference can be overridden by explicitly specifying a preference with the route-filter.

The routes contributing to an aggregate can be identified by their associated attributes:

- Protocol type (RIP, OSPF, BGP, Static, Direct, Aggregate, IS-IS).
- Autonomous system from which the route was learned.
- AS path associated with a route. When BGP is configured, all routes are assigned an AS path when they are added to the routing table. For interior routes, this AS path specifies IGP as the origin and no ASs in the AS path (the current AS is added when the route is exported). For BGP routes, the AS path is stored as learned from BGP.
- Tag associated with a route. Both OSPF and RIP version 2 currently support tags. All other protocols have a tag of zero.

In some cases, a combination of the associated attributes can be specified to identify the routes contributing to an aggregate.

Route-Filter

This component specifies the individual routes that are to be aggregated or summarized. The preference to be associated with these routes can also be explicitly specified using this component.

The contributing routes are ordered according to the aggregation preference that applies to them. If there is more than one contributing route with the same aggregating preference, the route's own preferences are used to order the routes. The preference of the aggregate route will be that of contributing route with the lowest aggregate preference.

A route may only contribute to an aggregate route that is more general than itself; it must match the aggregate under its mask. Any given route may only contribute to one aggregate route, which will be the most specific configured, but an aggregate route may contribute to a more general aggregate.

An aggregate-route only comes into existence if at least one of its contributing routes is active.

19.1.5 Authentication

Authentication guarantees that routing information is only imported from trusted routers. Many protocols like RIP V2 and OSPF provide mechanisms for authenticating protocol exchanges. A variety of authentication schemes can be used. Authentication has two components – an Authentication Method and an Authentication Key. Many protocols allow different authentication methods and keys to be used in different parts of the network.

Authentication Methods

There are two main authentication methods:

Simple Password In this method, an authentication key of up to 8 characters is included in the packet. If this does not match what is expected, the packet is discarded. This method provides little security, as it is possible to learn the authentication key by watching the protocol packets.

MD5 This method uses the MD5 algorithm to create a crypto-checksum of the protocol packet and an authentication key of up to 16 characters. The transmitted packet does not contain the authentication key itself; instead, it contains a crypto-checksum, called the digest. The receiving router performs a calculation using the correct authentication key and discard the packet if the digest does not match. In addition, a sequence number is maintained to prevent the replay of older packets. This method provides a much stronger assurance that routing data originated from a router with a valid authentication key.

Many protocols allow the specification of two authentication keys per interface. Packets are always sent using the primary keys, but received packets are checked with both the primary and secondary keys before being discarded.

Authentication Keys and Key Management

An authentication key permits the generation and verification of the authentication field in protocol packets. In many situations, the same primary and secondary keys are used on several interfaces of a router. To make key management easier, the concept of a *key-chain* was introduced. Each key-chain has an identifier and can contain up to two keys. One key is the primary key and other is the secondary key. Outgoing packets use the primary authentication key, but incoming packets may match either the primary or secondary authentication key. In Configure mode, instead of specifying the key for each interface (which can be up to 16 characters long), you can specify a key-chain identifier.

The RS supports MD5 specification of OSPF RFC 2178 which uses the MD5 algorithm and an authentication key of up to 16 characters. Thus there are now three authentication schemes available per interface: none, simple and RFC 2178 OSPF MD5 authentication. It is possible to configure different authentication schemes on different interfaces.

RFC 2178 allows multiple MD5 keys per interface. Each key has two times associated with the key:

- A time period that the key will be generated
- A time period that the key will be accepted

The RS only allows one MD5 key per interface. Also, there are no options provided to specify the time period during which the key would be generated and accepted; the specified MD5 key is always generated and accepted. Both these limitations would be removed in a future release.

19.2 CONFIGURING SIMPLE ROUTING POLICIES

Simple routing policies provide an efficient way for routing information to be exchanged between routing protocols. The **`redistribute`** command can be used to redistribute routes from one routing domain into another routing domain. Redistribution of routes between routing domains is based on route policies. A route policy is a set of conditions based on which routes are redistributed. While the **`redistribute`** command may fulfill the export policy requirement for most users, complex export policies may require the use of the commands listed under Export Policies.

The general syntax of the redistribute command is as follows:

ip-router policy redistribute from-proto <*protocol*> **to-proto** <*protocol*> [**network** <*ipAddr-mask*> [**exact|refines|between** <*low-high*>]] [**metric** <*number*>|**restrict**] [**source-as** <*number*>] [**target-as** <*number*>]

The **from-proto** parameter specifies the protocol of the source routes. The values for the from-proto parameter can be **rip**, **ospf**, **bgp**, **direct**, **static**, **aggregate, isis-level-1, isis-level-2** and **ospf-ase**. The **to-proto** parameter specifies the destination protocol where the routes are to be exported. The values for the **to-proto** parameter can be **rip**, **ospf, ospf-nssa, isis-level-1, isis-level-2,** and **bgp**. The network parameter provides a means to define a filter for the routes to be distributed. The network parameter defines a filter that is made up of an IP address and a mask. Routes that match the filter are considered as eligible for redistribution.

Every protocol (RIP, OSPF, IS-IS and BGP) has a configurable parameter that specifies the default-metric associated with routes exported to that protocol. If a metric is not explicitly specified with the redistribute command, then it is inherited from the default-metric associated with the protocol to which the routes are being exported.

19.2.1 Redistributing Static Routes

Static routes may be redistributed to another routing protocol such as RIP or OSPF by the following command. The **network** parameter specifies the set of static routes that will be redistributed by this command. If all static routes are to be redistributed set the **network** parameter to **all**. Note that the **network** parameter is a filter that is used to specify routes that are to be redistributed.

To redistribute static routes, enter one of the following commands in Configure mode:

To redistribute static routes into RIP.	**ip-router policy redistribute from-proto static to-proto rip network all**
To redistribute static routes into OSPF.	**ip-router policy redistribute from-proto static to-proto ospf network all**

19.2.2 Redistributing Directly Attached Networks

Routes to directly attached networks are redistributed to another routing protocol such as RIP or OSPF by the following command. The **network** parameter specifies a set of routes that will be redistributed by this command. If all direct routes are to be redistributed set the **network** parameter to **all**. Note that the **network** parameter is a filter that is used to specify routes that are to be redistributed.

To redistribute direct routes, enter one of the following commands in Configure mode:

To redistribute direct routes into RIP.	**ip-router policy redistribute from-proto direct to-proto rip network all**
To redistribute direct routes into OSPF.	**ip-router policy redistribute from-proto direct to-proto ospf network all**

19.2.3 Redistributing RIP into RIP

The RS routing process requires RIP redistribution into RIP if a protocol is redistributed into RIP.

To redistribute RIP into RIP, enter the following command in Configure mode:

To redistribute RIP into RIP.	**ip-router policy redistribute from-proto rip to-proto rip**

19.2.4 Redistributing RIP into OSPF

RIP routes may be redistributed to OSPF.

To redistribute RIP into OSPF, enter the following command in Configure mode:

To redistribute RIP into OSPF.	**ip-router policy redistribute from-proto rip to-proto ospf**

19.2.5 Redistributing OSPF to RIP

For the purposes of route redistribution and import-export policies, OSPF intra- and inter-area routes are referred to as **ospf** routes, and external routes redistributed into OSPF are referred to as **ospf-ase** routes. Examples of **ospf-ase** routes include **static** routes, **rip** routes, **direct** routes, **bgp** routes, or **aggregate** routes, which are redistributed into an OSPF domain.

OSPF routes may be redistributed into RIP. To redistribute OSPF into RIP, enter the following command in Configure mode:

To redistribute ospf-ase routes into RIP.	**ip-router policy redistribute from-proto ospf-ase to-proto rip**
To redistribute ospf routes into RIP.	**ip-router policy redistribute from-proto ospf to-proto rip**

19.2.6 Redistributing Aggregate Routes

The **aggregate** parameter causes an aggregate route with the specified IP address and subnet mask to be redistributed.

Note The aggregate route must first be created using the **aggr-gen** command**.** This command creates a specified aggregate route for routes that match the aggregate.

To redistribute aggregate routes, enter one of the following commands in Configure mode:

To redistribute aggregate routes into RIP.	**ip-router policy redistribute from-proto aggregate to-proto rip**
To redistribute aggregate routes into OSPF.	**ip-router policy redistribute from-proto aggregate to-proto ospf**

19.2.7 Simple Route Redistribution Example: Redistribution into RIP

For all examples given in this section, refer to the configurations shown in Figure 19-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its RIP configuration

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
 interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure a default route through 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route default gateway 170.1.1.7
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure static routes to the 135.3.0.0 subnets reachable through
! R3.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 135.3.1.0/24 gateway 130.1.1.3
 ip add route 135.3.2.0/24 gateway 130.1.1.3
 ip add route 135.3.3.0/24 gateway 130.1.1.3
```

```
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.190.1.2
 ip add route 160.1.5.0/24 gateway 120.190.1.2
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Box Level Configuration
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip start
 rip set default-metric 2
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Interface Configuration. Create a RIP interfaces, and set
 ! their type to (version II, multicast).
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip add interface to-r41
 rip add interface to-r42
 rip add interface to-r6
 rip set interface to-r41 version 2 type multicast
 rip set interface to-r42 version 2 type multicast
 rip set interface to-r6  version 2 type multicast
```

Exporting a Given Static Route to All RIP Interfaces

Router R1 has several static routes of which one is the default route. We would export this default route over all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network default
```

Exporting All Static Routes to All RIP Interfaces

Router R1 has several static routes. We would export these routes over all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network all
```

Exporting All Static Routes Except the Default Route to All RIP Interfaces

Router R1 has several static routes. We would export all these routes except the default route to all RIP interfaces.

```
ip-router policy redistribute from-proto static to-proto rip network all
ip-router policy redistribute from-proto static to-proto rip network default restrict
```

19.2.8 Simple Route Redistribution Example: Redistribution into OSPF

For all examples given in this section, refer to the configurations shown in Figure 19-2.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
  interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
   interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
   interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
   interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
   interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ip add route 202.1.0.0/16 gateway 120.1.1.2
   ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ospf start
   ospf create area 140.1.0.0
   ospf create area backbone
   ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
   ospf add interface 140.1.1.1 to-area 140.1.0.0
   ospf add interface 140.1.2.1 to-area 140.1.0.0
   ospf add interface 140.1.3.1 to-area 140.1.0.0
   ospf add interface 130.1.1.1 to-area backbone
```

Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We would like to export all these static routes and direct-routes (routes to connected networks) into OSPF.

```
ip-router policy redistribute from-proto static to-proto ospf
ip-router policy redistribute from-proto direct to-proto ospf
```

Note The network parameter specifying the network-filter is optional. The default value for this parameter is **all**, indicating all networks. Since in the above example, we would like to export all static and direct routes into OSPF, we have not specified this parameter.

Exporting All RIP, Interface & Static Routes to OSPF

Note Also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 19-2, suppose we decide to run RIP Version 2 on network 120.190.0.0/16, connecting routers R1 and R2.

Router R1 would like to export all RIP, interface, and static routes to OSPF.

```
ip-router policy redistribute from-proto rip to-proto ospf
ip-router policy redistribute from-proto direct to-proto ospf
ip-router policy redistribute from-proto static to-proto ospf
```

Router R1 would also like to export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

```
ip-router policy redistribute from-proto direct to-proto rip
ip-router policy redistribute from-proto static to-proto rip
ip-router policy redistribute from-proto rip to-proto rip
ip-router policy redistribute from-proto ospf to-proto rip
ip-router policy redistribute from-proto ospf-ase to-proto rip
```

19.3 CONFIGURING ADVANCED ROUTING POLICIES

Advanced Routing Policies are used for creating complex import/export policies that cannot be done using the redistribute command. Advanced export policies provide granular control over the targets where the routes are exported, the source of the exported routes, and the individual routes which are exported. It provides the capability to send different routes to the various route-peers. They can be used to provide the same route with different attributes to the various route-peers.

Import policies control the importation of routes from routing protocols and their installation in the routing database (Routing Information Base and Forwarding Information Base). Import policies determine which routes received from other systems are used by the RS routing process. Using import policies, it is possible to ignore route updates from an unreliable peer and give better preference to routes learned from a trusted peer.

19.3.1 Export Policies

Advanced export policies can be constructed from one or more of the following building blocks:

- Export Destinations - This component specifies the destination where the routes are to be exported. It also specifies the attributes associated with the exported routes. The interface, gateway or the autonomous system to which the routes are to be redistributed are a few examples of export-destinations. The metric, type, tag, and AS-Path are a few examples of attributes associated with the exported routes.
- Export Sources - This component specifies the source of the exported routes. It can also specify the metric to be associated with the routes exported from this source. The routes to be exported can be identified by their associated attributes, such as protocol type, interface or the gateway from which the route was received, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be distributed. Routes that match a filter are considered as eligible for redistribution. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for redistribution. The identifier associated with a route-filter is used in the **ip-router policy export** command.
  - Specifying the networks as needed in the **ip-router policy export** command.

  If you want to create a complex route-filter, and you intend to use that route-filter in several export policies, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

After you create one or more building blocks, they are tied together by the **iprouter policy export** command.

To create route export policies, enter the following command in Configure mode:

Create an export policy.	**ip-router policy export destination** <*exp-dest-id*> **[source** <*exp-src-id*> **[filter** <*filter-id*>**|[network** <*ipAddr-mask*> **[exact|refines|between** <*low-high*>**] [metric** <*number*>**|restrict]]]]**

<*exp-dest-id*> The identifier of the export-destination which determines where the routes are to be exported. If no routes to a particular destination are to be exported, then no additional parameters are required.

<*exp-src-id*> If specified, is the identifier of the export-source which determines the source of the exported routes. If a export-policy for a given export-destination has more than one export-source, then the **ip-router policy export destination** <*exp-dest-id*> command should be repeated for each <*exp-src-id*>.

<*filter-id*> If specified, is the identifier of the route-filter associated with this export-policy. If there is more than one route-filter for any export-destination and export-source combination, then the **ip-router policy export destination** <*exp-dest-id*> **source** <*exp-src-id*> command should be repeated for each <*filter-id*>.

19.3.2 Creating an Export Destination

To create an export destination, enter one the following commands in Configure mode:

Create a RIP export destination.	**ip-router policy create rip-export-destination** <*name*>
Create an OSPF export destination.	**ip-router policy create ospf-export-destination** <*name*>
Create an IS-IS export destination.	**ip-router policy create isis-export-destination** <*name*>

19.3.3 Creating an Export Source

To create an export source, enter one of the following commands in Configure mode:

Create a RIP export source.	**ip-router policy create rip-export-source** <*name*>
Create an OSPF export source.	**ip-router policy create ospf-export-source** <*name*>
Create an IS-IS export source.	**ip-router policy create isis-export-source** <*name*>

19.3.4 Import Policies

Import policies can be constructed from one or more of the following building blocks:

- Import-source - This component specifies the source of the imported routes. It can also specify the preference to be associated with the routes imported from this source. The routes to be imported can be identified by their associated attributes, including source protocol, source interface, or gateway from which the route was received, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be imported. Routes that match a filter are considered as eligible for importation. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for importation. The identifier associated with a route-filter is used in the **ip-router policy import** command.
  - Specifying the networks as needed in the **ip-router policy import** command.

  If you want to create a complex route-filter, and you intend to use that route-filter in several import policies, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

After you create one or more building blocks, they are tied together by the **ip-router policy import** command.

To create route import policies, enter the following command in Configure mode:

Create an import policy.	**ip-router policy import source** *<imp-src-id>* **[filter** *<filter-id>***|[network** *<ipAddr-mask>* **[exact|refines|between** *<low-high>***] [preference** *<number>***|restrict]]]**

<imp-src-id> The identifier of the import-source that determines the source of the imported routes. If no routes from a particular source are to be imported, then no additional parameters are required.

<filter-id> If specified, is the identifier of the route-filter associated with this import-policy. If there is more than one route-filter for any import-source, then the **ip-router policy import source** *<imp-src-id>* command should be repeated for each *<filter-id>*.

19.3.5 Creating an Import Source

Import sources specify the routing protocol from which the routes are imported. The source may be RIP or OSPF.

To create an import source, enter one of the following commands in Configure mode:

Create a RIP import destination.	**ip-router policy create rip-import-source** *<name>*
Create an OSPF import destination.	**ip-router policy create ospf-import-source** *<name>*

19.3.6 Creating a Route Filter

Route policies are defined by specifying a set of filters that will match a certain route by destination or by destination and mask.

To create route filters, enter the following command in Configure mode:

Create a route filter.	**ip-router policy create filter** *<name-id>* **network** *<IP-address/mask>*

19.3.7 Creating an Aggregate Route

Route aggregation is a method of generating a more general route, given the presence of a specific route. The routing process does not perform any aggregation unless explicitly requested. Aggregate-routes can be constructed from one or more of the following building blocks:

- Aggregate-Destination - This component specifies the aggregate/summarized route. It also specifies the attributes associated with the aggregate route. The preference to be associated with an aggregate route can be specified using this component.
- Aggregate-Source - This component specifies the source of the routes contributing to an aggregate/summarized route. It can also specify the preference to be associated with the contributing routes from this source. The routes contributing to an aggregate can be identified by their associated attributes, including protocol type, tag associated with a route, and so on.
- Route Filter - This component provides the means to define a filter for the routes to be aggregated or summarized. Routes that match a filter are considered as eligible for aggregation. This can be done using one of two methods:
  - Creating a route-filter and associating an identifier with it. A route-filter has several network specifications associated with it. Every route is checked against the set of network specifications associated with all route-filters to determine its eligibility for aggregation. The identifier associated with a route-filter is used in the **ip-router policy aggr-gen** command.
  - Specifying the networks as needed in the **ip-router policy aggr-gen** command.
- If you want to create a complex route-filter, and you intend to use that route-filter in several aggregates, then the first method is recommended. It you do not have complex filter requirements, then use the second method.

After you create one or more building blocks, they are tied together by the **ip-router policy aggr-gen** command.

To create aggregates, enter the following command in Configure mode:

Create an aggregate route.	**ip-router policy aggr-gen destination** <*aggr-dest-id*> [source <*aggr-src-id*> **[filter** <*filter-id*>**|[network** <*ipAddr-mask*> **[exact|refines|between** <*low-high*>**]** **[preference** <*number*>**|restrict]]]]**

<*aggr-dest-id*> The identifier of the aggregate-destination that specifies the aggregate/summarized route.

<*aggr-src-id*> The identifier of the aggregate-source that contributes to an aggregate route. If an aggregate has more than one aggregate-source, then the **ip-router policy aggr-gen destination** <*aggr-dest-id*> command should be repeated for each <*aggr-src-id*>.

<*filter-id*> The identifier of the route-filter associated with this aggregate. If there is more than one route-filter for any aggregate-destination and aggregate-source combination, then the **ip-router policy aggr-gen destination** <*aggr-dest-id*> **source** <*aggr-src-id*> command should be repeated for each <*filter-id*>.

19.3.8 Creating an Aggregate Destination

To create an aggregate destination, enter the following command in Configure mode:

Create an aggregate destination.	**ip-router policy create aggr-gen-dest** <*name*> **network** <*ipAddr-mask*>

19.3.9 Creating an Aggregate Source

To create an aggregate source, enter the following command in Configure mode:

Create an aggregate source.	**ip-router policy create aggr-gen-source** <*name*> **protocol** <*protocol-name*>

19.3.10 Import Policies Example: Importing from RIP

The importation of RIP routes may be controlled by any of protocol, source interface, or source gateway. If more than one is specified, they are processed from most general (protocol) to most specific (gateway).

RIP does not support the use of preference to choose between routes of the same protocol. That is left to the protocol metrics.

For all examples in this section, refer to the configuration shown in Figure 19-1.

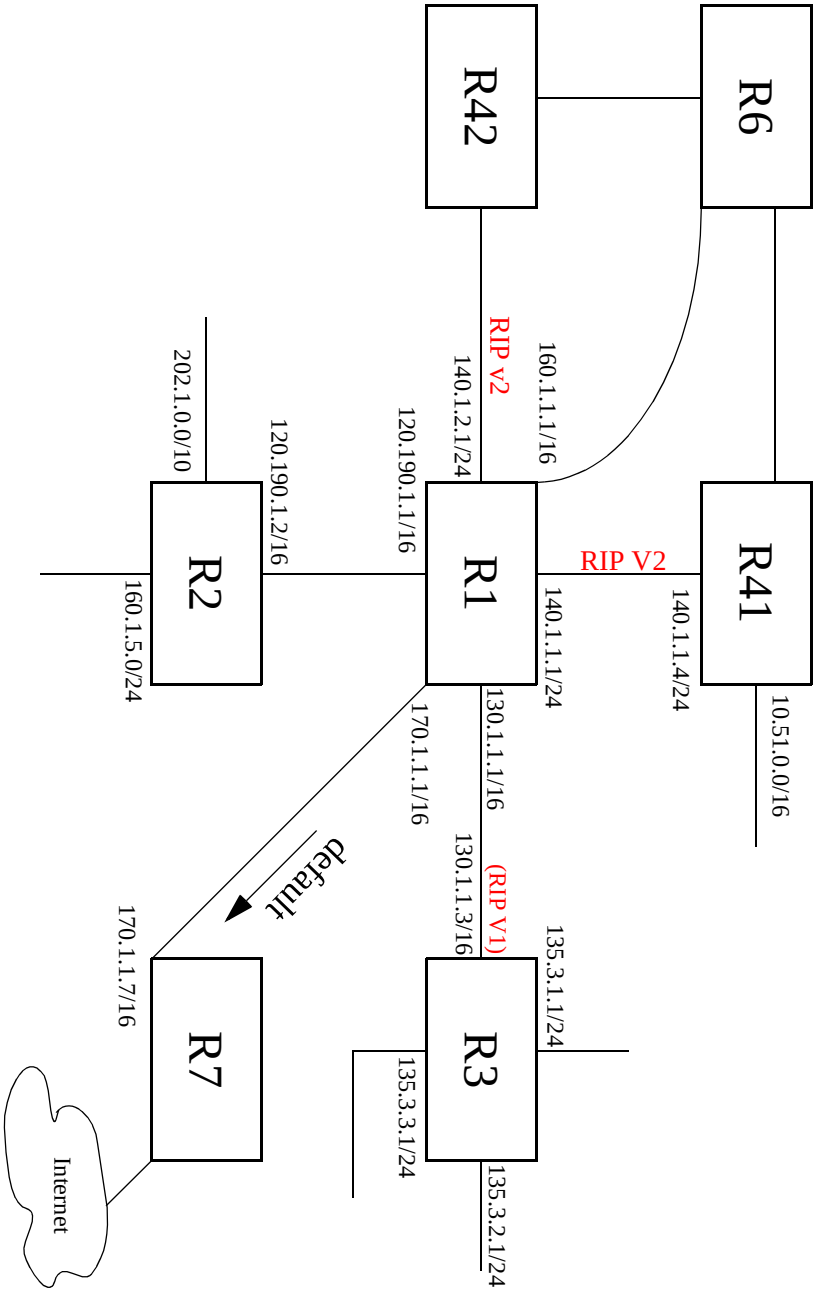


Figure 19-1 Exporting to RIP

The configuration commands shown below for router R1:

- Determine the IP address for each interface.
- Specify the static routes configured on the router.
- Determine its RIP configuration.

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure a default route through 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route default gateway 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the 135.3.0.0 subnets reachable through
! R3.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route 135.3.1.0/24 gateway 130.1.1.3
ip add route 135.3.2.0/24 gateway 130.1.1.3
ip add route 135.3.3.0/24 gateway 130.1.1.3
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
ip add route 202.1.0.0/16 gateway 120.190.1.2
ip add route 160.1.5.0/24 gateway 120.190.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! RIP Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
rip start
rip set default-metric 2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! RIP Interface Configuration. Create a RIP interfaces, and set
! their type to (version II, multicast).
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
rip add interface to-r41
rip add interface to-r42
rip add interface to-r6
rip set interface to-r41 version 2 type multicast
rip set interface to-r42 version 2 type multicast
rip set interface to-r6  version 2 type multicast
```

Importing a Selected Subset of Routes from One RIP Trusted Gateway

Router R1 has several RIP peers. Router R41 has an interface on the network 10.51.0.0. By default, router R41 advertises network 10.51.0.0/16 in its RIP updates. Router R1 would like to import all routes except the 10.51.0.0/16 route from its peer R41.

1. Add the peer 140.1.1.41 to the list of trusted and source gateways.

```
rip add source-gateways 140.1.1.41
rip add trusted-gateways 140.1.1.41
```

2. Create a RIP import source with the gateway as 140.1.1.41 since we would like to import all routes except the 10.51.0.0/16 route from this gateway.

```
ip-router policy create rip-import-source ripImpSrc144 gateway 140.1.1.41
```

3. Create the Import-Policy, importing all routes except the 10.51.0.0/16 route from gateway 140.1.1.41.

```
ip-router policy import source ripImpSrc144 network all
ip-router policy import source ripImpSrc144 network 10.51.0.0/16 restrict
```

Importing a Selected Subset of Routes from All RIP Peers Accessible Over a Certain Interface

Router R1 has several RIP peers. Router R41 has an interface on the network 10.51.0.0. By default, router R41 advertises network 10.51.0.0/16 in its RIP updates. Router R1 would like to import all routes except the 10.51.0.0/16 route from all its peer which are accessible over interface 140.1.1.1.

1. Create a RIP import source with the interface as 140.1.1.1, since we would like to import all routes except the 10.51.0.0/16 route from this interface.

```
ip-router policy create rip-import-source ripImpSrc140 interface 140.1.1.1
```

2. Create the Import-Policy importing all routes except the 10.51.0.0/16 route from interface 140.1.1.1

```
ip-router policy import source ripImpSrc140 network all
ip-router policy import source ripImpSrc140 network 10.51.0.0/16 restrict
```

19.3.11 Import Policies Example: Importing from OSPF

Due to the nature of OSPF, only the importation of ASE routes may be controlled. OSPF intra-and inter-area routes are always imported into the RS routing table with a preference of 10. If a tag is specified, the import clause will only apply to routes with the specified tag.

It is only possible to restrict the importation of OSPF ASE routes when functioning as an AS border router.

Like the other interior protocols, preference cannot be used to choose between OSPF ASE routes. That is done by the OSPF costs. Routes that are rejected by policy are stored in the table with a negative preference.

For all examples in this section, refer to the configuration shown in Figure 19-2.

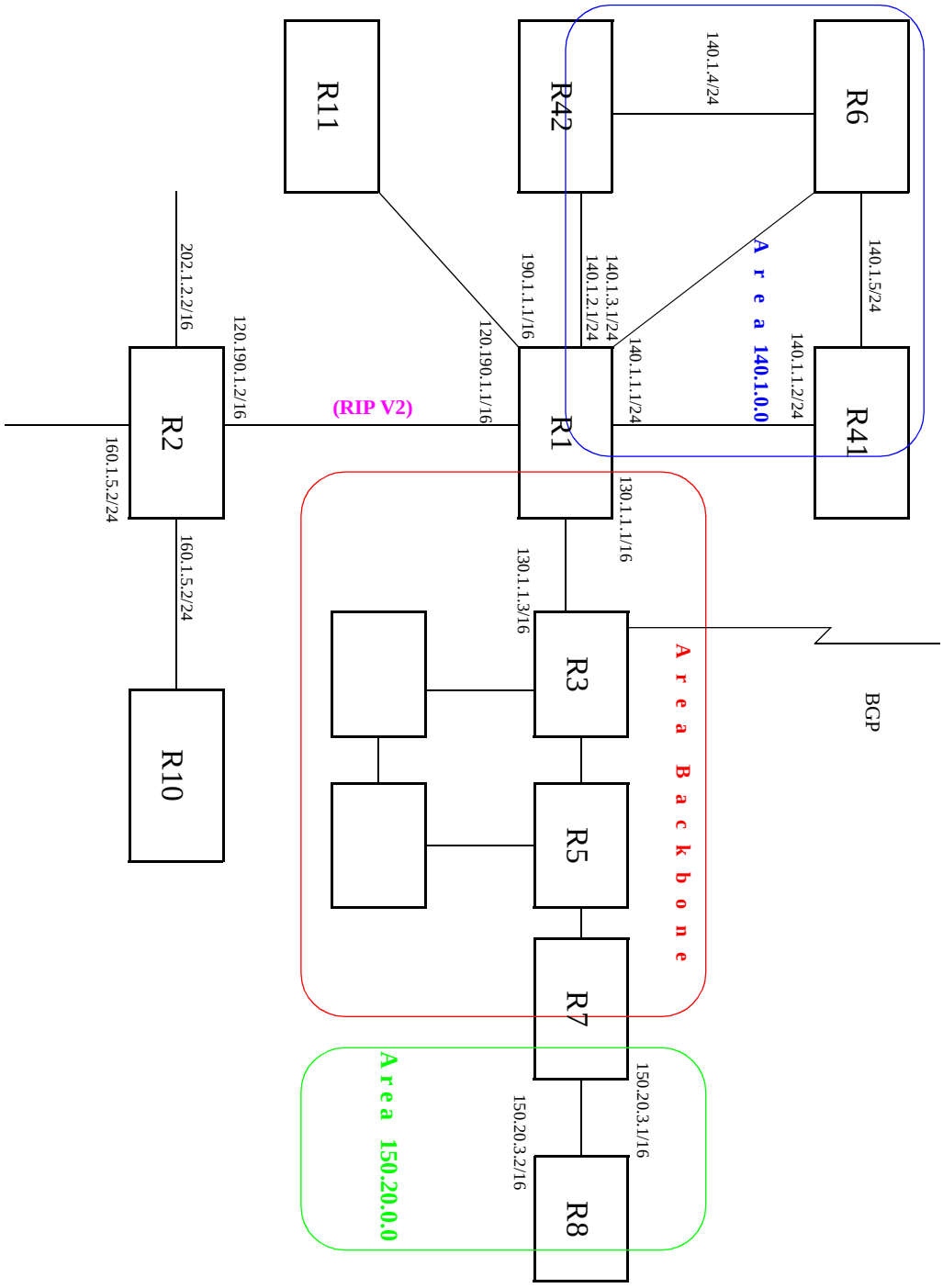


Figure 19-2 Exporting to OSPF

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router

- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.1.1.2
 ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```

Importing a Selected Subset of OSPF-ASE Routes

1. Create a OSPF import source so that only routes that have a tag of 100 are considered for importation.

```
ip-router policy create ospf-import-source ospfImpSrct100 tag 100
```

2. Create the Import-Policy importing all OSPF ASE routes with a tag of 100 except the default ASE route.

```
ip-router policy import source ospfImpSrct100 network all
ip-router policy import source ospfImpSrct100 network default
restrict
```

19.3.12 Export Policies Example: Exporting to RIP

Exporting to RIP is controlled by any of protocol, interface or gateway. If more than one is specified, they are processed from most general (protocol) to most specific (gateway).

It is not possible to set metrics for exporting RIP routes into RIP. Attempts to do this are silently ignored.

If no export policy is specified, RIP and interface routes are exported into RIP. If any policy is specified, the defaults are overridden; it is necessary to explicitly specify everything that should be exported.

RIP version 1 assumes that all subnets of the shared network have the same subnet mask so it is only able to propagate subnets of that network. RIP version 2 removes that restriction and is capable of propagating all routes when not sending version 1 compatible updates.

To announce routes which specify a next hop of the loopback interface (i.e. static and internally generated default routes) via RIP, it is necessary to specify the metric at some level in the export policy. Just setting a default metric for RIP is not sufficient. This is a safeguard to verify that the announcement is intended.

For all examples in this section, refer to the configuration shown in Figure 19-1.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its RIP configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  160.1.1.1/16 port et.1.6
 interface create ip to-r7  address-netmask  170.1.1.1/16 port et.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure a default route through 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route default gateway 170.1.1.7
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the 135.3.0.0 subnets reachable through
 ! R3.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 135.3.1.0/24 gateway 130.1.1.3
 ip add route 135.3.2.0/24 gateway 130.1.1.3
 ip add route 135.3.3.0/24 gateway 130.1.1.3
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.190.1.2
 ip add route 160.1.5.0/24 gateway 120.190.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! RIP Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip start
 rip set default-metric 2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

```
 ! RIP Interface Configuration. Create a RIP interfaces, and set
 ! their type to (version II, multicast).
!+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 rip add interface to-r41
 rip add interface to-r42
 rip add interface to-r6
 rip set interface to-r41 version 2 type multicast
 rip set interface to-r42 version 2 type multicast
 rip set interface to-r6  version 2 type multicast
```

Exporting a Given Static Route to All RIP Interfaces

Router R1 has several static routes, of which one is the default route. We would export this default route over all RIP interfaces.

1. Create a RIP export destination since we would like to export routes into RIP.

```
ip-router policy create rip-export-destination ripExpDst
```

2. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

As mentioned above, if no export policy is specified, RIP and interface routes are exported into RIP. If any policy is specified, the defaults are overridden; it is necessary to explicitly specify everything that should be exported.

Since we would also like to export/redistribute RIP and direct routes into RIP, we would also create export-sources for those protocols.

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source since we would like to export direct/interface routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the export-policy redistributing the statically created default route, and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc network default
ip-router policy export destination ripExpDst source ripExpSrc network all
ip-router policy export destination ripExpDst source directExpSrc network all
```

Exporting a Given Static Route to a Specific RIP Interface

In this case, router R1 would export/redistribute the default route over its interface 140.1.1.1 only.

1. Create a RIP export destination for interface with address 140.1.1.1, since we intend to change the rip export policy only for interface 140.1.1.1.

```
ip-router policy create rip-export-destination ripExpDst141 interface 140.1.1.1
```

2. Create a static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source since we would like to export direct/interface routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy redistributing the statically created default route, and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst141 source statExpSrc network default
ip-router policy export destination ripExpDst141 source ripExpSrc network all
ip-router policy export destination ripExpDst141 source directExpSrc network all
```

Exporting All Static Routes Reachable Over a Given Interface to a Specific RIP Interface

In this case, router R1 would export/redistribute all static routes accessible through its interface 130.1.1.1 to its RIP-interface 140.1.1.1 only.

1. Create a RIP export destination for interface with address 140.1.1.1, since we intend to change the rip export policy for interface 140.1.1.1

```
ip-router policy create rip-export-destination ripExpDst141 interface 140.1.1.1
```

2. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc130 interface 130.1.1.1
```

3. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

4. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy, redistributing all static routes reachable over interface 130.1.1.1 and all (RIP, Direct) routes into RIP.

```
ip-router policy export destination ripExpDst141 source statExpSrc130 network all
ip-router policy export destination ripExpDst141 source ripExpSrc network all
ip-router policy export destination ripExpDst141 source directExpSrc network all
```

Exporting Aggregate-Routes into RIP

In the configuration shown in Figure 19-1, suppose you decide to run RIP Version 1 on network 130.1.0.0/16, connecting routers R1 and R3. Router R1 desires to announce the 140.1.1.0/24 and 140.1.2.0/24 networks to router R3. RIP Version 1 does not carry any information about subnet masks in its packets. Thus it would not be possible to announce the subnets (140.1.1.0/24 and 140.1.2.0/24) into RIP Version 1 without aggregating them.

1. Create an Aggregate-Destination which represents the aggregate/summarized route.

```
ip-router policy create aggr-gen-dest aggrDst140 network 140.1.0.0/16
```

2. Create an Aggregate-Source which qualifies the source of the routes contributing to the aggregate. Since in this case, we do not care about the source of the contributing routes, we would specify the protocol as all.

```
ip-router policy create aggr-gen-source allAggrSrc protocol all
```

3. Create the aggregate/summarized route. This command binds the aggregated route with the contributing routes.

```
ip-router policy aggr-gen destination aggrDst140 source allAggrSrc network
    140.1.1.0/24
ip-router policy aggr-gen destination aggrDst140 source allAggrSrc network
    140.1.2.0/24
```

4. Create a RIP export destination for interface with address 130.1.1.1, since we intend to change the rip export policy only for interface 130.1.1.1.

```
ip-router policy create rip-export-destination ripExpDst130 interface 130.1.1.1
```

5. Create a Aggregate export source since we would to export/redistribute an aggregate/summarized route.

```
ip-router policy create aggr-export-source aggrExpSrc
```

6. Create a RIP export source since we would like to export RIP routes.

```
ip-router policy create rip-export-source ripExpSrc
```

7. Create a Direct export source since we would like to export Direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy redistributing all (RIP, Direct) routes and the aggregate route 140.1.0.0/16 into RIP.

```
ip-router policy export destination ripExpDst130 source aggrExpSrc network
    140.1.0.0/16
ip-router policy export destination ripExpDst130 source ripExpSrc network all
ip-router policy export destination ripExpDst130 source directExpSrc network all
```

19.3.13 Export Policies Example: Exporting to OSPF

It is not possible to create OSPF intra- or inter-area routes by exporting routes from the RS routing table into OSPF. It is only possible to export from the RS routing table into OSPF ASE routes. It is also not possible to control the propagation of OSPF routes within the OSPF protocol.

There are two types of OSPF ASE routes: type 1 and type 2. The default type is specified by the **`ospf set ase-defaults type 1/2`** command. This may be overridden by a specification in the **`ip-router policy create ospf-export-destination`** command.

OSPF ASE routes also have the provision to carry a tag. This is an arbitrary 32-bit number that can be used on OSPF routers to filter routing information. The default tag is specified by the **`ospf set ase-defaults tag`** command. This may be overridden by a tag specified with the **`ip-router policy create ospf-export-destination`** command.

Interface routes are not automatically exported into OSPF. They have to be explicitly done.

For all examples in this section, refer to the configuration shown in Figure 19-2.

The following configuration commands for router R1:

- Determine the IP address for each interface
- Specify the static routes configured on the router
- Determine its OSPF configuration

```
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Create the various IP interfaces.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 interface create ip to-r2  address-netmask  120.190.1.1/16 port et.1.2
 interface create ip to-r3  address-netmask  130.1.1.1/16 port et.1.3
 interface create ip to-r41 address-netmask  140.1.1.1/24 port et.1.4
 interface create ip to-r42 address-netmask  140.1.2.1/24 port et.1.5
 interface create ip to-r6  address-netmask  140.1.3.1/24 port et.1.6
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! Configure default routes to the other subnets reachable through R2.
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ip add route 202.1.0.0/16 gateway 120.1.1.2
 ip add route 160.1.5.0/24 gateway 120.1.1.2
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Box Level Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf start
 ospf create area 140.1.0.0
 ospf create area backbone
 ospf set ase-defaults cost 4
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ! OSPF Interface Configuration
!++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 ospf add interface 140.1.1.1 to-area 140.1.0.0
 ospf add interface 140.1.2.1 to-area 140.1.0.0
 ospf add interface 140.1.3.1 to-area 140.1.0.0
 ospf add interface 130.1.1.1 to-area backbone
```

Exporting All Interface & Static Routes to OSPF

Router R1 has several static routes. We would export these static routes as type-2 OSPF routes. The interface routes would redistributed as type 1 OSPF routes.

1. Create a OSPF export destination for type-1 routes since we would like to redistribute certain routes into OSPF as type 1 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```

2. Create a OSPF export destination for type-2 routes since we would like to redistribute certain routes into OSPF as type 2 OSPF-ASE routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

3. Create a Static export source since we would like to export static routes.

```
ip-router policy create static-export-source statExpSrc
```

4. Create a Direct export source since we would like to export interface/direct routes.

```
ip-router policy create direct-export-source directExpSrc
```

5. Create the Export-Policy for redistributing all interface routes and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
```

Exporting All RIP, Interface & Static Routes to OSPF

Note Also export interface, static, RIP, OSPF, and OSPF-ASE routes into RIP.

In the configuration shown in Figure 19-2, suppose we decide to run RIP Version 2 on network 120.190.0.0/16, connecting routers R1 and R2.

We would like to redistribute these RIP routes as OSPF type-2 routes, and associate the tag 100 with them. Router R1 would also like to redistribute its static routes as type 2 OSPF routes. The interface routes would redistributed as type 1 OSPF routes.

Router R1 would like to redistribute its OSPF, OSPF-ASE, RIP, Static and Interface/Direct routes into RIP.

1. Enable RIP on interface 120.190.1.1/16.

```
rip add interface 120.190.1.1
rip set interface 120.190.1.1 version 2 type multicast
```

2. Create a OSPF export destination for type-1 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType1 type 1 metric 1
```

3. Create a OSPF export destination for type-2 routes.

```
ip-router policy create ospf-export-destination ospfExpDstType2 type 2 metric 4
```

4. Create a OSPF export destination for type-2 routes with a tag of 100.

```
ip-router policy create ospf-export-destination ospfExpDstType2t100 type 2 tag 100
    metric 4
```

5. Create a RIP export source.

```
ip-router policy export destination ripExpDst source ripExpSrc network all
```

6. Create a Static export source.

```
ip-router policy create static-export-source statExpSrc
```

7. Create a Direct export source.

```
ip-router policy create direct-export-source directExpSrc
```

8. Create the Export-Policy for redistributing all interface, RIP and static routes into OSPF.

```
ip-router policy export destination ospfExpDstType1 source directExpSrc network all
ip-router policy export destination ospfExpDstType2 source statExpSrc network all
ip-router policy export destination ospfExpDstType2t100 source ripExpSrc network all
```

9. Create a RIP export destination.

```
ip-router policy create rip-export-destination ripExpDst
```

10. Create OSPF export source.

```
ip-router policy create ospf-export-source ospfExpSrc type OSPF
```

11. Create OSPF-ASE export source.

```
ip-router policy create ospf-export-source ospfAseExpSrc type OSPF-ASE
```

12. Create the Export-Policy for redistributing all interface, RIP, static, OSPF and OSPF-ASE routes into RIP.

```
ip-router policy export destination ripExpDst source statExpSrc network all
ip-router policy export destination ripExpDst source ripExpSrc network all
ip-router policy export destination ripExpDst source directExpSrc network all
ip-router policy export destination ripExpDst source ospfExpSrc network all
ip-router policy export destination ripExpDst source ospfAseExpSrc network all
```

20 MULTICAST ROUTING CONFIGURATION

Multicast routing is used to transmit traffic from a single source to multiple receivers. Some applications that use multicasting include teleconferencing or video conferencing.

This chapter describes the RS's implementation of multicast routing. It provides an overview of multicast routing, and describes the multicast features supported by the RS. It contains the following sections:

- For an overview of multicast routing, refer to Section 20.1, *"Multicast Routing Overview."*
- To configure Internet Group Management Protocol Version 2.0 (IGMPv2), refer to Section 20.2, *"Configuring IGMP."*
- To configure IGMP snooping, refer to Section 20.3, *"IGMP Snooping."*
- To use the multicast replication feature, refer to Section 20.4, *"Multicast Replication."*
- To configure administrative scoping, refer to Section 20.5, *"Using TTL Values and Administratively Scoped Groups."*
- For information on monitoring multicast routing, refer to Section 20.6, *"Monitoring Multicast."*

Note The RS supports the Distance Vector Multicast Routing Protocol (DVMRP) and the Protocol Independent Multicast- Sparse Mode (PIM-SM) protocol. For information on DVMRP, refer to Chapter 21, *"DVMRP Routing Configuration."* For information on PIM-SM, refer to Chapter 22, *"PIM-SM Routing Configuration."*.

20.1 MULTICAST ROUTING OVERVIEW

Multicast routing is used to transmit traffic from a source to a group of receivers. Any host can be a source, and the receivers can be anywhere on the Internet as long as they are members of the group to which the multicast packets are addressed. Only the members of a group can receive the multicast data stream.

Multicast group memberships are established and maintained through the Internet Group Management Protocol (IGMP). The RS supports IGMPv2, as defined in RFC 2236.

Hosts and routers run IGMP to establish group memberships. Routers use IGMP to keep track of members on their directly connected networks.

The RS uses IGMP to learn about multicast group memberships. To forward multicast traffic on the RS, you must run a multicast routing protocol, such as DVMRP or PIM. For information on running IGMP on the RS, refer to Section 20.2, *"Configuring IGMP."*

20.1.1 IP Multicast Addresses

Multicast IP addresses represent receiver groups and not individual receivers. IP multicast addresses use Class D addresses, which are from 224.0.0.0 to 239.255.255.255. Certain addresses are reserved by the Internet Assigned Numbers Authority (IANA); for a complete list, go to *ftp://ftp.isi.edu/in-notes/iana/assignments/multicast-addresses*.

20.1.2 Multicast Protocols

There are two types of multicast routing protocols:

- dense-mode protocols
- sparse-mode protocols

Dense-mode protocols assume that the receivers are densely distributed, meaning most subnets have at least one receiver. Dense-mode protocols use a “flood and prune” technique wherein multicast traffic is flooded throughout the network and paths with no receivers are pruned from the distribution tree. The RS supports the dense-mode multicast protocol, Distance Vector Multicast Routing Protocol (DVMRP), as specified in the `draft-ietf-idmr-dvmrp-v3-09.txt` file. For information on DVMRP, refer to Chapter 21, *"DVMRP Routing Configuration."*

Sparse-mode protocols assume that the receivers are widely dispersed and therefore flooding would be a waste of bandwidth. Sparse mode protocols transmit multicast traffic only to receivers that explicitly request it. The RS supports the Protocol Independent Multicast- Sparse Mode (PIM-SM) protocol as defined in the `draft-ietf-pim-sm-v2-new-04.txt` file. For information on PIM-SM, refer to Chapter 22, *"PIM-SM Routing Configuration."*

Note You cannot configure PIM and DVMRP on the same interface.

On the RS, multicast protocols are configured on a per-interface basis. The RS supports up to 4096 multicast interfaces.

20.1.3 Distribution Trees

Multicast traffic is transmitted to all receivers on the network through multicast distribution trees. There are two types of multicast distribution trees:

- source distribution trees
- shared distribution trees

A source distribution tree is a spanning tree from the source of the multicast data stream to all receivers on the network. It is also referred to as the shortest path tree (SPT) because packets are forwarded on the path with the smallest metric. Packets are forwarded based on the source address and the multicast group address. The forwarding state is referred to as an (S,G) pair, where S is the IP address of the source, and G is the multicast group address.

A shared distribution tree has its root at one common point from which all multicast traffic is forwarded down to all receivers. Multicast data sources send their multicast traffic to this common point, referred to as the Rendezvous Point (RP), for distribution to all receivers. Multicast packets are forwarded based on the multicast group address only. The forwarding state is referred to as (*, G) where the * represents any source, and G is the multicast group address.

DVMRP uses source distribution tree to propagate multicast traffic. PIM-SM uses both shared and source distribution trees to propagate multicast traffic.

20.1.4 Multicast Forwarding

All multicast routing protocols use reverse path forwarding (RPF) to build shortest path distribution trees to all receivers. On the RS, RPF uses the routing information in the multicast routing information base (MRIB) to determine the router's upstream and downstream neighbors; the router forwards a multicast packet only if the packet was received from an upstream interface. When an interface receives a multicast packet, it checks if the packet arrived on the interface the router would use to send out packets to the source. If it did, the router forwards the packet downstream. If it did not, the packet is dropped. This RPF check ensures that traffic is forwarded correctly down the distribution tree.

20.2 CONFIGURING IGMP

The RS uses IGMP to learn which multicast groups have members on its directly attached networks. To run a multicast protocol on the RS, you need to enable IGMP first. The RS supports IGMPv2 as defined in RFC 2236. This section provides the following information:

- for an overview of IGMP, refer to Section 20.2.1, *"IGMP Overview."*
- to enable IGMP on the RS, refer to Section 20.2.2, *"Starting IGMP."*
- to modify IGMP query defaults, refer to Section Note, *"If you are running IGMP on ATM interfaces, you may have to enable forced bridging on those interfaces. Configuring IGMP Query Intervals."*
- to modify the robustness variable default, refer to Section 20.2.3, *"Configuring the Robustness Variable."*
- to set IGM interface parameters, refer to Section 20.2.4, *"Configuring IGMP Interface Parameters."*
- to configure IGMP static groups, refer to Section 20.2.5, *"Configuring Static IGMP Groups."*

20.2.1 IGMP Overview

Multicast routers and IP hosts use IGMP to dynamically maintain group membership information in a network. A designated router on a network, called the *Querier,* solicits membership information by periodically sending general queries to its attached network. In response to these queries, hosts periodically multicast membership reports. Hosts also send membership reports when they join a new multicast group.

Each multicast router maintains a list of multicast groups that have at least one member on its attached network. When a router receives a membership report, it adds the group to the list of multicast groups on the network on which it received the report and sets a timer for the membership. If the router doesn't receive a membership report before the timer expires or if it receives a leave group message from a particular group, then the router removes the group from the list and stops forwarding multicast packets for that group on that network.

The router tracks the number of hosts that are subscribed to any particular group. After each host leaves, the router queries the group's other subscribers to see if they wish to continue subscribing to the group. In an ATM network, the router does not send this query when the last member of the group leaves.

20.2.2 Starting IGMP

IGMP is disabled on the RS by default. It does not automatically run when you start a multicast routing protocol, such as DVMRP. You must enable IGMP on all interfaces with directly connected senders and receivers.

IGMP is run on a per-IP interface basis. Since multiple physical ports can be configured with the same IP interface on the RS (for example, VLANs), IGMP keeps track of multicast host members on a per-port basis. Ports belonging to an IP VLAN without any IGMP membership will *not* be forwarded any multicast traffic. The following example starts IGMP on the RS and on the interface *pc1*:

```
rs (config)# igmp start
rs (config)# igmp add interface pc1
```

Note IGMP is used only to establish group memberships. You must run either DVMRP or PIM-SM to route multicast traffic.

Note If you are running IGMP on ATM interfaces, you may have to enable forced bridging on those interfaces. Configuring IGMP Query Intervals

When you start IGMP on the RS, it assumes the role of the Querier on each attached network. The Querier sends two types of membership queries, general queries and group-specific queries. General queries are periodically sent out to obtain membership information. In addition, the Querier sends a group-specific query after it receives a leave group message for a group with members on one of its interfaces.

The RS has default values for the timers associated with these queries. You can change the defaults either globally or on a per-interface basis. This section describes how to set these timers globally. For information on setting these timers for a specific interface, refer to Section 20.2.4, *"Configuring IGMP Interface Parameters."*

The RS functions as the Querier unless it hears a query from another multicast router with a lower IP address; then it becomes a non-Querier. Normally, there is only one Querier per physical network.

Note On ATM networks, the RS does not send a group-specific membership query after the last host belonging to a group leaves.

Setting General Query Intervals

The Querier periodically sends a *general query* to its attached networks to solicit membership information. On the RS, the default time interval for general queries is 125 seconds. The following example sets the global interval between general queries to 175 seconds:

```
rs (config)# igmp set query interval 175
```

After a Querier sends out a general query, it waits a certain interval for the membership reports from its attached hosts. On the RS, the default for this response time is 10 seconds. Changing this value affects the burstiness of IGMP messages. If you increase this value, host responses are spread over a longer interval causing the IGMP traffic to be less bursty. The following example increases the maximum response time to 30 seconds:

```
rs (config)# igmp set max-resp-time 30
```

Setting the Group-Specific Query Interval

The Querier sends a *group-specific query* when it receives a leave group message for a group with members on one of its interfaces. If the Querier does not receive a membership report within a specified period, then it assumes that the group has no more local members. The default value is 1 second. The following example sets the global last member query interval to 2 seconds:

```
rs (config)# igmp set last-mem-query-interval 2
```

20.2.3 Configuring the Robustness Variable

The robustness variable provides for the expected packet loss on a subnet. The default robustness variable is 2. If the subnet is expected to be lossy, then you can increase this variable. You can change this default globally or on a per-interface basis. The following example increases the global robustness variable to 3:

```
rs (config)# igmp set robustness 3
```

20.2.4 Configuring IGMP Interface Parameters

Use the **igmp set interface** command for per interface control of the following:

- the general query interval
- the maximum response time
- the group-specific query interval
- the robustness variable

The following example enables IGMP on the interface *pc1* and sets parameters for this interface:

```
rs (config)# igmp add interface pc1
rs (config)# igmp set interface pc1 max-response-time 8 last-mem-query-interval 2
```

Use the **igmp show interfaces** command to view IGMP information about a specified interface, as shown in the following example:

```
rs# igmp show interface pc1
IGMP Interfaces information
interface: pc1 150.20.20.100/24, enabled, owner: dvmrp
        Querier: 150.20.20.100 (this system)
        Query timer running, next query in: 6
        Query Invl: 2:05, Max Resp: 8, Joins: 1 Robust: 2
                pc1   224.1.2.1       age    30:37 timeout 2:23
```

Note If you are running IGMP on ATM interfaces, you may have to enable forced bridging on those interfaces.

20.2.5 Configuring Static IGMP Groups

When IGMP is enabled on an interface, at least one group member needs to be present on the interface for the RS to retain the group on its list of multicast group memberships for the interface. You can configure a static IGMP group for an interface; a static group can exist without any group members present on the interface.

The following example configures a static IGMP group on the interface *pc1*:

```
rs(config)# igmp add interface pc1
rs(config)# igmp join group 224.1.2.1 interface pc1
```

To view static memberships, use the **igmp show static-memberships** command as shown in the following example:

```
rs# igmp show static-memberships all
Group Address   Source Address  Interface
--------------- --------------- ------------------------------
224.1.2.1       0.0.0.0         pc1(150.20.20.100)
```

20.2.6 Configuring IGMP Implicit Leave

When a host that is already joined to one multicast group tries to join another group, you can configure the RS to treat the second join as also an implicit leave of the first subscription. Thus, a host can be joined to only one group at a time, and any future joins will cause it to be disconnected from its current group. You can use this feature on bandwidth-contrained links to prevent the traffic of multiple subscribed groups from overwhelming the link and causing jitter.

Configure the implicit leave feature on a per-interface basis using the **igmp set interface implicit-leave** command:

```
rs(config)# igmp set interface et0 implicit-leave
```

Use the **igmp set leave-exclude-groups** command to exclude multicast group(s) from the implicit leave feature:

```
rs(config)# igmp set leave-exclude-groups “229.1.1.1”
```

20.2.7 Configuring IGMP Host-Group Filters

The RS allows you to specify sets of host-group (H,G) pairs on which to permit or deny subscriptions.

Creating Host-Group Filters

Create a filter using the **route-map** command with the **match-host** or **match-group** option. The following example creates a filter that denies subscriptions between host 172.17.8.1 and group 229.1.1.1:

```
rs(config)# route-map A deny 10 match-host 172.17.8.1 match-group 229.1.1.1
```

Applying Host-Group Filters

Apply the filter in one of two ways:

- globally by using the **igmp set route-map-in** command, or
- on a per-interface basis using the **igmp set interface route-map-in** command.

The following example applies the created route map globally:

```
rs(config)# igmp set route-map-in A
```

The following example applies the created route map on an interface:

```
rs(config)# igmp set interface et0 route-map-in A
```

Viewing Host-Group Filters

Use the **route-map show** command to view filters:

```
rs(config)# route-map show all
route-map A, deny, sequence 10
  Match clauses
    host 172.17.0.0      255.255.0.0     group 229.1.1.1       255.255.255.255
  Set clauses
```

Use the **igmp show** command to see which route maps are applied on which interfaces.

20.3 IGMP SNOOPING

Use IGMP snooping to manage multicast traffic in a switched network. When you enable IGMP snooping on a VLAN, the switch monitors traffic between the hosts and the router to determine the following:

- IGMP querier ports on the VLAN
- multicast groups on the VLAN
- ports in a VLAN that belong to the multicast groups

The switch forwards multicast traffic only to those ports associated with multicast groups. This task is independent of L3 multicasting.

20.3.1 Configuring IGMP Snooping

Before you run IGMP snooping, specify the VLAN(s) on which it will be enabled.

```
rs(config)# igmp-snooping add vlan blue
rs(config)# igmp-snooping start
```

The RS has default parameters that enable the switch to operate with multicast routers. Use the **`igmp-snooping set vlan`** command to modify these parameters. Following is an example:

```
rs(config)# igmp-snooping set vlan blue host-timeout 200 leave-timeout 7
```

To view multicast information for a VLAN, use the **`igmp-snooping show vlans`** command, as shown in the following example:

```
rs# igmp-snooping show vlans
Vlan: blue VLAN-ID: 100    Ports: et.2.(5-8)

Querier Ports: et.2.5

Group: 224.2.127.254      Ports:et.2.(5-6,8)

Group: 225.1.10.10        Ports:et.2.(5-6,8)
```

Note Layer-3 multicasting has built-in snooping capabilities. Therefore, layer-2 snooping cannot be run simultaneously with layer-3 multicasting on the same VLAN.

20.4 MULTICAST REPLICATION

The RS can forward multicast traffic on a trunk port to more than one VLAN in a multicast group. It replicates the multicast packets on the outgoing ports and forwards the packets to the VLANs in the multicast group. (This feature is supported only on 802.1Q trunk ports because only trunk ports can belong to more than one VLAN.)

By default, all ports support replication. The maximum number of replications and (S,G) entries that a port supports depends on the number of ports in a module. For example, by default, a 2-port Gigabit Ethernet module can support up to 32 replications and 2048 (S,G) entries, and a 16-port 10/100 Ethernet module can support up to 8 replications and 1024 (S,G) entries. Table 20-1 shows the number of ports and their corresponding maximum number of replications and (S,G) entries.

Table 20-1 Replication Table

Number of Ports on Module	Number of Replications	Number of (S,G) Entries
1	32	4096
2	32	2048
4	32	1024
8	16	1024
12	8	1024
16	8	1024

If the number of VLANs in a multicast group exceeds the number of replications supported by a trunk port, you can increase the number of replications or the number of (S,G) entries a module can support by using the **system set port-replication-in-module** command. This command configures the port to increase the number of (S,G) entries or to replicate the multicast packets to more VLANs than the default supported by the hardware.

Use Table 20-1 as a reference when you change the number of replications or (S,G) entries supported by a module. You can set the number of replications or (S,G) entries only to the numbers shown in the table. Therefore, when you use the **system set port-replication-in-module** command, you can either set the number of replications to 8, 16 or 32, or you can set the number of (S,G) entries to 1024, 2048, or 4096. Note that, as shown in Table 20-1, increasing the number of replications or (S,G) entries decreases the number of ports in a module that support replication.

In the following example, a 16-port 10/100 Ethernet card is on slot 7 of the RS. As shown in Table 20-1, the default maximum number of replications for a module with 16 ports is only 8. You can increase the number of replications to 16 or 32. The following example increases the number of replications to 16:.

```
rs(config)# system set port-replication-in-module 7 num-of-replications 16
```

After you execute the **system set port-replication-in-module** command, use the **system show port-replication-information** command to determine which ports support replication. The following example shows the ports that support replication in the 16-port 10/100 module *before* the number of replications was increased.

```
rs# system show port-replication-information module 7

Port Replication Configuration Information follow:
==================================================

============================================================
| Slot | No. of reps. | No of Indexes       | Rep. ports |
============================================================
| 7    | 8            | 1024                | et.7.1     |
|      |              |                     | et.7.2     |
|      |              |                     | et.7.3     |
|      |              |                     | et.7.4     |
|      |              |                     | et.7.5     |
|      |              |                     | et.7.6     |
|      |              |                     | et.7.7     |
|      |              |                     | et.7.8     |
|      |              |                     | et.7.9     |
|      |              |                     | et.7.10    |
|      |              |                     | et.7.11    |
|      |              |                     | et.7.12    |
|      |              |                     | et.7.13    |
|      |              |                     | et.7.14    |
|      |              |                     | et.7.15    |
|      |              |                     | et.7.16    |
============================================================
```

The following example shows the ports that support replication *after* the number of replications was increased.

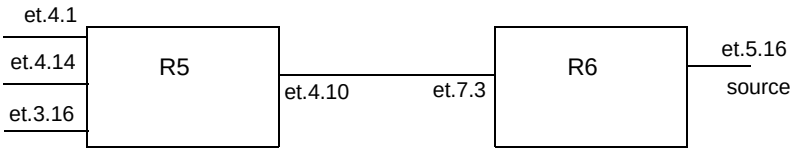
```
rs# system show port-replication-information module 7

Port Replication Configuration Information follow:
==================================================

============================================================
| Slot | No. of reps. | No of Indexes       | Rep. ports |
============================================================
| 7    | 16           | 1024                | et.7.1     |
|      |              |                     | et.7.2     |
|      |              |                     | et.7.3     |
|      |              |                     | et.7.4     |
|      |              |                     | et.7.5     |
|      |              |                     | et.7.6     |
|      |              |                     | et.7.7     |
|      |              |                     | et.7.8     |
============================================================
```

20.4.1 Configuration Example

In the following example, R6 receives multicast packets on port et.5.16. R5 and R6 are connected through 802.1Q trunk ports. The trunk ports on both routers belong to the same VLANs. There are 10 VLANs which have at least one host that belongs to the same multicast group (234.131.145.100). The trunk port on R6 is on a 16-port 10/100 Ethernet module which, by default, supports up to 8 replications only. Therefore, the module is re-configured to support up to 16 replications, allowing R6 to forward multicast traffic to all 10 VLANs in the multicast group.



R5 is operating as an L2 switch. Therefore, you just need to configure the trunk port between R5 and R6, and the necessary VLANs. Following is the configuration for R5:

```
! Configure the trunk port
rs(config)# vlan make trunk-port et.4.10

!Create the VLANs
rs(config)# vlan create vlan10 ip id 10
rs(config)# vlan create vlan11 ip id 11
rs(config)# vlan create vlan12 ip id 12
rs(config)# vlan create vlan13 ip id 13
rs(config)# vlan create vlan14 ip id 14
rs(config)# vlan create vlan15 ip id 15
rs(config)# vlan create vlan16 ip id 16
rs(config)# vlan create vlan17 ip id 17
rs(config)# vlan create vlan18 ip id 18
rs(config)# vlan create vlan19 ip id 19
rs(config)# vlan add ports et.4.10 to vlan10
rs(config)# vlan add ports et.4.1 to vlan10
rs(config)# vlan add ports et.4.10 to vlan11
rs(config)# vlan add ports et.4.1 to vlan11
rs(config)# vlan add ports et.4.10 to vlan12
rs(config)# vlan add ports et.4.1 to vlan12
rs(config)# vlan add ports et.4.10 to vlan13
rs(config)# vlan add ports et.4.14 to vlan13
rs(config)# vlan add ports et.4.10 to vlan14
rs(config)# vlan add ports et.4.14 to vlan14
rs(config)# vlan add ports et.4.10 to vlan15
rs(config)# vlan add ports et.4.14 to vlan15
rs(config)# vlan add ports et.4.10 to vlan16
rs(config)# vlan add ports et.4.14 to vlan16
rs(config)# vlan add ports et.4.10 to vlan17
rs(config)# vlan add ports et.3.16 to vlan17
rs(config)# vlan add ports et.4.10 to vlan18
rs(config)# vlan add ports et.3.16 to vlan18
rs(config)# vlan add ports et.4.10 to vlan19
rs(config)# vlan add ports et.3.16 to vlan19
```

As previously stated, by default, module 7 on R6 supports 8 replications per port, as shown in the following example:

```
rs# system show port-replication-information module 7

Port Replication Configuration Information follow:
==================================================

============================================================
|Module| No. of reps. | No of Indexes       | Rep. ports |
============================================================
| 7    | 8            | 1024                | et.7.1     |
|      |              |                     | et.7.2     |
|      |              |                     | et.7.3     |
|      |              |                     | et.7.4     |
|      |              |                     | et.7.5     |
|      |              |                     | et.7.6     |
|      |              |                     | et.7.7     |
|      |              |                     | et.7.8     |
|      |              |                     | et.7.9     |
|      |              |                     | et.7.10    |
|      |              |                     | et.7.11    |
|      |              |                     | et.7.12    |
|      |              |                     | et.7.13    |
|      |              |                     | et.7.14    |
|      |              |                     | et.7.15    |
|      |              |                     | et.7.16    |
============================================================
```

Therefore, the number of replications supported by slot 7 must be increased to 16.

Following is the configuration for R6:

```
! Configure the trunk port
rs(config)# vlan make trunk-port et.7.3
!Create the VLANs
rs(config)# vlan create vlan10 ip id 10
rs(config)# vlan create vlan11 ip id 11
rs(config)# vlan create vlan12 ip id 12
rs(config)# vlan create vlan13 ip id 13
rs(config)# vlan create vlan14 ip id 14
rs(config)# vlan create vlan15 ip id 15
rs(config)# vlan create vlan16 ip id 16
rs(config)# vlan create vlan17 ip id 17
rs(config)# vlan create vlan18 ip id 18
rs(config)# vlan create vlan19 ip id 19
rs(config)# vlan add ports et.7.3 to vlan10
rs(config)# vlan add ports et.7.3 to vlan11
rs(config)# vlan add ports et.7.3 to vlan12
rs(config)# vlan add ports et.7.3 to vlan13
rs(config)# vlan add ports et.7.3 to vlan14
rs(config)# vlan add ports et.7.3 to vlan15
rs(config)# vlan add ports et.7.3 to vlan16
rs(config)# vlan add ports et.7.3 to vlan17
rs(config)# vlan add ports et.7.3 to vlan18
rs(config)# vlan add ports et.7.3 to vlan19
!Configure the interfaces
rs(config)# interface create ip ip10 address-netmask 10.1.1.1/16 vlan vlan10
rs(config)# interface create ip ip11 address-netmask 11.1.1.1/16 vlan vlan11
rs(config)# interface create ip ip12 address-netmask 12.1.1.1/16 vlan vlan12
rs(config)# interface create ip ip13 address-netmask 13.1.1.1/16 vlan vlan13
rs(config)# interface create ip ip14 address-netmask 14.1.1.1/16 vlan vlan14
rs(config)# interface create ip ip15 address-netmask 15.1.1.1/16 vlan vlan15
rs(config)# interface create ip ip16 address-netmask 16.1.1.1/16 vlan vlan16
rs(config)# interface create ip ip17 address-netmask 17.1.1.1/16 vlan vlan17
rs(config)# interface create ip ip18 address-netmask 18.1.1.1/16 vlan vlan18
rs(config)# interface create ip ip19 address-netmask 19.1.1.1/16 vlan vlan19
```

```
!Enable IGMP on the interfaces
rs(config)# igmp add interface ip10
rs(config)# igmp add interface ip11
rs(config)# igmp add interface ip12
rs(config)# igmp add interface ip13
rs(config)# igmp add interface ip14
rs(config)# igmp add interface ip15
rs(config)# igmp add interface ip16
rs(config)# igmp add interface ip17
rs(config)# igmp add interface ip18
rs(config)# igmp add interface ip19

!Start DVMRP and IGMP
rs(config)# dvmrp start
rs(config)# igmp start

!Set the port replication parameters
rs(config)# system set port-replication-in-module 7 num-of-replications 16
```

The following example shows that the number of ports that support replication decreased from 16 to 8 after the number of replications was increased. If the trunk port, et.7.3, did not support replication (due to the decrease in the number of ports that support replication), you would have had to change the trunk port connecting R6 to R5.

```
rs# system show port-replication-information module 7

Port Replication Configuration Information follow:
================================================


=========================================================
|Module| No. of reps. | No of Indexes       | Rep. ports |
=========================================================
| 7    | 16           | 1024                | et.7.1     |
|      |              |                     | et.7.2     |
|      |              |                     | et.7.3     |
|      |              |                     | et.7.4     |
|      |              |                     | et.7.5     |
|      |              |                     | et.7.6     |
|      |              |                     | et.7.7     |
|      |              |                     | et.7.8     |
=========================================================
```

You can also view information about the multicast group, as shown in the following example.

```
rs# multicast show replication-info

Multicast group replication information:
================================================================================
| Group           | Source             | Index | OIF      | No. of reps. | VLANS |
================================================================================
| 234.131.145.100 | 100.1/16           | 1     | et.7.3   | 10           |     10|
|                 |                    |       |          |              |     11|
|                 |                    |       |          |              |     12|
|                 |                    |       |          |              |     13|
|                 |                    |       |          |              |     14|
|                 |                    |       |          |              |     15|
|                 |                    |       |          |              |     16|
|                 |                    |       |          |              |     17|
|                 |                    |       |          |              |     18|
|                 |                    |       |          |              |     19|
================================================================================
```

20.5 USING TTL VALUES AND ADMINISTRATIVELY SCOPED GROUPS

You can use time-to-live (TTL) threshold values and scopes to control internetwork traffic on each multicast interface. The TTL value controls whether packets are forwarded from an interface. The following are guidelines for assigning TTL values to a multicast application and their corresponding RS setting for the threshold:

Table 20-2 TTL values and their corresponding thresholds on the RS

TTL Value	Threshold	Restrictions
1	1	Application restricted to subnet
< 16	16	Application restricted to a site
< 64	64	Application restricted to a region
< 128	128	Application restricted to a continent
255		Application not restricted

By default, the TTL threshold for all RS interfaces is 1. You can change this value on a per-interface basis, as shown in the following example:

```
rs (config)# multicast set interface int100 threshold 3
```

TTL thresholding is not always considered useful. There is another approach of a range of multicast addresses for "administrative" scoping. In other words, such addresses would be usable within a certain administrative scope, a corporate network, for instance, but would not be forwarded across the internet. The range of addresses from 239.0.0.0 through 239.255.255.255 is reserved for administratively-scoped applications. Any organization can assign this range of addresses and the packets will not be sent out of the organization. In addition, multiple scopes can be defined on a per-interface basis. The following example specifies a multicast address and subnet mask:

```
rs (config)# multicast set interface int100 boundary 239.0.0.0/8
```

20.6 MONITORING MULTICAST

The RS provides various commands for displaying multicast routing information. This section contains examples of these commands.

The **multicast show cache** command displays the multicast forwarding cache (MFC) tables. The following is an example of the **multicast show cache** command:

```
rs# multicast show cache
Source Address  Group Address   Incoming I/f    Outgoing I/f    Exit
Ports
--------------  -------------   --------------- ---------------
----------
150.20.20.1     225.1.1.1       145to152        145to141        et.3.1
150.10.10.1     224.1.2.1       145to141        145to152
150.20.20.1     224.2.2.2       145to152        145to141        et.3.1
rs145#
```

The **multicast show counts** command displays byte and packets statistics for each (S,G) group. The following is an example:

```
rs# multicast show counts
Source Address  Group Address   Packet Cnt          Byte Count
--------------  -------------   ------------        ------------
10.10.1.11      224.2.127.254   3                   1422
10.10.1.11      225.1.10.10     18010               16208772
10.10.1.11      224.2.190.120   720                 229575
```

The **multicast show statistics** command displays various statistics and error counts. The following is an example:

```
rs# multicast show statistics
Multicast forwarding cache statistics information:
-------------------------------------------------
  MFC entries:                          3
  MFC lookups:                          2144
  MFC misses:                           2053
  Packet upcalls:                       2
  Upcall overflow count:                2040
  Upcall socket full count:             0
  Packets that arrived on wrong if.:    0
  Packets that arrived with no MFC entry: 2050
  MFC entry cleanup due to upcall expiry: 0
  Packets with bad tunnel ip address:   0
  Count of tunnel errors:               0
```

The **`multicast show vifs`** commdand displays interfaces on which multicast protocols are enabled. Following is an example:

```
rs# multicast show vifs
F  ->  0x01 - Vif is tunnel end-point
       0x02 - Tunnel is using IP source routing
       0x04 - Vif is used for register encap/decap
       0x08 - Vif register with kernel encap
       0x10 - Vif owner is DVMRP
       0x20 - Vif owner is PIM
Vif Interface       F  Local Addr      Portmask
--- ---------       -  ----------      --------
  0 register_vif    4  127.0.0.2
  1 icast_svr       0  10.10.1.10      et.1.1
  2 2_fr2           0  100.1.1.1       et.1.2
```

Note If you have routing protocols running that are using multicast IP addresses, but DVMRP is not enabled, the slave module in a Dual-Control Module system still counts these routing protocol multicast routes as kernel routes.

21 DVMRP ROUTING CONFIGURATION

On the RS, DVMRP routing is implemented as specified in the **`draft-ietf-idmr-dvmrp-v3-09.txt`** file, which is an Internet Engineering Task Force (IETF) document.

This chapter provides the following information:

- for an overview of DVMRP, refer to Section 21.1, *"DVMRP Overview."*
- to start DVMRP on the RS, refer to Section 21.2, *"Starting DVMRP."*
- to set the DMRP metric, refer to Section 21.3, *"Setting the DVMRP Routing Metric."*
- to define DVMRP tunnels, refer to Section 21.4, *"Configuring a DVMRP Tunnel."*

21.1 DVMRP OVERVIEW

DVMRP is a dense-mode protocol that uses a “flood and prune” technique to propagate multicast data. For each data source, DVMRP initially floods the multicast data throughout the network. Routers that have no interested receivers send prune messages upstream towards the source. The upstream routers stop sending the multicast traffic to these routers, which are then pruned from the distribution tree. Paths that were previously pruned may be “grafted” back onto the distribution tree when new receivers join the multicast group.

DVMRP builds and maintains a source distribution tree for each data source. A source distribution tree is a shortest path tree that is rooted at the source. DVMRP has a built-in unicast routing protocol which is a distance vector protocol that functions like the Routing Information Protocol (RIP); it uses metrics or hop counts to determine the shortest path back to the source. In DVMRP, the Reverse Path Forwarding (RPF) checks are based on the source address. (For information on distribution trees and RPF checks, refer to Section 20.1, *"Multicast Routing Overview."*)

To avoid the sending of duplicate packets in a multi-access network, a designated forwarder is selected to forward multicast data on a shared network. The designated forwarder has the lowest metric to the source network. If multiple routers have the same metric, the router with the lowest IP address becomes the designated forwarder.

Not all routers support native multicast routing. Therefore DVMRP supports the tunneling of multicast IP datagrams between routers separated by gateways that do not support multicast routing. The tunnel acts as a virtual network between two routers running DVMRP.

21.2 STARTING DVMRP

On the RS, DVMRP is disabled by default. You must enable DVMRP on all interfaces that require multicast routing, including those running IGMP. The following example starts DVMRP on the interface *pc2*:

```
rs (config)# interface create ip pc2 address-netmask 150.10.10.100/24 port et.2.3
rs (config)# dvmrp add interface 150.10.10.100
rs (config)# dvmrp start
```

Note For information on IGMP, refer to Section 20.2, *"Configuring IGMP."*

To view the status of a DVMRP interface, use the **`dvmrp show interface`** command, as shown in the following example.

```
rs# dvmrp show interface pc2
Address         Interface       Component Vif Nbr   #Bad  #Bad
                                            Count Pkts  Routs
--------------- --------------- --------- --- ----- ----- -----
150.10.10.100   pc2             dvmrp       2     0     0     0
```

Note If you are running DVMRP on ATM interfaces, you may have to enable forced bridging on those interfaces.

21.3 SETTING THE DVMRP ROUTING METRIC

Each route to a source network has a metric associated with it. This metric is the sum of the metrics of all interfaces between the reporting router and the source network. On the RS, the default metric for all DVMRP interfaces is 1. Use the **dvmrp set default-metric** command to set the metric for all DVMRP interfaces on the RS. Use the **dvmrp set interface** command to set the metric for a specific interface.

The following example sets the global DVMRP metric to 2:

```
rs(config)# dvmrp set default-metric 2
```

The following example sets the metric of the *interface to_group1* to 3:

```
rs(config)# dvmrp set interface to_group1 metric 3
```

21.4 CONFIGURING A DVMRP TUNNEL

The RS supports DVMRP tunnels to the MBONE (the multicast backbone of the Internet). Configure a DVMRP tunnel to send multicast traffic when there are non-multicast capable routers between two DVMRP neighbors.

Tunnels are CPU-intensive as they are not switched directly through the RS's multi-tasking ASICs. The RS supports a maximum of eight tunnels.

The following example creates a DVMRP tunnel called *tun12* between 10.3.4.15 (the local end of the tunnel) and 10.5.3.78 (the remote end of the tunnel).

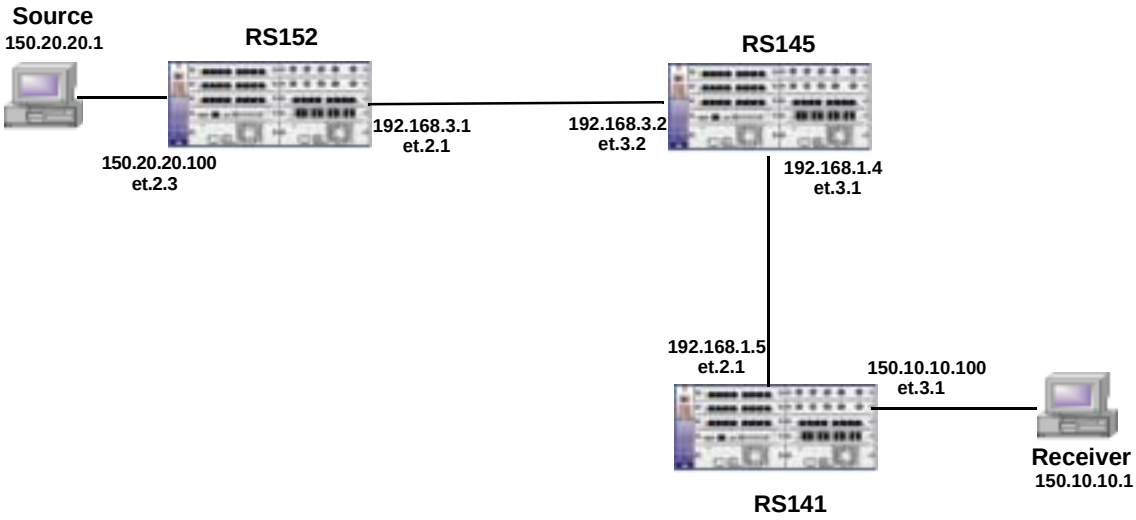
```
rs(config)# dvmrp create tunnel tun12 local 10.3.4.15 remote 10.5.3.78
```

If the router at the remote end is running mrouteD, you need to specify the **mrouted-compatible** parameter.

Note Tunnel traffic is not optimized on a per-port basis, and it goes to all ports on an interface, even though IGMP keeps per-port membership information. This is done to minimize CPU overload for tunneled traffic.

21.5 CONFIGURATION EXAMPLE

Following is an example of a basic DVMRP configuration.



In the example, the multicast data source (150.20.20.1) is connected to RS 152. One of the receivers is 150.10.10.1, which is connected to RS 141.

Following is the configuration for RS152, which is connected to the source:

```
! Create the interfaces
interface create ip pc1 address-netmask 150.20.20.100/24 port et.2.3
interface create ip 152to145 address-netmask 192.168.3.1/24 port et.2.1
! Configure IGMP
igmp add interface pc1
igmp start
! Configure DVMRP
dvmrp add interface 152to145
dvmrp add interface pc1
dvmrp start
```

Following is the configuration for RS145:

```
! Create the interfaces
interface create ip 145to152 address-netmask 192.168.3.2/24 port et.3.2
interface create ip 145to141 address-netmask 192.168.1.4/24 port et.3.1
! Configure DVMRP
dvmrp add interface 192.168.1.4
dvmrp add interface 192.168.3.2
dvmrp start
```

Following is the configuration for RS141, which is connected to the receiver:

```
! Create the interfaces
interface create ip pc2 address-netmask 150.10.10.100/24 port et.2.3
interface create ip 141 address-netmask 192.168.1.5/24 port et.2.1
! Configure IGMP
igmp add interface 150.10.10.100
igmp start
! Configure DVMRP
dvmrp add interface 192.168.1.5
dvmrp add interface 150.10.10.100
dvmrp start
```

You can use the **`dvmrp show neighbors`** command to display information about a DVMRP router's neighbors. The following example shows that router RS145 is the DVMRP neighbor of router RS152 and RS 141:

```
rs145# dvmrp show neighbors
Interface  : 145to152         Local Addr: 192.168.3.2      Neighbor Addr: 192.168.3.1
Uptime     : 1:11:16          Expires   : 29               Genid        : 0x3c6d3bf5
Major Ver  : 3                Minor Ver : 255              Nbr Flags    : DVMRP_NBR_TWOWAY
Capabilities: Prune GENID Mtrace Netmask 3xff

Interface   : 145to141         Local Addr: 192.168.1.4      Neighbor Addr: 192.168.1.5
Uptime      : 31:10            Expires   : 35               Genid        : 0x3c6d362b
Major Ver   : 3                Minor Ver : 255              Nbr Flags    : DVMRP_NBR_TWOWAY
Capabilities: Prune GENID Mtrace Netmask 3xff
```

You can use the **`dvmrp show routes`** command to display DVMRP routing information.

```
rs145# dvmrp show routes
Proto       Route/Mask   NextHop         Holddown Age  Metric
----- ------------------ --------------- -------- ---- ------
DVMRP       150.20.20/24 192.168.3.1     0        38   2
```

The **multicast** facility also has various show commands that you can use to show multicast routing information. One such command is the **multicast show cache** command, shown below. (For additional information on other **multicast show** commands, refer to Section 20.6, *"Monitoring Multicast."*)

```
rs145# multicast show cache
Source Address  Group Address   Incoming I/f    Outgoing I/f    Exit Ports
--------------  -------------   --------------- --------------- ----------
150.20.20.1     224.2.2.2       145to152        145to141        et.3.1
```

22 PIM-SM ROUTING CONFIGURATION

Use the Protocol Independent Multicast (PIM) protocol to forward traffic to multicast groups throughout an internetwork. Unlike the Distance Vector Multicast Protocol (DVMRP), which has its own unicast routing protocol, PIM relies on the unicast routing protocol that is active on the network for forwarding information. It is “independent” in that it can use any unicast routing protocol to provide routing information.

PIM has two operational modes, Dense Mode and Sparse Mode. The RS supports PIM in Sparse Mode (PIM-SM) as defined in the `draft-ietf-pim-sm-v2-new-04.txt` file. This chapter provides the following information:

- An overview of the PIM-SM protocol (Section 22.1, *"PIM-SM Overview."*)
- How to enable PIM on the RS (Section 22.2, *"Enabling PIM-SM."*)
- How to configure candidate Bootstrap Router (C-BSR) parameters (Section 22.3, *"Configuring Candidate BSR (C-BSR) Parameters."*)
- How to configure candidate Rendezvous Point (C-RP) parameters (Section 22.4, *"Configuring Candidate RP (C-RP) Parameters."*)
- How to modify default PIM parameters globally (Section 22.5, *"Setting PIM Global Parameters."*)
- How to modify default PIM parameters on a per-interface basis (Section 22.6, *"Setting PIM Interface Parameters."*)

22.1 PIM-SM OVERVIEW

PIM-SM is a sparse-mode multicast routing protocol. ‘Sparse mode’ implies that instead of flooding multicast packets like DVMRP, PIM-SM sends multicast traffic only to receivers that explicitly request it. Routers that run PIM-SM join and leave multicast groups by sending join/prune messages.

PIM-SM distributes multicast traffic through a shared distribution tree with the rendezvous point (RP) at the root. The RP receives all requests to join groups and forwards multicast packets down the common distribution tree. When the traffic reaches a configured threshold, an RP or a router in the shared distribution tree can join the source distribution tree, and prune the source’s packets off the shared distribution tree.

22.1.1 Neighbor Discovery

Neighboring PIM routers discover each other and maintain their relations by periodically exchanging Hello messages. In multi-access networks, these Hello messages contain a router’s priority for becoming the designated router (DR) for the LAN. (For additional information on DRs, refer to Section 22.1.7, *"Multi-Access LANs."*

22.1.2 Registering Sources

A source or a first-hop router (that is, a router directly connected to the source) sends data packets encapsulated in Register messages to the RP. Upon receiving the Register message, the RP decapsulates the Register message and forwards the data packet downstream on the shared distribution tree. Thus all the downstream members of the multicast group receive the multicast data stream from the RP through the shared distribution tree.

22.1.3 Joining a Multicast Group

To join a multicast group, each locally connected host conveys its membership information through IGMP. The last-hop router (or the DR in a multi-access LAN) sends a join message towards the RP for the group it wants to join. When an intermediate router receives the join message, it checks if it already supports the requested route. If it does, it adds the requesting router to the established distribution tree. If it does not, then it forwards the request to the RP. As subsequent join messages are received for the same group, they are “joined” to the established route.

When no receivers exist for a particular source packet, the RP caches the data for three minutes. This allows the RP to instantly service receiver requests by distributing cached copies of the source packet as soon as it receives a request.

22.1.4 Multicast Forwarding

As previously stated, PIM-SM relies on the unicast routing protocol that is running on the network for forwarding information. On the RS, static routes or routes learned through OSPF or ISIS can be installed in the multicast routing information base (MRIB).

PIM-SM also uses Reverse Path Forwarding (RPF) to ensure that multicast traffic is forwarded correctly downstream. The RPF check for shared distribution trees is based on the IP address of the RP. The RPF check for source distribution trees is based on the IP address of the source. (For information on RPF and other multicast concepts, refer to Section 20.1, *"Multicast Routing Overview."*)

22.1.5 Obtaining RP Information

The RS provides two methods for obtaining RP information: dynamically and by configuring static RPs.

To obtain RP information dynamically, routers within a PIM domain collect bootstrap messages. (A domain is a contiguous set of PIM routers configured to operate within a common boundary.) Bootstrap messages indicate which RPs are “up.” Each PIM domain has one bootstrap router that is responsible for sending the bootstrap messages. The bootstrap router is selected through an election where the candidate bootstrap router (C-BSR) with the highest priority is elected as the BSR for the domain. Candidate bootstrap routers are user-configurable.

Typically, the C-BSR is also configured as a candidate RP (C-RP). C-RPs periodically unicast C-RP advertisements to the BSR of the domain. The RP is then selected through a well-known hash function. A router can be an RP for more than one multicast group.

Alternatively, you can configure a static RP for a particular multicast group. If you do so, do not configure C-BSRs and C-RPs. Instead, configure the static RP on all multicast routers in the domain.

22.1.6 Switching from a Shared to a Source Distribution Tree

An RP or a router with directly connected members can switch to a source’s shortest path tree (SPT). When an RP receives a register message for a new source, the RP sends a join message back to the source. This results in an SPT being built from the source to the RP, allowing the multicast traffic to flow directly from the source to the RP, and down the shared distribution tree. Once the RP starts receiving the data packets natively directly from the source, then the RP sends a Register Stop message to the first-hop router to let it know that it should stop sending Register messages. The RP can initiate the switch to the source’s SPT immediately after receiving the first Register message or after a configured threshold is reached. On the RS, the default behavior is for the RP to switch to the source’s SPT immediately after receiving the first Register message. It is highly recommended that you do not change this default.

A DR or a router with directly connected members can initiate the switch from the shared distribution tree to the source distribution tree immediately after receiving the first data packet or when the data rate reaches a configured threshold. Once a router moves to an SPT, it sends a prune message to its upstream router.

22.1.7 Multi-Access LANs

When there are multiple routers connected to a multi-access network, a DR is elected for the LAN. To maintain group memberships, the DR periodically sends join/prune messages toward the RP of each group for which it has active members. In addition, the DR of a data source sends register messages to the RP, which forwards the packets down the shared tree toward the group members. When the data rate reaches a configured threshold, the DR can switch to the source path tree.

PIM-SM also uses an assert mechanism when there are parallel paths in a multi-access LAN. The routers exchange assert messages which contain their priority for becoming the designated forwarder. The router with the highest priority is selected as the designated forwarder. The designated forwarder is responsible for sending the join/prune messages for the group.

22.2 ENABLING PIM-SM

To run PIM-SM on the RS you need to do the following:

- Install unicast routes (either static, ISIS, or OSPF) in the MRIB.
- Start PIM-SM.

The following sections describe each task.

22.2.1 Installing Routes in the MRIB

PIM-SM uses unicast routes to populate the MRIB. By default, when you run a unicast routing protocol, the routes are installed in the unicast RIB. To install the routes on the MRIB, you need to determine which unicast protocol will be used. On the RS, static, OSPF and ISIS routes can be installed in the MRIB.

To install static routes in the MRIB, define the static routes then use the **`ip add route`** command with the **`multicast-rib`** option, as shown in the following example:

```
rs (config)# ip add route multicast-rib
```

To install OSPF routes in the MRIB, configure OSPF and use the command shown in the following example:

```
rs (config)# ospf set rib multicast
```

For information on OSPF, refer to Chapter 13, *"OSPF Configuration Guide."*

To install ISIS routes in the MRIB, enable ISIS and use the command shown in the following example:

```
rs (config)# isis set rib multicast
```

For information on ISIS, refer to Chapter 14, *"IS-IS Configuration Guide."*

22.2.2 Starting PIM-SM

PIM-SM is disabled on the RS by default. You must enable PIM-SM on all interfaces that require multicast routing, including those running IGMP. The following example starts PIM-SM:

```
rs (config)# pim sparse add interface all
rs (config)# pim sparse start
```

Note On the RS, IGMP is also disabled by default. You must enable IGMP on the interfaces with directly connected senders and receivers. For information on IGMP, refer to Section 20.2, *"Configuring IGMP."*

22.3 CONFIGURING CANDIDATE BSR (C-BSR) PARAMETERS

Unless there is a static RP, each PIM domain must have a bootstrap router (BSR). The BSR periodically sends bootstrap messages to propagate RP information. PIM routers use the most current bootstrap message to update their knowledge of the RPs.

Bootstrap messages are also used for the BSR election. They contain a C-BSR's priority for becoming the BSR. The candidate BSR with the highest priority is elected as the BSR.

Use the **pim sparse cbsr** command to configure the RS as a C-BSR. When you do so, specify the interface name or IP address that will be used for the C-BSR. Generally, this address is the loopback address.

When you specify the **pim sparse cbsr** command, you can also set the following bootstrap-related parameters:

- The interval at which bootstrap messages are sent. By default, bootstrap messages are sent every 60 seconds.
- The priority used during the BSR election. The default is 0, which means the router cannot become a bootstrap router.
- The period of time within which if no bootstrap messages are sent, the BSR is considered unreachable and a new BSR is elected. By default, this is set to 30 seconds.
- The hash mask for the hash algorithm used in calculating the RP in a group. The default hash mask length is 30.

In addition, you can use the **deny-crp** parameter to prevent specific C-RPs from being included in bootstrap messages.

The following example configures 10.1.0.1 as the C-BSR address and sets its priority to 100:

```
rs (config)# pim sparse cbsr address 10.1.0.1 priority 100
```

To view bootstrap information, use the **pim show bsr-info** as shown in the following example:

```
rs# pim show bsr-info
Comp Status     CBSR-Pri CBSR-Addr       CBSR-mask Deny-CRPs
---- ------     -------- ---------       --------- ---------
sm0  Elected    100      10.1.0.1        30        N/A

Comp Elec-Pri Elec-Addr       Elec-mask Interval
---- -------- ---------       --------- --------
sm0  100      10.1.0.1        30        00:01:00
```

In the example, 10.1.0.1 is the elected BSR.

22.4 CONFIGURING CANDIDATE RP (C-RP) PARAMETERS

The RP is the root of the shared tree. It is responsible for forwarding multicast packets down the shared tree towards group members. There is only one RP in a PIM-SM domain.

Typically, the C-BSR is also configured as a candidate RP (C-RP). Use the **pim sparse crp** command to configure the RS as a C-RP. When you do so, specify the interface name or IP address that will be used for the C-RP. Generally, this address is the loopback address.

When you use the **pim sparse crp** command, you can also set the following parameters:

- The interval at which C-RP advertisements are sent to the BSR. By default, C-RP advertisements are sent every 60 seconds.
- The period of time the C-RP advertisements are valid. If no C-RP advertisements are received within this time, the RP is removed from the candidate list. By default, this value is 150 seconds.
- The priority used during the RP election; this is included in the router's bootstrap messages. By default, the router's priority is 0.

The following example configures 10.1.0.1 as the C-RP address and sets its priority to 100:

```
rs (config)# pim sparse crp address 10.1.0.1 priority 100
```

For interoperability with routers from other vendors, you may need to disable the use of the priority during the RP election. To do so, use the command shown in the following example:

```
rs (config)# pim sparse global cisco-hash
```

To view information about the C-RP, use the **pim show crp** command as shown in the following example:

```
rs# pim show crp grp-address all
Component Name:     sm0
CRP Address:        10.1.0.1
CRP Holdtime:       14:50:38 seconds
CRP Priority:       100
CRP Adv. Time:      14:48:16 seconds

Group/Mask         Group Pri
----------         ---------
224/4              100
```

22.4.1 Specifying Multicast Groups

By default, a router is the RP for all multicast groups. You can use the **pim sparse crp-group-add** command to limit the groups for which the router is an RP. The following is an example:

```
rs (config)# pim sparse crp-group-add 234.132.143.100
```

22.4.2 Configuring a Static RP

You can configure a static RP for a particular group. Configuring a static RP decreases the control packets transmitted by the PIM-SM routers, thus minimizing bandwidth usage. When you configure a static RP, do not configure a C-BSR and a C-RP on the routers in that group. Instead, use the **pim sparse static-rp** command to configure the static RP on all the multicast routers in the domain. You should also use an address that is reachable from all routers. Generally, this address is a loopback address.

Use the **pim sparse static-rp** command to specify the interface address of the static RP and the multicast group for which it is an RP. Following is an example:

```
rs (config)# pim sparse static-rp address 100.10.10.1 group 234.132.143.100
```

The default hash mask length for the hash algorithm used in calculating the RP in a group is 30. You can use the **pim global static-rp-hashmask-len** command to change this default for groups with static RPs as shown in the following example:

```
rs (config)# pim sparse global static-rp-hashmask-len 35
```

22.5 SETTING PIM GLOBAL PARAMETERS

The RS has various default PIM parameters that can be globally configured. This section describes these parameters.

22.5.1 Switching to the Source Tree

Only the DR and the RP can initiate the switch to a source's SPT. By default, the RP switches to the source SPT when it receives the first Register message from the DR. To change this default behavior, use the **pim sparse global** command as shown in the following example:

```
rs (config)# pim sparse global no-rp-switch-immediate threshold-rp 100
```

- The **no-rp-switch-immediate** parameter specifies that the RP should not switch to the source tree immediately after it receives the first Register message from the DR.
- The **threshold-rp** parameter specifies the data rate (in bytes per second) that triggers the RP to switch to the source tree.

By default, the DR switches to the source SPT when it receives the first data packet from a source. To prevent this, use the **pim sparse global** command as shown in the following example:

```
rs (config)# pim sparse global no-dr-switch-immediate threshold-dr 100
```

22.5.2 Setting the DR Priority

As stated earlier, when there are multiple routers connected to a multi-access network, a DR is elected for the LAN. The router with the highest priority is elected as the DR for the LAN. In the case of a tie, the router with the lowest IP address becomes the DR.

A router's priority is contained in the hello messages exchanged between PIM neighbors. By default, the RS interfaces have a priority of 1. To change the priority for all the RS interfaces, use the **pim global set hello-priority** command. To change the priority of a particular interface, use the **pim sparse add interface** command. Note that the interface priority overrides the global priority value. In the following example, the global priority is set to 5 and the priority for the interface to_group1 is set to 6:

```
rs (config)# pim global set hello-priority 5
rs (config)# pim sparse add interface to_group1 hello-priority 6
```

22.5.3 Setting PIM Timers

The RS has default values for various PIM message timers. These timers can be set globally or on a per-interface basis. This section describes how to set these timers globally. To set these timers for a specific interface, refer to Section 22.6, *"Setting PIM Interface Parameters."*

Assert Messages

When there are parallel upstream routers connected to a multi-access LAN, assert messages determine which of the routers will act as the designated forwarder. The designated forwarder is responsible for forwarding packets on the LAN. Downstream routers listen to the assert messages so they know which router is the forwarder, and where to send subsequent join/prune messages. The default interval between assert messages is 180 seconds. The following example decreases this interval to 150 seconds:

```
rs (config)# pim global set assert-holdtime 150
```

Hello Messages

Hello messages are periodically exchanged by PIM neighbors to establish and maintain neighbor relationships. They also contain a router's priority for becoming a DR. By default, hello messages are sent every 30 seconds and time out after 105 seconds. The following example illustrates how to change these defaults:

```
rs (config)# pim global set hello-holdtime 60 hello-interval 20
```

Join/Prune Messages

The DR periodically sends join/prune messages toward the RP for each group for which it has active members. By default, join/prune messages are sent every 60 seconds and time out after 210 seconds. The following example illustrates how to change these defaults:

```
rs (config)# pim global set join-prune-holdtime 100 join-prune-interval 30
```

Register Messages

As stated earlier, a data source's first-hop router sends register messages to the RP when a multicast packet needs to be transmitted on the shared distribution tree. The RP sends Register-Stop messages to the router if the RP has no downstream receivers for the group (or for that particular source), or if the RP has already joined the source tree. When the router receives the Register-Stop message from the RP, it starts the Register-Suppression timer and stops encapsulating data packets in Register messages while the timer is running. If there is data to be registered, the router sends a null Register (a Register message with a zero-length data portion in the inner packet) to the RP for a defined period of time (probe period) before the Register-Suppression timer expires. When the Register- Suppression timer expires, the router resumes sending data packets encapsulated in Register messages to the RP.

Be default, the Registration Suppression timer is set to 60 seconds and the probe period is set to 5 seconds. To increase the Registration Suppression timeout value to minimize the bursts of traffic to the RP, change these default values using the **pim sparse global** command, as shown in the following example:

```
rs (config)# pim sparse global reg-sup-timeout 100 probe-period 10
```

For Register messages, you can also configure PIM-SM to do a check sum calculation on the entire packet, instead of on the PIM-SM header only. This feature is provided for interoperability with routers from other vendors. Use the command shown in the following example:

```
rs (config)# pim sparse global whole-packet-checksum
```

22.6 SETTING PIM INTERFACE PARAMETERS

Use the **pim sparse add interface** command to change the defaults for the following timers for a specific interface:

- the assert message timer
- the hello message timers
- the join/prune message timers

For join/prune messages, you can set two other timers in addition to the holdtime and interval. (Refer to *"Join/Prune Messages"* for information on these timers.) You can set the join/prune suppression timer and the delay timeout. The join/prune suppression timer is used to reduce redundant join/prune messages. When an interface receives a join/prune message which has a higher holdtime than the interface's own holdtime, the join/prune suppression timer is started. While this timer is running, no join/prune messages are sent for the group. Its default is 75 seconds.

The join/prune delay timeout is the interval between the time a router's RPF neighbor changes and the time the router sends a triggered join/prune message to its new RPF neighbor. (A router's RPF neighbor may change due to changes in the unicast routing table or because of the assert process.)

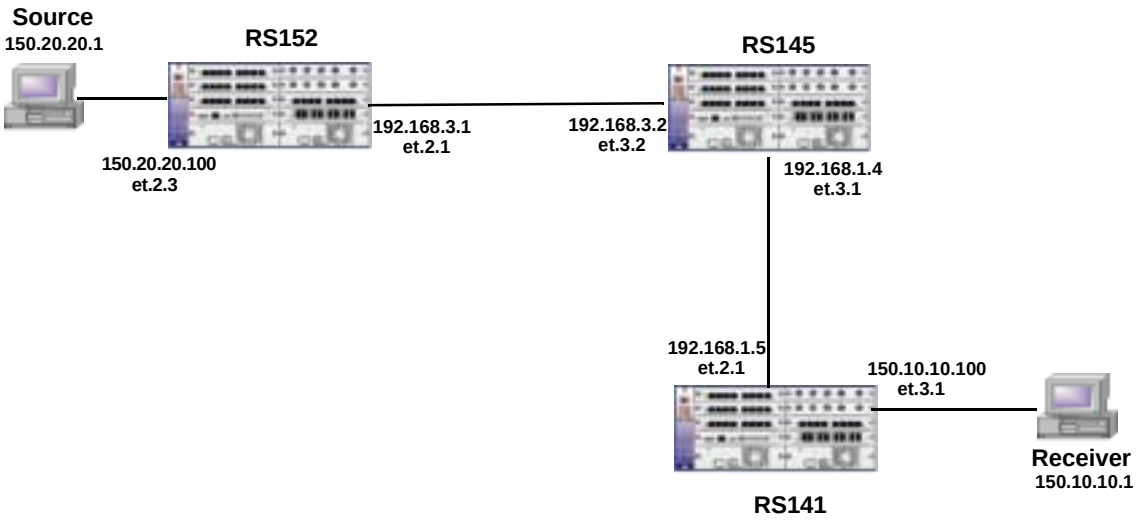
The following example sets parameters for the interface 152to145:

```
rs (config)# pim sparse add interface 152to145 hello-priority 3
```

22.7 CONFIGURATION EXAMPLE

The following example illustrates a basic PIM-SM configuration.

.



The source is connected to RS152. It is sending data for the multicast group 225.1.1.1. One of the receivers in that group is connected to RS 141. RS 145 is configured as the BSR and RP. The routers are also running OSPF.

