ipinfusion™

ZebOS®
Advanced Routing Suite
Version 5.4

Configuration Guide

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CHAPTER 1 Introduction

About This Publication

Network administrators and application developers intending to configure ZebOS® protocols should use this Configuration Guide.

This Guide attempts to make configuration simpler by adding topology illustrations and configuration samples. It covers basic configurations for OSPF, BGP, RIP, PIM-SM, BGP4+, RIPng, IS-IS, OSPFv3 and VPN. Use this Guide in conjunction with the Command References to get complete information on the commands used in the configurations displayed in this Guide.

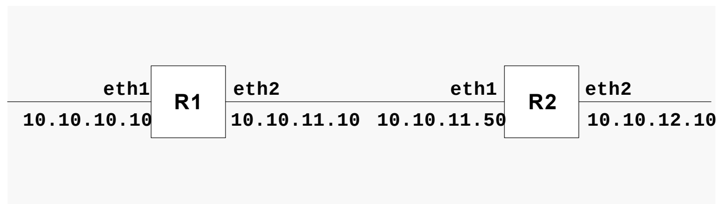
Conventions Used in this Guide

Conventions for the syntax and procedures describing how to enter information and how information is displayed on the console are given in the following table.

Convention	Description
`command syntax`	This monospaced font represents command strings entered on a command line and sample source code.
`UPPERCASE`	A variable parameter. Enter a value according to the descriptions that follow.
`lowercase`	A keyword parameter. Enter lowercase values exactly as shown
|	The vertical bar. Delimits choices; select one from the list.
`()`	Parenthesis. Delimits optional parameters. Do not enter parentheses as part of any command.
`[]`	Square brackets: groups parameters and keywords into a single unit. Take all parts within these brackets. Do not enter brackets as part of any command.
`< >`	Angle brackets: enclose a numeric range for a keyword. Do not enter angle brackets as part of any command.
description	Proportional font gives specific details about a parameter.
=	Equal sign: separates the command syntax from explanatory text.

Note: Unless otherwise stated, press Enter after each command entry.

Format used in the Configuration Examples

Scenario Description The examples begin with a description of the topology and the scenario. This is an explanation of what is to be achieved by the specified configuration.	**Enabling RIP** This example shows the minimum configuration required for enabling RIP on an interface...............
Illustration This section includes the illustration of the complete topology used in the example. The figure uses the exact IP addresses and names of routers used in the example.	
Configuration Includes the complete configuration of the routers involved in the example. The prompt shows the execution modes of the commands. Each example begins from the Privileged Exec mode. The method to reach every command mode is illustrated in the *Daemon Command Modes* section. For modes specific to different protocols, please refer to the corresponding Command Reference (for OSPF command modes, refer to the *OSPF Command Reference*). Explanation This is the grey section next to the configuration statements and is not to be typed in the CLI. It provides step-by-step explanation of the actions performed by the configuration.	R1 `ZebOS# configure terminal` — Enter the Configure mode. `ZebOS(config)# router rip` — Define the RIP process... `ZebOS(config-router)# net..` — Associate networks with.... `ZebOS(config-router)# net..`
Names of Commands Used This section lists the names of the commands used in the example. Use these command names to look up the command details in the Command References. To avoid repetition, this list does not include a few common commands such as `configure terminal` or `interface`. These common commands are explained in the *Common Commands* chapter of the *NSM Command Reference*.	Names of Commands Used router rip, network
Validation Commands These commands are usually show commands that display outputs and are used to validate the configuration.	Validation Commands show ip rip

Command Line Interface Primer

The ZebOS™ Command Line Interface (CLI) is a text-based facility similar to industry standards. Many of the commands may be used in scripts to automate many configuration tasks. Each command CLI is usually associated with a specific function or a common function performing a specific task. Multiple users can telnet and issue commands using the Exec mode and the Privileged Exec mode. However, only one user is allowed to use the Configure mode at a time, to avoid multiple users from issuing configuration commands simultaneously.

The VTY shell, described in the ZebOS VTY Shell User Guide, gives users and administrators the ability to issue commands to several daemons from a single telnet session.

Command Line Help

The ZebOS CLI contains a text-based help facility. Access this help by typing in the full or partial command string then typing "?". The ZebOS CLI displays the command keywords or parameters plus a short description.

For example, at the CLI command prompt, type `show` ? (the CLI does not display the question mark).
The CLI displays this keyword list with short descriptions for each keyword:

```
bgpd# show
  debugging       Debugging functions (see also 'undebug')
  history         Display the session command history
  ip              IP information
  memory          Memory statistics
  route-map       route-map information
  running-config  running configuration
  startup-config  Contents of startup configuration
  version         Displays ZebOS version
```

Syntax Help

The ZebOS CLI can complete the spelling of command or parameter keywords. Begin typing the command or parameter then press TAB. At the CLI command prompt type `sh`:

```
Router> sh
```

Press TAB. The CLI shows:

```
Router> show
```

If the command or parameter partial spelling is ambiguous, the ZebOS CLI displays the choices that match the abbreviation. Type `show i`. Press TAB. The CLI shows:

```
Router> show i
interface  ip
Router> show i
```

The interface displays the `interface` and `ip` keywords. Type `n` to select `interface` and press TAB. The CLI shows:

```
Router> show in
Router> show interface
```

Type ? and the CLI shows the list of parameters for the `show interface` command.

```
  [IFNAME]  Interface name
Router> show interface
```

This command has but one positional parameter, an interface name. Supply a value for the `IFNAME` parameter.

Command Abbreviations

The ZebOS CLI accepts abbreviations for commands. For example,

```
sh in 7
```

is the abbreviation for the `show interface` command.

Command line errors

If the router does not recognize the command after ENTER is pressed, it displays this message:

```
% Unknown command.
```

If a command is incomplete it displays this message:

```
% Command incomplete.
```

Some commands are too long for the display line and can wrap in mid-parameter or mid-keyword if necessary:

```
area 10.10.0.18 virtual-link 10.10.0.19 authent
ication-key 57393
```

Daemon Command Modes

The commands available for each protocol are separated into several modes (nodes) arranged in a hierarchy; Exec is the lowest. Each mode has its own special commands; in some modes, commands from a lower mode are available.