Following is the configuration for RS 152, which is connected to the source:

```
! Create the interfaces
interface create ip 152to145 address-netmask 192.168.3.1 port et.2.1
interface create ip pc1 address-netmask 150.20.20.100/24 port et.2.3
interface add ip lo0 address-netmask 10.1.0.3/24
! Configure OSPF
ip-router global set router-id 10.1.0.3
ospf create area backbone
ospf add stub-host 10.1.0.3 to-area backbone cost 3
ospf add interface all to-area backbone
ospf set rib multicast
ospf start
! Configure IGMP
igmp add interface pc1
igmp start
! Configure PIM-SM
pim sparse add interface all
pim sparse add interface 152to145 hello-priority 3
pim sparse crp address 10.1.0.3 priority 10
pim sparse start
pim sparse cbsr address 10.1.0.3 priority 10
```

Following is the configuration for RS 141, which is connected to the receiver:

```
!Create the interfaces
interface create ip 141 address-netmask 192.168.1.5 port et.2.1
interface create ip pc2 address-netmask 150.10.10.100/24 port et.2.3
interface add ip lo0 address-netmask 10.1.0.2/24
!Configure OSPF
ip-router global set router-id 10.1.0.2
ospf create area backbone
ospf add stub-host 10.1.0.2 to-area backbone cost 3
ospf add interface all to-area backbone
ospf set rib multicast
ospf start
!Configure IGMP
igmp add interface pc2
igmp start
!Configure PIM-SM
pim sparse add interface all
pim sparse crp address 10.1.0.2 priority 20
pim sparse start
pim sparse cbsr address 10.1.0.2 priority 20
```

Following is the configuration for RS145:

```
!Create the interfaces
interface create ip 145to141 address-netmask 192.168.1.4 port et.3.1
interface create ip 145to152 address-netmask 192.168.3.2/24 port et.3.2
interface add ip lo0 address-netmask 10.1.0.1/24
!Configure OSPF
ip-router global set router-id 10.1.0.1
ospf create area backbone
ospf add stub-host 10.1.0.1 to-area backbone cost 5
ospf add interface all to-area backbone
ospf set rib multicast
ospf start
!Configure PIM-SM
pim sparse add interface all
pim sparse crp address 10.1.0.1 priority 100
pim sparse start
pim sparse cbsr address 10.1.0.1 priority 100
```

You can use the **`pim show routes source 150.20.20.1`** command to display the PIM routing table. The following example displays route information for the source 150.20.20.1:

```
rs145# pim show routes source 150.20.20.1

PIM Multicast Routing Table
Flags: S - Sparse, C - Directly connected host, L - Local, P - Pruned
       R - RP-bit set, T - SPT-bit set
       J - Join SPT, F - Directly connected source, E - External join
Timers: Uptime/Expires
Interface state: Interface, Timers, Output Ports

 (150.20.20.1/32, 225.1.1.1/32), 01:56:18/00:02:47, flags: ST
  Total packet/byte count: 15640999/1751475608, Rate: 1493160 bytes/sec
  Incoming interface: 145to152, RPF nbr 192.168.3.1,
  Outgoing interface list:
     145to141 (192.168.1.4), 01:56:18/00:03:13, et.3.1,
```

You can also use the **`multicast show cache`** command to display the multicast forwarding cache as shown in the following example:

```
rs145# multicast show cache
Source Address  Group Address   Incoming I/f    Outgoing I/f    Exit
Ports
--------------  -------------   --------------- ---------------
----------
150.20.20.1     225.1.1.1       145to152        145to141        et.3.1
```

23 IP POLICY-BASED FORWARDING CONFIGURATION

You can configure the RS to route IP packets according to policies that you define. IP policy-based routing allows network managers to engineer traffic to make the most efficient use of their network resources.

IP policies forward packets based on layer-3 or layer-4 header information. You can define IP policies to route packets to a set of next-hop IP addresses based on any combination of the following IP header fields:

- IP protocol
- Source IP address
- Destination IP address
- Source Socket
- Destination Socket
- Type of service

For example, you can set up an IP policy to send packets originating from a certain network through a firewall, while letting other packets bypass the firewall. Sites that have multiple Internet service providers can use IP policies to assign user groups to particular ISPs. You can also create IP policies to select service providers based on various traffic types.

23.1 CONFIGURING IP POLICIES

To implement an IP policy, you first create a profile for the packets to be forwarded using an IP policy. For example, you can create a profile defined as “all telnet packets going from network 9.1.0.0/16 to network 15.1.0.0/16”. You then associate the profile with an IP policy. The IP policy specifies what to do with the packets that match the profile. For example, you can create an IP policy that sends packets matching a given profile to next-hop gateway 100.1.1.1.

Configuring an IP policy consists of the following tasks:

- Defining a profile
- Associating the profile with a policy
- Applying the IP policy to an interface

23.1.1 Defining an ACL Profile

An ACL profile specifies the criteria packets must meet to be eligible for IP policy routing. You define profiles with the **acl** command. For IP policy routing, the RS uses the packet-related information from the **acl** command and ignores the other fields.

For example, the following **acl** command creates a profile called “prof1” for telnet packets going from network 9.1.0.0 to network 15.1.0.0:

```
rs(config)# acl prof1 permit ip 9.1.0.0/16 15.1.0.0/16 any any telnet 0
```

See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **acl** command.

Note ACLs for non-IP protocols cannot be used for IP policy routing.

23.1.2 Associating the Profile with an IP Policy

Once you have defined a profile with the **acl** command, you associate the profile with an IP policy by entering one or more **ip-policy** statements. An **ip-policy** statement specifies the next-hop gateway (or gateways) where packets matching a profile are forwarded. (See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **ip-policy** command.)

For example, the following command creates an IP policy called “p1” and specifies that packets matching profile “prof1” are forwarded to next-hop gateway 10.10.10.10:

```
rs(config)# ip-policy p1 permit acl prof1 next-hop-list 10.10.10.10
```

You can also set up a policy to prevent packets from being forwarded by an IP policy. For example, the following command creates an IP policy called “p2” that prevents packets matching prof1 from being forwarded using an IP policy:

```
rs(config)# ip-policy p2 deny acl prof1
```

Packets matching the specified profile are forwarded using dynamic routes instead.

Creating Multi-Statement IP Policies

An IP policy can contain more than one **ip-policy** statement. For example, an IP policy can contain one statement that sends all packets matching a profile to one next-hop gateway, and another statement that sends packets matching a different profile to a different next-hop gateway. If an IP policy has multiple **ip-policy** statements, you can assign each statement a sequence number that controls the order in which they are evaluated. Statements are evaluated from lowest sequence number to highest.

For example, the following commands create an IP policy called "p3", which consists of two IP policy statements. The **ip policy permit** statement has a sequence number of 1, which means it is evaluated before the **ip policy deny** statement, which has a sequence number of 900.

```
rs(config)# ip-policy p3 permit acl prof1 next-hop-list 10.10.10.10 sequence 1
rs(config)# ip-policy p3 deny acl prof2 sequence 900
```

Setting the IP Policy Action

You can use the **action** parameter with the **ip-policy permit** command to specify when to apply the IP policy route with respect to dynamic or statically configured routes. The options of the **action** parameter can cause packets to use the IP policy route first, then the dynamic route if the next-hop gateway specified in the IP policy is unavailable; use the dynamic route first, then the IP policy route; or drop the packets if the next-hop gateway specified in the IP policy is unavailable.

For example, the following command causes packets that match the profile to use dynamic routes first and use the IP policy gateway only if a dynamic route is not available:

```
rs(config)# ip-policy p2 permit acl prof1 action policy-last
```

Setting Load Distribution for Next-Hop Gateways

You can specify up to 16 next-hop gateways in an **ip-policy** statement. If you specify more than one next-hop gateway, you can use the **ip-policy set load-policy** command to control how the load is distributed among them.

By default, each new flow uses the first available next-hop gateway. You can use the **ip-policy set load-policy** command to cause flows to use all the next-hop gateways in the **ip-policy permit** statement sequentially. For example, the following command picks the next gateway in the list for each new flow for policy 'p1':

```
rs(config)# ip-policy p1 set load-policy round-robin
```

Verifying Next-Hop Gateways

The **ip-policy set pinger on** command can be used to check the availability of next-hop gateways by periodically querying them with ICMP_ECHO_REQUESTS. Only gateways that respond to these requests are used for forwarding packets. For example, the following command checks the availability of next-hop gateways specified in the policy ‘p1’:

```
rs(config)# ip-policy p1 set pinger on
```

Note Some hosts may have disabled responding to ICMP_ECHO packets. Make sure each next-hop gateway can respond to ICMP_ECHO packets before using this option.

When the **ip-policy set pinger on** command is issued, the RS can verify the state of a next-hop gateway by sending a ping to the gateway at 5-second intervals. If the RS does not receive a reply from a gateway after four ping requests, the gateway is considered to be “down.”

If you specify that the RS use TCP connection requests to check the gateway (instead of sending ICMP echo requests), the RS checks that an application session on the gateway can be established by sending a TCP connection request on the configured port of the gateway at 15-second intervals. If the RS does not receive a reply from the gateway after four tries, the application is considered to be “down.”

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the gateway or application to be “down.”

For example, the following commands cause the RS to check the availability of next-hop gateways for the IP policy ‘p1’ by pinging every 10 seconds:

```
rs(config)# ip-policy p1 set pinger on
rs(config)# ip-policy set pinger-options p1 ping-int 10
```

You can also have the RS verify the *content* of an application on one or more next-hop gateways. For this type of verification, you specify the following:

- A string that the RS sends to a single gateway or to a group of next-hop gateways. The string can be a simple HTTP command to get a specific HTML page. Or, it can be a command to execute a user-defined CGI script that tests the operation of the application.
- The reply that the application on each gateway sends back that the RS will use to validate the content. In the case where a specific HTML page is retrieved, the reply can be a string that appears on the page, such as “OK.” If a CGI script is executed on the gateway, it should return a specific response (for example, “OK”) that the RS can verify.

Application verification, whether a simple TCP handshake or a user-defined action-response check, involves opening and closing a connection to a next-hop gateway. Some applications require specific commands for proper closure of the connection. For example, a connection to an SMTP server application should be closed with the “quit” command. You can configure the RS to send a specific string to close a connection on a server.

The following is an example of how to configure a simple verification check where the RS will issue an HTTP command to retrieve an HTML page and check for the string ‘OK’:

```
rs(config)# ip-policy p1 set pinger-options acv-command “GET /test.html” acv-reply “OK”
read-till index 25
```

23.1.3 Applying an IP Policy to an Interface

After you define the IP policy, it must be applied to an inbound IP interface with the **ip-policy apply** command. Once the IP policy is applied to the interface, packets start being forwarded according to the IP policy. (See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **ip-policy apply** command.)

For example, the following command applies the IP policy ‘p2’ to the interface ‘int2’:

```
rs(config)# ip-policy p2 apply interface int2
```

Applying an IP Policy to Locally Generated Packets

You can apply an IP policy to locally-generated packets (that is, packets generated by the RS). For example, the following command applies the IP policy ‘p2’ to locally-generated packets:

```
rs(config)# ip-policy p2 apply local
```

23.2 IP POLICY CONFIGURATION EXAMPLES

This section presents some examples of IP policy configurations. The following uses of IP policies are demonstrated:

- Routing traffic to different ISPs
- Prioritizing service to customers
- Authenticating users through a firewall
- Firewall load balancing

23.2.1 Routing Traffic to Different ISPs

Sites that have multiple Internet service providers can create IP policies that cause different user groups to use different ISPs. You can also create IP policies to select service providers based on various traffic types.

In the sample configuration in Figure 23-1, the policy router is configured to divide traffic originating within the corporate network between different ISPs (100.1.1.1 and 200.1.1.1).

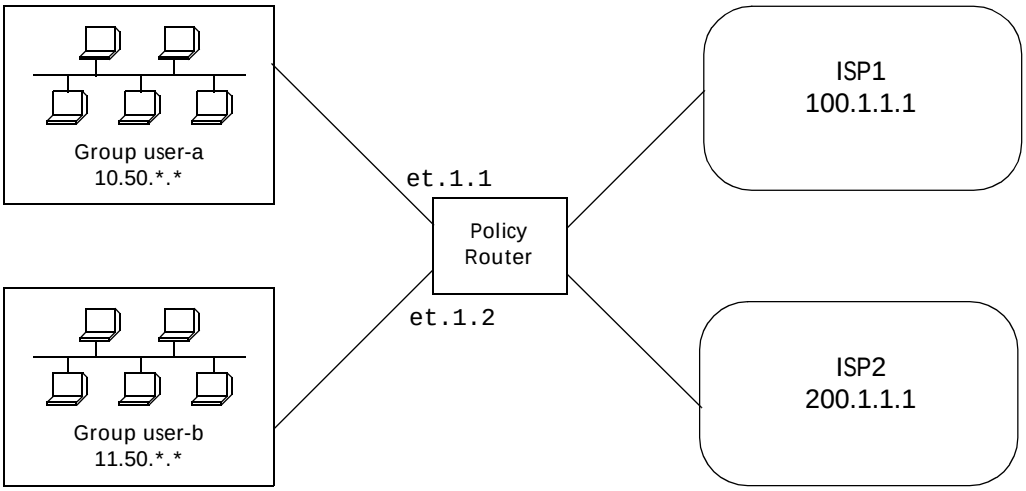


Figure 23-1 Using an IP policy to route traffic to two different ISPs

HTTP traffic originating from network 10.50.0.0 for destination 207.31.0.0/16 is forwarded to 100.1.1.1. Non-HTTP traffic originating from network 10.50.0.0 for destination 207.31.0.0/16 is forwarded to 200.1.1.1. All other traffic is forwarded to 100.1.1.1.

The following is the IP policy configuration for the Policy Router in Figure 23-1:

```
interface create ip user-a address-netmask 10.50.1.1/16 port et.1.1
interface create ip user-b address-netmask 11.50.1.1/16 port et.1.2

acl user-a-http  permit ip 10.50.0.0/16 207.31.0.0/16 any http 0
acl user-a  permit ip 10.50.0.0/16 207.31.0.0/16 any any 0
acl user-b  permit ip 11.50.0.0/16 any any any 0

ip-policy net-a permit acl user-a-http next-hop-list 100.1.1.1 action policy-first
sequence 20

ip-policy net-a permit acl user-a next-hop-list 200.1.1.1 action policy-only
sequence 25

ip-policy net-a apply interface user-a

ip-policy net-b permit acl user-b next-hop-list 200.1.1.1 action policy-first

ip-policy net-b apply interface user-b
```

23.2.2 Prioritizing Service to Customers

An ISP can use policy-based routing on an access router to supply different customers with different levels of service. The sample configuration in Figure 23-2 shows an RS using an IP policy to classify customers and route traffic to different networks based on customer type.

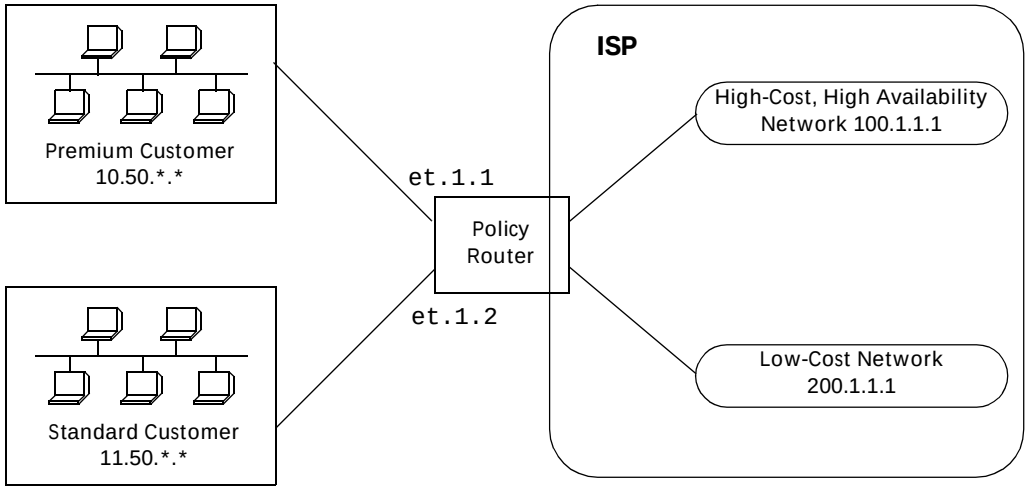


Figure 23-2 Using an IP policy to prioritize service to customers

Traffic from the premium customer is load balanced across two next-hop gateways in the high-cost, high-availability network. If neither of these gateways is available, then packets are forwarded based on dynamic routes learned via routing protocols.

Traffic from the standard customer always uses one gateway (200.1.1.1). If for some reason that gateway is not available, packets from the standard customer are dropped.

The following is the IP policy configuration for the Policy Router in Figure 23-2:

```
interface create ip premium-customer address-netmask 10.50.1.1/16 port et.1.1

interface create ip standard-customer address-netmask 11.50.1.1/16 port et.1.2

acl premium-customer permit ip 10.50.0.0/16 any any any 0
acl standard-customer   permit ip 11.50.0.0/16 any any any 0

ip-policy p1 permit acl premium-customer next-hop-list "100.1.1.1
200.1.1.1" action policy-first sequence 20

ip-policy apply interface premium-customer

ip-policy p2 permit acl standard-customer next-hop-list 200.1.1.1 action
policy-only sequence 30

ip-policy apply interface standard-customer
```

23.2.3 Authenticating Users through a Firewall

You can define an IP policy that authenticates packets from certain users via a firewall before accessing the network. If, for some reason the firewall is not responding, the packets to be authenticated are dropped. Figure 23-3 illustrates this kind of configuration.

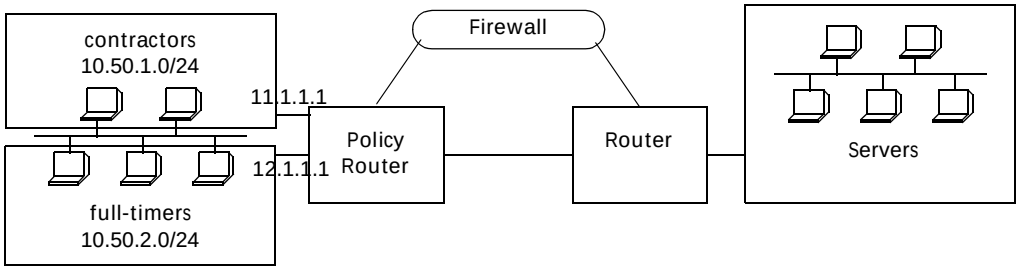


Figure 23-3 Using an IP policy to authenticate users through a firewall

Packets from users defined in the “contractors” group are sent through a firewall. If the firewall cannot be reached packets from the contractors group are dropped. Packets from users defined in the “full-timers” group do not have to go through the firewall.

The following is the IP policy configuration for the Policy Router in Figure 23-3:

```
interface create ip mls0 address-netmask 10.50.1.1/16 port et.1.1

acl contractors permit ip 10.50.1.0/24 any any any 0
acl full-timers permit ip 10.50.2.0/24 any any any 0

ip-policy access permit acl contractors next-hop-list 11.1.1.1 action policy-only
ip-policy access permit acl full-timers next-hop-list 12.1.1.1 action policy-first
ip-policy access apply interface mls0
```

23.2.4 Firewall Load Balancing

Figure 23-4 shows a simplified example of firewall load balancing. This example shows how to provide protection from a complete firewall failure, but it does not show how to protect against asymmetrical paths if a single link failure occurs.

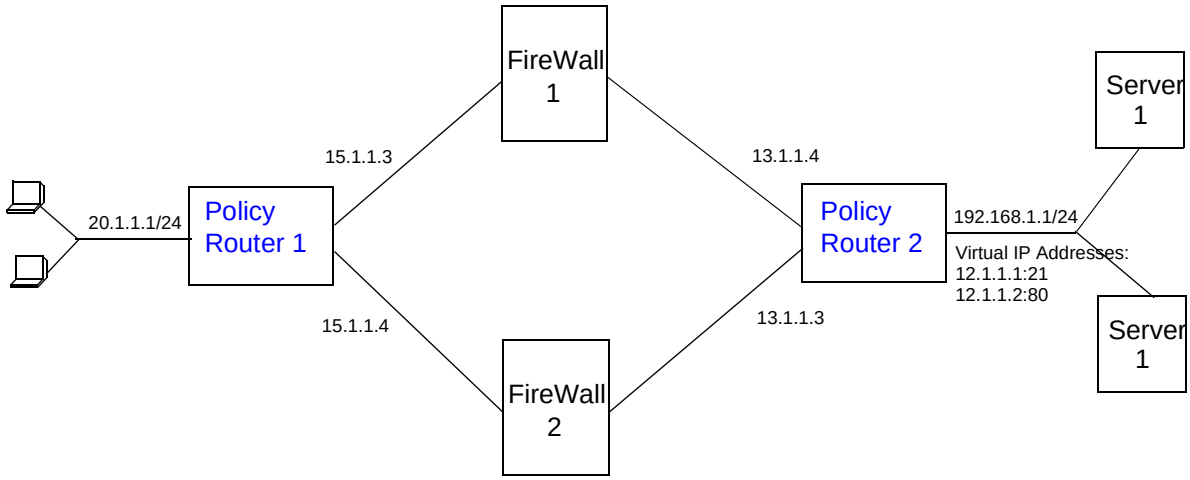


Figure 23-4 Firewall load balancing example

On Policy Router 1, an ACL profile allows traffic from the clients to the virtual IP addresses of the server (12.1.1.0/24). IP policy configuration will distribute the traffic across the two next hops (the firewalls) based on a hashing of the *source* IP address (the client's address, as provided by DHCP). The following is the configuration for Policy Router 1 in Figure 23-4.

```
! Create client VLAN
vlan create vClient ip id 10
vlan add ports et.1.1 to vClient
vlan add ports et.1.2 to vClient
vlan add ports et.1.3 to vClient
vlan add ports et.1.4 to vClient
! Create Firewall VLAN
vlan create vFirewall ip id 20
vlan add ports et.2.1 to vFirewall
vlan add ports et.2.2 to vFirewall
! Create interfaces
interface create ip iClient address-netmask 20.1.1.1/24 vlan vClient
interface create ip iFirewall address-netmask 15.1.1.1/24 vlan vFirewall
! Create ACL to allow client traffic to pass to server VIPs
acl AclToLB permit ip any 12.1.1.0/24 any any
! Configure IP policy
ip-policy polToLB permit acl AclToLB next-hop-list “15.1.1.3 15.1.1.4” action
policy-only
ip-policy PolToLB apply interface iClient
ip-policy PolToLB set load-policy ip-hash sip
ip-policy PolToLB set pinger on
! Configure DHCP server to provide clients with IP address pool
dhcp dClient define pool 20.1.1.10-20.1.1.100
dhcp dClient define parameters gateway 20.1.1.1 address-netmask 20.1.1.0/24
```

On Policy Router 2, load balancing groups an ACL profile allows traffic to pass to the clients. IP policy configuration will distribute the traffic across the two next hops (the firewalls) based on a hashing of the *destination* IP address (the client's address). The following is the configuration for Policy Router 2 in Figure 23-4.

```
! Create server VLAN
vlan create vServices ip id 10
vlan add ports et.1.1 to vServices
vlan add ports et.1.2 to vServices
vlan add ports et.1.3 to vServices
vlan add ports et.1.4 to vServices
! Create Firewall VLAN
vlan create vFirewall ip id 20
vlan add ports et.2.1 to vFirewall
vlan add ports et.2.2 to vFirewall
! Create interfaces
interface create ip iServices address-netmask 192.168.1.1/24 vlan vServices
interface create ip iFirewall address-netmask 13.1.1.1/24 vlan vFirewall
! Create ACL to allow server traffic to pass to clients
acl AclToClient permit ip any any any any
! Configure IP policy
ip-policy polToClient permit acl AclToClient next-hop-list “13.1.1.3 13.1.1.4”
action policy-only
ip-policy PolToClient apply interface iServices
ip-policy PolToClient set load-policy ip-hash sip
ip-policy PolToClient set pinger on
! Configure load balancing group for FTP on servers
load-balance create group-name MyFtp virtual-ip 12.1.1.1 virtual-port 21 protocol
tcp
load-balance add host to group 192.168.1.3 port 21 group-name MyFtp
load-balance add host to group 192.168.1.4 port 21 group-name MyFtp
! Configure load balancing group for HTML on servers
load-balance create group-name MyWeb virtual-ip 12.1.1.2 virtual-port 80 protocol
tcp
load-balance add host to group 192.168.1.3 port 80 group-name MyWeb
load-balance add host to group 192.168.1.4 port 80 group-name MyWeb
```

Note Although the configuration of the firewall devices are not shown here, you need to ensure that services are allowed to pass through the firewall while providing site security.

23.3 MONITORING IP POLICIES

The **`ip-policy show`** command reports information about active IP policies, including profile definitions, policy configuration settings, and next-hop gateways. The command also displays statistics about packets that have matched an IP policy statement as well as the number of packets that have been forwarded to each next-hop gateway.

For example, to display information about an active IP policy called “p1”, enter the following command in Enable mode:

```
rs# ip-policy show policy-name p1

-------------------------------------------------------------------------------
IP Policy name     : p1 ❶
Applied Interfaces : int1  ❷
Load Policy        : first available  ❸

❹               ❺               ❻              ❼        ❽        ❾  ❿
ACL          Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS Prot
---          --------------     -------------      --------- --------- --- ----
prof1        9.1.1.5/32         15.1.1.2           any       any         0 IP
prof2        2.2.2.2/32         anywhere           any       any         0 IP
everything   anywhere           anywhere           any       any         0 IP

                                                      Next Hop Information
                                                      --------------------
 ⓫    ⓬     ⓭          ⓮    ⓯                          ⓰             ⓱   ⓲
Seq   Rule   ACL        Cnt  Action                   Next Hop        Cnt  Last
---   ----   --------   ---  -----------              --------        ---  ----
10    permit prof1      0    Policy Only              11.1.1.2        0    Dwn
20    permit prof2      0    Policy Last              1.1.1.1         0    Dwn
                                                      2.2.2.2         0    Dwn
                                                      3.3.3.3         0    Dwn
999   permit everything 0    Policy Only              drop            N/A  N/A
65536 deny   deny       0    N/A                      normal fwd      N/A  N/A
⓳
```

Legend:

1. The name of the IP policy.
2. The interface where the IP policy was applied.
3. The load distribution setting for IP-policy statements that have more than one next-hop gateway; either first available (the default) or round-robin.
4. The names of the profiles (created with an **`acl`** statement) associated with this IP policy.
5. The source address and filtering mask of this flow.
6. The destination address and filtering mask of this flow.
7. For TCP or UDP, the number of the source TCP or UDP port.
8. For TCP or UDP, the number of the destination TCP or UDP port.
9. The TOS value in the packet.
10. The protocol of this profile (IP, ICMP, TCP UDP).
11. The sequence in which the statement is evaluated. IP policy statements are listed in the order they are evaluated (lowest sequence number to highest).
12. The rule to apply to the packets matching the profile: either permit or deny
13. The name of the profile (ACL) of the packets to be forwarded using an IP policy.

14. The number of packets that have matched the profile since the IP policy was applied (or since the **`ip-policy clear`** command was last used)
15. The method by which IP policies are applied with respect to dynamic or statically configured routes; possible values are Policy First, Policy Only, or Policy Last.
16. The list of next-hop gateways in effect for the policy statement.
17. The number of packets that have been forwarded to this next-hop gateway.
18. The state of the link the last time an attempt was made to forward a packet; possible values are up, down, or N/A.
19. Implicit deny rule that is always evaluated last, causing all packets that do not match one of the profiles to be forwarded normally (with dynamic routes).

See the *Riverstone RS Switch Router Command Line Interface Reference Manual* for complete syntax information for the **`ip-policy show`** command.

24 NETWORK ADDRESS TRANSLATION CONFIGURATION

Network Address Translation (NAT) allows an IP address used within one network to be translated into a different IP address used within another network. NAT is often used to map addresses used in a private, local intranet to one or more addresses used in the public, global Internet. NAT provides the following benefits:

- Limits the number of IP addresses used for private intranets that are required to be registered with the Internet Assigned Numbers Authority (IANA).
- Conserves the number of global IP addresses needed by a private intranet (for example, an entity can use a single IP address to communicate on the Internet).
- Maintains privacy of local networks, as internal IP addresses are hidden from public view.

With NAT, the local network is designated the *inside* network and the global Internet is designated the *outside* network. In addition, the RS supports Port Address Translation (PAT) for either static or dynamic address bindings.

The RS allows you to create the following NAT address bindings:

- Static, one-to-one binding of inside, local address or address pool to outside, global address or address pool. A static address binding does not expire until the command that defines the binding is negated. IP addresses defined for static bindings cannot be reassigned. For static address bindings, PAT allows TCP or UDP port numbers to be translated along with the IP addresses.
- Dynamic binding between an address from a pool of local addresses to an address from a pool of outside addresses. With dynamic address binding, you define local and global address pools from which the addresses bindings can be made. IP addresses defined for dynamic binding are reassigned whenever they become free. For dynamic address bindings, PAT allows port address translation if no addresses are available from the global address pool. PAT allows port address translation for each address in the global pool. The ports are dynamically assigned between the range of 1024 to 4999. Hence, you have about 4,000 ports per global IP address.

  Dynamic bindings are removed automatically when the flow count goes to zero. At this point, the corresponding port (if PAT enabled) or the global IP address is freed and can be reused the next time. Although there are special cases like FTP where the flows are not installed for the control path, the binding will be removed only by the dynamic binding timeout interval.

24.1 CONFIGURING NAT

The following are the steps in configuring NAT on the RS:

1. Setting the NAT interfaces to be “inside” or “outside.”
2. Setting the NAT rules (static or dynamic).

24.1.1 Setting Inside and Outside Interfaces

When NAT is enabled, address translation is only applied to those interfaces which are defined to NAT as “inside” or “outside” interfaces. NAT only translates packets that arrive on a defined inside or outside interface.

To specify an interface as inside (local) or outside (global), enter the following command in Configure mode.

Define an interface as inside or outside for NAT.	**nat set interface** <*InterfaceName*> **inside|outside**

24.1.2 Setting NAT Rules

Static

You create NAT static bindings by entering the following command in Configure mode.

Enable NAT with static address binding.	**nat create static protocol ip|tcp|udp local-ip** <*local-ip-add/address range*> **global-ip** <*global-ip-add/address range*> **[local-port** <*tcp/udp local-port*>**|any] [global-port** <*tcp/udp global-port*>**|any]**

Dynamic

You create NAT dynamic bindings by entering the following command in Configure mode.

Enable NAT with dynamic address binding.	**nat create dynamic local-acl-pool** <*local-acl*> **global-pool** <*ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask*> **[matches-interface** <*interface*>**] [enable-ip-overload]**

For dynamic address bindings, you define the address pools with previously-created ACLs. You can also specify the **enable-port-overload** parameter to allow PAT.

24.2 FORCING FLOWS THROUGH NAT

If a host on the outside global network knows an inside local address, it can send a message directly to the inside local address. By default, the RS will route the message to the destination. You can force *all* flows between the inside local pool and the outside global network to be translated. This prevents a host on the outside global network from being allowed to send messages directly to any address in the local address pool.

You force address translation of all flows to and from the inside local pool by entering the following command in Configure mode.

Force all flows to and from local address pool to be translated.	**nat set secure-plus on|off**

24.3 MANAGING DYNAMIC BINDINGS

As mentioned previously, dynamic address bindings expire only after a period of non-use or when they are manually deleted. The default timeout for dynamic address bindings is 1440 minutes (24 hours). You can manually delete dynamic address bindings for a specific address pool or delete all dynamic address bindings.

To set the timeout for dynamic address bindings, enter the following command in Configure mode.

Set timeout for dynamic address bindings.	**nat set dynamic-binding-timeout** <*minutes*> **|disable**

To flush dynamic address bindings, enter the following command in Enable mode.

Flush all dynamic address bindings.	**nat flush-dynamic-binding all**
Flush dynamic address bindings based on local and global ACL pools.	**nat flush-dynamic-binding pool-specified local-acl-pool** <*local-acl*> **global-pool** <*ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask*>
Flush dynamic address bindings based on binding type.	**nat flush-dynamic-binding type-specified dynamic|overloaded-dynamic**
Flush dynamic address bindings based on application.	**nat flush-dynamic-binding owner-specified dns|ftp-control|ftp-data**

24.4 NAT AND DNS

NAT can translate an address that appears in a Domain Name System (DNS) response to a name or inverse lookup. For example, if an outside host sends a name lookup to an inside DNS server, the inside DNS server can respond with a local IP address, which NAT translates to a global address.

To enable NAT DNS translation, enter the following command in Configure mode:

```
nat set dns-translation-state enable
```

You create NAT dynamic bindings for DNS by entering the following command in Configure mode.

Enable NAT with dynamic address binding for DNS query/reply.	**nat create dynamic local-acl-pool** *<outside-local-acl>* **global-pool** *<ip-addr/ip-addr-range/ip-addr-list/ip-addr-mask>*

DNS packets that contain addresses that match the ACL specified by **outside-local-acl-pool** are translated using local addresses allocated from **inside-global-pool**.

The default timeout for DNS dynamic address bindings is 30 minutes. You can change this timeout by entering the following command in Configure mode:

Specify the timeout for DNS bindings.	**nat set dns-session-timeout** *<minutes>*

24.5 NAT AND ICMP PACKETS

NAT translates addresses embedded in the data portion of the following types of ICMP error messages:

- Destination unreachable (type 3)
- Source quench (type 4)
- Redirect (type 5)
- Time exceeded (type 11)
- Parameter problem (type 12)

24.6 NAT AND FTP

File Transfer Protocol (FTP) packets require special handling with NAT, because the FTP PORT command packets contain IP address information within the data portion of the packet. It is therefore important for NAT to know which control port is used for FTP (the default is port 21) and the timeout for the FTP session (the default is 30 minutes). If FTP packets will arrive on a different port number, you need to specify that port to NAT.

To define FTP parameters to NAT, enter the following commands in Configure mode.

Specify the FTP control port.	**nat set ftp-control-port** *<port number>*
Specify the FTP session timeout.	**nat set ftp-session-timeout** *<minutes>*

If PAT is enabled, NAT checks packets for the FTP PORT command. If a packet is to be translated (as determined by the ACL specified for the dynamic address binding), NAT creates a dynamic binding for the PORT command. An outside host will only see a global IP address in an FTP response and not the local IP address.

24.7 MONITORING NAT

To display NAT information, enter the following command in Enable mode.

Display NAT information.	**nat show [translations all|**<*type*>**] [timeouts] [statistics]**

24.8 CONFIGURATION EXAMPLES

This section shows examples of NAT configurations.

24.8.1 Static Configuration

The following example configures a static address binding for inside address 10.1.1.2 to outside address 192.50.20.2:

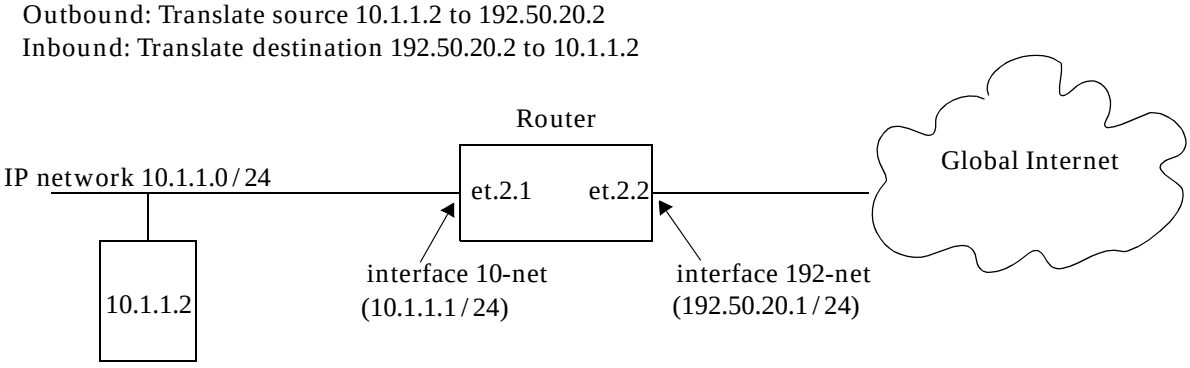


Figure 24-1 Static address binding configuration

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT static rules:

```
nat create static protocol ip local-ip 10.1.1.2 global-ip 192.50.20.2
```

Using Static NAT

Static NAT can be used when the local and global IP addresses are to be bound in a fixed manner. These bindings never get removed nor time out until the static NAT command itself is negated. Static binding is recommended when you have a need for a permanent type of binding.

The other use of static NAT is when the out to in traffic is the first to initialize a connection, i.e., the first packet is coming from outside to inside. This could be the case when you have a server in the local network and clients located remotely. Dynamic NAT would not work for this case as bindings are always created when an in to out Internet connection occurs. A typical example is a web server inside the local network, which could be configured as follows:

```
nat create static protocol tcp local-ip 10.1.1.2 global-ip 192.50.20.2 local-port 80
global-port 80
```

This server, 10.1.1.2, is advertised as 192.50.20.2 to the external network.

24.8.2 Dynamic Configuration

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside address 192.50.20.0/24:

Outbound: Translate source pool 10.1.1.0 / 24 to global pool 192.50.20.0 / 24

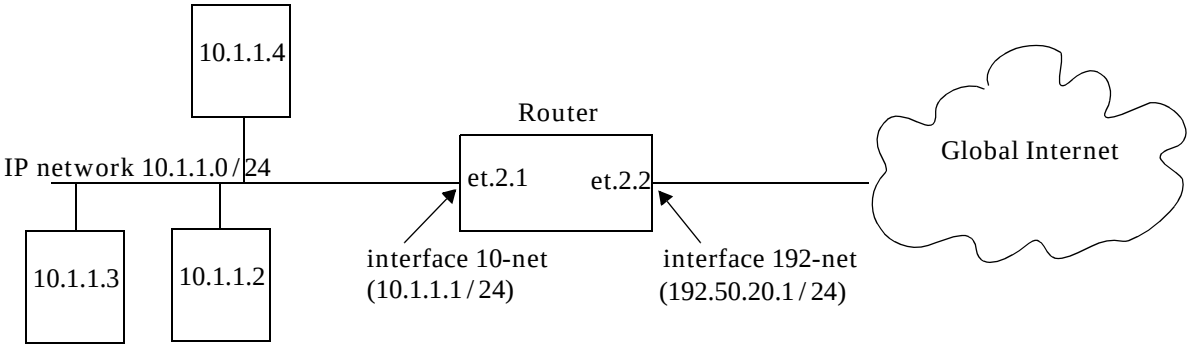


Figure 24-2 Dynamic address binding configuration

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.0/24
```

Using Dynamic NAT

Dynamic NAT can be used when the local network (inside network) is going to initialize the connections. It creates a binding at run time when a packet is sent from a local network, as defined by the NAT dynamic local ACl pool. The network administrator does not have to worry about the way in which the bindings are created; the network administrator just sets the pools and the RS automatically chooses a free global IP from the global pool for the local IP.

Dynamic bindings are removed when the flow count for that binding goes to zero or the timeout has been reached. The free globals are used again for the next packet.

A typical problem is that if there are more local IP addresses as compared to global IP addresses in the pools, then packets will be dropped if all the globals are used. A solution to this problem is to use PAT with NAT dynamic. This is only possible with TCP or UDP protocols.

24.8.3 Dynamic NAT with IP Overload (PAT) Configuration

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside address 192.50.20.0/24:

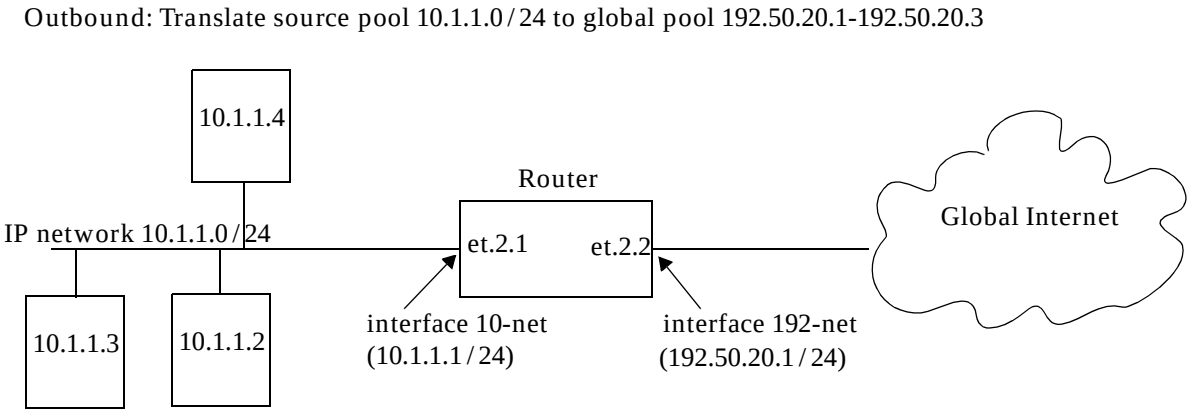


Figure 24-3 Dynamic address binding with PAT

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.1-192.50.20.3
enable-ip-overload
```

Using Dynamic NAT with IP Overload

Dynamic NAT with IP overload can be used when the local network (inside network) will be initializing the connections using TCP or UDP protocols. It creates a binding at run time when the packet comes from a local network defined in the NAT dynamic local ACL pool. The difference between the dynamic NAT and dynamic NAT with PAT is that PAT uses port (layer 4) information to do the translation. Hence, each global IP has about 4000 ports that can be translated. NAT on the RS uses the standard BSD range of ports from 1024-4999 which is fixed and cannot be configured by the user. The network administrator does not have to worry about the way in which the bindings are created; he/she just sets the pools and the RS automatically chooses a free global IP from the global pool for the local IP.

Dynamic bindings are removed when the flow count goes to zero or the timeout has been reached. The removal of bindings frees the port for that global and the port is available for reuse. When all the ports for that global are used, then ports are assigned from the next free global. If no more ports and globals are available, the packets will be dropped.

24.8.4 Dynamic NAT with DNS

The following example configures a DNS dynamic address binding for outside address 192.50.20.2-192.50.20.9 to inside addresses 10.1.1.0/24:

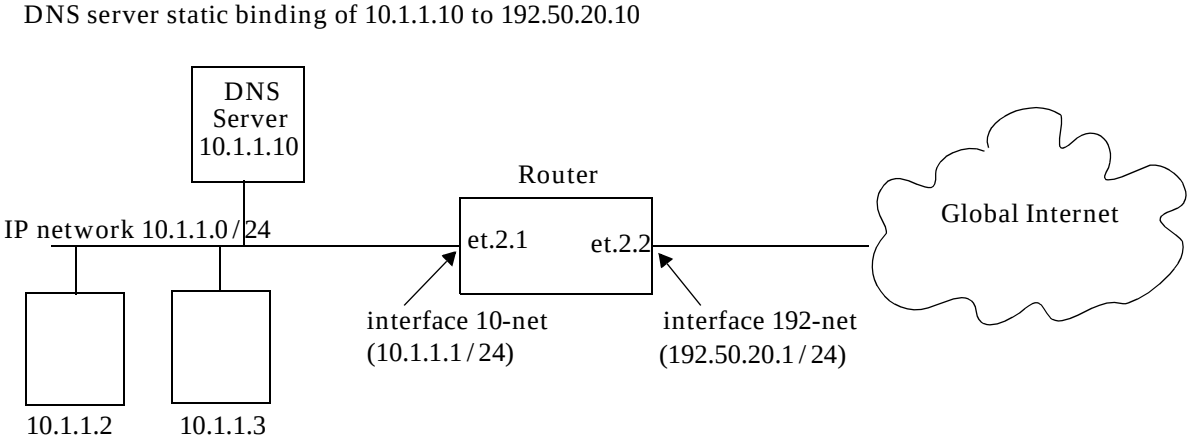


Figure 24-4 Dynamic address binding with DNS

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.1/24 port et.2.2
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.2-192.50.20.9
nat create static local-ip 10.1.1.10 global-ip 192.50.20.10 protocol ip
```

Using Dynamic NAT with DNS

When a client from outside sends a query to the static global IP address of the DNS server, NAT will translate the global IP address to the local IP address of the DNS server. The DNS server will resolve the query and respond with a reply. The reply can include the local IP address of a host inside the local network (for example, 10.1.1.2); this local IP address will be translated by NAT into a global IP address (for example, 192.50.20.2) in a dynamic binding for the response.

24.8.5 Dynamic NAT with Outside Interface Redundancy

The following example configures a dynamic address binding for inside addresses 10.1.1.0/24 to outside addresses 192.50.20.0/24 on interface 192-net and to outside addresses 201.50.20.0/24 on interface 201-net:

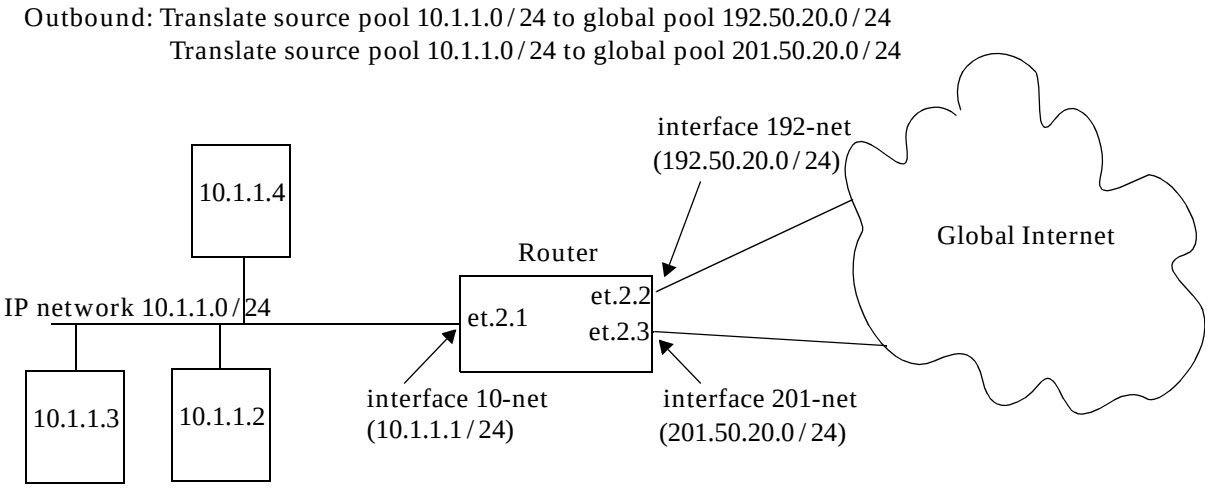


Figure 24-5 Dynamic address binding with outside interface redundancy

1. The first step is to create the interfaces:

```
interface create ip 10-net address-netmask 10.1.1.1/24 port et.2.1
interface create ip 192-net address-netmask 192.50.20.0/24 port et.2.2
interface create ip 201-net address-netmask 201.50.20.0/24 port et.2.3
```

2. Next, define the interfaces to be NAT “inside” or “outside”:

```
nat set interface 10-net inside
nat set interface 192-net outside
nat set interface 201-net outside
```

3. Then, define the NAT dynamic rules by first creating the source ACL pool and then configuring the dynamic bindings:

```
acl lcl permit ip 10.1.1.0/24
nat create dynamic local-acl-pool lcl global-pool 192.50.20.0/24 matching-interface
192-net
nat create dynamic local-acl-pool lcl global-pool 210.50.20.0/24 matching-interface
201-net
```

Using Dynamic NAT with Matching Interface Redundancy

If you have redundant connections to the remote network via two different interfaces, you can use NAT for translating the local address to the different global pool specified for the two connections. This case is possible when you have two ISPs connected on two different interfaces to the Internet. Through a routing protocol, some routes will result in traffic going out of one interface and for others going out on the other interface. NAT will check which interface the packet is going out from before selecting a global pool. Hence, you can specify two different global pools with the same local ACL pool on two different interfaces.

25 WEB HOSTING CONFIGURATION

Accessing information on websites for both work or personal purposes is becoming a normal practice for an increasing number of people. For many companies, fast and efficient web access is important for both external customers who need to access the company websites, as well as for users on the corporate intranet who need to access Internet websites.

The following features on the RS provide ways to improve web access for external and internal users:

- Load balancing allows incoming HTTP requests to a company's website to be distributed across several physical servers. If one server should fail, other servers can pick up the workload.
- Web caching allows HTTP requests from internal users to Internet sites to be redirected to cached Web objects on local servers. Not only is response time faster since requests can be handled locally, but overall WAN bandwidth usage is reduced.

Note Load balancing and web caching can be performed using application software. However, the RS can perform these functions much faster as the redirection is handled by specialized hardware.

25.1 LOAD BALANCING

You can use the load balancing feature on the RS to distribute session load across a group of servers. If you configure the RS to provide load balancing, client requests that go through the RS can be redirected to any one of several predefined hosts. With load balancing, clients access servers through a virtual IP address. The RS transparently redirects the requests with no change required on the clients or servers; all configuration and redirection is done on the RS.

Following are the steps in configuring load balancing on the RS:

1. Create a logical group of load balancing servers and define a virtual IP address for the group.
2. Define the servers in the group.
3. Specify optional operating parameters for the group of load balancing servers or for individual servers in the group.

25.1.1 Creating the Server Group

To use load balancing, you create a logical group of load balancing servers and define a virtual IP address that the clients will use to access the server pool.

The following example configures the “abccompany-www” load balancing group:

```
rs(config)# load-balance create group-name abccompany-www virtual-ip
207.135.89.16 virtual-port 80 protocol tcp
```

Specifying a Protocol

When you configure a load balancing group, you need to specify the protocol of the traffic that will be load balanced. There is no default. Select the protocol based on what you think the majority of traffic will be for that group. For example, you may want to specify TCP if you expect the majority of traffic to be HTTP requests.

- Specify **ip** to perform Layer 3 load balancing. This protocol uses an IP-hash algorithm to load balance.
- Specify **tcp** if you want the RS to perform application load balancing and application health checks. You can specify a port to control which port performs the load balancing. If you don’t specify a port, any one of the ports in the group will be used for load balancing. When you specify **tcp** as the protocol, the default load balancing policy is round robin. You can change the load balancing policy to weighted round-robin, fastest, predictive, or least loaded. (See *"Specifying a Load Balancing Policy"* for more information about these policies.) UDP traffic through a TCP load-balanced group is load balanced using the IP hash algorithm.
- Specify **udp** to perform UDP load balancing, such as DNS. For UDP sessions, it is difficult to signal the end of a session because UDP is connectionless. Therefore, a fixed IP-hash policy is used to ensure that the client always goes to the same server.

Intrinsic Persistence Checking

Load balancing clients connect to a *virtual* IP address, which in reality is redirected to one of several physical servers in a load balancing group. In many web page display applications, a client may have its requests redirected to and serviced by different servers in the group. In certain situations, however, it may be critical that all traffic for the client be directed to the same physical server for the duration of the session; this is the concept of *session persistence*.

When the RS receives a new session request from a client for a specific virtual address, the RS creates a *binding* between the client (source) IP address/port socket and the (destination) IP address/port socket of the load balancing server selected for this client. Subsequent packets from clients are compared to the list of bindings: if there is a match, the packet is sent to the same server previously selected for this client; if there is not a match, a new binding is created. How the RS determines the binding match for session persistence is configured with the **persistence-level** option when the load balancing group is created.

There are several configurable levels of session persistence:

- TCP persistence: a binding is determined by the matching the source IP/port address as well as the virtual destination IP/port address. For example, requests from the client address of 134.141.176.10:1024 to the virtual destination address 207.135.89.16:80 is considered one session and would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1). A request from a different source socket from the same client address to the same virtual destination address would be considered another session and may be directed to a different load balancing server (for example, the server with IP address 10.1.1.2). This is the default level of session persistence.
- SSL persistence: a binding is determined by matching the source IP address and the virtual destination IP/port address. Note that requests from *any* source socket with the client IP address are considered part of the same session. For example, requests from the client IP address of 134.141.176.10:1024 or 134.141.176.10:1025 to the virtual destination address 207.135.89.16:80 would be considered one session and would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1).
- Sticky persistence: a binding is determined by matching the source and destination IP addresses only. This allows all requests from a client to the same virtual address to be directed to the same load balancing server. For example, both HTTP and HTTPS requests from the client address 134.141.176.10 to the virtual destination address 207.135.89.16 would be directed to the same load balancing server (for example, the server with IP address 10.1.1.1).
- Virtual private network (VPN) persistence: for VPN traffic using Encapsulated Security Payload (ESP) mode of IPSec, a binding is determined by matching the source and destination IP addresses in the secure key transfer request to subsequent client requests. This allows both the secure key transfer and subsequent data traffic from a particular client to be directed to the same load balancing server. The default port number recognized by the RS for secure key transfer in VPN is 500; you can use the **`load-balance set vpn-dest-port`** command to specify a different port number.
- IP persistence: Used for L3 persistence of load balancing sessions. Note that for IP persistence, there can be only one virtual IP address associated with one load balancing group. In addition, a load balancing server may belong to one IP group only.

The RS also supports *netmask persistence*, which can be used with any of the five levels of session persistence. A netmask (configured with the **`load-balance set client-proxy-subnet`** command) is applied to the source IP address and this address is compared to the list of bindings: if a binding exists, the packet is sent to the same load balancing server previously selected for this client; if there is not a match, a new binding is created.

This feature allows a range of source IP addresses (with different port numbers) to be sent to the same load balancing server. This is useful where client requests may go through a proxy that uses Network Address Translation or Port Address Translation or multiple proxy servers. During a session, the source IP address can change to one of several sequential addresses in the translation pool; the netmask allows client requests to be sent to the same server.

The following example configures the load balancing group “abccompany-www” with a persistence level of SSL:

```
rs(config)# load-balance create group-name abccompany-www virtual-ip
207.135.89.16 virtual-port 80 protocol tcp persistence-level ssl
```

25.1.2 Adding Servers to the Load Balancing Group

Once a logical server group is created, you specify the servers that can handle client requests. When the RS receives a client request directed to the virtual server address, it redirects the request to an actual server address and port. Server selection is done according to the specified policy.

The following example adds servers to the “abccompany-www” load balancing group:

```
rs(config)# load-balance add host-to-group 10.1.1.1-10.1.1.4 group-name
abccompany-www port 80
```

You can add backup servers to a load balancing group by specifying the **status backup** parameter in the **load-balance add host-to-group** command. The backup servers are sent client requests *only* if a load balancing server or an application on a load balancing server is “down” (as determined by the RS’s verification checking). In the following example, the server with an IP address of 10.1.1.5 is added as a backup server:

```
rs(config)# load-balance add host-to-group 10.1.1.5 group-name
abccompany-www port 80 status backup
```

You can also issue the **load-balance set server-status** command to set a load balancing server to a “down” state. When the server or application that was “down” is again able to receive requests, the backup server finishes processing its current client requests but no new requests will be directed to it.

25.1.3 Setting Timeouts for Load Balancing Mappings

The mapping between a host (source) and a load-balancing server (destination) times out after a certain period of non-activity. After the mapping times out, any server in the load balancing group can be selected. The default timeout depends upon the session persistence level configured, as shown below:

Table 25-1 Default binding timeouts

Persistence Level	Default Binding Timeout
TCP	3 minutes
SSL	120 minutes
Sticky	120 minutes
VPN	3 minutes
IP	3 minutes

You can change the default timeout for a server group with the **load-balance set aging-for-src-maps** command. In the following example, the default timeout was changed to 100 for the “mktgroup” server group. All other groups use the defaults listed in Table 25-1:

```
rs(config)# load-balance set aging-for-src-maps mktgroup aging-time 100
```

You can use the **load-balance show source-mappings** command to display information about the current list of bindings.

25.1.4 Optional Group or Server Operating Parameters

The **load-balance set server-options** command and **load-balance set group-options** command have several parameters that affect the operations of individual servers or the entire group of load balancing servers. In many cases, there are default parameter values and you only need to specify a different value if you wish to change the default operation. For example, you can specify the policy to be used for distributing the workload for a group of load balancing servers created with the parameter **protocol tcp**. By default, the RS assigns sessions to these servers in a round-robin (sequential) manner.

Specifying a Load Balancing Policy

The default policy for distributing workload among load balancing servers is "round-robin," where the RS selects the server on a rotating basis without regard to the load on individual servers. Other policies can be chosen for the group as follows:

- least loaded, where the server with the fewest number of sessions bound to it is selected to service a new session.
- weighted round robin, a variation of the round-robin policy where each server takes on new sessions according to its assigned weight. If you choose the weighted round robin policy, you must assign a weight to each server that you add to the load balancing group.
- fastest, where the server with the fastest response time is selected to service a new session.
- predictive, where the server with the fastest decreasing response time is selected to service a new session.

Note These policies only affect TCP traffic; UDP and IP traffic are load-balanced using a fixed IP-hash policy.

The following example sets the load balancing policy of the "mktgroup" server group to least-loaded:

```
rs(config)# load-balance set group-options mktgroup policy least-loaded
```

Specifying a Connection Threshold

By default, there is no limit on the number of sessions that a load balancing server can service. You can specify the maximum number of connections that each server in a group can service. The following example sets the maximum number of connections for each server in the "mktgroup" group:

```
rs(config)# load-balance set group-options mktgroup group-conn-threshold 800
```

Note This limits the number of connections for *each* server in the group, not the total number of connections for the group.

Checking Servers and Applications

The RS *automatically* performs the following types of verification for the attached load balancing servers/applications:

- Verifies the state of the server by sending a ping to the server at 5-second intervals. If the RS does not receive a reply from a server after four ping requests, the server is considered to be "down."
- Checks that an application session on the server can be established by doing a simple TCP handshake with the application on the configured physical port of the server at 15-second intervals. If the RS does not receive a reply from the application after four tries, the application is considered to be "down."

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the server or application to be "down." You can change these parameters for all servers in a load balancing group or for specific servers.

The following example modifies the defaults for the pings from the RS to the "mktgroup" server group:

```
rs(config)# load-balance set group-options mktgroup ping-tries 3 ping-int 10
```

The following example sets the time between handshakes at port 80:

```
rs(config)# load-balance set server-options 135.142.179.14 app-int 8 port 80
```

In addition, the RS can also check the status of any attached Domain Name Servers (DNS) servers and RADIUS servers. To verify the state of a DNS server, the RS sends a lookup request for a host name. The RS then checks the response of the DNS server for the specified IP address and host-name. The following example sets the IP address and host name:

```
rs(config)# load-balance set group-options mktgroup dns-host-ip 135.142.179.10
dns-host-name www-fast
```

The RS verifies the status of a RADIUS server by sending it queries and verifying the response it receives. You define the user name, password, and MD5 encryption key that the RS will include in its queries. You can specify invalid values for the user name and password. A positive response to a query with valid values or a negative response to a query with invalid values indicates that the RADIUS server is "up." The following example sets the values for the query to the RADIUS server:

```
rs(config)# load-balance set group-options mktgroup radius-username radiusserv
radius-password a1b2c3e4f5 radius-md5 abcdegh
```

Verifying Extended Content (Comprehensive Server Checking)

You can also have the RS verify the *content* of an application on one or more load balancing servers. For this type of verification, specify the following:

- A string that the RS sends to a single server or to the group of load balancing servers. The string can be a simple HTTP command to get a specific HTML page. Or, it can be a command to execute a user-defined CGI script that tests the operation of the application.
- The reply that the application on each server sends back. The RS uses this reply to validate the content. In the case where a specific HTML page is retrieved, the reply can be a string that appears on the page, such as "OK." If a CGI script is executed on the server, it should return a specific response (for example, "OK") that the RS can verify.

Note that you can specify this type of verification for a group of load balancing servers or for a specific server.

Application verification, whether a simple TCP handshake or a user-defined action-response check, involves opening and closing a connection to a load balancing server. Some applications require specific commands for proper closure of the connection. For example, a connection to an SMTP server application should be closed with the "quit" command. You can configure the RS to send a specific string to close a connection on a server.

If you have a proprietary protocol, you can verify whether the protocol is "up" by specifying the files for the application content verification request, reply and quit strings.

25.1.5 Using Health Check Clusters

The RS automatically performs health checks on its attached load balancing servers. It verifies the state of each server and checks that an application session on the server can be established. When a load balancing server has multiple IP addresses, you can configure a health check cluster so the RS health checks only one designated IP address instead of all the IP addresses assigned to the server.

Following are the steps for configuring a health check cluster:

1. Create the health check cluster.
2. Add servers to the health check cluster.
3. Optionally, set parameters for the health check cluster.

The following example configures the "hcc1" health check cluster:

```
load-balance create health-check-cluster hcc1 ip-to-check 135.142.179.12 port-to-check
10
load-balance add-host-to-group 135.142.179.15-135.142.179.18 group-name hcc1
health-check-cluster hcc1
```

25.1.6 Setting Server Status

It may become necessary at times to prevent new sessions from being directed to one or more load balancing servers. For example, if you need to perform maintenance tasks on a server system, you might want new sessions to temporarily *not* be directed to that server. Setting the status of a server to "down" prevents new sessions from being directed to that server. The "down" status does not affect any current sessions on the server. When the server is again ready to accept new sessions, you can set the server status to "up."

The following example sets the status of port 80 at address 135.142.179.14 to up:

```
rs # load-balance set server-status server-ip 135.142.179.14
server-port 80 group-name engservers status up
```

25.1.7 Load Balancing and FTP

File Transfer Protocol (FTP) packets require special handling with load balancing, because the FTP packets contain IP address information within the data portion of the packet. If the FTP control port used is not port 21, it is important for the RS to know the port number that is used for FTP. Therefore you need to specify the FTP control port as shown in the following example:

```
rs(config)# load-balance set ftp-control-port 10
```

25.1.8 Allowing Load Balancing Servers to Access the Internet

A load balancing server may need to occasionally make its own request to the Internet in order to complete a client's request. For example, a DNS server that is being load balanced may need to send a request to another DNS server on the Internet to resolve a hostname. To allow Network Address Translation (NAT) for the server's Internet request (and the reply), you must specify the port numbers that the load balancing servers will use for these requests.

Following example specifies a range of ports for Internet requests by the "mktgroup" load balancing group:

```
rs(config)# load-balance set wildcard-lsnapt-range mktgroup
source-port-range 11-15
```

25.1.9 Allowing Access to Load Balancing Servers

Load balancing causes both source and destination addresses to be translated on the RS. It may be undesirable in some cases for a source address to be translated; for example, when data is to be updated on an individual server. Specified hosts can be allowed to directly access servers in the load balancing group without address translation. Note, however, that such hosts cannot use the virtual IP address and port number to access the load balancing group of servers.

In the following example, access is allowed to servers in the IP address range of 135.142.179.14 to 135.142.179.21:

```
rs(config)# load-balance allow access-to-servers client-ip
135.142.179.14-135.142.179.21 group-name mktgroup
```

25.1.10 Virtual State Replication Protocol (VSRP)

VSRP provides redundancy in a dual load balancer setting. It runs between two RS's that have the same load balancing group configured, enabling them to mirror each other's session information for a particular load balancing group. VSRP runs in the active-active mode, so the RS's share persistence information in real time. Thus, should one RS go down, the other is able to immediately take over.

For VSRP to run properly, configure the same load balancing group on the two RS's. (Note that the group's configuration on both RS's should be exactly the same.) Then, enter the **`load-balance create state-mirror-peer`** command and the **`load-balance add group-for-mirroring`** command on both RS's.

VSRP Example

The group www.fast.net is configured on two RS's. The IP address of RS A is 100.1.1.1 and the IP address of RS B is 100.1.1.2. The two RS's are configured to mirror each other's session information for the group www.fast.net.

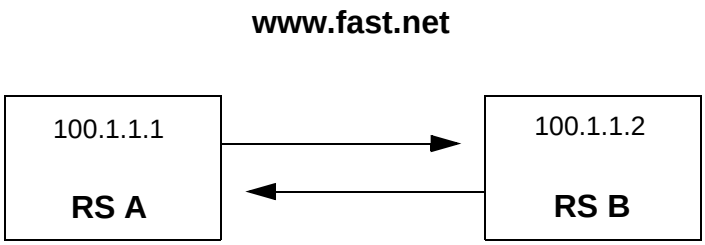


Figure 25-1 VSRP configuration example

To mirror the sessions of RS A, enter the following commands on RS A:

```
load-balance create state-mirror-peer 100.1.1.2 src-ip-to-use 100.1.1.1
load-balance add group-for-mirroring www.fast.net ip-of-peer 100.1.1.2
```

To mirror the sessions of RS B, enter the following commands on RS B:

```
load-balance create state-mirror-peer 100.1.1.1 src-ip-to-use 100.1.1.2
load-balance add group-for-mirroring www.fast.net ip-of-peer 100.1.1.1
```

25.1.11 Displaying Load Balancing Information

To display load balancing information, enter the following commands in Enable mode:

Show the groups of load balancing servers.	**load-balance show virtual-hosts [group-name** *<group name>***][virtual-ip** *<ipaddr>***][virtual-port** *<port number>*|*ip***]**
Show source-destination bindings.	**load-balance show source-mappings [client-ip** *<ipaddr/range>***][virtual-ip** *<ipaddr>***][virtual-port** *<port number>*|*ip***] [destination-host-ip** *<ipaddr>***]**
Show load balancing statistics.	**load-balance show statistics [group-name** *<group name>***][virtual-ip** *<ipaddr>***] [virtual-port** *<port number>*|*ip***]**
Show load balance hash table statistics.	**load-balance show hash-stats**
Show load balance options for verifying the application.	**load-balance show acv-options [group-name** *<group name>***][destination-host-ip** *<virtual-ipaddr>***][destination-host-port** *<virtual-port-number>*|*ip***]**
Show information about the health check clusters.	**load-balance show health-check-clusters**
Show session mirroring information.	**load-balance show session-mirror-info peer-ip** *<ipaddr>*

25.1.12 Configuration Examples

This section shows examples of load balancing configurations.

Web Hosting with One Virtual Group and Multiple Destination Servers

In the following example, a company web site is established with a URL of www.abccompany.com. The system administrator configures the networks so that the RS forwards web requests among four separate servers, as shown below.

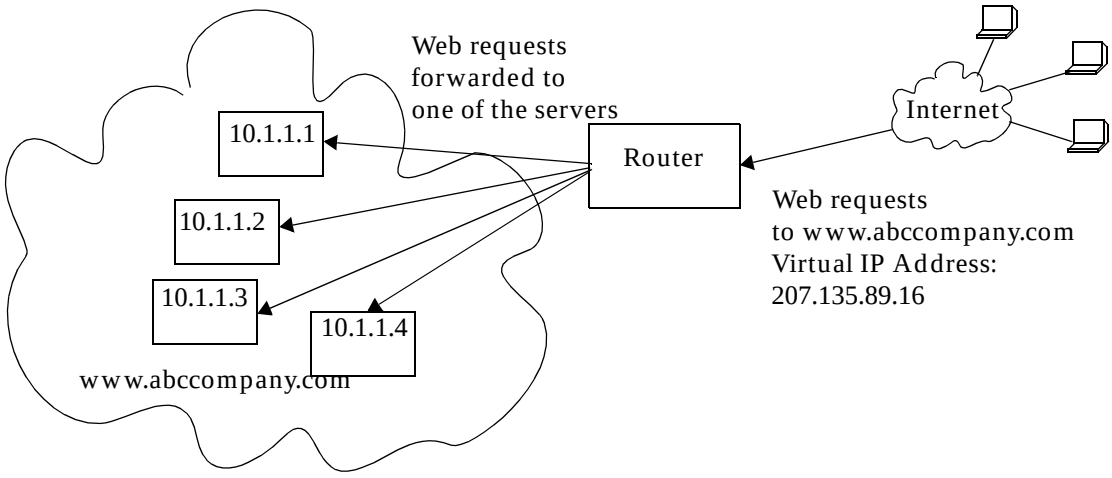


Figure 25-2 Load balancing with one virtual group

Domain Name	Virtual IP	TCP Port	Real Server IP	TCP Port
www.abccompany.com	207.135.89.16	80	10.1.1.1	80
			10.1.1.2	80
			10.1.1.3	80
			10.1.1.4	80

The network shown above can be created with the following **`load-balance`** commands:

```
load-balance create group-name abccompany-www virtual-ip 207.135.89.16 virtual-port 80
protocol tcp
load-balance add host-to-group 10.1.1.1-10.1.1.4 group-name abccompany-www port 80
```

The following is an example of how to configure a simple verification check where the RS will issue an HTTP command to retrieve an HTML page and check for the string “OK”:

```
load-balance set group-options abccompany-www acv-command “GET /test.html” acv-reply
“OK” read-till-index 25
```

The **read-till-index** option is not necessary if the file test.html contains “OK” as the first two characters. The **read-till-index** option is helpful if the exact index of the **acv-reply** string in the file is not known to the user. In the above example, the RS will search from the beginning of the file up to the 25th character for the start of the string “OK.”

Web Hosting with Multiple Virtual Groups and Multiple Destination Servers

In the following example, three different servers are used to provide different services for a site.

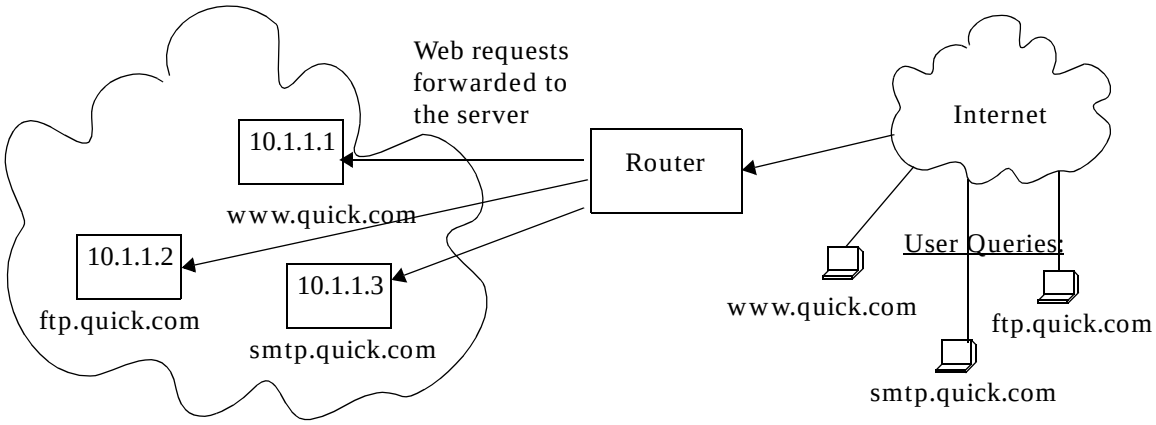


Figure 25-3 Load balancing with multiple virtual groups

Domain Name	Virtual IP	TCP Port	Real Server IP	TCP Port
www.quick.com	207.135.89.16	80	10.1.1.1	80
ftp.quick.com	207.135.89.16	21	10.1.1.2	21
smtp.quick.com	207.135.89.16	25	10.1.1.3	25

The network shown above can be created with the following load-balance commands:

```
load-balance create group-name quick-www virtual-ip 207.135.89.16 virtual-port 80
protocol tcp
load-balance create group-name quick-ftp virtual-ip 207.135.89.16 virtual-port 21
protocol tcp
load-balance create group-name quick-smtp virtual-ip 207.135.89.16 virtual-port 25
protocol tcp
load-balance add host-to-group 10.1.1.1 group-name quick-www port 80
load-balance add host-to-group 10.1.1.2 group-name quick-ftp port 21
load-balance add host-to-group 10.1.1.3 group-name quick-smtp port 25
```

If no application verification options are specified, the RS will do a simple TCP handshake to check that the application is "up." Some applications require specific commands for proper closure of the connection. The following command shows an example of how to send a specific string to close a connection on a server:

```
load-balance set group-options quick-smtp acv-quit "quit"
```

Virtual IP Address Ranges

ISPs who provide web hosting services for their clients require a large number of virtual IP addresses (VIPs). The **load-balance create vip-range-name** and **load-balance add host-to-vip-range** commands were created specifically for this. An ISP can create a range of VIPs for up to an entire class C network with the **load-balance create vip-range-name** command. Once the vip-range is in place, the ISP can then create the corresponding secondary addresses on their destination servers. Once these addresses have been created, the ISP can add these servers to the vip-range with the **load-balance add host-to-vip-range** command. These two commands combined help ISPs take advantage of web servers like Apache that serve different web pages based on the destination address in the HTTP request.

The following example illustrates this.

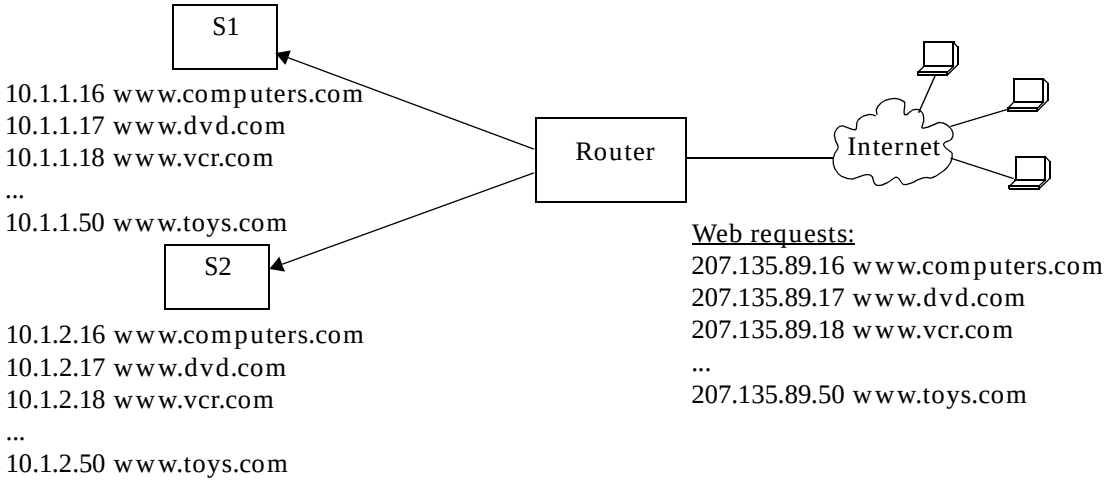


Figure 25-4 Virtual IP address ranges

Group Name	Virtual IP	TCP Port	Destination Server IP	TCP Port
www.computers.com	207.135.89.16	80	S1: 10.1.1.16 S2: 10.1.2.16	80
www.dvd.com	207.135.89.17	80	S1: 10.1.1.17 S2: 10.1.2.17	80
www.vcr.com	207.135.89.18	80	S1: 10.1.1.18 S2: 10.1.2.18	80
www.toys.com	207.135.89.50	80	S1: 10.1.1.50 S2: 10.1.2.50	80

The network shown in the previous example can be created with the following load-balance commands:

```
load-balance create vip-range-name mywwwrange 207.135.89.16-207.135.89.50
virtual-port 80 protocol tcp
load-balance add host-to-vip-range 10.1.1.16-10.1.1.50 vip-range-name mywwwrange port
80
load-balance add host-to-vip-range 10.1.2.16-10.1.2.50 vip-range-name mywwwrange port
80
```

Session and Netmask Persistence

In the following example, traffic to a company web site (www.abccompany.com) is distributed between two separate servers. In addition, client traffic will have two separate ranges of source IP addresses. The same load balancing server will handle requests from clients of the same source IP subnet address.

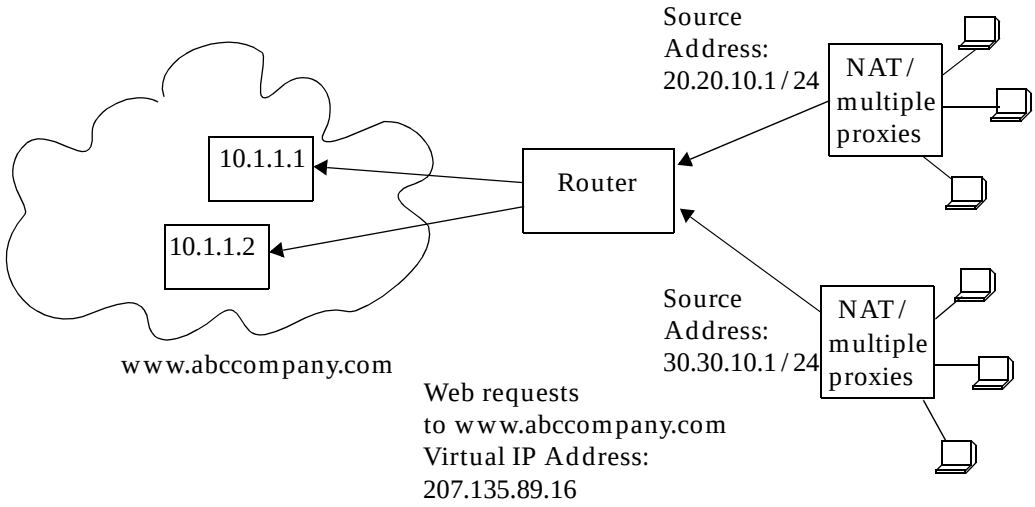


Figure 25-5 Session and netmask persistence

Client IP Address	Domain Name	Virtual IP	Real Server IP	TCP Port
20.20.10.1 - 20.20.10.254	www.abccompany.com	207.135.89.16	10.1.1.1	80
30.30.10.1 - 30.30.10.254			10.1.1.2	80

The network shown above can be created with the following load-balance commands:

```
load-balance create group-name abccompany-sec virtual-ip 207.135.89.16 protocol tcp
persistence-level ssl virtual-port 443
load-balance add host-to-group 10.1.1.1-10.1.1.2 group-name abccompany-sec port 443
load-balance set client-proxy-subnet abccompany-sec subnet 24
```

Load Balancing with NAT

In the following example, several services (including DNS) are distributed between two separate servers. Occasionally, the load balancing server will need to make its own DNS request to the Internet in order to resolve a client's DNS request. Network Address Translation (NAT) on the RS allows the load balancing servers to use a "global" IP address for Internet requests. NAT translates the "local" address of the load balancing server to the global address for the outgoing request and translates the global address back to the local address for the incoming reply. This process is illustrated in Figure 25-6.

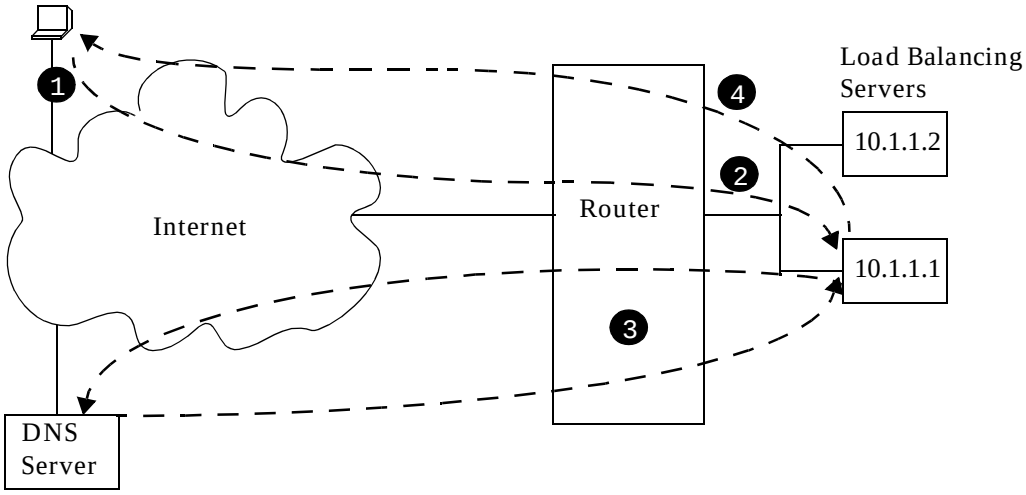


Figure 25-6 Load balancing with NAT

The following explains the data flows shown in Figure 25-6:

1. The client sends a DNS request to the virtual IP address 135.1.1.1:53.
2. The client's DNS request is redirected to a load balancing server.
3. The load balancing server sends a request to an authoritative DNS server on the Internet. NAT on the RS translates the load balancing server's internal IP address (10.1.1.1) to the global IP address 136.1.1.100 for the request. For the reply, NAT translates the global IP address back to the internal IP address and sends the reply message to the load balancing server.
4. The load balancing server sends a DNS reply back to the client.

The network shown in the example can be created with the following commands:

```
! create the load balancing group 'service2' with virtual IP address 135.1.1.1
load-balance create group-name service2 virtual-ip 135.1.1.1 protocol udp
load-balance add host-to-group 10.1.1.1-10.1.1.2 group-name service2
load-balance set wildcard-lsnapt-range service2 source-port-range 1024-65535

! traffic from these source ports will not be translated by NAT
acl nat-acl deny tcp any any 53 any
acl nat-acl deny udp any any 53 any
acl nat-acl deny tcp any any 80 any
acl nat-acl deny tcp any any 443 any

! traffic from these source ports will be translated by NAT
acl nat-acl permit tcp 10.1.0.0/16 any 1024-65535 any
acl nat-acl permit udp 10.1.0.0/16 any 1024-65535 any

! requests from 10net servers using ports 1024-65535 are translated to global
! address 136.1.1.100 with PAT, and vice versa
nat set interface 10net inside
nat set interface 136net outside
nat create dynamic local-acl-pool nat-acl global-pool 136.1.1.100 enable-ip-overload
```

25.2 WEB CACHING

Web caching provides a way to store frequently accessed Web objects on a cache of local servers. Each HTTP request is transparently redirected by the RS to a configured cache server. When a user first accesses a Web object, that object is stored on a cache server. Each subsequent request for the object uses this cached object. Web caching allows multiple users to access Web objects stored on local servers with a much faster response time than accessing the same objects over a WAN connection. This can also result in substantial cost savings by reducing the WAN bandwidth usage.

Note The RS itself does not act as cache for web objects. It redirects HTTP requests to local servers on which the web objects are cached. One or more local servers are needed to work as cache servers with the RS's web caching function.

25.2.1 Configuring Web Caching

The following are the steps in configuring Web caching on the RS:

1. Create the cache group (a list of cache servers) to cache Web objects.
2. Specify the hosts whose HTTP requests will be redirected to the cache servers. This step is optional; if you do not explicitly define these hosts, then *all* HTTP requests are redirected.
3. Apply the caching policy to an outbound interface or port to redirect HTTP traffic on that interface or port to the cache servers.

Creating the Cache Group

You can specify either a range of contiguous IP addresses or a list of up to four IP addresses to define the servers when the cache group is created. If you specify multiple servers, load balancing is based on the destination address of the request. If any cache server fails, traffic is redirected to the other active servers.

The following example configures the “testweb1” caching policy for the “weblist1” cache group:

```
rs(config)# web-cache testweb1 create server-list weblist1 range
“10.10.10.1 10.10.10.100”
```

Note If a range of IP addresses is specified, the range must be contiguous and contain no more than 256 IP addresses.

Specifying the Client(s) for the Cache Group (Optional)

You can explicitly specify the hosts whose HTTP requests are or are not redirected to the cache servers. If you do not explicitly specify these hosts, then *all* HTTP requests are redirected to the cache servers.

The following example specifies that HTTP requests from the address range 135.142.179.14 to 135.142.179.21 should be redirected to the cache servers:

```
rs(config)# web-cache testweb1 permit hosts range “135.142.179.14
135.142.179.21”
```

Redirecting HTTP Traffic on an Interface or Port

To start the redirection of HTTP requests to the cache servers, you need to apply the caching policy to a specific outbound interface or port. This interface or port is typically an interface that connects to the Internet. If you apply the caching policy to an interface, the interface should not be on the same subnet as the web cache servers.

Apply a caching policy to a port when redirecting bridged traffic. When you do so, L4 bridging must be enabled, and the clients, servers, and ports must belong to the same VLAN. In addition, for 802.1Q trunk ports, you can specify a particular VLAN.

Note By default, the RS redirects HTTP requests on port 80. Secure HTTP (https) requests do not run on port 80, therefore these types of requests are not redirected by the RS.

The following example applies the policy “testweb1” to port et.3.1:

```
rs(config)# web-cache testweb1 apply port et.3.1
```

25.2.2 Configuration Example

In the following example, a cache group of seven local servers is configured to store Web objects for users in the local network:

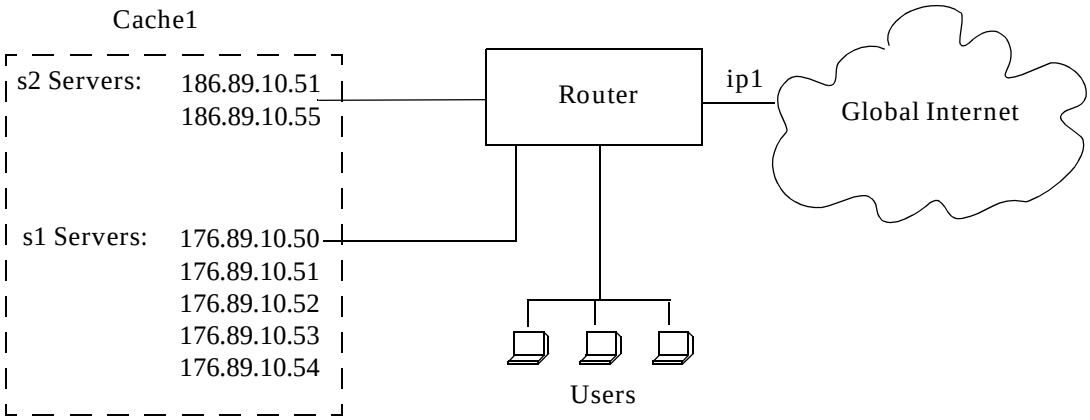


Figure 25-7 Web cache configuration

The following commands configure the cache group ‘cache1’ that contains the servers shown in the figure above and applies the caching policy to the interface ‘ip1’:

```
rs(config)# web-cache cache1 create server-list s1 range “176.89.10.50 176.89.10.54”
rs(config)# web-cache cache1 create server-list s2 list “186.89.10.51 186.89.10.55”
rs(config)# web-cache cache1 apply interface ip1
```

Note that in this example, HTTP requests from *all* hosts in the network are redirected as there are no **web-cache permit** or **web-cache deny** commands.

25.2.3 Other Web-Cache Options

This section discusses other commands that may be useful in configuring Web caching in your network.

Bypassing Cache Servers

Some Web sites require source IP address authentication for user access, therefore HTTP requests for these sites *cannot* be redirected to the cache servers. You can specify the sites for which HTTP requests are not redirected to the cache servers, as shown in the following example:

```
rs(config)# web-cache testweb1 create bypass-list range “135.142.179.14
135.142.179.21”
```

In the preceding example, a bypass list for testweb1 is created. The list has an address range of 135.142.179.14 to 135.142.179.21. HTTP requests for these sites will not be redirected

Proxy Server Redundancy

Some networks use proxy servers that receive HTTP requests on a non-standard port number (i.e., not port 80). When the proxy server is available, all HTTP requests are handled by the proxy server. The RS can provide proxy server redundancy by transparently redirecting HTTP connections to the cache servers should the proxy server fail. To achieve this, the RS must be configured to redirect HTTP requests on the (non-standard) HTTP port used by the proxy server.

In the following example, the HTTP port number for testweb1 is set to port 40:

```
rs(config)# web-cache testweb1 set http-port 40
```

Disabling Redirection on an Inbound Interface or Port

When you apply a caching policy, HTTP requests that are received on *all* inbound interfaces on the RS are redirected to the local cache servers. You can specify that redirection of requests *not* be done for a particular inbound interface or port.

In the following example, HTTP requests on the interface int100 will not be redirected:

```
rs(config)# web-cache testweb1 create filter interface int100
```

Specifying Protocol for Redirected Traffic

By default, only TCP traffic is redirected to the local cache servers. You can specify a different IP protocol for the traffic that is to be redirected. For example, you can specify that UDP traffic be redirected. For any protocol other than TCP or UDP, you will need to specify the assigned IP protocol number as defined in RFC 1060.

The following example specifies that UDP traffic will be redirected:

```
rs(config)# web-cache testweb1 set redirect protocol udp
```

Configuring the traffic to be redirected (with the **`web-cache set redirect-protocol`** command) and the HTTP port (with the **`web-cache set http-port`** command) allows transparent redirection of traffic for any application that is supported by the cache servers.

Distributing Frequently-Accessed Sites Across Cache Servers

The RS uses the destination IP address of the HTTP request to determine to which cache server to send the request. However, if there is a Web site that is being accessed very frequently, the cache server serving requests for this destination address may become overloaded with user requests. You can specify one of the following policies for distributing certain destination addresses across the cache servers:

- round-robin, where the RS selects the cache server on a rotating basis regardless of the load on individual servers

- weighted round robin, a variation of the round-robin policy where the RS selects the cache server according to its assigned weight
- weighted hash.

When you select either weighted round robin or weighted hash, you will need to specify the weight of the server group with the **web-cache set server-options** command.

The following example specifies that the weighted round-robin policy will be used to distribute the specified address range across the cache servers:

```
rs(config)# web-cache testweb1 selection-policy weighted-round-robin range
"135.142.179.14 135.142.179.21"
rs(config)# web-cache testweb1 set server-options webgrp1 wrr-weight 2
```

Specifying a Connection Threshold

By default, the RS will redirect up to 2000 HTTP requests to a web caching server. You can configure the maximum number of connections that each server can handle.

The following example sets the maximum number of connections to 200:

```
rs(config)# web-cache testweb1 set maximum-connections webgrp1 200
```

Note This command limits the number of connections for *each* server in the group, not the total number of connections for the group.

Verifying Servers

The RS can verify the state of the cache server by sending a ping to the server at 5-second intervals. If the RS does not receive a reply from a server after four ping requests, the server is considered to be "down."

If you specify that the RS use TCP connection requests to check the gateway (instead of sending ICMP echo requests), the RS checks that an application session on the server can be established by sending a TCP connection request to the application on the configured port of the server at 15-second intervals. If the RS does not receive a reply from the application after four tries, the application is considered to be "down."

You can change the intervals at which pings or handshakes are attempted and the number of times that the RS retries the ping or handshake before considering the server or application to be "down."

In the following example, the servers in the weblist1 server group will be pinged at 7-second intervals. If the RS does not receive a reply after 3 ping requests, the server will be considered "down."

```
rs(config)# web-cache testweb1 set server-options weblist1 ping-tries 3
ping-int 7
```

25.2.4 Monitoring Web-Caching

To display Web-caching information, enter the following commands in Enable mode.

Show information for all caching policies and all server lists.	**web-cache show all**
Show caching policy information.	**web-cache show cache-name** <*cache-name*> **|all**
Show cache server information.	**web-cache show servers cache** <*cache-name*> **|all**
Show statistics for the specified cache policy.	**web-cache show statistics**

26 ACCESS CONTROL LIST CONFIGURATION

This chapter explains how to configure and use Access Control Lists (ACLs) on the RS. ACLs consist of rules, which in turn are defined by match criteria. When used in conjunction with certain RS features, ACLs provide control over the forwarding of layer-3 and layer-4 traffic.

26.1 ACL BASICS

An ACL consists of a protocol type and one or more rules which tell the RS to either *permit* or *deny* packets that match the match criteria on which each rule is based. These rules describe particular types of IP packets. ACLs can be simple, consisting of only one rule or they can be complicated, containing a number of rules for assessing packets.

Each ACL is identified by a name, consisting of alphanumeric characters. The ACL name can be a meaningful string such as **denyFTP** or it can be a simple number such as **100** or **101**.

For example, the following ACL (**101**) consists of a single rule that permits all IP packets from subnet **140.134.170.0/24** to go out through the interface named "**to-marketing**."