Note: Multiple users can telnet and issue commands using the Exec mode and the Privileged Exec mode. However, only one user is allowed to use the Configure mode at a time, to avoid multiple users from issuing configuration commands simultaneously.

Modes Common to Protocols

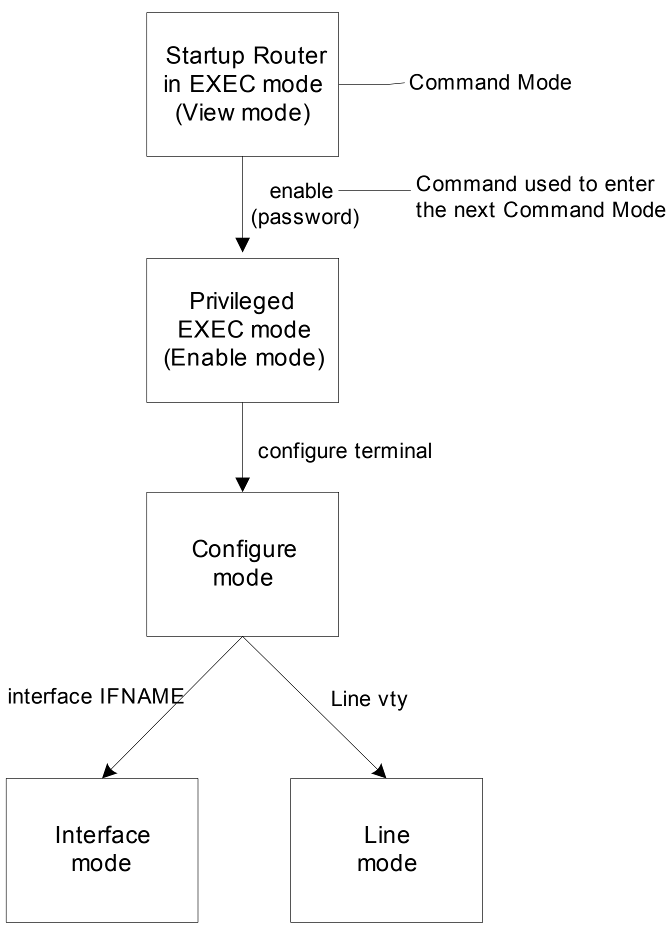
Exec This mode, also called the View mode, is the base mode from where users can perform basic commands like show, exit, quit, help, list, and enable. All ZebOS daemons have this mode.

Privileged Exec This mode, also called the Enable mode, allows users to perform debugging commands, the write commands (for saving and viewing the configuration), show commands, and so on.

Configure Sometimes referred to as Configure Terminal, this mode serves as a gateway into the Interface, Router, Line, Route Map, Key Chain and Address Family modes. All ZebOS daemons have this mode.

Interface This mode is used to configure protocol-specific settings for a particular interface. Any attribute configured in this mode overrides an attribute configured in the router mode.

Line This mode makes available access-class commands.



Modes Specific to Protocols

The following command modes are not common to all protocols and the command used to enter these modes is different for different protocols. For an illustration of these command modes refer to the corresponding Command References.

Router Sometimes referred to as Configure Router mode, this mode is available for the LDP, BGP, OSPF, RSVP-TE and RIP protocols only and makes available router and routing commands.

Route-map This mode is used to set route metric, route-length and cost data. It is available for the BGP, OSPF, and RIP protocols only.

Address Family This mode allows support for multiprotocol BGP extension. It includes address family-specific commands.

Key Chain This mode, available for the RIP protocol only, manages the key chain.

Trunk This mode is used to create or modify RSVP trunks. A trunk is the static definition for a Labeled Switch Path (LSP). Each trunk creates a corresponding LSP, and this LSP is signalled from the machine where the trunk was created, to the egress, as specified in the trunk's configuration.

Path Use this mode to create or modify RSVP paths. You can define a possible path to be taken between two points in a network. This path could be a complete description (with each node specified) or a partial one specifying certain hops that the path must take.

CHAPTER 2 Message Logging

ZebOS has a comprehensive logging facility for developing traces of messages as they occur in various protocols and components. For complete information about the logging commands, consult the ZebOS *NSM Command Reference*.

Basic Message Structure

There are two basic structures for a ZebOS message, determined by the log record-priority command;

```
2003/05/15 15:23:59 error bgpd  eth0 [FSM] Timer (keepalive timer expire)
2003/05/15 15:23:59 bgpd eth0 [FSM] Timer (keepalive timer expire)
```

The message string is determined by the module and there are no restrictions on its content or format.

Basic User Session

To turn on logging, where none has been requested either through initial configuration or through CLI manipulation, gather these important data:

- the level of logging required
- the daemon or daemons for which logging is required
- the name of the file or the type of output to receive the data

The logging priority level has several choices. The order of this list is important as each item includes the logging messages from one above it. For example, `alerts` turns on `alert` message level reporting and `emergency` message level reporting; `debugging` turns on debug level message reporting and `informational, notifications, warnings, errors, critical, alerts` and `emergencies`.

`emergencies` = Serious operating system error requires Systems Administrator action is.

`alerts` = Fatal application error requires Application Administrator action.

`critical` = Potentially fatal application error requires operator intervention.

`errors` = Application generated error might require operator action for succesful processing.

`warnings` = Application generated warning might require operator action for succesful processing.

`notifications` = Application genterated notice not requiring operator intervention.

`informational` = Application generated data that might be useful for application programmer.

`debugging` = Application generated data that is useful for the application programmer.

`disable` turns off all logging.

If debugging is needed for all the daemons running on a device, repeat the following steps for each daemon:

1. telnet into daemon
2. enter configure mode
3. use the logging commands to turn on logging
4. exit the configure mode
5. exit the daemon

Controlling Log File content

Several commands control the format, number and content of the messages that the logging manager commits to the file.

Message levels

The log destination trap and log trap command control the number of messages reported to the file by specifying the priority level of the messages. In the following list, each parameter includes the output of the parameters listed before it. `Emergencies` is the least amount of data reported, and `debugging` is the most. Use `disable` to turn off all reporting.