```
rs(config)# acl 101 permit ip 140.134.170.0/24
rs(config)# acl 101 apply interface to-marketing output
```

The following example is a more sophisticated ACL, consisting of three rules, and is applied to inbound packets on interface **Int-2**:

```
rs(config)# acl 102 permit ip 134.121.96.0/24 any any any
rs(config)# acl 102 deny ip 141.77.132.0/24 any any any
rs(config)# acl 102 deny tcp any any any any
rs(config)# acl 102 apply interface Int-2 input
```

In the previous example, each rule is added to the ACL using separate entries of the **acl** command.

Note Notice in the examples above that ACL rules are defined as either **permit** or **deny**. All ACL rules must either permit a packet or deny it, no other choices of action are permitted.

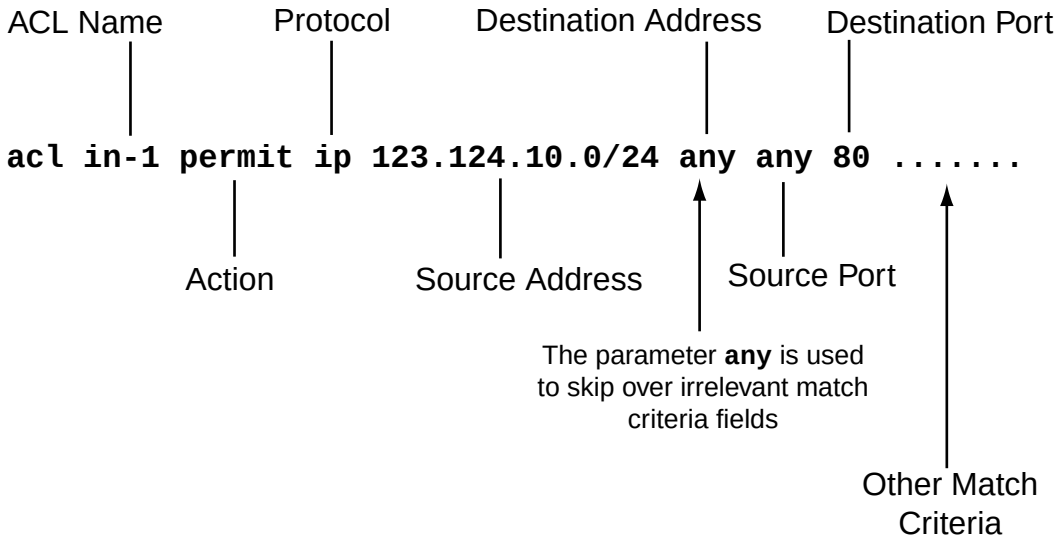


Figure 26-1 Basic components of an ACL

26.1.1 Match Criteria and Creating Rules for ACLs

ACL rules are based on a set of *match criteria*. Match criteria in an ACL describes characteristics about a packet, which is to be either permitted or denied. These match criteria are used to create *rules*. In turn, a set of rules define an ACL. In the first example, ACL **101** consisted of a single rule whose match criteria is:

1. Check if packet is an IP packet
2. Check whether the packet came from subnet **140.134.170.0**

If the above match criteria is met, the packet is permitted to exit through the interface **to-marketing**.

For each protocol type, each match criteria field is position-sensitive. For example, for an IP ACL, the source address is specified first, followed by the destination address, followed by the source port, followed by the destination port, and so on. Specifically, each criterion that define ACL rules are ANDed in order of position from left-to-right. Any match criteria fields that are left blank are wild carded.

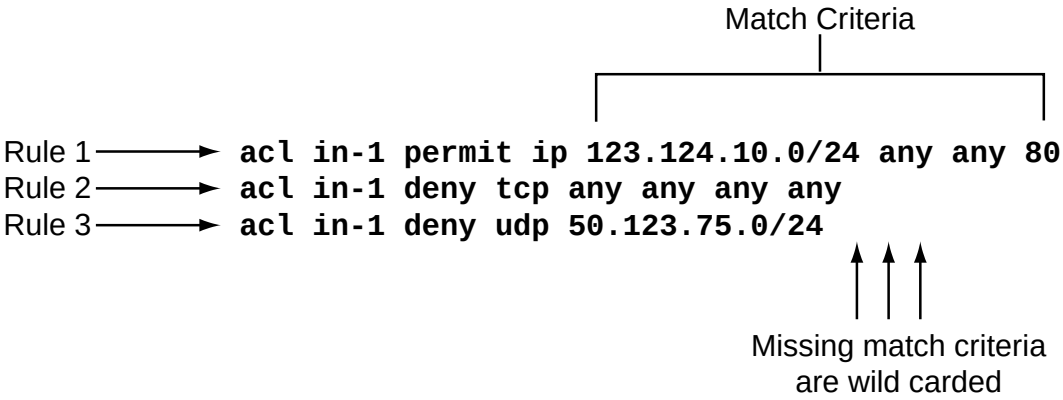


Figure 26-2 Relationship between match criteria and rules

Match Criteria According to Protocol Type

Match criteria differs depending on the protocol type specified in the ACL. The protocol type is not a match criteria and cannot contain the **any** parameter or be left blank. The protocol type for the ACL must be specified.

For example, an ACL rule of protocol type **ip** can include the following elements as match criteria:

- Source IP address
- Destination address
- Source port number
- Destination port number
- TOS
- Accounting

Note The **accounting** keyword specifies that accounting information about the flow is sent to the configured Flow Accounting Server (FAS) or other accounting application using the Light-Weight Flow Accounting Protocol (LFAP). The **accounting** parameter must be followed by one of three *checkpoint* time interval parameters: **5-minutes**, **15-minutes**, or **hourly**. See Chapter 31 *"LFAP Configuration Guide"* for more information.

Table 26-1 lists the match criteria for each protocol type and the position in which each must appear within the corresponding ACL.

Table 26-1 ACL protocol types and match criteria

Protocol-type[1]	Match Criteria[2]
icmp	Source address and mask, destination address and mask, TOS
igmp	Source address and mask, destination address and mask, TOS
ip	Source address and mask, destination address and mask, source port[4], destination port[4], TOS, TOS mask, accounting
ip-protocol[3]	Protocol number, source address and mask, destination address and mask, TOS
route-filter	IP address and mask
tcp	Source address and mask, destination address and mask, source port, destination port, TOS, TOS mask, accounting, established
udp	Source address and mask, destination address and mask, source port, destination port, TOS, TOS mask, accounting

1. All protocol-types match criteria support the **log** parameter for sending ACL activity to a Syslog server.
2. Most of these match criteria can be skipped by using the keyword **any**.
3. For a list of **ip-protocol** numbers, see the *Riverstone Networks RS Switch Router Command Line Interface Reference.*
4. For a list of **port** numbers, see the *Riverstone Networks RS Switch Router Command Line Interface Reference.*

The Any Parameter and Wild Cards

When defining an ACL it may be desirable to skip a match criteria field. For example, an ACL is defined where the source address is immaterial, but the destination address is required. Since each match criteria field is position-sensitive, the keyword **any** is used to skip a field – in this case, the source address. In effect, **any** says "Accept any value for this match criteria."

For example, the following ACL denies Telnet traffic between any source and destination address and illustrates both the use of the **any** parameter and the use of wild carding:

```
rs(config)# acl NoTelnet deny ip any any telnet telnet
```

Notice in the previous example that both the source address and the destination address are skipped over using the **any** parameter. Also, notice that the 5th field (the TOS field) is left blank and is treated as a wildcard. The keyword **any** is needed only to skip a field in order to explicitly specify another field whose position is further along in the ACL On the other hand, if the skipped criteria is at the end of the ACL rule it can be left blank, representing a wildcard.

For example, the following ACL permits all IP-based traffic to pass through the interface **Int-1** because all match criteria for protocol type **ip** are left blank (wild cards):

```
rs(config)# acl All-IP permit ip
rs(config)# acl All-IP apply interface Int-1 input output
```

26.1.2 How Multiple ACL Rules are Evaluated

The sequence of the rules within an ACL consisting of multiple rules is important. When the RS checks a packet against an ACL, it applies rules in the order in which they reside within the ACL – from first to last. If a packet matches a rule, it is forwarded or dropped based on the **permit** or **deny** keyword in the rule. All subsequent rules are ignored. That is, a first-match algorithm is used when applying rules to packets.

Consequently, rules that are more specific (contain more match criteria) should usually be listed ahead of rules that are less specific. For example, the following ACL permits all TCP traffic except any TCP traffic from subnet **100.20.20.0/24**:

```
rs(config)# acl 101 deny tcp 100.20.20.0/24
rs(config)# acl 101 permit tcp
```

Notice in the previous example that ACL **101** includes two rules:

1. Deny TCP packets from subnet **100.20.20.0**
2. Permit TCP packets

A TCP packet coming from subnet **10.2.0.0/16** matches the first ACL rule, which results in the packet being dropped. However, a TCP packet coming from any other subnet does not match the first ACL rule. Instead, it matches the second ACL rule, which allows the TCP packet through.

Consider the case where the ACL rules in the previous example are reversed:

```
rs(config)# acl 101 permit tcp
rs(config)# acl 101 deny tcp 100.20.20.0/24
```

All TCP packets are allowed through, including packets from subnet **100.20.20.0**. Because TCP traffic coming from **100.20.20.0** matches the first rule, “all TCP packets are allowed through.” The second rule is not applied because the first rule that matches determines the action taken on the packet.

Note Remember that the first rule that applies to a packet is the only rule that affects the packet. The packet is permitted or denied according to the first rule it satisfies; none of the remaining ACL rules have any effect on the packet.

Implicit Deny Rule

At the end of each ACL, the RS automatically appends the *implicit deny rule*. For a packet that doesn’t match any of the user-specified rules, the implicit deny rule acts as a catch-all rule that denies all packets – all packets match this rule.

The implicit deny rule exists for security reasons. If an ACL is misconfigured, and a packet that should be allowed to go through is blocked by the implicit deny rule, the worst that happens is an inconvenience. However, a security breach results if a packet that should not be allowed through is sent through. As a result, the implicit deny rule serves as a fail-safe against the accidental misconfiguration of ACLs.

To illustrate how the implicit deny rule works, consider the following ACL:

```
rs(config)# acl 101 permit ip 100.20.30.40/24
rs(config)# acl 101 permit ip 124.123.220.10/24 any nntp
```

With the implicit deny rule, this ACL actually has three rules as shown in the following example:

```
rs(config)# acl 101 permit ip 100.20.30.40/24
rs(config)# acl 101 permit ip 124.123.220.10/24 any nntp
rs(config)# acl 101 deny any any any any any
```

If a packet comes in and doesn't match either of the first two rules, the packet is dropped, because the third rule (the implicit deny rule) matches all packets. Although the implicit deny rule may seem obvious in the previous example, this is not always the case.

For example, consider the following ACL rule:

```
rs(config)# acl 102 deny ip 140.124.200.0/24
```

If a packet comes in from a subnet other than **140.124.200.0**, one might expect the packet to go through, because it doesn’t match the first rule, however, this is not the case. With the implicit deny rule attached, the rule looks like this:

```
rs(config)# acl 102 deny ip 140.124.200.0/24
rs(config)# acl 102 deny any any any any any
```

A packet coming from a subnet other than **140.124.200.0** would not match the first rule, but would match the implicit deny rule. As a result, no packets would be allowed through. Notice that the first rule is a subset of the second rule.

To allow packets from a subnet other than **140.124.200.0** to pass through, a rule must be explicitly defined to permit other packets to go through. To change the previous example so that it accepts packets from other subnets, a new rule must be added ahead of the implicit deny rule that permits packets to pass.

For example:

```
rs(config)# acl 101 deny ip 10.1.20.0/24 any any any
rs(config)# acl 101 permit ip
rs(config)# acl 101 deny any any any any any
```

Notice that the second rule in this example forwards all IP packets that are not denied by the first rule, and this occurs before the implicit deny rule can be applied.

Because of the implicit deny rule, an ACL works similarly to a firewall that denies all traffic. ACL rules are then created that essentially open “doors” within the firewall that permit specific types of packets to pass.

26.2 EDITING ACLS

The RS provides three mechanisms for modifying ACLs:

- Editing ACLs on a remote workstation and uploading them to the RS using TFTP or RCP
- Using the RS’ built-in ACL editor
- Using an external SNMP-based application to change ACLs

26.2.1 Editing ACLs on a Remote Workstation

With this method, ACLs are created and edited on a workstation, and then uploaded to the RS through TFTP or RCP. Use a text editor to edit, delete, replace, or reorder ACL rules and match criteria in a text file. The following example describes how to use this method to affect ACLs on the RS.

Suppose that ACL **104** is defined and applied to an interface on the RS, the following steps are performed to change the ACL using a text editor.

1. Use the **no** command to remove the definition and all reference of ACL **104**:

```
rs(config)# no acl 104 *
```

   Basically, the **no acl 104 *** command cleans up the system for the new rules for ACL **104** (enter **no acl *** to remove all ACL definitions and references).

2. On a workstation, the new ACL rules and references are entered into the text file. In this example the text file is named **acl.changes**, which contains the changes to ACL **104** and its application to interface **int12**:

```
acl 104 deny tcp 10.11.0.0/16 10.12.0.0/16
acl 104 permit tcp 10.11.0.0 any
acl 104 apply interface int12 input
```

3. Once the file **acl.changes** is placed on a TFTP server that is reachable by the RS, and the file is uploaded to the RS. Once uploaded, the changes are and made active using the following commands:

```
rs# copy tftp://10.1.1.12/config/acl.changes to scratchpad
rs# copy scratchpad to active
```

The first **copy** command uploads the file **acl.changes** from the TFTP server to the configuration scratchpad. The next **copy** command makes the changes take effect by copying them into the active configuration.

Copying the changes into the scratchpad allows the ACL changes to be checked before committing them to the active configuration. If it's necessary to modify the ACL information residing within the scratchpad, the changes must be made in the file on the TFTP server, and then uploaded to the scratchpad once again.

26.2.2 Using the RS ACL Editor

The ACL editor in the RS CLI provides a simple and user-friendly mechanism for editing ACLs. The ACL editor is a facility that is used at the console or through a Telnet session. If you edit an ACL that is currently applied to an object (an interface or port, for example), the changes take effect immediately. There is no need to first remove all references to an ACL before making changes.

The ACL Editor is accessed within Configure mode by specifying the ACL name together with the **acl-edit** command. For example, to edit ACL **101**, issue the command **acl-edit 101**. Within the ACL editor, you can add new rules, delete existing rules, and re-order rules. To save the changes, use the **save** command or simply exit the ACL Editor.

ACL Editor Example

The following is a simple example of an **acl-edit** session. In this example it is assumed that:

- The RS active configuration contains an ACL named **lfap**, which contains the following rule, **acl lfap permit ip any any any any accounting 15-minutes**
- A rule is added to **lfap** so that packets from the subnet **134.128.77.0** are dropped

```
rs(config)# acl-edit lfap
 1*: acl lfap permit ip any any any any accounting 15-minutes
rs(acl-edit)>

rs(acl-edit)> acl lfap deny ip 134.128.77.0/24 any any any
 1*: acl lfap permit ip any any any any accounting 15-minutes
 2*: acl lfap deny ip 134.128.77.0/24 any any any
rs(acl-edit)>

rs(acl-edit)> move 1 after 2
 1*: acl lfap deny ip 134.128.77.0/24 any any any
 2*: acl lfap permit ip any any any any accounting 15-minutes
rs(acl-edit)>

rs(acl-edit)> exit
Do you want to commit your ACL changes (yes: commit, no: discard) [yes]? y

rs(config)#
```

Notice in the example above that the **acl-edit** command changes the prompt, lists the current definition for the ACL, and gives it a line number (**1***). Next, the new rule, which denies packets from **134.128.77.0** is added (line **2***). If denying packets is going to occur, we need to change the order in which the ACL rules are applied. This is done using the **move** command. Finally, the **exit** command is entered, a prompt appears, and the ACL is saved.

After the ACL editor session, the ACL **lfap** now appears in the active configuration as:

```
acl lfap deny ip 134.128.77.0/24 any any any any
acl lfap permit ip any any any any accounting 15-minutes
```

26.2.3 Editing ACLs by SNMP

Certain SNMP-based applications such as the *Granite* SDK (made available to Riverstone customers) have the ability to access and affect ACLs on an RS. Because ACLs within the RS active configuration file and ACLs applied to ports and interfaces are contained within two separate lists, an SNMP-based application can view and edit ACLs independently at both the port/interface level and at the active configuration file level.

To make editing possible through an SNMP-based application, the **acl-policy enable** command must be set to **external**.

For example:

```
rs(config)# acl-policy enable external
rs(config)# save active
rs(config)# save startup
```

When **acl-policy** is set to **external**, an SNMP-based application can view and edit any ACL within the active configuration file. Furthermore, the application can see all ACLs currently applied to ports and interfaces, and modify them directly at the port/interface level. Note that while the application can directly modify an ACL on a port or interface, it cannot modify that ACL within the active configuration file until the ACL is removed from the port or interface. Once removed, the ACL can be edited within the active configuration file. The changes then take effect when the ACL is reapplied to the port or interface.

SNMP Editing ACLs at the Ports/Interfaces Level

The **policy** option of the **acl apply** command controls whether an applied ACL can be changed by a remote SNMP-based application.

When an ACL is applied to a port or interface, the **policy** option can be set to the keywords **external** or **local** (by default, ACLs are set to **external**). If an ACL is applied to a port or interface with the policy option set to **local**, the ACL cannot be changed by the SNMP-based application at the port/interface level.

For example, consider the following two command lines that apply ACLs to interfaces:

```
rs(config)# acl 101 apply interface In-1 input policy external
rs(config)# acl 102 apply interface In-2 input policy local
```

ACL **101** applied to interface **In-1** can be modified directly on the interface by an SNMP-based application because its **policy** is set to **external**. However, ACL **102** applied to interface **In-2** cannot be modified directly on the interface because its **policy** is set to **local**.

For an SNMP-based application to be able to modify ACL **102**, it must first be removed from the interface by commenting out (or deleting) the line in the active configuration that applies the ACL to the interface. With the ACL removed from the interface, the SNMP-based application can edit ACL **102** within the active configuration file. After changes to ACL **102** are made at the active configuration file level, the altered version of ACL **102** would then be reapplied to the interface.

Note Visit http://www.nmops.org for information about the Granite SDK.

26.3 USING THE ACL APPLY COMMAND

It is important to understand that an ACL is simply a set of one or more rules made up of match criteria and an indicator that specifies whether to permit or deny packets that meet the rules. For an ACL to actually do something on the RS, an ACL must be *applied* in one of the following ways:

- To an interface, which permits or denies traffic to or from the RS. ACLs used in this way are known as *interface ACLs.*
- To a port operating in Layer-4 bridging mode, which permits or denies bridged traffic. ACLs used in this way are known as *layer-4 Bridging ACLs.*
- To a service, which permits or denies access to services reached through the RS. ACLs used in this way are known as *service ACLs*.
- To an RS facility such as NAT or web-caching, which specifies the criteria that packets must meet to be relevant to these facilities. ACLs used in this way are known as *profile ACLs.*

26.3.1 Applying ACLs to Interfaces

An ACL can be applied to an interface to make decisions about either inbound or outbound traffic. Inbound traffic is traffic coming into the RS. Outbound traffic is traffic going out of the RS. For each interface, only one ACL can be applied for the same protocol in the same direction. For example, you cannot apply two or more IP ACLs to the same interface in the inbound direction. You can apply two ACLs to the same interface if one is for inbound traffic and one is for outbound traffic. However, this restriction does not prevent you from specifying many rules in an ACL. Just put all of these rules into one ACL and apply it to the interface.

When a packet enters the RS through an interface where an inbound ACL is applied, the RS compares the packet to the rules specified by that ACL. If it is permitted, the packet is allowed into the RS. If not, the packet is dropped. If that packet is to be forwarded to go out another interface (the packet is to be routed), a second ACL check is possible at the output interface. The outbound packet is compared to the rules specified in this outbound ACL. Consequently, it is possible for a packet to go through two separate checks, once at the inbound interface and once more at the outbound interface.

Note To specify whether an ACL is applied to inbound or outbound interface, the keywords **input** and **output** are used, respectively.

In general, ACLs should be applied at the inbound interfaces instead of the outbound interfaces. If a packet is denied, the packet should be dropped as early as possible, which is at the inbound interface. Otherwise, the RS has to process the packet and determine where the packet should go, only to have the packet dropped at the outbound interface. In some cases, however, it may not be simple or possible for the administrator to know ahead of time that a packet should be dropped at the inbound interface. Nonetheless, for performance reasons, ACLs should be applied to the inbound interface.

The following is an example of applying ACL **101** to the interface **In-1** in the inbound direction:

```
rs(config)# acl 101 permit ip 124.131.77.0/24
rs(config)# acl 101 apply interface In-1 input
```

26.3.2 Applying ACLs to Layer-4 Bridging Ports

ACLs can be applied to one or more ports operating in layer-4 bridging mode. Traffic that is switched at layer-2 through the RS can have ACLs applied on the layer-3 and layer-4 information contained in the packet. ACLs that are applied to layer-4 bridging ports affect only bridged traffic. ACLs that are applied to an interface containing these ports affect routed traffic.

Like ACLs that are applied to interfaces, ACLs that are applied to layer-4 bridging ports can be applied to either inbound or outbound traffic. For each port, only one ACL can be applied to the inbound direction and only one to the outbound direction.

In the following example, VLAN **group-1** is created and layer-4 bridging is enabled on all five of its Ethernet ports. ACL **101** is then applied to all of the VLAN's ports:

```
rs(config)# vlan create group-1 ip
rs(config)# vlan add ports et.4.2-6 to group-1
rs(config)# vlan enable l4-bridging on group-1
rs(config)# acl 101 apply port et.4.2-6 input
```

26.3.3 Applying ACLs to Services

ACLs can be created that permit or deny access to system services reached through the RS. This type of ACL is known as a *service* ACL. Service ACLs affect access to the following services:

- HTTP
- SNMP
- Secure shell (SSH)
- Telnet

Service ACLs are used to control inbound packets attempting to reach a service on a specific interface on the RS. For example, on a particular interface, it's possible to grant Telnet server access from a few specific hosts or deny web server access from a particular subnet.

The same thing can be done with ordinary ACLs, however, the service ACL is created specifically to control access to services on specified interfaces of the RS. As a result, only inbound (**input**) traffic to the RS is checked.

Note If a service does not have an ACL applied, that service is accessible to everyone. To control access to a service, an ACL must be used.

In the following example, the ACL **telnet-check** allows only the host with source address **123.142.77.15** to access the Telnet service:

```
rs(config)# acl telnet-check permit ip 123.142.77.15 any any any
rs(config)# acl telnet-check apply service telnet
```

Notice in this example that although the ACL **telnet-check** is a **permit** ACL, all other hosts are denied because of the implicit deny rule that exists at the end of all ACLs.

26.3.4 Using ACLs as Profiles

ACLs can be used to define a *profile*. A profile specifies the criteria that addresses, flows, hosts, or packets must meet to be relevant to certain RS facilities. Once an ACL profile is defined, it is used with the configuration command for that feature. For example, the Network Address Translation (NAT) facility on the RS allows you to create address pools for dynamic bindings. An ACL profile is then used to represent the appropriate pools of IP addresses.

Table 26-2 lists the RS features that use ACL profiles.

Table 26-2 Features that use ACL profiles

RS Feature	ACL Profile Usage
IP policy	Specifies the packets that are subject to the IP routing policy.
Dynamic NAT	Defines local address pools for dynamic bindings.
Port mirroring	Defines traffic to be mirrored.
Rate limiting	Specifies the incoming traffic flow to which rate limiting is applied.
Route maps	Specifies which advertised routes will be accepted by the RS.
Web caching	Specifies which HTTP traffic should always (or never) be redirected to the cache servers. Specifies characteristics of web objects that should not be cached.

Profile ACL Restrictions

Note the following about using profile ACLs:

- Only IP ACLs can be used as profile ACLs. ACLs for non-IP protocols *cannot* be used as profile ACLs.

- The **permit/deny** keywords, while required in the ACL rule definition, are *disregarded* in the commands for the RS features. In other words, the **permit** and **deny** keywords exist within these ACLs only because an ACL definition requires that an action be specified. However, when the ACL is used as a profile ACL, the **permit** and **deny** keywords are ignored.
- Only certain ACL match criteria are relevant for each configuration command. For example, the configuration command to create NAT address pools for dynamic bindings (the **nat create dynamic** command) looks at only the source IP address in the specified ACL rule. The destination IP address, ports, and TOS parameters are ignored.

The following sections contain specific examples of using profile ACLs.

Using Profile ACLs with the IP Policy Facility

The IP policy facility uses a profile ACL to define criteria that determines which packets should be forwarded according to an IP policy. Packets that meet the criteria defined in the profile ACL are forwarded according to the **ip-policy** command that references the profile ACL.

For example, an IP policy can be defined that causes all Telnet packets travelling from source network 9.1.1.0/24 to destination network 15.1.1.0/24 to be forwarded to destination address 10.10.10.10. The profile ACL defines the match criteria (in this case, Telnet packets travelling from source network 9.1.1.0/24 to destination network 15.1.1.0/24). Then, the **ip-policy** command specifies what happens to packets that match the match criteria (in this example, forward them to address 10.10.10.10). The following commands are an example of profile ACLs used with the **ip-policy** facility.

This command creates a profile ACL called **prof1** that uses as its match criteria all Telnet packets travelling from source network **9.1.1.0/24** to destination network **15.1.1.0/24**:

```
rs(config)# acl prof1 permit ip 9.1.1.0/24 15.1.1.0/24 any any
```

This profile ACL is then used in conjunction with the **ip-policy** command to cause packets matching **prof1**'s match criteria (that is, telnet packets travelling from **9.1.1.0/24** to **15.1.1.0/24**) to be forwarded to **10.10.10.10**:

```
rs(config)# ip-policy p5 permit acl prof1 next-hop-list 10.10.10.10
```

See Chapter 23 *"IP Policy-Based Forwarding Configuration"* for more information on using the **ip-policy** command.

Using Profile ACLs with the Traffic Rate Limiting Facility

Traffic rate limiting is a mechanism that allows the control of bandwidth usage by incoming traffic on a per-flow basis. A flow meeting certain criteria can have its packets re-prioritized or dropped if its bandwidth usage exceeds a specified limit.

For example, packets in flows from source address 1.2.2.2 are dropped if their bandwidth usage exceeds 10 Mbps. Use a profile ACL to define the match criteria (in this case, flows from source address 1.2.2.2). Then, use the **service** <*name*> **create rate-limit** and **service** <*name*> **apply rate-limit** commands to specify what happens to packets that match the match criteria (in this example, drop them if their bandwidth usage exceeds 10 Mbps). The following commands are an example of profile ACLs used with rate limiting.

This command creates a profile ACL called **prof2** that uses as its match criteria all packets originating from source address **1.2.2.2**:

```
rs(config)# acl prof2 permit ip 1.2.2.2
```

The following command creates a rate limit definition that causes flows matching the profile ACL's match criteria (that is, traffic from **1.2.2.2**) to be restricted to 10 Mbps for each flow. If this rate limit is exceeded, packets are dropped.

```
rs(config)# service client1 create rate-limit per-flow rate 10000000 exceed-action
drop-packets
rs(config)# service client1 apply rate-limit acl prof2 interface int1
```

When the rate limit definition is applied to an interface (with the **service** <*name*> **apply rate-limit interface** command), packets in flows originating from source address **1.2.2.2** are dropped if their bandwidth usage exceeds 10 Mbps.

Using Profile ACLs with Dynamic NAT

Network Address Translation (NAT) allows for the mapping of an IP address used within one network to a different IP address used within another network. NAT is often used to map addresses used in private, local intranets to one or more addresses used in the public, global Internet.

The RS supports two kinds of NAT: *static* NAT and *dynamic* NAT. With dynamic NAT, an IP address within a range of local IP addresses is mapped to an IP address within a range of global IP addresses. For example, IP addresses on network 10.1.1.0/24 can be configured to use an IP address in the range of IP addresses in network 192.50.20.0/24. A profile ACL is used to define the ranges of local IP addresses.

The following command creates a profile ACL called **local**. The local profile specifies as its match criteria the range of IP addresses in network **10.1.1.0/24**.

```
rs(config)# acl local permit ip 10.1.1.0/24
```

Note When a profile ACL is defined for dynamic NAT, only the source IP address field in the ACL statement is evaluated. All other fields in the ACL statement are ignored.

Once the profile ACL is defined, use the **nat create dynamic** command to bind the range of IP addresses defined in the local profile to a range in network **192.50.20.0/24**.

```
rs(config)# nat create dynamic local-acl-pool local global-pool 192.50.20.10/24
```

See Chapter 24 *"Network Address Translation Configuration"* for more information on using dynamic NAT.

Using Profile ACLs with the Port Mirroring Facility

Port mirroring refers to the RS' ability to copy traffic on one or more ports to a "mirror" port, where an external analyzer or probe can be attached. In addition to mirroring traffic on one or more ports, the RS can mirror traffic that matches the match criteria defined within a profile ACL.

For example, all IGMP traffic on the RS can be mirrored to a particular port. Use a profile ACL to define the match criteria of "all IGMP traffic." Then, use the **port mirroring** command to copy packets that match the match criteria to a specified mirror port. The following is an example of using profile ACLs with port mirroring.

This command creates a profile ACL called **prof3** that uses as its match criteria all IGMP traffic on the RS:

```
rs(config)# acl prof3 permit igmp
```

The following command causes packets matching the profile ACL's match criteria (all IGMP traffic) to be copied to mirror port **et.1.2**.

```
rs(config)# port mirroring monitor-port et.1.2 target-acl prof3
```

See Section 29, *"Performance Monitoring"* for more information on using the **port mirroring** command.

Using Profile ACLs with the Web Caching Facility

Web caching is the RS' ability to direct HTTP requests for frequently accessed web objects to local cache servers, rather than to the Internet. Since the HTTP requests are handled locally, response time is faster than if the web objects were retrieved from the Internet.

Profile ACLs are used with web caching in two ways:

- Specifying which HTTP traffic should always (or never) be redirected to the cache servers
- Specifying characteristics of web objects that should not be cached

By default, when web caching is enabled all HTTP traffic from all hosts is redirected to the cache servers unless otherwise specified.

For example, packets with a source address of 10.10.10.10 and a destination address of 1.2.3.4 can be specified to always go to the Internet and never to the cache servers. The following commands illustrate this example.

This command creates a profile ACL called **prof4** that uses as its match criteria all packets with a source address of **10.10.10.10** and a destination address of **1.2.3.4**:

```
rs(config)# acl prof4 permit ip 10.10.10.10 1.2.3.4
```

The following command creates a web caching policy that prevents packets matching the profile ACL's match criteria (packets with a source address of **10.10.10.10** and a destination address of **1.2.3.4**) from being redirected to a cache server. Packets that match the profile ACL's match criteria are sent to the Internet instead.

```
rs(config)# web-cache policy1 deny hosts acl prof4
```

When the web caching policy is applied to an interface (with the **web-cache apply interface** command), HTTP traffic with a source address of **10.10.10.10** and a destination address of **1.2.3.4** goes to the Internet instead of to the cache servers.

Profile ACLs also can be used to prevent certain web objects from being cached. For example, information in packets originating from Internet site 1.2.3.4 and destined for local host 10.10.10.10 can be restricted from the cache servers.

The following command creates a profile ACL called **prof5** that uses as its match criteria all packets with a source address of **1.2.3.4** and a destination address of **10.10.10.10**:

```
rs(config)# acl prof5 permit ip 1.2.3.4 10.10.10.10
```

To make packets that match the profile ACL's match criteria bypass the cache servers, use the following command:

```
rs(config)# web-cache policy1 create bypass-list acl prof5
```

When the web caching policy is applied to an interface, information in packets originating from source address **1.2.3.4** and destined for address **10.10.10.10** are not sent to the cache servers.

See Section 25.2, *"Web Caching"* for more information on using the **web-cache** command.

Using Profile ACLs with the Route Map Facility

Route maps allow you to create a set of match criteria that defines the conditions for importing routes from a peer and redistributing routes from any routing protocol into a routing peer. Once a route map is defined, it is used as a parameter within other routing configuration commands.

Like ACLs, the **route-map** command provides match criteria – one of these criteria is **match-acl**. The **match-acl** match criteria acts on a policy ACL that uses only the **route-filter** ACL match criteria, where **route-filter** specifies a particular route. Route maps (like ACLs) use a *first-match* policy when evaluating ACLs through the **match-acl** match criteria.

The following example illustrates how the **route-map** command uses policy ACLs to affect routes.

This command creates a profile ACL called **prof6** that uses the **route-filter** match criteria, and permits the route **100.10.10.0/24**:

```
rs(config)# acl prof6 permit route-filter 100.10.10.0/24
```

This command creates a route map called **r1** that uses **match-acl** as its match criteria, and specifies the profile ACL **prof6**:

```
rs(config)# route-map r1 permit 1 match-acl prof6
```

Notice in the previous example that both the ACL and the route map command contained *action* statements (permit or deny). The ACL and route map action statements interact through a logical AND operation. This AND operation leads to four possible interactions (listed in Table 26-3) between the ACL and the route map:

Table 26-3 ACL and route map rule interactions

Action in ACL Rule	Action in Route Map	Result
Permit	Permit	Use route specified in ACL rule
Permit	Deny	Do not use route specified in ACL rule

Table 26-3 ACL and route map rule interactions

Action in ACL Rule	Action in Route Map	Result
Deny	Deny	Do not use route specified in ACL rule
Deny	Permit	Do not use route specified in ACL rule

See Section 15.2.14, *"Using Route Maps"* for more information on using the **route-map** command.

26.4 ACL LOGGING AND VIEWING

ACLs can be monitored through ACL logging. Logging causes messages to be printed to the console and sent to a Syslog server (if configured). The RS also provides several show commands that display ACL definitions and how they are applied on the RS.

26.4.1 Enabling ACL Logging

To see whether incoming packets are permitted or denied by an ACL, enable ACL logging.

The following commands define an ACL and apply the ACL to an interface, with logging enabled for the ACL:

```
rs(config)# acl 101 deny ip 10.2.0.0/16
rs(config)# acl 101 permit ip
rs(config)# acl 101 apply interface int1 input logging on
```

When ACL logging is turned on, the router prints messages on the console about whether a packet is dropped or forwarded. If you have a Syslog server configured for the RS, the same information is also sent to the Syslog server.

Per-Rule Logging

To enable per-rule logging, enter the **log** parameter within each rule within the ACL for which logging is required. Next, specify the **logging off** option within the **acl apply** command. This enables logging only on the ACL rule that contain the **log** parameter. The following commands define an ACL with logging for only one rule. The ACL is then applied to an interface:

```
rs(config)# acl 101 deny ip 10.2.0.0/16 any any any log
rs(config)# acl 101 permit ip any any any any
rs(config)# acl 101 apply interface int1 input logging off
```

For the above commands, the router prints messages on the console only when packets that come from subnet **10.2.0.0/16** on interface **int1** are dropped.

ACL Logging and Performance

Before enabling ACL logging, you should consider its impact on performance. With ACL logging enabled, the router prints a message at the console before the packet is actually forwarded or dropped. Even if the console is connected to the router at a high baud rate, the delay caused by the console message is still significant. This can get worse if the console is connected at a low baud rate, for example, 1200 baud. Furthermore, if a Syslog server is configured, then a Syslog packet must be sent to the Syslog server, creating additional delay. For these reasons, you should consider the potential performance impact before turning on ACL logging.

26.4.2 Viewing ACLs

The RS provides a set of show commands that display the ACLs, their rules, and their association to interfaces, ports and services.

Table 26-4 ACL show commands supported by the RS

Show Command	Action
acl show all	Show all ACL definitions
acl show aclname <*name*> | **all**	Show a specific ACL definition
acl show interface <*name*>	Show an ACL on a specific interface
acl show interface all-ip	Show ACLs on all IP interfaces
acl show port	Show ACLs applied to a port
acl show service	Show ACLs applied to services

The following is an example of the display from the **`acl show all`** command

```
rs# acl show all

ACL "121":
Applied Interface(s): none
Applied Port(s): none
Forward Count Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK   Prot Flags
------- ----- --------------     -------------      --------- --------- --- ---------  ---- -----
Permit  0     123.141.77.0       anywhere           any       any       any  None      IP
Deny    0     anywhere           anywhere           any       any       any any

Flags: E - Established TCP connections only.

ACL "lfap":
Applied Interface(s): none
Applied Port(s): none
Forward Count Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK   Prot Flags
------- ----- --------------     -------------      --------- --------- --- ---------  ---- -----
Permit  0     anywhere           anywhere           any       any       any  None      IP
Deny    0     anywhere           anywhere           any       any       any any

Flags: E - Established TCP connections only.

ACL "test":
Applied Interface(s): none
Applied Port(s): et.4.(2-6,10-16)
Forward Count Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK   Prot Flags
------- ----- --------------     -------------      --------- --------- --- ---------  ---- -----
Deny    0     anywhere           anywhere           any       any       any  None      IP
Permit  0     anywhere           anywhere           any       any       any  None      TCP
Deny    0     anywhere           anywhere           any       any       any any

Flags: E - Established TCP connections only.
```

Notice that each ACL is listed along with its match criteria arranged on lines that represent the ACL's rules.

26.5 ACLS STORED IN HARDWARE

The primary purpose of the ACL hardware feature is to allow hardware based routing on ports on which *any* type of ACL rules have been applied.

The ACL CAM feature works by writing the ACL rules into specialized Content Addressable Memory (CAM), which is examined by hardware for each packet. When the hardware matches a rule it increments a per rule 32-bit counter, then performs the configured operation (permit or deny). All other packet processing happens independently, in the usual way.

Note Hardware ACLs work only on inbound traffic; they cannot be applied to outbound traffic.

The ACL CAM feature works on all MPLS gigabit and MPLS POS cards. 10/100 ethernet, T1/T3, ATM, and non-MPLS POS and gigabit cards have no support for this feature.

Before the ACL CAM feature can be used, it must first be enabled on the desired ports. The command used to do this is **`port enable acl-cam ports`** <*port-list*>. If there are ACLs applied directly to the ports being enabled or if there are ACLs applied to interfaces which include the ports, those ACL rules are written into the CAM. Similarly, if there are ACLs applied to all interfaces (i.e. all-ip), those are also written into the CAM on every port which has an interface.

Once these ACL rules are added to the CAM, subsequent packets have these rules applied to them in hardware at wire rate. This means ACL deny rules drop packets without the packets ever going to software. Packets matching ACL permit rules still undergo the normal forwarding processing. This means that if HRT is not enabled on the port, flow lookups are done in hardware for each of the packets – those packets that do not have matching flows are sent to software for a flow entry to be installed to match subsequent packets in the flow. If HRT is enabled on the port then the packet is forwarded directly by the hardware.

It should be noted that the per-rule statistics are incremented independent of the permit/ deny decision. These statistics can be observed with the **`acl show-cam-stats port`** <*port-list*> **`acl`** <*acl-name*> command. The optional "**`acl`**" option restricts the output to a particular rule.

The output of the command is as follows:

```
rs# acl show-cam-stats port gi.4.1 acl acl1

                            Acl acl1 on VLAN 2
                        --------------------------------
Forward Count Source IP/Mask     Dest. IP/Mask      SrcPort   DstPort   TOS TOS-MASK   Prot Flags
------- ----- --------------    -------------      --------- --------- --- ---------  ---- -----
Permit  0     50.10.10.1/32      anywhere           any       any    34    30       IP
Deny    0     anywhere           anywhere           any       any    any   any
```

Note that the counters record only the number of packets that match the rule. The counters are 32-bit, and can eventually wrap around. The counters can be cleared with the **`acl clear-cam-stats port`** <*port-list*> **`acl`** <*acl-name*> command. Also note that the statistics for the implicit deny that terminates every ACL set are also shown.

New ACLs applied to ACL CAM enabled ports or interfaces have their rules written into the CAM hardware on these ports. In addition, when ACL CAM enabled ports are added to VLANs on which interfaces with ACLs are applied, the ACL rules are written into the CAM hardware. Conversely, when ACLs are removed, ports are removed from VLANs or the ACL CAM is disabled on a port, and the ACL rules that are no longer valid are removed from the CAM.

27 SECURITY CONFIGURATION

The RS provides security features that help control access to the RS and filter traffic going through the RS. Access to the RS can be controlled by:

- Enabling RADIUS
- Enabling TACACS
- Enabling TACACS+
- Password authentication
- Secure shell protocol
- Port-based authentication.

Traffic filtering on the RS enables:

- Layer-2 security filters - Perform filtering on source or destination MAC addresses.
- Layer-3/4 Access Control Lists - Perform filtering on source or destination IP address, source or destination TCP/UDP port, TOS or protocol type for IP traffic. Perform access control to services provided on the RS, for example, Telnet server and HTTP server.

Note Currently, Source Filtering is available on RS WAN cards; however, application must take place on the entire WAN card.

27.1 CONFIGURING RS ACCESS SECURITY

This section describes the following methods of controlling access to the RS:

- RADIUS
- TACACS
- TACACS+
- Passwords
- Secure shell
- Port-based authentication

27.1.1 Configuring RADIUS

You can secure login or Enable mode access to the RS by enabling a Remote Authentication Dial-In Service (RADIUS) client. A RADIUS server responds to the RS RADIUS client to provide authentication.

You can configure as many RADIUS server targets as you have memory for on the RS, essentially this is unlimited. A timeout is set to tell the RS how long to wait for a response from RADIUS servers.

Note Verify parameter values before saving radius commands to the active or startup configuration file on the RS. Any misconfiguration can effectively lock you out of the CLI.

To configure RADIUS security, enter the following commands in Configure mode:

Specify a RADIUS server and configure server-specific parameters.	**radius set server** <*IP-addr*> <*server-options*>
Set time that RADIUS server is ignored after it has failed.	**radius set deadtime** <*minutes*>
Set authentication key for RADIUS server.	**radius set key** <*string*>
Determine the RS action if there is no server response within a given time. [a]	**radius set last-resort password|succeed|deny**
Set the maximum number of times the RADIUS server is contacted for authentication.	**radius set retries** <*number*>
Set the source IP address or interface for use with RADIUS server.	**radius set source** <*ipaddr*>**|**<*interface*>
Set the maximum time to wait for a RADIUS server reply.	**radius set timeout** <*seconds*>
Enable RADIUS.	**radius enable**
Cause RADIUS authentication at user login or when user tries to access Enable mode.	**radius authentication login|enable**
Logs specified types of command to RADIUS server.	**radius accounting command level** <*level*>
Logs to RADIUS server when shell is stopped or started on RS.	**radius accounting shell start|stop|all**
Logs to RADIUS server SNMP changes to startup or active configuration.	**radius accounting snmp active|startup**
Logs specified type(s) of messages to RADIUS server.	**radius accounting system fatal|error|warning|info**

a. If this command is not specified, the RS tries the next configured authentication method (including TACACS+ configuration commands). Otherwise, if the server does not reply within the configured timeout period for the configured number of retries, user authentication will fail.

Monitoring RADIUS

You can monitor RADIUS configuration and statistics within the RS.

To monitor RADIUS, enter the following commands in Enable mode:

Show RADIUS server statistics.	**radius show stats**
Show all RADIUS parameters.	**radius show all**

27.1.2 Configuring RADIUS Attributes

You can configure the RADIUS server's user database to return the Riverstone-User-Level attribute along with an Access-Accept response. The Riverstone-User-Level is a Riverstone vendor-specific attribute defined in the dictionary file provided with ROS release. 9.1 and greater. The latest revision of the dictionary file can be found at

- http://www.nmops.org

and at

- http://www.riverstonenet.com/support/support_docs.shtml

The RS uses the value of this attribute, which is an integer from 0 to 15, to determine a user's command mode (in single-user mode) or privilege level (in multi-user mode).

If the RADIUS server does not include a Riverstone-User-Level attribute in the Access-Accept response, the RS checks the standard RADIUS Service-Type attribute and uses this attribute's value to determine the user's command mode or privilege level. Whenever both Riverstone-User-Level and Service-Type attributes are present in an Access-Accept response, the Riverstone-User-Level always takes precedence.

The following sections describe how these attributes are used when the RS is in single-user mode and when it is in multi-user mode.

Single-User Mode

When the RS is in single-user mode, users that have been authenticated are placed in Login mode, where they have to specify the **`enable`** command to move up to Enable mode. You can use the Riverstone-User-Level attribute to automatically place authenticated users in Enable mode (instead of Login mode).

To use this feature, specify the **`radius set direct-promotion`** command. This enables the RS to place a user directly in Enable mode when it receives an Access-Accept packet with a Riverstone-User-Level attribute of 15 (or a Service-Type attribute of 6, administrative). If the Riverstone-User-Level or the Service-Type attribute contains any other value, the user is placed in Login mode.

Multi-User Mode

In multi-user mode, the value of the Riverstone-User-Level attribute indicates a user's privilege level. In the absence of the Riverstone-User-Level attribute, the RS checks the value of the RADIUS Service-Type attribute. If the value of this attribute is 6 (Administrative), the RS treats this as if the user has level 15 privileges, providing full access to the system. Any other value will be the same as if the attribute is not there; the RS places the user at access level 1.

Note For information on configuring the RS for multi-user mode, refer to Section 3.7.1, *"Setting Up Multi-User Access."*

Note When negating configuration commands from within multi-user mode, not only do you need sufficient permission to use the **`negate`** command, but you must also have sufficient permission to run the commands you are negating

27.1.3 Configuring TACACS

In addition, Enable mode access to the RS can be made secure by enabling a Terminal Access Controller Access Control System (TACACS) client. Without TACACS, TACACS+, or RADIUS enabled, only local password authentication is performed on the RS. The TACACS client provides user name and password authentication for Enable mode. A TACACS server responds to the RS TACACS client to provide authentication.

You can configure up to five TACACS server targets on the RS. A timeout is set to tell the RS how long to wait for a response from TACACS servers.

To configure TACACS security, enter the following commands in the Configure mode:

Specify a TACACS server.	**tacacs set server** <*hostname or IP-addr*>
Set the TACACS time to wait for a TACACS server reply.	**tacacs set timeout** <*number*>
Determine RS action if no server responds.	**tacacs set last-resort password|succeed**
Enable TACACS.	**tacacs enable**

Monitoring TACACS

You can monitor TACACS configuration and statistics within the RS.

To monitor TACACS, enter the following commands in Enable mode:

Show TACACS server statistics.	**tacacs show stats**
Show all TACACS parameters.	**tacacs show all**

27.1.4 Configuring TACACS+

You can secure login or Enable mode access to the RS by enabling a TACACS+ client. A TACACS+ server responds to the RS TACACS+ client to provide authentication.

You can configure up to five TACACS+ server targets on the RS. A timeout is set to tell the RS how long to wait for a response from TACACS+ servers.

To configure TACACS+ security, enter the following commands in Configure mode:

Specify a TACACS+ server and configure server-specific parameters.	**tacacs-plus set server** <*IP-addr*> <*server-options*>
Set time that TACACS+ server is ignored after it has failed.	**tacacs-plus set deadtime** <*minutes*>
Set authentication key for TACACS+ server.	**tacacs-plus set key** <*string*>

Determine the RS action if there is no server response within a given time. [a]	**tacacs-plus set last-resort password|succeed|deny**
Set the maximum number of times the TACACS+ server is contacted for authentication.	**tacacs-plus set retries** <*number*>
Set the source IP address or interface for use with TACACS+ server.	**tacacs-plus set source** <*ipaddr*>**|**<*interface*>
Set the maximum time to wait for a TACACS+ server reply.	**tacacs-plus set timeout** <*seconds*>
Enable TACACS+.	**tacacs-plus enable**
Cause TACACS+ authentication at user login or when user tries to access Enable mode.	**tacacs-plus authentication login|enable**
Logs specified types of command to TACACS+ server.	**tacacs-plus accounting command level** <*level*>
Logs to TACACS+ server when shell is stopped or started on RS.	**tacacs-plus accounting shell start|stop|all**
Logs to TACACS+ server SNMP changes to startup or active configuration.	**tacacs-plus accounting snmp active|startup**
Logs specified type(s) of messages to TACACS+ server.	**tacacs-plus accounting system fatal|error|warning|info**

a. If this command is not specified, the RS tries the next configured authentication method (including RADIUS configuration commands). Otherwise, if the server does not reply within the configured timeout period for the configured number of retries, user authentication will fail.

Monitoring TACACS+

You can monitor TACACS+ configuration and statistics within the RS.

To monitor TACACS+, enter the following commands in Enable mode:

Show TACACS+ server statistics.	**tacacs-plus show stats**
Show all TACACS+ parameters.	**tacacs-plus show all**

27.1.5 Configuring Passwords

The RS provides password authentication for accessing the User and Enable modes. If TACACS, TACACS+, or RADIUS is not enabled on the RS, only local password authentication is performed.

To configure RS passwords, enter the following commands in Configure mode:

Set User mode password.	**system set password login** <*string*>
Set Enable mode password.	**system set password enable** <*string*>

27.1.6 Configuring SSH

Secure shell (SSH) is a protocol used to securely login to a remote RS and execute commands. SSH provides secure communications because connections are authenticated and communications over the network are encrypted. The RS contains both an SSH server and an SSH client. As a result, encrypted SSH sessions can be made between two RS switch routers or between a workstation containing an SSH client and an RS.

Typically, SSH communication takes place using port 22, however, the port on which the RS listens can be changed using the **ssh server options listen-port** Configure command. Any port number can be used from 1 to 65535. for example, the following sets the SSH listen port to 500:

```
rs(config)# ssh server options listen-port 500
```

Both the RS server and client support SSH version 1 and version 2. By default, both the SSH v1 and v2 processes are are running, however, either server is not fully operable until a key is generated for that server. Use the **ssh-server generate-key** command to create either an SSHv1 or SSHv2 key.

Either or both SSH servers can be disabled using the **system disable ssh-server** Configure command. This command can disable the SSH v1 server, the SSH v2 server, or both SSH servers.

The following is an example of disabling the SSH v1 server:

```
rs(config)# system disable ssh-server ssh1
```

If TACACS or RADIUS authentication is enabled on the router, passwords are authenticated by the TACACS or RADIUS server

Note SSH public and encrypted keys are supplied on a per-RS basis, and are not provided on a per-user basis.

Establishing SSH Sessions

The SSH server on the RS must have a public key and a host key generated using the **ssh-server generate-key** <*length*> command, where length is optional and allows the setting of the number of encryption bits. The possible number of bits is from 512 to 1024.

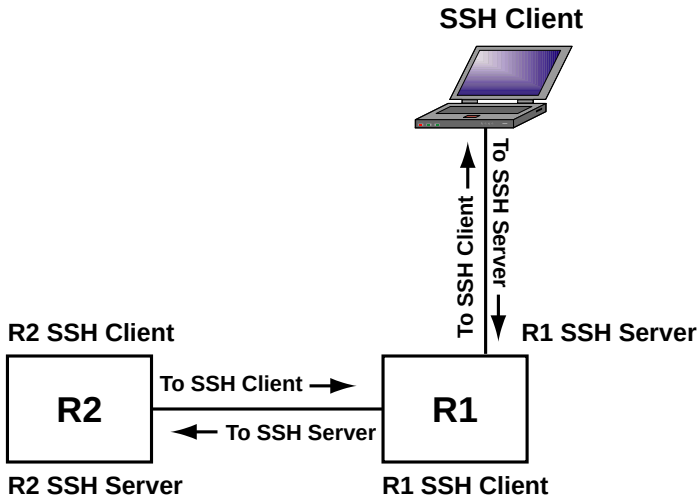


Figure 27-1 SSH client server interactions

Note For security reasons, keys cannot be generated through a telnet session. The key generation command can be entered only at the RS' serial console or terminal session.

Note To *escape* an SSH client session between one RS as client and another RS as server, use the RS SSH escape string, "**~.**".

Keys are generated with the SSH version taken into consideration. Specifically, an **rsa1** generated key is used by SSH v1, while **rsa** or **dsa** generated keys are used by SSH v2.

For example, the following command generates a key for version 2 SSH with 800 bit encryption:

```
rs# ssh-server generate_key rsa 800
Generating RSA host keyGenerating public/private rsa key pair.

Warning - key generation is CPU intensive.
This could take 10-50 seconds to complete.

Your identification has been saved in /int-flash/cfg/ssh/ssh_host_rsa_key.
Your public key has been saved in /int-flash/cfg/ssh/ssh_host_rsa_key.pub.
The key fingerprint is:
06:46:51:f0:06:2d:27:8f:e1:1d:16:12:a9:32:3e:de RSA Host key (comment)
```

Notice that both the key and your identification are saved in files on the internal Flash RAM of the RS.

To access a remote RS through SSH, use the **slogin** command from within in Enable mode. The slogin command is much like telnet in that it requires either the hostname or IP address of the remote RS. Alternately, access to the RS can be obtained using a username. The default username is **root**.

For example, using SSH, RS following command to log into the remote RS "**r1**," from RS "**r2**," using the username "**login**:"

```
r2# slogin login@r1
```

The SSH server on **r1** responds with its public host and server keys. The client on **r2** checks the received host key to make sure that the key has not changed since the last SSH session between **r1** and **r2**. If the host key is different from the host key used in previous SSH sessions with **r1**'s server, the following message appears on **r2**'s console:

```
r2# slogin login@r1

SSH_ERROR: @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
SSH_ERROR: @    WARNING: REMOTE HOST IDENTIFICATION HAS CHANGED!     @
SSH_ERROR: @@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@
SSH_ERROR: IT IS POSSIBLE THAT SOMEONE IS DOING SOMETHING NASTY!
SSH_ERROR: Someone could be eavesdropping on you right now (man-in-the-middle attack)!
SSH_ERROR: It is also possible that the RSA host key has just been changed.

Do you want to replace the existing key and continue (yes/no)?
```

Notice that you are asked if you want to continue to connect to **r1**'s server. This is a precaution to ensure that the SSH client is connecting to the intended device. To continue the server connection, answer "*yes*," **r2** then encrypts a random number using both the public host and server keys and sends the encrypted number to **r1**'s SSH server. Both the SSH server and client use this random number as a key to encrypt communications as the session continues.

You can use CLI commands in the SSH session as you normally would through a console or telnet connection. Furthermore, from this SSH session, you can use the **slogin** command to access other SSH servers on other remote RS switch routers.

To end an SSH session, simply type **exit**.

Note If a new key is generated while there are active SSH sessions on the RS, those sessions are not severed. This occurs because the keys are used only for initial connection of an SSH session.

Using the ssh Command

Along with the **slogin** command, an SSH session can be set up using the **ssh** command. The **ssh** command is used like the telnet command, where **ssh** is followed by either a host's name or IP address. For example, to SSH login to another RS with an IP address of 130.141.143.75, enter the following from Enable mode:

```
rs# ssh 130.141.143.75
rs156# ssh 134.141.179.136
The authenticity of host '130.141.143.75 (130.141.143.75)' can't be
    established.
RSA key fingerprint is a1:39:89:c2:e5:06:a5:b8:de:38:0b:bb:71:90:e2:c1.
Are you sure you want to continue connecting (yes/no)? yes
2003-04-17 09:22:15 %SSH-I-INFO, Warning: Permanently added
    '134.141.179.136' (RSA) to the list of known hosts.


------------------------------------------------------------------------
RS 3000 System Software, Version 9.4.0.0
Riverstone Networks, Inc., Copyright (c) 2000-2003. All rights reserved.
System started on 2003-03-24 14:57:13
------------------------------------------------------------------------


Press RETURN to activate console . . .

Password:
```

SSH Connections to Workstations

When attempting to create an SSH connection between an RS and a workstation running an SSH server, the workstation replies to the RS assigning it a default user name: "**default_ssh_usr**," and prompts the RS for the default user password. Unfortunately, there is no user account for the RS, and the requested password does not exist. As a result, the connection fails.

There are two ways in which a connection from an RS can be made to a workstation running an SSH server.

- Have the personnel responsible for the SSH server workstation set up an account for a user called **default_ssh_usr**.
  - Note that adding the default RS user makes this workstation accessible to all RS switch routers on the network.
- If you have an account on the SSH server workstation, perform the SSH login using your account name and password.

- For example, if user John Smith has an account (**jsmith**) on the SSH server workstation, he would log in by doing the following:

```
rs# ssh jsmith@130.141.143.75
The authenticity of host '130.141.143.75 (130.141.143.75)' can't be established.
RSA key fingerprint is 43:fa:26:54:73:a3:bc:30:77:da:b9:d4:4e:73:0f:10.
Are you sure you want to continue connecting (yes/no)? yes
2003-04-17 10:55:25 %SSH-I-INFO, Warning: Permanently added '130.141.143.75' (RSA) to
    the list of known hosts.
jsmith@130.141.143.75's password:******
Last login: Wed Apr 16 10:27:28 2003 from 100.141.17.156
Sun Microsystems Inc.   SunOS 5.5.1     Generic May 1996
Sun Microsystems Inc.   SunOS 5.5.1     Generic May 1996
ssh-server%
```

Monitoring SSH Sessions

The RS allows up to 12 simultaneous Telnet *or* SSH sessions. There are commands that allow you to monitor SSH use on the RS and to end a specific SSH session. You can also specify the number of minutes an SSH connection can remain idle before the connection is terminated by the control module. The default is 5 minutes. You can disable this feature, by setting the time-out value to zero.

Display the last five SSH connections to the RS.	**system show ssh-access**
Specify the time-out value for SSH connections.	**system set idle-time-out ssh** <*num*>
Show current Telnet and SSH users and session IDs.	**system show users**
End the specified SSH session.	**system kill ssh-session** <*session-id*>

Note If security is a major matter of concern on your network, it is recommended that you disable telnet and perform all command interactions with the RS through either the serial console port or through SSH.

To disable telnet enter the following into the RS' active and startup configuration files: **system disable telnet-server**.

27.2 PORT-BASED AUTHENTICATION

Local area networks (LANs) are often deployed in environments where unauthorized devices or clients may attempt to access the LAN. To prevent unauthorized access to the network, you can configure the RS to use port-based authentication. The RS supports the IEEE 802.1x standard for authenticating devices connected to a LAN port. It prevents unauthorized users from accessing a network and its services.

The 802.1x standard can be used only when the client at the other end of the LAN also supports 802.1x. If the client does not support 802.1x, you can configure an authorization filter and apply it to a port. The RS will then use the filter to authenticate the 802.1x-unaware client on that port. This section describes both types of port-based authentication.

27.2.1 Port-Based Network Access Control on the RS (802.1x)

The IEEE 802.1x standard defines a protocol for authenticating and authorizing devices attached to a LAN port. This section provides an overview of that protocol and how it is implemented on the RS.

802.1x Overview

The IEEE 802.1x standard defines 3 entities:

- the supplicant or client, at one end of a point-to-point LAN segment, is the device being authenticated before it can access the services offered by the authenticator
- the authenticator, at the other end of the LAN segment, authenticates clients attached to its ports before allowing them to access the available services
- the authentication server, which provides the authentication service, determines whether the client is allowed to access the services provided by the authenticator.

You can configure the RS to function as the authenticator. The RS communicates with the client and with the authentication server, facilitating the exchange of information during the authentication process. The protocol between the RS and the client is the Extensible Authentication Protocol (EAP). The RS supports RADIUS with EAP extensions as the authentication server. The RADIUS client on the RS interacts with the RADIUS authentication server.

Authenticating a Client

By default, the RS ports transmit and receive traffic without authenticating the attached devices. When you enable 802.1x on an RS port, the port transitions to an *unauthorized* state, where it allows only EAP frames. Normal traffic is not allowed through a port that is in an unauthorized state. A port remains in this state until authentication is successfully completed.

Both the client and the RS can initiate authentication. Authentication begins when the RS port transitions from down to up or when the client sends an authentication request. During authentication, the RS transmits the EAP frames between the client and the authentication server. The authentication server is transparent to the client. The client may be authenticated based on the user name and password, or the user name, password and MAC address, depending on the RADIUS server setting.

If authentication succeeds, the port transitions to an *authorized* state and allows normal traffic to be transmitted and received. After the port is authorized, the port can receive packets only from the authenticated client. If a packet's source address does not match the authenticated address, the port drops the packet.

If authentication fails or if the RS is unable to contact the authentication server, the port remains in the unauthorized state. Additionally, the port transitions back to the unauthorized state when its link state goes down.

Configuring the RS for 802.1x Authentication

Following are the tasks required to configure the RS to use 802.1x authentication:

- Configure 802.1x parameters for the RADIUS server.
- Enable 802.1x on the RS ports.

The following sections describe these tasks in detail.

Setting 802.1x Parameters for the RADIUS Server

Use the **dot1x add server** command to specify the RADIUS server(s) that will be used for 802.1x authentication. The **dot1x add server** command has a **usage** parameter which specifies whether a RADIUS server will be used for authentication, for accounting, or for both. The authentication server is used to authenticate the client, while the accounting server logs each time a port is authorized or unauthorized.

In addition, the RS has default parameters it uses when it communicates with the RADIUS authentication server. You can change these defaults with the **dot1x set server** command. Following are the values that can be configured:

- Deadtime, which is the number of minutes the RS ignores the RADIUS server after it has failed. The default is 0.
- Authentication key the RS shares with the server.
- Number of times the RS attempts to contact the RADIUS server. The default is 3 times.
- Source IP address or interface name used when contacting the RADIUS server. The default is the IP address of the interface that is used to communicate with the RADIUS server.
- Timeout, which is the number of seconds the RS waits for a response from the RADIUS server. The default is 3 seconds.
- Port numbers used for authentication and/or accounting. The default port for authentication is port 1812, and the default for accounting is port 1813.

The following example defines one RADIUS server for both authentication and accounting, and sets its authentication key:

```
rs (config)# dot1x add server 10.10.10.1 usage both
rs (config)# dot1x set server 10.10.10.1 key riverstone
```

Use the **dot1x show server** command to display the 802.1x-related parameters that affect the RS's communication with the authentication server, as shown in the following example.

```
rs# dot1x show server

RADIUS servers listed in order of priority:

Server:               10.10.10.1
Usage:                authentication accounting
Authentication Port:  1812
Accounting Port:      1813
key:                  riverstone
Timeout (seconds):    5
Retries:              3                    <Default>
Deadtime (minutes):   -1                   <Default>
Source IP:            <Default>

RADIUS server statistics:

Host                Accepts   Rejects   Challenges   Timeouts
10.10.10.1          0         0         0            0
```

In addition to displaying the configurable 802.1x parameters, the output also displays the number of client authentication requests that were authorized and that were rejected, the number of challenges, and the number of requests that timed out.

Enabling 802.1x on the RS port(s)

By default, 802.1x authentication is not enabled on the RS. Specify the following commands to enable 802.1x on the RS ports:

- **dot1x enable** to enable this feature on the desired port(s)
- **dot1x set port** to set the port's authorization state to use 802.1x authentication, as described in the following section

Setting a Port's Authorization State

You can manually set a port's authorization state by using the **port-control** parameter of the **dot1x set port** command. This parameter has three options:

- **auto** - the port uses 802.1x to authenticate a client before allowing normal traffic. Specify this option to use 802.1x authentication.
- **force-unauth** - the port is forced to transition to the unauthorized state. The port remains in an unauthorized state until it is manually reset. When you specify this keyword, authentication is not possible because the port ignores all attempts from the client to be authenticated.

  While in this state, packets are blocked in or out of the port depending on what was configured in the **admin-control-direction** parameter.

- **force-auth** - the port allows access without authentication, effectively disabling 802.1x authentication. This is the default.

The following example enables 802.1x authentication on port et.2.1:

```
rs (config)# dot1x set port et.2.1 port-control auto
rs (config)# dot1x enable port-list et.2.1
```

Client Authentication Through Access-ports and Trunk-ports

The following describes how clients authenticate with the server through access-ports and trunk-ports.

1. By default, the first client to authenticate on an access-port is the only client allowed on that port. However, this situation exists only as long as that client keeps authenticating. If the client stops authenticating, another client can authenticate on that access-port.
2. By using the **dot1x set** <*port*> **do-not-verify-source** command, when the first client authenticates, the access-port is opened for all clients connected to that port.
3. Use the **dot1x enable port-list** <*ports*> **multiple-instances** command on a trunk-port to allow clients within different VLANs to authenticate.
4. The client authentication behavior of clients within VLANs is the same as the client authentication behavior for an access-port, as described in 1 and 2.
   - By default, the first client to authenticate on a VLAN is the only client on that VLAN that can authenticate.
   - By using the **dot1x set** <*port*> **do-not-verify-source** command on the trunk-port, the first client to authenticate opens the VLAN for all clients on that VLAN.

Setting a Port's 802.1x Timers

Once 802.1x has been enabled on a port, it uses the following operational timers which you can configure with the **dot1x set port** command:

- Maximum number of reauthentication attempts before the port becomes unauthorized. The default is 2.
- Maximum number of authentication requests that can be sent before the authentication session expires. The default is 2.
- Number of seconds between an authentication attempt failed and is tried again. The default is 60 seconds.
- Time period between the retransmission of authentication requests to the client. The default is 30 seconds.
- Timeout period for the authentication server. The default is 30 seconds.
- Timeout period for the client. The default is 30 seconds.

Once you have configured a port's 802.1x parameters, use the **dot1x show parm** command to verify the configuration as shown in the following example.

```
rs# dot1x show parm all-ports

802.1X parameters ---
Parameters for port et.2.1:
  Port 802.1X Enabled = TRUE
  Multiple 802.1X instances = FALSE
  802.1X protocol aware = TRUE
  Reauthentication Enabled = FALSE
  Port Control = Force Authorized
  Control Direction = Both
  Transmit period = 30 sec
  Quiet period = 60 sec
  Supplicant Timeout = 30 sec
  Server Timeout = 30 sec
  Reauthentication period = 3600 sec
  Max Req sent = 2
  Max Reauthenticate sent = 2
```

Reauthenticating a Port

After a client has been authenticated on a port, you can set the RS to reauthenticate the client periodically. You can also manually reauthenticate a client at any time. To set periodic reauthentication, specify the **reauth-enable** parameter of the **dot1x set port** command and use the **reauth-period** parameter to specify the reauthentication interval. (The default reauthentication interval is 3600 seconds.) The following example enables periodic reauthentication on port et.2.1 and sets the interval to 4200 seconds:

```
rs (config)# dot1x set port et.2.1 reauth-enable reauth-period 4200
```

To manually reauthenticate a port, use the **dot1x reauthenticate** command as shown in the following example:

```
rs # dot1x reauthenticate port-list et.2.1
```

If a port was authorized before the **dot1x reauthenticate port** command was issued, the port remains authorized until reauthentication fails.

Reinitializing a Port

If you change previously configured 802.1x parameters, you must reinitialize ports on which 802.1x is enabled so they can use the updated 802.1x parameters. The following example reinitializes port et.2.1:

```
rs # dot1x initialize port-list et.2.1
```

Note If you don't reinitialize the 802.1x ports after revising the 802.1x parameters, the ports will continue to use the old parameters. To enable the ports to use the updated parameters, use the **`dot1x initialize`** command.

802.1x Configuration Example

In the following example, RS1 is the authenticator. When the end station (an 802.1x-aware device) requests authentication, the RS communicates with the RADIUS server, which in turn, authenticates the end station.

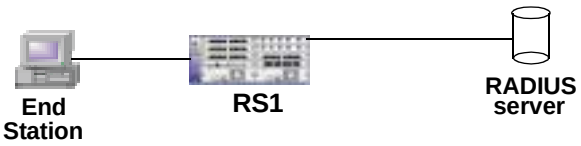


Figure 27-2 Authenticating an 802.1x-aware client

Following is the configuration for RS1:

```
! Define the RADIUS server to be used for 802.1x authentication
rs (config)# dot1x set server 10.10.10.1 key riverstone
rs (config)# dot1x add server 10.10.10.1 usage both
!Enable 802.1x authentication on the RS
rs (config)# dot1x set port et.2.1. port-control auto
rs (config)# dot1x enable port-list et.2.1
```

Use the **`dot1x show statistics`** command to display statistics on Extensible Authentication Protocol over LAN (EAPOL) frames exchanged with the clients.

```
rs# dot1x show statistics all-ports
802.1X statistics ---
Statistics for port et.2.1 vlan -1:
  Total Frames Received = 0         Total Frames Transmitted = 1
    Resp/Id Received    = 0           Req/Id Transmitted     = 0
    Other Resp Received = 0           Other Req Transmitted  = 0
    Start Received      = 0
    Logoff Received     = 0
  Invalid Received    = 0
  Length Err Received = 0
  Latest Version Received = 0
  Latest Source Received = 000000:000000
rs#
```

Use the **dot1x show status** command to display the authentication status of the port.

```
rs# dot1x show status all-ports
802.1X status ---
Status for port et.2.1:
  Port Authorized
  Port enabled = TRUE
  Link state   = DOWN
  vlan = -1
    Port Status = Authorized
    authenticator state = Force_auth
    backend state = Idle
```

Applying 802.1x Authentication to VLANs

By default, an 802.1x-enabled port authenticates only one client. This works well with access ports that belong to only one VLAN. Trunk ports, though, transmit traffic for multiple VLANs which may represent different clients. Therefore, trunk ports may have to authenticate multiple clients. To configure a port to authenticate multiple clients, specify the **multiple-instances** parameter of the **dot1x enable** command.

For example, in Figure 27-2, if port et.2.1 on RS1 was a trunk port, its configuration would be as follows:

```
!Configure the trunk port
rs (config)# vlan make trunk-port et.2.1
!Create the VLANs and add the trunk port
rs (config)# vlan create red ip
rs (config)# vlan create blue ip
rs (config)# vlan create white ip
rs (config)# vlan add ports et.2.1 to red
rs (config)# vlan add ports et.2.1 to blue
rs (config)# vlan add ports et.2.1 to white
! Define the RADIUS server to be used for 802.1x authentication
rs (config)# dot1x set server 10.10.10.1 key riverstone
rs (config)# dot1x add server 10.10.10.1 usage both
!Enable 802.1x authentication on the RS
rs (config)# dot1x set port et.2.1. port-control auto
rs (config)# dot1x enable port-list et.2.1 multiple-instances
```

Reauthenticating a Trunk Port

When you manually reauthenticate a trunk port, you can limit authentication to a specific VLAN or you can specify all VLANs. The following example reauthenticates VLAN BLUE (with VID 21) on port et.2.1:

```
rs # dot1x reauthenticate port-list et.2.1 vlan 21
```

27.2.2 Authenticating 802.1x-Unaware Devices

When an RS port is connected to a device that does not support 802.1x, the port can authenticate the client by using an authorization filter. When the RS receives a packet on a port to which an authorization filter is applied, the port uses the source address (SA) of the packet to query the authentication filter. If the SA matches an address that is on the filter, then the RS accepts the packet. If the SA does not have a match, then the RS drops the packet. Additionally, if the client sends out packets with different source addresses, only the first SA is authenticated, even if both addresses are in the filter.

To enable the RS to authenticate 802.1x-unaware clients:

- Configure an authorization filter.
- Enable 802.1x on the ports to which the client is connected.

The following sections describe each of these tasks.

Configuring an Authorization Filter

An authorization filter contains a list of end-station MAC addresses that are authorized. Only the MAC addresses specified in the filter are authenticated. Frames with source MAC addresses that are not specified in the filter are dropped. When you configure a filter, specify the following:

- Name of the authorization filter
- MAC address of the end-station to be authenticated
- Input ports that the frames with the specified source addresses can use
- Optionally, a mask to be applied against the source MAC

Following is an example of an authorization filter:

```
rs (config)# filters add authorization-filter name filter 100 source-mac
000000:0000a0
            in-port-list et.3.2
```

Enabling 802.1x on RS Ports

The commands for enabling 802.1x on ports connected to 802.1x-unaware clients are much the same as those used for ports connected to 802.1x-aware clients. The only difference is that when you specify the **dot1x set port** command, use the **dot1x-protocol** parameter to specify that the client on the other end does not support 802.1x, as shown in the following example:

```
rs (config)# dot1x set port et.2.1. port-control auto dot1x-protocol unaware
rs (config)# dot1x enable port-list et.2.1
```

802.1x-Unaware Configuration Example

In the following example, the RS is connected to an 802.1x-unaware device. In this situation, the RS does not use the RADIUS server for authentication. Instead, it uses a previously configured authorization filter. If the end station's MAC address is not in the filter, then that end station's packets are denied.

Figure 27-3 Authenticating an 802.1x-unaware client

The following example is the configuration for RS1:

```
! Configure the authorization filter
rs (config)# filters add authorization-filter name filter_100 source-mac 000000:0000a0
in-port-list et.3.2

!Enable 802.1x authentication on the RS
rs (config)# dot1x set port et.3.2 port-control auto dot1x-protocol unaware
rs (config)# dot1x enable port-list et.3.2
```

Use the **filters show authorization-filter** command to display the authorization filter, as shown in the following example.

```
rs# filters show authorization-filter all-source


Name:           filter_100
----
VLAN:           any VLAN
Source MAC:     000000:0000A0
Dest MAC:       000000:000000
In-List ports:  et.3.2
```

27.3 LAYER-2 SECURITY FILTERS

Layer-2 security filters on the RS allow you to configure ports to filter specific MAC addresses. When defining a Layer-2 security filter, you specify to which ports you want the filter to apply. You can specify the following security filters:

Address filters	These filters block traffic based on the frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Address filters are always configured and applied to the input port.
Port-to-address lock filters	These filters prohibit a user connected to a locked port or set of ports from using another port.
Static entry filters	These filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port.
Secure port filters	A secure filter shuts down access to the RS based on MAC addresses. All packets received by a port are dropped. When combined with static entries, however, these filters can be used to drop all received traffic but allow some frames to go through.

27.3.1 Configuring Layer-2 Address Filters

If you want to control access to a source or destination on a per-MAC address basis, you can configure an address filter. Address filters are always configured and applied to the input port. You can set address filters on the following:

- A source MAC address, which filters out any frame coming from a specific source MAC address
- A destination MAC address, which filters out any frame destined to specific destination MAC address
- A flow, which filters out any frame coming from a specific source MAC address that is also destined to a specific destination MAC address

To configure Layer-2 address filters, enter the following commands in Configure mode:

Configure a source MAC based address filter.	**filters add address-filter name** <*name*> **source-mac** <*MACaddr*>**|any source-mac-mask** <*mask*>**|any vlan** <*VLAN-num*>**|any in-port-list** <*port-list*>
Configure a destination MAC based address filter.	**filters add address-filter name** <*name*> **dest-mac** <*MACaddr*>**|any dest-mac-mask** <*mask*> **vlan** <*VLAN-num*>**|any in-port-list** <*port-list*>
Configure a Layer-2 flow address filter.	**filters add address-filter name** <*name*> **source-mac** <*MACaddr*>**|any source-mac-mask** <*mask*> **dest-mac** <*MACaddr*>**|any dest-mac-mask** <*mask*> **vlan** <*VLAN-num*>**|any in-port-list** <*port-list*>

27.3.2 Configuring Layer-2 Port-to-Address Lock Filters

Port address lock filters allow you to bind or "lock" specific source MAC addresses to a port or set of ports. Once a port is locked, only the specified source MAC address is allowed to connect to the locked port and the specified source MAC address is not allowed to connect to any other ports.

To configure Layer-2 port address lock filters, enter the following commands in Configure mode:

Configure a port address lock filter.	**filters add port-address-lock name** <*name*> **source-mac** <*MACaddr*> **vlan** <*VLAN-num*> **in-port-list** <*port-list*>

27.3.3 Configuring Layer-2 Static Entry Filters

Static entry filters allow or force traffic to go to a set of destination ports based on a frame's source MAC address, destination MAC address, or both source and destination MAC addresses in flow bridging mode. Static entries are always configured and applied at the input port. You can set the following static entry filters:

- Source static entry, which specifies that any frame coming from source MAC address will be allowed or disallowed
- Destination static entry, which specifies that any frame destined to a specific destination MAC address will be allowed, disallowed, or forced to go to a set of ports
- Flow static entry, which specifies that any frame coming from a specific source MAC address that is destined to specific destination MAC address will be allowed, disallowed, or forced to go to a set of ports

To configure Layer-2 static entry filters, enter the following commands in Configure mode:

Configure a source static entry filter.	**filters add static-entry name** <*name*> **restriction allow|disallow source-mac** <*MACaddr*>**|any source-mac-mask** <*mask*> **vlan** <*VLAN-num*>**|any in-port-list** <*port-list*> **out-port-list** <*port-list*>
Configure a destination static entry filter.	**filters add static-entry name** <*name*> **restriction allow|disallow|force dest-mac** <*MACaddr*> **dest-mac-mask** <*mask*>**|any vlan** <*VLAN-num*>**|any in-port-list** <*port-list*> **out-port-list** <*port-list*>

27.3.4 Configuring Layer-2 Secure Port Filters

Secure port filters block access to a specified port. You can use a secure port filter by itself to secure unused ports. Secure port filters can be configured as source or destination port filters. A secure port filter applied to a source port forces all incoming packets to be dropped on a port. A secure port filter applied to a destination port prevents packets from going out a certain port.

You can combine secure port filters with static entries in the following ways:

- Combine a source secure port filter with a source static entry to drop all received traffic but allow any frame coming from specific source MAC address to go through.
- Combine a source secure port filter with a flow static entry to drop all received traffic but allow any frame coming from a specific source MAC address that is destined to specific destination MAC address to go through.
- Combine a destination secure port with a destination static entry to drop all received traffic but allow any frame destined to specific destination MAC address go through.
- Combine a destination secure port filter with a flow static entry to drop all received traffic but allow any frame coming from specific source MAC address that is destined to specific destination MAC address to go through.

To configure Layer-2 secure port filters, enter the following commands in Configure mode:

Configure a source secure port filter.	**filters add secure-port name** <*name*> **direction source vlan** <*VLAN-num*> **in-port-list** <*port-list*>
Configure a destination secure port filter.	**filters add secure-port name** <*name*> **direction destination vlan** <*VLAN-num*> **in-port-list** <*port-list*>

27.3.5 Monitoring Layer-2 Security Filters

The RS provides display of Layer-2 security filter configurations contained in the routing table.

To display security filter information, enter the following commands in Enable mode.

Show address filters.	**filters show address-filter [all-source|all-destination|all-flow] [source-mac** <*MACaddr*> **dest-mac** <*MACaddr*>**] [ports** <*port-list*>**] [vlan** <*VLAN-num*>**]**
Show port address lock filters.	**filters show port-address-lock ports [ports** <*port-list*>**] [vlan** <*VLAN-num*>**] [source-mac** <*MACaddr*>**]**
Show secure port filters.	**filters show secure-port**
Show static entry filters.	**filters show static-entry [all-source|all-destination|all-flow] ports** <*port-list*> **vlan** <*VLAN-num*> **[source-mac** <*MACaddr*> **dest-mac** <*MACaddr*>**]**

27.3.6 Layer-2 Filter Examples

Figure 27-4shows the router connections for which layer-2 security filters will be configured.

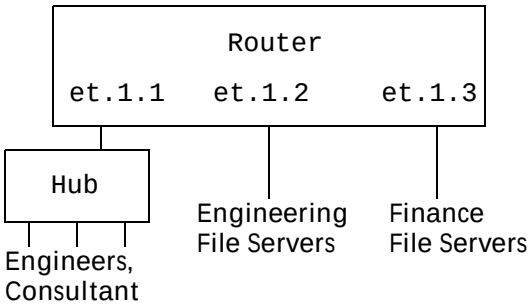


Figure 27-4 Source filter example

Example 1: Address Filters

Source filter: The consultant is not allowed to access any file servers. The consultant is only allowed to interact with the engineers on the same Ethernet segment – port et.1.1. All traffic coming from the consultant's MAC address will be dropped.

```
filters add address-filter name consultant source-mac 001122:334455 vlan 1
    in-port-list et.1.1
```

Destination filter: No one from the engineering group (port et.1.1) should be allowed to access the finance server. All traffic destined to the finance server's MAC will be dropped.

```
filters add address-filter name finance dest-mac AABBCC:DDEEFF vlan 1 in-port-list
    et.1.1
```

Flow filter: Only the consultant is restricted access to one of the finance file servers. Note that port et.1.1 should be operating in flow-bridging mode for this filter to work.

```
filters add address-filter name consult-to-finance source-mac 001122:334455 dest-mac
    AABBCC:DDEEFF vlan 1 in-port-list et.1.1
```

Static Entries Example

Source static entry: The consultant is only allowed to access the engineering file servers on port et.1.2.

```
filters add static-entry name consultant source-mac 001122:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Destination static entry: Restrict "login multicasts" originating from the engineering segment (port et.1.1) from reaching the finance servers.

```
filters add static-entry name login-mcasts dest-mac 010000:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.3 restriction disallow
```

or

```
filters add static-entry name login-mcasts dest-mac 010000:334455 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Flow static entry: Restrict "login multicasts" originating from the consultant from reaching the finance servers.

```
filters add static-entry name consult-to-mcasts source-mac 001122:334455  dest-mac
    010000:334455 vlan 1 in-port-list et.1.1 out-port-list et.1.3 restriction disallow
```

Port-to-Address Lock Examples

You have configured some filters for the consultant on port et.1.1 If the consultant plugs his laptop into a different port, he will bypass the filters. To lock him to port et.1.1, use the following command:

```
filters add port-address-lock name consultant source-mac 001122:334455 vlan 1
    in-port-list et.1.1
```

Note If the consultant's MAC is detected on a different port, all of its traffic will be blocked.

Example 2: Secure Ports

Source secure port: To block all engineers on port 1 from accessing all other ports, enter the following command:

```
filters add secure-port name engineers direction source vlan 1
    in-port-list et.1.1
```

To allow ONLY the engineering manager access to the engineering servers, you must "punch" a hole through the secure-port wall. A "source static-entry" overrides a "source secure port".

```
filters add static-entry name eng-mgr source-mac 080060:123456 vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

Destination secure port: To block access to all file servers on all ports from port et.1.1 use the following command:

```
filters add secure-port name engineers direction dest vlan 1
    in-port-list et.1.1
```

To allow all engineers access to the engineering servers, you must "punch" a hole through the secure-port wall. A "dest static-entry" overrides a "dest secure port".

```
filters add static-entry name eng-server dest-mac 080060:abcdef vlan 1 in-port-list
    et.1.1 out-port-list et.1.2 restriction allow
```

27.4 LAYER-3 ACCESS CONTROL LISTS (ACLS)

Access Control Lists (ACLs) allow you to restrict Layer-3/4 traffic going through the RS. Each ACL consists of one or more rules describing a particular type of IP traffic. An ACL can be simple, consisting of only one rule, or complicated with many rules. Each rule tells the router to either permit or deny the packet that matches the rule's packet description.

For information about defining and using ACLs on the RS, see Chapter 26, *"Access Control List Configuration."*

27.5 LAYER-4 BRIDGING AND FILTERING

Layer-4 bridging is the RS's ability to use layer-3/4 information to perform filtering or QoS during bridging. As described in Section 27.3, *"Layer-2 Security Filters."* above, you can configure ports to filter traffic using MAC addresses. Layer-4 bridging adds the ability to use IP addresses, layer-4 protocol type, and port number to filter traffic in a bridged network. Layer-4 bridging allows you to apply security filters on a "flat" network, where the client and server may reside on the same subnet.

Note Ports that are included in a layer-4 bridging VLAN must reside on updated RS hardware.

To illustrate this, the following diagram shows an RS serving as a bridge for a consultant host, file server, and an engineering host, all of which reside on a single subnet.

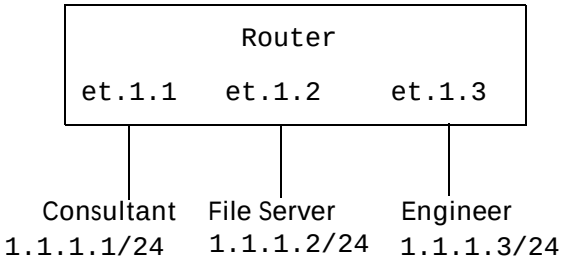


Figure 27-5 Sample VLAN for layer-4 bridging

You may want to allow the consultant access to the file server for e-mail (SMTP) traffic, but not for Web (HTTP) traffic and allow e-mail, Web, and FTP traffic between the engineer and the file server. You can use Layer-4 bridging to set this up.

Setting up Layer-4 bridging consists of the following steps:

- Creating an IP VLAN
- Placing the ports on the same VLAN
- Enabling Layer-4 Bridging on the VLAN
- Creating an ACL that specifies the selection criteria
- Applying an ACL to a port

27.5.1 Creating an IP VLAN for Layer-4 Bridging

To enable Layer-4 bridging on a VLAN, the VLAN must be configured to pass only IP traffic. (Therefore, you cannot enable Layer-4 bridging on port-based VLANS.) To create an IP or IPX VLAN, enter the following command in Configure mode:

Create an IP or IPX VLAN.	**vlan create** <*vlan-name*> <*type*> **id** <*num*>

For example, to create an IP VLAN called “blue” with an ID of 21, enter the following command in Configure mode:

```
rs(config)# vlan create blue ip id 21
```

27.5.2 Placing the Ports on the Same VLAN

Once you have created a VLAN for the ports to be used in layer-4 bridging, you add those ports to the VLAN. To add ports to a VLAN, enter the following command in Configure mode:

Add ports to a VLAN.	**vlan add ports** <*port-list*> **to** <*vlan-name*>

To add the ports in the example in Figure 27-5, to the blue VLAN you would enter the following command:

```
rs(config)# vlan add ports et.1.1,et.1.2,et.1.3 to blue
```

27.5.3 Enabling Layer-4 Bridging on the VLAN

After adding the ports to the VLAN, you enable Layer-4 Bridging on the VLAN. To do this, enter the following command in Configure mode:.

Enable Layer 4 bridging.	**vlan enable l4-bridging on** <*vlan-name*>

For example, to enable Layer-4 Bridging on the blue VLAN:

```
rs(config)# vlan enable l4-bridging on blue
```

27.5.4 Creating ACLs to Specify Selection Criteria for Layer-4 Bridging

Access control lists (ACLs) specify the kind of filtering to be done for Layer-4 Bridging.

In the example in Figure 27-5, to allow the consultants access to the file server for e-mail (SMTP) traffic, but not for Web (HTTP) traffic — and allow e-mail, Web, and FTP traffic between the engineers and the file server, you would create ACLs that allow only SMTP traffic on the port to which the consultants are connected and allow SMTP, HTTP, and FTP traffic on the ports to which the engineers are connected.

The following is an example:

```
acl 100 permit ip any any smtp
acl 100 deny ip any any http

acl 200 permit any any smtp
acl 200 permit any any http
acl 200 permit any any ftp
```

ACL 100 explicitly permits SMTP traffic and denies HTTP traffic. Note that because of the implicit deny rule appended to the end of the ACL, all traffic (not just HTTP traffic) other than SMTP is denied.

ACL 200 explicitly permits SMTP, HTTP, and FTP traffic. The implicit deny rule denies any other traffic. See Section 26.2, *"Editing ACLs."* for more information on defining ACLs.

27.5.5 Applying a Layer-4 Bridging ACL to a Port

Finally, you apply the ACLs to the ports in the VLAN. To do this, enter the following command in Configure mode:

Apply a Layer-4 bridging ACL to a port	**acl** <*name*> **apply port** <*port-list*>

For the example in Figure 27-5, to apply ACL 100 (which denies all traffic except SMTP) to the consultant port:

```
rs(config)# acl 100 apply port et.1.1 output
```

To apply ACL 200 (which denies all traffic except SMTP, HTTP, and FTP) to the engineer port:

```
rs(config)# acl 200 apply port et.1.3 output
```

27.5.6 Notes

- Layer-4 Bridging works for IP and IPX traffic only. The RS will drop non-IP/IPX traffic on a Layer-4 Bridging VLAN. For Appletalk and DECnet packets, a warning is issued before the first packet is dropped.
- If you use a SmartTRUNK in a with Layer-4 Bridging VLAN, the RS maintains the packet order on a per-flow basis, rather than per-MAC pair. This means that for traffic between a MAC pair consisting of more than one flow, the packets may be disordered if they go through a SmartTRUNK. For traffic that doesn't go through a SmartTRUNK, the per-MAC pair packet order is kept.
- ACLs applied to a network interface (as opposed to a port) do not have an effect on Layer-4 Bridged traffic, even though the interface may include ports used in Layer-4 Bridging.

28 QOS CONFIGURATION

The RS allows network managers to identify traffic and set Quality of Service (QoS) policies without compromising wire speed performance. The RS can guarantee bandwidth on an application by application basis, thus accommodating high-priority traffic even during peak periods of usage. QoS policies can be broad enough to encompass all the applications in the network, or relate specifically to a single host-to-host application flow.

The RS provides four different features to satisfy QoS requirements:

Traffic Prioritization – Allows network administrators to differentiate between mission-critical network traffic and non-critical network traffic and segregate the traffic into different priority queues. Once a packet has been identified, it can be assigned to any one of the four priority queues in order to ensure delivery. Priority can be allocated based on any combination of Layer-2, Layer-3, or Layer-4 traffic.

Weighted Random Early Detection (WRED) – Alleviates traffic congestion by randomly dropping packets before the queues pass their upper thresholds. WRED is intended to work with connection-oriented protocols (especially TCP). However, WRED when applied to a port receiving connection less traffic can reduce latency on that port.

Type of Service (ToS) – ToS Rewrite provides network administrators access to the ToS octet in an IP packet. The ToS octet is designed to provide feedback to the upper layer application. The administrator can mark packets using the ToS rewrite feature so that the application (a routing protocol, for example) can handle the packet based on a predefined mechanism.

Within the RS, QoS policies are used to classify Layer-2, Layer-3, and Layer-4 traffic into the following priority queues (in order from highest priority to lowest):

- Control
- High
- Medium
- Low

Note Control is for router control traffic. The remaining classes are for normal data flows.

Separate buffer space is allocated to each of these four priority queues. By default, buffered traffic in higher priority queues is forwarded ahead of pending traffic in lower priority queues. This is the *strict priority* queuing policy. During heavy loads, low-priority traffic can be dropped to preserve the throughput of the higher-priority traffic. This ensures that critical traffic will reach its destination even if the exit ports for the traffic are experiencing greater-than-maximum utilization. To prevent low-priority traffic from waiting indefinitely as higher-priority traffic is sent, you can apply the Weighted Fair Queuing (WFQ) queuing policy to set a minimum bandwidth for each class. You can also apply WRED to keep the congestion of TCP traffic under control.

28.1 LAYER-2, LAYER-3 AND LAYER-4 FLOW SPECIFICATION

In the RS, traffic classification is accomplished by mapping Layer-2, -3, or -4 traffic to one of the four priorities. Each traffic classification is treated as an individual traffic flow in the RS.

For Layer-2 traffic, you can define a flow based on MAC packet header fields, including source MAC address, destination MAC address, and VLAN IDs. A list of incoming ports can also be specified.

For Layer-3 (IP) traffic, you can define flows, blueprints or templates of IP packet headers:

Ip Fields – The source IP address, destination IP address, UDP/TCP source port, UDP/TCP destination port, TOS (Type of Service), transport protocol (TCP or UDP), and a list of incoming interfaces.

For Layer-4 traffic, you can define a flow based on source/destination TCP/UDP port number in addition to the Layer-3 source/destination IP address.

The flows specify the contents of these fields. If you do not enter a value for a field, a wildcard value (all values acceptable) is assumed for the field.

28.2 PRECEDENCE FOR LAYER-3 FLOWS

A precedence from 1 to 7 is associated with each field in a flow. The RS uses the precedence value associated with the fields to break ties if packets match more than one flow. The highest precedence is 1 and the lowest is 7. Here is the default precedence of the fields:

- IP
  - Destination port – 1
  - Destination IP address – 2
  - Source port – 3
  - Source IP address – 4
  - ToS – 5
  - Interface – 6
  - Protocol – 7

Use the **`qos precedence ip`** command to change the default precedence.

28.3 RS QUEUING POLICIES

There are two types of queuing policies you can use on the RS:

Strict priority – Assures the higher priorities of throughput but at the expense of lower priorities. For example, during heavy loads, low-priority traffic can be dropped to preserve throughput of control-priority traffic. This is the default queuing policy.

Weighted fair queuing – Distributes priority throughput among the four priorities based on percentages. This queuing policy is set on a per-port basis.

28.4 TRAFFIC PRIORITIZATION FOR LAYER-2 FLOWS

QoS policies applied to Layer-2 flows allow you to assign priorities based on source and destination MAC addresses. A QoS policy set for a Layer-2 flow allows you to classify the priority of traffic from:

- A specific source MAC address to a specific destination MAC address (use only when the port is in flow bridging mode).
- Any source MAC address to a specific destination MAC address.

Before applying a QoS policy to a Layer-2 flow, you must first determine whether a port is in the address-bridging mode or flow-bridging mode. If a port is operating in address-bridging mode (default), you can specify the priority based on the destination MAC address and a VLAN ID. You can also specify a list of ports to apply the policy.

If a port is operating in the flow-bridging mode, you can be more specific and configure priorities for frames that match both a source and a destination MAC address and a VLAN ID. You can also specify a list of ports to apply the policy.

The VLAN ID in the QoS configuration must match the VLAN ID assigned to the list of ports to which the QoS policy is applied. In a Layer-2 only configuration, each port has only one VLAN ID associated with it and the QoS policy should have the same VLAN ID. When different VLANs are assigned to the same port using different protocol VLANs, the Layer-2 QoS policy must match the VLAN ID of the protocol VLAN.

Note In the flow mode, you can also ignore the source MAC address and configure the priority based on the destination MAC address only.

28.4.1 Configuring Layer-2 QoS

When applying QoS to a layer-2 flow, priority can be assigned as follows:

- The frame gets assigned a priority within the switch. Select low, medium, high or control.
- The frame gets assigned a priority within the switch, and if the exit ports are VLAN trunk ports, the frame is assigned an 802.1Q priority. Select a number from 0 to 7.

To set a QoS priority on a layer-2 flow, enter the following command in the Configure mode:

Set a layer-2 QoS policy.	`qos set l2 name` <*name*> `source-mac` <*MACaddr*> `dest-mac` <*MACaddr*> `vlan` <*vlanID*> `in-port-list` <*port-list*> `priority control | high | medium | low |` <t*runk-priority*> `ignore-ingress-802.1p`

Note When applying this command to WAN ports, the ports in <*port-list*> defining **`in-port-list`** are limited to physical ports only. For example, logical channels such as t1.3.1:2 are not supported.

28.4.2 802.1p Class of Service Priority Mapping

The following table shows the default mappings of 802.1p Class of Service (CoS) values to internal priorities for frames:

Table 28-1 802.1p default priority mappings

802.1p CoS values	Internal priority queue
0, 1	Low
2, 3	Medium
4, 5	High
6, 7	Control

You can create one or more priority maps that are different from the default priority map and then apply these maps to some or all ports on the RS. The new priority mapping replaces the default mappings for those ports.

Creating and Applying a New Priority Map

To specify a priority map on a per-port basis, enter the following commands in the Configure mode:

Create a new priority mapping.	**`qos create priority-map`** <*name*> <*CoS number*> **`control | high | medium | low`**
Apply new priority mapping to ports.	**`qos apply priority-map`** <*name*> **`ports`** <*port-list*>

For example, the following command creates the priority map *all-low* which maps all 802.1p priorities to the low internal priority queue:

```
qos create priority-map all-low 0 low 1 low 2 low 3 low 4 low 5 low 6 low 7 low
```

Once a priority map is created, it can then be applied to a set of ports, as shown in the following example:

```
qos apply priority-map all-low ports et.1.1-4, gi.4.*
```

In the above example, ports et.1.1-4 and ports gi.4.* will use the *all-low* priority map. All other ports, including ports et.1.5-8, will use the default priority map.

You do not need to specify mappings for all 802.1p values. If you do not specify a particular mapping, the default mapping for that 802.1p priority is used. The following example creates a priority map *no-ctrl* with the same mappings as the default priority map, except that the 802.1p priority of 7 is mapped to the internal priority high instead of control.

```
qos create priority-map no-ctrl 7 high
```

Removing or Disabling Per-Port Priority Map

Negating a **qos create priority-map** command removes the priority map. Before you can remove a priority map, you must negate all commands that use the priority map. Negating a **qos apply priority-map** command causes the configured ports to use the default priority mapping.

The ability to specify per-port priority maps is enabled on the RS by default. You can disable use of per-port priority maps on the RS. All ports on the RS will then be configured to use the default priority map only. If the commands to create and apply priority maps exist in the active configuration, they will remain in the configuration but be ineffective.

To disable the use of priority maps, enter the following command in the Configure mode:

Disable use of per-port priority maps on the RS.	**qos priority-map off**

If the above command is negated, ports on the RS can use per-port priority maps. If the commands to create and apply priority maps exist in the active configuration, they are reapplied.

Displaying Priority Map Information

To display priority maps and the ports on which they are applied, enter the following command in Enable mode:

Display priority mapping.	**qos show priority-map** <*name*> **| all**

28.5 TRAFFIC PRIORITIZATION FOR LAYER-3 & LAYER-4 FLOWS

QoS policies applied at Layer-3 and -4 allow you to assign priorities based on specific fields in the IP headers. You can set QoS policies for IP flows based on source IP address, destination IP address, source TCP/UDP port, destination TCP/UDP port, type of service (TOS) and transport protocol (TCP or UCP). A QoS policy set on an IP flow allows you to classify the priority of traffic based on:

- Layer-3 source-destination flows
- Layer-4 source-destination flows
- Layer-4 application flows

28.5.1 Configuring IP QoS Policies

To configure an IP QoS policy, perform the following tasks:

1. Identify the Layer-3 or -4 flow and set the IP QoS policy.
2. Specify the precedence for the fields within an IP flow.

Setting an IP QoS Policy

To set a QoS policy on an IP traffic flow, use the following command in the Configure mode:

Set an IP QoS policy.	**qos set ip** <*name*> <*priority*> <*srcaddr/mask*> | **any** <*dstaddr/mask*> | **any** <*srcport*> | **any** <*dstport*> | **any** <*tos*> | **any** <*port list*> | <interface-list> | **any** <*protocol*> | **any** <*tos-mask*> | **any** <*tos-precedence-rewrite*> | **any** <*tos-rewrite*> | **any**

For example, the following command assigns control priority to any traffic coming from the 10.10.11.0 network:

```
qos set ip xyz control 10.10.11.0/24
```

Specifying Precedence for an IP QoS Policy

To specify the precedence for an IP QoS policy, use the following command in the Configure mode:

Specify precedence for an IP QoS policy.	**qos precedence ip** [**sip** <*num*>] [**dip** <*num*>] [**srcport** <*num*>] [**destport** <*num*>] [**tos** <*num*>] [**protocol** <*num*>] [**intf** <*num*>]

28.6 CONFIGURING WEIGHTED FAIR QUEUEING

The default queuing policy for all ports on the RS is strict priority. You can change the queueing policy from strict priority to weighted fair queueing on a port by port basis. The following example sets the queueing policy of port et.4.14 to weighted fair queueing.

```
rs(config)# qos set queueing-policy weighted-fair port et.4.14
```

Use the **qos show weighted-fair** command to show a port's bandwidth allocation, as shown in the following example.

```
rs# qos show weighted-fair port et.4.14
Port      Policy  Control       High          Medium        Low           Idle
--------- ------- ------------- ------------- ------------- ------------- -----
et.4.14   WFQ     25            25            25            25            0
```

28.6.1 Allocating Bandwidth

When you set a port's queueing policy to weighted-fair, the bandwidth allocation is set by default to 25% in each queue (control, high, medium, and low). You can change these defaults, as shown in the following example:

```
rs(config)# qos set weighted-fair control 30 high 30 medium 30 low 10
```

Normally, a priority queue is allowed to "borrow" bandwidth from other queues when it has bursty traffic that goes above its limit and the other queues are not using their bandwidth. When you set a queue's bandwidth, you can also specify from which queue a priority queue can borrow bandwidth, as shown in the following example:

```
rs(config)# qos set weighted-fair control 30 control-burst low-medium high 30
high-burst low-medium  medium 30 medium-burst none low 10 low-burst none port et.4.14
```

The example specifies the following:

- the control queue and the high queue are each allocated 30% of the bandwidth and can borrow bandwidth from the low and medium queues
- the medium queue is allocated 30% of the bandwidth and the low queue is allocated 10%; neither of them can borrow bandwidth from another queue. This is specified by the keyword **none** used with the **medium-burst** and **low-burst** parameters. Use this keyword when you want to enforce the bandwidth allocation of any of the queues. It prevents a priority queue from using more bandwidth than is specified, even if other queues have unused bandwidth.

28.6.2 Running different queueing algorithms

You can also configure priority queues to run different queueing algorithms simultaneously. For example, you can set the control queue to use strict priority, while the other queues use weighted fair, as shown in the following example:

```
rs(config)# qos set weighted-fair strict control high 60 medium 30 low 10
```

Note If you want to revert the RS queuing policy from weighted-fair to strict priority (default), use the **negate** command.

WFQ Using Line Cards with Fifth Generation ASICs

The line cards equipped with 5th generation ASICs use somewhat different queuing algorithms. These algorithms provide additional functionality and use the concepts **limit**, **strict**, and **idle** differently. The following explains the use of these terms as applied to line cards with 5th generation ASICs.

limit – the queue cannot exceed the specified percent of the physical bandwidth of the port. For example, setting the low-limit 3 on a 100Mbps port, means that low priority traffic cannot exceed 3Mbps.

strict – strict priority queuing is enforced for this queue. For example, if the control queue is set to strict, while high, medium, and low are set to WFQ, control priority traffic is sent at any time, regardless of the queue that should be sending out traffic based on the WFQ settings.

idle – this is the percent of the time that the port should remain idle. For example, if this is set to 75% on a 100Mbps link, the port can send only at a maximum rate of 25Mbps.

The following is an example of using the **idle** parameter to control bandwidth on a port – A 100Mbps physical port is assigned to a user with the restriction that the user is to have 20Mbps of throughput, but no other restrictions. To accomplish this, the port is idled by 80%:

```
rs(config)# qos set weighted-fair idle 80 control 20 strict control port et.5.1
```

This allow all the traffic to be transmitted at up to 20Mbps, while at the same time giving control traffic priority.

28.7 WEIGHTED RANDOM EARLY DETECTION (WRED)

WRED is a dynamic process for controlling congestion on RS ports and the segments of the network associated with the WRED enabled ports. The WRED process consists of setting a *minimum queue threshold* (min-threshold) and a *maximum queue threshold* (max-threshold) on any of the four queues (low, medium, high, and control) belonging to a port. Associated with these thresholds is an *average queue size*, which is dynamically calculated as the instantaneous average buffer depth. If the average queue size is below the min-threshold, no packets are discarded. However, if the average queue size rises above the min-threshold, WRED uses a *packet-marking probability* algorithm to randomly mark packets for discard. As the average queue size increases toward the max-threshold, the probability of packet drop also increases. Eventually, if the average queue size exceeds the max-threshold, the probability of packet drop becomes 1 (100% of packets are dropped). This increase in the probability of packet drop increases in a linear fashion from 0 to 1 (0% dropped to 100% dropped). Notice that the probability of packet drop roughly depends on bandwidth, i.e.; the more packets sent by a particular connection, the greater the probability that packets will be dropped from that connection.

Note WRED is not supported on 10/100 Mbps line cards that contain fifth generation ASICs.

28.7.1 WRED's Effect on the Network

WRED's full capabilities to reduce congestion are best used with TCP (and other connection-oriented protocols). As TCP traffic increases on a WRED port, and the average queue size rises above the min-threshold, some TCP packets begin to drop. Each TCP source interprets dropped packets as an indication of congestion. As a result, each TCP source that has experienced a dropped packet reduces its window, the average queue size decreases, and congestion is alleviated.

Although connection-less protocols do not have the response capability of TCP to sense congestion. Nevertheless, WRED's technique of dropping packets based on rising probability assures that those connections that are sending the most packets or using the most bandwidth will be more likely to have their packets dropped than lower bandwidth connections. This provides at least some assurance of equality of throughput on a WRED port for connection-less protocols.

28.7.2 Weighting Algorithms in WRED

The following algorithm parameters are all found under the of the **`qos wred`** command.

WRED provides for the "fine-tuning" of both the average queue size algorithm and the packet-marking probability algorithm. Control over the average queue size algorithm is provided by the **`exponential-weighting-constant`** parameter. Control over the packet-marking probability algorithm is provided by the **`mark-prob-denominator`** parameter.

The **`exponential-weighting-constant`** parameter specifies how fast the average queue size changes in response to changes in the actual queue depth. In effect, the rate of change of the average queue size can be dampened. The **`exponential-weighting-constant`** accepts values from zero (0) to three (3) when WRED is applied to input queues, and from zero (0) to seven (7) when WRED is applied to output queues. Note that 0 provides the least amount of dampening, while larger numbers provide greater amounts of dampening.

This ability to dampen the response time of the average queue size changes WRED's response to bursty traffic. For example, notice in Figure 28-1 that while the traffic (solid line) bursts at times, the average queue size (dotted curve) is dampened such that it does not rise above the minimum threshold within the duration of the bursts. This keeps the port from discriminating against traffic that might burst slightly at times.

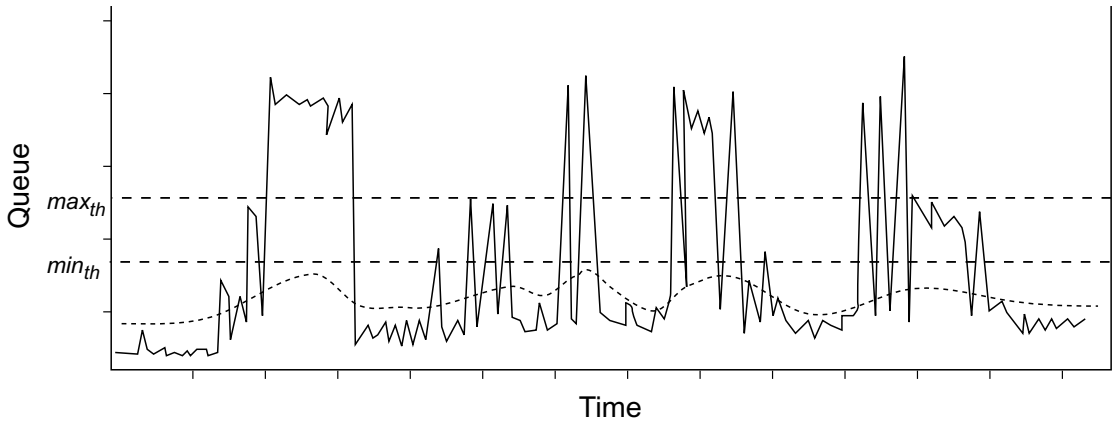


Figure 28-1 Average queue size and bursty traffic

The **mark-prob-denominator** parameter is used to determine the probability of a packet being dropped when the average queue size is between the minimum and maximum thresholds. The **mark-prob-denominator** accepts values from zero (0) to three (3) when WRED is applied to input queues and from zero (0) to seven (7) when WRED is applied to output queues. Note that the lower the value specified, the higher the probability that packets will be dropped.

Both the **exponential-weighting-constant** value and the **mark-prob-denominator** value are somewhat allegorical in the sense that neither of these values have a direct numerical significance other than acting as control values for WRED. For example, if the value for **exponential-weighting-constant** is increased from 1 to 2, the dampening of the average queue size response is not twice as slow. Because of this non-specific nature of **exponential-weighting-constant** and **mark-prob-denominator** and the fact that each network is different, a discussion of recommend, specific settings for these values is beyond the scope of this User Guide.

When first implementing WRED on your RS, it is recommended to initially use the default values for min-threshold, max-threshold, the weighting constant, and the probability denominator. If you begin or continue to experience congestion, especially with TCP traffic, try adjusting WRED by making small changes in the various parameters (one-at-a-time), and observing their effect on congestion.

To enable WRED on queues of specific input or output ports, enter the **qos wred input** | **output** command in Configure mode. To create a WRED profile to be used an Advance Service Module (ASM) line card, use the **qos wred asm** command in Configure mode:

Set parameters for the WRED algorithm	**qos wred** [**asm** <*name*> <*asm-parameters*>] [**input** | **output** **exponential-weighting-constant** <*num*> | **mark-prob-denominator** <*num*> | **max-queue-threshold** <*num*> | **min-queue-threshold** <*num*> | **port** <port list> | **all-ports** | {**queue control** | **high** | **medium** | **low**} | **type assured-forward** | **expedite-forward** | **marked-packets**] [**exp-weight** <*port*> <*num*>] [**one-p-weight** <*port*> <*num*>] [**size-weight** <*port*> <*num*>] [**tos-precedence-weight** <*port*> <*num*>]

To set the order in which precedence parameters are evaluated on a port or set of ports, use the **qos wred asm-precedence** command. This command allows the ordering in which Exp-bits, 802.1p tags, internal queues, and tos-precedence are evaluated.

Sets the order of precedence and evaluation	**qos wred asm -precedence exp** | **internal** | **one-p** | **port** *<port-list>* | **tos-precedence**

For example, to set the precedence for port **gi.11.1** to tos-precedence first, Exp-bits second, 802.1p tags as third, and internal priority queues as last, enter the following:

```
rs(config)# qos wred asm-precedence tos-precedence exp one-p internal port gi.11.1
```

For more information on using QoS and WRED, see the *QoS* chapter of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

28.8 TOS REWRITE

IP packets that use different paths are subject to delays, as there is little inherent knowledge of how to optimize the paths for different packets from different applications or users. The IP protocol actually provides a facility, which has been part of the IP specification since the protocol's inception, for an application or upper-layer protocol to specify how a packet should be handled. This facility is called the Type of Service (ToS) octet.

The ToS octet part of the IP specification, however, has not been widely employed in the past. The IETF is looking into using the ToS octet to help resolve IP quality problems. Some newer routing protocols, like OSPF and IS-IS, are designed to be able to examine the ToS octet and calculate routes based on the type of service.

The ToS octet in the IP datagram header consists of three fields:

Figure 28-2 ToS fields

- The three-bit Precedence field is used to indicate the priority of the datagram.
- The four-bit ToS field is used to indicate trade-offs between throughput, delay, reliability, and cost.
- The one-bit "must be zero" (MBZ) field is not currently used. (In the RS configuration, there is no restriction on this bit and it is included as part of the ToS field.)

For example, setting the ToS field to 0010 specifies that a packet will be routed on the most reliable paths. Setting the ToS field to 1000 specifies that a packet will be routed on the paths with the least delay. (Refer to RFC 1349 for the specification of the ToS field value.)

With the ToS rewrite command, you can access the value in the ToS octet (which includes both the Precedence and ToS fields) in each packet. The upper-layer application can then decide how to handle the packet, based on either the Precedence or the ToS field or both fields. For example, you can configure a router to forward packets using different paths, based on the ToS octet. You can also change the path for specific applications and users by changing the Precedence and/or ToS fields.

Note In RFC 2574, the IETF redefined the ToS octet as the *DiffServ* byte. You will still be able to use the ToS rewrite feature to implement *DiffServ* when this standard is deployed.

28.8.1 Configuring ToS Rewrite for IP Packets

The ToS rewrite for IP packets is set with the **`qos set`** command in the Configure mode. You can define the QoS policy based on any of the following IP fields:

- Source IP address
- Destination IP address
- Source port
- Destination port
- ToS
- Port
- Interface

When an IP packet is received, the ToS field of the packet is ANDed with the <*tos-mask*> and the resulting value is compared with the ANDed value of <*tos*> and <*tos-mask*> of the QoS policy. If the values are equal, the values of the <*tos-rewrite*> and <*tos-precedence-rewrite*> parameters will be written into the packet.

The <*tos*> and <*tos-mask*> parameters use values ranging from 0 to 255. They are used in conjunction with each other to define which bit in the <*tos*> field of the packet is significant. The <*tos-precedence-rewrite*> value ranges from 0 to 7 and is the value that is rewritten in the ToS Precedence field (the first three bits of the ToS octet). The <*tos-rewrite*> value ranges from 0 to 31 and is the value that is rewritten in the ToS field.

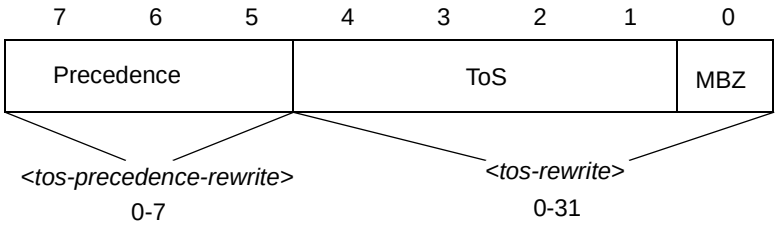


Figure 28-3 ToS rewrite

The ToS byte rewrite is part of the QoS priority classifier group. The entire ToS byte can be rewritten or only the precedence part of the ToS byte can be rewritten. If you specify a value for <*tos-precedence-rewrite*>, then only the upper three bits of the ToS byte are changed. If you set <*tos-precedence-rewrite*> to **any** and specify a value for

<*tos-rewrite*>, then the upper three bits remain unchanged and the lower five bits are rewritten. If you specify values for both <*tos-precedence-rewrite*> and <*tos-rewrite*>, then the upper three bits are rewritten to the <*tos-precedence-rewrite*> value and the lower five bits are rewritten to the <*tos-rewrite*> value.

For example, the following command will rewrite the ToS Precedence field to 7 if the ToS Precedence field of the incoming packet is 6:

```
qos set ip tosp6to7 low any any any any 222 any any 224 7
```

In the above example, the <*tos*> value of 222 (binary value 1101 1110) and the <*tos-mask*> value of 224 (binary value 1110 0000) are ANDed together to specify the ToS Precedence field value of 6 (binary value 110). Changing the value in the <*tos-mask*> parameter determines the bit in the ToS octet field that will be examined.

The following example will rewrite the ToS Precedence and the ToS fields to 5 and 30 if the incoming packet is from the 10.10.10.0/24 network with the ToS Precedence field set to 2 and the ToS field set to 7. In this example, the MBZ bit is included in the ToS field. The figure below shows how the parameter values are derived.

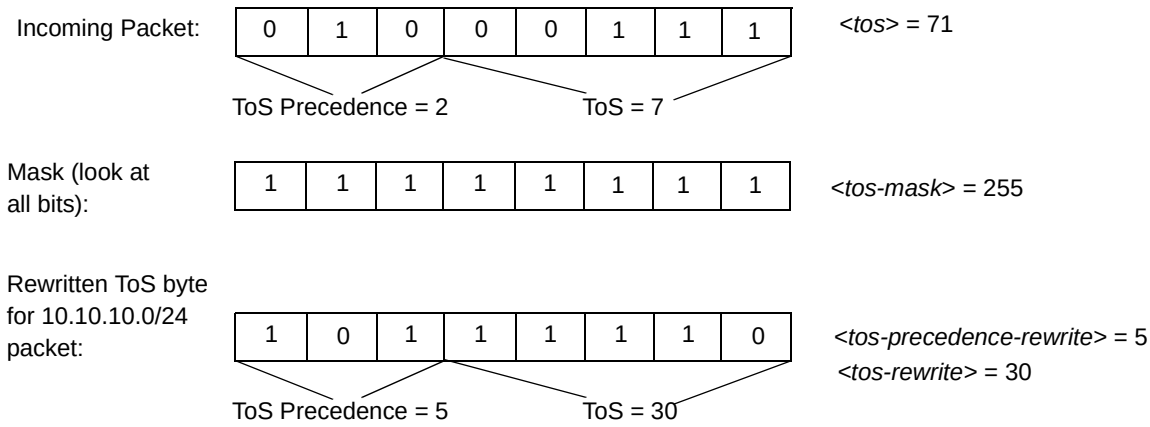


Figure 28-4 ToS rewrite example

The <*tos-mask*> value determines the ToS bit to be examined, which is all eight bits in this example. The following command configures the ToS rewrite for the example:

```
qos set ip tos30to7 low 10.10.10.0/24 any any any 71 any any 255 5 30
```

28.9 MONITORING QOS

The RS provides display of QoS statistics and configurations contained in the RS.

To display QoS information, enter the following commands in Enable mode:

Show all IP QoS flows.	**qos show ip**
Show all Layer-2 QoS flows.	**qos show l2 all-destination all-flow ports** *<port-list>* **vlan** *<vlanID>* **source-mac** *<MACaddr>* **dest-mac** *<MACaddr>*
Show RED parameters for each port.	**qos show red** [**input port** *<port-list>* **| all-ports**] [**output port** *<port-list>* **| all-ports**] [**port** *<port-list>* **| all-ports**]
Show IP precedence values.	**qos show precedence ip**
Show WFQ bandwidth allocated for each port.	**qos show wfq** [**port** *<port-list>* **| all-ports**] [**input** *<slot num>*] **| all-modules**]
Show priority mappings.	**qos show priority-map all**

29 PERFORMANCE MONITORING

The RS is a full wire-speed layer-2, 3 and 4 switching router. As packets enter the RS, layer-2, 3, and 4 flow tables are populated on each line card. The flow tables contain information on performance statistics and traffic forwarding. Thus the RS provides the capability to monitor performance at Layer 2, 3, and 4.

Layer-2 performance information is accessible to SNMP through MIB-II and can be displayed by using the **`l2-tables`** command in the CLI. Layer-3 and 4 performance statistics are accessible to SNMP through RMON/RMON2 and can be displayed by using the **`statistics show`** command in the CLI. In addition to the monitoring commands listed, you can find more monitoring commands listed in each chapter of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

To access statistics on the RS, enter the following commands in Enable mode:

Show DVMRP routes.	**`dvmrp show routes`**
Show all TCP/UDP connections and services.	**`ip show connections`**
Show all IP routes.	**`ip show routes`**
Show all MAC addresses currently in the L2 tables.	**`l2-tables show all-macs`**
Show info about MACs residing in a port's L2 table.	**`l2-tables show port-macs`** <*port-list*>
Show all L2 flows (for ports in flow-bridging mode.	**`l2-tables show all-flows`**
Show information about the master MAC table.	**`l2-tables show mac-table-stats`**
Show information about a particular MAC address.	**`l2-tables show mac`**
Show info about multicasts registered by IGMP.	**`l2-tables show igmp-mcast-registrations`**
Show whether IGMP is on or off on a VLAN.	**`l2-tables show vlan-igmp-status`**
Show info about MACs registered by the system.	**`l2-tables show bridge-management`**
Show SNMP statistics.	**`snmp show statistics`**
Show ICMP statistics.	**`statistics show icmp`**
Show IP interface's statistics.	**`statistics show ip`**
Show unicast routing statistics.	**`statistics show ip-routing`**
Show multicast statistics.	**`statistics show multicast`**
Show port error statistics.	**`statistics show port-errors`**
Show potential physical layer errors.	**`statistics show phy-errors`**

Show port normal statistics.	**statistics show port-stats**
Show RMON etherStats statistics.	**statistics show rmon**
Show traffic summary statistics.	**statistics show summary-stats**
Show most active tasks.	**statistics show top**
Show TCP statistics.	**statistics show tcp**
Show UDP statistics.	**statistics show udp**
Show TACACS server statistics.	**tacacs show stats**
Show broadcast monitoring information for ports.	**port show bmon [config][detail][port** <*port list*>**][stats]**
Show all VLANs.	**vlan list**

29.1 CONFIGURING THE RS FOR PORT MIRRORING

The RS allows you to monitor activity with port mirroring. Port mirroring allows you to monitor the performance and activities of ports on the RS or for traffic defined by an ACL through just a single, separate port. While in Configure mode, you can configure your RS for port mirroring with a simple command line like the following:

Configure port mirroring.	**port mirroring monitor-port** <*port number*> **target-port** <*port number*> **target-acl** <*acl name*>

Note Only one target port may be defined for a given RS, and only one monitor port may be defined. Also, Riverstone recommends that you monitor Gigabit ports through other Gigabit ports—you would almost certainly experience speed-inconsistency-related problems monitoring a Gigabit port through a 10Base-T or 100Base-TX port.

Note To display 802.1Q tagged packets on the mirroring port, configure the mirroring port as a trunk port using the **vlan make trunk-port** <*port*> command.

29.2 MONITORING BROADCAST TRAFFIC

The RS allows you to monitor broadcast traffic for one or more ports, and for the control module. You can specify that a port be shut down if its broadcast traffic reaches a certain rate limit for a particular period of time. Additionally, you can configure the RS to shut down for a specified period, if the packets sent to the control module reach a certain limit during a specified time interval. Packets to be monitored can be limited to broadcast packets only or all packets.

To specify the monitoring of broadcast traffic and the shut down threshold for one or more ports, enter the following command in Configure mode:

Configure monitoring of broadcast traffic.	**port bmon** <*port list*> **rate** <*number*> **duration** <*number*> **shutdown** <*number*> **packets-limited all|broadcast**

30 RMON CONFIGURATION

The Remote Network Monitoring (RMON) specifications primarily define Management Information Base (MIB) modules for network monitoring. The RS supports both the RMON 1 (RFC 2819) and RMON 2 (RFC 2021) specifications. The objects in the RMON 1 and RMON 2 MIB modules define the functions and information exchanged between a network monitoring system (or probe) and network management stations. The RMON 1 MIB modules provide for the monitoring of frames at the MAC layer. The RMON 2 MIB modules focus on monitoring traffic at the network layer through the application-layer (layer-3 through layer-7 of the OSI model) so you can monitor higher-layer protocols running above the network-layer. Management stations can access the RMON 1 and 2 MIB objects via SNMP or the ROS CLI.

To run RMON on the RS, enable SNMP first, then enable RMON. When you enable RMON on the RS, the RS functions as a probe or remote monitor. It allocates a certain amount of its resources to monitoring network traffic and gathering statistics. Thus, a network administrator can use RMON to analyze traffic patterns and troubleshoot the network.

This chapter describes how you can use the ROS CLI to run RMON on the RS, configure the RMON MIB objects and view RMON statistics.

This chapter provides the following information:

- The RMON 1 and RMON 2 MIB objects are divided into functional groups. To learn about the RMON 1 and RMON 2 functional groups and how they are organized in the RS, refer to Section 30.1, *"RMON Groups."*
- To enable RMON on the RS, refer to Section 30.2, *"Enabling RMON."*
- To configure the RMON groups, refer to Section 30.3, *"Configuring RMON Groups."*
- To allocate memory to RMON, refer to Section 30.4, *"Allocating Memory to RMON."*
- To use CLI filters to limit the display of **`rmon show`** commands, see Section 30.5, *"Setting RMON CLI Filters."*
- To troubleshoot RMON, see Section 30.6, *"Troubleshooting RMON."*

30.1 RMON GROUPS

The RMON 1 and RMON 2 MIB objects are divided into functional groups; each group collects specific information about the network. RMON 1 defines 10 functional groups which provide statistics on network segments at the MAC layer. The RS supports nine RMON 1 functional groups. It does not support the token ring functional group.

WIth RMON 2, you can monitor or show host-to-host connections and the applications and protocols being used. It defines nine functional groups which provide information at the network-layer through the application-layer of the OSI model. Note that in RMON 2, the layers above the network layer (transport, session, presentation and application) are all referred to as application layer. The RS supports all nine RMON 2 functional groups.

Each functional group has read-write objects and read-only objects. The read-write objects specify the parameters for the collection of data. These control parameters define what statistics are to be collected. The read-only objects are the collected statistics. In some functional groups, these objects are contained in one table. In most functional groups though, these objects are stored in 2 separate tables; the control parameters are in a control table, and the collected data are in a data table. (For detailed information on the objects and tables in the RMON 1 and RMON 2 groups, refer to RFC 2819 and RFC 2021, respectively.)

Regardless of whether the objects are in one or in two separate tables, the RS provides CLI support for configuring the control parameters and for viewing the collected data. For information on configuring the read-write objects in each group and for viewing the resulting statistics, refer to Section 30.3, *"Configuring RMON Groups."*

The RS provides three levels of support: Lite, Standard and Professional. Each level supports a different set of RMON groups. The Lite and Standard levels support the RMON 1 groups, and the Professional level supports the RMON 2 groups. To run RMON on the RS, you need to enable at least one level of support. The following tables define the RMON functional groups supported in each level.

Table 30-1 Lite RMON groups

Group	Function
EtherStats	Records Ethernet statistics (for example, packets dropped, packets sent, etc.) for specified ports.
Event	Controls event generation and the resulting action (writing a log entry or sending an SNMP trap to the network management station).
Alarm	Generates an event when specified alarm conditions are met.
History	Records statistical samples for specified ports.

Table 30-2 Standard RMON groups

Group	Function
Host	Records statistics about the hosts discovered on the network.
Host Top N	Gathers the top n hosts, based on a specified rate-based statistic. This group requires the Host group.
Matrix	Records statistics for source and destination address pairs.
Filter	Specifies the type of packets to be matched and how and where the filtered packets should flow (the channel).
Packet Capture	Specifies the capture of filtered packets for a particular channel.

Table 30-3 Professional RMON groups

Group	Function
Protocol Directory	Contains a list of protocols supported by the RS and monitored by RMON. See the RMON 2 Protocol Directory appendix in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.
Protocol Distribution	Records the packets and octets for specified ports on a per protocol basis.
Application Layer Host	Monitors traffic at the application layer for protocols defined in the Protocol Directory.
Network Layer Host	Monitors traffic at the network layer for protocols defined in the Protocol Directory.
Application Layer Matrix (and Top N)	Monitors traffic at the application layer for protocols defined in the Protocol Directory. Top N gathers the top n application layer matrix entries.
Network Layer Matrix (and Top N)	Monitors traffic at the network layer for protocols defined in the Protocol Directory. Top N gathers the top n network layer matrix entries.
Address Map	Records MAC address to network address bindings discovered for specified ports.
User History	Records historical data on user-defined statistics.
Probe	Monitors the probe's operations. (Use the **`rmon show probe-config`** command.))

30.2 ENABLING RMON

By default, RMON is disabled on the RS. To enable RMON, the following steps are required:

1. Enable at least one RMON level of support: Lite, Standard, and/or Professional.
2. Start RMON.

Note SNMP must be enabled on the RS before you can enable RMON. (For information on SNMP, see Chapter 36, *"SNMP Configuration."*)

3. If you are using RMON to collect statistics, then you need to enable RMON on the ports for which data will be collected. Refer to Section 30.2.3, *"Enabling RMON on Ports."* But if you are using RMON to generate events and record alarms only, you do not need to enable RMON on ports.

30.2.1 Enabling RMON Groups

To run RMON on the RS, you must enable at least one level: Lite, Standard, and/or Professional. (For a list of the RMON groups in each level, refer to Section 30.1, *"RMON Groups."*) Enabling an RMON level allows you to configure control parameters for the groups in that level. For example, if you enable the Lite level, then you can configure control parameters for the Etherstats, Event, Alarm, and History groups. After configuring the parameters, you can view the resulting data with the various **`rmon show`** commands. (For information on configuring control parameters for each group, refer to Section 30.3, *"Configuring RMON Groups."*)

When you enable an RMON support level, you can also enable default parameters for some RMON groups in that level. When you turn on the defaults, the RS collects statistics for all groups that have defaults and for all ports on which RMON is enabled. Default control parameters increase the amount of memory used by RMON. To cut back on the resources used by RMON, it is highly recommended, especially for the Professional group, that you enable an RMON level of support without the default parameters. Then, configure only the control parameters you need, as described in Section 30.3, *"Configuring RMON Groups."*

You can configure each level of support independently of each other, with default control parameters turned on or off. For example, you can enable the Lite group with default parameters for ports et.1.(1-8), and then enable the Standard group with no default parameters for the same ports. You *cannot* configure Lite on one set of ports and Standard on another set of ports.

Following is a list of the groups that have default control parameters:

- Lite Group
  - Etherstats
  - History
- Standard
  - Host
  - Matrix
- Professional
  - Protocol Distribution
  - Address Map
  - Application Layer/Network Layer Host
  - Application Layer/Network Layer Matrix

In the following example, the Lite level is enabled with default control parameters, and the Standard and Professional groups are enabled without the defaults.

```
rs#(config) # rmon set lite default-tables yes
rs#(config) # rmon set standard default-tables no
rs#(config) # rmon set professional default-tables no
```

30.2.2 Starting and Stopping RMON

By default, RMON is disabled on the RS. Use the **rmon enable** command to start RMON. This command requires that at least one RMON level be enabled. Following is an example:

```
rs(config)# rmon set lite default-tables no
rs(config)# rmon enable
rs(config)# save active
%RMON-I-REGISTER_v1, RMONv1 has automatically registered.
2001-09-05 14:15:03 %RMON-I-ENABLED, RMON has been enabled.
%RMON-I-ADD_MEM, A total of 4120000 bytes has been allocated for RMON
```

Once RMON is started, the RS continues to collect data until you disable RMON using the **negate** command. Stopping RMON frees up all resources associated with RMON, including any memory allocations. In the following example, the commands enabling RMON are on lines 16 and 17.

```
rs(config)# show active
Running system configuration:
     !
     ! Last modified from Telnet (134.141.173.241) on 2001-09-05 14:15:03
     !
 1 : port set t3.4.3 wan-encapsulation ppp
 2 : port set t1.4.1:1 timeslots 1-12 wan-encapsulation ppp
 3 : port set t1.4.1:2 timeslots 13-24 wan-encapsulation ppp
     !
 4 : vlan create xyz ip
 5 : vlan add ports et.2.1 to xyz
 6 : vlan add ports et.2.2 to xyz
 7 : vlan add ports et.2.3 to xyz
 8 : vlan add ports et.2.4 to xyz
     !
 9 : interface create ip t3port address-netmask 100.50.50.1/24 port t3.4.3 up
10 : interface create ip t1port-1 address-netmask 100.30.30.1/24 port t1.4.1:1 up
11 : interface create ip t1port-2 address-netmask 100.40.40.1/24 port t1.4.1:2 up
12 : interface add ip en0 address-netmask 134.141.179.141/27
     !
13 : ip add route 134.141.173.0/24 gateway 134.141.179.129
14 : ip add route 134.141.176.0/24 gateway 134.141.179.129
15 : ip add route 134.141.178.0/24 gateway 134.141.179.129
     !
16 : rmon set lite default-tables no
17 : rmon enable
     !
18 : system set idle-timeout telnet 0
19 : system set idle-timeout serial 0
     !
20 : snmp set community public privilege read-write
```

Then, lines 16 and 17 are negated, and as a result, RMON is disabled on the RS. The following example shows the messages displayed after disabling RMON.

```
rs(config)# negate 16-17
rs(config)# save active
%RMON-I-DEREGISTER_v1, RMONv1 has automatically deregistered.
%RMON-I-LITE_OFF, Lite has been disabled.
2001-09-05 14:21:41 %RMON-I-DISABLED, RMON has been disabled.
%RMON-I-ADD_MEM, A total of 0 bytes has been allocated for RMON
```

30.2.3 Enabling RMON on Ports

When you use RMON to collect statistics, you must enable RMON on the ports for which data will be collected. Because RMON 1 and RMON 2 use a lot of resources, you should enable RMON only on the ports that you want to monitor. In the following example, RMON is enabled on ports et.2.1 through et.2.4, and defaults are turned on for the Lite groups.

```
rs(config)# rmon set lite default-tables yes
rs(config)# rmon set ports et.2.(1-4)
rs(config)# rmon enable
rs(config)# save active
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.1
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.2
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.3
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.4
2001-07-30 06:07:07 %RMON-I-ENABLED, RMON has been enabled.
%RMON-I-ADD_MEM, A total of 1480000 bytes has been allocated for RMON
```

As shown in the preceding example, after the commands are saved to the active configuration file, the RS confirms that RMON has been enabled on the specified ports and indicates how much memory has been allocated to RMON.

To add ports to the list of RMON-enabled ports, specify the new ports *and* the existing ports on which RMON is enabled. The following example enables RMON on ports et.2.6 and et.2.7, in addition to ports et.2.1 through et.2.4.

```
rs(config)# rmon set ports et.2.(1-4,6,7)
rs(config)# save active
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.6
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.7
```

As shown in the preceding example, after the command is saved to the active configuration, RMON register messages are displayed for the newly added ports. RMON commands that affect ports are automatically applied to the newly added ports. Therefore, because default control parameters for the Lite group were turned on, default control parameters are automatically created for ports et.2.6 and et.2.7.

Note that RMON is disabled on ports that are not specified in the **rmon set ports** command. In the following example, only ports et.2.6 and 2.7 are specified. Therefore, RMON is disabled on all the other ports (ports et.2.1 through et.2.4).

```
rs(config)# rmon set ports et.2.(6,7)
rs(config)# save active
%SNMP-I-DS_UNREGISTERED, RMON Data Source un-registered et.2.1
%SNMP-I-DS_UNREGISTERED, RMON Data Source un-registered et.2.2
%SNMP-I-DS_UNREGISTERED, RMON Data Source un-registered et.2.3
%SNMP-I-DS_UNREGISTERED, RMON Data Source un-registered et.2.4
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.6
%SNMP-I-DS_REGISTERED, RMON Data Source registered et.2.7
```

Use the **rmon show status** command to check which levels have been enabled and on what ports, as shown in the following example.

```
rs# rmon show status
RMON Status
-----------
* RMON is ENABLED
* RMON updates ENABLED
* RMON initialization successful.
+--------------------------+
| RMON Group Status        |
+-------+--------+---------+
| Group | Status | Default |
+-------+--------+---------+
| Lite  |     On |     Yes |
+-------+--------+---------+
| Std   |    Off |      NA |
+-------+--------+---------+
| Pro   |    Off |      NA |
+-------+--------+---------+

Ports RMON enabled on: et.2.(1-4)

RMON Memory Utilization
-----------------------
        Total Bytes Available:   20146176

Total Bytes Allocated to RMON:    4120000
             Total Bytes Used:     547184
             Total Bytes Free:    3572816
```

30.3 CONFIGURING RMON GROUPS

As stated earlier, the RS provides CLI support for configuring control parameters for each RMON functional group. This section describes how to configure control parameters and view the data of each group.

To configure control parameters, first enable one or more RMON support levels. For example, to configure control parameters for the Etherstats group, use the **rmon set lite** command to enable the Lite support level.

Because RMON uses a lot of resources, it is highly recommended that you enable the RMON groups without default parameters. Then, configure control parameters only for the groups that you need.

After configuring the RMON control parameters, use the appropriate **rmon show** commands to display the RMON statistics. These statistics can also be viewed from a management station through SNMP. You can also use CLI filters to limit the amount of information displayed with the **rmon show** commands. For additional information, refer to Section 30.5, *"Setting RMON CLI Filters."*

Note To display Ethernet statistics and related statistics for WAN ports, RMON has to be activated on those ports. To activate RMON on a port, use the **frame-relay define service** or **ppp define service** command, and the **frame-relay apply service** or **ppp apply service** command. For additional information, refer to Section 32.3.3, *"Configuring Frame Relay Interfaces for the RS."* (for frame relay) and Section 32.4.3, *"Setting up a PPP Service Profile."* (for PPP).

30.3.1 Lite RMON Groups

This section describes the RMON groups in the Lite support level. They are:

- *"The Etherstats Group"*
- *"The History Group"*
- *"The Event Group"*
- *"The Alarm Group"*

The Etherstats Group

The Etherstats group provides MAC-layer, port-based statistics on frames passing through a port. The RMON 1 specifications define one table, the etherStatsTable, for the Etherstats group.

On the RS, when you turn on defaults for the Lite level, a default control row is automatically created in the Etherstats table. But if you don't turn on the defaults, you can configure a row in the Etherstats table using the **rmon etherstats** command. The parameters include the owner and the port(s) for which data will be collected. Following is an example:

```
rs(config)# rmon set lite default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs (config) # rmon etherstats index 500 owner fma port et.3.1
```

Use the **rmon show etherstats** command, as show in the following example, to view the various counts and error conditions on frames received on the specified port. You can use these statistics to evaluate the network load.

```
rs# rmon show etherstats all-ports
RMON I Ethernet Statistics Table
Index: 500, Port: et.3.1, Owner: fma
-----
RMON EtherStats                Total
---------------                -----
Octets                       1568315
Frames                         22503
Broadcast Frames                 573
Multicast Frames               21639
Collisions                         0
64 Byte Frames                 16214
65-127 Byte Frames              6115
128-255 Byte Frames              171
256-511 Byte Frames                3
512-1023 Byte Frames               0
1024-1518 Byte Frames              0
```

The History Group

The History group collects statistical samples for a particular port during a specified interval. The History group consists of one control table, historyControlTable, and one data table, etherHistoryTable.

On the RS, when you turn on defaults for the Lite level, a default control row is automatically created in the History control table. But if you don't turn on the defaults, you can configure a row in the History control table using the **rmon history** command. The parameters include the owner, the sampling interval, and the number of samples.

The following example configures a row in the History control table:

```
rs(config)# rmon set lite default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.2.1
rs(config)# rmon history index 500 port et.2.1 interval 300
```

Use the **rmon show history** command to view the collected data as shown in the following example:

```
rs# rmon show history et.2.1
RMON I History Table
Index Port       Interval(secs) Buckets Owner
  500 et.2.1               300  50/50  monitor
  Index SysUpTime         Octets Packets   Bcst   Mcst  Colls  %Util  Othern
    1 02D 00H 55M 22S          0       0      0      0      0      0      0
      2 02D 01H 00M 22S          0       0      0      0      0      0      0
      3 02D 01H 05M 22S          0       0      0      0      0      0      0
      4 02D 01H 10M 22S          0       0      0      0      0      0      0
      5 02D 01H 15M 22S          0       0      0      0      0      0      0
      6 02D 01H 20M 22S          0       0      0      0      0      0      0
      7 02D 01H 25M 22S          0       0      0      0      0      0      0
      8 02D 01H 30M 22S          0       0      0      0      0      0      0
      9 02D 01H 35M 22S          0       0      0      0      0      0      0
     10 02D 01H 40M 23S          0       0      0      0      0      0      0
     11 02D 01H 45M 23S          0       0      0      0      0      0      0
     12 02D 01H 50M 23S          0       0      0      0      0      0      0
     13 02D 01H 55M 23S          0       0      0      0      0      0      0
     14 02D 02H 00M 23S          0       0      0      0      0      0      0
     15 02D 02H 05M 23S          0       0      0      0      0      0      0
     16 02D 02H 10M 23S          0       0      0      0      0      0      0
     17 02D 02H 15M 23S          0       0      0      0      0      0      0
```

The Event Group

The Event group consists of one control table, eventTable, and one data table, logTable.The Event group defines the action to be taken when certain conditions occur. Two actions can occur, information is logged in the logTable and an SNMP notification is sent to the management station.

To generate an Event, define the Event then link it to either the Alarm or the Channel group.The Alarm and the Channel groups specify the conditions that trigger the event. Linking the Event group with the Alarm group generates both an alarm and event when the configured alarm threshold is crossed. (Refer to *"The Alarm Group"* for additional information on linking the Event group with the Channel group.) Linking the Event group with the Channel group generates an event when a packet is matched. (Refer to *"The Filter and Channel Group"* for additional information on linking the Event group with the Channel group.)

Use the **rmon event** command to define the Event. The following example specifies that the event is both logged in the Event data table and an SNMP trap generated with the community string “public.”

```
rs(config)# rmon set lite default-tables no
rs(config)# rmon enable
rs(config)# rmon event index 15 type both community public description
"Interface added or module hot swapped in" owner "help desk"
```

The Alarm Group

The Alarm group allows the RS to poll itself at user-defined intervals. Alarms that constitute an event are logged into the Event data table which can then be polled by the management station. The management station can also be sent notifications.

An alarm can be recorded when the actual value or the difference between actual values rises above or falls below defined rising and falling thresholds. Crossing one threshold does not trigger an alarm. For example, if you configure an alarm for when a falling threshold is crossed, both the rising and the falling thresholds must be crossed before the alarm is actually generated.

You can configure the Alarm group to work with the Event group to generate both an alarm and an event. The Alarm group consists of one table, the alarmTable.When you configure an alarm, you need to specify the following:

- SNMP object to be monitored
- rising threshold
- falling threshold
- alarm sample type

The following example configures the RS to create an event when a module is hot swapped into the chassis or when any new IP interface is configured. The managed object ifTableLastChanged (from RFC 2233) has an object identifier (OID) of 1.3.6.1.2.1.31.1.5.0 and the RS will poll this OID every 5 minutes (300 seconds).

The **`rmon event`** command line configures the following attributes:

- Index number 15 to identify this entry in the Event control table.
- The event is both logged in the Event data table and an SNMP trap generated with the community string “public.”
- Event owner is “help desk.

The **`rmon alarm`** command line configures the following attributes:

- Index number 20 to identify this entry in the Alarm table.
- The OID 1.3.6.1.2.1.31.1.5.0 identifies the attribute to be monitored.
- Samples taken at 300 second (5 minute) intervals.
- A “Startup” alarm generation condition instructing the RS to generate an alarm if the sample is greater than or equal to the rising threshold or less than or equal to the falling threshold.
- Compare value at time of sampling (absolute value) to the specified thresholds.
- Rising and falling threshold values are 1.
- Rising and falling event index values are 15, which will trigger the Event.

```
rs(config)# rmon set lite default-tables no
rs(config)# rmon enable
rs#(config) rmon event index 15 type both community public description
"Interface added or module hot swapped in" owner "help desk"
rs#(config) rmon alarm index 20 variable 1.3.6.1.2.1.31.1.5.0 interval 300
startup both type delta-value rising-threshold 1 falling-threshold 1
rising-event-index 15 falling-event-index 15 owner "help desk"
```

Use the **rmon show events** command to view the events, as shown in the following example

```
rs# rmon show events
RMON I Event table
Index Type Community       Description              Owner
   15 both pub             interface added          helpdesk
No event logs found
```

Use the **rmon show alarms** command to view the alarms, as shown in the following example

```
rs# rmon show alarms
RMON I Alarm Table
Index: 20, Variable: 1.3.6.1.2.1.31.1.5.0, Owner:
-----
Rising Event Index    :          0
Falling Event Index   :          0
Rising Threshold      :          1
Falling Threshold     :          1
Interval              :        300
Current/Absolute Value:        100/0
Sample Type           :   absolute
Startup Type          :       both
```

30.3.2 Standard RMON Groups

This section describes the RMON groups that are supported when you enable the Standard support level. They are:

- *"The Host Group"*
- *"The Host Top-N Group"*
- *"The Matrix Group"*
- *"The Filter and Channel Group"*
- *"The Capture Group"*

The Host Group

The Host group collects various MAC-layer statistics based on frames transmitted to and from a particular host. The Host group consists of three tables, a control table, hostControlTable, and two data tables: hostTable and HostTimeTable.

On the RS, when you turn on defaults for the Standard level, a default control row is automatically created in the Host control table. If you don't turn on the defaults, you can configure a row in the Host control table using the **rmon host** command. Parameters include the owner and the port(s) for which data will be collected.

The following example configures the following parameters: an owner of *fma* and an index of *500*.

```
rs(config)# rmon set standard default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon host index 500 port et.3.1 owner fma status
```

Use the **rmon show hosts** command to view the host-based statistics, as shown in the following example:

```
rs# rmon show hosts all-ports
RMON I Host Table

Index: 500, Port: et.3.1, Owner: fma
Address           InPkts   InOctets    OutPkts  OutOctets   Out Bcst   Out Mcst
-------           ------   --------    -------  ---------   --------   --------
00001D:4F46E9          0          0      21623    1493726          0          0
00001D:A9AAEF        179      29476          0          0          0          0
00001D:A9B6B7          0          0          3        192          0          0
00001D:A9B6B8          0          0        103       6592          0          0
00001D:A9B938          1         64         36       2304          0          0
00C048:1E8820          0          0        304      19456          0          0
00E063:DEFCB1          0          0         15        960          0          0
080009:7B965C          1        159         24       1536          0          0
080020:B31886          0          0        248      34126          0          0
080020:B57CF5          0          0         27       1755          0          0
```

The preceding example enables you to monitor traffic on a per-host basis. It displays packets transmitted through port et.3.1 for each host. The hosts are identified by their MAC addresses in the **Address** column.

The Host Top-N Group

The Host Top-N group provides statistics about a set of hosts during a specified interval. For example, you can collect statistics for the top 10 hosts with the highest number of input packets during a 20-second interval.

The Host Top-N statistics are gathered from statistics collected for a particular Host control row. Therefore, to configure the Host Top-N control row, you must first configure the Host control entry with the **rmon host** command. Then use the **rmon host-top-n** command to gather the top statistics from the configured host control entry.

The Host Top-N group consists of one control table, hostTopNControlTable, and one data table, hostTopNTable. When you configure a Host Top-N control row, specify the following:

- the index of the Host control row on which the statistics will be based
- the type of statistics to collect
- the ports on which to collect statistics
- the number of hosts to include in the table

Whenever you want to do a sampling, enter the **rmon host-top-n** command to start the sampling. Then, wait the specified sampling interval before using the **rmon show host-top-n** command to view the results. The Host Top-N report only runs every time you specify the command.

The following example reports on the top 7 hosts with the highest number of outgoing packets. The statistics to be gathered are from the host control row with an index of 500.

```
rs(config)# rmon set standard default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon host index 500 port et.3.1
rs(config)# rmon host-top-n index 600 base out-packets duration 20 host-index 500 size 7
```

The following shows the top 7 hosts based on the specified statistics:

```
rs# rmon show host-top-n
RMON I HostTopN Table
---------------------
Index: 600, HostIndex: 500
RateBase: Out-Packets
Time Remaining: 0
Duration:       20
Requested Size: 10
Granted Size:   10
StartTime: 00D 00H 04M 03S
Owner:

Address             Rate
-------             ----
00001D:4F46E9         19
080020:B31886          1
00001D:A9B938          0
00C048:1E8820          0
00E063:2341A1          0
080020:B57CF5          0
00001D:A9AAEF          0
```

The Matrix Group

The Matrix group provides flow-based statistics on frames transmitted from a source address to a destination address. To collect layer-2 matrix information, ports must be configured for flow-bridging mode. (By default, ports on the RS operate in address-bridging mode.)

The Matrix group consists of one control table, matrixControlTable, and two data tables, matrixSDTable and matrixDSTable.

On the RS, when you turn on defaults for the Standard level, a default control row is automatically created in the Matrix control table. If you don't turn on the defaults, you can configure a row in the Matrix control table using the **rmon matrix** command. The following example configures an entry for the Matrix control table for port et.3.1:

```
rs(config)# port flow-bridging et.3.1
rs(config)# rmon set standard default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon matrix index 500 owner fma port et.3.1
```

The following example displays the flow-based statistics for port et.3.1. It displays statistics for each source and destination pair.

```
rs# rmon show matrix et.3.1
RMON I Matrix Table

Port: et.3.1, Index: 500, Owner: fma
SrcAddr       DstAddr          Packets     Octets
-------       -------          -------     ------
00001D:4F46E9 01001D:000000       6744     553008
00001D:4F46E9 0180C2:000000      17151    1097664
00001D:A9B6B7 FFFFFF:FFFFFF          3        192
00001D:A9B6B8 FFFFFF:FFFFFF        114       7296
00001D:A9B938 FFFFFF:FFFFFF         36       2304
00C048:1E8820 FFFFFF:FFFFFF        336      21504
00E063:DEFCB1 080020:B57CF5          1         64
00E063:DEFCB1 FFFFFF:FFFFFF         15        960
080009:7B965C FFFFFF:FFFFFF         27       1728
080020:B31886 00001D:A9AAEF        189      31134
080020:B31886 00001D:A9B6B8          1         86
080020:B31886 00001D:A9B938          4        305
080020:B31886 00E063:78FFA1          1        159
080020:B31886 080009:7B965C          1        159
080020:B31886 FFFFFF:FFFFFF         67       4288
080020:B57CF5 00001D:A9AAEF          4        368
080020:B57CF5 FFFFFF:FFFFFF         30       1920
```

The Filter and Channel Group

The Filter group provides a mechanism for screening packets. You can configure a data filter or a status filter. A data filter specifies which packets to match based on a packet's contents. A status filter monitors packets based on their status. The stream of packets that match the filter is called a channel. A channel can be configured to generate an event defined in the Event group. The packets in the channel can also be captured, if defined in the Capture group.

To configure a Filter control table entry, define the Channel entry first, then the Filter. In the following example, the following are configured for the channel:

- Index number 601. This index is used to link this channel to the filter.
- Packets that match the data and status filters will be accepted.
- Data will be collected from port et.3.1.
- Data, status and events will flow through this channel.

The following are configured for the filter:

- The data to be matched, the data mask and inversion mask to be applied during the match process.
- The channel with an index of 601 is linked with this filter.

:

```
rs(config)# rmon channel index 601 accept-type matched port et.3.1 data-control on
rs(config)# rmon filter index 600 data "01 80" status enable channel-index 601
data-mask "FF FF" data-offset 0 data-not-mask "00 00"
```

Use the **rmon show channels** command to view the channels that were configured, as shown in the following example:

```
rs# rmon show channels
RMON I Channel Table
Index Port       AcceptType Flow Status E-Idx OnIdx OffIdx Owner
  601 et.3.1     Matched    On   Ready      0     0      0
```

Use the **rmon show filters** command to view the filters that were configured, as shown in the following example:

```
rs# rmon show filters
RMON I Filter Table
Index: 600, ChannelIndex: 601, Offset: 0, Owner:
-----
Data:        0180
DataMask:    FFFF
DataNotMask: 0000
Status:                0
StatusMask:            0
StatusNotMask:         0
```

The Capture Group

The Capture group is an extension of the Filter group. It is used for storing and retrieving the captured packets. You can also set up a buffering scheme for capturing packets from one of the channels.

The following example configures the packets to be captured:

- Packets from the channel identified by index 601 will be captured
- The action of the buffer when it becomes full, which is to wrap around
- The maximum number of octets to save is 2048
- The maximum number of octets to download during an SNMP retrieval is 25
- The maximum number of octets to save in the buffer is 30

:

```
rs(config)# rmon channel index 601 accept-type matched port et.3.1 data-control on
rs(config)# rmon filter index 600 data "01 80" status enable channel-index 601
data-mask "FF FF" data-offset 0 data-not-mask "00 00"
rs(config)# rmon capture index 600 channel-index 601 full-action wrap max-octets 2048
download-slice-size 25 slice-size 30
```

Use the **rmon show packet-capture** command to view the packets that were captured, as shown in the following example:

```
rs# rmon show packet-capture
RMON I Packet Capture Table & Logs
Index: 600, Channel Index: 601, Owner:
-----
Bytes Requested:                    2048
Bytes Granted:                      2048
Capture Buffer Size (bytes):          30
SNMP Download Size (bytes):           25
SNMP Download Offset (bytes):          0
Space Availability:           Full
Action of Buffer when full:   Wrap
SysUpTime when capture buffer was turned on: 00D 00H 00M 00S

   Index CtrlIndex PktId Length Time            Status
    2454       600  4135     80 00D 01H 23M 17S      0
ADDR   HEX                                             ASCII
0000:  01 80 C2 00 00 00 00 00 1D 4F 46 E9 00 2E 42 42 | .........OF...BB
0010:  03 00 00 00 00 00 01 F4 00 00 1D 72 97 AE       | ...........r..

   Index CtrlIndex PktId Length Time            Status
    2455       600  4136     80 00D 01H 23M 19S      0
ADDR   HEX                                             ASCII
0000:  01 80 C2 00 00 00 00 00 1D 4F 46 E9 00 2E 42 42 | .........OF...BB
0010:  03 00 00 00 00 00 01 F4 00 00 1D 72 97 AE       | ...........r..
.
.
.
```

30.3.3 Professional RMON Groups

This section describes the RMON 2 groups that are supported when you enable the Professional level. They are:

- *"The Protocol Directory Group"*
- *"The Protocol Distribution Group"*
- *"Higher-Layer Host Group"*
- *"Higher-Layer Matrix Group"*
- *"Address Map Group"*
- *"User History Group"*

On the RS, the Higher-Layer Host group includes the RMON 2 Application-Layer and Network Layer Host groups; and the Higher-Layer Matrix group includes the RMON 2 Application-Layer and Network-Layer Matrix groups. Note that in RMON 2, all protocols above the network layer are considered application layer.

When you enable the Professional level, you can enable defaults for the following groups: Protocol Distribution, Address Map, Application Layer and Network Layer Hosts groups, and the Application Layer and Network Layer Matrix groups. Turning on the defaults for these groups uses a lot of memory. It is highly recommended that you do not enable the defaults and instead, configure control parameters only for the groups you need.

The Protocol Directory Group

The Protocol Directory lists the protocols that the RS interprets. The RS's RMON 2 protocol directory contains over 500 protocols that can be decoded for UDP and TCP ports. For the list of protocols supported by the RS, refer to *Appendix A* in the *Riverstone RS Switch Router Command Line Interface Reference Manual*. (For additional information on the protocols, refer to RFC 2895.)

Use the **`rmon set protocol-directory`** command to specify which protocols are interpreted when statistics are collected for each of the following RMON groups: Host, Matrix, and Address Mapping. The command provides the following options:

- turn on support for a protocol
- turn off support for a protocol
- turn off support for a protocol and make the corresponding SNMP object read-only. This prevents the protocol from being set using SNMP.

The following example turns on support for the ether2 protocol for all three groups:

```
rs(config)# rmon set protocol-directory ether2 address-map on
rs(config)# rmon set protocol-directory ether2 host on
rs(config)# rmon set protocol-directory ether2 matrix on
```

Use the **rmon show protocol-directory** command to check which protocols are interpreted for each of the RMON groups. As shown in the following example, ether2 is now turned on for all three groups.

```
rs# rmon show protocol-directory all-protocols
RMON II Protocol Directory Table
Last Change: 00D 00H 00M 00S
Index AddrMap Host Matrix Status         Protocol
    1 On      On   On     Active         ether2
    2 NA      Off  Off    Active         idpf
    3 NA      Off  Off    Active         ip-v4
    4 NA      Off  Off    Active         chaosnet
    5 NA      Off  Off    Active         arp
    6 NA      Off  Off    Active         rarp
    7 NA      Off  Off    Active         vip
    8 NA      Off  Off    Active         vloop
    9 NA      Off  Off    Active         vloop2
   10 NA      Off  Off    Active         vecho
   11 NA      Off  Off    Active         vecho2
13 NA      Off  Off    Active         netbios-3com
   14 NA      Off  Off    Active         atalk
   15 NA      Off  Off    Active         aarp
   16 NA      Off  Off    Active         dec
```

The Protocol Distribution Group

The Protocol Distribution group is used to determine the protocol encapsulations used in a network. It displays statistics for packets and octets on a per protocol, per port basis. The Protocol Distribution group consists of one control table, protocolDistcontrolTable, and one data table, protocolDistStatsTable.

The following example configures a row in the Protocol Distribution control table for port et.3.1:

```
 rs(config)# rmon protocol-distribution index 500 owner fma port et.3.1
```

Use the **rmon show protocol-distribution** command to view the collected statistics. It displays the kinds of protocol traffic being received on the specified port.

```
rs# rmon show protocol-distribution all-ports
RMON II Protocol Distribution Table

Index: 500, Port: et.3.1, Owner: fma
      Pkts     Octets   Protocol
      ----     ------   --------
       127      20388   ether2
       127      20388   *ether2.ip-v4
       127      20388   *ether2.ip-v4.udp
       127      20388   *ether2.ip-v4.udp.snmp
```

Higher-Layer Host Group

The Higher-Layer Host group includes the Application-Layer Host group and the Network-Layer Host group. The Network-Layer Host group monitors traffic for each network-layer address. It is similar to the RMON 1 Host group, but it provides more detailed information; for a specific interface, it provides per-protocol statistics for each discovered network address. The Network-Layer Host group consists of one control table, nlHostControlTable, and one data table, nlHostTable.

The Application-Layer Host group monitors traffic, by protocol, for each host. It provides information for all application-layer protocols for each source and destination address. For example, you can determine how much traffic is generated and received by Microsoft Mail for a specific host. The Application-Layer Host group consists of one table, the alHostTable.

Use the **rmon hl-host** command to configure a control row in the Higher-Layer Host control table. This table, when configured, is used by both application-layer and network-layer host data. Following is an example:

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon hl-host index 500 al-max-entries 15 nl-max-entries 15 port et.3.1
```

The following example shows application-layer, host-based statistics displayed when you use the **rmon show al-host** command. The output displays the protocol at the top layer of the protocol stack.

```
rs# rmon show al-host all-ports
RMON II Application Layer Host Table

Index: 500, Port: et.3.1, Inserts: 11, Deletes: 0, Owner:
Address             InPkts   InOctets    OutPkts  OutOctets  Protocol
-------             ------   --------    -------  ---------  --------
10.50.7.4                0          0         88       8636  ip-v4
10.50.7.4                0          0          3        364  icmp
10.50.7.4                0          0         85       8272  udp
10.50.7.4                0          0         85       8272  snmp
10.50.7.6              364      52746          0          0  ip-v4
10.50.7.6                3        364          0          0  icmp
10.50.7.6              361      52382          0          0  udp
10.50.7.6              361      52382          0          0  snmp
10.50.7.45               0          0        276      44110  ip-v4
10.50.7.45               0          0        276      44110  udp
10.50.7.45               0          0        276      44110  snmp
```

The following example shows the network-layer, host-based statistics displayed when you use the **rmon show nl-host** command.

```
rs# rmon show nl-host all-ports
RMON II Network Layer Host Table

Index: 500, Port: et.3.1, Inserts: 3, Deletes: 0, Owner: monitor
Address             InPkts   InOctets    OutPkts  OutOctets  Protocol
-------             ------   --------    -------  ---------  --------
10.50.7.4                0          0          1         91  ip-v4
10.50.7.6              179      29476          0          0  ip-v4
10.50.7.45               0          0        178      29385  ip-v4
```

Higher-Layer Matrix Group

The Higher-Layer Matrix group includes both the Application-Layer and Network-Layer Matrix groups. These groups provide information about protocol-specific traffic between pairs of hosts. This can help to diagnose protocol problems.

The Network Layer Matrix group collects flow-based statistics based on the network-layer flows. It consists of two control tables and three data tables. One control table, nlMatrixControlTable, and its two associated data tables, nlMatrixSDTable and nlMatrixDStable, collect matrix statistics. The other control table (nlMatrixTopNControlTable) and data table (nlMatrixTopNTable) collect top-n statistics, which are discussed later in this section.

The Application-Layer Matrix group collects flow-based statistics based on the application-layer protocols and flows. The Application-Layer Matrix group is controlled by the nlMatrixControlTable. Its two data tables, alMatrixSDTable and alMatrixDStable, collect matrix statistics.

Use the **rmon hl-matrix** command to configure a control row in the Higher-Layer Matrix control table. This table, when configured, is used by both application-layer and network-layer matrix data. Following is an example:

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon hl-matrix index 500 al-max-entries 15 nl-max-entries 15 port et.3.1
```

The following example shows the network-layer, flow-based statistics displayed when you use the **rmon show nl-matrix** command.

```
rs# rmon show nl-matrix all-ports
RMON II Network Layer Matrix Table

Index: 500, Port: et.3.1, Inserts: 2, Deletes: 0, Owner: monitor
SrcAddr         DstAddr           Packets     Octets  Protocol
-------         -------           -------     ------  --------
10.50.7.4       10.50.7.6              18       1752  ip-v4
10.50.7.45      10.50.7.6             109      18636  ip-v4
```

The following example shows the application-layer, flow-based statistics displayed when you use the **rmon show al-matrix** command. It displays the packet and octet counts, per protocol, for each host and destination pair.

```
rs# rmon show al-matrix all-ports
RMON II Application Layer Host Table

Index: 500, Port: et.3.1, Inserts: 6, Deletes: 0, Owner: monitor
SrcAddr         DstAddr            Packets     Octets  Protocol
-------         -------            -------     ------  --------
10.50.7.4       10.50.7.6               18       1752  ip-v4
10.50.7.4       10.50.7.6               18       1752  udp
10.50.7.4       10.50.7.6               18       1752  snmp
10.50.7.45      10.50.7.6              109      18636  ip-v4
10.50.7.45      10.50.7.6              109      18636  udp
10.50.7.45      10.50.7.6              109      18636  snmp
```

You can also collect and view top-n matrix statistics at the network-level and at the application-level. The top-n statistics rank the traffic between hosts based on a particular parameter.

The Network Layer Matrix group has one control table, nlMatrixTopNControlTable, and data table, nlMatrixTopNTable, for the collection of top-n statistics. The Application Layer Matrix group has one control table, alMatrixTopNControlTable, and data table, alMatrixTopNTable, for the collection of top-n statistics at the application level.

The application-level and network level top-n matrix statistics are gathered from the application-level and network level matrix statistics. Therefore, to configure any of these tables, you must first configure the higher-level matrix with the **rmon-hl matrix** commands. Then, you can configure the network level and application-level top-n matrix.

The following example configures the network layer top-n matrix control table:.

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon hl-matrix index 500 al-max-entries 15 nl-max-entries 15 port et.3.1
rs(config)# rmon nl-matrix-top-n index 100 matrix-index 500 ratebase all-packets
duration 60
```

Following is an example of the **rmon show nl-matrix-top-n** command:

```
rs# rmon show nl-matrix-top-n
RMON II Nl Matrix Table


Index M-Index RateBase     TimeRem Duration Size StartTime       Reports Owner
    1     500 Octets            20       20    5 00D 00H 51M 37S       1 User


SrcAddr         DstAddr            PktRate  R-PktRate  OctetRate R-OctetRate Protocol
-------         -------            -------  ---------  --------- ----------- --------
192.100.81.3    10.60.89.88             23          0      19986           0
*ether2.ip-v4
192.100.81.1    192.100.81.3            0          0          0          0 *ether2.ip-v4
192.100.81.3    192.100.81.1            0          0          0          0 *ether2.ip-v4
10.60.89.88     192.100.81.3              0         23          0      19986
*ether2.ip-v4
```

The following example configures the application layer top-n matrix control table:

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon hl-matrix index 500 al-max-entries 15 nl-max-entries 15 port et.3.1
rs(config)# rmon al-matrix-top-n index 100 matrix-index 500 ratebase all-packets
duration 60 size 100
```

Following is an example of the **rmon show al-matrix-top-n** command:

```
rs# rmon show al-matrix-top-n
RMON II Al Matrix Table


Index M-Index RateBase     TimeRem Duration Size StartTime       Reports Owner
    1     500 All-Packets       14       20    5 00D 00H 50M 25S       1 SML


SrcAddr         DstAddr      PktRate  R-PktRate  OctetRate R-OctetRate Protocol
-------         -------      -------  ---------  --------- ----------- --------
192.100.81.3    10.60.89.88       21          0      19836           0
*ether2.ip-v4.tcp.telnet
192.100.81.3    10.60.89.88      21          0      19836          0  *ether2.ip-v4.tcp
192.100.81.3    10.60.89.88       21          0      19836           0  *ether2.ip-v4
192.100.81.1    192.100.81.3       0          0          0           0  *ether2.ip-v4
192.100.81.3    192.100.81.1       0          0          0           0  *ether2.ip-v4
```

Address Map Group

The Address Map group lists MAC to network address bindings discovered by the RS on a per-port basis. You can use the Address Map group to discover duplicate IP addresses.

The Address Map group consists of a control table, address-MapControlTable, and a data table, addressMapTable. To configure a row in the Address Map control table, specify the port for which statistics will be collected and the owner. You can also configure the scalar object, addressMapMaxDesiredEntries with the **rmon address-map scalars** command. This scalar object refers to the maximum number of entries in the data table.

Following is a configuration example for the Address Map group:

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon address-map index 200 port et.3.1
rs(config)# rmon address-map scalars max-entries 3
```

Following is an example of the information that is displayed for the Address Map group. The information displayed is similar to what is displayed with the **arp show all** command, except that this display is on a per-port basis.

```
rs# rmon show address-map-logs all-ports
RMON II Address Map Control Table
Port        macAdd        nlAdd           Protocol
----        ------        -----           --------
et.3.1      080020:B57CF5 10.50.7.4       ip-v4
et.3.1      080020:B31886 10.50.7.45      ip-v4
```

User History Group

The User History group allows you to poll certain objects or variables and log the data based on user-configured parameters. It consists of two control tables, the usrHistoryControlTable and the usrHistoryObjectTable, and the data table, usrHistoryTable.

Following are the steps for configuring the User History group on the RS:

- use the **rmon user-history-control** command to configure a row in the usrHistoryControlTable. You specify the sampling parameters, such as the number of objects to be sampled and the sampling interval.
- use the **rmon user-history-objects** command to configure a row in the usrHistoryObjectTable. You specify the object identifier to be monitored and the method of sampling.
- use the **rmon user-history-apply** command to apply the sampling parameters specified in the **rmon user-history-control** command to the objects specified in the **rmon user-history-objects** command

The following commands were used to configure the example:

- the **rmon user-history-control** command configures a control row for one MIB object, with an interval of 10 seconds, and 5 sampling periods
- the **rmon user-history-objects** command specifies the object identifier to be monitored and specifies that during the specified interval the object's change in value will be compared to the threshold value
- the **rmon user-history-apply** command applies the parameters to the object defined by *obj1*

```
rs(config)# rmon set professional default-tables no
rs(config)# rmon enable
rs(config)# rmon set ports et.3.1
rs(config)# rmon user-history-control index 600 interval 10 objects 1 samples 5
rs(config)# rmon user-history-objects obj1 variable 1.3.6.1.2.1.16.1.1.1.5.500 type
delta-value
rs(config)# rmon user-history-apply obj1 status enable to 600
```

Use the **rmon show user-history** command, as shown in the following example to view the data in the usrHistoryTable:

```
rs# rmon show user-history all-indexes
RMON II User History Table
Index Objects Interval Buckets Owner Group
  600       1       10   5/5         obj1
Index Variable             Start           End             Value Status
    5 1.3.6.1.2.1.16.1.1.1.5.500 00D 00H 33M 41S 00D 00H 33M 41S Delta 0)  NA
    6 1.3.6.1.2.1.16.1.1.1.5.500 00D 00H 33M 51S 00D 00H 33M 51S Delta( 0)  NA
    7 1.3.6.1.2.1.16.1.1.1.5.500 00D 00H 34M 01S 00D 00H 34M 01S Delta( 2067) Pos
    8 1.3.6.1.2.1.16.1.1.1.5.500 00D 00H 34M 11S 00D 00H 34M 11S Delta( 7) Pos
    9 1.3.6.1.2.1.16.1.1.1.5.500 00D 00H 34M 21S 00D 00H 34M 21S Delta( 8) Pos
```

30.4 ALLOCATING MEMORY TO RMON

RMON allocates memory depending on the number of ports enabled for RMON, the RMON groups that have been configured, and whether default tables have been turned on or off. Enabling RMON with all groups (Lite, Standard, and Professional) with default tables uses approximately 300 Kbytes per port. If necessary, you can dynamically allocate additional memory to RMON. Later, if the additional memory is longer required, it can be removed. This will take effect only after you re-start RMON. This is because memory cannot be freed if RMON is still using it. If the amount of memory specified is less than what RMON has currently allocated, the RS displays a warning message and ignores the command. To display the amount of memory that is currently allocated to RMON, use the **rmon show status** command.

Any memory allocation failures are reported. The following is an example of the information shown with the **rmon show status** command:

```
rs# rmon show status
RMON Status
-----------
* RMON is ENABLED
* RMON initialization successful.

+--------------------------+
| RMON Group Status |
+-------+--------+---------+
| Group | Status | Default |
+-------+--------+---------+
| Lite  |     On |     Yes |
+-------+--------+---------+
| Std   |     On |     Yes |
+-------+--------+---------+
| Pro   |     On |     Yes |
+-------+--------+---------+

RMON is enabled on: et.5.1, et.5.2, et.5.3, et.5.4, et.5.5, et.5.6, et.5.7, et.5.8

RMON Memory Utilization
-----------------------
        Total Bytes Available:     48530436
Total Bytes Allocated to RMON:     4000000
             Total Bytes Used:     2637872
             Total Bytes Free:     1362128
```

The maximum amount of memory that you can allocate to RMON depends upon the RS model, as shown in the table below.

Table 30-4 Maximum memory allocations to RMON

RS platform	Maximum memory
RS 32000	96 MB
RS 8600	48 MB
RS 8000	24 MB
RS 3000, RS 1000	12 MB
RS 38000	
RS 16000	

Use the **rmon set memory** command to dynamically increase the amount of memory allocated to RMON. Specify the total number of megabytes to be allocated to RMON and not an increment. In the following example, the memory is increased to 24 Mbytes, which is the maximum on an RS 8000.

```
rs(config)# rmon set memory 24
```

30.5 SETTING RMON CLI FILTERS

Because a large number of statistics can be collected for certain RMON groups, you can define and use CLI filters to limit the amount of information displayed with the **rmon show** commands. An RMON CLI filter can only be applied to a current Telnet or Console session. You can clear a filter by using the **rmon clear cli-filter** command.

RMON CLI filters can be used with the following groups:

- Hosts
- Matrix
- Protocol Distribution
- Application Layer Host
- Network Layer Host
- Application Layer Matrix
- Network Layer Matrix

The following shows Host table output *without* a CLI filter:

```
rs# rmon show hosts et.5.4
RMON I Host Table

Index: 503, Port: et.5.4, Owner: monitor
Address           InPkts   InOctets    OutPkts  OutOctets   Bcst   Mcst
-------           ------   --------    -------  ---------   ----   ----
00001D:921086          0          0        102       7140      0      0
00001D:9D8138       1128      75196        885     114387      0      0
00001D:A9815F          0          0        102       7140      0      0
00105A:08B98D          0          0        971     199960      0      0
004005:40A0CD          0          0         51       3264      0      0
006083:D65800          0          0       2190     678372      0      0
0080C8:E0F8F3          0          0        396      89818      0      0
00E063:FDD700          0          0        104      19382      0      0
01000C:CCCCCC       2188     678210          0          0      0      0
01005E:000009        204      14280          0          0      0      0
0180C2:000000       1519      97216          0          0      0      0
030000:000001        168      30927          0          0      0      0
080020:835CAA        885     114387       1128      75196      0      0
980717:280200          0          0       1519      97216      0      0
AB0000:020000          2        162          0          0      0      0
FFFFFF:FFFFFF       1354     281497          0          0      0      0
```

The following shows the same **rmon show hosts** command with a filter applied so that only hosts with inpkts greater than 500 are displayed:

```
rs(config)# rmon set cli-filter 4 inpkts > 500
rs# rmon apply cli-filter 4
rs# rmon show hosts et.5.4
RMON I Host Table
Filter: inpkts > 500
Address     Port      InPkts  InOctets   OutPkts  OutOctets  Bcst  Mcst
-------     ----      ------  --------   -------  ---------  ----  ----
00001D:9D8138 et.5.4     1204     80110       941    121129     0     0
01000C:CCCCCC et.5.4     2389    740514         0         0     0     0
0180C2:000000 et.5.4     1540     98560         0         0     0     0
080020:835CAA et.5.4      940    121061      1204     80110     0     0
FFFFFF:FFFFFF et.5.4      1372     285105          0          0
```

You can list the CLI filters as shown below:

```
rs# rmon show cli-filters
RMON CLI Filters
Id   Filter
--   ------
 4   inpkts > 500
You have selected a filter: inpkts > 500
```

30.6 TROUBLESHOOTING RMON

If you are not seeing the information you expected with an **rmon show** command, or if the network management station is not collecting the desired statistics, first check that the port is up. Then, use the **rmon show status** command to check the RMON configuration on the RS.

Check the following fields on the **rmon show status** command output:

```
rs# rmon show status
RMON Status
-----------
* RMON is ENABLED ❶
* RMON initialization successful.

             ❷
+--------------------------+
| RMON Group Status        |
+-------+--------+---------+
| Group | Status | Default |
+-------+--------+---------+
| Lite  |     On |     Yes |   ❹
+-------+--------+---------+
| Std   |     On |     Yes |
+-------+--------+---------+
| Pro   |     On |     Yes |
+-------+--------+---------+

RMON is enabled on: et.5.1, et.5.2, et.5.3, et.5.4, et.5.5, et.5.6, et.5.7, et.5.8 ❸

RMON Memory Utilization
-----------------------
        Total Bytes Available:   48530436

Total Bytes Allocated to RMON:    4000000
             Total Bytes Used:    2637872    ❺
             Total Bytes Free:    1362128
```

1. Make sure that RMON has been enabled on the RS. When the RS is booted, RMON is off by default. RMON is enabled with the **rmon enable** command.
2. Make sure that at least one of the RMON support levels—Lite, Standard, or Professional—is turned on with the **rmon set lite|standard|professional** command.
3. Make sure that RMON is enabled on the port for which you want statistics. Use the **rmon set ports** command to specify the port on which RMON will be enabled.
4. Make sure that the control table is configured for the report that you want. Depending upon the RMON group, default control tables may be created for all ports on the RS. Or, if the RMON group is not one for which default control tables can be created, you will need to configure control table entries using the appropriate **rmon** command.

   If you or your application are unable to create a control table row, check the **snmp show status** output for errors. Make sure that there is a read-write community string. Verify that you can ping the RS and that no ACLs prevent you from using SNMP to access the RS.
5. Make sure that RMON has not run out of memory.

31 LFAP CONFIGURATION GUIDE

31.1 LFAP OVERVIEW

This chapter provides information about version 5.0 of Riverstone's Lightweight Flow Accounting Protocol (LFAP) accounting architecture. It explain how service providers can use LFAP's capabilities to improve their network management and to transition to a usage-based billing model.

The RS platform was engineered with the ability to account for every byte and packet of every flow without affecting routing and switching performance. Riverstone's LFAP accounting capabilities are integrated into the ASIC architecture of all RS switch routers. LFAP is particularly valuable for gathering information for layer-3 and layer-4 flows. Accounting data for layer-2 networks can also be collected using LFAP as long as the RS is running in layer-4 bridging mode.

Across the RS platform, flow and traffic data is accounted for by the hardware, rather than software, so that enabling accounting features does not impact system performance. Periodically, the router gathers flow data and sends the information through TCP (for connection-oriented delivery guarantee) to an accounting server using the LFAP protocol.

The following information is collected for IP flows:

- Source/destination IP address
- Source/destination AS
- Source/destination port
- Ingress/egress port
- Type of service (DSCP)
- Protocol
- Total bytes
- Total packets
- Total time of flow account
- VLAN ID
- VLAN priority

The following information is collected for MPLS flows:

- Source/destination switch address
- Ingress/egress port
- Incoming/outgoing MPLS labels
- LDP FEC
- Source/destination VLAN ID

- Next hop address
- Total bytes
- Total packets
- Total time of flow account

The following information is collected for ATM flows:

- Outgoing flows
  - Source/destination IP address associated with the PVC
  - Protocol – LLC MUX or VC MUX
  - Egress port
  - CCE address
  - Source/destination VLAN
  - VPI/VCI
  - Byte count, excluding ATM header
  - Packets – AAL5 frames, including LLC header
  - Start/end time
- Incoming flows
  - Source/destination IP address associated with the PVC
  - Protocol – LLC MUX or VC MUX
  - Ingress port
  - CCE address
  - VPI/VCI
  - Byte count, excluding ATM header
  - start/end time

Note If the ATM PVC is a trunk port or there are multiple peer addresses, no address is reported.

Note See the *Riverstone RS Switch Router Command Line interface Reference* for an explanation of all LFAP commands and parameters.

31.2 LFAP STRUCTURE

LFAP is designed to deliver real-time flow data, even in the middle of a flow.As the flow continues, the RS periodically (configurable down to one minute) reads the ASIC counter and transmits the data to the accounting server.

LFAP also allows for the configuration of up to two fail-over servers using the **`lfap set server`** command. When an RS is configured with multiple accounting servers, a connection is established with a primary server; two additional backup servers can also be specified. In the event that the primary server fails, the router automatically recognizes the failure and sends traffic data to the backup server.

RapidOS also provides a MIB that is used to monitor the LFAP accounting process in the RS. Monitoring these MIB objects keeps you informed about the functioning of the accounting processes. If an accounting process fails, the SNMP agent will send an alert. The MIB also provides access to the number of bytes and packets, if any, that are not accounted for during a sever failure. This is crucial to determining the impact of any accounting server outage.

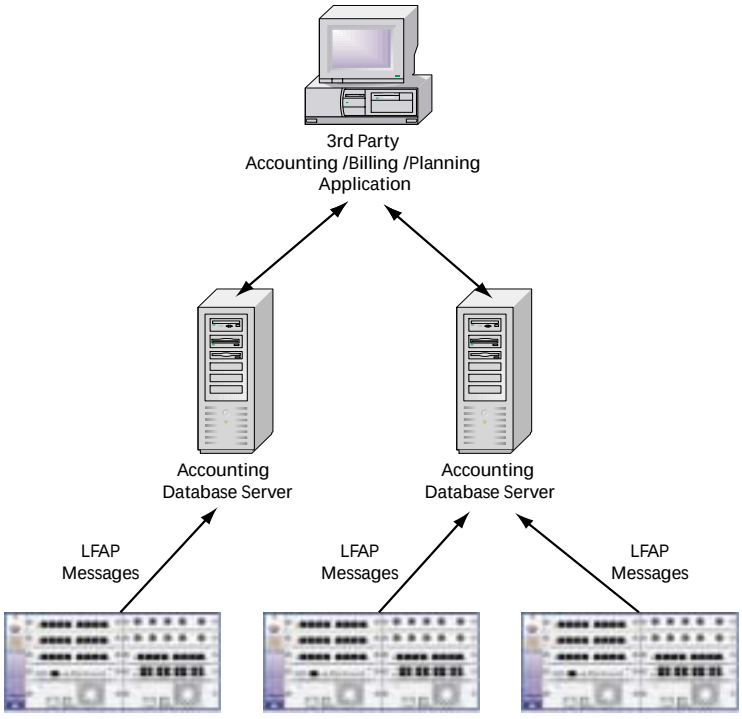


Figure 31-1 Topology of LFAP to servers and applications

31.3 CONFIGURING LFAP

The process of configuring LFAP on an RS switch router consists of five main tasks:

1. Specifying the IP address of the accounting server(s) on the RS
2. Specifying the list of information to be sent to the accounting server
3. Creating and applying ACLs that further define the information sent to the server (ACLs are not required for MPLS accounting)
4. Applying the ACLs to interfaces
5. Starting the LFAP agent process on the RS

31.3.1 Specifying Accounting Server(s)

Use the **lfap set server** command to specify the IP address of one or more servers. If specifying more than one server, enclose the list of IP address in quotation marks. The following is an example of configuring a single accounting server.

```
rs(config)# lfap set server 134.141.179.153
```

The following is an example of configuring a primary accounting server and two backup accounting servers.

```
rs(config)# lfap set server “134.141.179.153 134.141.179.22 134.141.179.37”
```

The position (from left-to-right) of the servers addresses in the list specifies their role as *primary server*, *first backup server*, and *second backup server*.

Note Make sure that the accounting servers specified are reachable by the RS.

31.3.2 Specifying Information Sent by LFAP

Use the **lfap set send** command to specify the information to be sent to the accounting server. Notice that when you list the information objects that you can choose, most of these objects are enabled by default. The following is an example of specifying information for an IP flow.

```
rs(config)# lfap set send ?
 dest-as                  - destination AS number, default is disabled.
 egress                   - egress port, default is enabled.
 ingress                  - ingress port, default is enabled.
 priority                 - priority queue, default is enabled.
 protocol                 - protocol id, default is enabled.
 src-as                   - source AS number, default is disabled for performance.
 src-cce-addr             - source CCE address, default is enabled.
 src-port                 - source port, default is enabled.
 tos                      - type of service, default is enabled.

rs(config)# lfap set send  dest-as enable
```

MPLS Flow Accounting

MPLS flow accounting is enabled using the **mpls set global enable-accounting** and the **lfap set export-flow** commands. The following is an example of specifying that MPLS flow information should be sent to the accounting server.

```
rs(config)# mpls set global enable-accounting
rs(config)# lfap set export-flow mpls enable
```

In the case of MPLS, the **lfap set send** command is not used. Currently, the information sent with regard to MPLS flows is predetermined and is not configurable.

Note ACLs are not used with MPLS flow accounting.

31.3.3 Creating Accounting ACLs

Packets that match the ACLs are counted. For example:

```
rs(config)# acl account-1 permit ip any any any any accounting 15-minutes
```

In the previous example, all packets are counted because all fields are wildcarded by the **any** parameter. However, the use of ACLs allows IP accounting data to be narrowed as desired.

If, for example, the source address 10.2.3.0/24 is specified in the ACL definition, then only those packets originating in subnet 10.2.3 would be counted.

The keyword **15-minutes** is the checkpoint parameter that tells the LFAP server how to break up long lasting flows. For example, if a video conference lasted 45 minutes, the **15-minute** parameter tells the LFAP server to checkpoint the flow as three 15 minute records – this ability is useful for bit rate billing calculations.

Note The checkpoint interval does not affect the RS in any way. It is merely information passed on to the server.

Next, the ACL is applied to one or more interfaces:

```
rs(config)# acl account-1 apply interface all-ip input output
```

In the previous example, the ACL **account-1** is applied to the input and output of all IP interfaces.

Note If accounting is applied to ports within a VLAN, that VLAN must be running layer-4 bridging.

31.3.4 Starting the LFAP Process

Make sure your accounting server is running and reachable by the RS. Then, use the **lfap start** command in Configuration mode to start the LFAP accounting agent. For example:

```
rs(config)# lfap start
rs(config)# save active

rs(config)# 2001-12-19 13:39:53 %LFAP-I-START, started LFAP Service
2001-12-19 13:39:53 %LFAP-I-CONNECT, creating a TCP connection to 134.141.179.153 on
dport 3145
```

Notice in the example above that after the **lfap start** command is saved to the active configuration, a message is displayed that indicates the RS is connected to the accounting server.

31.3.5 Configuration Examples

This section shows two LFAP configurations: one for a switched system, the other for a routed system. While other configurations are possible, these two simple configurations are shown to provide an idea of what's necessary to configure flow accounting on an RS.

LFAP on Switched Configuration

The following example shows the part of a configuration file that applies flow accounting to a switched configuration:

```
! Sample switch configuration with Accounting enabled
!
vlan create LAB_NMS ip
vlan add ports et.2.1-16 to LAB_NMS
vlan enable l4-bridging on LAB_NMS
!
! enable IP directly on gig port in slot 3
interface create ip to_core address-netmask 192.0.2.130/24 mac-addr 2 port gi.3.1
ip add route default gateway 192.0.2.1
!
ip disable proxy-arp interface all
!
! account for all ip flows being l4 bridged
!
acl lfap permit ip any any any any accounting hourly
acl lfap apply port et.2.1-16 input output
!
! send to one (up to 3 accounting servers may be specified)
!
lfap set server "192.0.2.15 192.0.2.25"
lfap start
```

In the example above, notice that the VLAN **LAB_NMS** is created as an IP-based VLAN instead of a port-based VLAN. This is necessary because layer-4 bridging can be applied only against IP VLANs.

LFAP on Routed Configuration

The following example shows the part of a configuration file that applies flow accounting to a routed configuration.

```
! Sample Router configuration with Accounting enabled
!
port description et.2.8 "To lab network"
vlan create LAB_NMS port-based
vlan add ports et.2.1-16 to LAB_NMS
interface create ip to_core address-netmask 192.0.2.130/30 mac-addr 2 port gi.3.1
interface create ip Lab-SW address-netmask 192.0.2.1/27 vlan LAB_NMS
ip disable proxy-arp interface all
!
! account for all ip (and icmp) flows
!
acl lfap permit ip any any any any accounting hourly
acl lfap apply interface to_core input output
!
! Router config
!
ip-router global set router-id 10.0.1.101
ip-router policy redistribute from-proto direct network 192.0.2.0/27 to-proto ospf
ospf create area 0.0.1.100
ospf add interface 192.0.2.1 to-area 0.0.1.100
ospf set interface 192.0.2.1 cost 4
ospf start
!
! send to one (up to 3 accounting servers may be specified)
!
lfap set server 192.0.172.15
lfap start
```

31.4 NETWORK ACCOUNTING

The other side of the network accounting equation is the accounting server and the applications that utilize collected data. Riverstone and LFAP essentially provide three tiers of accounting capabilities.

31.4.1 Tier One: Simple Flow Accounting Server

Riverstone makes available an application called the Simple Flow Accounting Server (SFAS). SFAS is a lightweight application designed primarily for troubleshooting and demonstration purposes; and is capable of receiving LFAP messages from a single RS only. SFAS can be obtained from the web site, http://www.nmops.org. The application can be compiled and run on most platforms. There is also a Windows pre-complied executable available at the same site.

Copy the SFAS file to a workstation that can reach the RS, compile (if necessary), then start SFAS at the prompt along with the name the file within which LFAP information will be stored. For example:

```
pterodactyl% ./sfas > data.txt
```

This starts SFAS and sends the recorded LFAP information to the file **`data.txt`**.

Example SFAS File

When SFAS is stopped, the **`data.txt`** file can be examined for flow accounting results. The following is an example of the contents of the data.txt file:

```
Riverstone Networks: trivial flow accounting server version 1.2
CCE: 134.141.179.156 connected on Thu Dec  6 15:28:36 2001
VR received
CR received
 FAS Address: 134.141.179.153
sent FER
U:1.2.28, 9502935, 1(inactive),(absolute) bytes rx 0,  tx 108, (absolute) pkts rx 0,  tx 1,
F:1.2.29, 9508081, 136.141.179.137, 137.141.179.159, 137, 137, 17(udp), 0, 0, 1, 17, None, 0, 134.141.179.156,
5-minute,  low, none, 2, 295,
U:1.2.29, 9512536, 1(inactive), (absolute) bytes rx 0,  tx 108, (absolute) pkts rx 0,  tx 1,
F:1.2.30, 9517114, 136.141.179.137, 137.141.179.159, 137, 137, 17(udp), 0, 0, 1, 17, None, 0, 134.141.179.156,
5-minute,  low, none, 2, 295,
U:1.2.30, 9520537, 1(inactive), (absolute) bytes rx 0,  tx 108, (absolute) pkts rx 0,  tx 1,
F:1.2.31, 9527415, 50.141.179.153, 136.141.179.137, 1345, 37, 17(udp), 0, 0, 17, 1, None, 0, 134.141.179.156,
5-minute,  low, none, 111, 2,
F:1.2.32, 9527415, 136.141.179.137, 50.141.179.153, 37, 1345, 17(udp), 0, 0, 1, 0, None, 0, 134.141.179.156,
5-minute,  low, none, 2, 3909,
U:1.2.32, 9531740, 1(inactive), (absolute) bytes rx 0,  tx 64, (absolute) pkts rx 0,  tx 1,
U:1.2.31, 9531740, 1(inactive), (absolute) bytes rx 0,  tx 46, (absolute) pkts rx 0,  tx 1,
F:1.2.33, 9535506, 50.141.179.150, 136.141.179.137, 1024, 37, 17(udp), 0, 0, 17, 1, None, 0, 134.141.179.156,
5-minute,  low, none, 111, 2,
F:1.2.34, 9535506, 136.141.179.137, 50.141.179.150, 37, 1024, 17(udp), 0, 0, 1, 0, None, 0, 134.141.179.156,
5-minute,  low, none, 2, 3595,

Caught signal 2 Exiting
Stats:bad opcode 0 bad handhshake 0 unexpected ara 0 unexpected vra 0
bad read 0 bad VR version received 0
lost session 0 number connections 1
messages 2329 bytes 295700
```

In the example above,

- the CCE is the *Connection Control Entity*, specifically, the RS switch router. In this case, it is identified by its IP address: 134.141.179.156.
- The FAS is the IP address of the SFAS workstation: 134.141.179.153.
- Lines within the files are identified by either a **U:** or an **F:**. These letters represent the type of information passing between the RS and SFAS:

  F: – Represents a Flow Accounting Request (FAR) sent by the RS to the server. These messages are sent when the RS identifies a new IP flow. The FAR includes all of the flow information that does not change over the life of the flow – For example, the FAR includes the source and destination IP addresses.

  U: – Represents a Flow Update Notification (FUN) sent by the RS to the server. These messages contain data that changes over the life of the flow – For example, the number of bytes and packets being sent over the flow.

Note For details about the LFAP protocol structure, its message packet types, and its packet structures, see the internet drafts: *draft-riverstone-lfap-00.txt* and *draft-riverstone-lfap-data-00.txt*. These documents can be obtained at http://www.IETF.org. Also, see RFC 2124.

The following is a list (from left-to-right) of the fields that appear on **F** (FAR) lines for IP flows:

- Flow ID
- Switch time at flow start
- Source IP address
- Destination IP address
- Source port
- Destination port
- Protocol (e.g.: TCP/UDP)
- Type of service inbound
- Type of service outbound
- Ingress port ifIndex
- Egress port ifIndex
- Source AS
- Switch IP address
- Checkpoint (flow accounting time – 5-minutes, 15-minutes, or hourly)
- Switch priority queue (low, medium, or high)
- Next hop address
- Source VLAN
- Destination VLAN

The following is a list (from left-to-right) of the fields that appear on **F** (FAR) lines for MPLS flows:

- Flow ID
- Switch time at flow start
- Source switch IP address

- Destination switch IP address
- MPLS
- Ingress port ifIndex
- Egress port ifIndex
- Switch IP address
- Checkpoint (see above)
- Switch priority queue (see above)
- {in label}
- {out label}
- {LDP FEC}
- Next hop address
- Source VLAN
- Destination VLAN

Note The fields previously listed for IP and MPLS FAR messages may be either blank or have a value of zero depending on how LFAP was configured.

The following is a list (from left-to-right) of the fields that appear on **U** (FUN) lines for both IP flows and MPLS flows:

- Flow ID
- Switch time at update
- State (active or inactive)
- Absolute and the delta of bytes received
- Bytes transmitted
- Absolute and the delta of packets received
- Packets transmitted.

31.4.2 Tier Two: APIs for Accounting and Monitoring Software Development

When considering network expansion, service providers should be asking questions such as:

- Which applications are consuming the most bandwidth?
- When are the peak traffic times?
- Do I need to add network capacity or can I implement network policies to improve performance?

The RS' ability to collect accurate flow and traffic accounting information allows service providers to gain an accurate understanding of how the network is being used.

With the data gathered with LFAP, service providers can create policies to influence end user behavior. For example, if Napster traffic is known to be prevalent on Friday evenings between certain hours, network policies can be put in place to limit the amount of bandwidth dedicated to Napster traffic (see Figure 31-2). The same can be done for streaming video or music applications. The key, however, is to be able to collect the data.

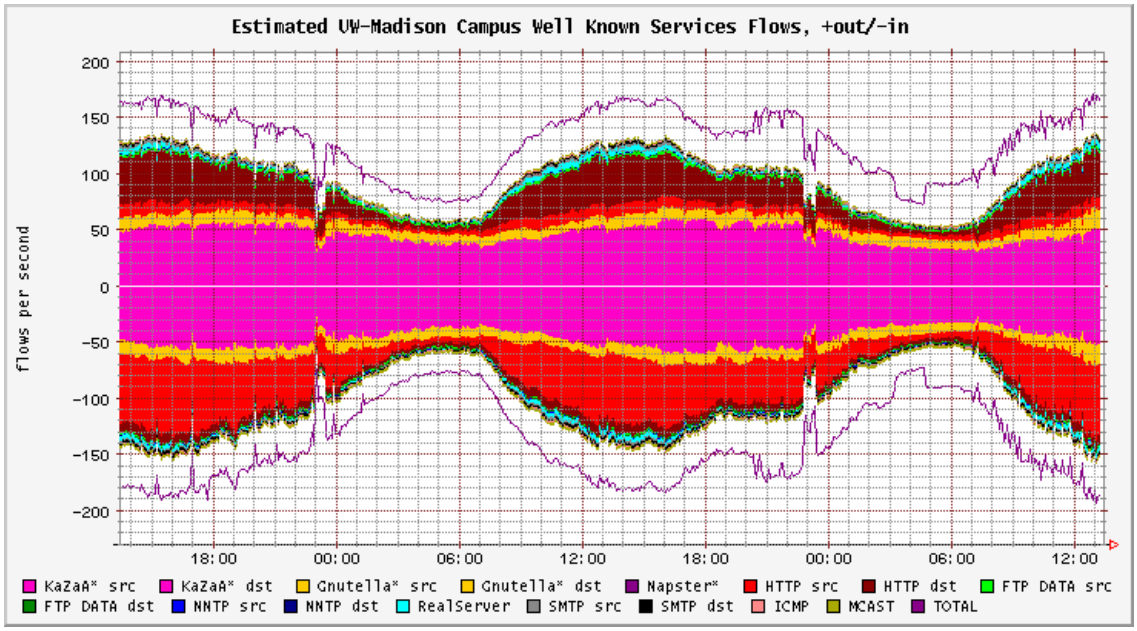


Figure 31-2 Graphic display of flows by FlowScan

Gathering and analyzing flow accounting data does not require a complex accounting system (though such systems are available for those who need them). Open source applications, used in conjunction with LFAP, can give an accurate graphical view of network traffic. For example, the *FlowScan* tool, developed by *Dave Plonka* of the University of Wisconsin–Madison, is a versatile tool that can meet many service providers' needs. FlowScan and the necessary tools required to gather flow accounting data can be found at Riverstone's open source network management web site at http://www.nmops.org.

LFAP can also be used to gain a better understanding of the value of existing peering relationships. FlowScan provides tools that allow tabular or graphical views of the AS[1] to AS traffic data. Table 31-1 and Table 31-2 were created from LFAP data gathered, using the FlowScan tool. The LFAP data was combined with data from ftp://ftp.arin.net/netinfo/asn.txt. Table 31-1 displays the amount of incoming traffic from the top 10 origin ASNs[2]. The ASNs are ranked by inbound bits/sec traffic. Table 31-2 shows the top 10 destination ASNs. The data in Table 31-2 is ranked by outbound bits/sec traffic. FlowScan includes a tool that will graphically display historical source and destination AS traffic data within a graphic format (see Figure 31-3).

Table 31-1 Top 10 origin ASNs for five minute sample

Rank	Origin-AS	Bits/sec in	% of total in	Bits/sec out	% of total out
1	UONET (3582)	2.3 M	62.3%	54.9 K	9.4%
2	NFSNETTEST14-AS (237)	241.3 K	6.5%	16.6 K	2.8%
3	AGIS-NET (4200)	123.9 K	3.4%	75.0 K	12.8%
4	CRITICALPATH (10627)	97.3 K	2.6%	3.2 K	0.5%
5	CNCX-AS1 (2828)	82.1 K	2.2%	2.2 K	0.4%
6	HURRICANE (6939)	66.8 K	1.8%	2.1 K	0.4%

Table 31-1 Top 10 origin ASNs for five minute sample (Continued)

Rank	Origin-AS	Bits/sec in	% of total in	Bits/sec out	% of total out
7	NETUSACOM-AS (3967)	65.9 K	1.8%	8.2 K	1.4%
8	QUOTECOM (11803)	41.9 K	1.1%	2.7 K	0.5%
9	MULTICASTTECH (16517)	35.4 K	1.0%	1.9 K	0.3%
10	ALTERNET-AS (701)	28.2 K	0.8%	7.3 K	1.2%
1 – Autonomous System 2 – Autonomous System Number					

Table 31-2 Top 10 destination ASNs for five minute sample

Rank	Origin-AS	Bits/sec in	% of total in	Bits/sec out	% of total out
1	PLAYBOY-BLK-1 (14068)	0.0	0.0%	226.3 K	38.6%
2	AGIS-NET (4200)	123.9 K	3.4%	75.0 K	12.8%
3	UONET (3582)	2.3 M	62.3%	54.9 K	9.4%
4	VERIO (2914)	21.7 K	0.6%	20.4 K	3.5%
5	NSFNETTEST14-AS (237)	241.3 K	6.5%	16.6 K	2.8%
6	ALTERNET-AS (703)	422.2	0.0%	14.6 K	2.5%
7	ATT-INTERNET4 (7018)	23.3 K	0.6%	8.7 K	1.5%
8	NETUSACOM-AS (3967)	65.9 K	1.8%	8.2 K	1.4%
9	ALTERNET-AS (701)	28.2 K	0.8%	7.3 K	1.2%
10	CISCOSYSTEMS (109)	10.0 K	0.3%	5.9 K	1.0%

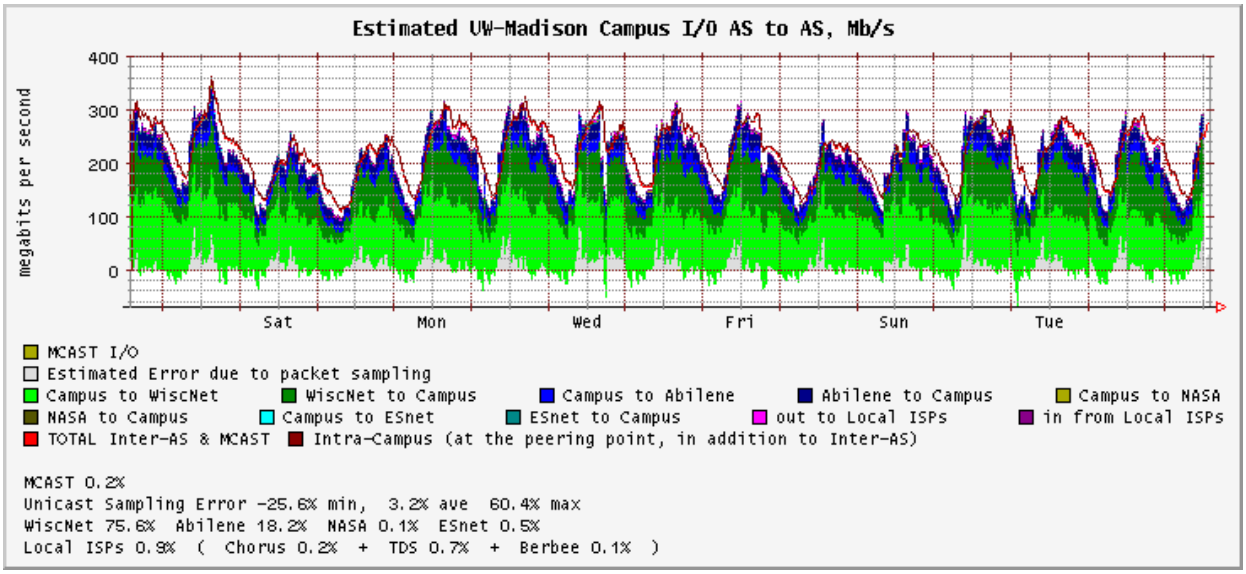


Figure 31-3 FlowScan graphic representation of AS to AS flows

31.4.3 Tier Three: Carrier Class Accounting

Some users may require sophisticated and full-featured network accounting applications that can handle every aspect of the accounting process from data collection to automated billing. For these users, Riverstone provides commercial applications through our software partners. Among these application, are Xacct®, an IP mediation application provider; and Portal®, an application for bill presentment and collection.

Riverstone also provides sophisticated LFAP flow collecting applications (*Mica* and *Basalt*) that can handle LFAP input from several RS switch routers. These applications also structure data so that it can be used with both Oracle® and Microsoft® databases.

MICA

Mica 3.0 is a full accounting server that has been implemented in a production environment in other service providers' networks. This package is able to collect data from several RS network elements and provides data persistency. The current version runs on Solaris 2.6 and above. When running on a Solaris 2.6 machine with 256 MB RAM, the server can handle over 8,000 flows per second. Most service provider networks have traffic with less than 1,000 flows per second. This package is available to Riverstone customers only.

Basalt

Basalt is an application that aggregates and processes LFAP flow record files. The first file contains the flow setup information (FAR messages). The second file contains the actual usage information (FUN messages), which is sent from the router to Mica in increments as low as every 5 minutes. Basalt is able to integrate the two files and aggregate the flow usage data. Like Mica, this package is available to Riverstone customers only

32 WAN CONFIGURATION

This chapter provides an overview of:

- Wide Area Network (WAN) applications in Section 32.2, *"Configuring WAN Interfaces"*.
- Frame Relay configuration in Section 32.3, *"Frame Relay Overview"*.
- PPP configuration in Section 32.4, *"Point-to-Point Protocol (PPP) Overview"*.
- Clear Channel T3 and E3 configurations in Section 32.8, *"Clear Channel T3 and E3 Services Overview"*
- Channelized T1, E1 and T3 configurations in Section 32.9, *"Channelized T1, E1, and T3 Services Overview"*.
- Cisco HDLC protocol in Section 32.5, *"Cisco HDLC WAN Port Configuration"*. This protocol is for WAN routing with Cisco routers that use the Cisco HDLC protocol; it is the default protocol used for WAN on Cisco routers.

In addition, you can view the following:

- Example of multi-router WAN configurations in Section 32.7, *"WAN Configuration Examples"*.
- Example Channelized T1, E1 and T3 configurations in Section 32.10, *"Scenarios for Deploying Channelized T1, E1 and T3"*.
- Example Clear Channel T3 and E3 configurations in Section 32.11, *"Scenarios for Deploying Clear Channel T3 and E3"*.

The configuration and monitoring CLI commands are described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

32.1 HIGH-SPEED SERIAL INTERFACE (HSSI) AND STANDARD SERIAL INTERFACES

On the Riverstone RS Switch Router, WAN routing is performed over a serial interface using two basic protocols: Frame Relay and point-to-point protocol (PPP). The protocols have their own set of configuration and monitoring CLI commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual.*

In both the Frame Relay and PPP environments on the RS, you can specify ports to be High-Speed Serial Interface (HSSI) or standard serial interface ports, depending, of course, on the type of hardware you have. Each type of interface plays a part in the nomenclature of port identification. You must use either the “hs.” or “se.” prefix for HSSI and serial interfaces, respectively, when specifying WAN port identities.

For example, you would specify a frame relay serial WAN port located at router slot 4, port 1, on VC 100 as “se.4.1.100.”

Using the same approach, a PPP high-speed serial interface (HSSI) WAN port located at router slot 3, port 2 would be identified as “hs.3.2.”

32.2 CONFIGURING WAN INTERFACES

Configuring IP interfaces for the WAN is generally the same as for the LAN. You can configure IP interfaces on the physical port or you can configure the interface as part of a VLAN for WAN interfaces. However, in the case of IP interfaces, you can configure multiple IP addresses for each interface. Refer to Section 10.2, *"Configuring IP Interfaces and Parameters"* and Section 26.4, *"Configuring IPX Interfaces and Parameters"* for more specific information.

There are some special considerations that apply only to WAN interfaces. These are detailed in this section.

32.2.1 Primary and Secondary Addresses

Like LAN interfaces, WAN interfaces can have primary and secondary IP addresses. For Frame Relay, you can configure primary and secondary addresses which are static or dynamic. For PPP, however, the primary addresses may be dynamic or static, but the secondary addresses must be static. This is because the primary addresses of both the local and peer routers are exchanged during IPCP negotiation.

Note There is no mechanism in PPP for obtaining any secondary addresses from the peer.

32.2.2 Static, Mapped, and Dynamic Peer IP Addresses

The following sections describe the difference between static, mapped, and dynamic peer IP addresses and provide simple command line examples for configuration.

Static Addresses

If the peer IP address is known before system setup, you can specify the peer address when the interface is created. This disables Inverse ARP (InArp) for Frame Relay on that source/peer address pair. However, InArp will still be enabled for any other addresses on that interface or other interfaces. A static peer address for PPP means that the address the peer supplies during IP Control Protocol (IPCP) negotiations will be ignored.

The following command line displays an example for a port:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 peer-address
10.50.1.2 port hs.3.1
```

The following command line displays an example for a VLAN:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 peer-address
10.50.1.2 vlan BLUE
```

Mapped Addresses

Mapped peer IP addresses are very similar to static addresses in that InArp is disabled for Frame Relay and the address negotiated in IPCP is ignored for PPP.

Mapped addresses are most useful when you do not want to specify the peer address using the **interface create** command. This would be the case if the interface is created for a VLAN and there are many peer addresses on the VLAN. If any of the peers on the VLAN do not support InArp or IPCP, then use a mapped address to configure the peer address.

The following command line displays an example for Frame Relay:

```
rs(config)# frame-relay set peer-address ip-address 10.50.1.1/16 ports se.4.1.204
```

The following command line displays an example for PPP:

```
rs(config)# ppp set peer-address ip-address 10.50.1.1/16 ports se.4.1
```

Dynamic Addresses

If the peer IP address is unknown, you do not need to specify it when creating the interface. When in the Frame Relay environment, the peer address will be automatically discovered via InArp. Similarly, the peer address will be automatically discovered via IPCP negotiation in a PPP environment.

The following command lines display examples for a port and a VC:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 port hs.3.1
```

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 port hs.5.2.19
```

The following command line displays an example for a VLAN:

```
rs(config)# interface create ip IPWAN address-netmask 10.50.1.1/16 vlan BLUE
```

32.2.3 Forcing Bridged Encapsulation

WAN for the RS has the ability to force bridged packet encapsulation. This feature has been provided to facilitate seamless compatibility with Cisco routers, which expect bridged encapsulation in certain operating modes.

The following command line displays an example for Frame Relay:

```
rs(config)# frame-relay set fr-encaps-bgd ports hs.5.2.19
```

The following command line displays an example for PPP:

```
rs(config)# ppp set ppp-encaps-bgd ports hs.5.2
```

32.2.4 Packet Compression

Packet compression can increase throughput and shorten the times needed for data transmission. You can enable packet compression for Frame Relay VCs and for PPP ports, however, both ends of a link must be configured to use packet compression.

Enabling compression on WAN serial links should be decided on a case by case basis. Important factors to consider include:

- Average packet size
- Nature of the data
- Link integrity
- Latency requirements

Each of these factors is discussed in more detail in the following sections and should be taken into consideration before enabling compression. Since the factors are dependent on the environment, you should first try running with compression histories enabled. If compression statistics do not show a very good long-term compression ratio, then select the “no history” option. If the compression statistics do not improve or show a ration of less than 1, then compression should be disabled altogether.

Average Packet Size

In most cases, the larger the packet size, the better the potential compression ratio. This is due to the overhead involved with compression, as well as the compression algorithm. For example, a link which always deals with minimum size packets may not perform as well as a link whose average packet size is much larger.

Nature of the Data

In general, data that is already compressed cannot be compressed any further. In fact, packets that are already compressed will grow even larger. For example, if you have a link devoted to streaming MPEG videos, you should not enable compression as the MPEG video data is already compressed.

Link Integrity

Links with high packet loss or links that are extremely over-subscribed may not perform as well with compression enabled. If this is the situation on your network, you should *not* enable compression histories. This applies only to PPP compressions. In Frame Relay compression, histories are always used.

Compression histories take advantage of data redundancy *between* packets. In an environment with high packet loss or over-subscribed links, there are many gaps in the packet stream resulting in very poor use of the compression mechanism. Compression histories work best with highly-correlated packet streams. Thus, a link with fewer flows will generally perform better than a link with many flows when compression histories are utilized.

The “no history” (max-histories = 0) option causes packets to be compressed on a packet-by-packet basis, thus packet loss is not a problem. Also, the number of flows is not an issue with this option as there is no history of previous packets.

Latency Requirements

The use of compression may affect a packet’s latency. Since the compressed packet is smaller, less time is needed to transmit it. On the other hand, each packet must undergo a compression/decompression process. Since the compression ratio will vary, the amount of latency will also vary.

Example Configurations

The following command line displays an example for Frame Relay:

```
rs(config)# frame-relay set payload-compress ports se.3.1.300
```

The following command line displays an example for PPP:

```
rs(config)# ppp set payload-compress port se.4.2
```

32.2.5 Packet Encryption

Packet encryption allows data to travel through unsecured networks. You can enable packet encryption for PPP ports, however, both ends of a link must be configured to use packet encryption.

The following command line displays an example:

```
rs(config)# ppp set payload-encrypt transmit-key 0x123456789abcdef receive-key
0xfedcba987654321 port se.4.2, mp.1
```

32.2.6 WAN Quality of Service

Increasing concentrations of audio, video, and data traffic are now presenting the networking industry with the significant challenge of employing the most effective use of WAN Quality-of-Service (QoS) as possible to ensure reliable end-to-end communication. For example, critical and time-sensitive traffic such as audio should have higher levels of bandwidth allocated than less time-sensitive traffic such as file transfers or e-mail. Simply adding more and more bandwidth to a network is not a viable solution to the problem. WAN access is extremely expensive, and there is a limited (albeit huge) supply. Therefore, making the most effective use of existing bandwidth is now a more critical issue than ever before.

The fact that IP communications to the desktop are clearly the most prevalent used today has made it the protocol of choice for end-to-end audio, video, and data applications. This means that the challenge for network administrators and developers has been to construct their networks to support these IP-based audio, video, and data applications along with their tried-and-true circuit-based applications over a WAN.

In addition, these audio, video, and data traffic transmissions hardly ever flow at a steady rate. Some periods will see relatively low levels of traffic, and others will temporarily surpass a firm's contracted Committed Information Rate (CIR). Carrier-based packet-switched networks such as Frame Relay and ATM are designed to handle these temporary peaks in traffic, but it is more cost- and resource- efficient to employ effective QoS configuration(s), thus relaxing the potential need to up your firm's CIR. By applying some of the following sorts of attributes to interfaces on your network, you can begin to shape your network's QoS configuration to use existing bandwidth more effectively.

Source Filtering and ACLs

Source filtering and ACLs can be applied to a WAN interface. However, they affect the entire module, not an individual port.

For example, if you want to apply a source MAC address filter to a WAN serial card located in slot 5, port 2, your configuration command line would look like the following:

```
rs(config)# filters add address-filter name wan1 source-mac 000102:030405 vlan 2
in-port-list se.5
```

Port se.5 is specified instead of se.5.2 because source filters affect the entire WAN module. Hence, in this example, **`source-mac 000102:030405`** would be filtered from ports se.5.1, se.5.2, se.5.3, and se.5.4 (assuming that you are using a four-port serial card).

ACLs work in a similar fashion. For example, if you define an ACL to deny all http traffic on one of the WAN interfaces, it will apply to the other WAN interfaces on that module as well. In practice, by making your ACLs more specific, for example by specifying source and destination IP addresses with appropriate subnet masks, you can achieve your intended level of control.

Weighted-Fair Queueing

Through the use of Weighted-Fair Queueing QoS policies, WAN packets with the highest priority can be allotted a sizable percentage of the available bandwidth and "whisked through" WAN interface(s). Meanwhile, the remaining bandwidth is distributed for "lower-priority" WAN packets according to the user's percentage-of-bandwidth specifications. Refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual* for more detailed configuration information.

Note Weighted-Fair Queueing applies only to best-effort traffic on the WAN card. If you apply any of the WAN specific traffic shaping commands, then weighted fair queuing will no longer be applicable unless you configure the **`wfq-aware`** option when defining the service profile. Also, control priority traffic on the WAN card is always treated as strict priority, and ignores the rules applied by weighted-fair queueing. This may alter the weighted-fair queuing statistics if a significant portion of the traffic is control priority traffic.

Congestion Management

One of the most important features of configuring the RS to ensure Quality of Service is the obvious advantage gained when you are able to avoid network congestion. The following topics touch on a few of the most prominent aspects of congestion avoidance when configuring the RS.

Random Early Discard (RED)

Random Early Discard (RED) allows network operators to manage traffic during periods of congestion based on policies. RED works with TCP to provide fair reductions in traffic proportional to the bandwidth being used. Weighted Random Early Discard (WRED) works with IP Precedence or priority, as defined in the **qos** configuration command line, to provide preferential traffic handling for higher-priority traffic.

The CLI commands related to RED in both the Frame Relay and PPP protocol environments allow you to set maximum and minimum threshold values for each of the low-, medium-, and high-priority categories of WAN traffic.

Adaptive Shaping

Adaptive shaping implements the congestion-sensitive rate adjustment function and has the following characteristics:

- No blocking of data flow under normal condition if the traffic rate is below Bc+Be.
- Reduction to a lower CIR upon detection of network congestion.
- Progressive return to the negotiated information transfer rate upon congestion abatement.

The CLI command related to adaptive shaping allows you to set threshold values for triggering the adaptive shaping function.

32.3 FRAME RELAY OVERVIEW

Frame relay interfaces are commonly used in a WAN to link several remote routers together via a single central switch. This eliminates the need to have direct connections between all of the remote members of a complex network, such as a host of corporate satellite offices. The advantage that Frame Relay offers to this type of geographic layout is the ability to switch packet data across the interfaces of different types of devices like switch-routers and bridges, for example.

Frame Relay employs the use of Virtual Circuits (VCs) when handling multiple logical data connections over a single physical link between different pieces of network equipment. The Frame Relay environment, by nature, deals with these connections quite well through its extremely efficient use of precious (sometimes scarce) bandwidth.

You can set up frame relay ports on your RS with the commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

32.3.1 Virtual Circuits

Think of a Virtual Circuit (VC) as a “virtual interface” (sometimes referred to as “sub-interfaces”) over which Frame Relay traffic travels. Frame Relay interfaces on the RS use one or more VCs to establish bidirectional, end-to-end connections with remote end points throughout the WAN. For example, you can connect a series of multi-protocol routers in various locations using a Frame Relay network.

32.3.2 Permanent Virtual Circuits (PVCs)

WAN interfaces can take advantage of connections that assure a minimum level of available bandwidth at all times. These standing connections, called Permanent Virtual Circuits (PVCs), allow you to route critical packet transmissions from host to peer without concern for network congestion significantly slowing, let alone interrupting, your communications. PVCs are the most prevalent type of circuit used today and are similar to dedicated private lines in that you can lease and set them up through a service provider.

In a corporate setting, network administrators can use PVCs in an internal network to set aside bandwidth for critical connections, such as videoconferencing with other corporate departments.

32.3.3 Configuring Frame Relay Interfaces for the RS

This section provides an overview of configuring a host of WAN parameters and setting up WAN interfaces. When working in the Frame Relay protocol environment, you must first define the type and location of the WAN interface. Having established the type and location of your WAN interfaces, you need to (optionally) define one or more service profiles for your WAN interfaces, then apply a service profile to the desired interface(s). An example of this process is covered in *"Frame Relay Port Configuration"*.

Defining the Type and Location of a Frame Relay and VC Interface

To configure a frame relay WAN port, you need to first define the type and location of one or more frame relay WAN ports or virtual circuits (VCs) on your RS. The following command line displays a simplified example of a frame relay WAN port definition:

Define the type and location of a frame relay WAN port.	**`port set`** <*port*> **`wan-encapsulation frame-relay speed`** <*number*>

Note If the port is a HSSI port that will be connected to a HSSI port on another router, you can also specify **`clock`** <*clock-source*> in your definition.

Then, you must set up a frame relay virtual circuit (VC). The following command line displays a simplified example of a VC definition:

Define the type and location of a frame relay VC.	**`frame-relay create vc port`** <*port*>

Setting up a Frame Relay Service Profile

Once you have defined the type and location of your Frame Relay WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for Frame Relay communications.

Note The RS comes with a set of "default values" for Frame Relay interface configuration settings, which means that setting up a Frame Relay service profile is not absolutely necessary to begin sending and receiving Frame Relay traffic on your RS.

After you configure one or more service profiles for your Frame Relay interface(s), you can then apply a service profile to active Frame Relay WAN ports, specifying their behavior when handling Frame Relay traffic. The following command line displays all of the possible attributes used to define a Frame Relay service profile:

Define a frame relay service profile.	**frame-relay define service** <*service name*> [**Bc** <*number*>] [**Be** <*number*>] [**becn-adaptive-shaping** <*number*>] [**cir** <*number*>] [**high-priority-queue-depth** <*number*>] [**low-priority-queue-depth** <*number*>] [**med-priority-queue-depth** <*number*>] [**red on | off**] [**red-maxTh-high-prio-traffic** <*number*>] [**red-maxTh-low-prio-traffic** <*number*>] [**red-maxTh-med-prio-traffic** <*number*>] [**red-minTh-high-prio-traffic** <*number*>] [**red-minTh-low-prio-traffic** <*number*>] [**red-minTh-med-prio-traffic** <*number*>] [**rmon on | off**] [**wfq-aware on | off**]

Applying a Service Profile to an Active Frame Relay WAN Port

Once you have created one or more frame relay service profiles, you can specify their use on one or more active frame relay WAN ports on the RS. The following command line displays a simplified example of this process:

Apply a service profile to an active WAN port.	**frame-relay apply service** <*service name*> **ports** <*port list*>

32.3.4 Monitoring Frame Relay WAN Ports

Once you have configured your frame relay WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in Enable mode:

Display a particular frame relay service profile	**frame-relay show service** <*service name*>
Display all available frame relay service profiles	**frame-relay show service all**
Display the last reported frame relay error	**frame-relay show stats ports** <*port name*> **last-error**
Display active frame relay LMI parameters	**frame-relay show stats ports** <*port name*> **lmi**
Display MIBII statistics for frame relay WAN ports	**frame-relay show stats ports** <*port name*> **mibII**
Display a summary of all LMI statistics	**frame-relay show stats ports** <*port name*> **summary**

32.3.5 Tracing Frame Relay Connections

The RS can be configured to trace Frame Relay control packets (LMI and DCP) on specified ports. The **frame-relay show trace** command is useful for debugging frame-relay circuits. By enabling packet tracing, traffic on a specified frame relay link is displayed on the console.

The following, lists the keywords and parameters are used with the frame-relay show trace command.

- **ctl-packet-trace** – Specifies tracing on control packets (supports LMI and DCP only).
  - **on** – Keyword, enables control packet tracing.
  - **off** – Keyword, disables control packet tracing.
- **max-packets-displayed** – Optional field that specifies how many control packets to display. Once the maximum is reached (default value is 60 packets), the packet tracing feature disables itself. If a 0 is entered, the trace runs continuously until the user turns it off.
- **packet-trace-level** – Optional field that specifies the level of detail displayed on the console.
  - **normal** – Compresses important information to a couple of lines.
  - **verbose** – Decodes all information and formats it to appear on separate lines.
  - **hex-only** – Shows only the raw hexadecimal data of the packets.
- **ports** – Required field that specifies on which ports to trace.

The following is an example of the output from the **frame-relay show trace** command:

```
rs# frame-relay show trace ctl-packet-trace on ports t1.4.3:1

Port 3 vc 0 FR Ingress, Unicast, DCLI 0, Status Enquiry, Full, Annex D,
Tx Seq 7, Rx Seq 6
Port 3 vc 0 FR Egress, Unicast, DCLI 0, Status, Full, Annex D, Tx Seq 7,
Rx Seq 7
     DLCI 100: N=1 A=0
     DLCI 200: N=1 A=0
Port 3 vc 0 FR Ingress, Unicast, DCLI 0, Status Enquiry, LIV, Annex D,
Tx Seq 8, Rx Seq 7
Port 3 vc 0 FR Egress, Unicast, DCLI 0, Status, LIV, Annex D, Tx Seq 8,
Rx Seq 8
Port 3 vc 0 FR Ingress, Unicast, DCLI 0, Status Enquiry, LIV, Annex D,
Tx Seq 9, Rx Seq 8
Port 3 vc 0 FR Egress, Unicast, DCLI 0, Status, LIV, Annex D, Tx Seq 9,
Rx Seq 9
Port 3 vc 0 FR Ingress, Unicast, DCLI 0, Status Enquiry, LIV, Annex D,
Tx Seq 10, Rx Seq 9
Port 3 vc 0 FR Egress, Unicast, DCLI 0, Status, LIV, Annex D, Tx Seq 10,
Rx Seq 10
Port 3 vc 0 FR Ingress, Unicast, DCLI 0, Status Enquiry, LIV, Annex D,
Tx Seq 11, Rx Seq 10
Port 3 vc 0 FR Egress, Unicast, DCLI 0, Stat LIV, Annex D, Tx Seq 11, Rx
Seq 11
```

32.3.6 Frame Relay Port Configuration

To configure frame relay WAN ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a typical frame relay WAN interface specification.

To define the location and identity of a serial frame relay WAN port located at slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set se.5.1 wan-encapsulation frame-relay speed 45000000
```

To define the location and identity of a High-Speed Serial Interface (HSSI) VC located at slot 4, port 1 with a DLC of 100:

```
rs(config)# frame-relay create vc port hs.4.1.100
```

Suppose you wish to set up a service profile called "profile1" that includes the following characteristics:

- Committed burst value of 2 million and excessive burst value of 1 million
- BECN active shaping at 65 frames
- Committed information rate (CIR) of 20 million bits per second
- Leave high-, low-, and medium-priority queue depths set to factory defaults
- Random Early Discard (RED) disabled
- RMON enabled

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# frame-relay define service profile1 Bc 2000000 Be 10000000
becn-adaptive-shaping 65 cir 20000000 red off rmon on
```

To assign the above service profile to the VC interface created earlier (slot 4, port 1):

```
rs(config)# frame-relay apply service profile1 ports hs.4.1.100
```

32.4 POINT-TO-POINT PROTOCOL (PPP) OVERVIEW

Because of its ability to quickly and easily accommodate IP protocol traffic, Point-to-Point Protocol (PPP) routing has become a very important aspect of WAN configuration. Using PPP, you can set up router-to-router, host-to-router, and host-to-host connections.

Establishing a connection in a PPP environment requires that the following events take place:

- The router initializing the PPP connection transmits Link Control Protocol (LCP) configuration and test frames to the remote peer to set up the data link.
- Once the connection has been established, the router which initiated the PPP connection transmits a series of Network Control Protocol (NCP) frames necessary to configure one or more network-layer protocols.

- Finally, when the network-layer protocols have been configured, both the host and remote peer can send packets to one another using any and all of the configured network-layer protocols.

The link will remain active until explicit LCP or NCP frames instruct the host and/or the peer router to close the link, or until some external event (i.e., user interruption or system time-out) takes place.

You can set up PPP ports on your RS with the commands described in the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

32.4.1 Use of LCP Magic Numbers

LCP magic numbers enable you to detect situations where PPP LCP packets are looped back from the remote system, resulting in an error message. The use of LCP magic numbers is enabled on the RS by default. However, should you employ a service profile in which the use of LCP magic numbers has been disabled, undetected “loopback” behavior may become a problem.

Note In the event that a PPP WAN interface remains unrecognized at startup due to loopback interference, you can use the **ppp restart** command in the CLI to remedy the situation.

32.4.2 Configuring PPP Interfaces

This section provides an overview of configuring a host of WAN parameters and setting up WAN interfaces. When working in the PPP environment, you must first define the type and location of your WAN interfaces. Having established the type and location of your WAN interfaces, you need to (optionally) define one or more service profiles for your WAN interfaces, then apply a service profile to the desired interface(s). Examples of this process are displayed in *"PPP Port Configuration"*.

Defining the Type and Location of a PPP Interface

To configure a PPP WAN port, you need to first define the type and location of one or more PPP WAN ports on your RS. The following command line displays a simplified example of a PPP WAN port definition:

Define the type and location of a PPP WAN port.	**port set** <*port*> **wan-encapsulation ppp speed** <*number*>

If the port is an HSSI port that will be connected to a HSSI port on another router, you can specify **clock** <*clock-source*> in the definition.

32.4.3 Setting up a PPP Service Profile

Once you have defined the type and location of your PPP WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for PPP communications.

Note The RS comes with a set of default values for PPP interface configuration settings, which means that setting up a PPP service profile is not absolutely necessary to begin sending and receiving PPP traffic on your RS.

After you configure one or more service profiles for your PPP interface(s), you can then apply a service profile to active PPP WAN ports, specifying their behavior when handling PPP traffic. The following command line displays all of the possible attributes used to define a PPP service profile:

Define a PPP service profile.	**ppp define service** <*service name*> [**bridging enable | disable ip enable | disable**] [**high-priority-queue-depth** <*number*>] [**lcp-echo on | off**] [**lcp-magic on | off**] [**low-priority-queue-depth** <*number*>] [**max-configure** <*number*>] [**max-failure** <*number*>] [**max-terminate** <*number*>] [**med-priority-queue-depth** <*number*>] [**red on | off**] [**red-maxTh-high-prio-traffic** <*number*>] [**red-maxTh-low-prio-traffic** <*number*>] [**red-maxTh-med-prio-traffic** <*number*>] [**red-minTh-high-prio-traffic** <*number*>] [**red-minTh-low-prio-traffic** <*number*>] [**red-minTh-med-prio-traffic** <*number*>] [**retry-interval** <*number*>] [**rmon on | off**]

Note If it is necessary to specify a value for bridging and/or IP, you must specify all three of these values at the same time. You cannot specify just one or two of them in the command line without the other(s).

Applying a Service Profile to an Active PPP Port

Once you have created one or more PPP service profiles, you can specify their use on one or more active PPP ports on the RS. The following command line displays a simplified example of this process:

Apply a service profile to an active WAN port.	**ppp apply service** <*service name*> **ports** <*port list*>

32.4.4 Configuring Multi-Link PPP Bundles

The multi-link PPP (MLP) standard defines a method for grouping multiple physical PPP links into a logical pipe, called an “MLP bundle.” PPP ports are bundled together on a single WAN module. Large packets are fragmented and transmitted over each physical link in an MLP bundle. At the destination, MLP reassembles the packets and places them in their correct sequence.

Note If you have a four-port Channelized T3 card, this is regarded as two separate WAN modules. Ports 1 and 2 are on one WAN module, and ports 3 and 4 are on the other WAN module. Therefore, you cannot add all four ports to a single MLP bundle.

The following table describes the commands for configuring MLP:

Add PPP port(s) to an MLP bundle.	**ppp add-to-mlp** <*mlp*> **port** <*port list*>
Create MLP bundle(s).	**ppp create-mlp** <*mlp list*> **slot** <*number*>
Set MLP encapsulation format.	**ppp set mlp-encaps-format ports** <*port list*> [**format short-format**]
Set the size of frames that fragmented for transmission on an MLP bundle.	**ppp set mlp-frag-size ports** <*port list*> **size** <*size*>
Set the depth of the queue used to hold MLP packets for preserving the packet order.	**ppp set mlp-orderq-depth ports** <*port list*> **qdepth** <*number-of-packets*>
Set the depth of the queue used to hold packet fragments for reassembly.	**ppp set mlp-fragq-depth ports** <*port list*> **qdepth** <*number-of-packets*>

32.4.5 Compression on MLP Bundles or Links

Compression can be applied on either a bundle or link basis if MLP is enabled on PPP links. If compression is enabled on a bundle, the packets will be compressed *before* processing by MLP. If compression is enabled on a link, the packets will be compressed *after* the MLP processing.

In general, choose bundle compression over link compression whenever possible. Compressing packets before they are “split” by MLP is much more efficient for both the compression algorithm and the WAN card. Link compression is supported to provide the widest range of compatibility with other vendors’ equipment.

32.4.6 Monitoring PPP WAN Ports

Once you have configured your PPP WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in the Enable mode:

Display a particular PPP service profile.	**ppp show service** <*service name*>
Display all available PPP service profiles.	**ppp show service all**
Display bridge NCP statistics for specified PPP WAN port.	**ppp show stats port** <*port name*> **bridge-ncp**
Display IP NCP statistics for specified PPP WAN port.	**ppp show stats ports** <*port name*> **ip-ncp**
Display link-status statistics for a specified PPP WAN port.	**ppp show stats ports** <*port name*> **link-status**
Displays information for PPP ports that are added to MLP bundles.	**ppp show mlp** <*mlp list*> **| all-ports**

32.4.7 PPP Port Configuration

To configure PPP WAN ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a typical PPP WAN interface specification.

To define the location and identity of a High-Speed Serial Interface (HSSI) PPP WAN port located at router slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set hs.5.1 wan-encapsulation ppp speed 45000000
```

When configuring a PPP connection between two multi-vendor equipment, make sure that the maximum transfer unit (MTU) and the maximum receive unit (MRU) are compatible for each machine. For instance, if Router1 has an MTU=4k/MRU=4k and Router2 has an MTU=9k/MRU=9k, there will be incompatibility issues and the PPP connection may fail. This is because Router1 cannot accommodate the bigger amount of traffic from Router2.