`emergencies` = turns on logging of only the most severe messages.

`alerts` = turns on logging of the above plus this level.

`critical` = turns on logging of the above plus this level.

`errors` = turns on logging of the above plus this level.

`warnings` = turns on logging of the above plus this level.

`notifications` = turns on logging of the above plus this level.

`informational` = turns on logging of the above plus this level.

`debugging` = turns on logging of the above plus this level. This level of logging is the most comprehensive

For example, this session turns on error logging for BGP and causes it to be written to a file named `mybgplog.log`:

```
telnet bgpd 2605
enable
config term
log file /var/log/zebos/mybgplog.log
log trap error
exit
exit
```

For example, this session turns on error logging for BGP and causes it to be written to a file named `mybgplog.log` and to the stdout output:

```
telnet bgpd 2605
enable
config term
log file /var/log/zebos/mybgplog.log
log trap error
log stdout trap error
exit
exit
```

Include Priority

The log record-priority command tells the logging manager to include the priority in the message log for each message.

Use the `log record-priority` command to include the priority:

```
2003/05/15 15:23:59 error bgpd  eth0 [FSM] Timer (keepalive timer expire)
```

Use the no `log record-priority` command to exclude the priority:

```
2003/05/15 15:23:59 bgpd eth0 [FSM] Timer (keepalive timer expire)
```

For example:

```
telnet bgpd 2605
enable
config term
log file /var/log/zebos/mybgplog.log
log trap error
log stdout trap error
log record-priority
exit
exit
```

Debugging with the Logging Manager

To include the imbedded debugging information in the logging reporting, specify the daemon debugging and include the `log trap debugging` command:

```
telnet bgpd 2605
enable
debug bgp
config term
log file /var/log/zebos/mybgplog.log
log trap debugging
log stdout trap error
log record-priority
exit
exit
```

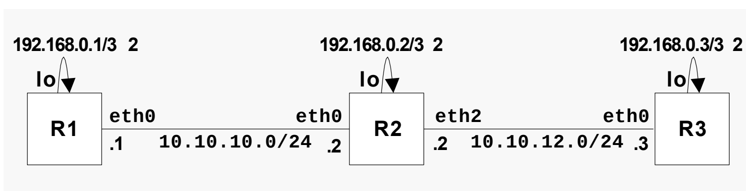
CHAPTER 3 NSM Configuration

This chapter contains basic NSM configuration examples. To see details on the commands used in these examples, or to see the outputs of the validation commands, refer to the *NSM Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the Commands Used section. The *NSM Command Reference* explains these common commands.

Enabling Static Routing

This example shows the complete configuration required to enable static routing in a simple network topology. Static routes are useful in small networks. They are a simple solution for making a few networks reachable. Large networks use dynamic routing protocols. A static route is composed of a network prefix (host address) and a nexthop (gateway).

Router `R1` is configured with three static routes, one for the remote network `10.10.12.0/24` and one each for the loopback addresses (host addresses) of routers `R2` and `R3`. In all three routes, interface `eth0` of router `R2` is the gateway. Router `R3` is configured with a default static route, which is equivalent to configuring separate static routes with the same gateway or nexthop address. Router `R2` has two routes, one for each of the remote routers' loopback address.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface lo	Specify loopback as the interface you want to configure.
ZebOS(config-if)# ip address 192.168.0.1/32	Configure the IP address on this interface and specify a 32-bit mask, making it a host address.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode.
ZebOS(config)# ip route 10.10.12.0/24 10.10.10.2 **ZebOS(config)#** ip route 192.168.0.2/32 10.10.10.2 **ZebOS(config)#** ip route 192.168.0.3/32 10.10.10.2	Specify the destination prefix and mask for the network for which a gateway is required, for example, 10.10.12.0/24. Add a gateway for each of them (in this case 10.10.10.2 for all). Since R2 is the only next hop available, you can configure a default route instead of configuring the same static route for individual addresses, see the configuration of R3.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface lo	Specify loopback as the interface you want to configure.
ZebOS(config-if)# ip address 192.168.0.2/32	Configure the IP address on this interface and specify a 32-bit mask, making it a host address.

ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode.
ZebOS(config)# ip route 192.168.0.1/32 10.10.10.1 **ZebOS(config)#** ip route 192.168.0.3/32 10.10.12.3	Specify the destination and mask for the network for which gateway is required and add a gateway for each of them.

R3

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface lo	Specify loopback as the interface you want to configure.
ZebOS(config-if)# ip address 192.168.0.3/32	Configure the IP address on this interface and specify a 32-bit mask, making it a host address.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode.
ZebOS(config)# ip route 0.0.0.0/0 10.10.12.2	Specify 10.10.12.2 as a default gateway to reach any network. Since 10.10.12.2 is the only route available you can specify it as the default gateway instead of specifying it as the gateway for individual network or host addresses.

Names of Commands Used

ip route, ip address, interface

Validation Commands

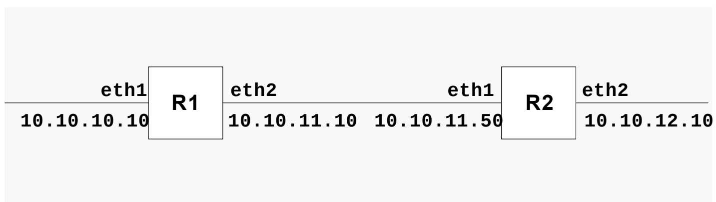
show ip route, show running-config

CHAPTER 4 RIP Configuration

This chapter contains basic RIP configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *RIP Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. These Common commands are explained in the *NSM Command Reference*.

Enabling RIP

This example shows the minimum configuration required for enabling RIP on an interface. R1 and R2 are two routers connecting to network 10.10.11.0/24. R1 and R2 are also connected to networks 10.10.10.0/24 and 10.10.12.0/24 respectively. To enable RIP, first define the RIP routing process and then associated a network with the routing process.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the `Router` mode.
ZebOS(config-router)# network 10.10.10.0/24 **ZebOS(config-router)#** network 10.10.11.0/24	Associate networks with the RIP process.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the `Router` mode.
ZebOS(config-router)# network 10.10.11.0/24 **ZebOS(config-router)#** network 10.10.12.0/24	Associate networks with the RIP process.