To set the MRU=10k and MTU=10k on the HSSI port hs.5.1:

```
rs(config)# port set hs.5.1 mtu 10000 mru 10000
```

Suppose you wish to set up a service profile called "profile2" that includes the following characteristics:

- Bridging enabled
- Leave high-, low-, and medium-priority queue depths set to factory defaults
- IP enabled
- Sending of LCP Echo Requests disabled
- Use of LCP magic numbers disabled
- The maximum allowable number of unanswered requests set to 8
- The maximum allowable number of negative-acknowledgment transmissions set to 5
- The maximum allowable number of unanswered/improperly answered connection-termination requests before declaring the link to a peer lost set to 4
- Random Early Discard disabled
- The number of seconds between subsequent configuration request transmissions (the "retry interval") set to 25
- RMON enabled

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# ppp define service profile2 bridging enable ip enable
lcp-echo off lcp-magic off max-configure 8 max-failure 5 max-terminate 4
red off retry-interval 25 rmon on
```

To assign the above service profile to the active PPP WAN port defined earlier (slot 5, port 1):

```
rs(config)# ppp apply service profile2 ports hs.5.1
```

32.5 CISCO HDLC WAN PORT CONFIGURATION

To configure Cisco HDLC ports, you must first define the type and location of the WAN interface, optionally "set up" a library of configuration settings, then apply those settings to the desired interface(s). The following examples are designed to give you a small model of the steps necessary for a Cisco HDLC WAN interface specification.

To define the location and identity of a High-Speed Serial Interface (HSSI) Cisco HDLC WAN port located at router slot 5, port 1 with a speed rating of 45 million bits per second:

```
rs(config)# port set hs.5.1 wan-encapsulation cisco-hdlc speed 45000000
```

When you apply cisco-hdlc encapsulation on a WAN port, a default service profile is used. This service profile uses the default values of the profile parameters. If you want to apply a non-default service profile, then you must create a profile and apply it to the port.

32.5.1 Setting up a Cisco HDLC Service Profile

Once you have defined the type and location of your Cisco HDLC WAN interface(s), you can configure your RS to more efficiently utilize available bandwidth for Cisco HDLC communications.

Note The RS comes with a set of "default values" for Cisco HDLC interface configuration settings, which means that setting up a Cisco HDLC service profile is not absolutely necessary to begin sending and receiving Cisco HDLC traffic on your RS.

Suppose you wish to set up a service profile called "ciscosp" that includes the following characteristics:

- Leave high-, low-, and medium-priority queue depths set to factory defaults
- Random Early Discard disabled
- The number of seconds between "keepalive" messages set to 15
- RMON enabled

32.5.2 Applying a Service Profile to an Active Cisco HDLC WAN Port

The command line necessary to set up a service profile with the above attributes would be as follows:

```
rs(config)# cisco-hdlc define service ciscosp red off keepalive 15 rmon on
```

To assign the above service profile to the active Cisco HDLC port defined earlier (slot 5, port 1):

```
rs(config)# cisco-hdlc apply service ciscosp ports hs.5.1
```

32.5.3 Assigning IP Addresses to a Cisco HDLC WAN Port

The interface address of the local Cisco HDLC WAN port and peer address must conform to the following rules:

1. The interface and peer addresses should belong to the same subnet.
2. The host part of the addresses should be either 1 or 2. If the host part of the interface address is 1, then the peer address should be 2, and vice-versa.

For example on routers RS1 and RS2, in subnet 123.45.67.0, the configuration is:

```
! RS1 Cisco HDLC WAN port
rs1(config)# interface create ip cisco_hdlc address-netmask 123.45.6.1/24
peer-address 123.45.67.2 port hs.5.1
```

```
! RS2 Cisco HDLC WAN port
rs2(config)# interface create ip cisco_hdlc address-netmask 123.45.6.2/24
peer-address 123.45.67.1 port hs.3.2
```

32.5.4 Monitoring Cisco HDLC Port Configuration

Once you have configured your Cisco HDLC WAN interface(s), you can use the CLI to monitor status and statistics for your WAN ports. The following table describes the monitoring commands for WAN interfaces, designed to be used in the Enable mode:

Display a particular Cisco HDLC service profile.	**cisco-hdlc show service** *<service name>*
Display all available Cisco HDLC service profiles.	**cisco-hdlc show service all**
Display statistics for Cisco HDLC WAN port(s).	**cisco-hdlc show stats ports** *<port name>* **| all-ports** [**summary**]
Clear the specified statistics counter on one or more Cisco HDLC WAN ports.	**cisco-hdlc clear stats-counter** [**frame-drop-qdepth-counter**] [**max-frame-enqued-counter**] [**frame-drop-red-counter**] [**rmon**] **port** *<port-list>*

32.5.5 Cisco HDLC Configuration Example

HSSI ports 1 and 2 in slot 5 are configured for Cisco HDLC encapsulation, and a speed of 45Mbps. A service profile "s1" is then created with the Keepalive set to 15 seconds, and RED disable. Finally, the service profile is applied to the HSSI ports:

```
rs(config)# port set hs.5.1,hs.5.2 wan-encapsulation cisco-hdlc speed 45000000
rs(config)# cisco-hdlc define service s1 keepalive 15 red off
rs(config)# cisco-hdlc apply service s1 ports hs.5.1,hs.5.2
```

32.6 WAN RATE SHAPING

WAN rate shaping provides a way to send traffic from Ethernet ports out through a WAN port in a controlled and equitable manner. For instance, incoming traffic from several Ethernet ports enter the WAN network through a single serial port. Normally, the Ethernet flows would compete with each other for bandwidth through the serial port, resulting in congestion and dropped packets. WAN rate shaping controls the flow of outbound traffic through the WAN port by restricting bandwidth and using packet buffers.

Use WAN rate shaping with the following WAN line cards:

- WAN serial line card
- WAN High Speed Serial (HSSI) line card
- T1/E1 and T3/E3 line cards in both framed and unframed modes
- Clear Channel T3/E3 line card

WAN rate shaping is compatible with the following encapsulation schemes:

- Point-to-Point protocol (PPP)
- Cisco-based High Level Data Link Control protocol (Cisco-HDLC)
- Multi-link Point-to-Point protocol (MLPPP)

32.6.1 Configuring WAN Rate Shaping

Configure WAN rate shaping using the two commands **`wan define`** and **`wan apply`**. Use **`wan define`** to create a rate shaping template, then use **`wan apply`** to apply the template to a physical WAN port.

Rate shaping is defined using the following parameters:

Name The name of the template used to identify it when applied to a WAN port.

Committed Information Rate (CIR) The amount of outbound WAN port bandwidth in Kbps used by each flow

Committed Burst Size (Bc) The number of bits that a flow can send through the WAN port during any sampling interval; the sampling interval is called the *Committed Rate Measurement Interval* (Tc)

Excess Burst Size (Be) The number of bits that a flow can send through the WAN port in excess of Bc if there is unutilized WAN port bandwidth (Be is optional)

Note The RS calculates the sampling interval (Tc) automatically, using the equation Tc = Bc / CIR.

In the example below, a WAN rate shaping template named "*WanTemp1*" is defined with CIR = 64 Kbps, Bc = 4000 bits, and Be = 2000 bits:

```
rs(config)# wan define rate-shape-parameters WanTemp1 cir 64000 bc 4000 be 2000
```

The RS calculates the sampling interval to be Bc / CIR = 2000 bits / 64000 bps = 1/32 sec. = Tc.

Note If Be is defined in a rate shaping template, a good rule of thumb is to set its value roughly equal to Bc / 2.

Use the **`wan apply`** command to apply the template to a WAN port. Specify Ethernet flows within the **`wan apply`** command using one of the following identifiers:

Destination IP address Any Ethernet flow attempting to reach this destination IP address is rate shaped according to the template.

Source IP address Any Ethernet flow with this source IP address is rate shaped according to the template.

Port number Any Ethernet flow originating from this physical port is rate shaped according to the template.

VLAN name Any Ethernet flow that is a member of this VLAN is rate shaped according to the template.

In the example below, the previously defined WAN rate shaping template (*WanTemp1*) is applied to a Clear Channel T3 WAN port, and the Ethernet flows to be rate shaped are identified by a source IP address:

```
rs(config)# wan apply rate-shape-parameters WanTemp1 port t3.3.1 source-ip-address
134.141.153.0/24
```

In the example above, notice that a subnet mask is specified with the source IP address. Adding the subnet mask causes the rate shaping template to be applied to all flows from the subnet 134.141.153.0. To apply rate shaping to a single source IP address, enter the IP address only, but do not specify a subnet mask.

The **`wan apply`** command also allows you to set the following parameters that affect rate shaping behavior:

burst-queue-depth: The depth (in packets) of the queue used to buffer packets when Bc or Bc + Be are exceeded.

no-shape-high-priority: Specifies that Ethernet traffic from the high-priority queue does not take part in rate shaping and transmits on the WAN port without bandwidth restrictions.

shape-control-priority: Normally, control-priority traffic (ARP, OSPF, and so on) are not subjected to rate shaping. However, control-priority traffic is included in the rate shaping process if this parameter is specified.

Note Rate shaping control-priority traffic is not recommended.

32.6.2 The WAN Rate Shaping Algorithm

The first step in rate shaping traffic through a WAN port is to allot some percentage of the WAN port's bandwidth (in Kbps) to each Ethernet flow. This allotted bandwidth is called the Committed Information Rate (CIR). Generally, the total of the CIRs for all rate shaped flows should not exceed the total bandwidth of the WAN port. However, depending on the characteristics of each flow, some oversubscribing of WAN port bandwidth is usually permissible.

Next, the number of bits from each rate-shaped Ethernet flow is measured as they pass through the WAN port. These measurements are taken during equal sampling intervals (Tc), which are some fraction of one second. During a sampling interval, if the number of bits from a flow exceeds a pre-set value, called the Committed Burst Size (Bc), the

rate shaping algorithm stops the Ethernet flow from sending packets directly through the WAN port. Instead, packets are sent to a queue, and the queue is emptied at a rate that does not exceed Bc. Because Bc is never exceeded, at the end of one second, the rate shaped Ethernet flow transmits a number of bits less than or equal to CIR.

Note Queue depth is not unlimited. Each queue for each flow can buffer a maximum of 256 packets.

If the traffic through the WAN port is bursty and there are periods when WAN bandwidth is not 100 percent utilized, the rate shaping algorithm can allow each rate shaped Ethernet flow to exceed its Bc by a specified amount called the Excess Burst Size (Be). As with Bc, if during a sampling interval, a particular flow exceeds its allocated Be, packets are buffered until the bit rate for the flow falls to Bc + Be. However, note that Be is not guaranteed because the amount of excess bandwidth typically changes over time. Because of this dynamic nature of excess bandwidth, queuing also can occur if the amount of excess WAN bandwidth falls below Bc + Be.

Figure 32-1 demonstrates how the parameters CIR, Bc, Be, and the sampling rate (Tc) interact to perform rate shaping. Note that in the example, Bc and Be are set to some number of bits and Tc is equal to 1/16 of a second.

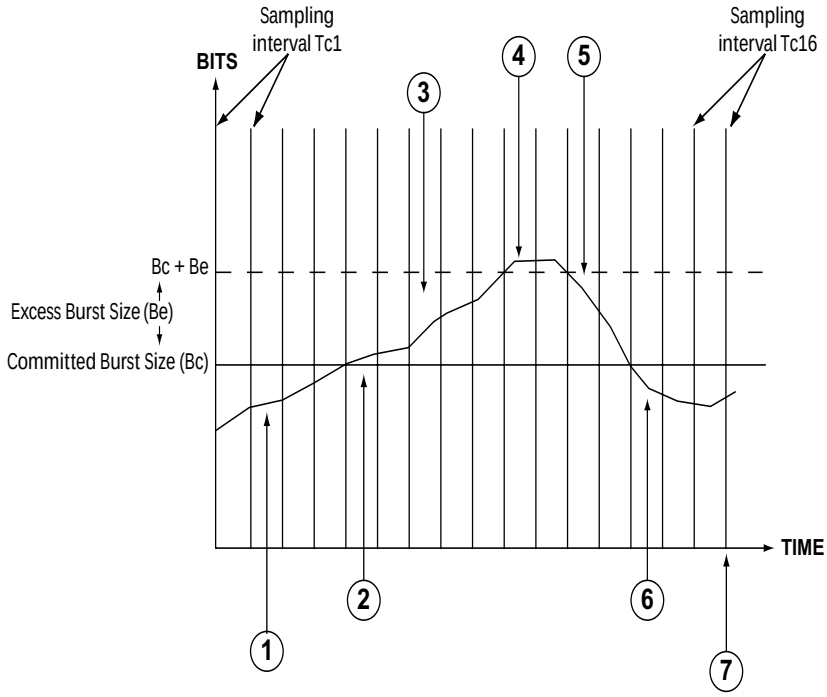


Figure 32-1 WAN rate shaping example

The following numbered list corresponds to the numbered points in Figure 32-1:

1. The number of bits sent through the WAN port during the sampling period Tc is less than Bc.
2. The number of bits sent through the WAN port exceeds Bc. If Be is not defined or if there is no extra bandwidth available on the WAN interface, packets begin to be queued.

3. The number of bits sent through the WAN port exceeds Bc. This occurs only if Be is defined and there is extra bandwidth available.
4. The number of bits sent through the WAN port has exceeds Bc + Be, and packets are queued.
5. The number of bits sent through the WAN port drops below Bc + Be; as long as excess bandwidth is available, the queue begins to empty.
6. The number of bits sent through the WAN port drops below Bc, the buffer empties and packets are once again passed directly through the WAN port.
7. One second has elapsed (the sum of the sampling intervals), and the rate shaping algorithm has controlled the Ethernet flow so that the number of bits sent through the WAN port is approximately equal to CIR.

Notice that if Be is defined and excess bandwidth is available, the amount of WAN port bandwidth utilized by an Ethernet flow can exceed its specified CIR. In the best possible case, where there is sustained excess bandwidth, a flow's bandwidth can attain a maximum equal to ((Be + Bc) / Bc) * CIR. For example, if CIR = 128 Kbps, Bc = 4000, and Be = 2000, the calculated maximum bandwidth that the Ethernet flow could potentially reach is:

Max Bandwidth = ((2000 + 4000) / 4000) * 128000 = 192000 or 192 Kbps

32.6.3 WAN Rate Shaping Example

In this example, computers on three different floors are connected to R1 through Ethernet switches. R1 connects to the WAN through a Clear Channel T3 line. Rate shaping is applied, and limits each switch to 150 Kbps of bandwidth on the Clear Channel T3 line. Flows from each switch are identified by the physical port to which they connect on R1; these ports are **et.2.1**, **et.2.7**, and **et.3.8**. At the other end of the WAN connection, R2 passes Ethernet flows onto the Metro backbone. Conversely, R2 rate shapes Ethernet flows from the Metro backbone that originate on subnet 124.141.77.0/24 and sends them through its own Clear Channel T3 line to R1 (see Figure 32-2).

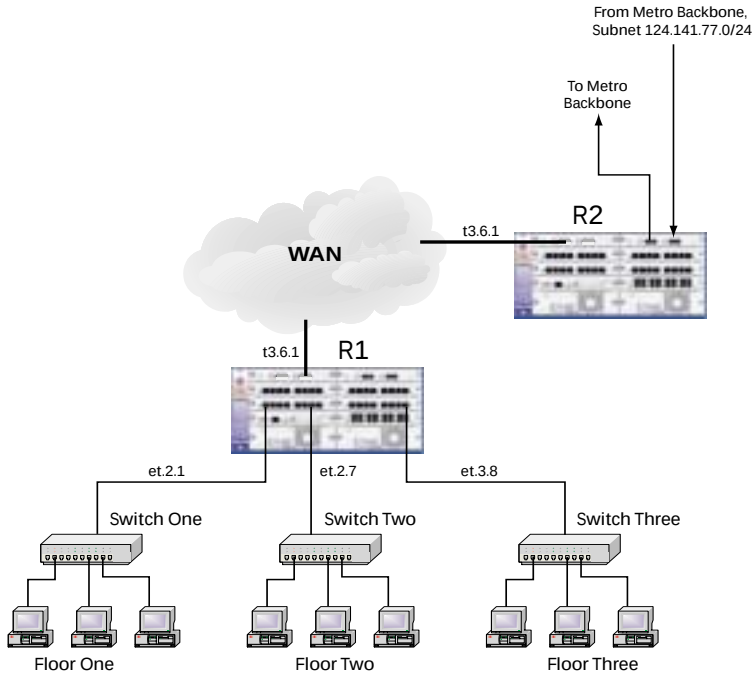


Figure 32-2 Rate shaping on destination IP address

First, the rate shaping template "*dest1"* is created on R1, with the rate shape parameters specified as CIR = 150 Kbps, Bc = 5000 bits, Be is unspecified, and R1 sets Tc automatically to Bc / CIR = 1/30 of a second:

```
rs(config)# wan define rate-shape-parameters dest1 cir 150000 bc 5000
```

Template *dest1* is applied to R1's Clear Channel T3 port for each port connected to an Ethernet switch:

```
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.2.1
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.2.7
rs(config)# wan apply rate-shape-parameters dest1 port t3.6.1 traffic-source-port
et.3.8
```

Next, the rate shaping template "*dest2"* is created on R2, with the rate shape parameters specified as CIR = 170 Kbps, Bc = 7000 bits, Be is unspecified, and R2 sets Tc automatically to Bc / CIR = 1/24 of a second:

```
rs(config)# wan define rate-shape-parameters dest2 cir 170000 bc 7000
```

Template *dest2* is applied to R2's Clear Channel T3 port for traffic originating from subnet 124.141.77.0/24:

```
rs(config)# wan apply rate-shape-parameters dest2 port t3.6.1 source-ip-address
124.141.77.0/24
```

Once the templates are applied, all Ethernet flows on R1 originating from ports et.2.1, et.2.7, and et.3.8 are rate shaped to a maximum of 150 kbps, while Ethernet flows on R2 originating from subnet 124.141.77.0 are rate shaped to a maximum of 170 Kbps in the opposite direction.

32.6.4 Using WAN Rate Shaping

The following section lists a few situations to keep in mind when using WAN rate shaping.

Using Multiple Rate Shaping Templates

The rate shaping algorithm can use only one identifier to determine whether an Ethernet flow should be rate shaped. Furthermore, the identifiers are tested against a flow in the following order:

1. Destination IP address
2. Source IP address
3. VLAN
4. Traffic source port

If more than one rate shaping template is applied to a WAN port, the first template with an identifier that matches an Ethernet flow's internal parameters (as shown in the ordered list above) is applied to the flow. Keep in mind this hierarchy of identifiers when configuring rate shaping to assure that Ethernet flows are rate shaped by the desired template.

For example, two templates are created (*temp1* and *temp2*), each with a different value for CIR and Bc:

```
rs(config)# wan define rate-shape-parameters temp1 cir 150000 bc 5000
rs(config)# wan define rate-shape-parameters temp2 cir 200000 bc 9000
```

Both templates are applied to a single Clear Channel T3 port, one using **traffic-source-port** as its identifier, the other using **vlan** as its identifier:

```
rs(config)# wan apply rate-shape-parameters temp1 port t3.2.1 traffic-source-port
et.1.2
rs(config)# wan apply rate-shape-parameters temp2 port t3.2.1 vlan west-district
```

Notice that **vlan** is higher in the identifier hierarchy than **traffic-source-port**. Because of this, the VLAN name is examined first. As a result, if **et.1.2** belongs to VLAN *west-district,* flows from port **et.1.2** will be shaped according to *temp2*, rather than *temp1*.

Rate Shaping by Best Effort

If CIR and Bc are both set to zero, and Be is set to some value greater than zero, packets from the Ethernet flow controlled by this template will pass through the WAN port only if there is surplus bandwidth equal to or greater than Be. This configuration does not provide any guarantee that the flow's packets will get through the WAN port; and bandwidth for this flow is attained only on a best-effort basis.

Performing Rate Limiting

If the **burst-queue-depth** is set to zero for a particular template, WAN rate shaping for the affected flows effectively becomes *rate limiting.* This switch to rate limiting occurs because without a queue, packets are simply dropped whenever the bit rate of a flow reaches Bc and/or Be.

Non-Rate Shaped Flows

If Ethernet flows that are not controlled by a WAN rate shaping template are mixed with flows that are controlled. The non-rate shaped flows will disregard the rate shaped flows and take as much bandwidth as they can. For this reason, it's generally not a good idea to mix rate shaped and non-rate shaped flows on a WAN port.

Rate Shaping in Both Directions

WAN rate shaping works best when it is applied in both directions. In other words, if you apply rate shaping to an RS WAN port going into the WAN, you also should apply rate shaping to the RS WAN port at the other end of the connection. Applying rate shaping to each RS allows connection-oriented protocols, such as TCP, to communicate more efficiently and experience fewer instances that could potentially trigger crank-back.

32.6.5 Collective Rate Shaping

WAN rate shaping parameters can be applied collectively to several source IP addresses, destination IP addresses, or VLANs.

For example, the following command lines configure 10.1.1.1 and 10.1.1.2 to both use a CIR of 128 Kbps:

```
rs(config)# wan define rate-shape-parameters RS1 cir 128000
rs(config)# wan apply rate-shape-parameters RS1 port se.2.1 source-ip-address
10.1.1.1
rs(config)# wan apply rate-shape-parameters RS1 port se.2.1 source-ip-address
10.1.1.2
```

In the example above, line-1 (10.1.1.1) and line-2 (10.1.1.2) are each rate shaping separate lines, each at a CIR of 128 Kbps.

The rate shaping parameter, **bandwidth-shared**, provides a way to make line-1 and line-2 collectively rate shape a CIR of 128 Kbps.

For example:

```
rs(config)# wan define rate-shape-parameters RS1 cir 128000 bandwidth-shared
rs(config)# wan apply rate-shape-parameters RS1 port se.2.1 source-ip-address
10.1.1.1
rs(config)# wan apply rate-shape-parameters RS1 port se.2.1 source-ip-address
10.1.1.2
```

In the example above, the keyword, **bandwidth-shared**, causes line-1 (10.1.1.1) and line-2 (10.1.1.2) to share a CIR of 128 Kbps, and collectively rate shape the bandwidth across the two lines

32.7 WAN CONFIGURATION EXAMPLES

32.7.1 Simple Configuration File

The following is an example of a simple configuration file used to test frame relay and PPP WAN ports:

```
port set hs.5.1 wan-encapsulation frame-relay speed 45000000
port set hs.5.2 wan-encapsulation ppp speed 45000000
interface create ip fr1 address-netmask 10.1.1.1/16 port hs.5.1.100
interface create ip ppp2 address-netmask 10.2.1.1/16 port hs.5.2
interface create ip lan1 address-netmask 10.20.1.1/16 port et.1.1
interface create ip lan2 address-netmask 10.30.1.1/16 port et.1.2
ip add route 10.10.0.0/16 gateway 10.1.1.2
ip add route 10.40.0.0/16 gateway 10.2.1.2
```

For a broader, more application-oriented WAN configuration example, see *"Multi-Router WAN Configuration"* next.

32.7.2 Multi-Router WAN Configuration

The following is a diagram of a multi-router WAN configuration encompassing three subnets. From the diagram, you can see that R1 is part of both Subnets 1 and 2, R2 is part of both Subnets 2 and 3, and R3 is part of subnets 1 and 3. You can click on the router label (in blue) to jump to the actual text configuration file for that router:

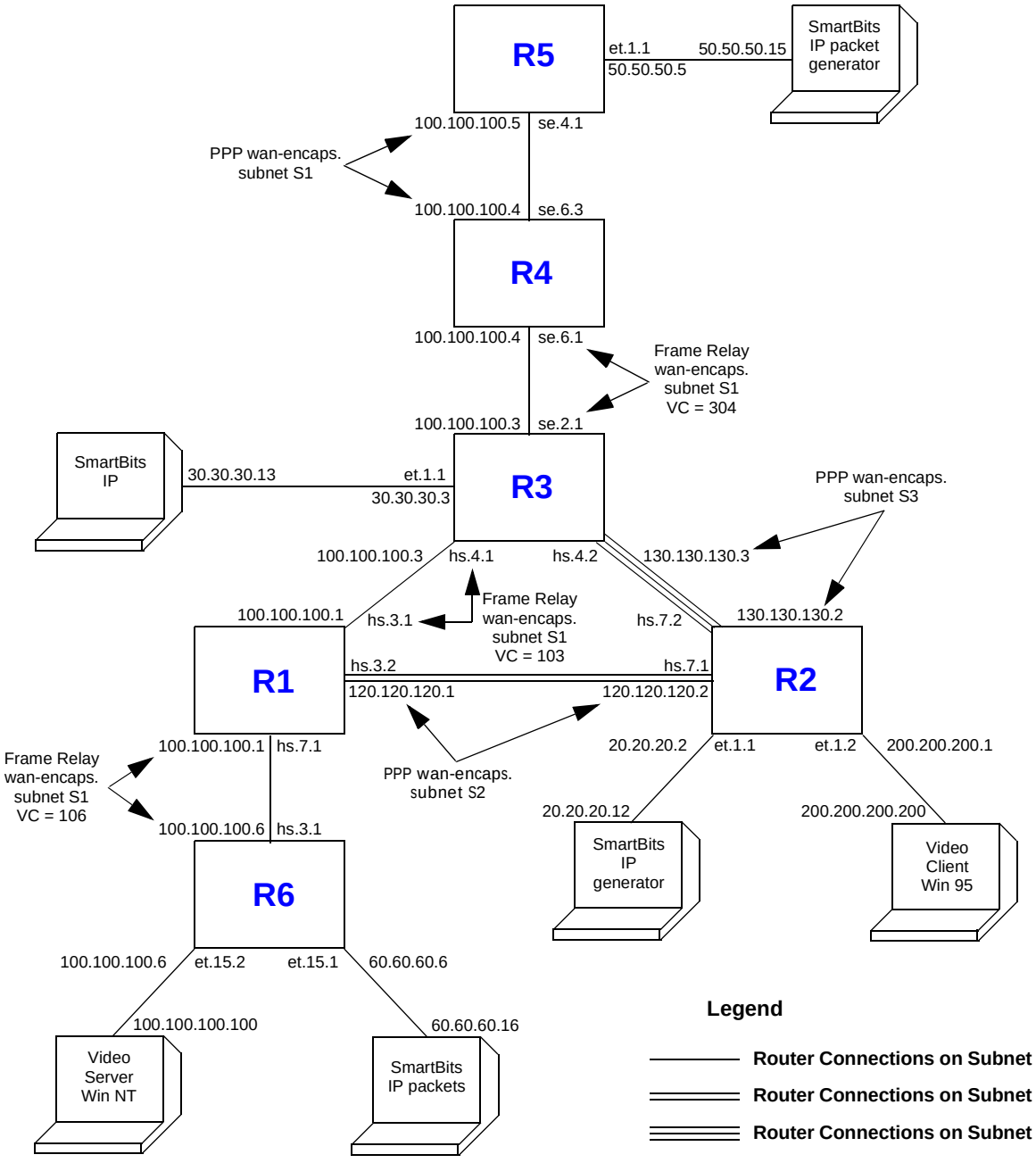


Figure 32-3 Multi-router WAN configuration

Router R1 Configuration File

The following configuration file applies to Router R1.

```
Configuration for ROUTER R1
-----------------------------------------------------------------------
port set hs.7.1 wan-encapsulation frame-relay speed 45000000
port set hs.3.1 wan-encapsulation frame-relay speed 45000000
port set hs.3.2 wan-encapsulation ppp speed 45000000
port set et.1.* duplex full
frame-relay create vc port hs.7.1.106
frame-relay create vc port hs.3.1.103
frame-relay define service CIRforR1toR6 cir 45000000 bc 450000
frame-relay apply service CIRforR1toR6 ports hs.7.1.106
vlan create s1 id 200
vlan create s2 id 300
vlan add ports hs.3.1.103,hs.7.1.106 to s1
vlan add ports hs.3.2 to s2
interface create ip s1 address-netmask 100.100.100.1/16 vlan s1
interface create ip s2 address-netmask 120.120.120.1/16 vlan s2
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set auto-summary enable
rip start
system set name R1
```

Router R2 Configuration File

The following configuration file applies to Router R2.

```
Configuration for ROUTER R2
-----------------------------------------------------------------------
port set hs.7.1 wan-encapsulation ppp speed 45000000
port set hs.7.2 wan-encapsulation ppp speed 45000000
port set et.1.* duplex full
vlan create s2 id 300
interface create ip PPPforR2toR3 address-netmask 130.130.130.2/16 peer-address
130.130.130.3 port hs.7.2
interface create ip SBitsLAN address-netmask 20.20.20.2/16 port et.1.1
vlan add ports hs.7.1 to s2
interface create ip s2 address-netmask 120.120.120.2/16 vlan s2
interface create ip VideoClient address-netmask 200.200.200.1/16 port et.1.2
qos set ip VideoFromNT high 100.100.100.100 200.200.200.200 any any
qos set ip VideoFrom95 high 200.200.200.200 100.100.100.100 any any
rip add interface all
rip set interface all version 2
rip set auto-summary enable
rip start
system set name R2
arp add 20.20.20.12 exit-port et.1.1 mac-addr 000202:020200
```

Router R3 Configuration File

The following configuration applies to Router 3.

```
Configuration for ROUTER R3
-----------------------------------------------------------------------
port set se.2.1 wan-encapsulation frame-relay speed 1500000
port set et.1.* duplex full
port set hs.4.1 wan-encapsulation frame-relay speed 45000000
port set hs.4.2 wan-encapsulation ppp speed 45000000
frame-relay create vc port se.2.1.304
frame-relay create vc port hs.4.1.103
vlan create s1 id 200
interface create ip SBitsLAN address-netmask 30.30.30.3/16 port et.1.1
vlan add ports hs.4.1.103,se.2.1.304 to s1
interface create ip PPPforR2toR3 address-netmask 130.130.130.3/16 peer-address
130.130.130.2 port hs.4.2
interface create ip s1 address-netmask 100.100.100.3/16 vlan s1
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set broadcast-state always
rip set auto-summary enable
rip start
system set name R3
arp add 30.30.30.13 exit-port et.1.1 mac-addr 000303:030300
```

Router R4 Configuration File

The following configuration file applies to Router R4.

```
Configuration for ROUTER R4
-----------------------------------------------------------------------
port set se.6.1 wan-encapsulation frame-relay speed 1500000
port set se.6.3 wan-encapsulation ppp speed 1500000
port set et.1.* duplex full
frame-relay create vc port se.6.1.304
vlan create s1 id 200
vlan add ports se.6.1.304,se.6.3 to s1
interface create ip s1 address-netmask 100.100.100.4/16 vlan s1
rip add interface all
rip set interface all version 2
rip set interface all xmt-actual enable
rip set broadcast-state always
rip set auto-summary enable
rip start
system set name R4
```

Router R5 Configuration File

The following configuration file applies to Router R5.

```
!Configuration for ROUTER R5
port set se.4.1 wan-encapsulation ppp speed 1500000
port set et.1.* duplex full
vlan create s1 id 200
interface create ip lan1 address-netmask 50.50.50.5/16 port et.1.1
vlan add ports se.4.1 to s1
interface create ip s1 address-netmask 100.100.100.5/16 vlan s1
rip add interface all
rip set auto-summary enable
rip set interface all version 2
rip start
system set name R5
arp add 50.50.50.15 mac-addr 000505:050500 exit-port et.1.1
```

Router R6 Configuration File

The following configuration file applies to Router R6.

```
!Configuration for ROUTER R6
port set et.15.* duplex full
port set hs.3.1 wan-encapsulation frame-relay speed 45000000
frame-relay create vc port hs.3.1.106
frame-relay define service CIRforR1toR6 cir 45000000 bc 450000
frame-relay apply service CIRforR1toR6 ports hs.3.1.106
vlan create BridgeforR1toR6 port-based id 106
interface create ip FRforR1toR6 address-netmask 100.100.100.6/16 vlan BridgeforR1toR6
interface create ip lan1 address-netmask 60.60.60.6/16 port et.15.1
vlan add ports hs.3.1.106 to BridgeforR1toR6
vlan add ports et.15.2 to BridgeforR1toR6
qos set ip VideoFromNT high 100.100.100.100 200.200.200.200 any any
qos set ip VideoFrom95 high 200.200.200.200 100.100.100.100 any any
rip add interface all
rip set interface all version 2
rip set auto-summary enable
rip start
system set name R6
arp add 60.60.60.16 mac-addr 000606:060600 exit-port et.15.1
```

32.8 CLEAR CHANNEL T3 AND E3 SERVICES OVERVIEW

Note For a detailed description of the clear channel T3 and E3 line cards discussed in the following section, see the appropriate *Riverstone Networks Getting Started Guide*.

Clear Channel T3 and E3 utilizes the full DS3 bandwidth for data transmission. Clear channel service cannot be divided into separate DS1 channels. Instead, no multiplexing occurs and the bandwidth is used as a single, large channel. The bandwidth of theses *clear-channel* T3 and E3 ports are shown in Table 32-1.

Table 32-1 Clear Channel T3 and E3 Interface Rates

Interface	Capacity (Mbps)
T3	44.736
E3	34.368

32.8.1 Clear Channel T3 and E3 WAN Interface Cards

The RS 8000/8600 supports the multi-rate WAN line card, which accepts WAN Interface Cards (WICs). Each Clear Channel T3 and E3 WIC has one port, and an internal CSU/DSU. The WICs have a BNC connector Transmit/Receive pair. Two T3 or E3 WICs, or a T3 and an E3 WIC, can be installed in a multi-rate WAN line card, giving a total of two ports.

32.9 CHANNELIZED T1, E1, AND T3 SERVICES OVERVIEW

Note For a detailed description of the channelized T1, E1, and T3 line cards discussed in the following sections, see the appropriate *Riverstone Networks Getting Started Guide*.

Channelized T1, E1, and T3 are full duplex TDM services that provide aggregation for low speed traffic, which have different bandwidth requirements – for example voice, data, video, each using one or more 64 kbps (DS0) channels. The number of channels, and the capacity of each interface is listed in Table 32-2.

Table 32-2 Channelized DS1, E1 and DS3 Interfaces

Interface	Number of Channels	Capacity (Mbps)	Line Speed (Mbps)
DS1	24 DS0 channels	1.536	1.544
E1	32 channels	1.920/ 1.984	2.048
DS3	28 DS1 lines	43.008	44.736

32.9.1 Channelized T1 and E1 WAN Interface Cards

The RS 8000/8600 supports the multi-rate WAN line card, which accepts WAN Interface Cards (WICs). Each T1 and E1 WIC has two ports and an internal CSU/DSU. Two T1 or E1 WICs, or a T1 and E1 WIC, can be installed in a Multi-Rate WAN module, giving a total of four ports. Each T1/E1 WIC has three modes of operation, depending on the service requirements:

- Channelized T1 and E1, for services that require multiples of 64 kbps bandwidth. A single channel is used for each service – for example, T1 can have 24 DS0 channels.
- Fractional T1 and E1, for services that require multiples of the 64 kbps channels. For example, T1 services may be high-speed data on a 512 kbps channel, plus 16 low speed data and voice channels at 64 kbps.
- Full (unstructured) T1 and E1, when a service requires the full T1 or E1 bandwidth. For example, point-to-point data transmission.

Warning Hot swapping WICs is not yet supported.

32.9.2 Dedicated Channelized T3 Line Cards

Riverstone offers two channelized T3 line cards, one for the RS 8000/8600, the other, for the RS 38000. The RS 8000/8600 T3 line card provides two channelized T3 ports. The RS 38000 version of the T3 line card four T3 ports. These line cards contain an internal DSU. Each T3 port on the RS 38000 line card has an associated RJ-48c T1 test port. The RS 8000/8600 version has no test ports.

Each channelized T3 port contains a total of 28 DS1 channels available for the serial transmission of data. Each DS1 channel can be configured to use either a portion of the DS1's bandwidth or the entire bandwidth for data transmission. Bandwidth for each DS1 channel can be configured for n x 56 kbps or n x 64 kbps (where n is 1 to 24).

These channelized T3 line cards provide sophisticated bandwidth aggregation functionality using the standards based *multi-link* PPP protocol.

DS1 Test Port Control for the RS 38000 Channelized Line Card

Each Channelized T3 port has an associated T1 test port, which provides access to any of the DS1 channels within a Channelized T3. You can configure the test port in either monitor or break-out mode.

- In *monitor mode*, you may connect an external analyzer to a test port to allow transparent monitoring of data on a given selected DS1 channel.
- In *break-out mode*, you can remove the selected DS1 channel from service, which allows you to connect external test equipment to verify the operation of the DS1 channel. The break-out mode is mainly intended for support of external BERT equipment (see Section 32.9.6, *"Bit Error Rate Testing"*).

32.9.3 Configuring Channelized T1, E1 and T3 Interfaces

This section discusses the basics of the Channelized T1, E1 and T3 interfaces. It provides the following examples for configuring these interfaces and basic interface function:

- Configuring a Channelized T1 interface
- Configuring an Channelized E1 interface
- Configuring a Channelized T3 interface
- Creating a MLP bundle
- Creating a VLAN

Configuring a Channelized T1 Interface

The following commands are an example of configuring a basic Channelized T1 interface.

```
rs(config)# port set t1.2.(1-4) framing esf fdl ansi lbo -7.5db
rs(config)# port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp
```

For the Channelized T1 interface example:

- **`port set t1.2.(1-4):1`** - Configures the following parameters for ports 1 through 4.
- **`framing esf`** - Sets the framing type to Extended Super Frame.
- **`fdl ansi`** - Sets the Facilities Data Link (data channel) to ANSI.
- **`lbo -7.5db`** - Sets the line loss to -7.5 db.
- **`timeslots 1-24`** - Sets the range of time slots to select in a frame from 1 to 24.
- **`wan-encapsulation ppp`** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **`timeslots`**.

Configuring a Channelized E1 Interface

The following commands are an example of configuring a basic Channelized E1 interface.

```
rs(config)# port set e1.2.(1-4) framing crc4 impedance 75ohm
rs(config)# port set e1.2.(1-4):1 timeslots 1-31 ts16 wan-encapsulation ppp
```

For the Channelized E1 interface example:

- **`port set e1.3.(1-4):1`** - Configures the following parameters for ports 1 through 4.
- **`framing crc4`** - Sets the framing type to Cyclic Redundancy Check 4.
- **`impedance 75ohm`** - Sets the impedance of the line to 75 ohm.
- **`timeslots 1-31`** - Sets the range of time slots to select in a frame from 1 to 31.
- **`ts16`** - Sets timeslot 16 to be used for data. If timeslot 16 is used with other timeslots, **`ts16`** must be specified on the same line as the **`timeslots`**.
- **`wan-encapsulation ppp`** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **`timeslots`** and **`ts16`**.

Configuring a Channelized T3 Interfaces

There are four ways to configure a channelized T3 interface:

- Configuring the full DS3 line as a single, large-capacity T3 interface
- Configuring partial DS1 bandwidth within the T3 into channels
- Configuring indices to divide DS0s into separate channels within the DS3 line
- Aggregating full or partial DS1 channels into multi-link PPP bundles

This section describes how to set up a channelized T3 line card for each of these configurations.

Assigning Partial DS1 Bandwidth Within a Channelized T3

Partial bandwidth of any of the T3's DS1s can be assigned to create a partial DS1 channel. The following example demonstrates this capability.

```
rs(config)# port set t3.6.1:4 timeslots 1-10 wan-encapsulation ppp
rs(config)# interface create ip T1-4 port t3.6.1:4 address-netmask 201.10.10.10/16
```

In the example above, the first 10 timeslots of the fourth DS1 are configured for PPP and assigned to interface **`T1-4`**. Notice that when using this type of partial DS1 assignment, the remaining timeslots (**`11-24`**) are filled with null data, and become unusable. In other words, timeslots 11-24 cannot be assigned to an interface and the bandwidth is lost.

Assigning Partial DS1 Bandwidth Using Indices

An alternate way of assigning DS1 bandwidth to channels uses a different convention for specifying T3 ports. Specifically, an index is added that allows all of a DS1's bandwidth to be divided among multiple DS0s. The index format for a T3 port uses the following convention: **`t3`**.<*slot*>.<*port*>.<*index*>:<*channel*>. In this format, the *index* identifies the DS1, and the *channel* identifies one or more DS0s within the DS1.

For example – to specify DS1 bandwidth as "index 1" of the "3rd channel" of "port 2" of the "T3 line card" in "slot five," enter the following: **`t3.5.2.1:3`**. Notice here that the index is specified as 1, but could be any number between 1 and 28.

In the following example, indices are used to assign half of a DS1's bandwidth to one interface and the remaining bandwidth to another interface:

```
rs(config)# port set t3.6.1.1:1 timeslots 1-10 wan-encapsulation ppp
rs(config)# port set t3.6.1.1:2 timeslots 11-24 wan-encapsulation ppp
rs(config)# interface create ip T1-1 port t3.6.1.1:1 address-netmask 100.10.10.10/16
rs(config)# interface create ip T1-2 port t3.6.1.1:2 address-netmask 200.10.10.10/16
```

Notice in the example above that unlike the previous example, all the bandwidth of the DS1 is utilized by assigning DS0$_{1}$ through DS0$_{10}$ to interface **T1-1** and DS0$_{11}$ through DS0$_{24}$ to interface **T1-2**.

In the next example, a channel containing a single DS0 is created and then assigned to an interface.

```
rs(config)# port set t3.6.1.1:1 timeslots 1 wan-encapsulation ppp
rs(config)# interface create ip DS0-1 port t3.6.1.1:1 address-netmask 220.10.10.10/16
```

In the example above, interface DS0-1 contains a channel containing a single DS0 line.

Note that while the use of indices could potentially allow each of the 28 DS1s within a T3 port to be divided into 24 independent DS0s (672 DS0s per T3 port), the RS does not support a sufficient number of interfaces. Each T3 port supports a maximum of 128 interfaces. Furthermore, channelized T3 is not intended to support single DS0 channels. Rather, channelized T3 is designed to transport channels containing many DS0s for related groups of DS1s.

Aggregating DS1 channels into Multi-Link PPP Bundles

The RS provides the ability to aggregate T3 bandwidth using multi-link PPP (MLP), whether the bandwidth is divided up among complete or partial DS1s on the same port or different ports. The only restriction to using MLP is that it cannot span multiple line cards.

The following example creates several DS0 channels on several DS1s on the T3 line card, assigns them to an MLP bundle, and then assigns the bundle to an interface.

```
rs(config)# port set t3.6.1.1:1 timeslots 1-10 wan-encapsulation ppp
rs(config)# port set t3.6.1.1:2 timeslots 11-24 wan-encapsulation ppp
rs(config)# port set t3.6.1.3:1 timeslots 1-5 wan-encapsulation ppp
rs(config)# port set t3.6.1.3:2 timeslots 6-24 wan-encapsulation ppp
rs(config)# port set t3.6.2.1:1 timeslots 1-24 wan-encapsulation ppp

rs(config)# ppp create-mlp mp.1 slot 6
rs(config)# ppp add-to-mlp port t3.6.1.1:1
rs(config)# ppp add-to-mlp port t3.6.1.1:2
rs(config)# ppp add-to-mlp port t3.6.1.3:1
rs(config)# ppp add-to-mlp port t3.6.1.3:2
rs(config)# ppp add-to-mlp port t3.6.2.1:1

rs(config)# interface create ip BUNDDLE-1 port mp.1 address-netmask 201.10.10.10/16
```

Basic Channelized T1, E1 and T3 Interface Functions

The following sections describe how interfaces are assigned to channelized T1, E1, and T3 ports.

MLPs

Multi-link PPP (MLPs) is a set of multiple physical links grouped into a logical pipe called an MLP bundle. Channelized T1 and E1 MLPs can be used for splitting, recombining and sequencing datagrams. Create a MLP with Channelized T1 lines using the following commands.

```
rs(config)# ppp create-mlp mp.1 slot 2
rs(config)# ppp add-to-mlp mp.1 port t1.2.(1-4)
```

For the MLP example:

- **`ppp create-mlp mp.1`** - Creates a multi-link PPP bundle named mp.1.
- **`slot 2`** - Designates the MLP slot number.
- **`ppp add-to-mlp mp.1`** - Adds ports to a previously defined bundle mp.1.
- **`port t1.2.(1-4)`** - Designates the ports to be added to the bundle.

Note MLP bundles cannot be created across multiple line cards.

VLANs

Channelized T1 or E1 VLANs can be created and used for bridging to MSP's. Create a VLAN using the following command.

```
rs(config)# vlan create vlan1 port-based id 100
```

For the VLAN example:

- **`vlan create vlan1 port-based`** - Creates a port-based VLAN.
- **`id 100`** - Names the VLAN.

T1 Lines

T1 lines (channels) can be created within the Channelized T3 interface. Channelized T3 interfaces with T1 lines can be used for multimedia transmission within one Channelized T3 interface. Create T1 lines for a Channelized T3 interface using the following commands.

```
rs(config)# port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
```

For the T1 lines example:

- **port set t3.4.1:(1-28)** - Configures the following parameters for all 28 T1 lines of the Channelized T3 interface on port 1.
- **timeslots 1-24** - Sets the range of time slots, on the T1 lines to select in a frame, from 1 to 24.
- **wan-encapsulation ppp** - Sets the WAN encapsulation type to PPP. This must be specified on the same line as the **timeslots**.

32.9.4 Configuring Frame Relay over Channelized T1, E1 and T3 Interfaces

Configure Frame Relay over a Channelized T1, E1 or T3 interface as follows:

```
port set t1.4.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set e1.5.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set t3.6.1:1 timeslots 1-4 wan-encapsulation frame-relay
frame-relay create vc port t1.4.1:1.103
frame-relay create vc port e1.5.1:1.105
frame-relay create vc port t3.6.1:1.104
frame-relay define service t1service cir 64000 bc 128000
frame-relay apply service t1service ports t1.4.1:1.103
frame-relay define service e1service cir 64000 bc 128000
frame-relay apply service e1service ports e1.5.1:1.104
frame-relay define service t3service cir 1544000 bc 2048000
frame-relay apply service t3service ports t3.6.1:1.105
interface create ip fr1 address-netmask 10.10.30.1/24 port t1.4.1:1 up
interface create ip fr2 address-netmask 10.10.40.1/24 port e1.5.1:1 up
interface create ip fr3 address-netmask 10.10.50.1/24 port t3.6.1:1 up
```

32.9.5 Displaying MAC Addresses Stored on WAN Line Cards

The **wan show mac-table** command displays the contents of the layer-2 MAC addresses table on the WAN line-cards. To use this command, the slot within which the WAN line card resides must be specified.

The following is an example of the **wan show mac-table** command applied to a T3 module residing in slot 4:

```
rs# wan show mac-table slot 4
Id            MAC          VLAN     Source Port       VC
------  -----------------  ----  -----------------  ------
     1  00:02:02:02:02:02      2       t3.4.1.1        102
     2  00:01:01:01:01:01      2       t3.4.1.1        101
```

32.9.6 Bit Error Rate Testing

The Bit Error Rate Testing (BERT) functionality allows you to test a DS1, DS0, or E1 interface or a DS1 line or DS0 channel within a DS3, for cable and signal problems while installed in a field environment. BERT consists of sending a data pattern for a configurable amount of time while monitoring the received data pattern. Since BERT expects to receive the same pattern that is being transmitted, you can either configure the line in a loopback configuration or the remote-end can be set up to send the same pattern; setting up a loopback prior to invoking BERT on a given DS1, DS0, or E1 connection is the most common setup. BERT keeps track of the bit receive count versus the number of receive bit errors over time, and the result is the Bit Error Rate.

The patterns available for BERT are selectable from a standard set of both pseudo-random and repetitive patterns (see the parameters for the **`port bert`** command).

BERT can only be performed on a single physical or logical port. To perform a BERT test on a single port in a multi-link bundle, the port must first be removed from the bundle.

Table 32-3 displays the loopback types available and the interfaces on which they are supported.

Table 32-3 Loopback types supported

Loopback	DS0	T1	E1	Ch T3	CC T3	CC E3	Description
local		X	X	X	X	X	Internally loops data back to itself
network-line		X	X	X	X	X	Loops incoming data back out to the line, without re-framing the data
network-payload	X	X	X				Loops incoming data back out to the line and re-frames the data
niu-remote-line-fdl-ansi		X					Sends an FDL ANSI coded request to a Network Interface Unit (NIU), asking the NIU to go into network-line loopback
niu-remote-line-inband		X					Sends an inband (5 seconds) request to a Network Interface Unit (NIU), asking the NIU to go into network-line loopback
remote-line-fdl-ansi		X					Sends an FDL ANSI coded request to the remote CSU/DSU, asking CSU/DSU to go into network-line loopback
remote-line-fdl-bellcore		X					Sends an FDL Bellcore coded request to the remote CSU/DSU, asking CSU/DSU to go into network-line loopback
remote-payload-fdl-ansi		X					Sends an FDL ANSI coded request to the remote CSU/DSU, asking CSU/DSU to go into network-payload loopback
remote-line-inband		X					Sends an inband (~5 seconds) coded request to the remote CSU/DSU, asking CSU/DSU to go into network-line loopback
remote-line-feac					X		Sends a FEAC (Far-End Access Control) coded request to the remote end, asking the remote end to go into network-line loopback

Note: T3 line must be in C-Bit framing when using the FEAC coded request.

Table 32-3 Loopback types supported (Continued)

Note: T1 lines can be either a T1 port on a WPIM or a T1 line broken out of a T3.

Note: T1 lines must be in ESF framing mode when using any of the FDL coded requests.

Table 32-4 lists the interface types on which BERT is supported:

Table 32-4 Bit error rate tests (BERT) supported

	DS0	T1	E1	Ch T3	CC T3	CC E3	Description
BERT	X	X	X		X	X	Tests line integrity by sending one of various (user selectable) bit patterns and recording whether same pattern is received

Note: To run a BERT successfully (without the aid of external test equipment), the remote side must be in a line loopback mode.

Note: To view results of BERT, use the '**`port show serial-link-info <port> all`**' command.

Example One: Using BERT Testing on a DS1 Interface

This example shows the use of BERT to test a structured DS1 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 speed-56 wan-encapsulation ppp
save active
exit
port loopback t1.2.1 remote-line-fdl-ansi
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t1.2.1 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t1.2.1 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t1.2.1 all
!-------------------------------------------------------------------------
! To stop the test before the one hour interval expires.
!-------------------------------------------------------------------------
port bert t1.2.1 stop
```

Example Two: Using BERT Testing on a DS3 Interface

This example shows the use of BERT to do an internal test of the 15th DS1 line of a DS3 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t3.2.1:15 framing esf
save active
exit
port loopback t3.2.1:15 remote-line-fdl-ansi
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t3.2.1:15 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t3.2.1:15 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t3.2.1:15 all
```

Example Three: Using BERT Testing on a DS0 Channel within a T1 interface

This example shows the use of BERT to an internal test of the first DS0 channel of a DS1 interface for the duration of one hour:

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t1.4.1:1 timeslots 1 wan-encapsulation ppp
save active
exit
port loopback t1.4.1 remote-line-fdl-ansi
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t1.4.1:1 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t1.4.1:1 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t1.4.1:1 all
```

Example Four: Using BERT Testing on a DS0 channel within a DS3 Interface

This example shows the use of BERT to do an internal test of the second DS0 channel within the third DS1 belonging to a channelized T3 interface for one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set t3.10.1.3:2 timeslots 1 wan-encapsulation ppp
save active
exit
port loopback t3.10.1.3:2 network-payload
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert t3.10.1.3:2 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
!To start the test.
!-------------------------------------------------------------------------
port bert t3.10.1.3:2 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info t3.10.1.3:2 all
```

Notice in the example above, a T3 index number (**3**) is used to specify the DS0 number (**2**).

Example Five: Using BERT Testing on a Channelized E1 Interface

This example shows the use of BERT to test a structured E1 interface for a duration of one hour.

```
enable
config
!-------------------------------------------------------------------------
! Configure loopback
!-------------------------------------------------------------------------
port set e1.3.1 framing nocrc4 international-bits 0
port set e1.3.1:1 timeslots 1-31 ts16 wan-encapsulation ppp
save active
exit
port loopback e1.3.1 network-line
!-------------------------------------------------------------------------
! Set the BERT pattern to use
!-------------------------------------------------------------------------
port bert e1.3.1 pattern 2^20-QRSS interval 60
!-------------------------------------------------------------------------
! To start the test.
!-------------------------------------------------------------------------
port bert e1.3.1 start
!-------------------------------------------------------------------------
! During the test, to display progress.
!-------------------------------------------------------------------------
port show serial-link-info e1.3.1 all
!-------------------------------------------------------------------------
! To stop the test before the one hour interval expires.
!-------------------------------------------------------------------------
port bert e1.3.1 stop
```

32.9.7 Configuring a Test using External Test Equipment

If you want to do a test using external test equipment, then enter the **`port testport`** <***port-list***> **`monitor`** command before any **`port set`** commands.

Using the BERT test on the DS3 interface as an example, the command sequence would be:

```
enable
config
port testport t3.2.1:15 monitor
port set t3.2.1:15 framing esf
save active
exit
port loopback t3.2.1:15 remote-line-fdl-ansi
port bert t3.2.1:15 pattern 2^20-QRSS interval 60
port bert t3.2.1:15 start
port show serial-link-info t3.2.1:15 all
```

32.10 SCENARIOS FOR DEPLOYING CHANNELIZED T1, E1 AND T3

This section describes some scenarios for deploying Channelized T1, E1 and T3. There are nine scenarios, which cover the deployment for:

- Bridged MSP MTU/MDU aggregation (see Section 32.10.1)
- Routed inter-office connections through an Internet Service Provider (ISP)
  - With only Channelized T1 on the RS 8000 and RS 8600 (see Section 32.10.2)
  - With Channelized T1 and T3 on the RS 8000 and RS 8600 (see Section 32.10.3)
- Routed Metropolitan Backbone
  - With only Channelized T1 on the RS 8000 and RS 8600 (see Section 32.10.4)
  - With Channelized T1 and T3 on the RS 8000 and RS 8600 (see Section 32.10.5)
- Routed inter-office connections through an Internet Service Provider (ISP) with Channelized E1 (see Section 32.10.6)
- Routed Metropolitan Backbone with Channelized E1 (see Section 32.11.2)
- Transatlantic connection using Channelized T1 and E1 (see Section 32.10.7)
- Frame Relay over Channelized T1 (see Section 32.10.8)

32.10.1 Scenario 1: Bridged MSP MTU/MDU Aggregation

In this scenario, a company has several sites that need to be connected. An MSP provides a Channelized T3 connection on their RS 38000. Each site has several LANs interconnected through an RS 3000, which also provides four T1 lines to the MSP. These T1 lines are grouped into a multi-link PPP bundle, so up to seven sites can be interconnected using a single Channelized T3 line. Note that in this scenario, each MTU/MDU has four T1 lines. In practice, an MSP may start with one T1 and grow as their business grows. There is also a cost consideration in that once the MSP uses a certain number of T1 lines it may become more economical to use T3 lines.

Note that if you require redundancy, backup T3 lines could be provided on other RS 38000s.

Figure 32-4 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the MSP, head office (hqsite), and the remote site, rsite2. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 38000	1 CT3 module with 4 T3 ports.
Each RS 3000	1 Multi-Rate WAN module with 2 T1 WICs.

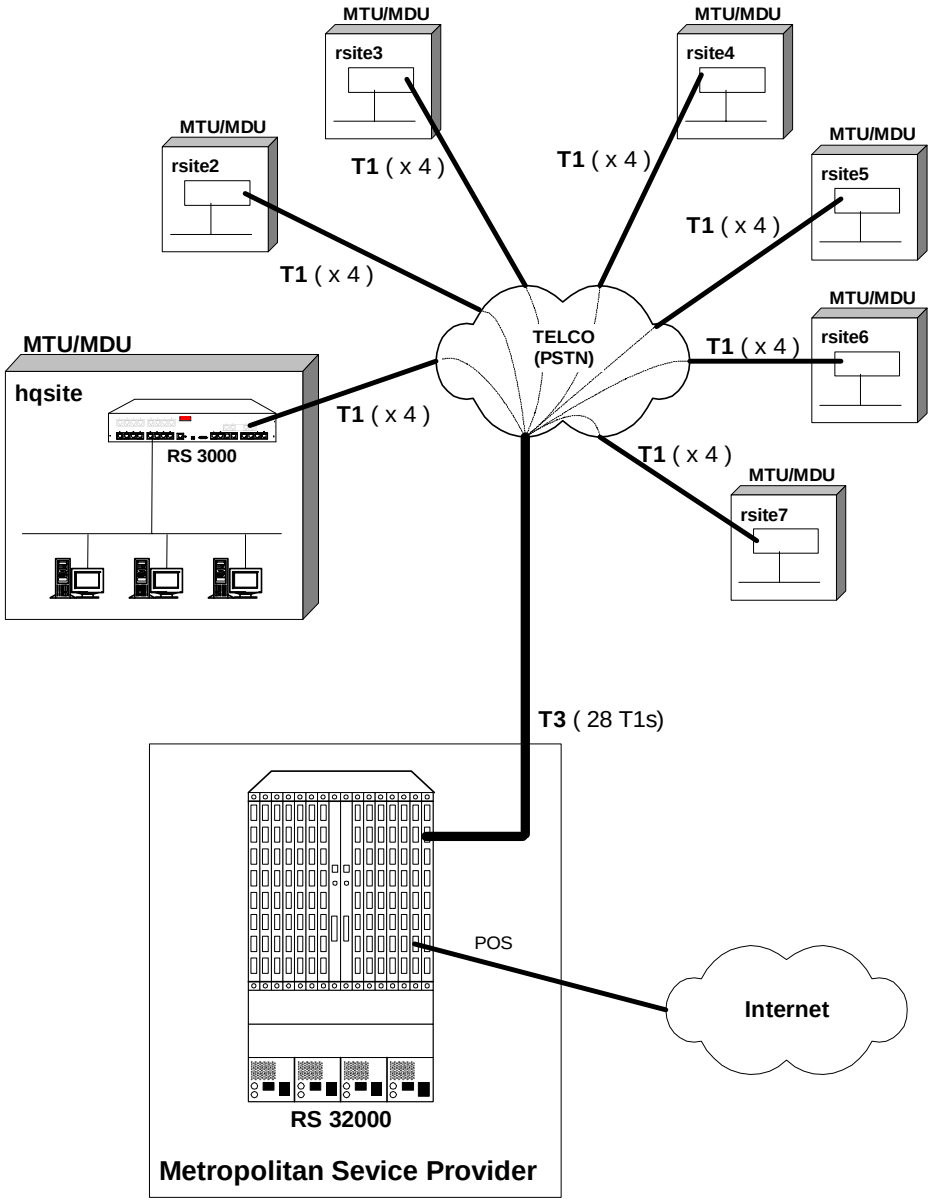


Figure 32-4 Bridged MSP MTU/MDU Aggregation

Metropolitan Service Provider RS 38000 Configuration

The following configuration applies to the RS 38000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)
!-------------------------------------------------------------------------
!Configure VLAN and bridging link to each site:
!-------------------------------------------------------------------------
vlan create vlan1 port-based id 100
vlan add ports mp.1 to vlan1
interface create ip to_vlan1 address-netmask 120.210.1.1/24 vlan vlan1 up
vlan create vlan2 port-based id 200
vlan add ports mp.2 to vlan2
interface create ip to_vlan2 address-netmask 120.210.2.1/24 vlan vlan2 up
vlan create vlan3 port-based id 300
vlan add ports mp.3 to vlan3
interface create ip to_vlan3 address-netmask 120.210.3.1/24 vlan vlan3 up
vlan create vlan4 port-based id 400
vlan add ports mp.4 to vlan4
interface create ip to_vlan4 address-netmask 120.210.4.1/24 vlan vlan4 up
vlan create vlan5 port-based id 500
vlan add ports mp.5 to vlan5
interface create ip to_vlan5 address-netmask 120.210.5.1/24 vlan vlan5 up
vlan create vlan6 port-based id 600
vlan add ports mp.6 to vlan6
interface create ip to_vlan6 address-netmask 120.210.6.1/24 vlan vlan6 up
vlan create vlan7 port-based id 700
vlan add ports mp.7 to vlan7
interface create ip to_vlan7 address-netmask 120.210.7.1/24 vlan vlan7 up
```

hqsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1

!-------------------------------------------------------------------------
!Configure VLAN and bridging for link to MSP:
!-------------------------------------------------------------------------
vlan create vlan1port-based id 100
vlan add ports mp.1 to vlan1
interface create ip vlan_to_msp address-netmask 120.210.1.2/24 vlan vlan1 up
```

rsite2 RS 3000 Configuration

The following configuration applies to router RS 3000 at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the SP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.2 slot 2
ppp add-to-mlp mp.2 port t1.2.(1-4):1
!-------------------------------------------------------------------------
!Configure VLAN and bridging for link to MSP:
!-------------------------------------------------------------------------
vlan create vlan2 port-based id 200
vlan add ports mp.2 to vlan2
interface create ip vlan_to_msp address-netmask 120.210.2.2/24 vlan vlan2 up
```

32.10.2 Scenario 2: Routed Inter-Office Connections with Only T1 on RS 8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. To access the shared data or the Internet, all sites have four T1 lines grouped into a multi-link PPP bundle to connect to the ISP, and so are just one hop away.

The company also has significant inter-office communications. All remote sites frequently communicate with head office, so a T1 line is provided to each remote site. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by a T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 38000, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 32-5 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 38000	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 3000 (rsite4)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 T1 WICs.

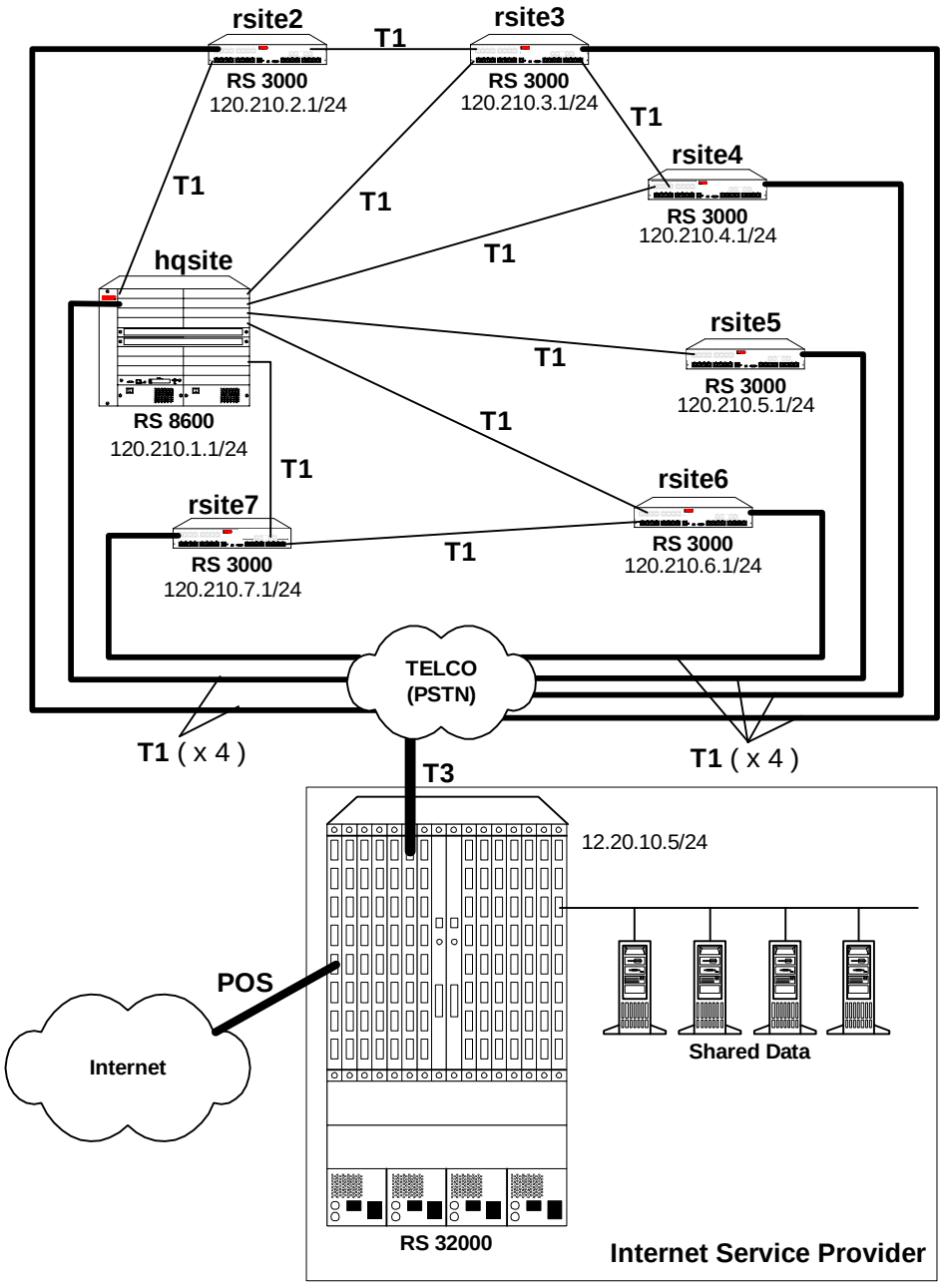


Figure 32-5 Routed Inter-Office Connections with Only T1 on RS 8x00

ISP RS 38000 Configuration

The following configuration applies to the RS 38000 router at the ISP.

```
!-------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_hqsite address-netmask 120.210.1.1/24 port mp.1 up
interface create ip to_rsite2 address-netmask 120.210.2.1/24 port mp.2 up
interface create ip to_rsite3 address-netmask 120.210.3.1/24 port mp.3 up
interface create ip to_rsite4 address-netmask 120.210.4.1/24 port mp.4 up
interface create ip to_rsite5 address-netmask 120.210.5.1/24 port mp.5 up
interface create ip to_rsite6 address-netmask 120.210.6.1/24 port mp.6 up
interface create ip to_rsite7 address-netmask 120.210.7.1/24 port mp.7 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```

hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.1.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the remote sites:
!-------------------------------------------------------------------------
port set t1.3.(1-4) framing esf lbo -7.5db
port set t1.3.(1-4):1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.12.2/24 port t1.3.1 up
interface create ip to_rsite3 address-netmask 120.210.13.3/24 port t1.3.2 up
interface create ip to_rsite4 address-netmask 120.210.14.4/24 port t1.3.3 up
interface create ip to_rsite5 address-netmask 120.210.15.5/24 port t1.3.4 up
port set t1.4.(1-2) framing esf lbo -7.5db
port set t1.4.(1-2):1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite6 address-netmask 120.210.16.6/24 port t1.4.1 up
interface create ip to_rsite7 address-netmask 120.210.17.7/24 port t1.4.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```

rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.12.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```

rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.13.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.4/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```

32.10.3 Scenario 3: Routed Inter-Office Connections with T1 and T3 on RS 8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. All remote sites have four T1 lines grouped into a multi-link PPP bundle to connect to the RS 8600 at the head office. Where significant traffic between two remote sites exists, they are also connected by a T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 38000, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 32-6 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 38000	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	1 CT3 module (with 2 T3 ports). 6 Multi-Rate WAN modules with 12 T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite4)	1 Multi-Rate WAN module with 2 T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 T1 WICs.

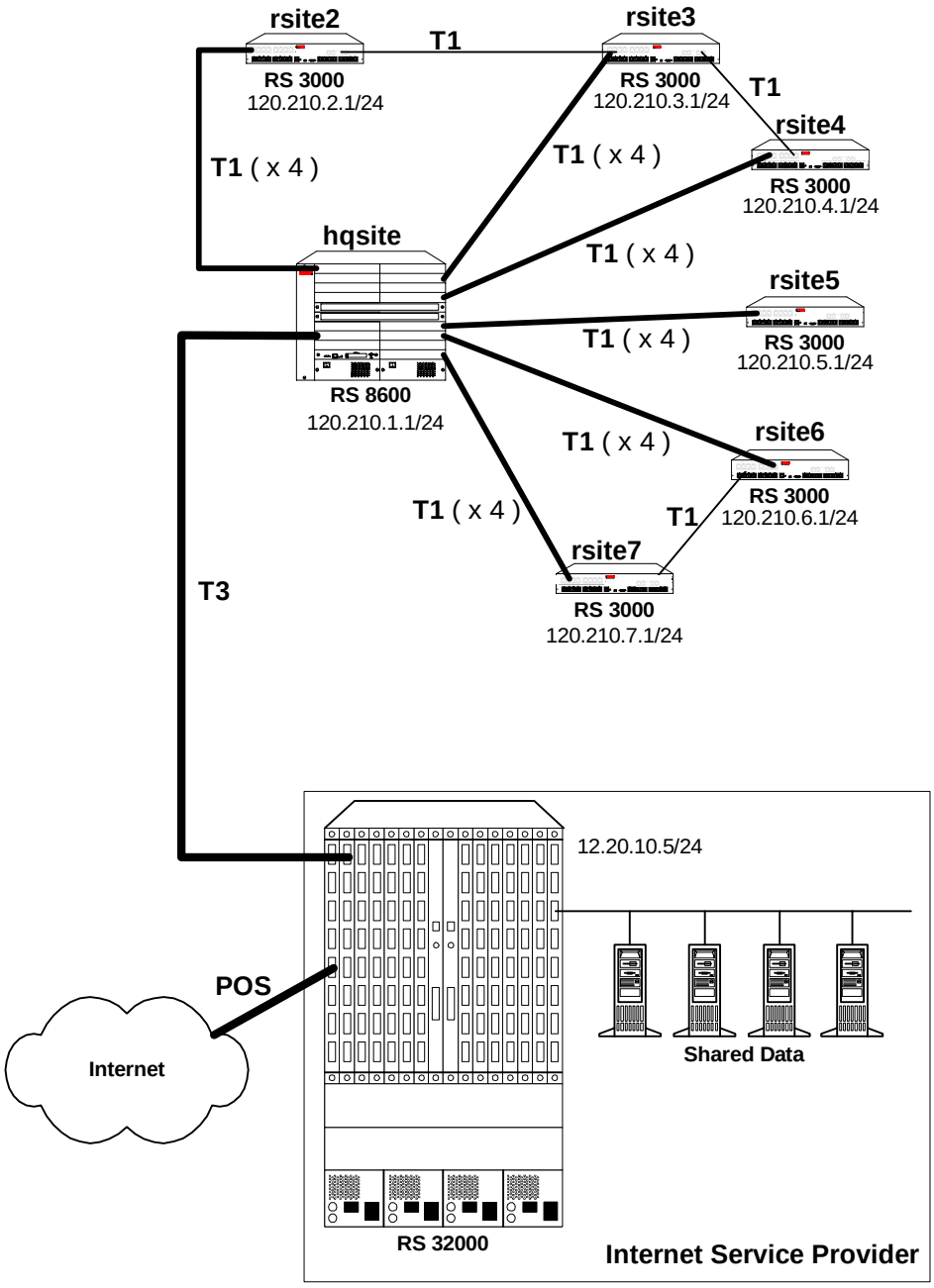


Figure 32-6 Routed Inter-Office Connections with T1 and T3 on RS 8x00

rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```

rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite4:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.3/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```

32.10.4 Scenario 4: Routed Metropolitan Backbone with Only T1 on RS 8x00

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 38000 connected by Packet Over SONET (POS) links.

An MSP provides a Channelized T3 service using an RS 38000. A company has two sites that connect to this service:

- The head office (hqsite) connects using multi-link PPP bundled T1 lines from an RS 8600.
- The remote site, rsite, connects to the MSP using a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the head office.

Internet Service Provider A uses a POS link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using multi-link PPP bundled T1 lines from an RS 8000.

Figure 32-7 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 38000 (MSP)	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 38000 (ISP B)	1 CT3 module (with 4 T3 ports).
RS 8000 (CP)	2 Multi-Rate WAN modules with 4 T1 WICs.
RS 8000 (ASP)	2 Multi-Rate WAN modules with 4 T1 WICs.

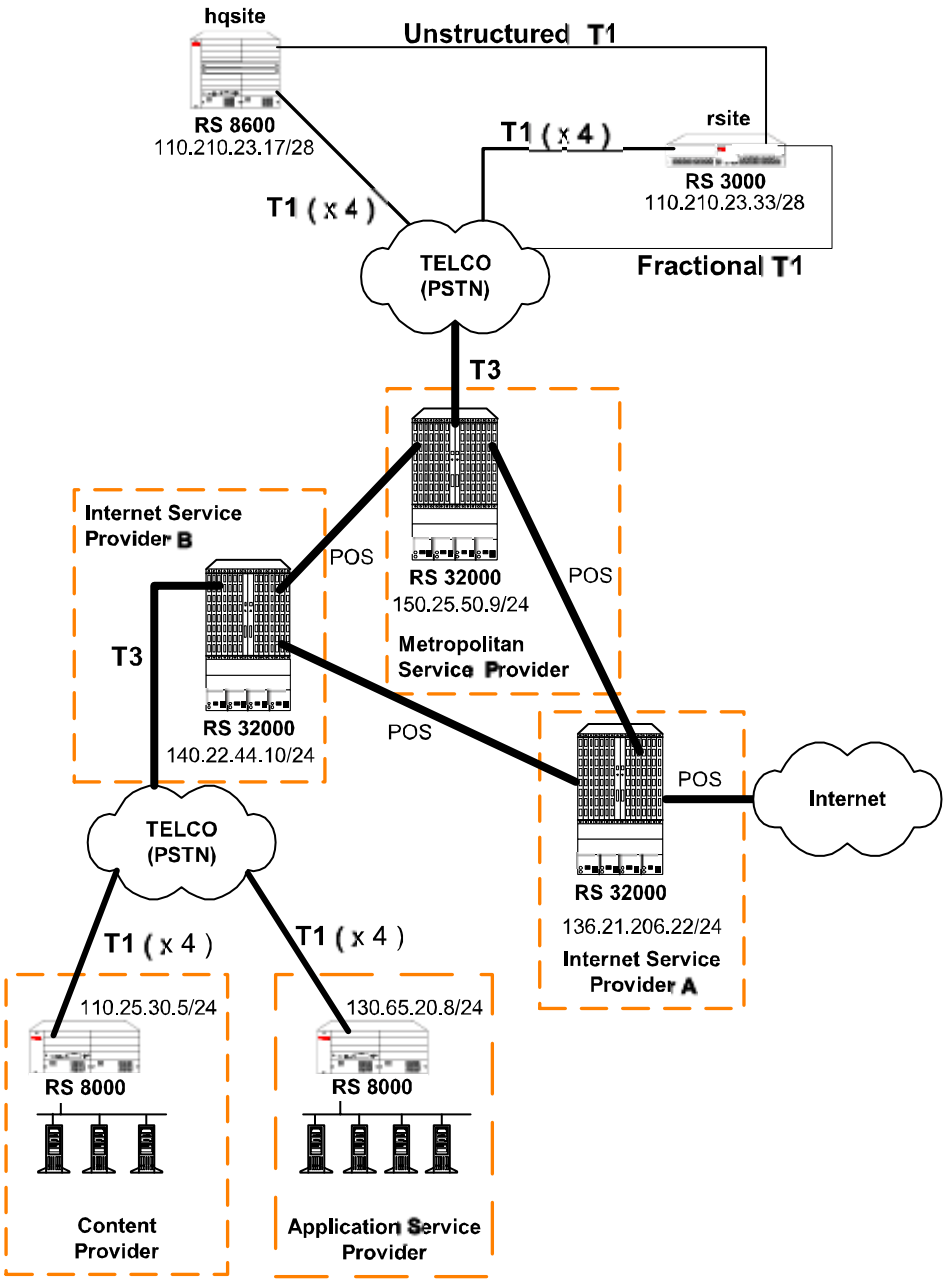


Figure 32-7 Routed Metropolitan Backbone with Only T1 on RS 8x00

Metropolitan Service Provider RS 38000 Configuration

The following configuration applies to the RS 38000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.23.19/28 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.23.49/28 port mp.2up
interface create ip to_rsite_ft1 address-netmask 120.210.23.65/28 port t3.4.1:13
up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip start
```

hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 120.210.23.18/28 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite address-netmask 120.210.23.35/28 port t1.3.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp
rip add interface to_rsite
rip start
```

rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the MSP:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp_mppp address-netmask 120.210.23.50/28 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the MSP:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_msp_ft1 address-netmask 120.210.23.66/28 port t1.3.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.23.34/28 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp_mppp
rip add interface to_msp_ft1
rip add interface to_hqsite
rip start
```

Internet Service Provider B RS 38000 Configuration

The following configuration applies to the RS 38000 router at Internet Service Provider B.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-20) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 4 consecutive T1 lines into multilink PPP bundles
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-8)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(13-20)

interface create ip to_cp address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_asp address-netmask 130.65.20.9/24 port mp.2 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_cp
rip add interface to_asp
rip start
```

Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-----------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-----------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp
ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 110.25.30.5/24 port mp.1 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_msp
rip start
```

Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.2.(1-4) framing esf lbo -7.5db
port set t1.2.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_msp address-netmask 130.65.20.8/24 port mp.1 up

!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_msp
rip start
```

32.10.5 Scenario 5: Routed Metropolitan Backbone with T1 and T3 on RS 8x00

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 38000 connected by Packet Over SONET (POS) links.

An MSP provides a Channelized T3 service using an RS 38000. A company has two sites that connect to this service:

- The head office (hqsite) connects using a T3 line from an RS 8600.
- The remote site, rsite, connects to the RS 8600 at head office using four T1 lines bundled with multi-link PPP, a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the RS 8600.

Internet Service Provider A uses a POS link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using T3 lines from an RS 8000.

Figure 32-8 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and T3 interfaces are described.

Hardware Requirements

Router	Hardware Requirements
RS 38000 (MSP)	1 CT3 module (with 4 T3 ports).
RS 8600 (hqsite)	1 CT3 module (with 2 T3 ports). 2 Multi-Rate WAN modules with 3 T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 T1 WICs.
RS 38000 (ISP B)	1 CT3 module (with 4 T3 ports).
RS 8000 (CP)	1 CT3 module (with 2 T3 ports).
RS 8000 (ASP)	1 CT3 module (with 2 T3 ports).

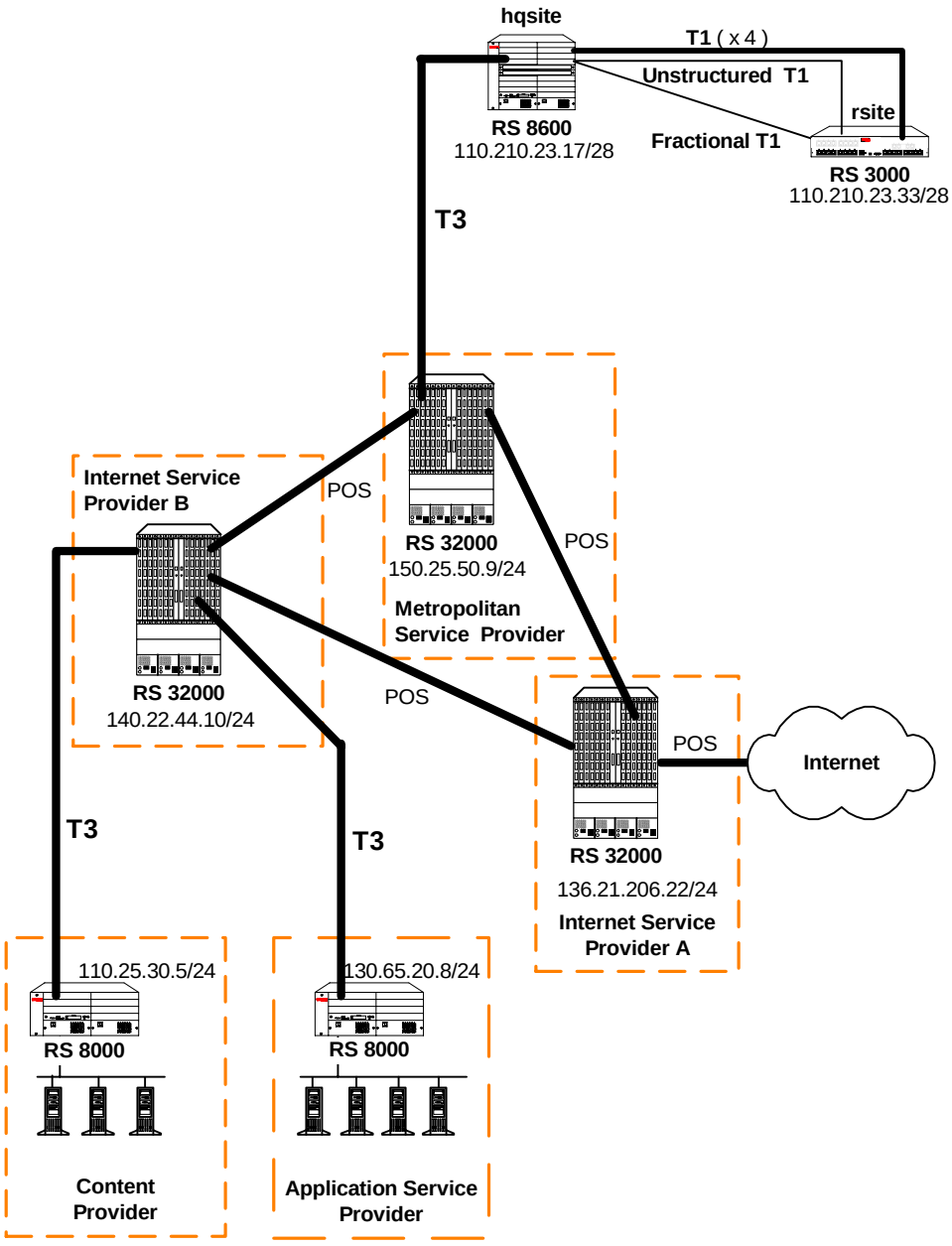


Figure 32-8 Routed Metropolitan Backbone with T1 and T3 on RS 8x00

Metropolitan Service Provider RS 38000 Configuration

The following configuration applies to the RS 38000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite_ft1 address-netmask 120.210.13.1/24 port t3.4.1:13 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip start
```

hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------------
!Configuration for the RS 8600 Channelized T3 interface
!-------------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------------
!Configure a multilink PPP bundle containing 4 consecutive T1 lines
!-------------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)

interface create ip to_msp address-netmask 120.210.11.2/24 port mp.1 up
!-------------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------------
rip add interface to_msp
rip start
```

The following configuration applies to the T1 interfaces on the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the rsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_rsite_mppp address-netmask 120.210.4.1/24 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite_fullt1 address-netmask 120.210.1.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.2:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.2:3 timeslots 19 wan-encapsulation ppp
port set t1.3.2:4 timeslots 20 wan-encapsulation ppp
port set t1.3.2:5 timeslots 21 wan-encapsulation ppp
port set t1.3.2:6 timeslots 22 wan-encapsulation ppp
port set t1.3.2:7 timeslots 23 wan-encapsulation ppp
port set t1.3.2:8 timeslots 24 wan-encapsulation ppp
interface create ip to_rsite_fract1 address-netmask 120.210.24.1/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite_mppp
rip add interface to_rsite_fullt1
rip add interface to_rsite_fract1
rip start
```

rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite_mppp address-netmask 120.210.4.2/24 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_hqsite_fract1 address-netmask 120.210.24.2/24 port t1.3.1
up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite_fullt1 address-netmask 120.210.1.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite_mppp
rip add interface to_hqsite_fract1
rip add interface to_hqsite_fullt1
rip start
```

Internet Service Provider B RS 38000 Configuration

The following configuration applies to the RS 38000 router at Internet Service Provider B.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 38000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip start
```

Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
interface create ip to_ispb1 address-netmask 110.25.30.4/24 port mp.1 up
interface create ip to_ispb2 address-netmask 110.25.31.5/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(13-16)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(17-20)
interface create ip to_ispb1 address-netmask 130.65.20.7/24 port mp.1 up
interface create ip to_ispb2 address-netmask 130.65.21.8/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

32.10.6 Scenario 6: Routed Inter-Office Connections with E1 on RS8x00

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8600, and the remote sites each have an RS 3000. To access the shared data or the Internet, all sites have four E1 lines grouped into a multi-link PPP bundle to connect to the ISP, and so are just one hop away.

The company also has significant inter-office communications. All remote sites frequently communicate with head office, so an E1 line is provided to each remote site. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by an E1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized E3 connection on their proprietary router, a LAN that connects to the servers containing the shared data required by the company, and a connection to the Internet.

Figure 32-9 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface. Only the configurations of the Channelized E1 interfaces are described.

Note The configurations in this example specify timeslots 1-31 for the E1 ports. This excludes the use of timeslot 16. If timeslot 16 is to be used, then **`ts16`** must be included in the relevant commands. For example:

```
port set e1.2.1:1 timeslots 1-31 ts16 wan-encapsulation ppp
```

Hardware Requirements

Router	Hardware Requirements
RS 8600 (hqsite)	2 Multi-Rate WAN modules with 4 E1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 4 E1 WICs.
RS 3000 (rsite4)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 E1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 E1 WICs.