Names of Commands Used

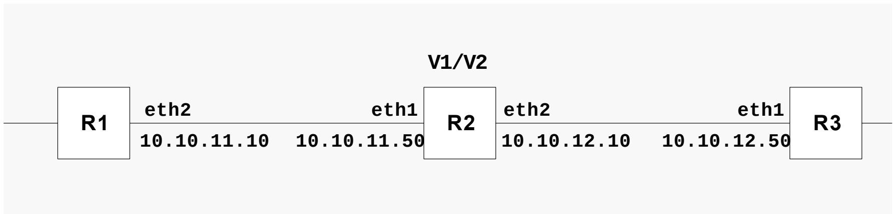
router rip, network

Validation Commands

show ip rip, show run, show ip protocols rip, show ip rip interface

Specifying the RIP version

Configure a router to receive and send specific version of packets on an interface. In this example, router R2 has been configured to receive and send RIP version 1 and version 2 information on both `eth1` and `eth2` interfaces.



R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Enable the RIP routing process.
ZebOS(config-router)# version 1	
ZebOS(config-router)# exit	
ZebOS(config)# interface eth1	Specify interface `eth1` as an interface you want to configure.
ZebOS(config-if)# ip rip send version 1 2	Allow sending RIP version 1 and version 2 packets out of this interface.
ZebOS(config-if)# ip rip receive version 1 2	Allow receiving of RIP version 1 and version 2 packets from the `eth1` interface.
ZebOS(config-if)# quit	Quit the `Interface` mode and return to `Configure` mode to configure the next interface.
ZebOS(config)# interface eth2	Specify interface `eth2` as the interface you want to configure.
ZebOS(config-if)# ip rip send version 1 2	Allow sending RIP version 1 and version 2 packets out of this interface.
ZebOS(config-if)# ip rip receive version 1 2	Allow receiving of RIP version 1 and version 2 packets from the `eth2` interface.

Names of Commands Used

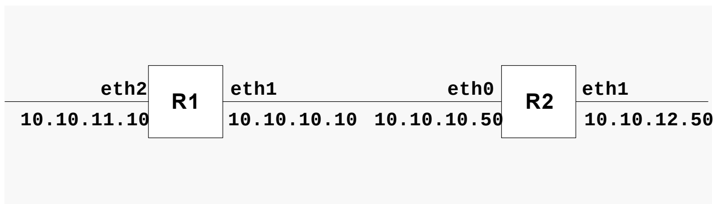
ip rip send version, ip rip receive version, version

Validation Commands

show run, show ip rip

RIPv2 authentication (single key)

ZebOS RIP implementation provides the choice of configuring authentication for a single key or for multiple keys. This example illustrates authentication of the routing information exchange process for RIP using a single key. Routers R1 and R2 are running RIP and exchange routing updates. To configure single key authentication on R1, specify an interface and then define a key or password for that interface. Next, specify an authentication mode. Any receiving RIP packet on this specified interface should have the same string as password. For an exchange of updates between R1 and R2, define the same password and authentication mode on R2.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the Router mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network `10.10.10.0/24` with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the Router mode and return to the `Configure` mode.
ZebOS(config)# interface eth1	Specify the interface (`eth1`) for authentication.
ZebOS(config-if)# ip rip authentication string IPI	Specify the authentication string (`IPI`) for this interface.
ZebOS(config-if)# ip rip authentication mode md5	Specify the authentication mode (plain text or MD5) to be used.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the Router mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network `10.10.10.0/24` with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the Router mode and return to the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`) for authentication.
ZebOS(config-if)# ip rip authentication string IPI	Specify the authentication string (`IPI`) on this interface.
ZebOS(config-if)# ip rip authentication mode md5	Specify the authentication mode (plain text or MD5) to be used.

Names of Commands Used

ip rip authentication string, ip rip authentication mode, redistribute, network

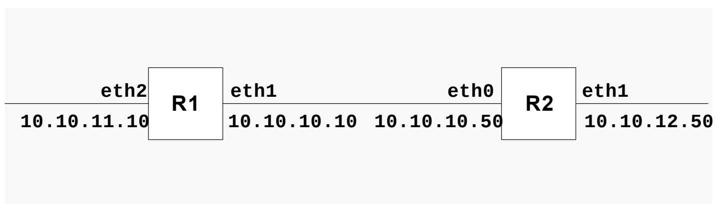
Validation Commands

show run, show ip rip, show ip protocol rip, show ip rip interface

RIPv2 text authentication (multiple keys)

This example illustrates text authentication of the routing information exchange process for RIP using multiple keys. Routers R1 and R2 are running RIP and exchanging routing updates. To configure authentication on R1, define a key chain, specify keys in the key chain and then define the authentication string or passwords to be used by the keys. Set the time period during which it is valid to receive or send the authentication key by specifying the accept and send lifetimes. After defining the key string, specify the key chain (or the set of keys) that will be used for authentication on each interface and also the authentication mode to be used.

R1 receives all packets that contain any key string that matches one of the key strings included in the specified key chain (within the accept lifetime) on that interface. The key ID is not considered for matching. For additional security, the accept lifetime and send lifetime are configured such that every fifth day the key ID and key string changes. To maintain continuity, the accept lifetime should be configured to overlap. This will accomodate different time-setup on machines. However, the send lifetime does not need to overlap and IPI recommends to configure no overlapping for send lifetime.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the Router mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network `10.10.10.0/24` with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the Router mode and return to the `Configure` mode.
ZebOS(config)# key chain SUN	Enter the key chain management mode to add keys to the key chain SUN.
ZebOS(config-keychain)# key 10	Add authentication key ID (`10`) to the key chain SUN.
ZebOS(config-keychain-key)# key-string IPI	Specify a password (`IPI`) to be used by the specified key.
ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 2 2003 14:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be received. In this case, key string `IPI` can be received from noon of March 2 to 2 pm March 7, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 2 2003 12:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be send. In this case, key string `IPI` can be received from noon of March 2 to noon of March 7, 2003.
ZebOS(config-keychain-key)# exit	Exit the `keychain-key` mode and return to `keychain` mode.
ZebOS(config-keychain)# key 20	Add another authentication key (`20`) to the key chain SUN.
ZebOS(config-keychain-key)# key-string Earth	Specify a password (`Earth`) to be used by the specified key.

ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 7 2003 14:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be received. In this case, key string `Earth` can be received from noon of March 7 to 2 pm March 12, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 7 2003 12:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be send. In this case, key string `IPI` can be received from noon of March 7 to noon of March 12, 2003.
ZebOS(config-keychain-key)# end	Enter `Privileged Exec` mode.
ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth1	Specify interface `eth1` as the interface you want to configure.
ZebOS(config-if)# ip rip authentication key chain SUN	Enable RIPv2 authentication on `eth1` interface and specify the key chain SUN to be used for authentication.
ZebOS(config-if)# ip rip authentication mode text	Specify `text` authentication mode to be used for RIP packets.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
Z**ebOS(config)#** router rip	Define a RIP routing process and enter the `Router` mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network `10.10.10.0/24` with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the `Router` mode and return to the `Configure` mode.
ZebOS(config)# key chain MOON	Enter the key chain management mode to add keys to the key chain `MOON`.
ZebOS(config-keychain)# key 30	Add authentication key ID (`30`) to the key chain `MOON`.
ZebOS(config-keychain-key)# key-string IPI	Specify a password (`IPI`) to be used by the specified key.
ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 2 2003 14:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be received. In this case, key string `IPI` can be received from noon of March 2 to 2 pm March 7, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 2 2003 12:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be send. In this case, key string `IPI` can be received from noon of March 2 to noon of March 7, 2003.
ZebOS(config-keychain)# key 40	Add another authentication key (`40`) to the key chain `MOON.`
ZebOS(config-keychain-key)# key-string Earth	Specify a password (`Earth`) to be used by the specified key.
ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 7 2003 14:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be received. In this case, key string `Earth` can be received from noon of March 7 to 2 pm March 12, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 7 2003 12:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be send. In this case, key string `IPI` can be received from noon of March 7 to noon of March 12, 2003.

ZebOS(config-keychain-key)# end	Enter Privileged Exec mode.
ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface eth0	Specify interface eth0 as the interface you want to configure.
ZebOS(config-if)# ip rip authentication key chain MARS	Enable RIPv2 authentication on eth1 interface and specify the key chain MARS to be used for authentication.
ZebOS(config-if)# ip rip authentication mode text	Specify authentication mode to be used for RIP packets.

Names of Commands Used

key chain, key, key-string, accept-lifetime, send-lifetime, ip rip authentication key-chain, ip rip authentication mode

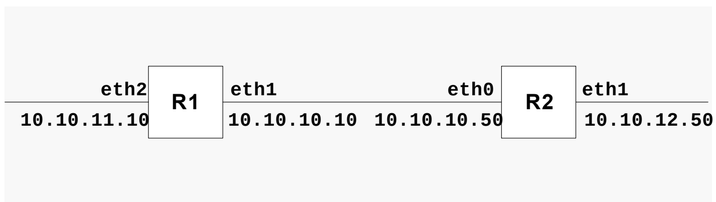
Validation Commands

show run, show ip rip, show ip protocol rip, show ip rip interface

RIPv2 md5 authentication (multiple keys)

This example illustrates the md5 authentication of the routing information exchange process for RIP using multiple keys. Routers R1 and R2 are running RIP and exchange routing updates. To configure authentication on R1, define a key chain, specify keys in the key chain and then define the authentication string or passwords to be used by the keys. Then set the time period during which it is valid to receive or send the authentication key by specifying the accept and send lifetimes. After defining the key string, specify the key chain (or the set of keys) that will be used for authentication on the interface and the authentication mode to be used. Configure R2 and R3 to have the same key ID and key string as R1 for the time that updates need to be exchanged.

In md5 authentication, both the key ID and key string are matched for authentication. R1 will receive only packets that match both the key ID and the key string in the specified key chain (within the accept lifetime) on that interface. In the following example, R2 has the same key ID and key string as R1. For additional security, the accept lifetime and send lifetime are configured such that every fifth day the key ID and key string changes. To maintain continuity, the accept lifetime should be configured to overlap; however, the send lifetime should not be overlapping.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router rip	Define a RIP routing process and enter the Router mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network 10.10.10.0/24 with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the Router mode and return to the Configure mode.
ZebOS(config)# key chain SUN	Enter the key chain management mode to add keys to the key chain SUN.
ZebOS(config-keychain)# key 1	Add authentication key ID (1) to the key chain SUN.
ZebOS(config-keychain-key)# key-string IPI	Specify a password (IPI) to be used by the specified key.
ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 2 2003 14:00:00 Mar 7 2003	Specify the time period during which authentication key string IPI can be received. In this case, key string IPI can be received from noon of March 2 to 2 pm March 7, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 2 2003 12:00:00 Mar 7 2003	Specify the time period during which authentication key string IPI can be send. In this case, key string IPI can be received from noon of March 2 to noon of March 7, 2003.
ZebOS(config-keychain-key)# exit	Exit the keychain-key mode and return to keychain mode.
ZebOS(config-keychain)# key 2	Add another authentication key (2) to the key chain SUN.
ZebOS(config-keychain-key)# key-string Earth	Specify a password (Earth) to be used by the specified key.

ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 7 2003 14:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be received. In this case, key string `Earth` can be received from noon of March 7 to 2 pm March 12, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 7 2003 12:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be send. In this case, key string `IPI` can be received from noon of March 7 to noon of March 12, 2003.
ZebOS(config-keychain-key)# end	Enter `Privileged Exec` mode.
ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth1	Specify interface `eth1` as the interface you want to configure.
ZebOS(config-if)# ip rip authentication key chain SUN	Enable RIPv2 authentication on `eth1` interface and specify the key chain SUN to be used for authentication.
ZebOS(config-if)# ip rip authentication mode md5	Specify `md5` authentication mode to be used for RIP packets.
ZebOS(config-if)# exit	Quit `Interface` mode and return to `Configure` mode.
ZebOS(config)# interface eth1	Specify interface `eth1` as the interface you want to configure.
ZebOS(config-if)# ip rip authentication key chain SUN	Enable RIPv2 authentication on `eth1` interface and specify the key chain SUN to be used for authentication.
ZebOS(config-if)# ip rip authentication mode md5	Specify `md5` authentication mode to be used for RIP packets.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
Z**ebOS(config)#** router rip	Define a RIP routing process and enter the `Router` mode.
ZebOS(config-router)# network 10.10.10.0/24	Associate network `10.10.10.0/24` with the RIP process.
ZebOS(config-router)# redistribute connected	Enable redistributing from connected routes.
ZebOS(config-router)# exit	Quit the `Router` mode and return to the `Configure` mode.
ZebOS(config)# key chain MOON	Enter the key chain management mode to add keys to the key chain `MOON`.
ZebOS(config-keychain)# key 1	Add authentication key ID (`1`) to the key chain `MOON`.
ZebOS(config-keychain-key)# key-string IPI	Specify a password (`IPI`) to be used by the specified key.
ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 2 2003 14:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be received. In this case, key string `IPI` can be received from noon of March 2 to 2 pm March 7, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 2 2003 12:00:00 Mar 7 2003	Specify the time period during which authentication key string `IPI` can be send. In this case, key string `IPI` can be received from noon of March 2 to noon of March 7, 2003.
ZebOS(config-keychain)# key 2	Add another authentication key (2) to the key chain `MARS.`
ZebOS(config-keychain-key)# key-string Earth	Specify a password (`Earth`) to be used by the specified key.

ZebOS(config-keychain-key)# accept-lifetime 12:00:00 Mar 7 2003 14:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be received. In this case, key string `Earth` can be received from noon of March 7 to 2 pm March 12, 2003.
ZebOS(config-keychain-key)# send-lifetime 12:00:00 Mar 7 2003 12:00:00 Mar 12 2003	Specify the time period during which authentication key string `Earth` can be send. In this case, key string `IPI` can be received from noon of March 7 to noon of March 12, 2003.
ZebOS(config-keychain-key)# end	Enter `Privileged Exec` mode.
ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify interface `eth0` as the interface you want to configure.
ZebOS(config-if)# ip rip authentication key chain MARS	Enable RIPv2 authentication on `eth1` interface and specify the key chain MARS to be used for authentication.
ZebOS(config-if)# ip rip authentication mode md5	Specify authentication mode to be used for RIP packets.

Names of Commands Used

key chain, key, key-string, accept-lifetime, send-lifetime, ip rip authentication key-chain, ip rip authentication mode

Validation Commands

show run, show ip rip, show ip protocol rip, show ip rip interface

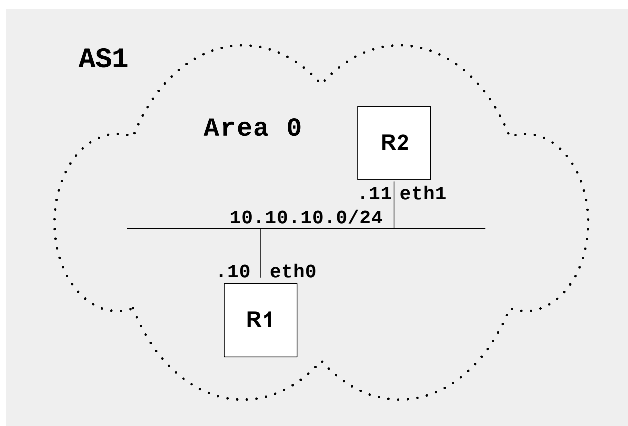
CHAPTER 5 OSPF Configuration

This chapter contains basic OSPF configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *OSPF Command Reference*. To avoid repetition, some Common commands, such as `configure terminal`, have not been listed under the *Commands Used* section. These Common commands are explained in the *NSM Command Reference*.

Enabling OSPF on an interface

This example shows the minimum configuration required for enabling OSPF on an interface. `R1` and `R2` are two routers in `Area 0` connecting to network 10.10.10.0/24.

Note: Configure one interface so that it belongs to only one area. However, you can configure different interfaces on a router to belong to different areas.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define the interface (10.10.10.0/24) on which OSPF runs and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

ZebOS# configure terminal	Enter the `Configure` mode
ZebOS(config)# interface eth1	Specify the interface `(eth1)`to be configured.

ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router ospf 200	Configure the Routing process and specify the Process ID `(200)`. The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define the interface `(10.10.10.0/24)` on which OSPF runs and associate the area ID `(0)` with the interface.

Names of Commands Used

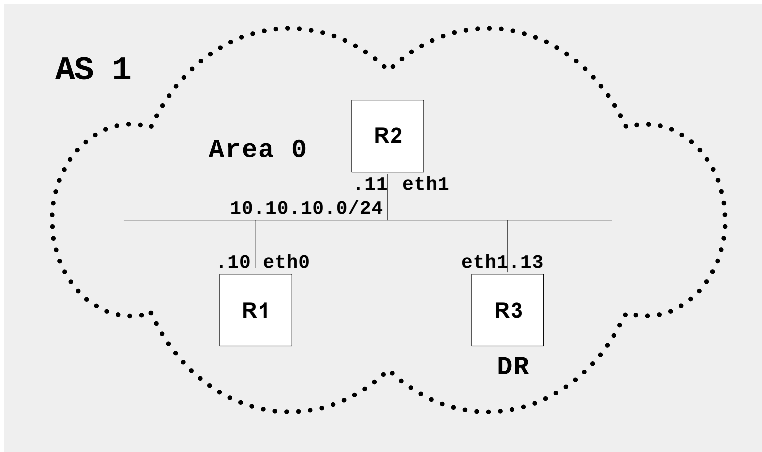
network area, router ospf

Validation Commands

show ip ospf, show ip ospf interface, show ip ospf neighbor

Setting priority

This example shows configuration for setting priority for an interface. You can set a high priority for a router to make it the Designated Router (DR). Router R3 is configured to have a priority of 10, which is higher than the default priority (default priority is 1) of R1 and R2; making it the DR.