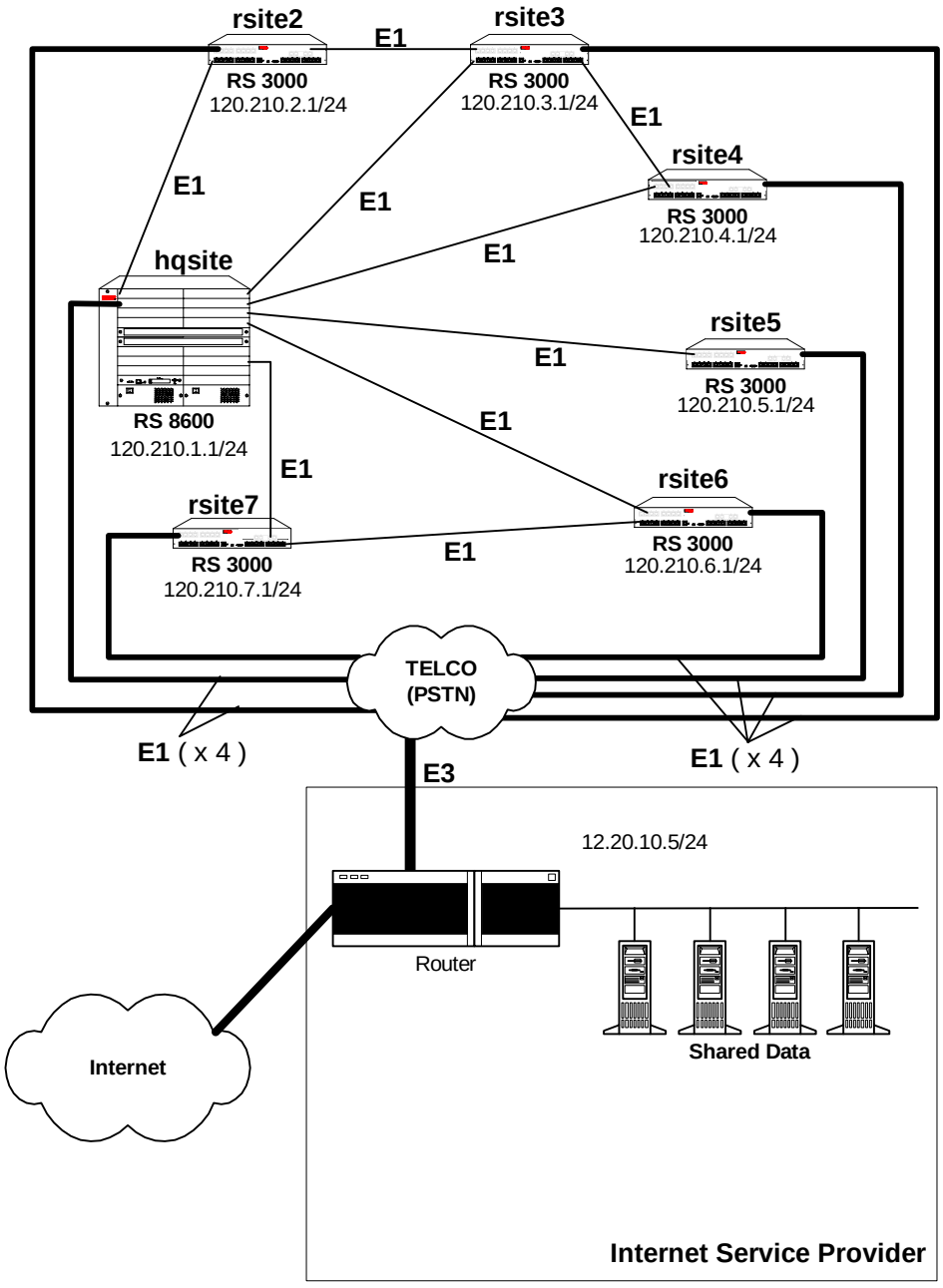


Figure 32-9 Routed Inter-Office Connections with E1 on RS 8x00

hqsite RS 8600 Configuration

The following configuration applies to the RS 8600 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.1.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the remote sites:
!-------------------------------------------------------------------------
port set e1.3.(1-4) framing crc4
port set e1.3.(1-4):1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.12.2/24 port e1.3.1 up
interface create ip to_rsite3 address-netmask 120.210.13.3/24 port e1.3.2 up
interface create ip to_rsite4 address-netmask 120.210.14.4/24 port e1.3.3 up
interface create ip to_rsite5 address-netmask 120.210.15.5/24 port e1.3.4 up
port set e1.4.(1-2) framing crc4
port set e1.4.(1-2):1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite6 address-netmask 120.210.16.6/24 port e1.4.1 up
interface create ip to_rsite7 address-netmask 120.210.17.7/24 port e1.4.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```

rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the hqsite:
!-------------------------------------------------------------------------
port set e1.3.1 framing crc4
port set e1.3.1:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.12.1/24 port e1.3.1 up
!-------------------------------------------------------------------------
!E1 interface to the rsite3:
!-------------------------------------------------------------------------
port set e1.3.2 framing crc4
port set e1.3.2:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.3/24 port e1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_isp
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```

rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 E1 interfaces
!-------------------------------------------------------------------------
!E1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set e1.2.1 framing crc4
port set e1.2.1:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.2 framing crc4
port set e1.2.2:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-31 wan-encapsulation ppp
port set e1.2.4 framing crc4
port set e1.2.4:1 timeslots 1-31 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port e1.2.(1-4):1
interface create ip to_isp address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!E1 interface to the hqsite:
!-------------------------------------------------------------------------
port set e1.3.1 framing crc4
port set e1.3.1:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_hqsite address-netmask 120.210.13.1/24 port e1.3.1 up
!-------------------------------------------------------------------------
!E1 interface to the rsite2:
!-------------------------------------------------------------------------
port set e1.3.2 framing crc4
port set e1.3.2:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.2/24 port e1.3.2 up
!-------------------------------------------------------------------------
!E1 interface to the rsite3:
!-------------------------------------------------------------------------
port set e1.3.3 framing crc4
port set e1.3.3:1 timeslots 1-31 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.4/24 port e1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```

32.10.7 Scenario 7: Transatlantic Connection using T1 and E1 on RS 8x00

In this scenario, a T1 link on an RS 8600 is used to connect a company’s site in the USA with its site in Europe. The European site has an RS 8000, with an E1 interface. The T1 interface is configured to use the SF framing at a speed of 56Kbps because the local loop does not support B8ZS. Also, the E1 interface assumes that the T1 is delivered on timeslots 1 to 24, including timeslot 16.

Figure 32-10 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations. Only the configurations of the Channelized T1 and E1 interfaces on each router are described.

Hardware Requirements

Router	Hardware Requirements
RS 8600 (USA)	1 Multi-Rate WAN module with 1 T1 WIC.
RS 8000 (Europe)	1 Multi-Rate WAN module with 1 E1 WIC.

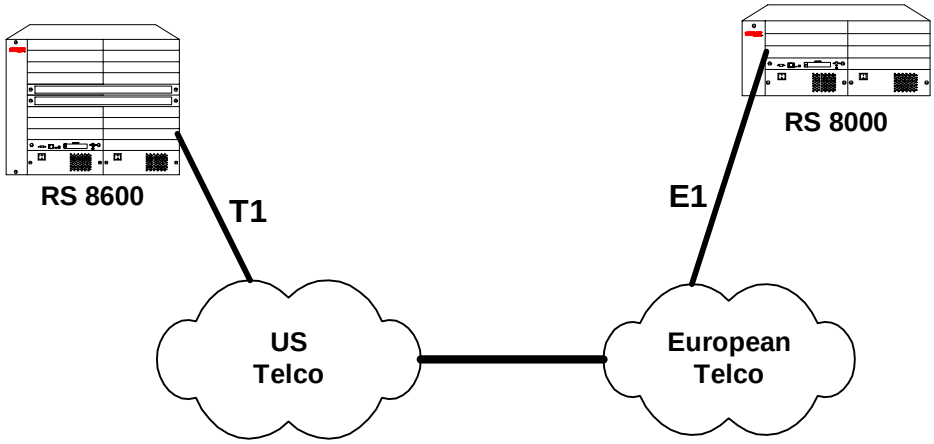


Figure 32-10 Transatlantic Connection Using a T1 and E1 Link

RS 8600 Configuration (USA)

The following configuration applies to the RS 8600 router.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8600 T1 interface
!-------------------------------------------------------------------------
!T1 interface to Europe:
!(speed-56 is used because the local loop does not support B8ZS)
!-------------------------------------------------------------------------
port set t1.2.1 framing sf
port set t1.2.1:1 timeslots 1-24 speed-56 wan-encapsulation ppp

interface create ip to_europe address-netmask 120.210.23.18/24 port t1.2.1 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_europe
rip start
```

RS 8000 Configuration (Europe)

The following configuration applies to the RS 8000 router.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 E1 interface
!-------------------------------------------------------------------------
!E1 interface to the USA:
!(assumes T1 is delivered on timeslots 1-24, including timeslot 16)
!-------------------------------------------------------------------------
port set e1.2.3 framing crc4
port set e1.2.3:1 timeslots 1-24 ts16 speed-56 wan-encapsulation ppp

interface create ip to_europe address-netmask 120.210.24.18/24 port e1.2.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_usa
rip start
```

32.10.8 Scenario 8: Configuring Frame Relay over Channelized T1 Interfaces

In this scenario, a Channelized T1 link on an RS 8600 is used to connect a company's headquarters to six remote sites. The headquarters site has an RS 8600, with a Channelized T1 interface. The Channelized T1 interface is configured to use the ESF framing. Each remote site is assigned a consecutive range of four timeslots as shown in Table 32-5. The Frame Relay CIR and Bc for each remote site is also shown. Remote sites, rsite1 and rsite2, have two VCs on the Channelized T1 interface.

Note The timeslot assignments for each site need not be different; they are different in this example for clarity.

Table 32-5 Timeslot and CIR Assignments

Router	Timeslot assignment	CIR	Bc	VC Number	Subnet
rsite1	1-4	64000 64000	128000 128000	106 107	110.110.110.0 110.110.115.0
rsite2	5-8	64000 64000	128000 128000	106 107	110.110.120.0 110.110.115.0
rsite3	9-12	128000	256000	106	110.110.130.0
rsite4	13-16	128000	256000	106	110.110.140.0
rsite5	17-20	128000	256000	106	110.110.150.0
rsite6	21-24	128000	256000	106	110.110.160.0

Figure 32-11 shows the network layout for this scenario. The tables following the figure show the commands used to configure the Channelized T1 interfaces for the routers at the various locations.

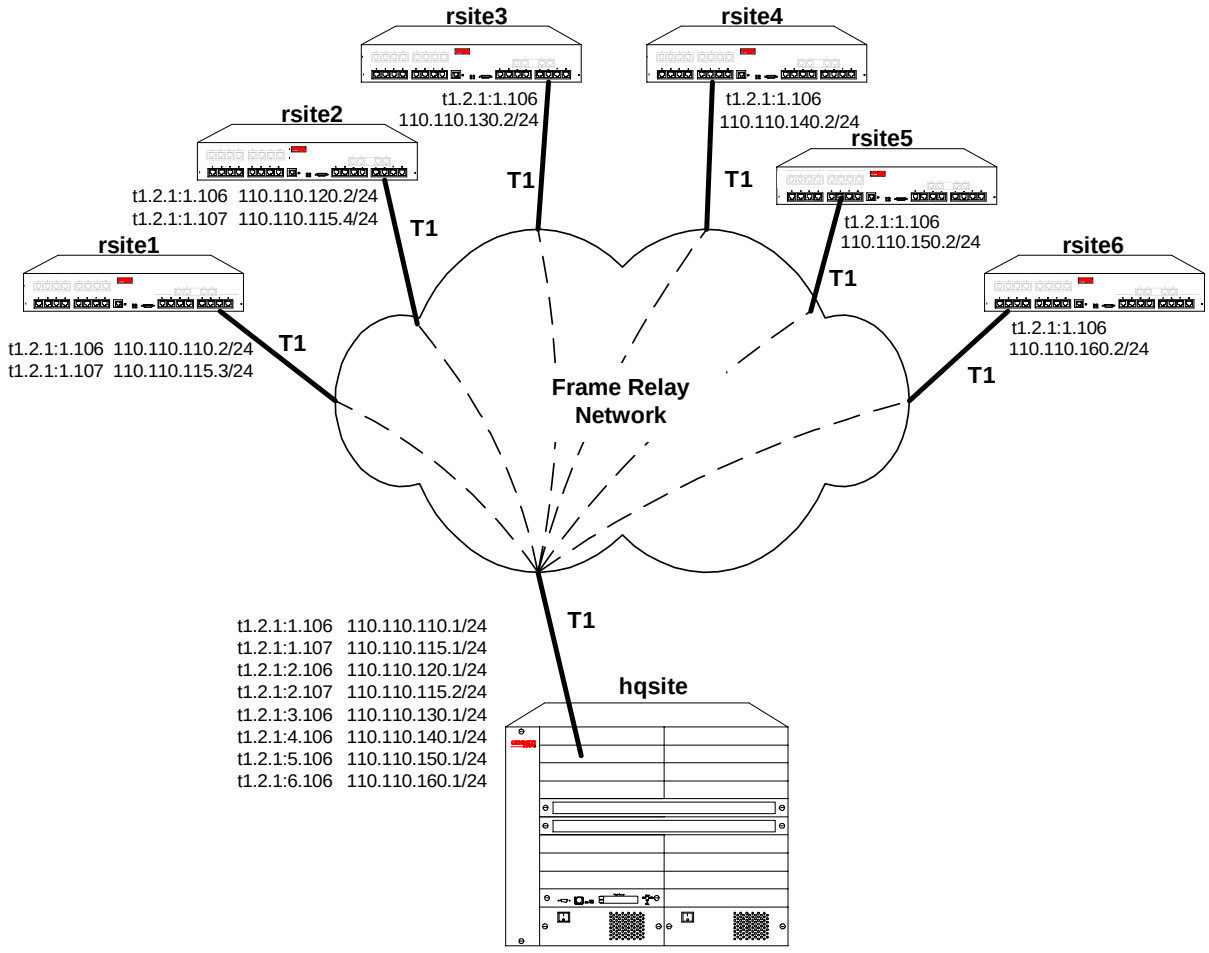


Figure 32-11 Frame Relay over Channelized T1

rsite1 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-4 wan-encapsulation frame-relay
interface create ip rs1_hq_1 address-netmask 110.110.110.2/24 port t1.2.1:1.106 up
interface create ip rs1_hq_2 address-netmask 110.110.115.3/24 port t1.2.1:1.107 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forR1toHQ cir 64000 bc 128000
frame-relay apply service CIR1forR1toHQ ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forR1toHQ cir 64000 bc 128000
frame-relay apply service CIR2forR1toHQ ports t1.2.1:1.107
```

rsite2 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 5-8 wan-encapsulation frame-relay
interface create ip rs2_hq_1 address-netmask 110.110.120.2/24 port t1.2.1:1.106 up
interface create ip rs2_hq_2 address-netmask 110.110.115.4/24 port t1.2.1:1.107 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forR2toHQ cir 64000 bc 128000
frame-relay apply service CIR1forR2toHQ ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forR2toHQ cir 64000 bc 128000
frame-relay apply service CIR2forR2toHQ ports t1.2.1:1.107
```

rsite3 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 9-12 wan-encapsulation frame-relay
interface create ip rs3_hq address-netmask 110.110.130.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR3toHQ cir 128000 bc 256000
frame-relay apply service CIRforR3toHQ ports t1.2.1:1.106
```

rsite4 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 13-16 wan-encapsulation frame-relay
interface create ip rs4_hq address-netmask 110.110.140.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR4toHQ cir 128000 bc 256000
frame-relay apply service CIRforR4toHQ ports t1.2.1:1.106
```

rsite5 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 17-20 wan-encapsulation frame-relay
interface create ip rs5_hq address-netmask 110.110.150.2/24 port t1.2.1:1 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR5toHQ cir 128000 bc 256000
frame-relay apply service CIRforR5toHQ ports t1.2.1:1.106
```

rsite6 RS 3000 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 21-24 wan-encapsulation frame-relay
interface create ip rs6_hq address-netmask 110.110.160.2/24 port t1.2.1:1.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIRforR6toHQ cir 128000 bc 256000
frame-relay apply service CIRforR6toHQ ports t1.2.1:1.106
```

hqsite RS 8600 Configuration

```
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-4 wan-encapsulation frame-relay
port set t1.2.1:2 timeslots 5-8 wan-encapsulation frame-relay
port set t1.2.1:3 timeslots 9-12 wan-encapsulation frame-relay
port set t1.2.1:4 timeslots 13-16 wan-encapsulation frame-relay
port set t1.2.1:5 timeslots 17-20 wan-encapsulation frame-relay
port set t1.2.1:6 timeslots 21-24 wan-encapsulation frame-relay
interface create ip rsite1_1 address-netmask 110.110.110.1/24 port t1.4.1:1.106 up
interface create ip rsite1_2 address-netmask 110.110.115.1/24 port t1.4.1:1.107 up
interface create ip rsite2_1 address-netmask 110.110.120.1/24 port t1.4.1:2.106 up
interface create ip rsite2_2 address-netmask 110.110.115.2/24 port t1.4.1:1.107 up
interface create ip rsite3 address-netmask 110.110.130.1/24 port t1.4.1:3.106 up
interface create ip rsite4 address-netmask 110.110.140.1/24 port t1.4.1:4.106 up
interface create ip rsite5 address-netmask 110.110.150.1/24 port t1.4.1:5.106 up
interface create ip rsite6 address-netmask 110.110.160.1/24 port t1.4.1:6.106 up
frame-relay create vc port t1.2.1:1.106
frame-relay define service CIR1forHQtoR1 cir 64000 bc 128000
frame-relay apply service CIR1forHQtoR1 ports t1.2.1:1.106
frame-relay create vc port t1.2.1:1.107
frame-relay define service CIR2forHQtoR1 cir 64000 bc 128000
frame-relay apply service CIR2forHQtoR1 ports t1.2.1:1.107
frame-relay create vc port t1.2.1:2.106
frame-relay define service CIR1forHQtoR2 cir 64000 bc 128000
frame-relay apply service CIR1forHQtoR2 ports t1.2.1:2.106
frame-relay create vc port t1.2.1:2.107
frame-relay define service CIR2forHQtoR2 cir 64000 bc 128000
frame-relay apply service CIR2forHQtoR2 ports t1.2.1:2.107
frame-relay create vc port t1.2.1:3.106
frame-relay define service CIRforHQtoR3 cir 128000 bc 256000
frame-relay apply service CIRforHQtoR3 ports t1.2.1:3.106
frame-relay create vc port t1.2.1:4.106
frame-relay define service CIRforHQtoR4 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR4 ports t1.2.1:4.106
frame-relay create vc port t1.2.1:5.106
frame-relay define service CIRforHQtoR5 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR5 ports t1.2.1:5.106
frame-relay create vc port t1.2.1:6.106
frame-relay define service CIRforHQtoR6 cir 192000 bc 256000
frame-relay apply service CIRforHQtoR6 ports t1.2.1:6.106
```

32.11 SCENARIOS FOR DEPLOYING CLEAR CHANNEL T3 AND E3

This section describes some scenarios for deploying Clear Channel T3.There are two scenarios, which cover the deployment for:

- Routed inter-office connections through an Internet Service Provider (ISP) (see Section 32.11.1)
- Routed Metropolitan Backbone (see Section 32.11.2)

32.11.1 Scenario 1: Routed Inter-Office Connections through and ISP

In this scenario, a company's sites share data that is held at the Internet Service Provider (ISP). The company's head office contains an RS 8000, and the remote sites each have an RS 3000. All remote sites have four Channelized T1 lines grouped into a multi-link PPP bundle to connect to the RS 8000 at head office. Where there is significant traffic between two remote sites, perhaps because they are in the same geographical region, they are also connected by a Channelized T1 line. All remote sites are a maximum of two hops away from any other remote site, and RIP is used as the routing protocol.

The ISP provides a Channelized T3 connection on their RS 8000, a LAN that connects to the servers containing the shared data required by the company, and a Clear Channel T3 connection to the Internet.

Figure 32-12 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the ISP, head office (hqsite), and the remote sites, rsite2 and rsite3. The interfaces on the routers at the remaining sites are configured in a similar way to the corresponding interfaces for rsite2, using the appropriate IP address for each interface.

Hardware Requirements

Router	Hardware Requirements
RS 8000	1 Channelized T3 module. 1 Multi-Rate WAN module with 1 Clear Channel T3 WIC
RS 8000 (hqsite)	1 Channelized T3 module. 6 Multi-Rate WAN modules with 12 Channelized T1 WICs.
RS 3000 (rsite2)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite3)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite4)	1 Multi-Rate WAN module with 2 Channelized T1 WICs.
RS 3000 (rsite5)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite6)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite7)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.

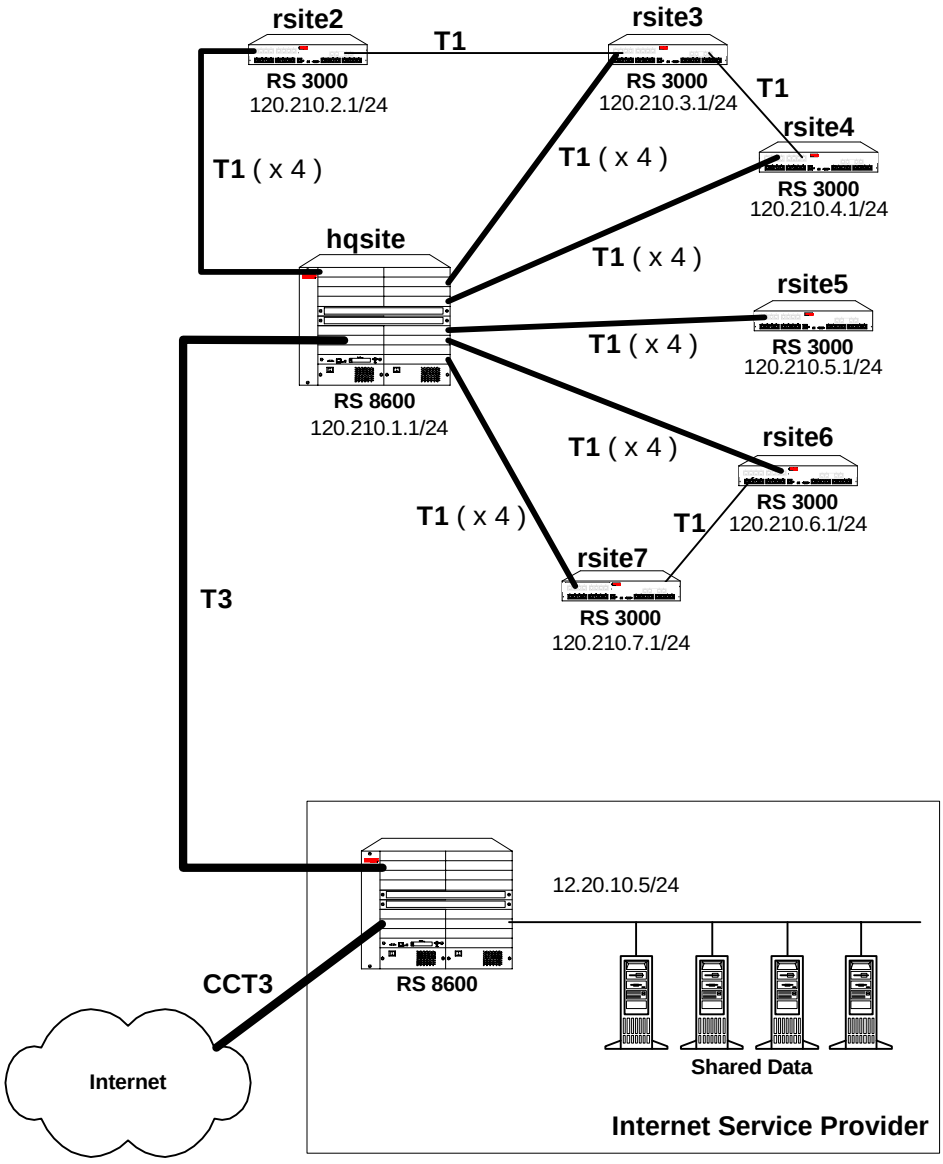


Figure 32-12 Routed Inter-Office Connections through an ISP

KEY:

T3 refers to Channelized T3

CCT3 refers to Clear Channel T3

ISP RS 8000 Configuration

The following configuration applies to the RS 8000 router at the ISP.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interface to the Internet
!-----------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_internet address-netmask 155.32.2.1/24 port t3.2.1 up
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite2 address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite3 address-netmask 120.210.13.1/24 port mp.3 up
interface create ip to_rsite4 address-netmask 120.210.14.1/24 port mp.4 up
interface create ip to_rsite5 address-netmask 120.210.15.1/24 port mp.5 up
interface create ip to_rsite6 address-netmask 120.210.16.1/24 port mp.6 up
interface create ip to_rsite7 address-netmask 120.210.17.1/24 port mp.7 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip add interface to_internet
rip start
```

hqsite RS 8000 Configuration

The following configuration applies to the RS 8000 router at the head office, hqsite.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-----------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-28) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 7 multilink PPP bundles each containing 4 consecutive T1 lines
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(9-12)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(13-16)
ppp create-mlp mp.5 slot 4
ppp add-to-mlp mp.5 port t3.4.1:(17-20)
ppp create-mlp mp.6 slot 4
ppp add-to-mlp mp.6 port t3.4.1:(21-24)
ppp create-mlp mp.7 slot 4
ppp add-to-mlp mp.7 port t3.4.1:(25-28)

interface create ip to_isp1 address-netmask 12.20.11.2/24 port mp.1 up
interface create ip to_isp2 address-netmask 12.20.12.2/24 port mp.2 up
interface create ip to_isp3 address-netmask 12.20.13.2/24 port mp.3 up
interface create ip to_isp4 address-netmask 12.20.14.2/24 port mp.4 up
interface create ip to_isp5 address-netmask 12.20.15.2/24 port mp.5 up
interface create ip to_isp6 address-netmask 12.20.16.2/24 port mp.6 up
interface create ip to_isp7 address-netmask 12.20.17.2/24 port mp.7 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_isp1
rip add interface to_isp2
rip add interface to_isp3
rip add interface to_sip4
rip add interface to_isp5
rip add interface to_isp6
rip add interface to_isp7
rip start
```

The following configuration applies to the T1 interfaces on the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the ISP:
!-------------------------------------------------------------------------
port set t1.5.(1-4) framing esf lbo -7.5db
port set t1.5.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.6.(1-4) framing esf lbo -7.5db
port set t1.6.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.7.(1-4) framing esf lbo -7.5db
port set t1.7.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.8.(1-4) framing esf lbo -7.5db
port set t1.8.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.9.(1-4) framing esf lbo -7.5db
port set t1.9.(1-4):1 timeslots 1-24 wan-encapsulation ppp
port set t1.10.(1-4) framing esf lbo -7.5db
port set t1.10.(1-4):1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.9 slot 5
ppp add-to-mlp mp.9 port t1.5.(1-4):1
interface create ip to_rsite2 address-netmask 120.210.2.1/24 port mp.9 up
ppp create-mlp mp.10 slot 6
ppp add-to-mlp mp.10 port t1.6.(1-4):1
interface create ip to_rsite3 address-netmask 120.210.3.1/24 port mp.10 up
ppp create-mlp mp.11 slot 7
ppp add-to-mlp mp.11 port t1.7.(1-4):1
interface create ip to_rsite4 address-netmask 120.210.4.1/24 port mp.11 up
ppp create-mlp mp.12 slot 8
ppp add-to-mlp mp.12 port t1.8.(1-4):1
interface create ip to_rsite5 address-netmask 120.210.5.1/24 port mp.12 up
ppp create-mlp mp.13 slot 9
ppp add-to-mlp mp.13 port t1.9.(1-4):1
interface create ip to_rsite6 address-netmask 120.210.6.1/24 port mp.13 up
ppp create-mlp mp.14 slot 10
ppp add-to-mlp mp.14 port t1.10.(1-4):1
interface create ip to_rsite7 address-netmask 120.210.7.1/24 port mp.14 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite2
rip add interface to_rsite3
rip add interface to_rsite4
rip add interface to_rsite5
rip add interface to_rsite6
rip add interface to_rsite7
rip start
```

rsite2 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite2.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.2.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite3:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.23.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite3
rip start
```

rsite3 RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite3.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite address-netmask 120.210.3.2/24 port mp.1 up
!-------------------------------------------------------------------------
!T1 interface to the rsite2:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite2 address-netmask 120.210.23.3/24 port t1.3.2 up
!-------------------------------------------------------------------------
!T1 interface to the rsite4:
!-------------------------------------------------------------------------
port set t1.3.3 framing esf lbo -7.5db
port set t1.3.3:1 timeslots 1-24 wan-encapsulation ppp
interface create ip to_rsite3 address-netmask 120.210.34.3/24 port t1.3.3 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite2
rip add interface to_rsite3
rip start
```

32.11.2 Scenario 2: Routed Metropolitan Backbone

In this scenario, a number of service providers are connected by a Metropolitan Backbone. The backbone consists of RS 8000s connected by Clear Channel T3 (CCT3) links.

An MSP provides a Channelized T3 (CT3) service using an RS 8000. A company has two sites that connect to this service:

- The head office (hqsite) connects using a Channelized T3 line from an RS 8000.
- The remote site, rsite, connects to the RS 8000 at head office using four Channelized T1 lines bundled with multi-link PPP, a fractional T1 line, which provides one 768 Kbps service, one 384 Kbps service, and six 64 Kbps services. Also, a full (unstructured) T1 link is connected directly to the RS 8000.

Internet Service Provider A uses a Clear Channel T3 link to the Internet. Internet Service Provider B provides a Channelized T3 service to an Application Service Provider and a Content Provider, both of which connect using Channelized T3 lines from an RS 8000.

Figure 32-13 shows the network layout for this scenario. The tables following the figure show the commands used to configure the interfaces for the routers at the various locations.

Hardware Requirements

Router	Hardware Requirements
RS 8000 (MSP)	1 Channelized T3 module (2 ports). 1 Multi-Rate WAN module with 2 Clear Channel T3 WICs
RS 8000 (hqsite)	1 Channelized T3 module (with 2 T3 ports). 2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 3000 (rsite)	2 Multi-Rate WAN modules with 3 Channelized T1 WICs.
RS 8000 (ISP A)	2 Multi-Rate WAN modules with 3 Clear Channel T3 WICs
RS 8000 (ISP B)	1 ChannelizedT3 module (2 ports). 1 Multi-Rate WAN module with 2 Clear Channel T3 WICs
RS 8000 (CP)	1 ChannelizedT3 module (with 2 T3 ports).
RS 8000 (ASP)	1 ChannelizedT3 module (with 2 T3 ports).

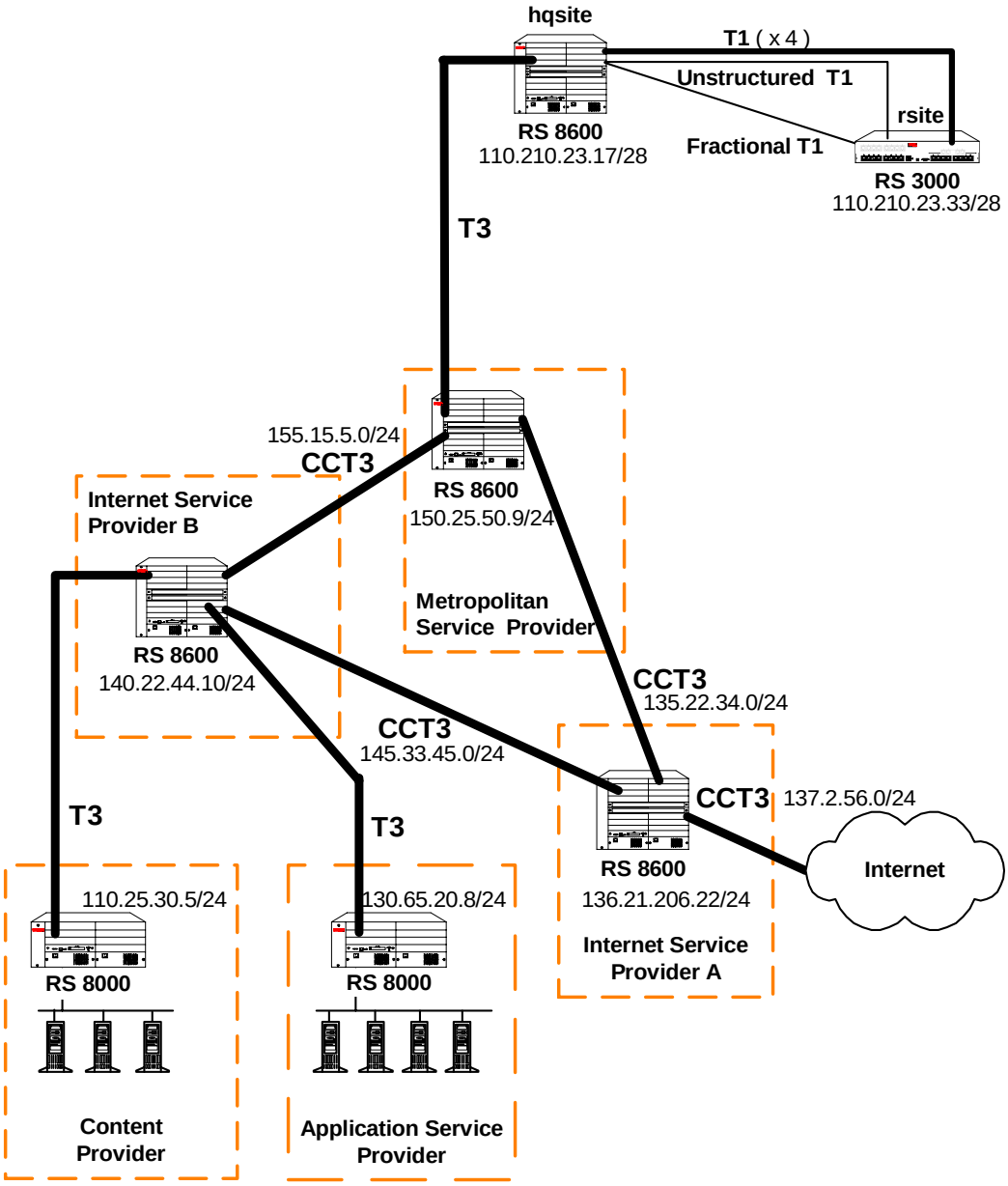


Figure 32-13 Routed Metropolitan Backbone

KEY:

T3 refers to Channelized T3

CCT3 refers to Clear Channel T3

Metropolitan Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Metropolitan Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_ispa address-netmask 135.22.34.2/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_ispb address-netmask 155.15.5.2/24 port t3.2.2 up
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(9-12) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:13 timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(9-12)

interface create ip to_hqsite address-netmask 120.210.11.1/24 port mp.1 up
interface create ip to_rsite_mppp address-netmask 120.210.12.1/24 port mp.2 up
interface create ip to_rsite_ft1 address-netmask 120.210.13.1/24 port t3.4.1:13 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite
rip add interface to_rsite_mppp
rip add interface to_rsite_ft1
rip add interface to_ispa
rip add interface to_ispb
rip start
```

hqsite RS 8000 Configuration

The following configuration applies to the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------------
!Configuration for the RS 8000 Channelized T3 interface
!-------------------------------------------------------------------------------
port set t3.4.1 cablelength 200
!-------------------------------------------------------------------------------
!Configure the T1 lines on the Channelized T3 interface
!-------------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------------
!Configure a multilink PPP bundle containing 4 consecutive T1 lines
!-------------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)

interface create ip to_msp address-netmask 120.210.11.2/24 port mp.1 up
!-------------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------------
rip add interface to_msp
rip start
```

The following configuration applies to the T1 interfaces on the RS 8000 router at the head office, hqsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
!Bundled T1 interfaces to the rsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_rsite_mppp address-netmask 120.210.4.1/24 port mp.1 up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing none wan-encapsulation ppp
interface create ip to_rsite_fullt1 address-netmask 120.210.1.1/24 port t1.3.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the rsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing esf lbo -7.5db
port set t1.3.2:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.2:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.2:3 timeslots 19 wan-encapsulation ppp
port set t1.3.2:4 timeslots 20 wan-encapsulation ppp
port set t1.3.2:5 timeslots 21 wan-encapsulation ppp
port set t1.3.2:6 timeslots 22 wan-encapsulation ppp
port set t1.3.2:7 timeslots 23 wan-encapsulation ppp
port set t1.3.2:8 timeslots 24 wan-encapsulation ppp
interface create ip to_rsite_fract1 address-netmask 120.210.24.1/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_rsite_mppp
rip add interface to_rsite_fullt1
rip add interface to_rsite_fract1
rip start
```

rsite RS 3000 Configuration

The following configuration applies to the RS 3000 router at the remote site, rsite.

```
!-------------------------------------------------------------------------
!Configuration for the RS 3000 T1 interfaces
!-------------------------------------------------------------------------
!T1 interfaces to the hqsite:
!-------------------------------------------------------------------------
port set t1.2.1 framing esf lbo -7.5db
port set t1.2.1:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.2 framing esf lbo -7.5db
port set t1.2.2:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.3 framing esf lbo -7.5db
port set t1.2.3:1 timeslots 1-24 wan-encapsulation ppp
port set t1.2.4 framing esf lbo -7.5db
port set t1.2.4:1 timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 2
ppp add-to-mlp mp.1 port t1.2.(1-4):1
interface create ip to_hqsite_mppp address-netmask 120.210.4.2/24 port mp.1 up
!-------------------------------------------------------------------------
!Fractional T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.1 framing esf lbo -7.5db
port set t1.3.1:1 timeslots 1-12 wan-encapsulation ppp
port set t1.3.1:2 timeslots 13-18 wan-encapsulation ppp
port set t1.3.1:3 timeslots 19 wan-encapsulation ppp
port set t1.3.1:4 timeslots 20 wan-encapsulation ppp
port set t1.3.1:5 timeslots 21 wan-encapsulation ppp
port set t1.3.1:6 timeslots 22 wan-encapsulation ppp
port set t1.3.1:7 timeslots 23 wan-encapsulation ppp
port set t1.3.1:8 timeslots 24 wan-encapsulation ppp
interface create ip to_hqsite_fract1 address-netmask 120.210.24.2/24 port t1.3.1
up
!-------------------------------------------------------------------------
!Full (unstructured) T1 interface to the hqsite:
!-------------------------------------------------------------------------
port set t1.3.2 framing none wan-encapsulation ppp
interface create ip to_hqsite_fullt1 address-netmask 120.210.1.2/24 port t1.3.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_hqsite_mppp
rip add interface to_hqsite_fract1
rip add interface to_hqsite_fullt1
rip start
```

Internet Service Provider A RS 8000 Configuration

The following configuration applies to the RS 8000 router at Internet Service Provider A.

```
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-----------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_internet address-netmask 137.2.56.1/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_msp address-netmask 135.22.34.1/24 port t3.2.2 up
port set t3.3.1 cablelength 200 wan-encapsulation ppp
interface create ip to_ispb address-netmask 145.33.45.1/24 port t3.3.1 up
!-----------------------------------------------------------------------------
!Configuration for the RS 8000 channelized T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-----------------------------------------------------------------------------
!Configure the T1 lines on the T3 interface
!-----------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-----------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-----------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-----------------------------------------------------------------------------
!Configure RIP:
!-----------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip add interface to_msp
rip add interface to_ispb
rip add interface to_internet
rip start
```

Internet Service Provider B RS 8000 Configuration

The following configuration applies to the RS 8000 router at Internet Service Provider B.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 Clear Channel T3 interfaces
!-------------------------------------------------------------------------
port set t3.2.1 cablelength 200 wan-encapsulation ppp
interface create ip to_msp address-netmask 155.15.5.1/24 port t3.2.1 up
port set t3.2.2 cablelength 200 wan-encapsulation ppp
interface create ip to_ispa address-netmask 145.33.45.2/24 port t3.2.2 up
!-------------------------------------------------------------------------
!Configuration for the RS 8000 channelized T3 interface
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!Configure the T1 lines on the T3 interface
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp
!-------------------------------------------------------------------------
!Configure 2 multilink PPP bundles each containing 4 consecutive
!T1 lines
!-------------------------------------------------------------------------
ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
ppp create-mlp mp.3 slot 4
ppp add-to-mlp mp.3 port t3.4.1:(13-16)
ppp create-mlp mp.4 slot 4
ppp add-to-mlp mp.4 port t3.4.1:(17-20)

interface create ip to_cp1 address-netmask 110.25.30.6/24 port mp.1 up
interface create ip to_cp2 address-netmask 110.25.31.7/24 port mp.2 up
interface create ip to_asp1 address-netmask 130.65.20.9/24 port mp.3 up
interface create ip to_asp2 address-netmask 130.65.21.10/24 port mp.4 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_cp1
rip add interface to_cp2
rip add interface to_asp1
rip add interface to_asp2
rip add interface to_msp
rip add interface to_ispa
rip start
```

Content Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Content Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(1-4) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(5-8) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(1-4)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(5-8)
interface create ip to_ispb1 address-netmask 110.25.30.4/24 port mp.1 up
interface create ip to_ispb2 address-netmask 110.25.31.5/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

Application Service Provider RS 8000 Configuration

The following configuration applies to the RS 8000 router at the Application Service Provider.

```
!-------------------------------------------------------------------------
!Configuration for the RS 8000 T1 interfaces
!-------------------------------------------------------------------------
port set t3.4.1 cablelength 250
!-------------------------------------------------------------------------
!T3 interface to the ISP B:
!-------------------------------------------------------------------------
port set t3.4.1:(13-16) timeslots 1-24 wan-encapsulation ppp
port set t3.4.1:(17-20) timeslots 1-24 wan-encapsulation ppp

ppp create-mlp mp.1 slot 4
ppp add-to-mlp mp.1 port t3.4.1:(13-16)
ppp create-mlp mp.2 slot 4
ppp add-to-mlp mp.2 port t3.4.1:(17-20)
interface create ip to_ispb1 address-netmask 130.65.20.7/24 port mp.1 up
interface create ip to_ispb2 address-netmask 130.65.21.8/24 port mp.2 up
!-------------------------------------------------------------------------
!Configure RIP:
!-------------------------------------------------------------------------
rip add interface to_ispb1
rip add interface to_ispb2
rip start
```

33 SERVICE CONFIGURATION

This chapter describes how to use the **`service`** commands to configure rate limiting and shaping. The Service facility provides rate limiting capabilities on ports and interfaces that support layer-2, layer-3, and layer-4 traffic. In addition, the Service facility also provides the ability to rate shape traffic. The procedure for configuring rate limiting and rate shaping services involves first creating the service, then applying it to a port or interface.

Note For additional information about QoS capabilities on the RS, see Chapter 28, *"QoS Configuration."*

Note Service commands automatically enter rows in the rsTBMeterTable, rsTBMeterApplyTable, and rsPortRLTable SNMP tables. Conversely, when Service table entries are configured from an SNMP management station, the equivalent Service commands are added to the RS configuration file.

33.0.1 Rate Limiting and Rate Shaping

Rate limiting differs from rate shaping in that rate limiting allows for the setting of a packet rate limit that when reached causes an exceed action to occur (either packet drop or reduced priority). On the other hand, rate shaping uses buffers and relies on both a packet rate and a burst size. The burst size allows inbound flows on a port or interface to exceed (burst) the predefined rate as long as the flow does not interfere with the committed access rate of other flows.

33.0.2 Rate Limiting and Rate Shaping Capabilities

The Service facility provides the following rate limiting and rate shaping capabilities:

- Supports rate limiting at layer-2, layers-3, and layer-4
- Supports burst-safe rate limiting
- Supports aggregate rate shaping on ingress ports
- Supports the application of rate limiting and shaping based on a wide number of criteria:
  - ACLs
  - filters and filter groups
  - Layer-2 Classifiers (L2 Classifiers) for layer-2 traffic

- Multi-Field Classifiers (MF Classifiers) for layer-3 traffic

33.1 RATE LIMITING SERVICES

With the exception of Burst-safe (see below), rate limiting is characterized by the setting of a committed traffic rate that when reached, an exceed action is performed. Typically, the exceed action drops packets.

The RS supports the following rate limit services:

- **Per-flow Rate Limiting** – Limits individual flows to a specified rate. This is the default rate limiting mode on the RS.
- **Aggregate Rate Limiting** – Limits an aggregation of flows to a specified rate. This type of rate limiting is performed completely in hardware and must be enabled on a per-line card basis. If you enable aggregate rate limiting on a line card, you cannot use per-flow or flow-aggregate rate limiting with that card. Aggregate rate limiting is only supported on certain line cards. Make sure the line card supports hardware rate limiting.
- **Port-level Rate Limiting** – Limits traffic coming into a particular port. This type of policy can be used to limit any type of traffic and is enabled on a per line card basis. If you enable port-level rate limiting on a line card, you cannot use per-flow or flow-aggregate rate limiting with that card.
- **Burst-safe Rate Limiting** – Limits any aggregate of flows on two levels: the committed access rate (CAR) and the burst-safe rate. Burst-safe rate limiting is supported only on line cards that support aggregate rate limiting.
- **Layer-2 Rate Limiting** – Limits layer-2 traffic coming into a particular port or VLAN. This type of rate limiting is performed completely in hardware and must be enabled on a per-line card basis. Furthermore, this type of rate limiting is supported only on line cards that contain 5th generation ASICs.

33.2 APPLYING RATE LIMITING SERVICES

After creating the rate limit service, it is applied it to one or more interfaces or ports. When you use the **`service`** command to apply a rate limiting services, the traffic to be rate limited is identified through the use of filters, ACLs, and by MF and L2 classifiers. For example, a rate limiting service is created, which specifies a rate and an exceed action. When applying the service to a port, there must be some way of identifying the *specific* traffic to be rate limited. Through the use of filters, ACLs, and Classifiers, the exact traffic to be rate limited is defined. For instance, traffic can be identified by its IP address, source and destination; MAC address, source and destination, ToS byte, 802.1P priority bits, and so on. The set of identifying parameters that define the exact traffic to be affected is often referred to as the *traffic profile*.

Note By default, all traffic uses the lowest priority. Because of this, the **`lower-priority`** option of the rate limit command does not lower the traffic priority unless the traffic was previously assigned a higher priority using the **`qos set ip`** policy command.

33.2.1 Applying Aggregate and Port-Level Rate Limiting

The following example shows how you can configure an aggregate rate limiting service and a port-level rate limiting service on the RS. The aggregate rate limiting service restricts traffic from 4 customers (S1, S2, S3, and S4) to 10 Mbps. The port-level rate limiting service restricts traffic from the Internet to 64 Mbps.

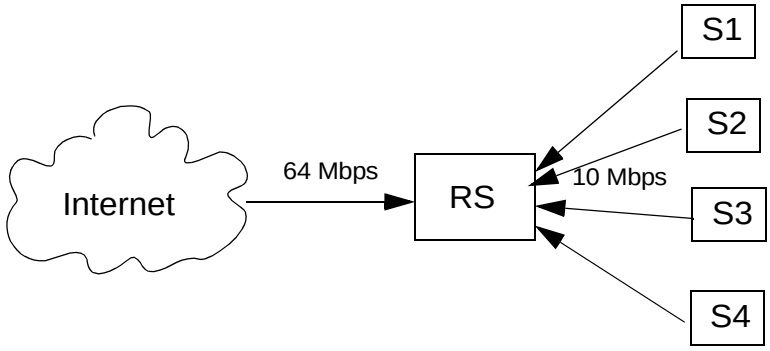


Figure 33-1 Applying aggregate and port-level rate limiting

The configuration shown in Figure 33-1 is created with the following commands. In this example, ACLs are used to define the traffic profile:

```
rs(config)# show active

Configure VLANs and interfaces
vlan create s1 ip
vlan create s2 ip
vlan create s3 ip
vlan create s4 ip
vlan add ports et.2.8 to s1
vlan add ports et.2.7 to s2
vlan add ports et.2.6 to s3
vlan add ports et.2.5 to s4
interface create ip from_s1 vlan s1 address-netmask 10.1.1.1
interface create ip from_s2 vlan s2 address-netmask 15.1.1.1
interface create ip from_s3 vlan s3 address-netmask 20.1.1.1
interface create ip from_s4 vlan s4 address-netmask 25.1.1.1

Configure the ACLs
acl s1 permit ip 10.1.1.1
acl s2 permit ip 15.1.1.1
acl s3 permit ip 20.1.1.1
acl s4 permit ip 25.1.1.1

Enable aggregate rate limiting

system enable aggregate-rate-limiting slot 2

Configure aggregate rate limiting
service flow1 create rate-limit aggregate rate 10000000 drop-packets

Apply the rate limit service to the traffic on the interfaces
service flow1 apply rate-limit acl s1 interface from_s1
service flow1 apply rate-limit acl s2 interface from_s2
service flow1 apply rate-limit acl s3 interface from_s3
service flow1 apply rate-limit acl s4 interface from_s4

Configure the port-level rate limit service
service flow2 create rate-limit input-portlevel rate 64000000 no-action port t1.4.1
```

The following example shows how you would use the MF-Classifier to define a traffic profile and apply a rate limit to it:

```
rs(config)# show active

Configure the VLANs and interfaces

vlan create s1 ip
vlan create s2 ip
vlan create s3 ip
vlan create s4 ip
vlan add ports et.2.1 to s1
vlan add ports et.2.2 to s2
vlan add ports et.2.3 to s3
vlan add ports et.2.4 to s4
interface create ip from_s1 vlan s1 address-netmask 10.1.1.1
interface create ip from_s2 vlan s2 address-netmask 15.1.1.1
interface create ip from_s3 vlan s3 address-netmask 20.1.1.1
interface create ip from_s4 vlan s4 address-netmask 25.1.1.1

Enable aggregate rate limiting

system enable aggregate-rate-limiting slot 2

Configure aggregate rate limiting

service flow1 create rate-limit aggregate rate 10000000 drop-packets

Apply the rate limit service to the specified traffic on the interfaces

service flow1 apply rate-limit mf-classifier interface from_s1
service flow1 apply rate-limit mf-classifier interface from_s2
service flow1 apply rate-limit mf-classifier interface from_s3
service flow1 apply rate-limit mf-classifier interface from_s4

Configure the port-level rate limit service

service flow2 create rate-limit input-portlevel rate 64000000 no-action port
t1.4.1
```

Use the **service show rate-limit** command to display information about the rate limit services that are configured:

```
rs# service show rate-limit all
Rate Limit name: flow1
 Type       Rate        Exceeds     Exceed Action
 ---------- ----------- ----------- -------------------------
 Aggregate  1.00 Mbps   0           Drop

Rate Limit name: flow2
 Type       Rate        Exceeds     Exceed Action
 ---------- ----------- ----------- -------------------------
 Input      64.00 Kbps  0           None
```

Use the **applied** keyword to display the rate limit services and where they were applied:

```
rs# service show rate-limit all applied
Rate Limit name: flow1
 Type       Rate        Exceeds     Exceed Action
 ---------- ----------- ----------- -------------------------
 Aggregate  1.00 Mbps   0           Drop

  Interface: from_s1
  Src Address/Mask   Dest Address/Mask  Src Port  Dest Port TOS/Mask Protocol
  ------------------ ------------------ --------- --------- -------- --------
  anywhere           anywhere           any       any       any      IP

  Interface: from_s2
  Src Address/Mask   Dest Address/Mask  Src Port  Dest Port TOS/Mask Protocol
  ------------------ ------------------ --------- --------- -------- --------
  anywhere           anywhere           any       any       any      IP

Rate Limit name: flow2
 Type       Rate        Exceeds     Exceed Action
 ---------- ----------- ----------- -------------------------
 Input      64.00 Kbps  0           None
```

33.2.2 Applying Burst Safe Rate Limiting

Burst-safe rate limiting is applied on a per layer-3 or layer-4 flow basis. It controls the bandwidth usage of incoming traffic. Use burst-safe rate limiting to specify limits for both the average rate and burst rate of a flow:

- **Committed Access Rate** – (CAR) traffic below this level is always guaranteed
- **Burst-safe rate** – the burst size allowed before a packet is considered for the exceed action

You can specify what action should be taken when traffic exceeds the CAR rate, but is below the burst-safe rate, as well as the action taken when traffic exceeds the burst-safe rate.

Note Port-level rate limiting must be disabled on a port that uses burst-safe rate limiting.

The following example shows how to apply burst-safe rate limiting to provide added bandwidth flexibility during bursty periods.

The configuration requirements of Customer Group 1 are:

- Set the CAR to one million bps
- Set the burst-safe rate to one hundred thousand bps
- Set the CAR exceed to priority dropped to medium
- Set the burst-safe rate exceed to packets are dropped

The configuration requirements of Customer Group 2 are:

- Set the CAR to nine million bps
- Set the burst-safe rate to one million bps
- Set the CAR exceed to priority dropped to low

- Set the burst-safe rate exceed to packets are dropped

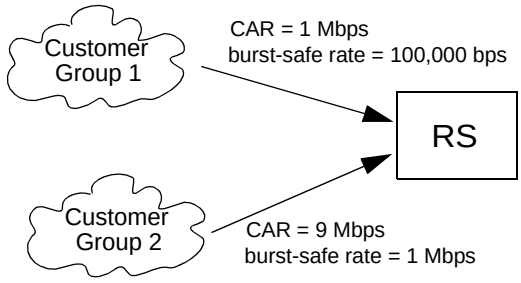


Figure 33-2 Burst-Safe configuration example

The configuration shown in Figure 33-2 is created with the following Configure mode commands:

Create the VLANs

```
vlan create customergroup1 ip
vlan add ports t1.4.1 to customergroup1
vlan create customergroup2 ip
vlan add ports t1.4.2 to customergroup2
```

Create the interfaces

```
interface create ip customergroup1 vlan customergroup1 address-netmask
100.99.98.97
interface create ip customergroup2 vlan customergroup2 address-netmask
101.99.98.97
```

Enable aggregate rate limiting

```
system enable aggregate-rate-limiting slot 4
```

Create the burst-safe services

```
service customergroup1 create rate-limit burst-safe car-rate 1000000
car-lower-priority burst-rate 100000 burst-drop-packets
service customergroup2 create rate-limit burst-safe car-rate 9000000
car-lower-priority burst-rate 1000000 burst-drop-packets
```

Apply burst-safe rate limiting

```
service customergroup1 apply rate-limit mf-classifier interface customergroup1
source-addr-mask 20.20.10.0/24
service customergroup2 apply rate-limit mf-classifier interface customergroup2
source-addr-mask 30.30.10.0/24
```

33.2.3 Applying Layer-2 Rate Limiting

When a layer-2 rate limiting service is applied to a port, the traffic profile is defined by various layer-2 parameters. These parameters can be specified within previously defined filters and/or by selecting layer-2 parameters from a list of classifiers, which are available while applying the service. The following, lists the parameters that can be used to identify layer-2 traffic:

- 802.1P priority
- Any 802.1P priority that is not in an 1p-grouping
- Port number
- Group name when multiple ports or filters are used
- Destination MAC address
- Destination MAC mask address
- Source MAC address
- Source MAC mask address
- VLAN list – specified by VLAN ID #

Layer-2 Rate Limiting Prerequisites

Before layer-2 rate limiting services can be applied to a port, both the line card and its physical ports must be set up for layer-2 rate limiting by performing the following five steps:

1. use the **`system enable l2-rate-limiting slot`** <*number*> **`range`** <*range*> command to set a refresh range on the line card to which layer-2 rate limiting will be applied.

   To set the proper range for a line card, first decide the **`rate`** that will be applied to each port on the line card. Next, use the **`system show rate-limit-range`** command to view a list of the ranges and to see whether they are supported on the line cards. Finally, select the range whose minimum and maximum values encompass the required rates.

   For example, rate limiting is to be performed on **`slot 9`**, on ports **`gi.9.1`** and **`gi.9.2`**. Traffic on **`gi.9.1`** will be rate limited to **`500 Kbps`**, while traffic on **`gi.9.2`** will be rate limited to **`5 Mbps`**. Enter the **`system show rate-limit-range`** command.

```
rs# system show rate-limit-range
Refresh        Minimum        Maximum
------- -------------- --------------
Highest      1.47 Mbps      1.00 Gbps
   High    366.23 Kbps    250.00 Mbps
 Middle     91.55 Kbps     62.50 Mbps
    Low     22.89 Kbps     15.62 Mbps
 Lowest      5.72 Kbps      3.91 Mbps

  Module         Refresh for Input Port Rate Limiting
  ------         ------------------------------------
  4              High       (9)
  8              Not supported
  9              All rates are supported
rs#
```

Notice in the example above that **500 Kbps** and **5 Mbps** falls between the minimum and maximum for the **high** range (**266.23 Kbps – 250.00 Mbps**). Because of this, the **high** range is set for **slot 9** using the **system enable l2-rate-limiting** command.

2. Use the **port l2-rate-limiting** command to set a rate limiting **mode** (**source**, **destination**, or **flow**). If **source** or **destination** mode is selected, a source or destination MAC address, respectively, must be specified within the rate limit service. Furthermore, the bridging-type of the port(s) on which rate limiting occurs must be set to *access-bridging* (the default). If **flow** mode is selected, the rate limit service must contain *both* a source and destination MAC address, and the port(s) on which rate limiting occurs must be set to **flow-based** bridging. This is done using the **port flow-bridging** <*port-list*> command.
3. Use the **port l2-rate-limiting** command to **enable** layer-2 rate limiting on the port(s).
4. If filters are to be used to identify traffic to be rate limited, use the **filters create rate-limit** command to create the filters.
5. If 802.1P priorities are to be used to identify traffic to be rate limited, use the **port l2-rate-limiting** command to create 802.1P groups (see the 802.1P example).

Layer-2 Rate Limiting Using Filters

The following example shows the configuration for an RS running layer-2 rate limiting with the following conditions:

- The line card is a Gigabit Ethernet card in **slot 5**
- The ports on which rate limiting is applied is **gi.5.1** and **gi.5.2**
- The rate limit **mode** is set to **source** (access-bridging on the ports)
- Traffic is to be limited to 10 Mbps
- Rate limiting is based on a filter (**Filter1**) that specifies the source MAC address from which traffic should be rate limited.
- Traffic is to be rate limited to 10 Mbps and the exceed action is “drop-packets”

```
Enable a time-select range for L2 rate limiting
system enable l2-rate-limiting slot 5 range high
Set the L2 rate limiting mode on the ports and enable L2 rate limiting
port l2-rate-limiting gi.5.1-2 mode source
port l2-rate-limiting gi.5.1-2 enable
Create the filter (filter1), which is used when applying the rate limiting service
filters create rate-limit name Filter1 source-mac 00102d:e34a55
Create the L2 rate limiting service and apply it
service Serv1 create rate-limit l2 rate 10000000 drop-packets
service Serv1 apply rate-limit filter Filter1 port-group gi.5.1-2 group-name gig1
```

Notice in the example above that when the service is applied to a group of ports, a **group-name** must be specified. The **group-name** is used by SNMP to identify the ports. In this case, the **group-name** is **gig1**.

It's possible to use a group of several filters for rate limiting, Note that when multiple filters are used, the filters are logically ORed together. In other words, traffic is rate limited if it meets the condition of the first filter "or" the second filter "or" the next filter, and so on. The following is an example of using multiple filters – notice the use of the **filter-group** command:

Create a set of filter to be used when applying the rate limiting service

```
filters create rate-limit name F1 source-mac 00102d:e34a55
filters create rate-limit name F2 vlan-list 1-5
```

*Create and apply the service (**Serv1**) using the two filters above*

```
service Serv1 create rate-limit l2 rate 10000000 drop-packets
service Serv1 apply rate-limit filter-group F1,F2 group-name F-group1
```

Notice in the example above that when the service is applied using a group of filters (**F1** and **F2**), the filter group must have a **group-name**. This **group-name** is used by SNMP to identify the filters. In this case, the filter **group-name** is **F-group1**.

Layer-2 Rate Limiting Using L2 Classifiers

The L2 Classifier parameter of the **service apply rate-limit** command can provide many of the layer-2 specifiers contained within filters. The following is an example of using an L2 Classifier to assign the same source MAC address that was assigned in the first example that used filters:

```
rs(config)# service Serv1 apply rate-limit l2-classifier ?

 1p-grouping              - 802.1P priority (1..4)
 destination-mac          - Destination MAC address
 destination-mac-mask     - Destination MAC Mask address (default ffffff:ffffff)
 group-name               - Group Name when multiple ports or filters are used
 other-1p-grouping        - Any 802.1P priority that is not in the 1p-grouping
 port                     - Apply the service to a port
 port-group               - Apply the service to a group of ports
 source-mac               - Source MAC address
 source-mac-mask          - Source MAC Mask address (default ffffff:ffffff)
 vlan-list                - list of VLANs (1..4094)

rs(config)# service Serv1 apply rate-limit l2-classifier source-mac 00102d:e34a55
port-group gi.9.1-2 group-name gig1
```

Layer-2 Rate Limiting Using 802.1P Priorities

Layer-2 rate limiting can be applied to traffic, which is identified by the priority values contained in the frame's 802.1P priority bits. In turn, these priority bit values (0 to 7) are associated with four priority groups (1 through 4). This association between priority values and priority groups is used to specify the traffic to be rate limited.

Use the **port l2-rate-limiting** <*port-list*> **1p-grouping** <*group-number*> **1p-list** <*priority-number*> command to create the association between the 1p-priorities and the 1p-groups.

The following example associates 1p-priorities with 1p-groups on port **gi.9.1**:

```
rs(config)# port l2-rate-limiting gi.9.1 1p-grouping 1 1p-list 0,3
rs(config)# port l2-rate-limiting gi.9.1 1p-grouping 2 1p-list 1,2
rs(config)# port l2-rate-limiting gi.9.1 1p-grouping 3 1p-list 7
```

The associations created in the example above can be visualized in the following table:

802.1P Group	802.1P priority
Group 1	0,3
Group 2	1,2
Group 3	7
Group 4	–
Group 5 contains any priority that has not been assigned to groups 1 through 4.	4, 5, 6

Note Notice that there is a fifth 1p-group, which acts as a "catch-all" group. This group contains all 1p-priorities that have not been assigned to an 1p-group.

Once the 1p-priority and 1p-group associations are defined, they can be used to identify traffic to rate limit. In the following example, rate limiting is assigned according to 802.1P priority values and is applied to port **gi.5.1**:

Enable a time-select range for L2 rate limiting

```
system enable l2-rate-limiting slot 5 range high
```

Set the L2 rate limiting mode on the ports and enable L2 rate limiting

```
port l2-rate-limiting gi.5.1 mode source
port l2-rate-limiting gi.5.1 enable
```

Associate 802.1p priorities with 802.1P groups

```
port l2-rate-limiting gi.5.1 1p-grouping 1 1p-list 0,3
port l2-rate-limiting gi.5.1 1p-grouping 2 1p-list 1,2
```

Create the L2 rate limiting service

```
service Serv1 create rate-limit l2 rate 10000000 drop-packets
service Serv2 create rate-limit l2 rate 50000000 mark-packets
```

Apply the rate limiting services, using the L2 Classifier "1p-grouping"

```
service Serv1 apply rate-limit l2-classifier 1p-grouping 1 port gi.5.1
service Serv2 apply rate-limit l2-classifier 1p-grouping 2 port gi.5.1
```

As traffic enters port **gi.5.1**, if the 802.1P priority bits contain either **0** or **3** (1p-group **1**), the rate is limited to 10 Mbps and the exceed action will drop packets. However, if the 802.1P priority bits contain either **1** or **2** (1p-group **2**), traffic is rate limited to 50 Mbps and the exceed action will mark packets for identification by Weighted Random Early Discard (WRED).

Rate limiting can also be applied using the fifth 1p-priority group, mentioned earlier. Modifying the example above, the L2 Classifier, **other-1p-grouping** is used to rate limit on traffic whose 1p-priority bit values have not been assigned to any 1p-groups. For example:

Enable a time-select range for L2 rate limiting

```
system enable l2-rate-limiting slot 5 range high
```

Set the L2 rate limiting mode on the ports and enable L2 rate limiting

```
port l2-rate-limiting gi.5.1 mode source
port l2-rate-limiting gi.5.1 enable
```

Associate 802.1p priorities with 802.1P groups

```
port l2-rate-limiting gi.5.1 1p-grouping 1 1p-list 0,3
port l2-rate-limiting gi.5.1 1p-grouping 2 1p-list 1,2
```

Create the L2 rate limiting service

```
service Serv1 create rate-limit l2 rate 10000000 drop-packets
service Serv2 create rate-limit l2 rate 50000000 mark-packets
service Serv3 create rate-limit l2 rate 100000000 drop-packets
```

Apply the rate limiting services, using the L2 Classifier "1p-grouping"

```
service Serv1 apply rate-limit l2-classifier 1p-grouping 1 port gi.5.1
service Serv2 apply rate-limit l2-classifier 1p-grouping 2 port gi.5.1
service Serv3 apply rate-limit l2-classifier other-1p-grouping port gi.5.1
```

In the example above, a third rate limit services is created (**Serv3**). Notice that traffic on port **gi.5.1** whose priority bits do not contain the values **0**, **1**, **2**, or **3** are rate limited to 100 Mbps and the exceed action is drop packets. This would include any traffic whose 1p-priority bit values are **4**, **5**, **6**, or **7**. These vales are the contents of 1p-group five.

33.2.4 Rate Limiting Compatibility

Table 33-1 displays the possible rate limiting schemes that can be used in conjunction with the 5th generation ASIC rate limiting capabilities. Number references coincide with the numbered notes at the end of the table.

Table 33-1 Rate limit inter-operability table

Limiting scheme	Per Flow RL	Aggregate RL	Port-level RL	Burst-safe RL	Layer-2 RL
Per Flow RL	*[4]	Yes	Yes	Yes	Yes
Aggregate RL	Yes	*[4]	Yes[1]	Yes[3]	Yes
Port-level RL	Yes	Yes[1]	*[5]	Y[2, 3]	Yes
Burst-safe RL	Yes	Yes[3]	Yes[2, 3]	*[4]	Yes[3]

Table 33-1 Rate limit inter-operability table (Continued)

Limiting scheme	Per Flow RL	Aggregate RL	Port-level RL	Burst-safe RL	Layer-2 RL
Layer-2 RL	Yes	Yes	Yes	Yes[3]	*[4]

1. Aggregate rate-limiting can use all but 16 'A' bucket while port-level rate-limiting is enabled (default) (256-16).
2. Burst-safe and input port level cannot be configured on the same port, but can be used within the same slot.
3. Burst-safe cannot be used with any other rate-limiting type (except per-flow) for the same traffic on the same port. This can be used on different traffic or port.
4. The same rate-limiting type can be configured multiple times on the same port as long as the classification matches different traffic patterns.
5. Multiple port-level policies cannot be applied to the same port, but can be applied to different ports.

33.3 RATE SHAPING SERVICES

The Service facility provides rate shaping on inbound traffic. Rate shaping differs from rate limiting in that rate shaping uses the port priority queues, which enables rate shaping to perform a certain amount of buffering. Like burst-safe rate limiting, rate shaping allows flows to exceed their committed bandwidth up to the burst rate when excess queue space is available. By doing so, rate shaping allows ports to be somewhat over subscribed and still provide adequate throughput. Of course, this is based on the assumption that not all connections will be running at the committed rate and/or bursting at the same time.

Note Rate shaping is supported only on line cards that contain 5th generation ASICs.

A rate shaping service is defined by the following:

- **Rate** – The guaranteed (committed) bit rate for traffic identified by the filter criteria
- **Burst** – The burst rate is a bit rate that exceeds the committed bit rate. If a queue of a particular priority is empty, traffic using other priority queues can borrow the empty queue's space. The extra (borrowed) queue space allows the specified traffic to increase its bit rate until it reaches its designated burst rate.

A Rate shaping service is applied to a port or interface by specifying the following:

- **Port** – The input port on which the rate shaping is to take place.
- **Queue** – One of the four internal priority queues. The queues are identified as low, medium, high, and control.

33.4 APPLYING RATE SHAPING SERVICES

A rate shaping service is applied to a port by performing the following steps:

1. Use the **`service`** <*name*> **`create rate-shape input rate`** <*number*> **`burst`** <*number*> command to create the rate shaping service.
2. Use the **`service`** <*name*> **`apply rate-shape port`** <*port-list*> **`queue`** <*queue-name*> command to apply the previously created rate shaping service to an input port queue.

   At this point, the rate shaping service has been applied to a port and a queue has been selected. Rate shaping will now occur on traffic arriving on that port and in that queue. However, there is no way to guarantee that the traffic we want to rate shape will arrive in the specified queue. To accurately specify the traffic to be rate shaped, additional identifying parameters are needed. These additional parameters are obtained by associating the rate shaping service with a *Quality of Service* (QoS) *profile* using the **`qos set`** command.
3. Use the **`qos set ip`** command to define a layer-3 or layer-4 QoS profile and associate it with the queue on which the rate shaping service is applied. Use the **`qos set l2`** command to define a layer-2 QoS profile and associate it with the queue that the rate shaping service is applied on.

33.4.1 Associating a Rate Shaping Service with a QoS Profile

Depending on the type of traffic to be rate shaped (layer-2, layer-3, or layer-4), certain prerequisites must be observed. The following is a list of these prerequisites for each type of traffic

- Layer-2 Traffic – **`qos set l2`**
  - The port (or ports) specified for the rate shaping service must be a member of a VLAN before it can be associated with a QoS profile.
  - If access-bridging is enabled (the default) and traffic is to be identified by a MAC address, only the destination MAC address can be used in the QoS profile.
  - If both a source MAC address and destination MAC address are needed to identify the traffic in the QoS profile, flow-bridging for that port(s) MUST be enabled using the **`port flow-bridging`** <*port-list*> command.
- Layer-3 Traffic – **`qos set ip`**
  - The port (or ports) specified by the rate shaping service must have an IP interface. The port is identified in the QoS profile by its interface name.
- Layer-4 – **`qos set ip`**
  - The port (or ports) specified by the rate shaping service must be a member of a VLAN and must be running layer-4 bridging using the **`vlan enable l4-bridging`** command.

33.4.2 Filter Parameters supported by QoS Profiles

Table 33-2 is a list of the filtering parameters that are provided by QoS profiles. Notice that these filter parameters can be wild carded by using the keyword **`any`**. Furthermore, filter parameters that are not specified after the last defined filter parameter can be left blank (no value or **`any`** keyword) – blanks are treated as wildcard values.

For example, **`qos set ip name Prof1 low any any 80`** specifies only the *source port*. The IP source and destination addresses are wild carded by the keyword **`any`**, and all filter parameters following the source port are simply left blank.

Table 33-2 QoS profile filter parameters

Layer-2 Filter Parameters (qos set l2)	Layer-3 Filter Parameters (qos set ip)
Destination MAC address	Source IP address and subnet mask
Destination MAC address mask	Destination IP address and subnet mask
Input port list	Source port
Priority (queue)	Destination port
Source MAC address	Priority (queue)
Source MAC address mask	port*/interface
VLAN	Protocol (UDP, TCP, **`any`**)
Ignore ingress 802.1Q	Type of Service (ToS)

Table 33-2 QoS profile filter parameters (Continued)

Layer-2 Filter Parameters (qos set l2)	Layer-3 Filter Parameters (qos set ip)
	ToS mask
	ToS rewrite
	ToS precedence rewrite

* If port is specified, it must be in a VLAN and layer-4 bridging must be enabled.

Applying Rate Shaping and QoS Profiles to Layer-3 Traffic

The following is an example configuration for rate shaping layer-3 traffic on a Gigabit Ethernet port (**gi.9.1**), which contains the interface **gig1**. Rate shaping will be performed on inbound packets from the **100.10.10.0** subnet. The **rate** is set to 10 Mbps, the **burst** is 15 Mbps, and the **high** priority queue is used.

For layer-3 rate shaping, create an interface on the port

```
interface create ip gig1 address-netmask 100.10.10.1/24 port gi.9.1
```

Define the rate shaping service

```
service rs1 create rate-shape input rate 10000000 burst 15000000
```

Apply the rate shaping service to a port and specify the priority queue

```
service rs1 apply rate-shape port gi.9.1 queue high
```

Associate a layer-3 QoS profile to the rate shaping service

```
qos set ip name qos1 high 100.10.10.0/24 any any any any gig1
```

Notice in the example above that both the **port** (identified by its interface) and the **queue** specified within the **qos set ip** command must be the same **port** and **queue** that was specified when the rate shaping service was applied.

Applying Rate Shaping and QoS Profiles to Layer-2 Traffic

The following is an example configuration for rate shaping layer-2 traffic on two Gigabit Ethernet ports (**gi.9.1** and **gi.9.2**), which are members of VLAN **VL1** (VLAN ID # 100). Rate shaping will be performed on inbound frames with destination MAC address **01002e:f53413**. The **rate** is set to 5 Mbps, the **burst** is 10 Mbps, and the **low** priority queue is used

For layer-2 rate shaping, create a VLAN and add ports to it

```
vlan create VL1 ip id 100
vlan add ports gi.9.1-2 to VL1
```

Define the rate shaping service

```
service rs2 create rate-shape input rate 5000000 burst 10000000
```

Apply the rate shaping service to a set of ports and specify the priority queue

```
service rs2 apply rate-shape port gi.9.1-2 queue low
```

Associate a layer-2 QoS profile to the rate shaping service

```
qos set l2 name qos2 dest-mac 01002e:f53413 in-port-list gi.9.1-2 vlan 100 priority
low
```

In the example above, rate shaping will occur on frames from MAC address **01002e:f53413** that appear in the **low** priority queues for ports **gi.9.1** and **gi.9.2**.

Note In the example above, any frames that winds up in **gi.9.1** or **gi.9.2**'s low priority queue (for example, because of their .1p value) are rate shaped.

33.5 ADVANCED RATE SHAPING

The Advanced Services Module (ASM) is a 1-slot, 2-port Gigabit Ethernet line card for the RS 1000, RS 1100, RS 3000, RS 3100, RS 3200, RS 8000 and RS 8600 platforms. The ASM supports all standard GBICs offered on the RS platform. In addition, the ASM is MPLS-enabled and significantly increases the scalability of the RS' MPLS support. The ASM line cards also provide the ability to perform rate-shaping in hardware on both the ingress and egress of the ports. This hardware rate-shaping uses the line card's Context Addressable Memory (CAM) as well as memory buffers contained in *on-card* memory.

Note The RS 1000 can only be configured with one ASM.

Note For basic rate-shaping concepts, see 33.3 *"Rate Shaping Services."* For specific information on WRED see 28.7 *"Weighted Random Early Detection (WRED)."*

ASM line cards have the following features and benefits:

- 256 shapers for ingress & egress
- 32 Mbytes per-port per-direction
- CAM with 16k entries for rate-shaper classifiers
- WRED on each shaper
- Separate drop weights configurable for each port – based on 802.1P or ToS-precedence
- Groups for shapers or individual shapers
- Express-lane per-port in each direction
- Default queue per-port in each direction
- Configurable buffer size for each shaper
- CAR rate and burst rate
- Exceed-actions – based on ToS byte, ToS-precedence, DSCP, or EXP bit rewrite
- Statistics for each queue and WRED instance
- Configurable priorities (4) per queue
- Jumbo frame support - Jumo frames sizes up to 9000 bytes are supported
- Additional filtering based on ACL, VLAN, 802.1P, MPLS label, and port-of-entry (POE)

Each shaper can be individually configured into one of three modes:

- Single-rate Shaping – Rate-shapers configured with only a Committed Access Rate (CAR)
- Dual-rate Shaping – Rate-shapers configured with a CAR and a burst size
- Shaper Groups – rate-shapers, each with a CAR, are aggregated into a group. The rate assigned to the group acts as the collective burst-size for the rate-shapers within the group.

33.5.1 Configuring ASM Rate-shapers

The process of configuring ASM rate-shapers is basically a four-part operation. The following bulleted list describes these basic steps.

Note All of the steps for creating and applying an ASM rate-shaper are performed in configure mode.

- Enable the ACL-CAM facility for each port on which an ASM rate-shaper will reside.
- If necessary, create any ACL, WRED profile, or VLAN to be used to classify traffic for the ASM rate-shaper
- Create the rate-shaper by specifying a Committed Access Rate (CAR), and, optionally, by specifying a burst rate and buffer size.
  - In this step, ToS-byte, ToS-precedence, DSCP, and EXP rewrites can be assigned to the rate-shaper
- Apply the rate-shaper to a port by specifying a port number, whether to affect input or output traffic, and an additional traffic classifier (if necessary).
  - Traffic classifiers provide additional information for identifying traffic to be rate-shaped. This is explained further in the *"Traffic Classifiers"* section.

The following is an example of creating and applying a simple rate-shaper. Later in this section, burst rates, buffer sizes, bit-rewrites, and special classifiers are discussed.

For this example, a rate-shaper is assigned to port **gi.11.1**, the CAR is set to 1,000,000 bps, and the rate-shaper is assigned to **output** traffic.

First, the hardware ACL-CAM capabilities are enabled on port **gi.11.1**:

```
rs(config)# port enable acl-cam ports gi.11.1
```

Next, create the rate-shaper – in this example, called "**rate1**":

```
rs(config)# service rate1 create rate-shape asm rate 1000000
```

Finally, the rate-shaper is applied to the output of port **gi.11.1**. Notice that the **port-of-entry** (PoE) is used as a classifier to identify the traffic on which the rate-shaper should act:

```
rs(config)# service rate1 apply rate-shape asm port-of-entry et.4.3 port gi.11.1
output
```

All traffic coming from the PoE of **et.4.3** and going out **gi.11.1** is rate-shaped.

Notice in the step above if the **port-of-entry** classifier was left out, the rate-shaper would simply rate-shape all traffic going out of port **gi.11.1**.

Note More than one rate-shaper can be applied to a port, as long as each rate-shaper is differentiated by input, output, and a unique classifier (if necessary).

Note The ASM rate-shape create parameter, “lsp-signal” allows LSPs affected by this rate-shaper to override the configured burst rate or group rate.

Rate-Shapers with Different Rates

When applying multiple ASM rate-shapers to a port, each rate-shaper can have a unique CAR. For example, one rate-shaper could have a CAR or 10^6 bps, while another rate-shaper on the same port could have a CAR of 10^7 bps. If the rate-shapers’ priorities are equal, each rate-shaper is allowed to send traffic at a rate equivalent of the CAR as a percentage of the total throughput.

For example, two rate-shapers (**`r1`** and **`r2`**) are assigned to a 1 gigabit port. The CAR of **`r1`** is 10^7 bps and the CAR of **`r2`** is 10^8 bps. Since 10^7 bps is 1% of the throughput and 10^8 bps is 10% of the throughput, for every bit sent by **`r1`**, 10-bits are sent by **`r2`**.

It is important to note that an ASM rate-shaper’s interaction with other ASM rate-shapers on the same port are affected by the rate-shapers’ priority settings and their configured burst-sizes. See *"Queues and Priorities"* and *"Burst Rates"* for more information on these topics.

Exceeding Throughput

Notice that the total of all CARs in either the input or output direction cannot exceed the possible throughput of the line card (10^9 bps).

For example, the following attempts to apply two rate-shapers to the output of port gi.11.1, where the collective CARs of the rate-shapers exceeds the throughput for port gi.11.1:

```
rs(config)# service r4 create rate-shape asm rate 1000000000
rs(config)# service r5 create rate-shape asm rate 10000000

rs(config)# service r4 apply rate-shape asm port gi.11.1 output

%SVC-I-SERVICE_PORT, Service 'r4' has been successfully attached to ports 'gi.11.1'

rs(config)# service r5 apply rate-shape asm port gi.11.1 output port-of-entry gi.11.2

%CLI-E-FAILED, Execution failed for "service r5 apply rate-shape asm port gi.11.1
output port-of-entry gi.11.2"
%SVC-E-ATSRATE, The rates of the shapers applied on the output of port 'gi.11.1'
exceeds port throughput
```

Notice that aside from their CARs, the definitions of **r4** and **r5** allow both rate-shapers to coincide on port **gi.11.1** because **r4** specifies output traffic, while **r5** specifies output traffic and the additional traffic classifier: *"entered the RS through port gi.11.2."* However, since **r4**'s CAR (10^9 bps) plus **r5**'s CAR (10^7 bps) exceeds the throughput of **gi.11.1**, applying both rate-shapers fails, and the error messages above are displayed.

Bit Value Rewrites

When creating an ASM rate-shaper, several *rewrite* capabilities are provided to allow the various precedence indicators of packets to be changed. Table 33-3 lists these rewrite capabilities:

Table 33-3 Packet rewrite capabilities

Rewrite Capability	Meaning
car-exp-rewrite	Rewrite the MPLS EXP value for packets exceeding the CAR rate
car-one-p-rewrite	Rewrite the 802.1P value for packets exceeding the CAR rate
car-tos-dscp-rewrite	Rewrite the ToS DSCP value for packets exceeding the CAR rate
car-tos-prec-rewrite	Rewrite the ToS precedence value for packets exceeding the CAR rate
car-tos-rewrite	Rewrite the ToS value for packets exceeding the CAR rate
exp-rewrite	Rewrite the MPLS EXP value for all packets that match this profile
one-p-rewrite	Rewrite the 802.1 value for all packets that match this profile
tos-dscp-rewrite	Rewrite the ToS DSCP value for all packets that match this profile
tos-prec-rewrite	Rewrite the ToS precedence value for all packets that match this profile
tos-rewrite	Rewrite the ToS value for all packets that match this profile

Notice that the only difference between the first five and the last five rewrite capabilities is the word "CAR." The concept here is that those rewrite capabilities without the word CAR perform their rewrite operations for conforming traffic. While the rewrite capabilities containing the word "CAR" go into effect only after traffic has bursted above the CAR rate.

A rewrite option and it's "CAR" counterpart can be included within the same rate-shaper. For example, the following ASM rate-shaper (**rate3**) rewrites the ToS value while the traffic rate is both below and above the CAR rate:

```
rs(config)# service rate3 create rate-shape asm tos-rewrite 34 car-tos-rewrite 54
rate 1000000 burst 20000
```

To view the rewrite parameters set for the rate-shaper, use the **service show rate-shape asm** command from Enable mode:

```
rs# service show rate-shape asm rate3
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
rate3           1000000    1020000    100ms (    32K) TOS Byte    ( 34/ 54)
```

Notice that the last column shows the type of rewrite and both the pre and post rewrite values.

Note If two rewrite options are being used within the same rate-shaper, they must be the same type. For example, **`tos-rewrite`** and **`car-tos-rewrite`** can be used within the same rate-shaper, but **`tos-rewrite`** and **`car-exp-rewrite`** cannot.

DSCP Rewrites

Of the possible rewrite options, the DSCP (Differentiated Services) rewrite option is the least straightforward and uses several coded presets. For this reason, the DSCP rewrite option requires additional explanation.

Differentiated Services (DiffServ) uses the six left-most bits of the ToS byte to define Differentiated Services Code Point (DSCP) values.

The DiffServ bits are arranged as follows within the ToS byte:

DS5	DS4	DS3	DS2	DS1	DS0	NU*	NU*

NU* = not used

Table 33-4 Left-most DiffServ bits and their precedence

Bits Pattern	Precedence
111	precedence 7
110	precedence 6
101	precedence 5
100	precedence 4
011	precedence 3
010	precedence 2
001	precedence 1
000	precedence 0

The following three bits are used to specify class parameters: delay, throughput, and reliability.

Table 33-5 Right-most DiffServ bits

Bits Position	Meaning
bit 3	Delay: 0 = normal, 1 = high
bit 4	Throughput: 0 = normal, 1 = high
bit 5	Reliability: 0 = normal, 1 = high

Note The last two bits of the byte are not used in the DSCP context, and are ignored.

The values specified for both **car-tos-dscp-rewrite** and **tos-dscp-rewrite** are predefined Per-Hop Behavior (PHB) code points.

For example, entering the **service rate4 create rate-shape asm tos-dscp-rewrite** command with a question mark displays the following list:

```
rs(config)# service rate4 create rate-shape asm tos-dscp-rewrite ?
[tos-dscp-rewrite] requires a value of one of these types:
   number                  - Value between 0 and 63, inclusive
   [keyword]               - One of the following keywords:
     AF11                  - DSCP AF11 (001010)
     AF12                  - DSCP AF12 (001100)
     AF13                  - DSCP AF13 (001110)
     AF21                  - DSCP AF21 (010010)
     AF22                  - DSCP AF22 (010100)
     AF23                  - DSCP AF23 (010110)
     AF31                  - DSCP AF31 (011010)
     AF32                  - DSCP AF32 (011100)
     AF33                  - DSCP AF33 (011110)
     AF41                  - DSCP AF41 (100010)
     AF42                  - DSCP AF42 (100100)
     AF43                  - DSCP AF43 (100110)
     CS0                   - DSCP CS0 (000000)
     CS1                   - DSCP CS1 (001000)
     CS2                   - DSCP CS2 (010000)
     CS3                   - DSCP CS3 (011000)
     CS4                   - DSCP CS4 (100000)
     CS5                   - DSCP CS5 (101000)
     CS6                   - DSCP CS6 (110000)
     CS7                   - DSCP CS7 (111000)
     EF-PHB                - DSCP EF-PHB (101110)
```

Table 33-6 displays the names and bit patterns for each PHB, as well as the effect they have on packets.

Table 33-6 PHB code point values

PHB Name	Bit Pattern	Behavior
AF11[1]	001010	Low Drop Probability
AF12	001100	Medium Drop Probability
AF13	001110	High Drop Probability
AF21	010010	Low Drop Probability
AF22	010100	Medium Drop Probability
AF23	010110	High Drop Probability
AF31	011010	Low Drop Probability

Table 33-6 PHB code point values (Continued)

PHB Name	Bit Pattern	Behavior
AF32	011100	Medium Drop Probability
AF33	011110	High Drop Probability
AF41	100010	Low Drop Probability
AF42	100100	Medium Drop Probability
AF43	100110	High Drop Probability
CS0[2]	000000	The default BHP.
CS1	001000	Precedence 1
CS2	010000	Precedence 2
CS3	011000	Precedence 3
CS4	100000	Precedence 4
CS5	101000	Precedence 5
CS6	110000	Precedence 6
CS7	111000	Precedence 7
EF-PHB	101110	Expedited Forwarding Can be used to build a low jitter, low loss, low latency, assured bandwidth service through Diffserv domains. The EF-PHB acts like a point-to- point connection.

[1] AF = Assured Forwarding
[2] CS = Class-Selector

CS values use only the precedence bits. The CS values are included primarily for backward compatibility with other IP precedence schemes.

Traffic Classifiers

When ASM rate-shapers are applied, two mandatory parameters must be specified. These parameters are the port number to which the rate-shaper is assigned and whether the rate-shaper affects incoming or outgoing (input/output) traffic. Additional parameters called *traffic classifiers* can be specified to further identify the traffic on which to act. Furthermore, traffic classifiers make it possible to assign more than one ASM rate-shaper to a port in the same direction (either input or output).

For example, a rate-shaper that uses an ACL as a traffic classifier that identifies traffic from a source address can coexist for the same direction on the same port with another rate shaper that uses an ACL containing a different source address.

```
rs(config)# acl source1 permit ip 100.10.10.1 any any any
rs(config)# acl source2 permit ip 200.10.10.1 any any any

rs(config)# service test1 create rate-shape asm rate 10000
rs(config)# service test2 create rate-shape asm rate 1000000

rs(config)# service test1 apply rate-shape asm acl source1 port gi.11.1 input
rs(config)# service test2 apply rate-shape asm acl source2 port gi.11.1 input
```

Traffic Classifiers and Memory

As traffic enters an ASM rate-shaped port, a check is made through the CAM for traffic classifiers belonging to the port. If a classifier exists, a pointer is used to find the rate-shaper's definition in context memory. Context memory also contains a pointer to the rate-shaper's queue in port memory. Conversely, if traffic entering the rate shaped port finds no CAM entry, the traffic is passed directly to the *default* queue. The default queue handles all such traffic and has a burst size of 10^9 bps (see Figure 33-3).

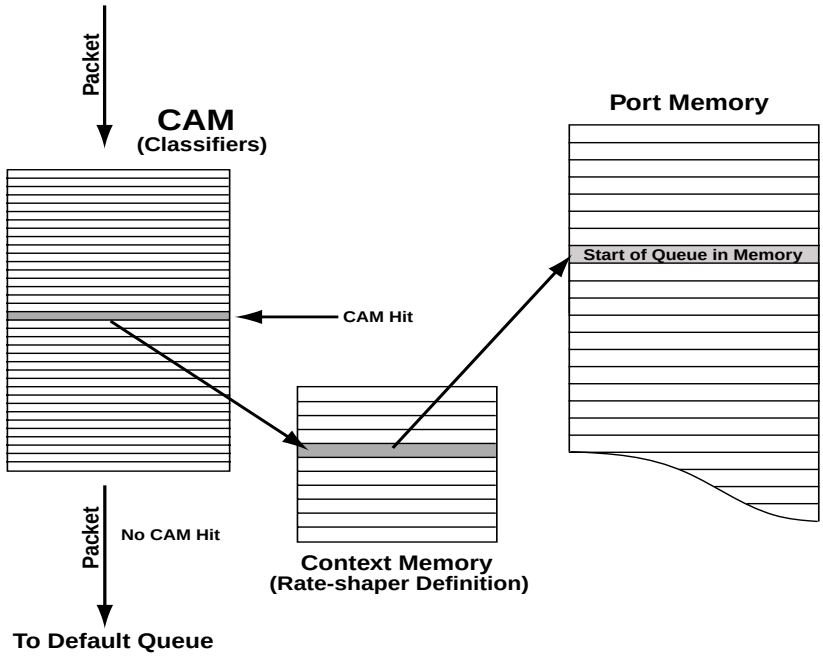


Figure 33-3 Traffic classifiers and memory

Table 33-7 lists the traffic classifiers that can be specified when the rate-shaper is applied to a port.

Table 33-7 ASM rate-shaper traffic classifiers

Classifier	Meaning
`acl`	Specify the ACL to classify the traffic
`input`	Apply the rate shaper to the ingress traffic
`lsp-name`	Specify MPLS LSP name to classify the traffic
`one-p-priority`	Specify the IEEE 802.1P value to classify the traffic
`output`	Apply the rate shaper to the egress traffic
`port-of-entry`	Apply the output rate shaper to traffic from the specified input port
`vlan`	Specify VLAN number to classify the traffic

Note If an ACL or a VLAN is to be used to classify traffic, it must already exist in the active configuration.

Note There are no precedence or priority differences between traffic classifiers.

In the following example, an ACL (**`source1`**) is created, which specifies a source address to be used as a traffic classifier for the ASM rate-shaper **`rate5`**:

```
rs(config)# port enable acl-cam ports gi.11.1
rs(config)# acl source1 permit ip 100.10.10.1 any any any
rs(config)# service rate5 create rate-shape asm rate 1000000 burst 20000
rs(config)# service rate5 apply rate-shape asm acl source1 port gi.11.1 input
```

In the example above, the ASM rate-shaper affects IP traffic with the source address 100.10.10.1 on port **`gi.11.1`**.

Use the **service show rate-shape asm** command with the **applied** option to view how the rate-shapers are applied. In the example below, notice that the classifiers are displayed and, in this case, the classifier for the rate-shaper **rate5** is the ACL **source1**.