R3

ZebOS(config)# interface eth1	Specify the interface (`eth1`) to be configured.
ZebOS(config)# ip ospf priority 10	Specify the router priority to a higher priority (10) to make R3 the Designated Router (DR).
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define the interface (`10.10.10.0/24`) on which OSPF runs and associate the area ID (`0`) with the interface.

R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`) to be configured.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define the interface (`10.10.10.0/24`) on which OSPF runs and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router ospf 200	Configure the Routing process and specify the Process ID (200). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define the interface (10.10.10.0/24) on which OSPF runs and associate the area ID (0) with the interface.

Names of Commands Used

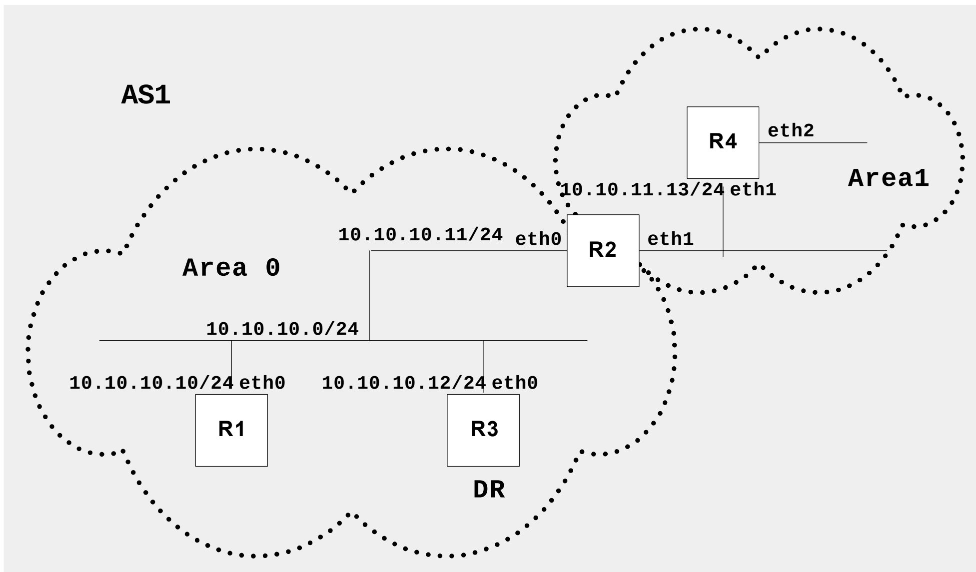
network area, ip ospf priority

Validation Commands

show ip ospf neighbor, show ip ospf interface

Configuring an Area Border Router

This example shows configuration for an Area Border Router. R2 is an Area Border Router (ABR). On R2, interface `eth0` is in `Area 0` and interface `eth1` is in the `Area 1`.



R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define one interface (`10.10.10.0/24`) on which OSPF runs and associate the area ID (`0`) with the interface.
ZebOS(config-router)# network 10.10.10.11/24 area 1	Define the other interface (`10.10.10.11/24`) on which OSPF runs and associate the area ID (`1`) with the interface.

Names of Commands Used

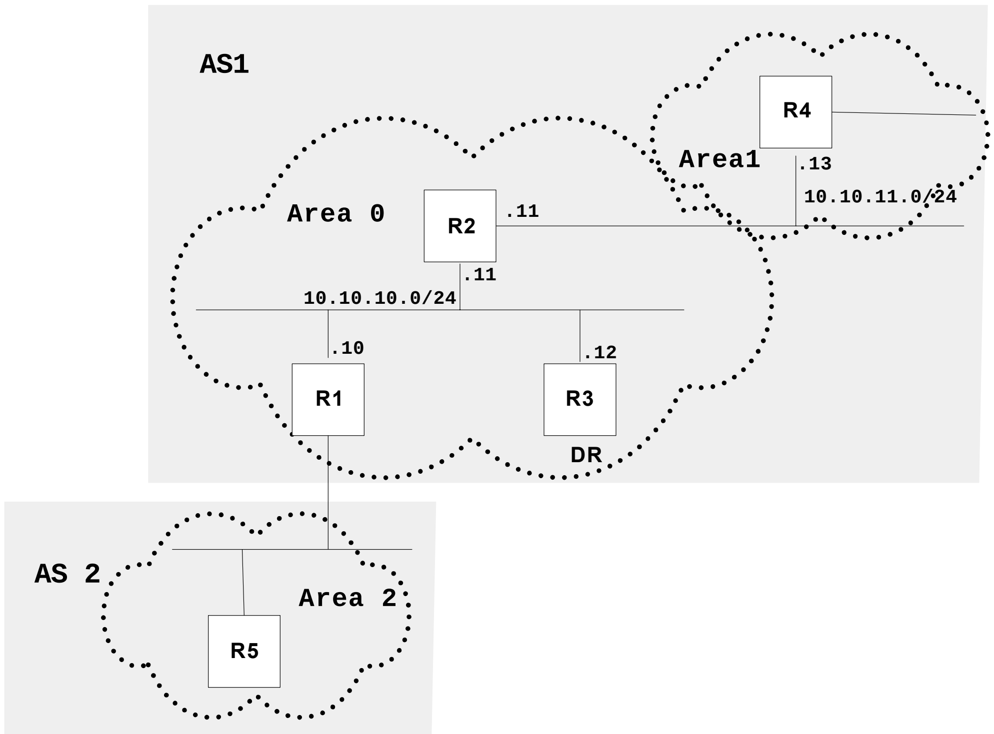
network area

Validation Commands

show ip ospf, show ip ospf interface

Redistributing routes into OSPF

In this example the configuration causes BGP routes to be imported into the OSPF routing table and advertised as `Type 5` External LSAs into `Area 0`.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0	Define one interface (`10.10.10.0/24`) on which OSPF runs and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
ZebOS(config-router)# redistribute bgp	Specify redistributing routes from other routing protocol (BGP) into OSPF.