```
rs# service show rate-shape asm rate5 applied

Service Name    Rate       Burst      Buffer           Rewrite Action
--------------- ---------- ---------- ---------------- ------------------------
rate5           1000000    1020000    100ms (    12K) None        (  0/  0)

  Ports         : gi.11.1
  Type          : Input              ACL Name      : source1
  Group Name    : (2) None
  Priority      : D                  POE           : None
  VLAN          : any                802.1P        : any
  Packet In     : 0                  Byte In       : 0
  Packet Out    : 0                  Byte Out      : 0
  Packet Drop   : 0                  Byte Drop     : 0
  Packet Exceed : 0                  Queue Used    : 0%
```

Note A special classifier exists within the classifier list, named "*express-lane*." The express-lane is a special queue that is never rate-shaped, and is used for control information (such as PDUs). Use this classifier to designate this rate-shaper as the express-lane for all traffic on a port for the specified direction (input or output).

Setting Buffers

Whenever a rate-shaper is created, a queue for buffering is created automatically. The default buffering size of any queue is 100 milliseconds. The buffer size can be changed by specifying an alternate buffer size while creating the ASM rate-shaper.

For example, the following creates a rate-shaper called **rate2** with a rate of 10^6 bps and a queue size of 200 milliseconds:

```
rs(config)# service rate2 create rate-shape asm rate 1000000 buffer 200
```

To see the sizes of the buffers used by rate-shapers, enter the **service show rate-shape asm** command from Enable mode:

```
rs# service show rate-shape asm all
Service Name    Rate       Burst      Buffer           Rewrite Action
--------------- ---------- ---------- ---------------- ------------------------
rate1           1000000    1000000    100ms (  12.5K) None        (  0/  0)
Service Name    Rate       Burst      Buffer           Rewrite Action
--------------- ---------- ---------- ---------------- ------------------------
rate2           1000000    1000000    200ms (    25K) None        (  0/  0)
```

Notice the difference between the buffer size of the rate-shaper that was created for **rate1** (100 ms), and the buffer size created for **rate2** (200 ms).

Typically, it is not necessary to alter the buffer size. The default buffer size has been calculated to work with most traffic situations. There are, however, two exceptions in which an altered buffer size can help performance. Each of these exceptions are related to network congestion.

For data traffic, if the CAR is set high and the network has congestion problems, a larger buffer may be required to avoid losing packets. This type of packet loss is known as *"tail-drop."*

For voice and video traffic, a smaller buffer may work better during congestion. The concept is that it's better to drop a word that can be repeated than to experience delay within a conversion. In this case, setting the buffer smaller may increase the chances of tail-drop, but reduces the chances of delay.

Calculating Buffer Size in Memory

While buffer size is specified in milliseconds, the length of time for a buffer is dependent upon how much memory is used by the queue. Because of this relationship between buffer time and memory, rate-shapers with different rates may need more or less memory to provide the same amount of buffering time.

For example if we create a rate-shaper called **test** that has a rate of 10^9 bps, more memory will be required to provide the same default 100 milliseconds of buffering:

```
rs(config)# service test create rate-shape asm rate 1000000000

rs# service show rate-shape asm all
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ----------------------
rate1           1000000    1000000    100ms (  12.5K) None        (  0/  0)
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ----------------------
rate2           1000000    1000000    200ms (    25K) None        (  0/  0)
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ----------------------
test            1000000000 1000000000 100ms ( 12500K) None        (  0/  0)
```

Notice that the rate-shaper **test** requires 1.25 megabytes of memory to provide the same 100 milliseconds of buffering.

To calculate the number of bytes of memory used for a particular buffer size, use the following equation:

$$\frac{t \times r}{8000} = b$$

Where:

t = Buffer size in milliseconds
r = Committed Access Rate in bits-per second
b = Bytes required to create the buffer

For example, using a buffer of 200 milliseconds and a CAR of 1000000 bps, the following calculation gives the number of bytes required for the buffer:

$$\frac{200 \times 1000000}{8000} = 25000$$

In this case, the number of bytes required is 25 Kilobytes.

Note Each set of 256 shapers (in each direction of each port) has 32 MB of packet buffer attached to it. Using the formula described in this section, you should set the buffering as indicated by your traffic patterns.

Queues and Priorities

Typically, if multiple rate-shapers with identical CARs and priorities are applied to a port, the rate-shapers deals with traffic in a “round-robin” fashion. This occurs regardless of the rate-shaper classifiers, which do not bestow any special priority.

However, one classifier, *priority*, determines in what order and rate each rate-shaper handles its traffic during times of congestion. There are four levels of priority, denoted by the letters A through D, where A is the highest priority and D is the lowest. Note here, that if there is no congestion, the rate-shapers use the standard round-robin technique for handling traffic.

For example, three VLANs (v1, v2, and v3) are created and assigned to a trunk port (gi.11.1). Three rate-shapers are created and applied to gi.11.1 such that incoming traffic from v1 has the highest priority, incoming traffic from v2 has the next highest priority, and v3 has the lowest priority. If the RS becomes congested, traffic from VLAN v1 is favored over traffic from either VLANs v2 or v3, and traffic from VLAN v2 is favored over traffic from v3 (see the following configuration example):

```
rs(config)# vlan create v1 ip id 100
rs(config)# vlan create v2 ip id 200
rs(config)# vlan create v3 ip id 300

rs(config)# vlan make trunk-port gi.11.1

rs(config)# vlan add ports gi.11.1 to v1
rs(config)# vlan add ports gi.11.1 to v2
rs(config)# vlan add ports gi.11.1 to v3

rs(config)# service r1 create rate-shape asm rate 1000000
rs(config)# service r2 create rate-shape asm rate 1000000
rs(config)# service r3 create rate-shape asm rate 1000000

rs(config)# service r1 apply rate-shape asm port gi.11.1 vlan 100 input priority a
rs(config)# service r2 apply rate-shape asm port gi.11.1 vlan 200 input priority b
rs(config)# service r3 apply rate-shape asm port gi.11.1 vlan 300 input priority c
```

Note The ASM can support the following number of shapers per priority:
- Up to 254 shapers can be configured with priority A
- Up to 128 shapers can be configured with priority B
- Up to 128 shapers can be configured with priority C
- Up to 128 shapers can be configured with priority D

Figure 33-4 shows how rate-shapers with different priorities behave as the RS becomes congested.

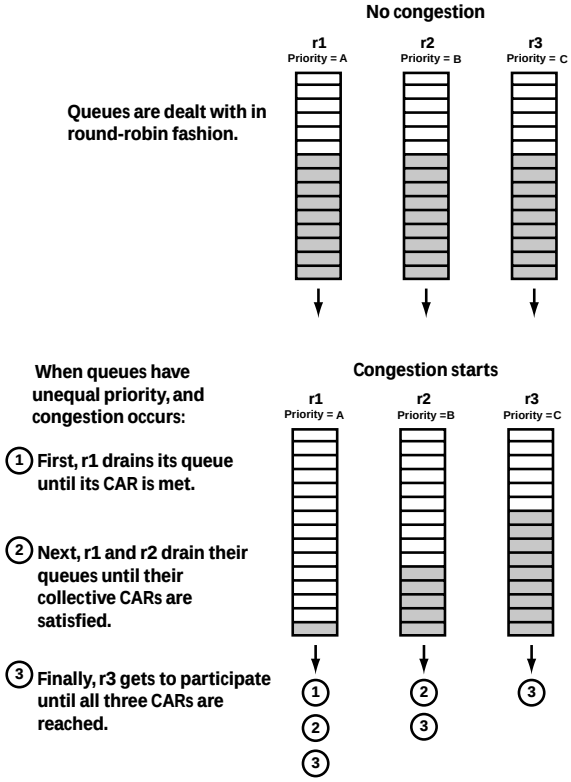


Figure 33-4 Priorities and rate-shaper behavior

Number of Queues for Priorities

When assigning priorities to ASM rate-shapers, the following explains queue allocations for each port:

- The “express lane” for a port is restricted to one queue (queue 0 in memory).
- The default queue for a port is restricted to one queue (queue 1 in memory)
- For low or high priorities (D and B), a port is restricted to 125 queues (queues 2-127 in memory)
- For medium priorities (C), a port is restricted to 127 queues (queues 128-255 in memory)
- For control priorities (A), a port can have 254 queues (queues 2-255 in memory)

Burst Rates

When creating an ASM rate-shaper, along with the CAR and buffer size a burst-rate can be configured. The burst-rate is the number of bits per second that a rate-shaper can send in excess of its CAR, provided that the CARs of all rate-shapers on the port have been met and there is still additional bandwidth available with respect to the port's total throughput.

For example, the following creates a rate-shaper that has a CAR of 10^6 bps and can burst to an additional 80,000 bps provided all CARs on the port to which it becomes assigned are first met and there is still available bandwidth:

```
rs(config)# service rate1 create rate-shape asm rate 1000000 burst 80000
```

To view CARs and burst-rates of ASM rate-shapers, enter the following:

```
rs# service show rate-shape asm all
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
rate1           1000000    1080000    100ms (    12K) None        (  0/  0)
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
rate2           1000000    1050000    100ms (    12K) None        (  0/  0)
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
rate3           5000000    5030000    100ms (    62K) None        (  0/  0)
```

In this case, there are three rate-shapers defined on this RS (**rate1**, **rate2**, and **rate3**). Notice that each rate-shaper has an additional amount burst bandwidth.

Note that once all CARs for all ASM rate-shapers on a port are satisfied and the rate-shapers are allowed to burst, the algorithm that determines how the remaining throughput is apportioned for bursting is identical to the algorithm used to determine how multiple CARs on the same port use the port's throughput. The burst algorithm determines burst traffic transmission by rate-shaper priority and percentage of total throughput.

Burst-Rate Example

When using burst-rates, the algorithm allows the first rate-shaper to send its CAR. The algorithm then moves on to the next rate-shaper and allows it to send its CAR and so on, until all 256 (possible) rate-shapers have sent their CAR. If there is time left in the time slot (i.e., the sum of the traffic sent as CAR was < 1 Gigabit), the algorithm returns to deal with each rate shaper that has a burst-rate. The algorithm inspects the queue for packets (the CAR and burst-rate share the same queue). If any packets are present, the algorithm transmits them as long as the total traffic sent by both the CAR and the burst-rate of the shaper does not exceed the port's throughput.

For example, assume that the time interval for scheduling is 1 second. ASM rate-shaper **Shape1** is configured as having a CAR = 600 Mbps, and no burst-rate. ASM rate-shaper **Shape2** is configured with a CAR = 400 Mbps and a burst-rate = 800 Mbps.

In the first interval:

- **Shape1**'s queue is filling up at 600 Mbps – It sends out 600 Mbits of CAR and nothing more
- **Shape2**'s queue is filling up at 800 Mbps – It sends out 400 Mbits of CAR; it cannot send out any more because there is no excess bandwidth available

In the second interval:

- **Shape1**'s queue is filling up at 100 Mbps – It sends out only 100 Mbits of CAR, and 500 Mbits is unused
- **Shape2**'s queue is filling up at 1000 Mbps – It sends out 400 Mbits of CAR. Since **Shape1** did not use all of its CAR, there is 500 Mbps of excess bandwidth remaining. However, **Shape2** cannot use all 500Mbps of the remaining bandwidth; it is allowed to burst only up to 800 Mbps, and so its sends out 400 Mbits to reach its burst-rate and then stops.

In the second time interval, **Shape2** sent 400 Mbps of CAR and another 400 Mbits of burst-rate to reach its peak of 800 Mbps

Rate-Shape Groups

Rate-shape groups are used to collectively assign a set of rate-shapers to be associated with a unique entity, such as a customer or set of users. For example, a customer needs 10^6 bps for data traffic and 10^4 bps for voice traffic. In this case, notice that voice and data require significantly different rate-shape handling, and each will each require its own rate-shaper. Groups, however, allow the creation of an association between these rate-shapers that identifies them for the same customer, and provides a common burst-rate for both rate-shapers.

Note One to 8 rate-shapers can be grouped together in a shaper group and up to 128 shaper groups can be configured in each direction of each port.

Assume that traffic for this customer is on VLAN 100. The following shows how the rate shapers and group are created and applied.

1. Create the ASM rate-shaper for data traffic

```
rs(config)# service r1 create rate-shape asm rate 1000000 buffer 150
```

Because rate-shaper **r1** is used for data, it can handle the delay that might come with a slightly larger buffer, which is set to 150 milliseconds.

2. Create the ASM rate-shaper for voice traffic:

```
rs(config)# service r2 create rate-shape asm rate 10000 buffer 50
```

Because rate-shaper **r2** is used for voice, it requires a smaller buffer to avoid delay in the signal; the buffer is set to 50 milliseconds.

3. Create the ASM group, "**customer1**" to which **r1** and **r2** will be applied:

```
rs(config)# service customer1 create rate-shape asm-group rate 10000000
```

Use the **service show rate-shape asm-group** command from Enable mode to view the group and its group rate:

```
rs# service show rate-shape asm-group customer1

Service Name    Rate
--------------- ----------
customer1       10000000
```

Note Individual rate-shaper burst-rates become inactive when applied to a group. The group rate acts as a collective burst-rate for the rate-shapers. In the example in step 3 (above), the group rate (collective burst-rate) is set to 10^7 bps.

4. Assign the ASM rate-shapers to the ASM group:

```
rs(config)# service r1 apply rate-shape asm asm-group customer1 output one-p-priority
1 port gi.11.1 vlan 100
rs(config)# service r2 apply rate-shape asm asm-group customer1 output one-p-priority
7 port gi.11.1 vlan 100
```

Notice that the traffic that each rate-shaper is responsible for is defined by its 802.1P priority within VLAN 100.

Use the to **`service show asm rate-shape all applied`** command from Enable mode to see the rate-shapers contained within each ASM group. For example:

```
rs# service show rate-shape asm all applied
Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
r1              1000000    1000000    150ms (    18K) None        (  0/  0)

  Ports         : gi.11.1
  Type          : Input              ACL Name      : r1_acl_5
  Group Name    : (2) customer1
  Priority      : D                  POE           : None
  VLAN          : 100                802.1P        : 1
  Packet In     : 0                  Byte In       : 0
  Packet Out    : 0                  Byte Out      : 0
  Packet Drop   : 0                  Byte Drop     : 0
  Packet Exceed : 0                  Queue Used    : 0%

Service Name    Rate       Burst      Buffer          Rewrite Action
--------------- ---------- ---------- --------------- ------------------------
r2              10000      10000       50ms (     2K) None        (  0/  0)

  Ports         : gi.11.1
  Type          : Input              ACL Name      : r2_acl_5
  Group Name    : (2) customer1
  Priority      : D                  POE           : None
  VLAN          : 100                802.1P        : 7
  Packet In     : 0                  Byte In       : 0
  Packet Out    : 0                  Byte Out      : 0
  Packet Drop   : 0                  Byte Drop     : 0
  Packet Exceed : 0                  Queue Used    : 0%
```

In the example above, notice that rate-shapers **`r1`** and **`r2`** are shown as belonging to ASM group **`customer1`**, and that each rate shaper has a different 802.1P priority. Also notice that the burst rate shown for each rate-shaper does not reflect their burst rate within the ASM group. While working as a member of group **`customer1`**, the rate-shaper's burst rate is the ASM group rate (10^7 bps in this case).

Group-Rate Example

The following is an example of how rate-shapers within an ASM group interact with the group's rate.

- ASM rate-shapers **Shape1** and **Shape2** are assigned to the group **Group1**. Assume that the time interval for scheduling is 1 second, and **Shape1** has a CAR of 100 Mbps, **Shape2** has a CAR of 150 Mbps, and **Group1** has a Group Access Rate (GAR) of 300 Mbps

In the first interval:

- **Shape1**'s queue is filling up at 100 Mbps – It sends out 100 Mbits of CAR and nothing more
- **Shape2**'s queue is filling up at 200 Mbps – It sends out 150 Mbits of CAR

Therefore, the group GAR used by **Group1** is 250 Mbps

In the second interval:

- **Shape1**'s queue is filling up at 50 Mbps – It sends out 50 Mbits of CAR and 50 Mbits is unused
- **Shape2**'s queue is filling up at 200 Mbps – It sends out 150 Mbits of CAR

Since **Shape1** did not use all of its CAR, there is 50 Mbps of bandwidth remaining. **Shaper2** sends out 50 Mbits to reach the GAR and then stops. So in the second time interval, **Shape2** sent 150 Mbps of CAR and another 50 Mbits of excess traffic, leaving 250 Mbps unused.

33.6 USING THE DIFFSERV MIB MODULE TO CONFIGURE SERVICES

When you use the **service** commands to configure rate limiting, these commands create entries in the Rate Limit MIB tables. In addition, you can also configure rate limiting from an SNMP management station. To do so, you configure data paths using the Differentiated Services (DiffServ) MIB module (RFC 2475). Following is a list of the supported data paths:

- DataPathStart->Classify->Meter
- DataPathStart->Classify->Meter->Action
- DataPathStart->Classify1->Meter->Action
  - ->Classify2->Meter->Action
  - ->Classify3->Meter->Action
  - ->Classify4->Meter->Action

Following is a list of the DiffServ MIB module tables that are used:

- diffServDataPathTable
- diffServClfrTable
- diffServClfrElementTable
- diffServMeterTable
- diffServActionTable
- diffServDscpMarkAcTable

The data paths result in equivalent entries in the following Rate Limit MIB module (RSTONE-RL-MIB.txt) tables:

- rsTBMeterTable
- rsTBMeterApplyTable
- rsPortRLTable

Once the entries in the Rate Limit MIB module tables are made, their corresponding **service** commands are added to the RS configuration file. The following table lists the Rate Limit tables and their equivalent CLI **service** commands.

Table 33-8 Rate limit tables and their corresponding service commands

Rate Limit Table	CLI command
rsTBMeterTable	**service** <*name*> **create rate-limit aggregate** **service** <*name*> **create rate-limit burst-safe** **service** <*name*> **create rate-limit flow-aggregate** **service** <*name*> **create rate-limit per-flow**
rsTBMeterApplyTable	**service** <*name*> **apply rate-limit acl**
rsPortRLTable	**service** <*name*> **create rate-limit input-port-level** **service** <*name*> **create rate-limit output-port-level**

DiffServMIB Implementation Limitations

This implementation has the following limitations:

1. On diffServ MIBs, only createAndGo(4), and destroy(6) are implemented.
2. To connect the DataPathStart row to the other elements, such as classifier, meter, action, etc., all the rows in the respective tables must be active.

33.6.1 Configuration Example

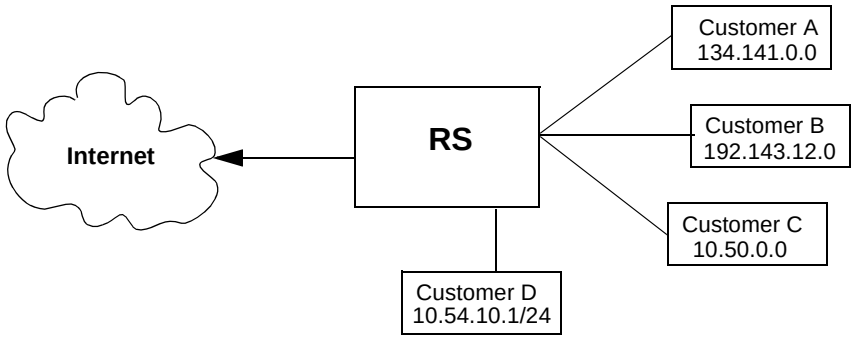
This example shows how you can configure DiffServ data paths using the DiffServ MIB module from an SNMP management station. It also shows how the corresponding CLI commands are added to the active configuration file.

There are four customers (A, B, C, and D) with different service level agreements:

- Customer A requires the gold policy all day, everyday.
- Customer B requires the silver policy from 9 am - 6 pm on weekdays.
- Customer C requires the bronze policy from 9 am - 6 pm on weekdays.
- Customer D requires the httpMeter policy all day, everyday.

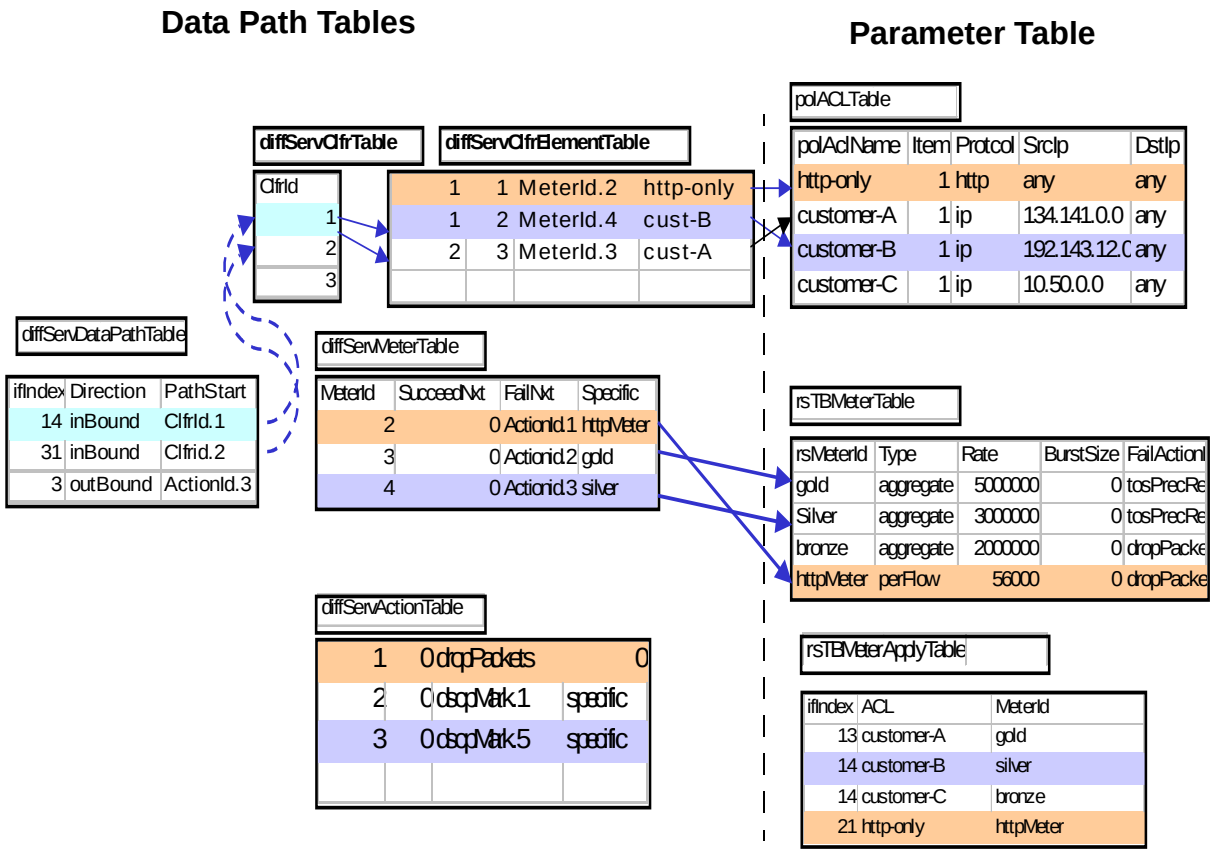
Each policy pertains to a particular rate limiting service:

- The **GOLD** policy is an aggregate rate limiting service that limits the aggregation of flows to 5 Mbps. If the traffic exceeds the limit, the ToS precedence of the packets will be set to 1.
- The **SILVER** policy is an aggregate rate limiting service that limits the aggregation of flows to 3 Mbps. If the traffic exceeds the limit, the ToS precedence of the packets will be set to 5.
- The **BRONZE** policy is an aggregate rate limiting service that limits the aggregation of flows to 2 Mbps. Traffic that exceeds the limit will be dropped.
- The **httpMETER** policy is a per-flow rate limiting service that limits each flow to 56 Kbps.



Customers A, B, and C are connected to the RS through port gi.7.2. Customer D is connected to the IP interface *custD*, on port et.3.1.

The following diagram illustrates the data path configuration for the rate liming services in the example:



Following is the initial configuration of the router:

```
rs(config)# show
Running system configuration:
     !
     ! Last modified from SNMP on 2001-07-18 13:41:36
     !
1: snmp set community public privilege read-write
 2 : vlan create customer id 50 ip
 3 : vlan enable l4-bridging on customer
 4 : vlan add ports gi.7.1 to customer
 5 : vlan add ports gi.7.2 to customer
     !
 6 : interface create ip custD address-netmask 10.54.10.1/24 port et.3.1
 7 : interface add ip en0 address-netmask 10.50.7.1/24
     !
 8 : acl http-only permit ip-protocol 80 any
 9 : acl customer-A permit ip 134.141.0.0 any
10 : acl customer-B permit ip 192.143.11.0 any
11 : acl customer-C permit ip 10.50.0.0/16 any
     !
12 : system enable aggregate-rate-limiting slot 7

rs(config)#
```

Following is the script an SNMP management application would use to create the data paths:

```
#service gold create rate-limit aggregate rate 5000000 no-action
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
rsTBMeterType.4.103.111.108.100 -i 3 \
rsTBMeterRate.4.103.111.108.100 -g 5000000 \
rsTBMeterStatus.4.103.111.108.100 -i 4

#service bronze create rate-limit aggregate rate 2000000 no-action
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
rsTBMeterType.6.98.114.111.110.122.101 -i 3 \
rsTBMeterRate.6.98.114.111.110.122.101 -g 2000000 \
rsTBMeterStatus.6.98.114.111.110.122.101 -i 4

#service silver create rate-limit aggregate rate 3000000 no-action
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
rsTBMeterType.6.115.105.108.118.101.114 -i 3 \
rsTBMeterRate.6.115.105.108.118.101.114 -g 3000000 \
rsTBMeterStatus.6.115.105.108.118.101.114 -i 4

#service httpMeter create rate-limit per-flow rate 56000
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
rsTBMeterType.9.104.116.116.112.77.101.116.101.114 -i 1 \
rsTBMeterRate.9.104.116.116.112.77.101.116.101.114 -g 56000 \
rsTBMeterStatus.9.104.116.116.112.77.101.116.101.114 -i 4

echo "Creating diffServActionEntry.8 with absoluteDrop(3)"
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionType.8 -i 3 \
diffServActionStatus.8 -i 4

echo "Creating diffServActionEntry.7 with Dscp = 5"
#1.3.6.1.2.1.12345.1.4.3.1.1 ==diffServDscpMark.5
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionSpecific.7 -d "1.3.6.1.2.1.12345.1.4.3.1.1.5" \
diffServActionType.7 -i 2 \
diffServActionStatus.7 -i 4

echo "Creating diffServActionEntry. with Dscp = 1"
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionSpecific.9 -d "1.3.6.1.2.1.12345.1.4.3.1.1.1" \
    diffServActionType.9 -i 2 \
  diffServActionStatus.9 -i 4

echo "Creating diffServMeterEntry.2 specific:bronze Fail next drop packets"
setany -v2c 10.50.7.1 \
diffServMeterFailNext.2 -d "1.3.6.1.2.1.12345.1.4.2.1.2.8" \
diffServMeterSpecific.2 -d "1.3.6.1.4.1.5567.2.25.5.4.1.2.6.98.114.111.110.122.101" \
diffServMeterStatus.2 -i 4
echo "Creating diffServMeterEntry.4 specific:silver: FailNext Mark with Dscp 5"
setany -v2c 10.50.7.1 \
diffServMeterFailNext.4 -d "1.3.6.1.2.1.12345.1.4.2.1.2.7" \
diffServMeterSpecific.4 -d "1.3.6.1.4.1.5567.2.25.5.4.1.2.6.115.105.108.118.101.114" \
diffServMeterStatus.4 -i 4
```

```
echo "Creating diffServMeterEntry.5 specific:gold: FailNext Mark with Dscp 1"
setany -v2c 10.50.7.1 \
diffServMeterFailNext.5 -d "1.3.6.1.2.1.12345.1.4.2.1.2.9" \
diffServMeterSpecific.5 -d "1.3.6.1.4.1.5567.2.25.5.4.1.2.4.103.111.108.100" \
diffServMeterStatus.5 -i 4

echo "Creating diffServMeterEntry.3 specific:httpMeter: Fail next drop packets"
setany -v2c 10.50.7.1 \
diffServMeterFailNext.3 -d "1.3.6.1.2.1.12345.1.4.2.1.2.8" \
diffServMeterSpecific.3 -d "rsTBMeterType.9.104.116.116.112.77.101.116.101.114" \
diffServMeterStatus.3 -i 4

echo "Creating diffServClfrEntry.2"
setany -v2c 10.50.7.1 \
diffServClfrStatus.2 -i 4

echo "Creating diffServClfrEntry.3"
setany -v2c 10.50.7.1 \
diffServClfrStatus.3 -i 4

#service gold5:10: create rate-limit aggregate rate 5000000 tos-precedence-rewrite 1
time-select 4
#echo "Creating diffServClfrElementEntry.2.1 with specific ACL Customer-A Next: meter
gold"
setany -v2c 10.50.7.1 \
diffServClfrElementSpecific.2.1 -d
"1.3.6.1.4.1.52.2501.1.12.4.1.3.10.99.117.115.116.111.109.101.114.45.65.1" \
diffServClfrElementNext.2.1 -d "1.3.6.1.2.1.12345.1.3.2.1.2.5" \
diffServClfrElementStatus.2.1 -i 4

#service bronze2:2: create rate-limit aggregate rate 2000000 drop-packets time-select
5
echo "Creating diffServClfrElementEntry.2.2 with specific ACL Customer-C Next: meter
bronze"
setany -v2c 10.50.7.1 \
diffServClfrElementSpecific.2.2 -d
"1.3.6.1.4.1.52.2501.1.12.4.1.3.10.99.117.115.116.111.109.101.114.45.67.1" \
diffServClfrElementNext.2.2 -d "1.3.6.1.2.1.12345.1.3.2.1.2.2" \
diffServClfrElementStatus.2.2 -i 4

#service silver4:10: create rate-limit aggregate rate 3000000 tos-precedence-rewrite 5
time-select 5
echo "Creating diffServClfrElementEntry.2.3 with specific ACL Customer-B Next:meter
Silver"
setany -v2c 10.50.7.1 \
diffServClfrElementSpecific.2.3 -d
"1.3.6.1.4.1.52.2501.1.12.4.1.3.10.99.117.115.116.111.109.101.114.45.66.1" \
diffServClfrElementNext.2.3 -d "1.3.6.1.2.1.12345.1.3.2.1.2.4" \
diffServClfrElementStatus.2.3 -i 4
```

```
#service httpMeter3:2: create rate-limit per-flow rate 56000 exceed-action
drop-packets time-select 7
echo "Creating diffServClfrElementEntry.3.1 with specific ACL http-only Next:meter
httpMeter"
setany -v2c 10.50.7.1 \
diffServClfrElementSpecific.3.1 -d
"1.3.6.1.4.1.52.2501.1.12.4.1.3.9.104.116.116.112.45.111.110.108.121.1" \
diffServClfrElementNext.3.1 -d "1.3.6.1.2.1.12345.1.3.2.1.2.3" \
diffServClfrElementStatus.3.1 -i 4

#diffServClfrStatus.2 =1.3.6.1.2.1.12345.1.2.2.1.2.2
echo "Creating diffServDataPathEntry.31.2"

#service httpMeter create rate-limit per-flow rate 56000

#service gold5:10: apply rate-limit acl customer-A port gi.7.2
#service bronze2:2: apply rate-limit acl customer-C port gi.7.2
#service silver4:10: apply rate-limit acl customer-B port gi.7.2
#gi.7.2 =14
setany -v2c 10.50.7.1 \
diffServDataPathStart.14.1 -d "1.3.6.1.2.1.12345.1.2.2.1.2.2" \
diffServDataPathStatus.14.1 -i 4

#service httpMeter3:2: apply rate-limit acl http-only interface custD
#custD = 14
setany -v2c 10.50.7.1 \
diffServDataPathStart.20.1 -d "1.3.6.1.2.1.12345.1.2.2.1.2.3" \
diffServDataPathStatus.20.1 -i 4
```

Following is the script content which displays the related DiffServ tables:

```
---start here,script(getmaster) to display all snmp table-
echo "=========rsTBMeterEntry=============="
getmany 10.50.7.1 rsTBMeterEntry
echo "=========rsTBMeterApplyEntry=============="
getmany 10.50.7.1 rsTBMeterApplyEntry
echo "=========diffServDataPathEntry=============="
getmany 10.50.7.1 diffServDataPathEntry
echo "=========diffServClfrEntry=============="
getmany 10.50.7.1 diffServClfrEntry
echo "=========diffServClfrElementEntry=============="
getmany 10.50.7.1 diffServClfrElementEntry
echo "=========diffServMeterEntry=============="
getmany 10.50.7.1 diffServMeterEntry
echo "=========diffServActionEntry=============="
getmany 10.50.7.1 diffServActionEntry
#getmany 10.50.7.1 diffServDscpMarkActEntry
---end here
```

Following is the result:

```
::demo1> getmaster
=========rsTBMeterEntry==============
=========rsTBMeterApplyEntry==============
=========diffServDataPathEntry==============
=========diffServClfrEntry==============
=========diffServClfrElementEntry==============
=========diffServMeterEntry==============
=========diffServActionEntry==============
::demo1>
```

Following is what happens when you execute the script:

```
abc:/home/demo1> masterScript
rsTBMeterType.4.103.111.108.100 = hardwareFlowAggregate(3)
rsTBMeterRate.4.103.111.108.100 = 5000000
rsTBMeterStatus.4.103.111.108.100 = createAndGo(4)
rsTBMeterType.6.98.114.111.110.122.101 = hardwareFlowAggregate(3)
rsTBMeterRate.6.98.114.111.110.122.101 = 2000000
rsTBMeterStatus.6.98.114.111.110.122.101 = createAndGo(4)
rsTBMeterType.6.115.105.108.118.101.114 = hardwareFlowAggregate(3)
rsTBMeterRate.6.115.105.108.118.101.114 = 3000000
rsTBMeterStatus.6.115.105.108.118.101.114 = createAndGo(4)
rsTBMeterType.9.104.116.116.112.77.101.116.101.114 = perFlow(1)
rsTBMeterRate.9.104.116.116.112.77.101.116.101.114 = 56000
rsTBMeterStatus.9.104.116.116.112.77.101.116.101.114 = createAndGo(4)
Creating diffServActionEntry.8 with absoluteDrop(3)
diffServActionType.8 = absoluteDrop(3)
diffServActionStatus.8 = createAndGo(4)
Creating diffServActionEntry.7 with Dscp = 5
diffServActionSpecific.7 = diffServDscpMarkActDscp.5
diffServActionType.7 = specific(2)
diffServActionStatus.7 = createAndGo(4)
Creating diffServActionEntry. with Dscp = 1
diffServActionSpecific.9 = diffServDscpMarkActDscp.1
diffServActionType.9 = specific(2)
diffServActionStatus.9 = createAndGo(4)
Creating diffServMeterEntry.2 specific:bronze Fail next drop packets
diffServMeterFailNext.2 = diffServActionNext.8
diffServMeterSpecific.2 = rsTBMeterType.6.98.114.111.110.122.101
diffServMeterStatus.2 = createAndGo(4)
Creating diffServMeterEntry.4 specific:silver: FailNext Mark with Dscp 5
diffServMeterFailNext.4 = diffServActionNext.7
diffServMeterSpecific.4 = rsTBMeterType.6.115.105.108.118.101.114
diffServMeterStatus.4 = createAndGo(4)
Creating diffServMeterEntry.5 specific:gold: FailNext Mark with Dscp 1
diffServMeterFailNext.5 = diffServActionNext.9
diffServMeterSpecific.5 = rsTBMeterType.4.103.111.108.100
diffServMeterStatus.5 = createAndGo(4)
Creating diffServMeterEntry.3 specific:httpMeter: Fail next drop packets
diffServMeterFailNext.3 = diffServActionNext.8
diffServMeterSpecific.3 = rsTBMeterType.9.104.116.116.112.77.101.116.101.114
diffServMeterStatus.3 = createAndGo(4)
Creating diffServClfrEntry.2
diffServClfrStatus.2 = createAndGo(4)
Creating diffServClfrEntry.3
diffServClfrStatus.3 = createAndGo(4)
diffServClfrElementSpecific.2.1 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.65.1
diffServClfrElementNext.2.1 = diffServMeterSucceedNext.5
diffServClfrElementStatus.2.1 = createAndGo(4)
Creating diffServClfrElementEntry.2.2 with specific ACL Customer-C Next: meter bronze
diffServClfrElementSpecific.2.2 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.67.1
diffServClfrElementNext.2.2 = diffServMeterSucceedNext.2
diffServClfrElementStatus.2.2 = createAndGo(4)
```

```
Creating diffServClfrElementEntry.2.3 with specific ACL Customer-B Next:meter
Silver
diffServClfrElementSpecific.2.3 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.66.1
diffServClfrElementNext.2.3 = diffServMeterSucceedNext.4
diffServClfrElementStatus.2.3 = createAndGo(4)
Creating diffServClfrElementEntry.3.1 with specific ACL http-only Next:meter
httpMeter
diffServClfrElementSpecific.3.1 =
polAclRestriction.9.104.116.116.112.45.111.110.108.121.1
diffServClfrElementNext.3.1 = diffServMeterSucceedNext.3
diffServClfrElementStatus.3.1 = createAndGo(4)
Creating diffServDataPathEntry.31.2
diffServDataPathStart.14.1 = diffServClfrStatus.2
diffServDataPathStatus.14.1 = createAndGo(4)
diffServDataPathStart.20.1 = diffServClfrStatus.3
diffServDataPathStatus.20.1 = createAndGo(4)
```

Following is the CLI configuration file after the master script is executed:

```
rs(config)# show
Running system configuration:
     !
     ! Last modified from SNMP on 2001-07-18 13:51:09
     !
 1 : snmp set community public privilege read-write
     !
 2 : vlan create customer id 50 ip
 3 : vlan enable l4-bridging on customer
 4 : vlan add ports gi.7.1 to customer
 5 : vlan add ports gi.7.2 to customer
     !
 6 : interface create ip custD address-netmask 10.54.10.1/24 port et.3.1
 7 : interface add ip en0 address-netmask 10.50.7.1/24
     !
 8 : acl http-only permit ip-protocol 80 any
 9 : acl customer-A permit ip 134.141.0.0 any
10 : acl customer-B permit ip 192.143.12.0 any
11 : acl customer-C permit ip 10.50.0.0/16 any
     !
12 : system enable aggregate-rate-limiting slot 7
!
13V: service httpMeter create rate-limit per-flow rate 56000
14 : service httpMeter3:2: create rate-limit per-flow rate 56000 exceed-action
drop-packets time-select 7
15V: service gold create rate-limit aggregate rate 5000000 no-action
16V: service bronze create rate-limit aggregate rate 2000000 no-action
17V: service silver create rate-limit aggregate rate 3000000 no-action
18: service bronze2:2: create rate-limit aggregate rate 2000000 drop-packets
time-select 5
19: service silver4:10: create rate-limit aggregate rate 3000000
tos-precedence-rewrite 5 time-select 5
20 : service gold5:10: create rate-limit aggregate rate 5000000
tos-precedence-rewrite 1 time-select 4
21 : service gold5:10: apply rate-limit acl customer-A port gi.7.2
22 : service bronze2:2: apply rate-limit acl customer-C port gi.7.2
23 : service silver4:10: apply rate-limit acl customer-B port gi.7.2
24 : service httpMeter3:2: apply rate-limit acl http-only interface custD
     !
```

Following are the SNMP tables after the scripts were executed:

```
getmaster

=========diffServDataPathEntry==============
diffServDataPathStart.14.1 = diffServClfrStatus.2
diffServDataPathStart.20.1 = diffServClfrStatus.3
diffServDataPathStatus.14.1 = active(1)
diffServDataPathStatus.20.1 = active(1)

=========diffServClfrEntry==============
diffServClfrStatus.2 = active(1)
diffServClfrStatus.3 = active(1)

=========diffServClfrElementEntry==============
diffServClfrElementOrder.2.1 = 0
diffServClfrElementOrder.2.2 = 0
diffServClfrElementOrder.2.3 = 0
diffServClfrElementOrder.3.1 = 0
diffServClfrElementNext.2.1 = diffServMeterSucceedNext.5
diffServClfrElementNext.2.2 = diffServMeterSucceedNext.2
diffServClfrElementNext.2.3 = diffServMeterSucceedNext.4
diffServClfrElementNext.3.1 = diffServMeterSucceedNext.3
diffServClfrElementSpecific.2.1 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.65.1
diffServClfrElementSpecific.2.2 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.67.1
diffServClfrElementSpecific.2.3 =
polAclRestriction.10.99.117.115.116.111.109.101.114.45.66.1
diffServClfrElementSpecific.3.1 =
polAclRestriction.9.104.116.116.112.45.111.110.108.121.1
diffServClfrElementStatus.2.1 = active(1)
diffServClfrElementStatus.2.2 = active(1)
diffServClfrElementStatus.2.3 = active(1)
diffServClfrElementStatus.3.1 = active(1)
=========diffServMeterEntry==============
diffServMeterSucceedNext.2 = zeroDotZero
diffServMeterSucceedNext.3 = zeroDotZero
diffServMeterSucceedNext.4 = zeroDotZero
diffServMeterSucceedNext.5 = zeroDotZero
diffServMeterFailNext.2 = diffServActionNext.8
diffServMeterFailNext.3 = diffServActionNext.8
diffServMeterFailNext.4 = diffServActionNext.7
diffServMeterFailNext.5 = diffServActionNext.9
diffServMeterSpecific.2 = rsTBMeterType.6.98.114.111.110.122.101
diffServMeterSpecific.3 = rsTBMeterType.9.104.116.116.112.77.101.116.101.114
diffServMeterSpecific.4 = rsTBMeterType.6.115.105.108.118.101.114
diffServMeterSpecific.5 = rsTBMeterType.4.103.111.108.100
diffServMeterStatus.2 = active(1)
diffServMeterStatus.3 = active(1)
diffServMeterStatus.4 = active(1)
diffServMeterStatus.5 = active(1)
```

:

```
=========diffServActionEntry==============
diffServActionNext.7 = zeroDotZero
diffServActionNext.8 = zeroDotZero
diffServActionNext.9 = zeroDotZero
diffServActionSpecific.7 = diffServDscpMarkActDscp.5
diffServActionSpecific.8 = zeroDotZero
diffServActionSpecific.9 = diffServDscpMarkActDscp.1
diffServActionType.7 = specific(2)
diffServActionType.8 = absoluteDrop(3)
diffServActionType.9 = specific(2)
diffServActionStatus.7 = active(1)
diffServActionStatus.8 = active(1)
diffServActionStatus.9 = active(1)
```

You can delete the data paths configured by the master script. Following is an example:

```
abc:/home/demo1> cat masterExciteDel
cat masterExciteDel
echo "Deleting diffServDataPathEntry.gi.7.2"
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
diffServDataPathStatus.14.1 -i 6

echo "Deleting diffServDataPathEntry.custA"
setany -v2c -timeout 1000 -retries 0 10.50.7.1 \
diffServDataPathStatus.20.1 -i 6

echo "Deleting diffServMeterEntry.2"
setany -v2c 10.50.7.1 \
diffServMeterStatus.2 -i 6

echo "Deleting diffServMeterEntry.4"
setany -v2c 10.50.7.1 \
diffServMeterStatus.4 -i 6

echo "Deleting diffServMeterEntry.5"
setany -v2c 10.50.7.1 \
diffServMeterStatus.5 -i 6

echo "Deleting diffServMeterEntry.3"
setany -v2c 10.50.7.1 \
diffServMeterStatus.3 -i 6

echo "Deleting rsTBMeterEntry.bronze"
setany 10.50.7.1 rsTBMeterStatus.6.98.114.111.110.122.101 -i 6

echo "Deleting rsTBMeterEntry.gold"
setany 10.50.7.1 rsTBMeterStatus.4.103.111.108.100 -i 6

echo "Deleting rsTBMeterEntry.silver"
setany 10.50.7.1 rsTBMeterStatus.6.115.105.108.118.101.114 -i 6

echo "Deleting rsTBMeterEntry.httpMeter"
setany 10.50.7.1 rsTBMeterStatus.9.104.116.116.112.77.101.116.101.114 -i 6

#General Drop Action
echo "Deleting diffServActionEntry.8"
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionStatus.8 -i 6

echo "Deleting diffServActionEntry.7"
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionStatus.7 -i 6

echo "Deleting diffServActionEntry.9"
setany -v2c -timeout 10000 -retries 0 10.50.7.1 \
diffServActionStatus.9 -i 6
```

:

```
echo "Deleting diffServClfrElementEntry.2.1"
setany -v2c 10.50.7.1 \
diffServClfrElementStatus.2.1 -i 6
echo "Deleting diffServClfrElementEntry.2.2"
setany -v2c 10.50.7.1 \
diffServClfrElementStatus.2.2 -i 6

echo "Deleting diffServClfrElementEntry.2.3"

setany -v2c 10.50.7.1 \
diffServClfrElementStatus.2.3 -i 6

echo "Deleting diffServClfrElementEntry.3.1"
setany -v2c 10.50.7.1 \
diffServClfrElementStatus.3.1 -i 6


echo "Deleting diffServClfrEntry.2"
setany -v2c 10.50.7.1 \
diffServClfrStatus.2 -i 6

echo "Deleting diffServClfrEntry.3"
setany -v2c 10.50.7.1 \
diffServClfrStatus.3 -i 6
```

Following is what happens when you delete the data paths:

```
abc:/home/demo1> masterExciteDel
Deleting diffServDataPathEntry.gi.7.2
diffServDataPathStatus.14.1 = destroy(6)
Deleting diffServDataPathEntry.custA
diffServDataPathStatus.20.1 = destroy(6)
Deleting diffServMeterEntry.2
diffServMeterStatus.2 = destroy(6)
Deleting diffServMeterEntry.4
diffServMeterStatus.4 = destroy(6)
Deleting diffServMeterEntry.5
diffServMeterStatus.5 = destroy(6)
Deleting diffServMeterEntry.3
diffServMeterStatus.3 = destroy(6)
Deleting rsTBMeterEntry.bronze
rsTBMeterStatus.6.98.114.111.110.122.101 = destroy(6)
Deleting rsTBMeterEntry.gold
rsTBMeterStatus.4.103.111.108.100 = destroy(6)
Deleting rsTBMeterEntry.silver
rsTBMeterStatus.6.115.105.108.118.101.114 = destroy(6)
Deleting rsTBMeterEntry.httpMeter
rsTBMeterStatus.9.104.116.116.112.77.101.116.101.114 = destroy(6)
Deleting diffServActionEntry.8
diffServActionStatus.8 = destroy(6)
Deleting diffServActionEntry.7
diffServActionStatus.7 = destroy(6)
Deleting diffServActionEntry.9
diffServActionStatus.9 = destroy(6)
Deleting diffServClfrElementEntry.2.1
diffServClfrElementStatus.2.1 = destroy(6)
Deleting diffServClfrElementEntry.2.2
diffServClfrElementStatus.2.2 = destroy(6)
Deleting diffServClfrElementEntry.2.3
diffServClfrElementStatus.2.3 = destroy(6)
Deleting diffServClfrElementEntry.3.1
diffServClfrElementStatus.3.1 = destroy(6)
Deleting diffServClfrEntry.2
diffServClfrStatus.2 = destroy(6)
Deleting diffServClfrEntry.3
diffServClfrStatus.3 = destroy(6)
```

The configuration file after you deleted the data paths:

```
rs(config)# show
Running system configuration:
     !
     ! Last modified from SNMP on 2001-07-18 14:01:25
     !
 1 : snmp set community public privilege read-write
     !
 2 : vlan create customer id 50 ip
 3 : vlan enable l4-bridging on customer
 4 : vlan add ports gi.7.1 to customer
 5 : vlan add ports gi.7.2 to customer
     !
 6 : interface create ip custD address-netmask 10.54.10.1/24 port et.3.1
 7 : interface add ip en0 address-netmask 10.50.7.1/24
     !
 8 : acl http-only permit ip-protocol 80 any
 9 : acl customer-A permit ip 134.141.0.0 any
10 : acl customer-B permit ip 192.143.12.0 any
11 : acl customer-C permit ip 10.50.0.0/16 any
     !
12 : system enable aggregate-rate-limiting slot 7

rs(config)#
```

Following are the tables after you deleted the data paths:

```
abc:/home/demo1> getmaster
=========diffServDataPathEntry==============
=========diffServClfrEntry==============
=========diffServClfrElementEntry==============
=========diffServMeterEntry==============
=========diffServActionEntry==============
abc:/home/demo/demo1>
```

34 SRP CONFIGURATION GUIDE

This chapter presents an overview and configuration examples of the Spatial Reuse Protocol (SRP) hardware. For a description of all commands that affect the SRP Interface boards, refer to the *SRP Commands* and *SONET Commands* chapters of the *Riverstone RS Switch Router Command Line Interface Reference Manual*.

34.1 PHYSICAL IMPLEMENTATION

SRP runs over a dual, counter-rotating ring topology at OC-48 speeds. Each SRP node on the ring can send and receive data and control traffic on either the inner or outer ring. Additionally, note that control traffic (Usage packets, Discovery packets, and so on) are sent point-to-point between adjacent nodes only.

An SRP interface is comprised of two physical line cards, line card (or side) A and line card (or side) B. Both line card A and B share a single MAC address. SRP line card pairs must reside within two RS 8000/8600 chassis slots that are vertically adjacent (see Figure 34-1). The two line cards are then connected together using a *bridge* module. Each line card is often referred to as the *mate* to the other line card.

Each physical port on each line card contains both a transmit and receive line. Within a multiple RS SRP ring, each SRP interface connects into the ring with side B's port connected to the next RS' side A port, and so on until the final B port of the final RS is connected to the original RS' A port. This essentially creates a *daisy-chain* connection among the RS switch routers. Figure 34-2 show a logical example of a four-node SRP ring, while Figure 34-3 shows the same four-node ring's physical topology. Figure 34-4 shows the ring relationship of the ports on each SRP line card to the rings on which they transmit and receive.

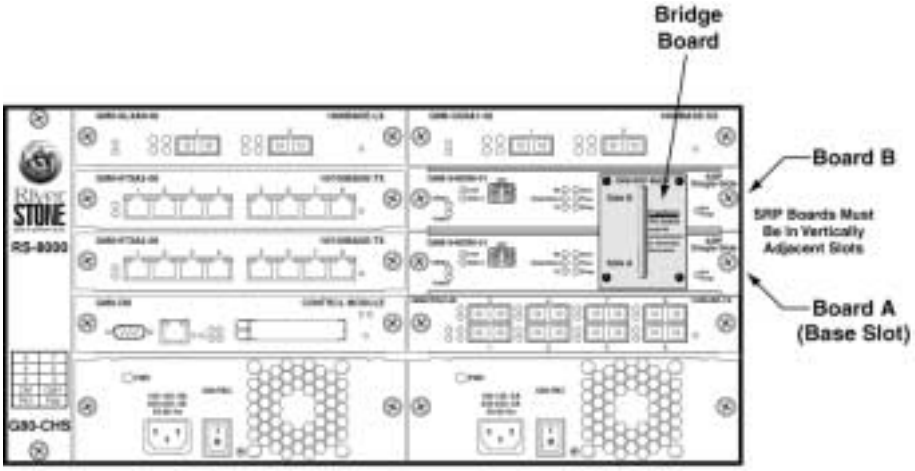


Figure 34-1 SRP boards in RS 8000 chassis

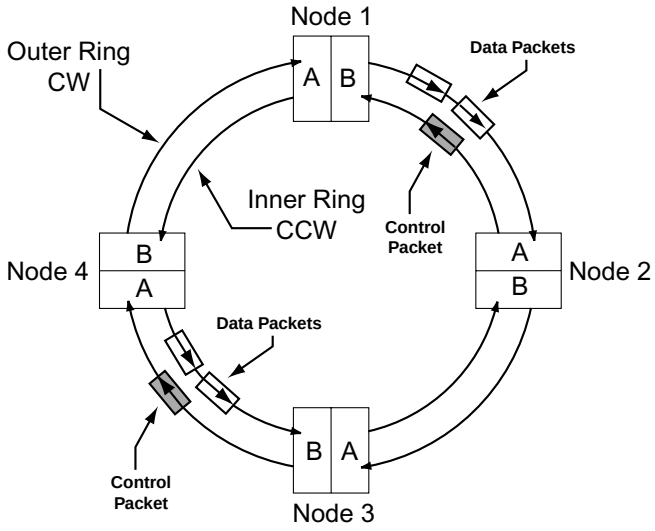


Figure 34-2 Four node SRP Counter-rotating ring logical topology

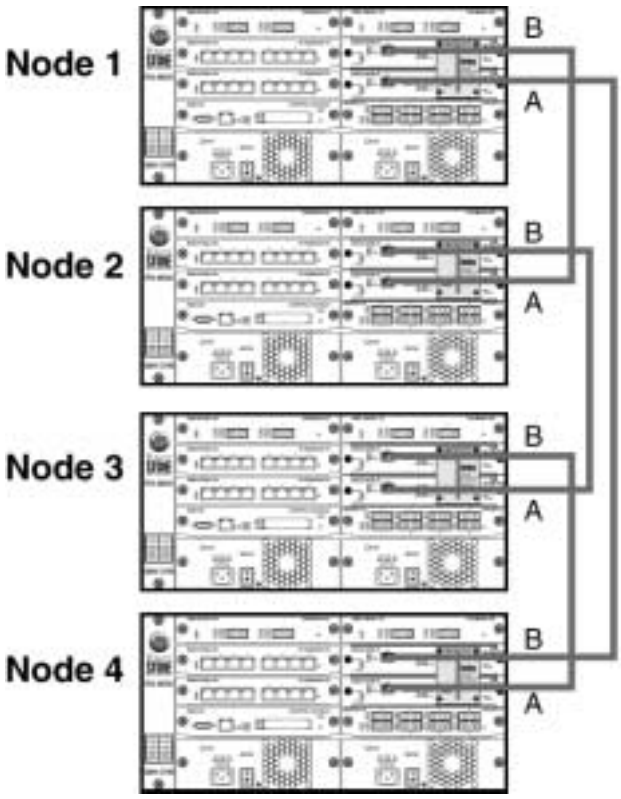


Figure 34-3 Four node SRP Counter-rotating ring physical topology

The connectors for side A are on the card in the lower-numbered slot and the side B connectors are on the card in the higher-numbered slot. Side A of the interface receives packets from the outer ring and transmits to the inner. Side B transmits packets to the outer ring and receives from the inner. Some of the **srp** and **sonet** commands allow the user to affect only one side of the SRP interface. The command syntax therefore includes the use of **.a** and **.b** suffixes to identify a specific side.

Notice in Figure 34-4 that SRP line card A does not correspond to one ring and SRP line card B does not correspond to the other ring. Instead, both rings are *split* (receive and transmit) between the fiber pairs that connect each SRP line card. The inner ring's receive is on SRP line card B and the inner ring's transmit is on SRP line card A. Corresponding, the outer ring's receive is on SRP line card A and the outer ring's transmit is on SRP line card B. The important idea to remember is that each fiber pair connecting two SRP line cards carries the transmit and receive of opposite rings.

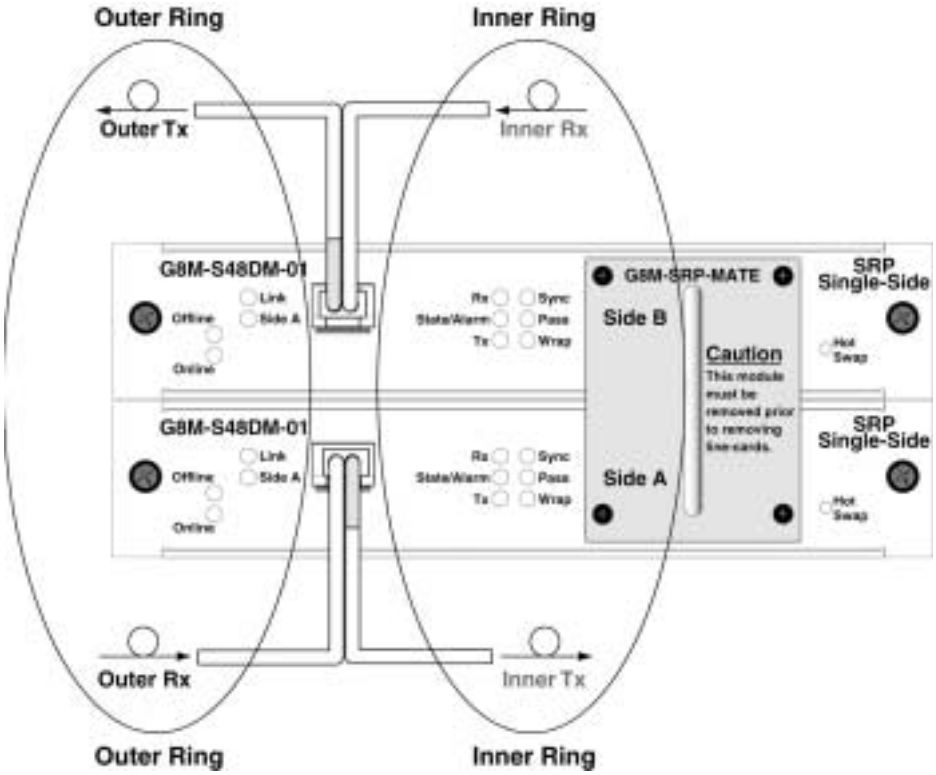


Figure 34-4 SRP ring relationship between cards A and B

The command **srp hw-module base-slot** <*ports*> **config dual-srp** is used to identify the card with Side A. Once the **srp hw-module base-slot** command executes, use the slot number containing Side A to identify the SRP interface when addressing it as a single entity. For example, in an RS 8000 chassis, if the card pair occupies slots 5 and 7, **sr.5.1** identifies the interface as a single entity, while **sr.5.1.a** identifies Side A of the interface and **sr.5.1.b** (not **sr.7.1.b**) identifies Side B of the interface.

The Riverstone SRP cards accept Small Form Factor Plug-able (SFP) transceivers. These SFPs provide a number of different tranmission distances.

34.2 SRP OVERVIEW

Spatial Reuse Protocol (SRP) is a MAC layer (layer-2) protocol that is defined in the RFC 2892 standards document titled: “The Cisco SRP MAC Layer Protocol.” The SRP protocol makes effective and efficient use of ring-based technologies. SRP runs over a bidirectional, dual counter-rotating ring topology much like FDDI. However, SRP does not suffer from the latency and bandwidth hit incurred by token passing. Furthermore, through the use of *destination node stripping*, unicast packets are removed from the ring by the destination node, and do not flood the rings. By using destination node packet stripping, the ring is not constantly circulating packets. This *asymmetry* in traffic allows SRP to claim *spacial* and *local reuse* of ring segments and bandwidth that are not currently being utilized.

Note Unlike unicast packets, SRP uses the same *source node stripping* strategy for multicast packets as do other ring-based protocols.

Additionally, during error conditions, SRP uses a Time To Live (TTL) counter within packets. A packet starts with a TTL count of 255. As packets circulate around a ring, each node decrements the packet’s TTL counter. When the packets TTL counter reaches 0, it is stripped from the ring. This prevents any packet from endlessly circulating through the ring. Considering that each node decrements the TTL counter, this sets a limit on the number of nodes on a wrapped ring to 128 nodes.

As with FDDI, SRP provides a mechanism for self-healing breaks in the ring. This healing capability is based on SRP’s Intelligent Protection Switching (IPS) protocol, and is accomplished by the *wrapping* of traffic back in the opposite direction by nodes adjacent to the break. SRP’s self-healing ability is extremely fast, occurring within less than 50 milliseconds. As a result, SRP experiences little data loss, even under severe conditions such as the loss of a node.

SRP has the ability to choose its optimal path to a particular node by choosing to send traffic on either the inner or outer ring. SRP decides the data path taken by data packets through the use of *topology discovery* packets. For example, consider the ring in Figure 34-2. Node 1 can reach node 4 by choosing the outer ring, which passes through node 2 and node 3. Alternately, Node 1 can reach node 4 through the inner ring – consisting of a path between adjacent nodes.

34.3 SRP INTERFACE

The following section describes the components of an SRP line card pair (an SRP interface).

34.3.1 SRP Interface Components

Each line card interface consists of the following main components:

- Framer for disassembling incoming SONET frames into packets and reassembling packets into SONET frames for transmission onto the rings.
- Transit buffer decision block, which determines whether the packets go to the transit buffer or to the receive buffer
- Lookup Content Addressable Memory (CAM) containing address information for this interface
- Low-priority transit buffer
- High-priority transit buffer
- Receive queue

- Transmit queue
- Connections to the layer-3 packet switching engine within the RS
- Bridge board connecting line card A with line card B

Figure 34-5 is a diagram of these SRP interface components and how they connect to one another.

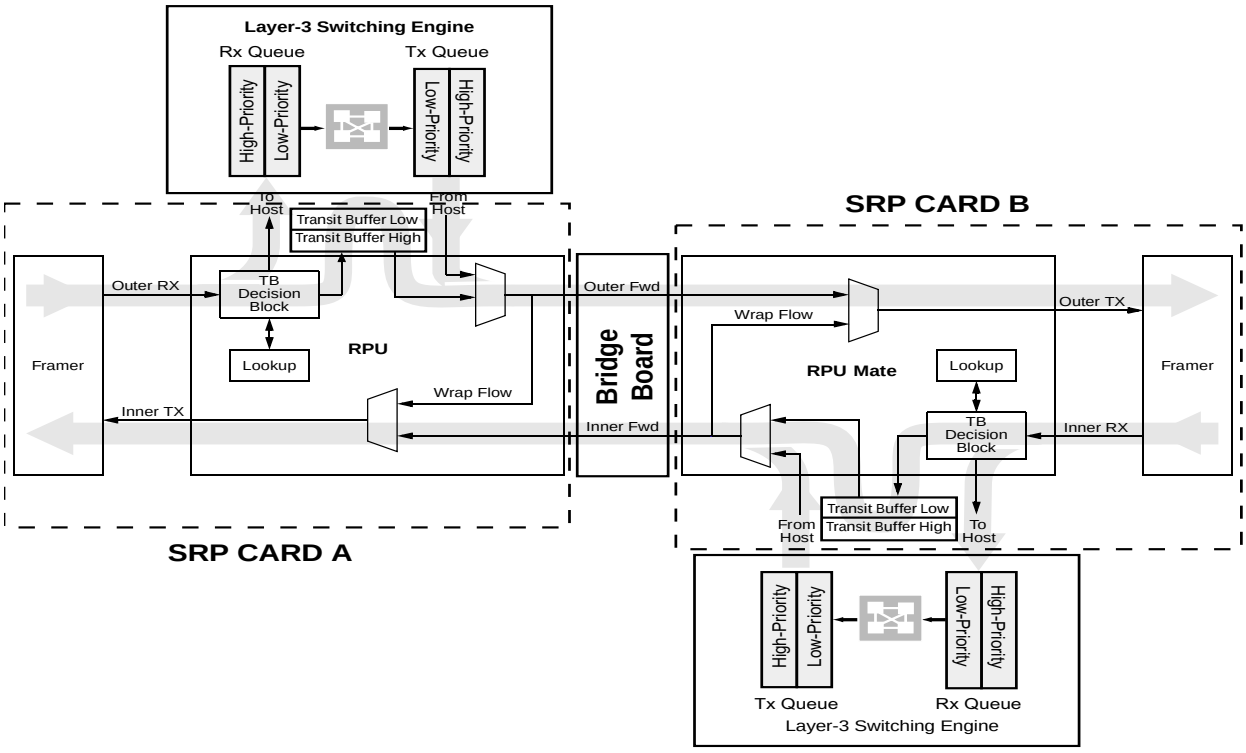


Figure 34-5 Diagram of SRP interface (card A and card B)

Note In Figure 34-5, notice that packets destined for the SRP node are placed in the receive queue. Packets destined for another node are placed in the transit buffer and sent out according to their priority.

A Receiving node performs one of the following actions on an incoming packet:

- Strips the packet from the ring. An example is a packet whose TTL value has reached 0.
- Strips the packet from the ring and receives the packet by placing it in the receive buffer. A packet with a Destination Address (DA) match is removed from the ring and passed to layer-3 for processing.
- Forwards the packet back onto the ring. The incoming packet is routed to the transit buffer for forwarding to the next node. This can happen if the packet is not destined for this node or if the node is in *passthrough* mode. A node in passthrough mode routes all packets to the transit buffer without receiving, that is, without passing the packet to layer-3. For more information, see section 34.8, *SRP Passthrough Mode*.

- Forwards the packet back onto the ring and receives the packet. The packet is sent to layer 3 and to the transit buffer. Forward and receive occurs with multicast packets.
- Wraps the packet back onto the opposite ring. If the node is in the wrapped state, it sends the packet out onto the opposite ring in the reverse direction.

34.3.2 Receive Packet Processing

When a packet is received by an SRP node, the receiving node processes a packet through the following actions.

Note For detailed diagrams and descriptions of all SRP packet structures and fields, see RFC 2892.

1. Examines the incoming packet's header fields (TTL, RI, Mode). If the packet is a control packet, the node determines its type based on the Mode and Control Type field settings. Topology discovery and IPS message packets are stripped and sent to their respective processing routine. Usage packets are stripped and forwarded to the other side of the interface. The mate processes the received packet through the SRP-fa (fairness) algorithm.
2. Matches the Ring ID field (RI) value with the ID of the incoming ring. Packets with the RI field value of 0 should be received only on the outer ring, while packets with an RI value of 1 should be received on the inner ring. If a node is wrapped, it accepts a packet with either RI value provided there is a destination address match. If the value of a packet's RI field does not match the incoming ring ID and the receiving station is not wrapped, the packet is forwarded to the transit buffer.
3. Checks the destination address against Content Addressable Memory (CAM). A match causes the packet to be removed from the ring and passed to layer-3.
4. Checks the TTL field value. Values of 1 or 0 causes the packet to be stripped from the ring. If the value is greater than 1, and the packet is not targeted for the processing node, the packet is sent to the transit buffer.

34.3.3 Transmit Operation

A transmitting node performs the following actions.

- Checks the priority of packets generated by the node and route them accordingly to the low-priority or high-priority queues of the transmit buffer.
- Schedules and transmits the next packet onto the ring. The node selects among the low-priority and high-priority queues within the transmit and transit buffers according to threshold settings. For more detail, see section 34.4, *Prioritizing Packets and Handling Prioritized Traffic*.
- Control local packet traffic using the SRP Fairness algorithm. Briefly, the processing node examines the volume of locally sourced and forwarded packets against the fairness information received from other nodes. If necessary, the processing node throttles its transmission rate. For more information, refer to section 34.6, *SRP Fairness (SRP-fa)*.

34.4 PRIORITIZING PACKETS AND HANDLING PRIORITIZED TRAFFIC

Applications running on network hosts may have constraints with regard to latency, thus the requirement for prioritizing traffic. To accommodate packet prioritization for locally-sourced packets, the source node maps the precedence bits in the ToS field of the IP header into the SRP packet's Priority field.

Note SRP does not set TOS values within packets. For TOS mapping to work, the TOS bits must have been specified for the flow by an ingress line card to the RS.

There are three bits in the Priority field; enough to represent eight levels of packet priority. As mentioned earlier, there are only two queues each in the transit buffers: low-priority and high-priority. SRP addresses this issue with a user-configurable threshold that sets the separation point for high-priority packets. Riverstone allows you to affect this threshold with the command

`srp set` <*port-list*> **`priority-map-transmit`** <*number*>

where <*number*> is in the range of 1 (lowest priority) to 7 (highest priority). This command sets the lowest SRP priority value (threshold) for the SRP high-priority transmit queue. Packets with lower values are sent to the low-priority transmit queue. Packets transiting the node are likewise separated and routed to the low-priority and high-priority queues in the transit buffer.

Note The **`srp set`** <*port-list*> **`priority-map-transmit`** <*number*> command is set on a per-SRP-node basis. Because of this, traffic with a particular TOS number may be low-priority on one SRP node and be high-priority on another SRP node. In this case, the SRP ring is considered misconfigured. Each node on the SRP ring should have the same priority-map level as every other node.

Packets are prioritized and queued based on the relationship between the following values:

- **PK(TB Low Depth)** – The number (in bytes) of low-priority packets currently in the low-priority transit buffer
- **THRESH_LOW** – A constant set to 480 Kilobytes (corresponds to 1.6 milliseconds of latency)
- **THRESH_HIGH** – A constant set to 600 Kilobytes (corresponds to 2.0 milliseconds of latency)

If the packet types are numbered in the order 1 through 4, the transmit hierarchy is derived according to the relationships shown in Table 34-1.

1. High-priority transit packets
2. High-priority transmit packets sourced by local host
3. Low-priority transmit packets sourced by local host
4. Low-priority transit packets

Table 34-1 Relationships for transmit hierarchy

Relationship	Transmit Hierarchy
PK(TB Low Depth) < THRESH_LOW	1 > 2 > 3 > 4
THRESH_LOW < PK(TB Low Depth) < THRESH_HIGH	1 > 2 > 4 > 3
THRESH_HIGH < PK(TB Low Depth)	1 > 4 > 2 > 3

In the execution of the hierarchy-based scheduling and transmitting, the source node must maintain the following conditions:

- Transmit high-priority packets ahead of low-priority packets.
- Avoid discarding packets traversing the ring for cases other than TTL expiration.
- Do not allow the transit buffer to overflow in favor of locally-generated traffic.
- Ensure the low-priority transit packets are not bottle necked in favor of locally generated, low-priority packets.

34.5 TOPOLOGY DISCOVERY

Each station on an SRP ring periodically transmits topology discovery packets. For the Riverstone SRP implementation, the transmission interval is user-configurable with the command

`srp set` <*port-list*> **`topology-timer`** <*seconds*>

where <*seconds*> specifies the interval between topology discovery packets in the range of from 1 to 600 seconds.

When a station receives a topology discovery packet, it adds its address and status to the packet and forwards it to the next node. The discovery packet traverses the entire ring and returns to the source. After the source node receives two identical discovery packets, it builds a ring topology map that includes the following for each node on the ring:

- Shortest path and hop-count information
- MAC address
- Ring wrap status

34.6 SRP FAIRNESS (SRP-FA)

As mentioned earlier, SRP does not use token passing to control media access. Instead, SRP-fa controls the level of packet transmission and forwarding for each node, which distributes fairness across the ring. Fairness distribution helps maintain ring performance in the face of growing traffic which lends scalability to SRP rings.

SRP-fa tracks ring traffic with counters and uses the counter values to adjust traffic as necessary. Each station monitors its sourced and forwarded traffic on separate counters. The associated counter values is increased for each packet sourced or forwarded. If a station encounters local congestion (transit buffer depth crossing a threshold), it transmits a usage packet to its upstream neighbor. This process is called advertising. The usage packet contains the value of the sending station’s transmit counter. The receiving station reads the usage packet, lowers its maximum transmit usage to the received value, and sends its own usage information further upstream.

SRP-fa affects only low-priority packets. An SRP node can source and transmit high-priority packets as long as there is sufficient transit buffer space. Riverstone provides a facility that limits the transmission rate of high-priority or low-priority packets from a specified SRP node. This facility is not part of the SRP specifications (RFC 2892) but is an additional feature that can prevent congestion on the ring. In particular, it affects high-priority traffic that would otherwise be unlimited. To rate-limit traffic, use the commands

`srp set` *<port-list>* **`tx-traffic-rate-high`** *<rate-limit>*

and

`srp set` *<port-list>* **`tx-traffic-rate-low`** *<rate-limit>*

where *<rate-limit>* is a numeric value, in Mbps, that specifies the transmission rate limit. By default, **`tx-traffic-rate-high`** is 20 Mbps and **`tx-traffic-rate-low`** is unlimited, that is, limited only by the fairness algorithm.

34.7 INTELLIGENT PROTECTION SWITCHING (IPS)

Intelligent Protection Switching (IPS) is an extension of Automatic Protection Switching (APS) and facilitates SRP ring recovery from a fiber cut or node failure by rerouting traffic. Nodes adjacent to the failure "wrap" the traffic back onto the (opposite) ring, which avoids the failure and restores ring continuity. An important characteristic of IPS packets is that they are never wrapped.

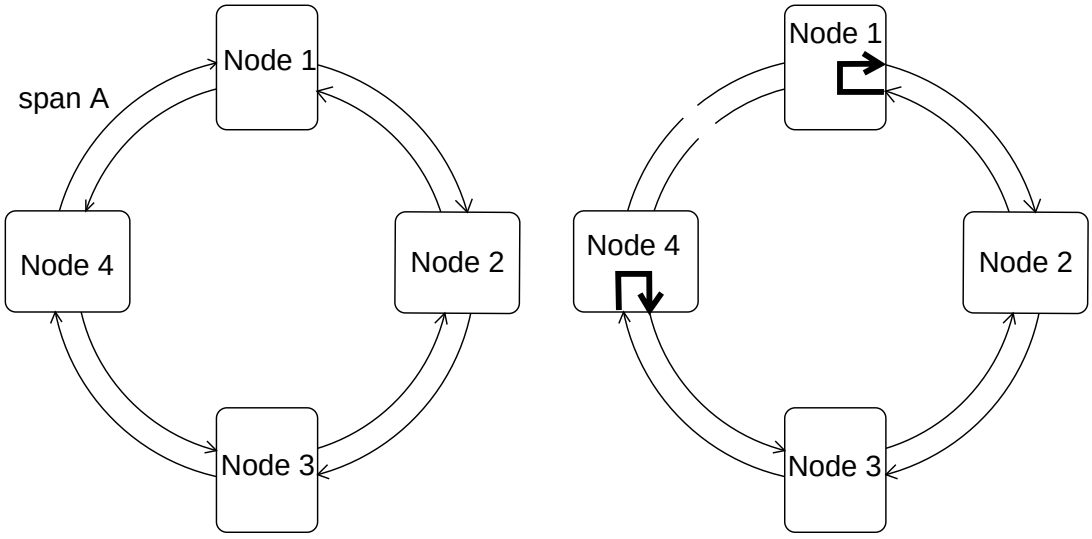


Figure 34-6 IPS ring wrap bypassing a fiber cut

Figure 34-6 shows how an IPS ring wrap bypasses a fiber cut in span A. Traffic between Node 1 and Node 4 normally flows across span A. Assuming there is a fiber cut in this path, Node 1 and Node 4 detect the cut and wrap the ring traffic to bypass the damaged span. The path from Node 1 to Node 4 must now go through Nodes 2 and 3. These intermediate nodes forward the traffic through their transit buffers.

Figure 34-7 Shows a somewhat more detailed view of what occurs during a fiber break and ring-wrap.

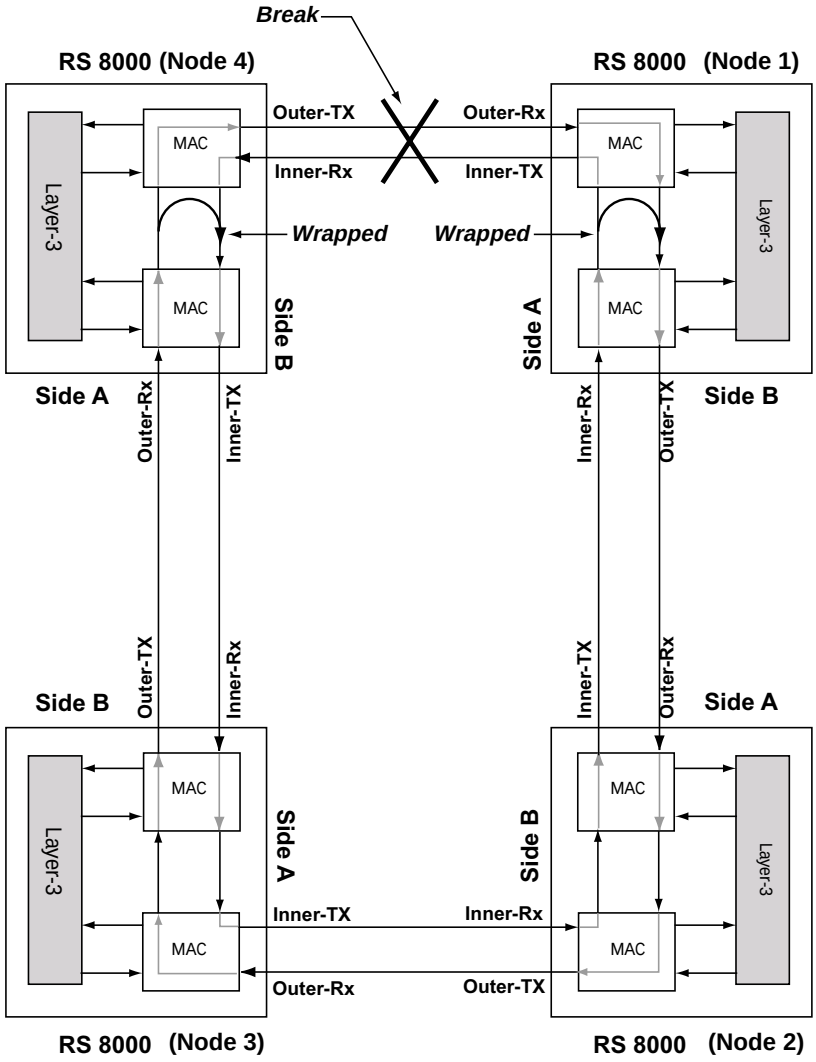


Figure 34-7 Ring wrap in a four node SRP ring

34.7.1 IPS Request Types

IPS requests are triggered automatically by certain events on the ring such as a node failure or fiber cut. The automatic request types are as follows:

- **Signal Fail** (**SF**) – is a “hard” media failure and is triggered when a node detects loss of signal, loss of frame, a line bit error rate (BER) threshold crossing, or a line alarm indication signal (AIS).
- **Signal Degrade** (**SD**) – is a “soft” media failure and is triggered by a node detecting a line or path bit error rate (BER) threshold crossing.
- **Wait-to-Restore** (**WTR**) – prevents the ring from unwrapping before it is ready to resume normal operation. The wait period is user-configurable using the **`srp set`** <*port-list*> **`ips-wtr-timer`** <*seconds*> command.

IPS requests can also be manually initiated, as follows:

- **Forced Switch** (**FS**) – allows the network administrator to force a wrapping at a specific node(s). This is done using the **`srp set`** <*port-list*> **`ips-request-forced-switch`** command. This command can be used to safely add a node to a ring.
- **Manual Switch** (**MS**) – is similar to forced switch but with a lower priority.

34.7.2 Path Indicator Messages

- **Short-path** – messages are exchanged between adjacent nodes across a span. Obviously, in the event of a break in the ring, a short path message may not reach its destination. Assuming it does, it is stripped by the receiving station and never forwarded.
- **Long-path** – messages are sent the opposite way from short path messages. They are sent by a wrapped node, traverse the ring, and are received by the wrapped node at the opposite end of the ring. Long path messages maintain the IPS event hierarchy, as shown in the following section.

34.7.3 IPS Event Hierarchy

To handle multiple, concurrent ring events, IPS follows an event hierarchy as follows:

1. Forced Switch (FS)
2. Signal Fail (SF)
3. Signal Degrade (SD)
4. Manual Switch (MS)
5. Wait to Restore (WTR)
6. No request (IDLE)

34.7.4 IPS States

Each SRP station implements an IPS state machine whose conditions are as follows:

- **Idle** – A node in this state is ready to implement a protection switch and sends IDLE IPS messages to adjacent nodes.
- **Passthrough** – A node in this IPS state implements protection switching by forwarding wrapped traffic and forwarding long-path IPS messages to adjacent nodes.
- **Wrapped** – A wrapped node implements protection switching by wrapping traffic from one ring to the other. This state is initiated two ways:
  - Automatically by failure detection
  - Manually through a network operator request

34.8 SRP PASSTHROUGH MODE

The SRP passthrough mode is not the same as the IPS passthrough mode described earlier in this chapter.

SRP passthrough is an operational mode in which a node simply forwards existing ring traffic. A node enters the passthrough mode because of a failure or through a network operator command, **`srp set`** <*port*> **`pass-through`**. The operating characteristics of a node in passthrough mode are as follows:

- High-priority and low-priority packets continue to be routed into their appropriate queues and transmitted based on the original priority schedule.
- Packets are not sourced or modified (for example, the TTL is not decremented).
- Packets are not passed to or from layer-3.
- SRP-fa is not executed.

34.9 SRP CONFIGURATION EXAMPLES

The following section contains configuration examples of SRP ring deployments. These examples cover the following configurations:

- Single SRP ring with each SRP interface belonging to the same subnet
- Two SRP rings connected by a Gigabit Ethernet link
- Two SRP rings in different routing domains and connected by a single RS containing two SRP interfaces
- Multiple SRP rings in multiple routing domains which terminate on multiple private networks

Note In examples one through three, it is assumed that the SRP line cards are in slots 5 and 7 of the RS.

34.9.1 Example One: Single SRP Ring in Same Subnet

Example one consists of a ring made up of four SRP nodes, one in each RS. Each SRP interface is in the same subnet.

The following is the configuration for R1:.

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr1 address-netmask 100.10.10.10/24 port sr.5.1
     !
```

The following is the configuration for R2:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr2 address-netmask 100.10.10.11/24 port sr.5.1
     !
```

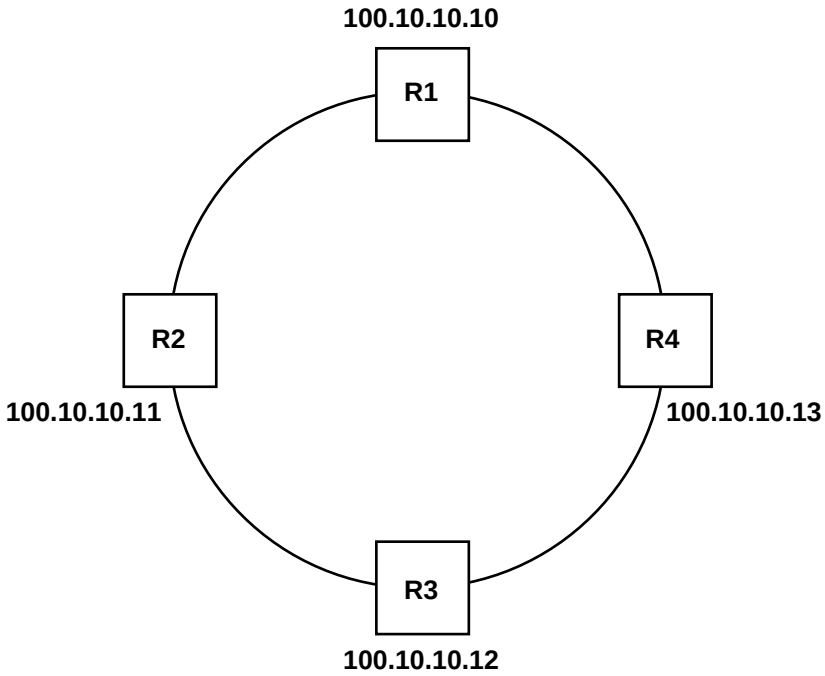


Figure 34-8 Single SRP ring in same subnet

The following is the configuration for R3:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr3 address-netmask 100.10.10.12/24 port sr.5.1
     !
```

The following is the configuration for R4:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr4 address-netmask 100.10.10.13/24 port sr.5.1
     !
```

34.9.2 Example Two: Dual SRP Rings with Gigabit Ethernet Link

In this example, the SRP interfaces within Ring A are in one subnet (100.10.10.0), and the SRP interfaces within Ring B are in a different subnet (100.20.10.0). The two rings are connected by a static route across a Gigabit Ethernet link connecting R2a in Ring A with R4b in Ring B.

The following is the configuration for R1a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr1a address-netmask 100.10.10.10/24 port sr.5.1
```

The following is the configuration for R2a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr2a address-netmask 100.10.10.11/24 port sr.5.1
```

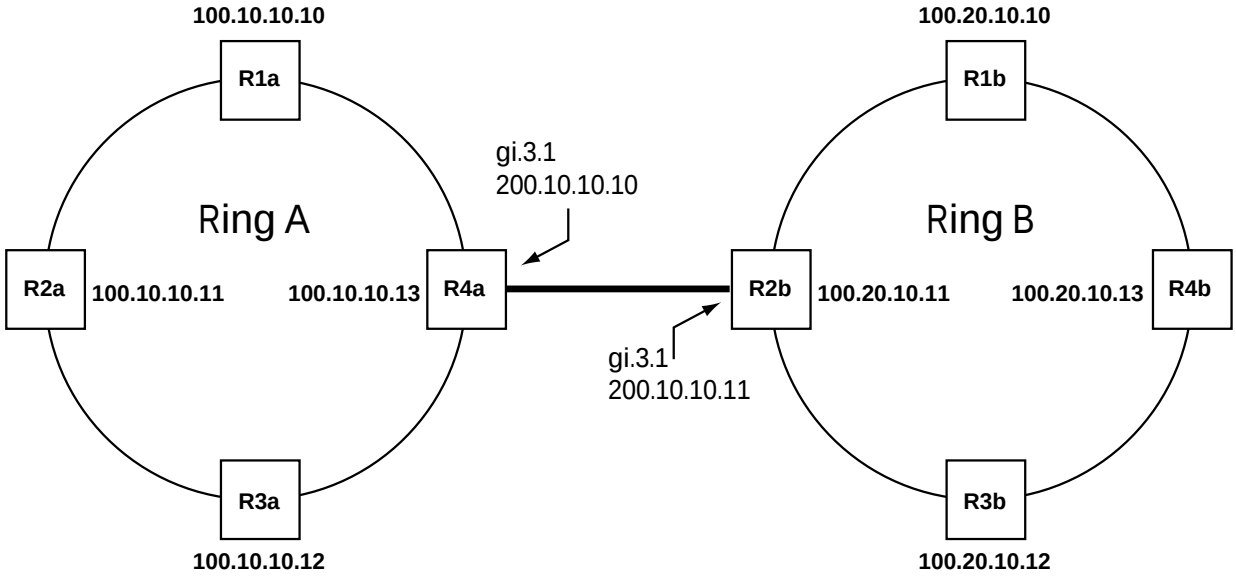


Figure 34-9 Dual SRP rings with Gigabit Ethernet connection

The following is the configuration for R3a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr3a address-netmask 100.10.10.12/24 port sr.5.1
```

The following is the configuration for R4a. Notice the creation of the Gigabit Ethernet interface and the static route:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr4a address-netmask 100.10.10.13/24 port sr.5.1
3 : interface create ip GigLinkA address-netmask 200.10.10.10/24 port gi.3.1
  : !
4 : ip add route 100.20.10.0/24 gateway 200.10.10.11
```

The following is the configuration for R1b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr1b address-netmask 100.20.10.10/24 port sr.5.1
```

The following is the configuration for R2b. Notice the creation of the Gigabit Ethernet interface and the static route:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr2b address-netmask 100.10.20.11/24 port sr.5.1
3 : interface create ip GigLinkB address-netmask 200.10.10.11/24 port gi.3.1
  : !
4 : ip add route 100.10.10.0/24 gateway 200.10.10.10
```

The following is the configuration for R3b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr3b address-netmask 100.20.10.12/24 port sr.5.1
```

The following is the configuration for R4b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr4b address-netmask 100.20.10.13/24 port sr.5.1
```

34.9.3 Example Three: Dual SRP Rings Connected by Single RS

Example four illustrates a configuration that an MSO might use to provide separate service to two different ISPs. Each ISP is provided its own SRP ring, and is unaware of the other ISP. In this case, RS R1c contains two SRP interfaces, one with a base-slot 12 and the other with base-slot 13. Each ring is in its own subnet and OSPF domain. Services are provided to each ISP's network through RS R1c.

The following is the configuration for R1c:

```
1 : srp hw-module base-slot 12 config dual-srp
2 : srp hw-module base-slot 13 config dual-srp
     !
3 : interface create ip srp1 address-netmask 100.10.10.11/24 port sr.12.1
4 : interface create ip srp2 address-netmask 100.20.10.11/24 port sr.13.1
     !
5 : ospf create area 100.10.10
6 : ospf create area 100.20.10
7 : ospf add interface srp1 to-area 100.10.10
8 : ospf add interface srp2 to-area 100.20.10
9 : ospf start
```

The following is the configuration for R1a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr1a address-netmask 100.10.10.10/24 port sr.5.1
     !
3 : ospf create area 100.10.10
4 : ospf add interface sr1a to-area 100.10.10
5 : ospf start
```

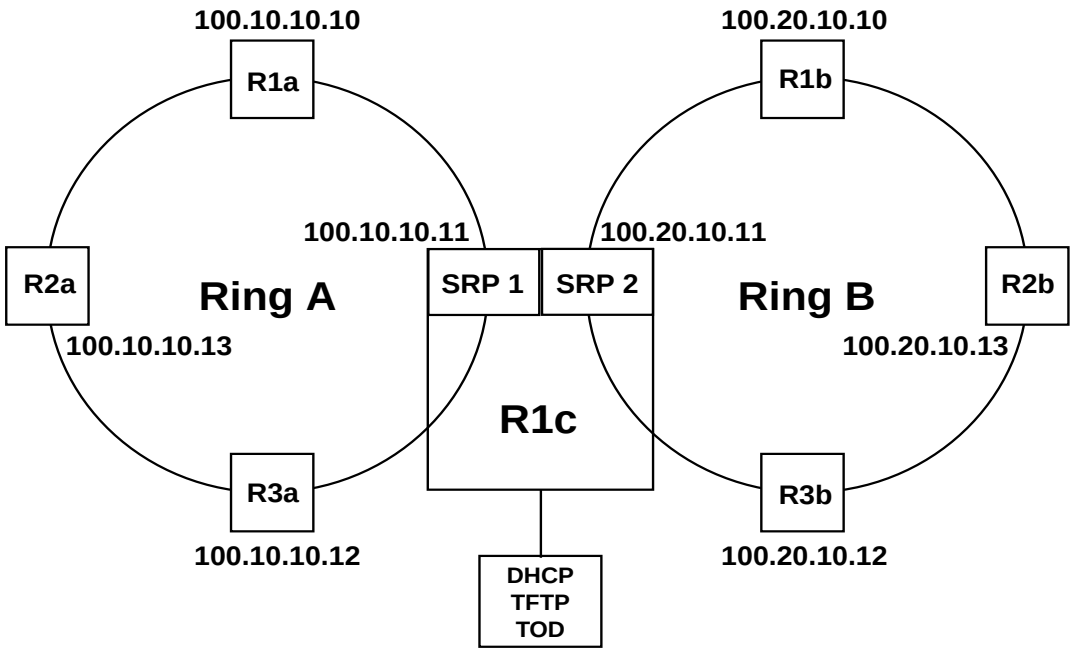


Figure 34-10Dual SRP rings connected to an RS with dual SRP interfaces

The following is the configuration for R2a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr2a address-netmask 100.10.10.13/24 port sr.5.1
     !
3 : ospf create area 100.10.10
4 : ospf add interface sr2a to-area 100.10.10
5 : ospf start
```

The following is the configuration for R3a:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr3a address-netmask 100.10.10.12/24 port sr.5.1
     !
3 : ospf create area 100.10.10
4 : ospf add interface sr3a to-area 100.10.10
5 : ospf start
```

The following is the configuration for R1b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr1b address-netmask 100.20.10.10/24 port sr.5.1
     !
3 : ospf create area 100.20.10
4 : ospf add interface sr1b to-area 100.20.10
5 : ospf start
```

The following is the configuration for R2b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr2b address-netmask 100.20.10.13/24 port sr.5.1
     !
3 : ospf create area 100.20.10
4 : ospf add interface sr2b to-area 100.20.10
5 : ospf start
```

The following id the configuration for R3b:

```
1 : srp hw-module base-slot 5 config dual-srp
     !
2 : interface create ip sr3b address-netmask 100.20.10.12/24 port sr.5.1
     !
3 : ospf create area 100.20.10
4 : ospf add interface sr3b to-area 100.20.10
5 : ospf start
```

Figure 34-11 shows a physical representation of the configuration described in example four. Notice that each ISP's domain is contained within the MSO's domain.

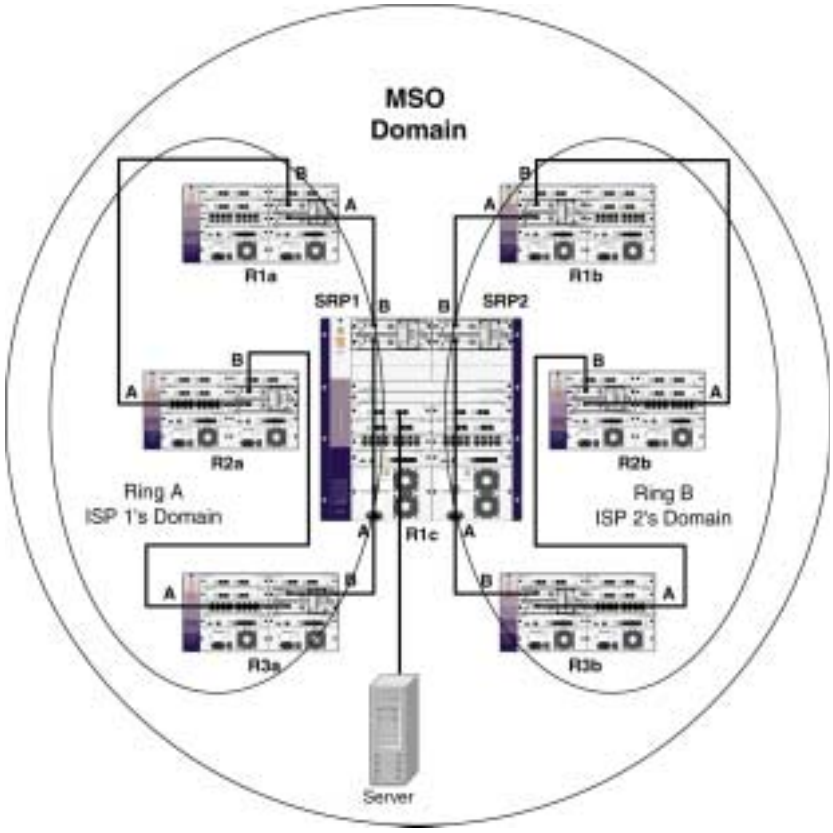


Figure 34-11Physical representation of example four

34.9.4 Example Four: Multiple SRP Rings as Wide Distribution Networks

This example shows how SRP can be used to distribute a large amount of network connectivity over a wide area using Virtual Private Networks (VPNs). In its entirety this example is fairly complex, consisting of many routers, switches, VLANs, and Interfaces. However, to reduce the complexity, the example follows the configuration of only a single distribution path from the core of the network to the end-user.

The following bulleted list describes the basic topology in more detail:

- Ring A consists of eight RS switch routers. Each RS contains two SRP nodes (four SRP line cards). One SRP node is in the same subnet. The other SRP node is in a different subnet and is a member of a different SRP ring (for example, Ring B), which contains three additional RS switch routers. These additional three RS switch routers contain only a single SRP node (two line cards).
- The SRP nodes within Ring B are all within the same subnet and belong to the OSPF routing domain, **`2.0.0.0`** (Ring A's OSPF routing domain is called **backbone**.).
- Each RS within Ring B has two Gigabit Ethernet connections that lead to separate subnets.
- Each of the Gigabit Ethernet connections is connected to an Ethernet distribution switch, which is capable of supporting 802.1Q trunking (see S1 in Figure 34-12).

- Each port S1 is a member of a separate subnet, and is connected to another Ethernet switch (see S2 in Figure 34-12) within a building. Switch S2 is on its own subnet and provides connections for a number of PCs – in this example, for Building #1 (see Figure 34-12).

Because of the scope of this example, only the configurations for a path leading from R1 in Ring A, through R2 in Ring B, and to Ethernet switch S2 in Building #1 is presented. All other distribution paths, however, are similar and have similar configurations.

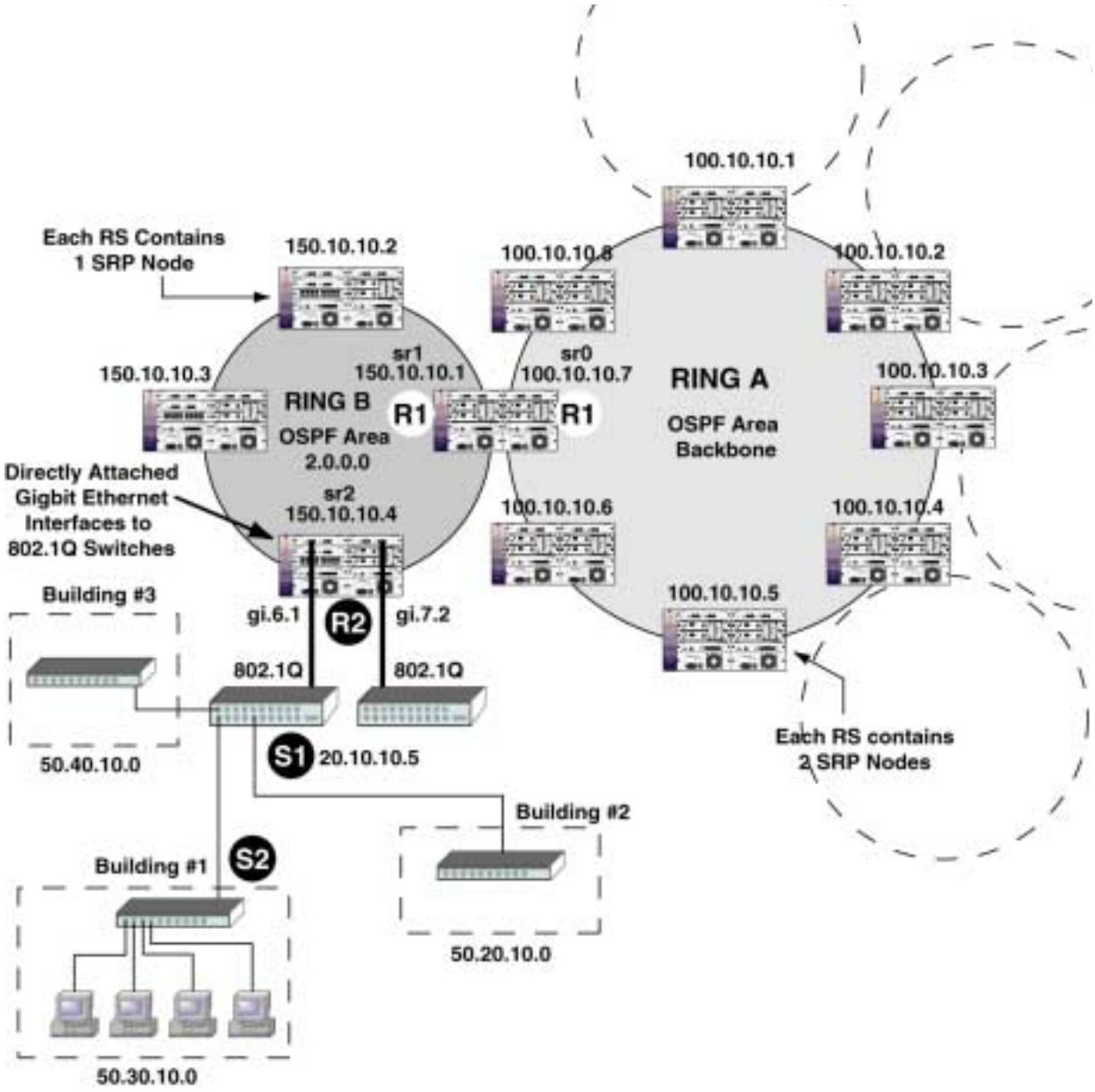


Figure 34-12Topology for single path through example four

The following is the configuration for RS switch router R1. Notice that R1 contains two SRP nodes.

```
     !
 1 : srp hw-module base-slot 2 config dual-srp
 2 : srp hw-module base-slot 3 config dual-srp

     !
 3 : interface create ip sr0 address-netmask 100.10.10.7/24 port sr.3.1
 4 : interface create ip sr1 address-netmask 150.10.10.1/24 port sr.2.1
      !
 5 : ospf create area backbone
 6 : ospf create area 2.0.0.0
 7 : ospf add interface sr0 to-area backbone
 8 : ospf add interface sr1 to-area 2.0.0.0
 9 : ospf start
     !
```

To achieve connectivity between the PCs within each building's VLAN and R2, the following items must be defined within R2's configuration:

1. The VLANs to which a building's PCs belong – lines 2 through 3
2. The ports that act as 802.1Q trunk ports – Lines 5 through 6
3. The 802.1Q trunk ports to which the VLANs are added – lines 7 through 9 (Only the path to S1 is shown here.)
4. The IP interfaces on R2, which are used as default gateways by the PCs (VLANs) in each building – lines 11 through 13 (Only the path through S2 is shown here.)

Here is R2's configuration for the items listed above:

```
     !
 1 : srp hw-module base-slot 3 config dual-srp
     !
 2 : vlan create Bldg1 ip id 10
 3 : vlan create Bldg2 ip id 11
 4 : vlan create Bldg3 ip id 12
 5 : vlan make trunk-port gi.6.1
 6 : vlan make trunk-port gi.7.2
 7 : vlan add ports gi.6.1 to Bldg1
 8 : vlan add ports gi.6.1 to Bldg2
 9 : vlan add ports gi.6.1 to Bldg3
   : !
10 : interface create ip sr2 address-netmask 180.10.10.1/24 port sr.3.1
11 : interface create ip IP50.30 address-netmask 50.30.10.1 vlan Bldg1
12 : interface create ip IP50.20 address-netmask 50.20.10.1 vlan Bldg2
13 : interface create ip IP50.40 address-netmask 50.40.10.1 vlan Bldg3
   :      !
14 : ip-router policy redistribute from-proto direct to-proto ospf
     !
15 : ospf create area 2.0.0.0
16 : ospf add interface sr2 to-area backbone
17 : ospf start
     !
```

By default, OSPF does not advertise directly connected interfaces. Because of this, the **`ip-router redistribute`** command is entered on line 14 to cause R2 to advertise its directly connected interfaces within the OSPF routing domain **`2.0.0.0`**.

Finally, a connection from S1 enters Building #1, where it connects to switch S2 – and S2 provides connectivity to the PCs. Notice that each PC specifies as its default gateway the IP address of the interface on R2 that corresponds to the PC's VLAN – lines 11 through 13.

35 TIME AND TASK SCHEDULING CONFIGURATION

This chapter discusses how to set time on the RS, how to synchronize time on the RS to a Network Time Protocol (NTP) server, and how to schedule tasks for execution on the RS.

35.1 SETTING TIME ON THE RS

Setting time on the RS includes the following tasks:

- Setting the time and date.
- Setting the time zone.
- Setting daylight saving time (disabled by default).

Note Setting the time zone and daylight saving time is mandatory if you will be using an NTP server to synchronize the clock on the RS.

These tasks are described in the following sections.

35.1.1 Setting the Time and Date

To set the date and time on the RS, use the **`system set date`** command in Enable mode. You can set any or all components of the date and time, including the year, month, day, hour, minute, or second. After entering the command, you see a confirmation of the time change.

For example, the following command sets the date to July 6, 2001 and the time to 10:10:40 in the morning:

```
rs# system set date year 2001 month july day 6 hour 10 minute 10 second 40
Time changed to: 2001-07-06 10:10:40
```

You can also use the **system set date** command to set a single component of the date and time. For example, the following command sets the minutes to 30:

```
rs# system set date minute 30
Time changed to: 2001-07-06 10:30:09
```

Use the **system show date** command in Enable mode to display the current date and time on the RS. For example:

```
rs# system show date
Current time: 2001-07-06 10:31:53
```

35.1.2 Setting the Local Time Zone

This section discusses setting the local time zone on the RS. If you will be using an NTP server to synchronize the clock on the RS, you must set the time zone and, if applicable, daylight saving time. For more information about NTP, see Section 35.2, *"Synchronizing Time to an NTP Server."* For more information about setting daylight saving time, see Section 35.1.3, *"Setting Daylight Saving Time."*

The local time zone can be defined by its offset (plus or minus hours) from Universal Coordinated Time (UCT), also called "Coordinated Universal Time." UCT is based on the prime meridian, the meridian that runs through the Greenwich Observatory outside of London, England. As there are roughly 24 time zones that occur at intervals of approximately 15 degrees longitude, the offset of most time zones from UCT would fall in the ranges of +1 to +12 hours or -1 to -12 hours. For example, New York's time zone can be defined as "UCT minus 5 hours." Note that there are locations in the world where the offset from UCT also includes a half hour; for example, India's time zone can be defined as "UCT plus 5 hours and 30 minutes."

For time zones in the United States, you have the alternative of defining the time zone as Eastern, Central, Mountain, or Pacific Standard Time.

To configure the local time zone on the RS, use the **system set timezone** command with one of the time zone keywords. For example, to configure the time zone on a router in California, you can use the following command:

```
rs(config)# system set timezone uct-8
```

The **uct-8** keyword specifies the local time zone by its offset from UCT—"UCT minues 8 hours."

Alternatively, you can configure the time zone on a router in California with the following command:

```
rs(config)# system set timezone pst
```

The **pst** keyword specifies the local time zone as “Pacific Standard Time.”

Use the **system show timezone** command in Enable mode to see the time zone setting on the RS. For example:

```
rs# system show timezone
Daylight saving = OFF
UCT Time offset = -8 hours
```

35.1.3 Setting Daylight Saving Time

This section discusses setting daylight saving time (DST) on the RS. DST is disabled by default on the RS. If you will be using an NTP server to synchronize the clock on the RS, you must set the local time zone and DST. For more information about NTP, see Section 35.2, *"Synchronizing Time to an NTP Server."* For more information about setting the time zone, see Section 35.1.2, *"Setting the Local Time Zone."*

DST on the RS can be set in one of three different ways:

- According to specific days, for example, from the first Sunday of April to the last Saturday of October.
- According to specific dates, for example, from April 1st to October 31st.
- By setting the RS’s time forward by an hour.

The following example sets DST to start at midnight on the last Sunday of March and end at 2 a.m. on the first Saturday of October:

```
rs(config)# system set dst-changing s-wk 5 s-dow 1 s-mo 3 e-wk 1 e-dow 7 e-mo 10 e-hr 2
```

The following example sets DST to start at 3 a.m. on April 1 and end at midnight on September 15:

```
rs(config)# system set dst-fixed s-mo 4 s-day 1 s-hr 3 e-mo 9 e-day 15
```

When you specify the **system set dst-changing** command or the **system set dst-fixed** command in the active configuration file, the RS automatically updates the time based on the parameters you entered.

When you set DST by setting the time forward by an hour, saving it to the active configuration file automatically activates the command, causing the time to immediately change forward one hour. Use the **negate** command to set the time back. Enter the following command in Configure mode to move the time forward by an hour:

```
rs(config)# system set dst-manual
```

35.2 SYNCHRONIZING TIME TO AN NTP SERVER

Network Time Protocol (NTP) is a protocol used to synchronize the clocks on devices in a network, ensuring consistent and accurate times across network operations. The RS includes an NTP client that can synchronize the clock on the RS with an NTP server.

Note To ensure that NTP has the correct time, you must configure the local time zone on the RS and daylight saving time, if applicable. For more information about setting the local time zone, see Section 35.1.2, *"Setting the Local Time Zone."* For more information about setting daylight saving time, see Section 35.1.3, *"Setting Daylight Saving Time."*

There are two ways that the NTP client can synchronize the clock on the RS with an NTP server:

- periodically, at regular intervals
- immediately, when you enter the appropriate CLI command

35.2.1 Periodic Clock Synchronization

Use the **ntp set server** command in Configure mode to have the NTP client periodically synchronize its clock with an NTP server. For example, the following command configures the NTP client on the RS to synchronize its clock with the NTP server at IP address 10.10.10.10:

```
rs(config)# ntp set server 10.10.10.10
```

By default, the NTP client sends a synchronization request to an NTP server every 60 minutes. With the **ntp set server** command, you can change this interval, as well as change the version of NTP packets sent to the server. For example, the following command changes the interval at which the NTP client on the RS sends requests to the NTP server to 45 minutes:

```
rs(config)# ntp set server 10.10.10.10 interval 45
```

35.2.2 Immediate Clock Synchronization

To cause the NTP client to immediately synchronize its clock with an NTP server, use the **ntp synchronize server** command in Enable mode. Unlike the **ntp set server** command (which is issued in Configuration mode), the **ntp synchronize server** command sends a single synchronization request to the NTP server. For example, the following command causes the NTP client to immediately synchronize its clock with the NTP server with IP address 10.10.10.10:

```
rs# ntp synchronize server 10.10.10.10
%NTP-I-TIMESYNC, Time synchronized to Thu Jan 23 23:11:28 1999
```

35.3 SCHEDULING TASKS ON THE RS

The **scheduler** facility on the RS allows specific tasks, namely CLI commands or SNMP SET operations, to be executed at specified times. You can schedule tasks in one of three ways:

- one-time execution at a specific date and time
- recurring execution at specific dates and times
- recurring execution at specific intervals

The information for a configured task is written as an entry in the scheduling MIB table (specified by RFC 2591), which can be accessed by SNMP management applications. SNMP management applications can therefore modify or delete a task in the MIB table, whether the entry is for a CLI command or for an SNMP SET operation. For a CLI command entry in the scheduling MIB table, the MIB variable (OID) is set to 0.0 (null) and the variable value is set to 0 (zero).

Use the **scheduler set cli** command to schedule a CLI Enable or Configure mode command to run at specified intervals or at a specific date and time. Use the **scheduler set snmp** command to schedule an SNMP SET command to run at specified intervals or at a specific date and time. When using the **scheduler set snmp** command, note the following:

- The variable to be set must be of the type INTEGER.
- The MIB table must be ReadCreate or ReadWrite.
- You must make sure that the index of the OID is valid and references a valid entry.

The following sections provide examples of how to use the **scheduler** commands.

35.3.1 Scheduling a One-Time Task Execution

To schedule a task to be executed once at a specific time:

1. Use the **scheduler set calendar** command to configure the time at which the one-time task is to be executed.
2. Use the **scheduler set cli** command or the **scheduler set snmp** command to define the task to be run and to attach the calendar to the task.

CLI Command Example

The following example shows how to use **scheduler** commands to start MPLS on the RS at noon on July 13, 2001.

The following command creates a calendar called ‘d-day’ for noon, July 13, 2001:

```
rs(config)# scheduler set calendar name d-day months 7 days 13 hours 12
```

The following command applies the calendar ‘d-day’ to the CLI command to start MPLS on the router:

```
rs(config)# scheduler set cli name startmpls owner rs cli-cmd “mpls start” one-shot d-day
desc “start MPLS at noon on 7/13/01”
```

SNMP SET Example

The following example shows how to use **scheduler** commands to bring an interface up at noon on July 13, 2001. The OID for the interface is 1.3.6.1.2.1.2.2.1.7.6 (ifAdminStatus for the ifTable of the IF-MIB); the value to bring the network interface up is 1.

The following command creates a calendar called ‘d-day’ for noon, July 13, 2001:

```
rs(config)# scheduler set calendar name d-day months 7 days 13 hours 12
```

The following command applies the calendar ‘d-day’ to the SNMP SET command which brings the interface up (note the value is set to 1):

```
rs(config)# scheduler set snmp name interface-on one-shot d-day owner mgr1 variable
1.3.6.1.2.1.2.2.1.7.6 value 1 context abc
```

35.3.2 Scheduling Tasks for Recurring Dates and Times

1. Use the **scheduler set calendar** command to configure the times at which the task is to be executed.
2. Use the **scheduler set cli** command or the **scheduler set snmp** command to define the task to be run and to attach the calendar to the task.

CLI Command Example

The following example shows how to use **scheduler** commands to compare the active configuration on the RS to the startup configuration every Friday evening.

The following command creates a calendar called ‘fridaypm’ for Fridays at 8:30 p.m.:

```
rs(config)# scheduler set calendar name fridaypm months all days all weekdays 6 hours 20
minutes 30
```

The following command applies the calendar ‘fridaypm’ to the CLI command that compares the configuration files on the RS:

```
rs(config)# scheduler set cli name compare owner rs cli-cmd “diff startup” calendar
fridaypm desc “compare configurations”
```

SNMP SET Example

The following example shows how to use **scheduler** commands to configure a network interface to be brought down every Friday at 8:30 p.m. The OID for the interface is 1.3.6.1.2.1.2.2.1.7.6 (ifAdminStatus for the ifTable of the IF-MIB); the value to bring the network interface down is 2.

The following command creates a calendar called 'fridaypm' for Fridays at 8:30 p.m.:

```
rs(config)# scheduler set calendar name fridaypm months all days all weekdays 6 hours 20
minutes 30
```

The following command applies the calendar 'fridaypm' to the SNMP SET command which sets the interface down:

```
rs(config)# scheduler set snmp name interface-off calendar fridaypm owner mgr1 variable
1.3.6.1.2.1.2.2.1.7.6 value 2 context abc
```

The following example shows how to use **scheduler** commands to bring the same interface back up every Monday at 5:30 a.m. The OID for the interface is 1.3.6.1.2.1.2.2.1.7.6 (ifAdminStatus for the ifTable of the IF-MIB); the value to bring the network interface up is 1.

The following command creates a calendar called 'mondayam' for Mondays at 5:30 a.m.:

```
rs(config)# scheduler set calendar name mondayam months all days all weekdays 2 hours 5
minutes 30
```

The following command applies the calendar 'mondayam' to the SNMP SET command which brings the interface up (note the value is set to 1):

```
rs(config)# scheduler set snmp name interface-on calendar mondayam owner mgr1 variable
1.3.6.1.2.1.2.2.1.7.6 value 1 context abc
```

35.3.3 Scheduling Tasks for Recurring Intervals

Use the **scheduler set cli** command or the **scheduler set snmp** command to define the task to be run and to specify the interval between executions of the task.

CLI Command Example

The following example shows how to use **scheduler** commands to ping a specified host on an hourly basis.

The following command executes the Enable mode CLI command that pings the host at 10.50.7.1 at hourly intervals:

```
rs(config)# scheduler set cli name test owner rs cli-cmd "E:ping 10.50.7.1" interval 3600
desc "ping host3"
```

35.3.4 Using the schedTable MIB

The following example shows how to create a schedule entry in the schedTable MIB (as defined by RFC 2591) through a script. This script transfers the active configuration file to a TFTP server at 60-second intervals. The script uses objects defined in the CTRON-SSR-CONFIG-MIB, which includes the variable cfgActivateTransfer (OID 1.3.6.1.4.1.52.2501.1.231.4.0.

```
#Set snmp manager address to 10.50.7.45,
#and tftpboot file to /import/tftpboot/startup.cfg
#ls -al
#-rwxrwxrwx 1 hongal staff 610 Jul 19 13:14 startup.cfg*
setany 10.50.7.1 \
cfgManagerAddress.0 -a 10.50.7.45 \
cfgFileName.0 -o "/import/tftpboot/startup.cfg" \
cfgTransferOp.0 -i 3
#1.3.6.1.4.1.52.2501.1.231.4.0 is cfgActivateTransfer
setany 10.50.7.1 \
schedInterval.1.97.1.97 -g 60 \
schedVariable.1.97.1.97 -d 1.3.6.1.4.1.52.2501.1.231.4.0 \
schedValue.1.97.1.97 -i 1 \
schedAdminStatus.1.97.1.97 -i 1 \
schedContextName.1.97.1.97 -o "snmp" \
schedRowStatus.1.97.1.97 -i 4
```

36 SNMP CONFIGURATION

The Simple Network Management Protocol (SNMP) is an application layer protocol used to monitor and manage TCP/IP-based networks. It provides for the storage and exchange of management information.

The RS supports all three SNMP versions:

- SNMP Version 1 (SNMPv1) (RFC 1157)
- SNMP Version 2c (SNMPv2c) (RFC 1901, RFC 1905, and RFC 1906)
- SNMP Version 3 (SNMPv3) (RFC 2570 - 2576)

SNMPv1, SNMPv2c and SNMPv3 can coexist in the same managed network (RFC 2576). You should configure the RS to run the SNMP version(s) supported by the SNMP management stations. You can run any or all of the SNMP versions on the RS, depending on the one used by the SNMP management stations. (For additional information on the different SNMP versions, refer to the RFCs for each version.)

You can use the CLI to perform various SNMP tasks. This chapter described how to perform these tasks. It contains the following sections:

- To configure access to the Management Information Base (MIB) objects on the RS, refer to Section 36.1, *"Configuring Access to MIB Objects."*
- To configure SNMP notifications, refer to Section 36.2, *"Configuring SNMP Notifications."*
- To configure SNMP MIB modules and for a list of MIB modules supported by the RS, refer to Section 36.3, *"MIB Modules."*

36.1 CONFIGURING ACCESS TO MIB OBJECTS

Riverstone supports most of the standard networking SNMP MIB modules, as well as proprietary MIB modules. Each MIB module is a collection of managed objects which can be accessed by the SNMP management stations. (For a list of MIB modules supported by the RS, refer to Section 36.3, *"MIB Modules."*)

SNMP management stations send SNMP SET and GET requests for the management objects stored in the MIB modules. The RS runs an SNMP agent, which is a software process that listens for these SNMP messages on UDP port 161. In SNMPv1 and v2c, the SNMP managers provide a community string (or password) when they send their requests. If the RS recognizes the community string, it processes the request. If it doesn't recognize the community string, it discards the message and increments the bad community name error counter (which can be viewed through the **`snmp show statistics`** command).

In SNMP v3, these requests are processed only if they are from a defined set of users and if they are for management objects in a predefined list. The following sections describe how to configure access to the MIB modules for each SNMP version.

36.1.1 SNMPv1 and v2c

Following are the tasks for configuring SNMP access if you are running SNMPv1 and v2c:

- Configure a community string. This is required.
- Create views.
- Associate views with community strings.
- Configure the agent's identity.
- Apply ACLS that define which management stations can access the RS.

Each of these tasks are discussed in the sections that follow.

Configuring Community Strings

To run SNMPv1 and v2c on the RS, you must define at least one community string. The RS has no default community strings. When you define an SNMP community string, you also need to specify its access level, which is either read-only (allows only SNMP GETs), or read-write (allows SNMP SETs and GETs). In the following example, separate community strings are defined for read-only access and for read-write access:

```
rs(config)# snmp set community public privilege read
rs(config)# snmp set community private privilege read-write
```

An SNMP manager that sends a GET request for a MIB object on the RS can provide the community string *public* or *private*; and an SNMP manager that sends a SET request should provide the community string *private*.

Creating Views

A view specifies a set of management objects. In the following example, 2 views are created: *rview1* which includes BGP objects only, and *wview1* which includes OSPF objects only.

```
rs(config)# snmp set view rview1 oid bgp type included
rs(config)# snmp set view wview1 oid ospf type included
```

Views can be used with all SNMP versions. In SNMPv1 and V2c, you can associate a view with a community string. SNMP management stations that provide that community string will be restricted to the management objects defined in the view. (For additional information, refer to *"Using Views with Community Strings."*) In SNMPv3, views are used with access groups. (For additional information, refer to *"Configuring Access Groups."*)

Using Views with Community Strings

When you define a view and associate it with a community string, SNMP management stations that provide that community string will be restricted to the management objects defined in the view.

You can create more than one view. You can create one view for read-only access, which specifies one or more sets of management objects, and create a view for read-write access, which includes a different set of management objects. Consider the following example:

```
rs(config)# snmp set view rview1 oid bgp type included
rs(config)# snmp set community public privilege read view rview
rs(config)# snmp set view wview1 oid ospf type included
rs(config)# snmp set community private privilege read-write view wview
```

The example configures the *rview* view that includes the BGP objects only, and the *wview* that includes OSPF objects only. The SNMP agent on the RS will process only SNMP GETs to the BGP management objects when an SNMP management station provides the community string *public*; and when an SNMP manager provides the community string *private*, SNMP GET and SET requests for the OSPF management objects will be allowed.

Configuring the SNMP Agent's Identity

You can use the CLI to set certain MIB objects, such as those that describe the agent's identity, as shown in the following example:

```
rs(config)# system set name RS8-1
rs(config)# system set contact “IT dept”
rs(config)# system set location “building 1 closet”
rs(config)# snmp set chassis-id “s/n 12345”
```

The example sets the MIB objects sysName to *RS8-1*, sysContact to *IT dept*, sysLocation to *building 1 closet*, and enterprise sysHwChassisId to *s/n 12345*.

Configuring the Source IP Address

When the RS responds to an SNMP management request, its source IP address is the IP address of the outgoing interface. You can configure the RS to use one source IP address for all its responses (typically the loopback address), regardless of the interface from which the response was sent. Using one source IP address enables SNMP managers to track responses from this device.

Use the **snmp set source-ip** command to specify the source IP address for SNMP responses, as shown in the following example. You can specify a valid interface name or IP address:

```
rs(config)# snmp set source-ip 10.10.10.1
```

Note The **snmp stop** command is designed to thwart certain DoS attacks. The **snmp stop** command stops SNMP access to the RS by closing the request/response and the trap/inform ports. The RS stills finish all active requests but will then disregard future requests. To reopen the ports, use the **no snmp stop** command.

TApplying ACLs to SNMP

SNMP v1 and v2c are not secure protocols. Messages containing community strings are sent in plain text from the SNMP managers to the agent on the RS. Anyone with a protocol decoder and access to the wire can capture, modify, and replay messages.

When using SNMPv1 and v2c, it is important to protect your RS by using a service Access Control List (ACL). This prevents unauthorized access and routes your SNMP traffic through trusted networks only. A service ACL controls which hosts can access individual services, such as SNMP, on the RS. A service ACL does not control packets going *through* the RS. It only controls packets that are *destined* for the RS, specifically, for one of the services provided by the RS. As a result, a service ACL, by definition, is applied only to check for inbound traffic to the RS. The destination host of a service ACL is, by definition, the RS. The destination port is the well-known port of the service, which for SNMP is UDP port 161.

In the following example, an ACL is applied to the SNMP service. The ACLs allow only messages from the source IP address 10.10.10.1 to be processed by the SNMP agent. Packets from any other source IP address are dropped.

```
rs(config)# snmp set community community1 privilege read
rs(config)# acl mgmt_only permit udp 10.10.10.1 any any any
rs(config)# acl mgmt_only apply service snmp
```

For information on Configuring ACLs, refer to Chapter 26, *"Access Control List Configuration."* For information on the ACL commands, refer to the *Riverstone RS Switch Router Command Line Interface Reference Manual.*

36.1.2 SNMP v3

Whereas SNMPv1 and v2c rely on password-like community strings to restrict access to the MIB objects on the RS, SNMPv3 provides more stringent security. In SNMPv3 only a defined set of users are allowed to access a specific set of management objects.

SNMPv3 also provides message level security. In SNMP v1 and v2c, messages containing community strings are sent in plain text from the SNMP managers to the agent on the RS. In SNMPv3, these messages can be protected by specifying an authentication protocol and encryption method.

The following tasks are required for configuring SNMP access if you are running SNMPv3:

1. Create views as described in *"Creating Views."*
2. Configure access groups.
3. Define the users that will have SNMP access to the RS.

In addition, you can configure the RS to use one source IP address for the responses it sends to SNMP managers. Refer to *Configuring the Source IP Address* for additional information.

Configuring Access Groups

An access group associates a user group with specific views and with a certain message security level. When you configure an access group, you specify which views the user group can access and at what level. You can specify three types of views:

- A read view, which allows read-only access to the MIB objects specified in the view.
- A write view, which allows read and write access to the MIB objects specified in the view.
- A notify view, which allows notifications to be generated for the MIB objects specified in the view.

In addition, an access group also defines the message security level of the users in the group. There are three security levels:

- *noAuthNoPriv* - the messages at this security level do not use authentication and encryption.
- *authNoPriv* - the messages at this security level use either MD5 (message digest) or Secure Hash Algorithm (SHA) authentication, but no encryption.
- *authPriv* - the messages at this security level use either MD5 or SHA authentication, and Data Encryption Standard (DES) encryption.

Messages to or from the users in the access group will be processed only if they use the authentication protocol and/or encryption method of the security level defined for the group.

In the following example, the first three commands create the following views: the *rview* which includes BGP objects only; the *wview* which includes OSPF objects only; and the *nview* which includes ATM objects only. The last command creates the access group, *group100*, and associates it with a read view, write view and notify view. The group's security level is also set to *authNoPriv.*

```
rs(config)# snmp set view rview oid bgp type included
rs(config)# snmp set view wview oid ospf type included
rs(config)# snmp set view nview oid atmMIB type included
rs(config)# snmp set group group100 v3 level auth notify nview read rview write wview
```

You can view each group's parameters by specifying the **`snmp show groups`** command as shown in the following example:

```
rs# snmp show groups

Access Groups Table:
                        Security                Exact
Group Name              Model   Level   Context   Match  ReadView  WriteView NotifyView  Last Change
group100                USM     auth    NULL      No     rview     wview     nview       2001-07-17,
14:19:38.00
v1_default_ro           v1      noAuth  NULL      No     All       None      All         2001-07-16,
14:33:29.00
v1_default_ro           v2c     noAuth  NULL      No     All       None      All         2001-07-16,
14:33:29.00
v1_default_ro           USM     noAuth  NULL      No     All       None      All         2001-07-16,
14:33:29.00
v1_default_rw           v1      noAuth  NULL      No     All       All       All         2001-07-16,
14:33:29.00
v1_default_rw           v2c     noAuth  NULL      No     All       All       All         2001-07-16,
14:33:29.00
```

Configuring Users

After you create the access groups, define the users for each group. The users will have access only to the views defined for the group. In addition, the RS will process SNMP messages from these users only. When you add a user to a group, the user's security level must match the group's security level. If a user's security level is *authnoPriv*, you will need to specify an authentication protocol (MD5 or SHA) and a password. If a user's security level is *authPriv*, you will need to specify an authentication protocol, a password, and an encryption key as well.

The following example defines the user *usr1*.

```
rs(config)# snmp set group group100 v3 level auth notify nview read rview write wview
rs(config)# snmp set user usr1 group group100 auth-protocol sha password asdfkl
```

In the example, *usr1* is associated with *group100*. Therefore *usr1's* access to the management objects is restricted to the views defined for *group100*. In addition, because the security level of *group100* is *authNoPriv,* an authentication protocol and password were also specified.

You can list users and view their parameters by specifying the **`snmp show users`** command as shown in the following example:

```
rs# snmp show users

User Table:
EngineID                User Name              Auth.Prot.  Priv.Prot.  Group/Security
Name      Last Change
000015bf000000e06336ab4e  usr1               SHA Hash   None      group100
2001-07-17, 14:19:39.00
000015bf000000e06336ab4e  default             None      None      default
2001-07-16, 14:33:29.00
```

SNMPv3 Sample Configuration

Following is an example of a basic SNMPv3 configuration on the RS:

```
rs(config)# snmp set view rview oid bgp type included
rs(config)# snmp set view wview oid ospf type included
rs(config)# snmp set view nview oid atmMIB type included
rs(config)# snmp set group group100 v3 level auth notify nview read rview write wview
rs(config)# snmp set user usr1 group group100 auth-protocol sha password asdfkl
rs(config)# snmp set target 123.45.6.7/24 community usr1 v3 auth type informs
```

The preceding example configured the read, write and notify views for *group100*. The group also has a security level of *authNoPriv* which means messages from its users use authentication, but no encryption. Therefore when *usr1* was configured with the **`snmp set user`** command, an authentication protocol and password were specified. The last line of the example specifies that the RS will send SNMP v3 inform notifications to IP address 123.45.6.7/24 with authentication. (Notifications are discussed in the next section.)

36.2 CONFIGURING SNMP NOTIFICATIONS

The RS sends notifications to pre-defined targets. The targets are the SNMP management stations that receive the notifications. Notifications inform the SNMP managers about conditions on the network, such as an error condition or an authentication failure.

SNMPv1 defined only one type of notification; these were called traps. SNMP agents sent traps to alert SNMP managers about conditions on the network. Traps did not require acknowledgements from the receivers. Therefore, the SNMP agent never knew whether a trap was received.

SNMP v2c introduced another type of notification, an Inform notification, which is essentially a trap that requires an acknowledgement from the receiver. In SNMPv2c, if the SNMP agent does not receive a response, then it knows the SNMP manager did not receive the notification and it has the option of re-sending it. Note, however, that this increased reliability comes with a price, in the form of network resources. The SNMPv1 traps generate less traffic and use less memory because they are discarded as soon as they are sent. The Inform notifications generate more traffic because of the response required and the retries when an Inform notification is not received. Therefore, when traffic or memory is a concern, it may be best to send SNMPv1 traps. But when acknowledgements are required, send Inform notifications.

The tasks for configuring SNMP notifications are the same for all three SNMP versions. They are:

- Specifying the targets. This is required.
- Enabling/disabling notifications.
- Filtering notifications.
- Testing notifications.
- Configuring the notification’s source address (SNMPv1 only).

Each task is described in the sections that follow.

36.2.1 Specifying the Targets

To send SNMP notifications, you need to specify the following:

- the targets that will receive the notifications.
- which notifications the targets will receive, SNMPv1 traps or SNMPv2c Inform notifications.
- a community string.

Targets are defined by their IP addresses. Each target that is defined receives a copy of the notifications generated and sent by the RS agent. A target can be configured to receive either a trap or an Inform.

In addition, you need to specify a community string for the notifications. For SNMPv3, the community string is the user name. For security reasons, the community strings in notifications should be different from the read/write community strings. So when the RS sends notifications, unauthorized users that capture the notifications will not be able to use the community string to access the MIB modules.

In the following example, Inform notifications will be sent to the target with address 10.10.10.1.

```
rs(config)# snmp set community community1 privilege read
rs(config)# snmp set target 10.10.10.1 community community1 v2c type informs
```

Note If the IP address of the target is more than one hop away from the RS, configure the RS with a static route to the target. If the RS is rebooted, the static route allows a cold-start notification to be sent to the target. Without a static route, the cold-start notification is lost while the routing protocols are converging.

36.2.2 Enabling/Disabling Notifications

A common security attack on an agent is to send a message containing an invalid community string, then capture the authentication failure notification to learn the correct community string. To avoid this, authentication failure notifications are disabled by default.

All other notifications, though, are enabled once a target is configured. You can globally disable or enable some types of notifications. Following is a list of these notifications:

```
rs(config)# snmp disable trap ?
 authentication           - Authentication generic trap
 bgp                      - bgpEstablished and bgpBackwardTransistion traps
 cmts                     - CMTS specific traps
 environmentals           - temperature, fan, power supply traps
 frame-relay              - DLCI up/down trap
 link-up-down             - Link up/down generic trap
 ospf                     - sixteen different OSPF traps
 spanning-tree            - newRoot and topologyChange traps
 vrrp                     - NewMaster and authFailure traps
```

LinkUp and linkDown notifications per port are also configurable through the ifXTable's ifLinkUpDownEnabled MIB object (introduced in RFC2233). The command **`snmp disable trap link-up-down`** disables linkUp and LinkDown notifications on all ports. The command **`snmp disable port-trap et.1.3`** affects only the specified ports.

In the following example, two targets are defined, but only one is active (10.50.24.55). In addition, the RS sends all notifications except for SNMPv1 authentication failure (which is disabled by default), OSPF and VRRP notifications. Link Down/Up notifications for port et.1.3 are also disabled.

```
rs(config)# snmp set target 10.50.24.55 community public status enable
rs(config)# snmp set target 10.60.21.23 community community1 status disable owner mrm
rs(config)# snmp disable port-trap et.1.3
rs(config)# snmp disable trap ospf
rs(config)# snmp disable trap vrrp
```

You can use the **snmp show trap** command to display information about the configured targets and to list the status of the notifications.

```
rs# snmp show trap

Trap Target Table:
Notification Name   Community String    Destination     Port
inform              community1          10.10.10.1      162
inform              usr1                123.65.6.1      162
trap                public              10.50.24.55     162
trap                community1          10.60.21.23     162


Traps by Type:
Authentication trap : disabled
Frame Relay  : enabled
OSPF         : disabled
Spanning Tree: enabled
BGP          : enabled
VRRP         : disabled
Environmental: enabled
Link Up/Down : enabled
CMTS : enabled
Link Up/Down Traps disabled by physical port:
et.2.1
Trap source address: default
Trap transmit rate: 1 per 2 seconds
```

36.2.3 Filtering Notifications

You can use filters to send different types of notifications to different targets. When the RS generates a notification, it compares it against the filters of each target that is supposed to receive notifications. It then sends the notification only to the targets that are authorized to receive it. You can configure as many filters as necessary and use them with any SNMP version.

Following are the steps for configuring filters:

1. Define the notification.
2. Define the notification filter. A notification filter specifies whether certain MIB objects should be included or excluded in the notifications.
3. Define the target parameters. The target parameters provide information about the target, such as the security level (*noAuth*, *auth* or *Priv*), and the type of messages that can be sent or received by the target.
4. Specify the target address and associate it with the target parameters.
5. Define a notification profile. A notification profile associates the notification filter with the target.

Following is an example:

```
rs(config)# snmp set notification note1 type traps tag n1
rs(config)# snmp set notification-filter note1 oid bgp type included
rs(config)# snmp set target-params grp100 level auth mp-model v3 security usr1
rs(config)# snmp set target-addr grp100 address 110.110.123.5 params grp100 tags n1
rs(config)# snmp set notification-profile filter note1 params grp100
```

In the preceding example, a notification filter is defined for the *note1* notification. The notification filter specifies that only notifications for BGP management objects will be sent to 110.110.123.5.

You can use the **`snmp show notification-filters`** command to display the notification filters, as shown in the following example:

```
rs# snmp show notification-filters

Notification Filters Table:
Filter Name             Object ID                   Mask              Incl./Excl. Last Change
note1                   bgp                         0                 Included    2001-07-17,
15:33:05.00
default                 iso                         0                 Included    2001-07-16,
14:33:29.00
default                 ospfTraps                   0                 Excluded    2001-07-17,
13:07:57.00
default                 vrrpNotifications           0                 Excluded    2001-07-17,
13:07:57.00
```

36.2.4 Testing Notifications

It is also useful to test notifications by using the CLI to verify basic notification configuration. From Enable mode, you can send any number of notifications which can be used to simulate events such as a coldstart/reboot of the system.

Following is a list of the notifications that you can test:

```
rs# snmp test trap type ?
[type] requires a value of this type:
   [keyword]              - One of the following keywords:
     PS-failure          - send power supply failure trap
     PS-recover          - send power supply recovery trap
     bgpBackwardTransiti - BGP Backward Transition trap
     bgpEstablished      - BGP Established trap
     coldStart           - send coldStart trap to manager
     linkDown            - send link down for ifIndex 1 to manager
     linkUp              - send link up for ifIndex 1 to manager
     vrrpNewMaster       - Virtual Router Redundancy New Master Trap
```

36.2.5 Configuring the Notification Source Address

You can use the **snmp set trap-source** command to configure the source address of SNMPv1 notifications. You can specify either an IP interface or an IP unicast address. If you specify an interface name, the first non-loopback interface is chosen. For example, the interface *to_admin_net* has two IP addresses:

```
rs(config)# interface create ip to_admin_net address-netmask 207.135.88.141/26
rs(config)# interface add ip to_admin_net address-netmask 135.78.23.15/29
rs(config)# snmp set trap-source to_admin_net
```

To configure a router for SNMP access so that the management station doesn't have to keep track of all the different interfaces, use an IP address on the loopback interface as follows:

```
rs(config)# ip-router global set router-id 10.1.1.1
rs(config)# interface add ip lo0 address-netmask 10.1.1.1/32
rs(config)# interface create ip to_admin_net address-netmask 207.135.88.141/26
rs(config)# interface create ip to_mgt_net address-netmask 207.136.88.121/28
rs(config)# interface create ip to_engr_net address-netmask 207.137.88.121/28
rs(config)# ospf create area backbone
rs(config)# ospf add interface to_admin_net to-area backbone
rs(config)# ospf add interface to_mgt_net to-area backbone
rs(config)# ospf add interface to_engr_net to-area backbone
rs(config)# ospf add stub-host 10.1.1.1 to-area backbone cost 1
rs(config)# ospf start
rs(config)# snmp set community privilege read
rs(config)# snmp set trap-source lo0
```

A management station configured with routing protocols or talking to a router via the default route which runs routing protocols can now reach the RS over any of the to_*_ net interfaces simply by using the 10.1.1.1 address. Notifications sent from the router will use the source IP address of 10.1.1.1 instead of the default behavior which would be the IP address of the interface chosen to send the notification to the management station (one of the to_*_ net addresses).

Note The **snmp set trap-source** command is valid for SNMPv1 only.

36.2.6 How the RS Agent Limits the Rate at which Notifications are Sent

SNMP notifications are managed internally by the RS. Various subsystems running in the RS that create SNMP notifications do so by inserting them into a queue managed by the SNMP subsystem (task).

When there is a notification in the queue, a timer is enabled. This timer goes off every two seconds, at which point the agent will extract in first in, first out (FIFO) order one notification off the queue and send it to the specified management station. Thus, one notification is sent every two seconds.

Use the MIB object frTrapMaxRate (milliseconds) described in RFC 2115 to change the notification transmit rate. Note that this value is truncated to seconds and the minimum value is two seconds.

Up to 64 notifications can be queued. The typical notification is between 50-150 bytes. This value is presently fixed in software. You can view the current state of the queue by using the **snmp show statistics** command as shown in the following example:

```
rs# snmp show statistics
SNMP Engine Info:
EngineID                  Reboots        Uptime(Secs)   Max. Message Size
000015bf000000e06336ab4e  0              342107         4096

SNMP Modules Last changed at : 2001-06-05, 09:29:52.00

SNMP statistics:
        20 packets received
                4 in get objects processed
                4 in get requests
                4 in get responses
                5 get-next requests
                3 in set requests
                0 in total objects set
                0 bad SNMP versions
                0 bad community names
                0 ASN.1 parse errors
                0 PDUs too big
                0 no such names
                0 bad values
                0 in read onlys
                0 in general errors
                0 silent Drops
                0 unknown security models
                0 messages with invalid components
                0 unknown PDU types
                0 unavailable contexts
                0 unknown contexts
                0 unknown/unavailable security level
                0 outside the engine window
                0 unknown user names
                0 unknown Engine IDs
                0 wrong digests
                0 decryption errors
17 packets sent
                3 out get requests
                3 get-next responses
                3 out set requests
                0 response PDUs too big
                0 no such name errors
                0 bad values
                0 general errors

                6 notifications sent
                2 notifications in queue
                0 notifications dropped due to queue overflow
                0 notifications dropped due to send failures
```

The status of the notifications are listed at the bottom of the output. Notifications that cannot be sent for reasons such as “no route to host” are retried after exponentially increasing the wait time in seconds from 2 seconds, 4 seconds, etc., up to a maximum of 8 retries.

36.2.7 Logging SNMP Notifications

The SNMP Notification Log MIB (RFC 3014) provides a mechanism for recording notifications. It provides a common infrastructure for other MIBs in the form of a local logging function. In addition, applications can poll the logs to verify if they have missed important notifications. It is intended primarily for senders, but can also be used by receivers.

This section describes how to set global parameters that affect the Notification Log MIB module and how to use the CLI to configure notification logs. It contains the following information:

- To set global parameters for the Notification Log MIB module on the RS, refer to *"Setting Global Notification Log Parameters."*
- To configure a notification log, refer to *"Configuring a Notification Log."*

Setting Global Notification Log Parameters

Using the CLI, you can limit the number of notifications that are stored and specify how long a notification is stored. By default, none of these limits are set. This can compromise memory usage. Therefore, it is strongly recommended that reasonable values be set for these parameters, based on your system configuration and requirements.

Setting the Log Limit

Use the **snmp set notification-log-limit** command to specify the maximum number of notifications that can be stored. When the number of notifications logged reaches this maximum number, the oldest notification is deleted. The following example sets the log limit to 100:

```
rs(config)# snmp set notification-log-limit 100
```

Setting the Aging Time

Use the **snmp set notification-log-ageout** command to set the maximum number of minutes a notification is stored. Setting this value enables older notifications to be deleted, freeing up memory. The following example sets the notification aging time to 60 minutes:

```
rs(config)# snmp set notification-log-ageout 60
```

Viewing Global Parameters

To view global parameters, use the **`snmp show notification-log globals`** command as shown in the following example:

```
rs# snmp show notification-log globals
nlmConfigGlobalEntryLimit         = 100
nlmConfigGlobalAgeOut             = 60
nlmStatsGlobalNotificationsLogged = 0
nlmStatsGlobalNotificationsBumped = 0
```

In addition to displaying the notification log limit and aging timeout, the output also displays the number of notifications that have been logged and the number of notifications that were discarded due to a lack of resources or because the log limit was reached.

Configuring a Notification Log

When you configure a notification log, you must specify which notifications will be recorded. To do so, configure a notification filter and associate it with a notification log.The filter specifies whether notifications for the objects in the filter will be logged. (For additional information on notification filters, refer to Section 36.2.3, *"Filtering Notifications."*)

In addition, you can configure a view-based access policy which limits users to pre-defined groups of management information. You can associate an access policy with a notification log, thus limiting which notifications are logged and which notifications are accessed.

- For SNMPv1 and v2c, you can associate views with community strings. For additional information, refer to *"Using Views with Community Strings."*
- For SNMPv3, you can associate views with access groups. For additional information, refer to *"Configuring Access Groups."*

The examples in the following sections illustrate how to configure notification logs.

Configuration Examples

The following examples illustrate how to configure the following notification logs:

- Notification log with no security attributes
- Notification log with filters
- Notification log controlled by views and security attributes

Example 1: Using the Default Filter

The following example illustrates how to configure a log that records all notifications that are sent out. The notification filter used is the default, which is a filter with ObjectID `iso`. Using this filter enables all outgoing notifications to be logged, as long as their security credentials match. In this example though, no security attributes are set, enabling all notifications to be logged and all users to access the log.

```
!Configure SNMP parameters
rs(config)# snmp set community public privilege read-write
rs(config)# snmp set target 172.16.5.62 community public
!Configure the notification log global parameters
rs(config)# snmp set notification-log-limit 100
rs(config)# snmp set notification-log-ageout 60
!Configure the notification log
rs(config)# snmp set notification-log log1 filtername default store non-volatile
```

The RS provides various commands for monitoring the notification logs. In the example below, the **`snmp show notification-log`** command displays information about the notification log, *log1*:

```
rs# snmp show notification-log config log1
nlmLogName                    : log1
nlmConfigLogFilterName        : default
nlmConfigLogEntryLimit        : 0
nlmConfigLogAdminStatus       : enabled(1)
nlmConfigLogOperStatus        : operational(2)
nlmConfigLogStorageType       : nonVolatile(3)
nlmConfigLogEntryStatus       : active(1)
nlmStatsLogNotificationsLogged: 1
nlmStatsLogNotificationsBumped: 0
 --Security Credentials--
No security credentials are set
```

Because no security data was given when the log was configured, there are no security credentials displayed. Therefore only the filter is checked when a notification is logged.

In the following example, the `snmp show notification-log config-log` command lists the notifications that were logged:

```
rs# snmp show notification-log config-log all
Name           = nlmLogName
TimeTicks      = nlmLogTime
DateAndTime    = nlmLogDateAndTime
TargetAddress  = nlmLogEngineTAddress
NotificationID = nlmLogNotificationID
Name            TimeTicks       DateAndTime          TargetAddress   NotificationID
----            ---------       -----------          -------------   --------------
log1            80051900        2002-05-01 16:55:10  172.16.5.62     linkDown
log1            80203200        2002-05-01 17:20:24  172.16.5.62     linkDown
```

You can use the **`detail`** option to view detailed information about each notification, as shown in the following example:

```
rs# snmp show notification-log config-log all detailed
nlmLogName           = log1
nlmLogTime           = 80051900
nlmLogDateAndTime    = 2002-05-01 16:55:10
nlmLogEngineTAddress = 172.16.5.62
linkDown
ifIndex.10  10
ifAdminStatus.10  1
ifOperStatus.10  2
ifDescr.10  Physical port: gi.3.2

nlmLogName           = log1
nlmLogTime           = 80203200
nlmLogDateAndTime    = 2002-05-01 17:20:24
nlmLogEngineTAddress = 172.16.5.62
linkDown
ifIndex.1  1
ifAdminStatus.1  1
ifOperStatus.1  1
ifDescr.1  Physical port: et.2.1
```

Example 2: Filtering to 2 Different Logs

The following example uses notification filters to record linkUp and linkDown notifications into two different logs.

```
!Configure SNMP parameters
rs(config)# snmp set community public privilege read-write
rs(config)# snmp set target 172.16.5.62 community public
!Configure notification log parameters
rs(config)# snmp set notification-log-limit 100
rs(config)# snmp set notification-log-ageout 60
!Configure the notification filters for linkUp notifications
rs(config)# snmp set notification-filter linkup store non-volatile type included oid
snmpTrapOID
rs(config)# snmp set notification-filter linkup store non-volatile type included oid
sysUpTime
rs(config)# snmp set notification-filter linkup store non-volatile type included oid
ifTable
rs(config)# snmp set notification-filter linkup store non-volatile type included oid
linkUp
!Configure the notification filters for linkDown notifications
rs(config)# snmp set notification-filter linkdown store non-volatile type included oid
linkDown
rs(config)# snmp set notification-filter linkdown store non-volatile type included oid
ifTable
rs(config)# snmp set notification-filter linkdown store non-volatile type included oid
snmpTrapOID
rs(config)# snmp set notification-filter linkdown store non-volatile type included oid
sysUpTime
!Configure the notification log for linkUp notifications
rs(config)# snmp set notification-log linkup filtername linkup store non-volatile
!Configure the notification log for linkDown notifications
rs(config)# snmp set notification-log linkdown filtername linkdown store non-volatile
```

You can view the notification filters that you configured by using the **`snmp show notification-filters`** command, as shown in the following example:

```
rs# snmp show notification-filters

Notification Filters Table:
Filter Name             Object ID                    Mask              Incl./Excl. Last Change
linkup              sysUpTime               0              Included   2002-04-30, 14:27:22.00
linkup              ifTable                 0              Included   2002-04-30, 14:27:23.00
linkup              snmpTrapOID             0              Included   2002-04-30, 14:27:22.00
linkup              linkUp                  0              Included   2002-04-30, 14:27:23.00
default             iso                     0              Included   2002-04-22, 10:34:25.00
linkdown            sysUpTime               0              Included   2002-04-30, 14:27:23.00
linkdown            ifTable                 0              Included   2002-04-30, 14:27:23.00
linkdown            snmpTrapOID             0              Included   2002-04-30, 14:27:23.00
linkdown            linkDown                0              Included   2002-04-30, 14:27:23.00
```

To test the configuration, you can send test linkUp and linkDown notifications, as shown in the following example:

```
rs# snmp test trap type linkup
%SNMP-I-SENT_TRAP, Sending notification linkUp to management station
rs# snmp test trap type linkDown
%SNMP-I-SENT_TRAP, Sending notification linkDown to management station
```

Then, you can view the notifications in each log, as shown in the following example:

```
rs# snmp show notification-log config-log all
Name           = nlmLogName
TimeTicks      = nlmLogTime
DateAndTime    = nlmLogDateAndTime
TargetAddress  = nlmLogEngineTAddress
NotificationID = nlmLogNotificationID
Name            TimeTicks       DateAndTime          TargetAddress   NotificationID
----            ---------       -----------          -------------   --------------
linkup          70554900        2002-04-30 14:32:20  172.16.5.62     linkUp

linkdown        70554100        2002-04-30 14:32:12  172.16.5.62     linkDown
```

Example 3: Using View-Based Access Control for Notification Logs

The following example illustrates how notifications are logged to two different targets with different views. One log accepts linkUp notifications only, and the other accepts linkDown notifications only. This example also shows how security credentials that are associated with the creator of the notification log are used to log notifications.

The example also includes a notification log that records all notifications sent out.

Following is the configuration for *log1*, the log that records linkUp notifications only:

```
!Configure the first target and its parameters
rs(config)# snmp set target-addr g1TA store non-volatile address 10.50.7.4 params g1PA
tags trap port 1612
rs(config)# snmp set target-params g1PA store non-volatile level priv v3 security s1
!Configure the linkup view
rs(config)# snmp set view linkup store non-volatile type included oid snmpTrapOID
rs(config)# snmp set view linkup store non-volatile type included oid sysUpTime
rs(config)# snmp set view linkup store non-volatile type included oid ifTable
rs(config)# snmp set view linkup store non-volatile type included oid linkUp
rs(config)# snmp set view linkup store non-volatile type included oid
notificationLogMIB.*.*.*.*.*.6.115.50.45.108.111.103
!Configure the access group and security attributes
rs(config)# snmp set notification-profile filter default params g1PA store
non-volatile
rs(config)# snmp set security2group s1 group g1 v3 store non-volatile
rs(config)# snmp set user s1 group g1 password g1 encryption-key g1 auth-protocol md5
rs(config)# snmp set group g1 level priv v3 store non-volatile read linkup write all no
tify linkup
!Configure the notification log, log1
rs(config)# snmp set notification-log log1 filtername default store non-volatile model
v3 level priv securityname s1
```

Following is the configuration for *log2*, the log that records linkDown notifications only:

```
!Configure the second target and its parameters
rs(config)# snmp set target-addr g2TA store non-volatile address 172.16.5.62 params
g2PA port 1611
rs(config)# snmp set target-params g2PA store non-volatile level priv v3 security s2
!Configure the linkdown view
rs(config)# snmp set view linkdown oid linkDown store non-volatile type included
rs(config)# snmp set view linkdown store non-volatile type included oid ifTable
rs(config)# snmp set view linkdown store non-volatile type included oid snmpTrapOID
rs(config)# snmp set view linkdown store non-volatile type included oid sysUpTime
rs(config)# snmp set view linkdown store non-volatile type included oid notificationLog
MIB.*.*.*.*.*.6.115.49.108.111.103
!Configure the access group and security attributes
rs(config)# snmp set notification-profile filter default params g2PA store
non-volatile
rs(config)# snmp set security2group s2 group g2 v3 store non-volatile
rs(config)# snmp set user s2 group g2 password g2 encryption-key g2 auth-protocol md5
rs(config)# snmp set group g2 level priv v3 store non-volatile read linkdown write all
notify linkdown
!Configure the notification log, log2
rs(config)# snmp set notification-log log2 filtername default store non-volatile model
v3 level priv securityname s2
```

Following is the configuration for *logall*, the log that records all notifications:

```
!Configure SNMP parameters
rs(config)# snmp set community public privilege read-write
rs(config)# snmp set target 172.16.5.62 community public
!Configure the notification log
rs(config)# snmp set notification-log logall filtername default store non-volatile
```

The following example sends three types of test notifications:

```
rs141# snmp test trap type ps-recover
%SNMP-I-SENT_TRAP, Sending notification rsEnvPowerSypplyRecovered to management
station
rs141# snmp test trap type linkdown
%SNMP-I-SENT_TRAP, Sending notification linkDown to management station
rs141# snmp test trap type linkUp
%SNMP-I-SENT_TRAP, Sending notification linkUp to management station
```

The following example shows that the LinkUp notification was logged to *log1*, and the linkDown notification was logged to *log2*. Additionally all notification were logged to *logall* which had no filters or security attributes:

```
rs# snmp show notification-log config-log all
Name           = nlmLogName
TimeTicks      = nlmLogTime
DateAndTime    = nlmLogDateAndTime
TargetAddress  = nlmLogEngineTAddress
NotificationID = nlmLogNotificationID
Name            TimeTicks       DateAndTime          TargetAddress   NotificationID
----            ---------       -----------          -------------   --------------

log1            418600          2002-05-02 10:24:11  172.16.5.62     linkUp

log2            417400          2002-05-02 10:23:58  172.16.5.62     linkDown

logall          415900          2002-05-02 10:23:44  172.16.5.62 rsEnvirPower
SupplyRecovered
logall          417400          2002-05-02 10:23:58  172.16.5.62     linkDown

logall          418600          2002-05-02 10:24:11  172.16.5.62     linkUp
```

36.3 MIB MODULES

Riverstone supports the following IETF and IEEE standard networking MIB modules and proprietary MIB modules. You can use these MIB modules with any SNMP version. This list can be obtained from the output of the **`snmp show mibs`** enable mode command.

Table 36-1 Supported MIBs

MIB II	Layer 1	Layer 2	Layer 3	System Related	Enterprise
IP-MIB RFC 2011	ETHERLIKE-MIB | RFC 2665	FRAME-RELAY-DTE-MIB | RFC 2115	BGP4-MIB RFC 1657	RADIUS-AUTH-CLIENT-MIB | RFC 2618	
TCP-MIB RFC 2012	SONET-MIB RFC 1595	BRIDGE-MIB RFC 1493	RIPv2-MIB RFC 1724	RADIUS-ACC-CLIENT MIB RFC 2620	
UDP-MIB RFC 2013	DS0 MIB RFC 2494	Q-BRIDGE-MIB RFC 2674	OSPF-MIB RFC 1850	DISMAN-SCHEDULE-MIB RFC 2591	RIVERSTONE-STP-MIB 7/16/00
IP-FORWARD-MIB RFC 2096	DS1-MIB RFC 2495	P-BRIDGE-MIB RFC 2674	OSPF-TRAP-MIB | RFC 1850	ENTITY-MIB | RFC2737	RIVERSTONE-RS-AGENT-CAP-MIB
IF-MIB RFC 2233	DS3-MIB RFC 2496	PPP-LCP-MIB RFC 1471	RMON2-MIB RFC 2021	SNMPv3-MIB Modules| RFC 2570-2576	RIVERSTONE-ATM-MIB | 1/31/01
SNMPv2-MIB RFC 1907	DS0BUNDLE-MIB RFC 2494	PPP-SEC-MIB RFC 1472	VRRP-MIB RFC 2787	DIFF-SERV-MIB | Draft #5	RIVERSTONE-IMAGE-MIB | 3/16/01
	MAU MIB RFC 2668	PPP-IP-NCP-MIB RFC 1473	DVMRP-MIB Draft #4	PING-MIB RFC 2925	CISCO-BGP-POL-ACCOUNTING-MIB | 12/17/99
		PPP-BRIDGE-NCP-MIB RFC 1474	IGMP-MIB RFC 2933	TRACEROUTE-MIB RFC 2925	RIVERSTONE-LFAP-MIB | 6/15/01
		RMON-MIB RFC 1757	ISIS-MIB Draft #4	NOTIFICATION LOG-MIB RFC 3014	RIVERSTONE-RL-MIB | 10/10/02
		ATM-MIB RFC 2515	MPLS-LSR-MIB Draft #7	DHCP-SERVER-MIB Draft #7	RIVERSTONE-SNMP-MIB 12/4/00
		LAG MIB | 802.3ad			RIVERSTONE-NOTIFICATIONS-MIB 3/12/02
		ATM2-MIB Draft #17			CTRON-LFAP (deprecated) 8/28/99
					CTRON-SSR-POLICY (deprecated) 8/11/99
					CTRON-SSR-CONFIG 6/27/00
					CTRON-SSR-HARDWARE (deprecated) 6/27/00
					CTRON-SSR-SERVICE-STATUS (deprecated) 6/27/00
					CTRON-SSR-CAPACITY-MIB 6/27/00
					RIVERSTONE-INVENTORY-MIB 8/22/01

Table 36-1 Supported MIBs (Continued)

	RIVERSTONE-MPLS-MIB 5/24/02
	RIVERSTONE-QUEUE-MIB 6/12/02
	RIVERSTONE-VLAN-EXTENSION-MIB 8/5/02
	RIVERSTONE-PING-EXTENSIONS-MIB 10/9//02
	RIVERSTONE-TRACEROUTE-EXTENSIONS-MIB 10/11/02
	RIVERSTONE-IF-MIB 10/17/02
	RIVERSTONE-VLAN-EXTENSIONS-MIB 8/5/02
	CISCO-SRP-MIB 3/28/01
	RIVERSTONE-DHCP-MIB 9/10/02
	RIVERSTONE-CONFIG-MIB 11/30/02

36.3.1 Enabling/Disabling MIB Modules

All MIB modules are enabled (or online) by default. If you don't configure views, all MIB modules can be accessed by SNMP management stations that provide the correct community strings. You may want to provide access to a smaller set of MIB modules without having to configure views. To do so, you can "disable" MIB modules by using the **`snmp set mib`** command as shown in the following example:

```
rs(config)# snmp set mib name bgp4-mib status disable
rs(config)# snmp set mib name ospf-mib status disable
rs(config)# snmp set mib name ripv2-mib status disable
```

You can then view the MIB modules, including their status, as shown in the following example:

```
rs# snmp show mibs
SNMP AGENT MIB Registry
Last Modified: 0 days 0 hours 1 min 34 secs
Index  Name                       Version    Status
-----  ----                       -------    ------
1      SNMPv2-MIB                 1907       online
2      EtherLike-MIB              2665       online
3      MAU-MIB                    2668       online
4      IF-MIB                     2233       online
5      IP-MIB                     2011       online
6      IP-FORWARD-MIB             2096       online
7      UDP-MIB                    2013       online
8      TCP-MIB                    2012       online
9      BGP4-MIB                   1657       offline
10     OSPF-MIB                   1850       offline
11     RIPv2-MIB                  1724       offline
12     BRIDGE-MIB                 1493+2674  online
13     FRAME-RELAY-DTE-MIB        2115       online
14     PPP-LCP-MIB                1471       online
15     PPP-SEC-MIB                1472       online
16     PPP-IP-NCP-MIB             1473       online
17     PPP-BRIDGE-NCP-MIB         1474       online
18     DS0-MIB                    2494       online
19     DS0BUNDLE-MIB              2494       online
.
.
.
```

36.3.2 SNMPv3 MIB Table Entries

The RS supports the standard SNMPv3 MIB tables. It provides commands you can use to create rows in these tables. Following is a list of tables and the commands used to add rows to each table.

Table 36-2 SNMPv3 Tables

Use this command...	for this table...	for additional information, see...
`snmp set snmp-community`	snmpCommunityTable	RFC 2576
`snmp set target-addr`	snmpTargetAddrTable	RFC 2573
`snmp set target-params`	snmpTargetParamsTable	RFC 2573
`snmp set notification`	snmpNotifyTable	RFC 2573
`snmp set notification-profile`	snmpNotifyFilterProfileTable	RFC 2573
`snmp set notification-filter`	snmpNotifyFilterTable	RFC 2573

Table 36-2 SNMPv3 Tables

Use this command...	for this table...	for additional information, see...
`snmp set user`	usmUserTable	RFC 2574
`snmp set security2group`	vacmSecurityToGroupTable	RFC 2575
`snmp set group`	vacmAccessTable	RFC 2575
`snmp set view`	vacmViewTreeFamilyTable	RFC 2575

Note It is recommended that you use the commands described in *Creating Views*, *Configuring Access Groups*, and *Configuring Users*, instead of the commands in Table 36-2 to configure the MIB tables directly.

37 WDM CONFIGURATION

The R38-WDMD9-04 line card uses Wave Division Multiplexing (WDM) to provide four channels of 1000Base-TX. While the WDM line card has only a single physical port, each channel acts as a virtual Gigabit Ethernet port, for a total of four Gigabit ports. These WDM *virtual ports* function as *physical ports* on the RS 38000; they can be assigned interfaces, added to VLANs, and incorporated into SmartTRUNK aggregations.

Table 37-1 shows the relationship between the channels, their wavelengths, and the ports they represent.

Table 37-1 WDM channel, wavelength, and port

Channel	Wavelength[1]	Corresponding Port[2]
l1	1500 nm	Port 1 – gi.x.1
l2	1520 nm	Port 2 – gi.x.2
l3	1540 nm	Port 3 – gi.x.3
l4	1560 nm	Port 4 – gi.x.4

[1] Wavelengths are approximate

[2] The X represents the number of the slot in which the WDM line card resides.

Note Notice in the table above that WDM ports use the same naming convention as other Gigabit Ethernet ports: **gi**.<*slot*>.<*port number*>.

37.1 ENABLING WDM CHANNELS

By default, each WDM Gigabit port is disabled and must be enabled using the **port enable wdm** command. For example, the following enables the first and second ports (channels) on the WDM line card in slot five of the RS 38000:

```
rs(config)# port enable wdm ports gi.5.1
rs(config)# port enable wdm ports gi.5.2
```

Note Keep in mind that when connecting two WDM line cards together, the identical channels (ports) must be enabled on both WDM line cards. For example, if channel l1 is enabled on one WDM line card, channel l1 must also be enabled on the other WDM line card, and so on.

37.2 WDM SAMPLE CONFIGURATIONS

The following section is a set of simple sample configurations using WDM ports. The hardware used in these examples is two RS 38000s, each containing a 4-port GBIC Gigabit Ethernet line card and a WDM line card. The setup in Figure 37-1 applies to each of the following four examples.

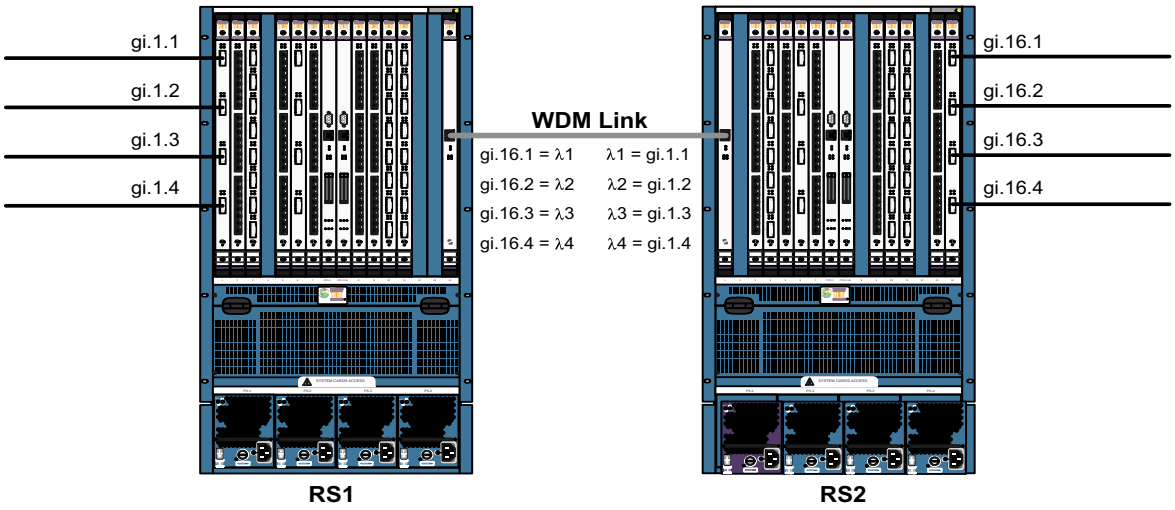


Figure 37-1 Physical setup for configuration examples

37.2.1 Example One: Layer-2 Port-by-Port Connection

In this example, four VLANs are created on each RS 38000. Each VLAN is assigned a WDM channel (port) and one of the Gigabit Ethernet ports on the GBIC line cards. All GBIC Gigabit Ethernet traffic is multiplexed across the WDM link

For RS1, enter the following configuration commands:

```
rs(config)# port enable wdm ports gi.16.1-4
rs(config)# vlan create wdm1 id 2
rs(config)# vlan create wdm2 id 3
rs(config)# vlan create wdm3 id 4
rs(config)# vlan create wdm4 id 5
rs(config)# vlan add port gi.16.1,gi.1.1 to wdm1
rs(config)# vlan add port gi.16.2,gi.1.2 to wdm2
rs(config)# vlan add port gi.16.3,gi.1.3 to wdm3
rs(config)# vlan add port gi.16.4,gi.1.4 to wdm4
```

For RS2, enter the following configuration lines:

```
rs(config)# port enable wdm ports gi.1.1-4
rs(config)# vlan create wdm1 id 2
rs(config)# vlan create wdm2 id 3
rs(config)# vlan create wdm3 id 4
rs(config)# vlan create wdm4 id 5
rs(config)# vlan add port gi.1.1,gi.16.1 to wdm1
rs(config)# vlan add port gi.1.2,gi.16.2 to wdm2
rs(config)# vlan add port gi.1.3,gi.16.3 to wdm3
rs(config)# vlan add port gi.1.4,gi.16.4 to wdm4
```

37.2.2 Example Two: Assigning WDM ports to a SmartTRUNK

In this example, all WDM ports are added to a SmartTRUNK. A single VLAN is created on each RS 38000, and both the SmartTRUNKs and the GBIC Gigabit Ethernet ports are added to the VLAN, which connect through the WDM link.

For RS1, enter the following configuration commands:

```
rs(config)# smarttrunk create st.1 protocol no-protocol
rs(config)# port enable wdm ports gi.16.1-4
rs(config)# smarttrunk add ports gi.16.1-4 to st.1
rs(config)# vlan create wdm id 12
rs(config)# vlan add ports st.1 to wdm
rs(config)# vlan add ports gi.1.1-4 to wdm
```

For RS2, enter the following configuration commands:

```
rs(config)# smarttrunk create st.1 protocol no-protocol
rs(config)# port enable wdm ports gi.1.1-4
rs(config)# smarttrunk add ports gi.1.1-4 to st.1
rs(config)# vlan create wdm id 12
rs(config)# vlan add ports st.1 to wdm
rs(config)# vlan add ports gi.16.1-4 to wdm
```

37.2.3 Example Three: Back-to-Back Layer-3 WDM Connection

In this example, each of the WDM ports are assigned interfaces on each RS 38000, where the corresponding WDM ports (channels) on each of the RS 38000s are on the same subnet. This creates four layer-3 connections across the WDM link.

For RS1, enter the following configuration commands:

```
rs(config)# port enable wdm ports gi.16.1-4
rs(config)# interface create ip wdm1 address-netmask 192.1.1.1/24 port gi.16.1
rs(config)# interface create ip wdm2 address-netmask 193.1.1.1/24 port gi.16.2
rs(config)# interface create ip wdm3 address-netmask 194.1.1.1/24 port gi.16.3
rs(config)# interface create ip wdm4 address-netmask 195.1.1.1/24 port gi.16.4
```

For RS2, enter the following configuration commands:

```
rs(config)# port enable wdm ports gi.1.1-4
rs(config)# interface create ip wdm1 address-netmask 192.1.1.2/24 port gi.1.1
rs(config)# interface create ip wdm2 address-netmask 193.1.1.2/24 port gi.1.2
rs(config)# interface create ip wdm3 address-netmask 194.1.1.2/24 port gi.1.3
rs(config)# interface create ip wdm4 address-netmask 195.1.1.2/24 port gi.1.4
```

37.2.4 Example Four: Layer-3 WDM Connection through Single Interface

In this example, the WDM ports are added to a SmartTRUNK on each RS 38000. The SmartTRUNK is assigned to an interface. As a result, the two RS 38000s are connected such that all WDM ports are within the same subnet.

For RS1, enter the following configuration commands:

```
rs(config)# port enable wdm gi.16.1-4
rs(config)# smarttrunk create st.1 protocol no-protocol
rs(config)# smarttrunk add ports gi.16.1-4 to st.1
rs(config)# interface create ip wdm address-netmask 192.10.31.1/24 port st.1
```

For RS2, enter the following configuration commands:

```
rs(config)# port enable wdm gi.1.1-4
rs(config)# smarttrunk create st.1 protocol no-protocol
rs(config)# smarttrunk add ports gi.1.1-4 to st.1
rs(config)# interface create ip wdm address-netmask 192.10.31.2/24 port st.1
```

38 RTR CONFIGURATION

This chapter discusses how to use the Response Time Reporter (RTR) facility on the RS to determine network availability, the response times between nodes on the network, and route paths between devices. RTR implements the functionality of the SNMP MIBs titled DISMAN-PING-MIB and DISMAN-TRACEROUTE-MIB as defined in RFC 2925. These commands allow you to set-up pre-configured tests to monitor the following:

- Connectivity between nodes
- Response time between nodes using either the ICMP Echo, a TCP connection operation, a UDP Echo operation, or and ATM OAM ping.
- The number of hops within a route between two nodes and the response time for each hop.
- Changes in routes between two nodes.

The data generated from these tests can be used to develop historical trends, send SNMP traps when a configured threshold is exceeded or a route has changed, or for periodic checks of network connectivity. Parameters are available that allow you to determine how much historical data is retained, and under which circumstances SNMP traps are generated.

This chapter contains the following two examples of how RTR can be used to perform response time monitoring:

- Section 38.1, *"Example of RTR Scheduled PING test,"* describes how to configure a scheduled ping test operation
- Section 38.2, *"Example of RTR Scheduled TRACEROUTE test,"* describes how to configure a scheduled traceroute test operation

Each of these examples describe how to configure a test, run it and then view the results of the test.

Note The RTR functionality is now available through SNMP using the RIVERSTONE-PING-EXTENSIONS-MIB and the RIVERSTONE-TRACEROUTE-EXTENSIONS-MIB.

38.1 EXAMPLE OF RTR SCHEDULED PING TEST

The example in Figure 38-1 shows an RTR scheduled ping test configured from R1 (source) to Host 1 (target). The test is configured on R1.

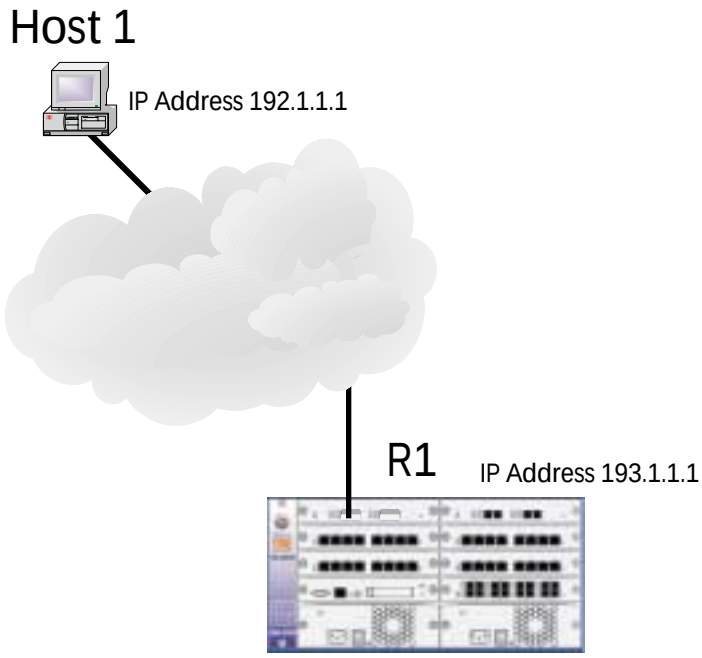


Figure 38-1 Configuring a RTR scheduled ping test

The following sections describe how to configure a scheduled ping test operation for this example, run it, and view the results:

- Section 38.1.1, *"Configuring an RTR Scheduled Ping test,"* describes how to configure a test
- Section 38.1.2, *"Running an RTR Scheduled Ping Test,"* describes how to run a test or test operation
- Section 38.1.3, *"Configuring an RTR Ping Operation to Execute at a Recurring Interval,"* describes how to configure a test operation to be performed at a recurring interval
- Section 38.1.5, *"Viewing the Parameters and Results of an RTR Scheduled Ping Test,"* describes how to view the configuration and results of a test or test operation
- Section 38.1.6, *"Using the RTR ATM OAM Ping facility,"* describes how to use the RTR ATM OAM ping capability

38.1.1 Configuring an RTR Scheduled Ping test

This example describes how to configure the test described in Section 38.1, *"Example of RTR Scheduled PING test."* When configuring a ping operation, there are three mandatory parameters: owner, test-name, and target. The owner/test-name combination comprises the index for the operation being defined and as such must be unique. This index is then used by other commands such as **`rtr start`** and **`rtr show`** to identify which configured ping operation that you want to start or display. The RTR facility will use the defaults defined in RFC 2925 for all other parameters, unless configured otherwise.

In this example, the ping operation is conducted using the Internet Control Message Protocol (ICMP) “ECHO” facility. The owner of the test is “ADMIN,” the test-name is “TEST1,” the **probe-fail limit** is set at 1 and the **probe-failure traps** parameter is set to send a trap if the ping operation fails. The SNMP traps will be sent to hosts defined using the **SNMP Set Target** command for the RS. **Source** and **target** for operation of this test are specified as defined in Figure 38-1. Defaults are accepted for all other parameters:

```
rs(config)# rtr schedule ping owner ADMIN probe-limit-fail 1 probe-failure-traps source
193.1.1.1 target 192.1.1.1 test-name TEST1
```

To finish creating the ping test operation, you must execute a **save active** command at the configuration prompt, as shown in the following example:

```
rs(config)# save active
%RTR-I-TESTCREATED, Successfully created Ping operation for owner "ADMIN", test
name "TEST1"
%RTR-I-NEWTESTINACTIVE, Newly created test operation is idle. To start the operation,
please use the enable mode command "rtr start ping"
rs(config)#
```

As shown in the example, the test operation is created in the idle state. To run the test operation you must either include the **immediate-start** parameter or use the **rtr start ping** command in Enable mode, as described in Section 38.1.2, *"Running an RTR Scheduled Ping Test."*

38.1.2 Running an RTR Scheduled Ping Test

RTR schedule ping test operations can be run from the Config mode using the **immediate-start** parameter or from Enable mode using the **rtr start ping** command. If you include the **immediate-start** parameter in the **rtr schedule ping** command during configuration, the command will begin to execute as soon as it is saved to the active configuration, as shown in the following example:

```
rs<config># rtr schedule ping owner ADMIN probe-limit-fail 1 probe-limit-traps source
193.1.1.1 target 192.1.1.1 test-name TEST1 immediate-start
rs<config># save active
%RTR-I-TESTCREATED, Successfully created Ping operation for owner "ADMIN", test
name "TEST2"
rs(config)#
```

If you didn't use the **immediate-start** parameter, you must use the **rtr start ping** command in Enable mode. This example runs the ping test operation configured in Section 38.1.1, *"Configuring an RTR Scheduled Ping test."* The owner/test-name defined during configuration is used with this command to identify the test operation you want to run.

```
rs# rtr start ping owner ADMIN test-name TEST1
```

38.1.3 Configuring an RTR Ping Operation to Execute at a Recurring Interval

Using the **frequency** parameter of the **rtr schedule** command, you can configure an RTR Test Operation to be performed at a recurring interval. This example describes how to configure the same test described in Section 38.1, *"Example of RTR Scheduled PING test,"* with the **frequency** parameter of the **rtr schedule** command set for a execution at a recurring interval.

In the following example, the **rtr schedule ping** command is used to configure the test operation to operate at a recurring interval. The frequency parameter is set to run the test operation once per day (every 86400 seconds) and the rest of the parameters are the same as defined in Section 38.1.2, *"Running an RTR Scheduled Ping Test."*

```
rtr schedule ping owner ADMIN test-name TEST1 probe-limit-fail 1 probe-limit-traps
source 192.1.1.1 target 193.1.1.1. frequency 86400
```

Once the RTR test operation has been configured it can be set in motion through use of the **rtr start** command, as described in Section 38.1.2, *"Running an RTR Scheduled Ping Test."* Alternatively, it could be started at configuration time by inserting the **immediate-start** parameter in the command. Once started, a command configured with a frequency parameter will run at the recurring interval until it is halted by an **rtr suspend** command.

38.1.4 Stopping a Running RTR Ping Test Operation

RTR ping test operations can be run from Enable Mode using the **rtr start** command or from Configure mode by setting the **immediate-start** parameter in the **rtr schedule** command. If the command is configured without the **frequency** parameter specified, it will halt after executing the test operation once. If the command is configured with the **frequency** parameter to operate at a recurring interval, as described in Section 38.1.3, *"Configuring an RTR Ping Operation to Execute at a Recurring Interval,"* you must halt it using the **rtr suspend** command from Enable mode. This example describes the command used to suspend the ping test operation configured in Section 38.1.1, *"Configuring an RTR Scheduled Ping test."* The owner/test-name defined during configuration is used with this command to identify the test operation you want to suspend.

```
rs(config)# rtr suspend ping owner ADMIN test-name TEST1
```

38.1.5 Viewing the Parameters and Results of an RTR Scheduled Ping Test

RTR ping test operations can be run from Enable mode using the **`rtr start`** command or from Configure mode by setting the **`immediate-start`** parameter in the **`rtr schedule`** command. Once a test is run, you need to use the **`rtr show ping`** command to view the results of a test. This example shows the parameters and results for the ping test configured in Section 38.1.1, *"Configuring an RTR Scheduled Ping test."* The owner/test-name defined during configuration is used with this command to identify the test operation whose parameters and results you want to view.

```
rs# rtr show ping all owner ADMIN test-name TEST1
Maximum Concurrent Scheduled Ping Operations: 10

Patterns stored in /int-flash/cfg/rtr/

Owner: ADMIN
Test Name: TEST1

  Status: Enabled
  Target: 192.1.1.1
  Source: 193.1.1.1

  Ping Type:                          ICMP Echo
  Probes per Test:                    1 packet
  Timeout:                            3 seconds
  Frequency:                          every 60 seconds
  Maximum History Table Size:         50 rows
  Probe Fail Limit:                   1 probe
  Test Fail Limit:                    1 probe


  Bypass Routing Table:               No
  ToS/DS Byte:                        0x00 (decimal: 0)
  Data Payload Size:                  0 octets
  Use Pattern File:                   No


  Send Trap on Probe Failure:         No
  Send Trap on Test Failure:          No
  Send Trap on Successful Test:       No

  2 packets transmitted, 2 packets received, 0% packet loss
  Round Trip Time (ms): min/avg/max/sum2 = 3.266/3.309/3.352/21.902

  Results History:

              Round Trip                          Return
    Index        Time              Status          Code        Timestamp
  ---------  --------------  --------------------  ------  -------------------
          1      3.266 msec  Response Received         0   12/11/2001 11:09:56
          1      3.266 msec  Response Received         0   12/11/2001 11:09:56
```

38.1.6 Using the RTR ATM OAM Ping facility

Note This section describes just the ATM OAM ping-specific capabilities of the RTR facility. All other RTR scheduling capabilities apply equally to the ATM OAM ping feature.

RTR provides the ability to perform ATM *end-to-end* or *segment* pings using Operation Administration and Management (OAM) flows. This is an ATM layer (layer-2) ping capability provided by OAM flows F4 and F5, which exist within the ATM cell header.

The F5 and F4 flows relate to VC and VP monitoring, respectively. Both F4 and F5 flows are designated as either *segment* or *end-to-end* inquiries, depending on the encoding within the ATM cell header. An end-to-end flow is from one end-point to another, and is received only by the device terminating the ATM connection. Conversely, *segment* flows are from one connection point to another – a connection point where a VCI or VPI is assigned, reassigned or terminated.

For F4 flows, the VCI field identifies the OAM as a *segment* type, if the VCI = 3; or as an *end-to-end* type, if the VCI = 4. In the case of F4 OAM flows the VPI is equal to that of the user's data cells.

F5 flows operate in much the same way as F4 flows, however, both the VPI and VCI are set to that of the data flow. In the case of F5 flows, the Path Termination (PT) is used to identify the type of OAM flow (segment or end-to-end). Note that the PT is specified automatically for F5 flows when either the **`segment`** or **`end-to-end`** option is selected.

Note For a complete list of RTR ATM ping options, see the *RTR chapter* of the *"Riverstone Networks Command Line Interface Reference Manual."*

Sending ATM OAM Pings

The following example uses the RTR facility to send an F5 flow to create an end-to-end OAM ping. The example assumes that a VCL of **`at.5.1.0.100`** has been created, and an ATM OAM service of end-to-end has been created and applied to the VCL:

```
rs(config)# rtr schedule atm-ping atm-flow-type end-to-end atm-port at.5.1.0.100 owner
IT test-name test1 immediate-start
```

The count of these F5 OAM pings can be viewed using the **atm show vc-stats oam** command. For example:

```
rs# atm show vc-stats port at.5.1.0.100 oam
at.5.1.0.100 Transmitted OAM Cells

      End Loop   Segment Loop      AIS           RDI
   +------------+-------------+------------+------------+
F5 |        112 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+
F4 |          0 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+

at.5.1.0.100 Received OAM Cells

      End Loop   Segment Loop      AIS           RDI
   +------------+-------------+------------+------------+
F5 |         74 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+
F4 |          0 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+

Cells Dropped: 0
```

The following example uses the RTR facility to send an F4 flow to create an end-to-end OAM ping. The example assumes that a VCL of **at.5.1.0.4** (VCI of 4 equals end-to-end for F4 OAM flows) has been created, and an ATM OAM service of end-to-end has been created and applied to the VCL

```
rs(config)# rtr schedule atm-ping atm-flow-type end-to-end atm-port at.5.1.0.4 owner
IT test-name test1 immediate-start
```

The count of these F4 OAM pings can be viewed using the **atm show vc-stats oam** command. For example:

```
rs# atm show vc-stats port at.5.1.0.4 oam
at.5.1.0.100 Transmitted OAM Cells

      End Loop   Segment Loop      AIS           RDI
   +------------+-------------+------------+------------+
F5 |          0 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+
F4 |        115 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+

at.5.1.0.100 Received OAM Cells

      End Loop   Segment Loop      AIS           RDI
   +------------+-------------+------------+------------+
F5 |          0 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+
F4 |        101 |          0  |          0 |          0 |
   +------------+-------------+------------+------------+

Cells Dropped: 0
```

38.2 EXAMPLE OF RTR SCHEDULED TRACEROUTE TEST

The example in Figure 38-2 shows an RTR scheduled traceroute test configured from R1 (source) to Host 1 (target). The test is configured on R2.

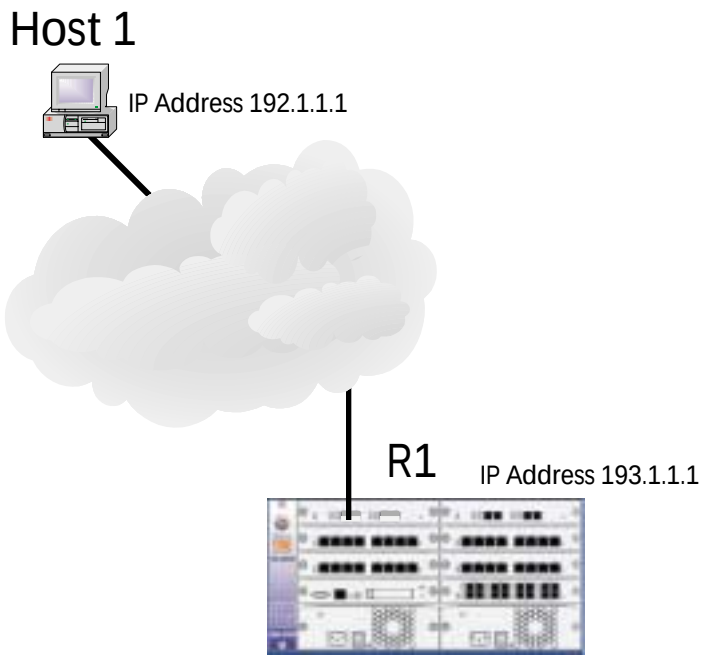


Figure 38-2 Configuring an RTR Scheduled Traceroute Test

The following sections describe how to configure a Scheduled Traceroute test for this example, run it, and view the results:

- To configure a traceroute test operation, see Section 38.2.1, *"Configuring an RTR Scheduled Traceroute Test Operation."*
- To run a traceroute test operation see Section 38.2.2, *"Running an RTR Scheduled Traceroute Test."*
- To configure a traceroute test operation to be performed at a recurring interval, see Section 38.2.3, *"Configuring an RTR Traceroute Operation to Execute at a Recurring Interval."*
- To view the configuration and results of a RTR traceroute test operation see Section 38.2.5, *"Viewing the Parameters and Results of an RTR Scheduled Traceroute Test."*

38.2.1 Configuring an RTR Scheduled Traceroute Test Operation

This example describes how to configure the test described in Section 38.2, *"Example of RTR Scheduled TRACEROUTE test."* When configuring a traceroute operation, there are three mandatory parameters: owner, test-name, and target. The owner/test-name combination comprises the index for the operation being defined and as such must be unique. This index is then used by other commands such as **`rtr start`** and **`rtr show`** to identify the configured traceroute operation that you want to start or view. The RTR facility will use the defaults defined in RFC 2925 for all other parameters, unless configured otherwise.

In this example, the owner of the test is “ADMIN,” the test-name is TEST1 and the **path-change-traps** parameter is set to send a trap if the path between Host 1 and R2 changes. Source and target are specified as defined in Figure 38-2. Defaults are accepted for all other parameters.

```
rs(config) rtr schedule traceroute owner ADMIN path-change-traps source 192.1.1.1
target 193.1.1.1 test-name TEST1
```

Note If you want to save path information during a traceroute test operation, you must add the **save-path** parameter to the command syntax.

To finish creating the traceroute test operation, you must execute a **save active** command at the configuration prompt, as shown in the following example:

```
rs(config)# save active
%RTR-I-TESTCREATED, Successfully created Traceroute operation for owner "ADMIN", test
name "TEST1"
%RTR-I-NEWTESTINACTIVE, Newly created test operation is idle. To start the operation,
please use the enable mode command "rtr start traceroute"
rs(config)#
```

As shown in the example, the test operation is created in the idle state. To run the test operation you must either include the **immediate-start** parameter or use the **rtr start traceroute** command in Enable mode as described in Section 38.2.2, *"Running an RTR Scheduled Traceroute Test."*

38.2.2 Running an RTR Scheduled Traceroute Test

RTR scheduled traceroute test operations can be run from the Config mode using the **immediate-start** parameter or from Enable Mode using the **rtr start traceroute** command. If you include the **immediate-start** parameter in the **rtr schedule traceroute** command during configuration, the command will begin to execute as soon as it is saved to the active configuration, as shown in the following example:

```
rs(config)# rtr schedule traceroute owner ADMIN path-change-traps source 193.1.1.1
target 192.1.1.1 test-name TEST1 immediate-start
rs(config)# save active
%RTR-I-TESTCREATED, Successfully created Traceroute operation for owner "ADMIN", test
name "TEST2"
rs(config)#
```

If you didn't use the **immediate-start** parameter, you must use the **rtr start traceroute** command in enable mode. This example runs the traceroute test operation configured in Section 38.2.1, *"Configuring an RTR Scheduled Traceroute Test Operation."* The owner/test-name defined during configuration is used with this command to identify the test operation you want to run.

```
rs# rtr start traceroute owner ADMIN test-name TEST1
```

38.2.3 Configuring an RTR Traceroute Operation to Execute at a Recurring Interval

Using the **frequency** parameter of the **rtr schedule traceroute** command, you can configure an RTR test operation to be performed at a recurring interval. This example describes how to configure the same test described in Section 38.2, *"Example of RTR Scheduled TRACEROUTE test,"* with the **frequency** parameter of the **rtr schedule traceroute** command set for a execution at a recurring interval.

In the following example, the **rtr schedule traceroute** command is used to configure the test operation to operate at a recurring interval. The frequency parameter is set to run the test operation once per day (every 86400 seconds) and the rest of the parameters are the same as defined in Section 38.1.2, *"Running an RTR Scheduled Ping Test."*

```
rs(config)# rtr schedule traceroute owner ADMIN test-name TEST1 path-change-traps
source 193.1.1.1 target 192.1.1.1 immediate-start frequency 86400
```

Once the RTR test operation has been configured it can be set in motion through use of the **rtr start traceroute** command as described in Section 38.2.2, *"Running an RTR Scheduled Traceroute Test."* Alternatively, it could be started at configuration time by inserting the **immediate-start** parameter in the command (as shown in this example). Once started, a command configured with a **frequency** parameter will run at the recurring interval until it is halted by an **rtr suspend traceroute** command.

38.2.4 Stopping a Running RTR Traceroute Test Operation

RTR traceroute test operations can be run from Enable mode using the **rtr start traceroute** command or from Configure mode by setting the **immediate-start** parameter in the **rtr schedule traceroute** command. If the command is configured without the **frequency** parameter specified, it will halt after executing the test operation once. If the command is configured with the **frequency** parameter to operate at a recurring interval, as described in Section 38.2.3, *"Configuring an RTR Traceroute Operation to Execute at a Recurring Interval,"* you must halt it using the **rtr suspend traceroute** command from Enable mode. This example describes the command used to suspend the traceroute test operation configured in Section 38.2.1, *"Configuring an RTR Scheduled Traceroute Test Operation."* The owner/test-name defined during configuration is used with this command to identify the test operation you want to suspend.

```
rs# rtr suspend traceroute owner ADMIN test-name TEST1
```

38.2.5 Viewing the Parameters and Results of an RTR Scheduled Traceroute Test

RTR show traceroute tests are run from Enable Mode. This example shows the parameters and results for the traceroute test configured in Section 38.2.1, *"Configuring an RTR Scheduled Traceroute Test Operation."*

```
rs(config)# rtr show ping all owner ADMIN test-name TEST1
```

38.2.6 Viewing the Parameters and Results of an RTR Scheduled Traceroute Test

RTR traceroute test operations can be run from Enable mode using the **rtr start traceroute** command or from Configure mode by setting the **immediate-start** parameter in the **rtr schedule traceroute** command. Once a test is run, you need to use the **rtr show traceroute** command to view the results of a test operation. This

example shows the parameters and results for the traceroute test configured in Section 38.2.1, *"Configuring an RTR Scheduled Traceroute Test Operation."*. The owner/test-name defined during configuration is used with this command to identify the test operation whose parameters and results you want to view.

```
rs# rtr show traceroute all owner ADMIN test-name TEST1
Maximum Concurrent Scheduled Traceroute Operations: 10

Owner: ADMIN
Test Name: TEST1

  Status: Enabled
  Target: 193.1.1.1
  Source: 192.1.1.1

  Probes Per Hop:                     3 packets
  Timeout:                            3 seconds
  Frequency:                          every 60 seconds
  Maximum History Table Size:         50 rows
  Save Path Information:              No

  Bypass Routing Table:               No
  ToS/DS Byte:                        0x00 (decimal: 0)
  Initial/Maximum TTL:                1/30
  Target UDP Port:                    33434
  Maximum Failures Before Termination: 5
  Data Payload Size:                  0 octets

  Send Trap on Path Change:           Yes
  Send Trap on Test Failure:          No
  Send Trap on Successful Test:       No

  1 tests started, 1 completed successfully.

  Results History:

              Round Trip                          Return
                 Time             Status           Code        Timestamp
             -------------  -------------------  ------  -------------------
  Index #1 - 193.1.1.1 (Probe #1 for TTL=1)
                 2.006 msec  Response Received        11   12/11/2001 16:01:31

  Index #2 - 134.141.179.129 (Probe #2 for TTL=1)
                 1.924 msec  Response Received        11   12/11/2001 16:01:32

  Index #3 - 134.141.179.129 (Probe #3 for TTL=1)
                 1.929 msec  Response Received        11   12/11/2001 16:01:33

  Index #4 - 134.141.171.177 (Probe #1 for TTL=2)
                 2.117 msec  Response Received        11   12/11/2001 16:01:33
```

39 LAYER-2 MAC-PING AND TRACE (ETHERNET OAM) CONFIGURATION GUIDE

This chapter describes operation of the MAC Ping facility. This facility allows you to perform management functions, such as performance monitoring and fault management at the physical (MAC) layer. Using this facility, you can send an EOAM mac ping frame to determine connectivity or include the tracepath option to trace the layer-2 path to a destination RS Switch Router.

Configuration and operation of this facility involves the following”

- Section 39.0.1, *"Setting an Authentication Key."*
- Section 39.0.2, *"Confirming a Layer-2 Connection."*
- Section 39.0.3, *"Sending a MAC Ping Tracepath Packet."*
- Section 39.0.4, *"Managing the name-mac-list Table."*
- Section 39.0.5, *"Displaying mac-ping Statistics."*
- Section 39.0.6, *"Enabling the Tracing Function."*

39.0.1 Setting an Authentication Key

In contrast to IP Ping which requires no special authorization, the MAC Ping facility requires use of an authentication key for operation. This key is also used to authorize any Riverstone equipment that is traversed to provide information when the MAC Ping utility is used. If there is non-Riverstone equipment or Riverstone equipment without a correct authentication key along the path between the originator and the target, the MAC Ping operation will succeed however, no trace information will be provided

Use of the authentication key differs somewhat depending on whether you are issuing a simple MAC Ping to determine connectivity and response time or using the traceroute option to identify routers along the path.

.The following sections determine each of these possible uses:

- *"Setting an Authentication Key for MAC Ping."*
- *"Setting an Authentication Key for MAC Ping with the Traceroute option."*

Setting an Authentication Key for MAC Ping

In a simple MAC Ping operation, only the Originator router and the Target router must be configured with the same EOAM authentication key. Routers that are on the path between the Originator and Target do not need to have an authentication key set. Figure 39-1 shows a network with four routers. In this example, R1 is being setup to send a MAC Ping packet to R4.

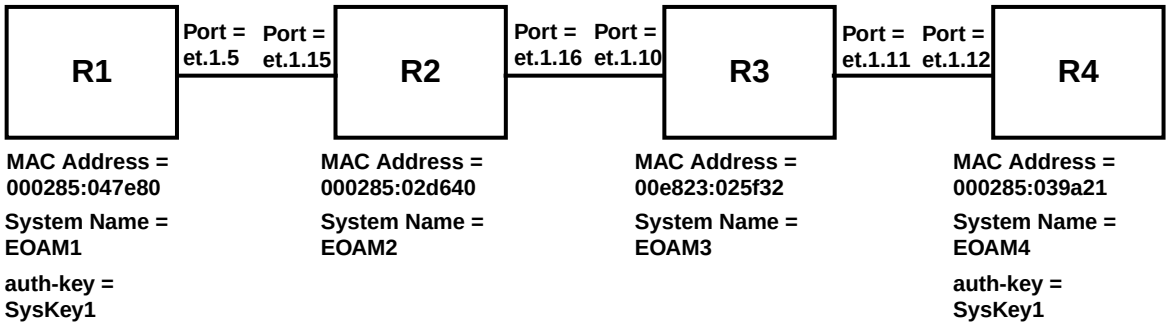


Figure 39-1 MAC Ping Example

To enable this operation, routers R1 and R4 would have to be configured with the same auth-key variable. The EOAM authentication key is a character string up to 32 characters long that is set using the **`eoam set auth-key`** command. The following example defines the authentication key as *SysKey1*.

```
rs(config)# eoam set auth-key SysKey1
```

This command must be performed in R1 and R4.

To determine if the authentication key is enabled you can use the **`eoam show globals`** command on each router, as shown in the following example.

```
rs # eoam show globals
Ethernet OAM enabled
```

The **`Ethernet OAM enabled`** message indicates that the authentication key is set.

Setting an Authentication Key for MAC Ping with the Traceroute option

In a MAC Ping operation using the Traceroute option, the Originator router, the Target router and all intermediate routers between them that you want to obtain Traceroute information about, must be configured with the same EOAM authentication key. Figure 39-2 shows a network with four routers. In this example, R1 is being setup to send a MAC Ping packet with the Traceroute option enabled to R4.

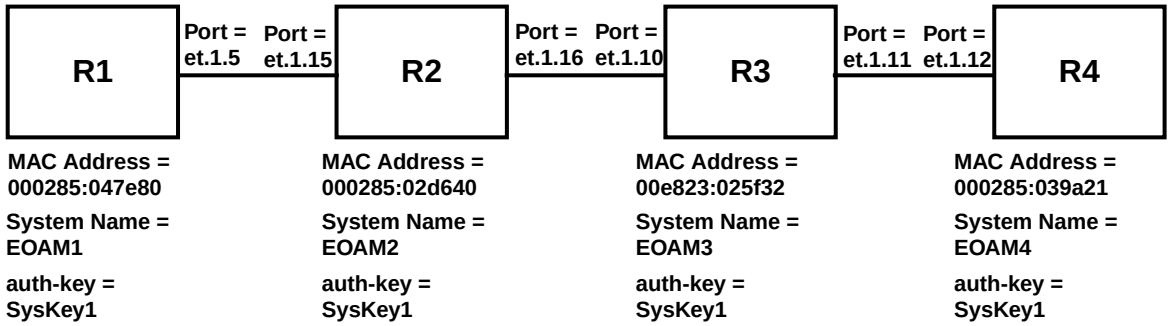


Figure 39-2 MAC Ping example with Traceroute

To enable this operation, routers R1, R2, R3 and R4 have to be configured with the same auth-key variable. The EOAM authentication key is a character string up to 32 characters long that is set using the **`eoam set auth-key`** command. The following example defines the authentication key as *SysKey1*.

```
rs(config)# eoam set auth-key SysKey1
```

This command must be performed in R1, R2, R3 and R4.

To determine if the authentication key is enabled you can use the **`eoam show globals`** command on each router, as shown in the following example.

```
rs # eoam show globals
Ethernet OAM enabled
```

The **`Ethernet OAM enabled`** message indicates that the authentication key is set.

39.0.2 Confirming a Layer-2 Connection

The EOAM facility allows you to confirm a layer-2 connection between an originator RS machine and a target RS machine. It also provides the transit time between the two machines. This is performed using the **mac-ping** command in enable mode. The mac-ping operation can be executed a single time, for a specified number of repetitions, or continuously until interrupted by the user. The output of the operation can be specified to be delivered in as a summary, detailed, or verbose.

To perform this operation, the same authentication key must be set on both the originator RS machine and a target RS machine, as described in *"Setting an Authentication Key for MAC Ping."*

To send an Mac Ping operation, you must at minimum specify the target you want to determine a connection to and the port on the originator that you want to send the EOAM frame out on. In the example shown in Figure 39-3, an EOAM frame is being sent to the target (R4) with Mac address of 000285:039a21. The port on the originator (R1) that the EOAM frame is being sent out on is et.1.5.

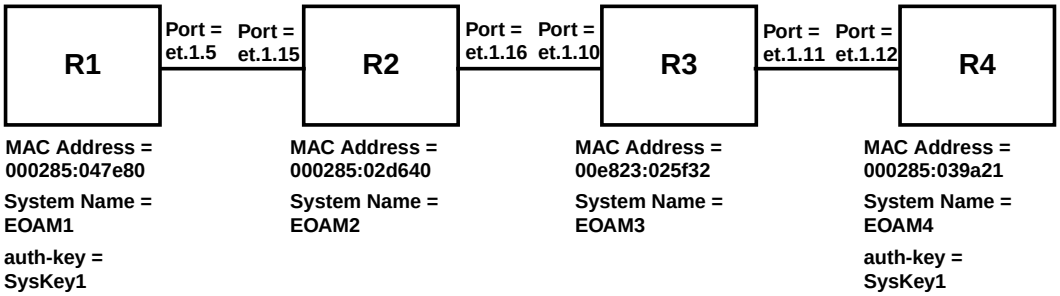


Figure 39-3 Mac Ping Example

The first example is set to deliver the output in summary format. The following examples will show the verbose and detailed output.

```
rs(config)# mac-ping 000285:039a21 port et.1.5 summary
67 bytes Ping frame sent from "00c863:047e80"

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   0.358/0.358/0.358/0.000 ms
```

The following example shows the results of setting the **mac-ping** command to deliver verbose output.

.

```
rs(config)# mac-ping 000285:039a21 port et.1.5 verbose
67 bytes Ping frame sent from "000285:047e80"
  115 bytes from "000285:039a21" seq no    1 time=      0.350 ms,

       BM = Bridging Mode,  F = Flow-Based, A = Address-Based
       PT = Port Type, T = Trunk Port, A = Access Port
       FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
       FT = Filter policy to Destination ,X = Filter Applied
       VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
        ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  -------------  -------- -- --
  1                                      000285:o47e80 et.1.5 A  A
  2.        et.1.12 A  A  -  D           000285:039a21

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   0.350/0.350/0.350/0.000 ms
```

The following example shows the results of setting the **mac-ping** command to deliver detailed output.

```
rs# mac-ping 000285:039a21 port et.1.5 detailed
67 bytes Ping frame sent from "000285:047e80"
  211 bytes from "000285:039a21" seq no    1 time=      0.368 ms,

       BM = Bridging Mode,  F = Flow-Based, A = Address-Based
       PT = Port Type, T = Trunk Port, A = Access Port
       FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
       FT = Filter policy to Destination ,X = Filter Applied
       VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
        ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  -------------  -------- -- --
  1                                      000285:o47e80 et.1.5 A  A
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]
  2.        et.1.12 A  A  -  D           000285:039a21
                                         [ EOAM4, RS 3000, 9.3.0.0-C11 ]

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   0.368/0.368/0.368/0.000 ms
```

Notice that the output for the detailed option displays the system names (EOAM1 and EOAM2) and the model names (RS 1000 and RS 3000) for each router. Using the **mac-ping** command with the **detailed** option populates the mac-name-list on the router that sent the mac-ping packet. This allows you to use the system name in place of the MAC Address for mac-ping operations.

39.0.3 Sending a MAC Ping Tracepath Packet

The EOAM facility can be used to obtain the layer-2 trace path information between an originator RS machine and a target RS machine. This is performed using the **mac-ping** command with the **trace-path** option set in enable mode. The **mac-ping** command can be executed a single time, for a specified number of repetitions, or continuously until interrupted by the user. The output of the operation can be specified to be delivered in summary, detailed, or verbose content format.

To perform this operation, the same authentication key must be set on the originator RS machine and the target RS machine. The authentication key must also be set for any nodes between the originator and target that you want to collect information from, as described in *"Setting an Authentication Key for MAC Ping with the Traceroute option."*

If there is non-Riverstone equipment or Riverstone equipment without a correct authentication key along the path between the originator and the target, the Mac-ping operation will succeed however, no trace information will be provided.

To execute the **mac-ping** command, you must at minimum specify the target you want to determine a connection to and the port on the originator that you want to send the EOAM tracepath frame out on. In the example shown in Figure 39-4, an EOAM frame is being sent to the target (R4) with Mac address of 000285:039a21. The port on the originator (R1) that the EOAM tracepath frame is being sent out on is et.1.5. The EOAM frame will traverse R2 and R3 and gather route information from them

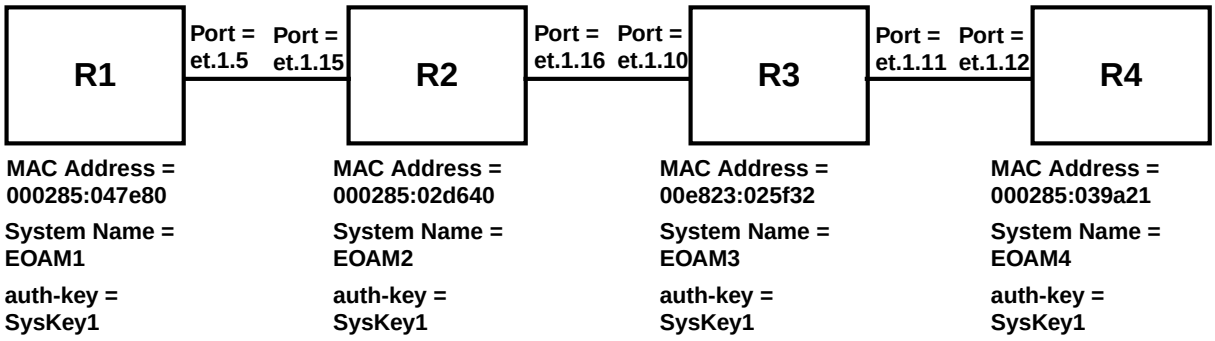


Figure 39-4 Mac Ping Tracepath Example

The first example is set to deliver the output in summary format. The following examples will show the verbose and detailed output.

```
rs# mac-ping 000285:039a21 port et.1.5 summary tracepath
67 bytes Trace-path frame sent from "000285:047e80"

---  Trace-Path Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
```

The following example shows the results of setting the **mac-ping** command to deliver verbose output...

```
rs# mac-ping 000285:039a21 port et.1.5 verbose tracepath
67 bytes Trace-path frame sent from "000285:047e80"
  355 bytes from "00c863:495091" seq no    1 time=    991.400 ms,

       BM = Bridging Mode,  F = Flow-Based, A = Address-Based
       PT = Port Type, T = Trunk Port, A = Access Port
       FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
       FT = Filter policy to Destination ,X = Filter Applied
       VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
        ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  --------------  -------- -- --
  1                                      000285:047e80 et.1.5                    A  A
                                         [ EOAM1, RS 3000, 9.3.0.0-C11 ]
  2.        et.1.15          A  A  -  D  000285:02d640 et.1.16                   A  A
                                         [ EOAM2, RS 3000, 9.3.0.0-B14 ]
  3.         et.1.8          A  A  -  D  00c863:495091
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]

---  Trace-Path Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max =       991.400/991.400/991.400 ms
```

The following example shows the results of setting the **mac-ping** command to deliver detailed output..

```
rs# mac-ping 00c863:495091 port et.1.16 detailed tracepath
67 bytes Ping frame sent from "00c863:495091"
  211 bytes from "000285:047e80" seq no    1 time=      0.368 ms,

       BM = Bridging Mode,  F = Flow-Based, A = Address-Based
       PT = Port Type, T = Trunk Port, A = Access Port
       FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
       FT = Filter policy to Destination ,X = Filter Applied
       VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
        ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  --------------  -------- -- --
  1                                      00c863:495091 et.1.8                    A  A
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]
  2.        et.1.16          A  A  -  D  000285:047e80
                                         [ EOAM2, RS 3000, 9.3.0.0-C11 ]

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   0.368/0.368/0.368/0.000 ms
```

39.0.4 Managing the name-mac-list Table

The name-mac-list table consists of a series of entries that match a MAC Address to its associated system name. When using the **`mac-ping`** command, you can use the system name instead of the MAC address if it is in the table. The following sections describe how to populate the table and how to clear it:

- *Populating the name-mac-list table* on page 9
- *Clearing the name-mac-list Table* on page 11

Populating the name-mac-list table

The name-mac-list table is populated using the mac-ping command with the detailed option. When this command is used, the system names are gathered for each of the RS devices that information is gathered from.

In the following example, you want to populate the name-mac-list table with the system names and MAC addresses for the four devices shown in Figure 39-5.

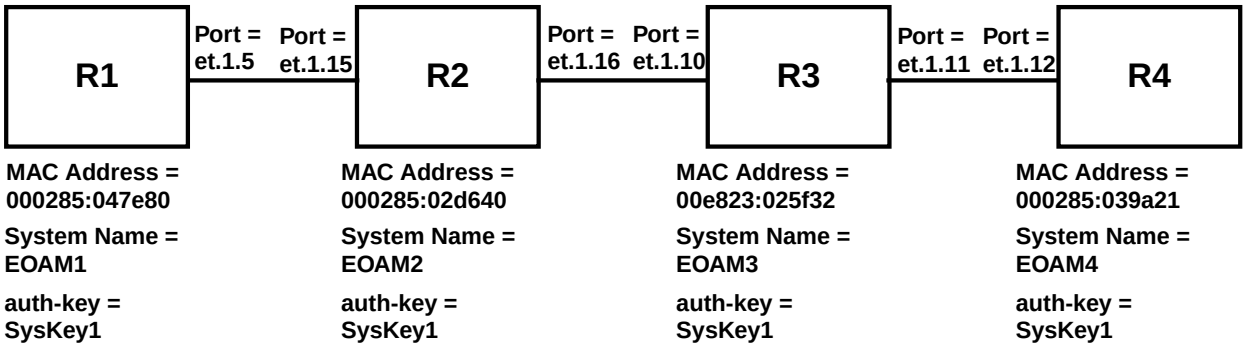


Figure 39-5 name-mac-list example

For the system name to be gathered from the devices, they must have their authorization keys set as described in *Setting an Authentication Key* on page 1.

Once the authorization keys are set, the following **`mac-ping`** command will gather the system and MAC address information for R1 and R4 and populate the table for R1.

```
rs# mac-ping 000285:039a21 port et.1.5 detailed
67 bytes Ping frame sent from "000285:047e80"
  211 bytes from "000285:039a21" seq no    1 time=     40.800 ms,

        BM = Bridging Mode,  F = Flow-Based, A = Address-Based
        PT = Port Type, T = Trunk Port, A = Access Port
        FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
        FT = Filter policy to Destination ,X = Filter Applied
        VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
         ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  --------------  -------- -- --
  1                                      000285:047e80 et.1.5 A  A
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]
  2.        et.1.12          A  A  -  D  000285:039a21
                                         [ EOAM4, RS 3000, 9.3.0.0-C11 ]

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   40.800/40.800/40.800/0.000 ms
```

You can view the generated name-mac-list table using the **`eoam show name-mac-list`** command as shown in the following.

```
rs# eoam show name-mac-list
       Switch Name                    Mac Address   DateAndTime
       -----------                    -----------   -----------
       EOAM1                          000285:047e80 2002-01-31 07:04:20

       EOAM4                          000285:039a21 2002-01-31 07:04:20
```

To obtain the system names for all of the RS devices along the path between the originator and target routers, you must set the authorization keys as described in *Setting an Authentication Key for MAC Ping with the Traceroute option* on page 3 and use the **`traceroute`** option with the **`mac-ping`** command. The following **`mac-ping`** command will gather the system and MAC address information for R1, R2, R3 and R4 and populate the table for R1...

```
rs# mac-ping 000285:039a21 port et.1.5 detailed
67 bytes Ping frame sent from "000285:047e80"
  211 bytes from "000285:039a21" seq no    1 time=     40.800 ms,

       BM = Bridging Mode,  F = Flow-Based, A = Address-Based
       PT = Port Type, T = Trunk Port, A = Access Port
       FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
       FT = Filter policy to Destination ,X = Filter Applied
       VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
        ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  --------------  -------- -- --
  1                                      000285:047e80 et.1.5 A  A
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]
  2.        et.1.15          A  A  -  D  000285:02d640 et.1.16
                                         [ EOAM2, RS 3000, 9.3.0.0-C11 ]
  3.        et.1.10          A  A  -  D  00e823:025f32 et.1.11
                                         [ EOAM3, RS 3000, 9.3.0.0-C11 ]
  4.        et.1.12          A  A  -  D  000285:039a21
                                         [ EOAM4, RS 3000, 9.3.0.0-C11 ]

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   40.800/40.800/40.800/0.000 ms
```

You can view the generated name-mac-list table for this example using the **eoam show name-mac-list** command as shown in the following.

```
rs# eoam show name-mac-list
        Switch Name                    Mac Address   DateAndTime
        -----------                    -----------   -----------
        EOAM1                          000285:047e80 2002-01-31 07:04:20
        EOAM2                          000285:02d640 2002-01-31 07:04:20
        EOAM3                          00e823:025f32 2002-01-31 07:04:20
        EOAM4                          000285:039a21 2002-01-31 07:04:20
```

Clearing the name-mac-list Table

To clear the name-mac-list table, use the **eoam clear name-mac-list** command as shown in the following example.

```
rs# eoam clear name-mac-list
```

You can view the generated name-mac-list table for this example using the **eoam show name-mac-list** command as shown in the following.

```
rs# eoam show name-mac-list
No records
```

39.0.5 Displaying mac-ping Statistics

The cumulative statistics gathered by the **mac-ping** command are kept on the originator router. They can be view using the **eoam show statistics** command as shown in the following example.

```
rs# eoam show statistics
                                          IN        OUT
                                    ---------- ----------
                     PING frames    :          4         30
                PING REPLY frames   :         22          4

                     TRACE frames   :         11         12
                TRACE REPLY frames  :         12         11
TRACE frame dropped as
 orignator mac did not match with source mac
                               target :          0
                              transit :          0
                            first hop :          0

                          TTL expired :          0
TRACE/PING  REPLY frame drop count
                          TTL expired :          0
      Target_mac and src_mac mismatch :          0
Previous transit and src_mac mismatch :          0
           Reverse path not validated :          0
           Never traversed this path  :          0
          No Ping/Trace-path sessions :          0
       Session ID not Ping/Trace-path :          0

                   No return TLS path :          0

                 EOAM Unknown frames  :          0
        EOAM Authentication failures  :          0
             Last cleared time stamp  : 2002-01-18 05:43:31
```

You can use the **eoam clear statistics** command to clear the values in the statistics table, as shown in the following example.

```
rs# eoam clear statistics
```

39.0.6 Enabling the Tracing Function

Using the configure mode command **`eoam enable tracing`**, you can display additional information about transmission of the mac-ping packet to the console or the sys log server, as shown in the following example.

```
rs(config)# eoam enable tracing
```

With this set, the mac-ping command will display additional information, as shown in the first line (**`EOAM:TXED Trace frame on port 56`**) of the following example.

```
rs# mac-ping 000285:039a21 port et.1.5 detailed
EOAM:TXED Trace frame on port 56
67 bytes Ping frame sent from "000285:047e80"
  211 bytes from "000285:039a21" seq no    1 time=     40.800 ms,

        BM = Bridging Mode,  F = Flow-Based, A = Address-Based
        PT = Port Type, T = Trunk Port, A = Access Port
        FL = L2 Flow Entry type,N = No Flow S = Static, D = Dynamic
        FT = Filter policy to Destination ,X = Filter Applied
        VLAN = vlan, P = Port Based Vlan, N = Not port based vlan ,
         ? = vlan does not exist, /T = vlan switching(translation) policy  applied

SNo      Input Port VLAN     BM PT FT FL MAC-ADDR      Output Port     VLAN     BM PT
---- -------------- -------- -- -- -- -- ------------  --------------  -------- -- --
  1                                      000285:047e80 et.1.5 A  A
                                         [ EOAM1, RS 1000, 9.3.0.0-B20 ]
  2.        et.1.15          A  A  -  D  000285:02d640 et.1.16
                                         [ EOAM2, RS 3000, 9.3.0.0-C11 ]
  3.        et.1.10          A  A  -  D  00e823:025f32 et.1.11
                                         [ EOAM3, RS 3000, 9.3.0.0-C11 ]
  4.        et.1.12          A  A  -  D  000285:039a21
                                         [ EOAM4, RS 3000, 9.3.0.0-C11 ]

---  Ping Statistics ---
    1 frames transmitted,     1 frames received, 0.00% frame loss
round-trip min/avg/max/dev =   40.800/40.800/40.800/0.000 ms
```