Names of Commands Used

redistribute, network area

Validation Commands

show ip ospf database external

OSPF Cost

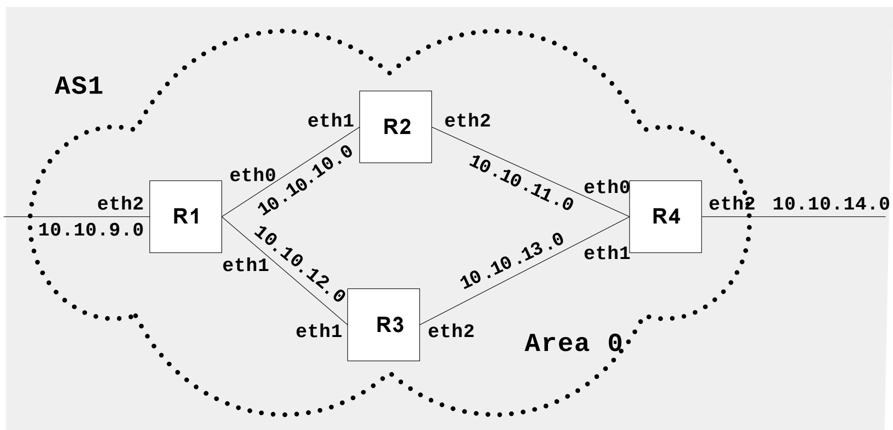
You can make a route the preferred route by changing its cost. In this example, cost has been configured to make R3 the next hop for R1.

The default cost on each interface is 10. Interface eth2 on R2 has a cost of 100 and Interface eth2 on R3 has a cost of 150. The total cost to reach 10.10.14.0/24 (R4) through R2 and R3:

R2: 10+100 = 110

R3: 10+150 = 160

Hence R1 will choose R2 as its next hop for destination 10.10.14.0/24.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.9.0/24 area 0 **ZebOS(config-router)#** network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 10.10.12.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).

R2

ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured.
ZebOS(config-if)# ip ospf cost 100	Set the OSPF cost of this link to 100.
ZebOS(config-if)# exit	Exit the Interface mode and return to Configure mode.

ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 10.10.11.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID (0) with the interface.

R3

ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured.
ZebOS(config-if)# ip ospf cost 150	Set the OSPF cost of this link to 100.
ZebOS(config-if)# exit	Exit the Interface mode and return to Configure mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.12.0/24 area 0 **ZebOS(config-router)#** network 10.10.13.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID (0) with the interface.

R4

ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.11.0/24 area 0 **ZebOS(config-router)#** network 10.10.13.0/24 area 0 **ZebOS(config-router)#** network 10.10.14.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID (0) with the interface.

Names of Commands Used

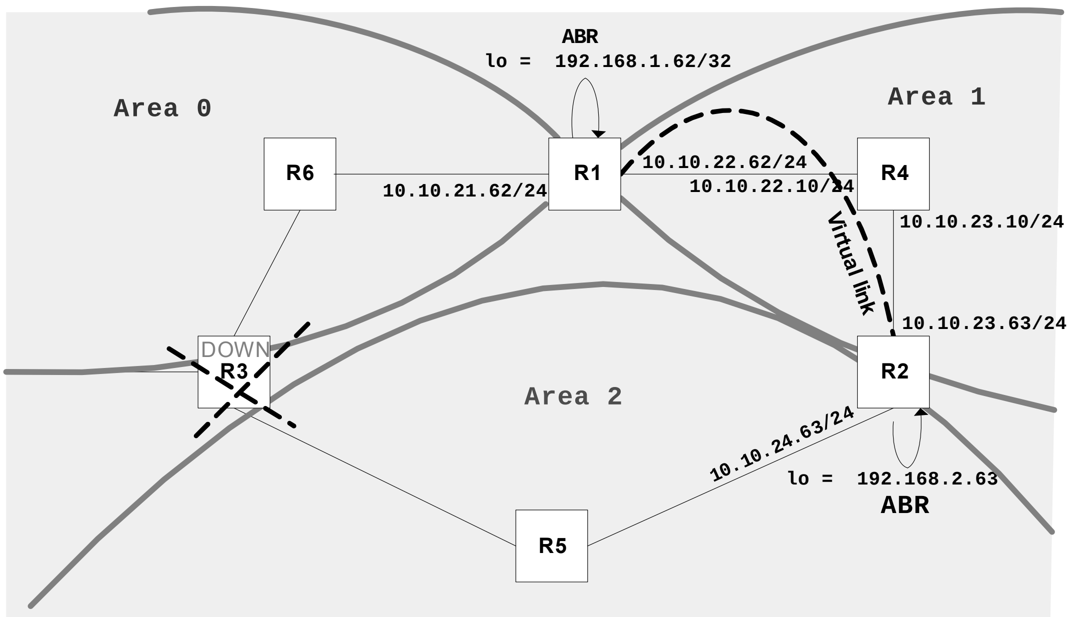
network area, ip ospf cost

Validation Commands

show ip ospf route 10.10.14.0/24

Configuring Virtual Links

Virtual links are used to connect a temporarily disjointed non-backbone area to the backbone area, or to repair a non-contiguous backbone area. In this example, the ABR R3 has temporarily lost connection to `Area 0` disconnecting `Area 2` from the backbone area. The virtual link between ABR R1 and ABR R2 connects `Area 2` to `Area 0`. Area 1 is used as a transit area.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface lo	Specify loopback as the interface you want to configure.
ZebOS(config-if)# ip address 192.168.1.62/32	Configure the IP address on this interface.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (`100`). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# ospf router-id 192.168.1.62	Configure OSPF Router ID (`192.168.1.62`) for this router.
ZebOS(config-router)# network 10.10.21.0/24 area 0 **ZebOS(config-router)#** network 10.10.22.0/24 area 1	Define interfaces on which OSPF runs and associate the area IDs (`0 and 1`) with the interface.
ZebOS(config-router)# area 1 virtual-link 192.168.2.63	Configure a virtual link between this router R1 and R2 (Router ID `192.168.2.63`) through transit area 1.

R2

ZebOS(config)# interface lo	Specify loopback as the interface you want to configure
ZebOS(config-if)# ip address 192.168.2.63/32	Configure the IP address on this interface.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode.

ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# ospf router-id 192.168.2.63	Configure OSPF Router ID (192.168.1.63) for this router.
ZebOS(config-router)# network 10.10.23.0/24 area 1 **ZebOS(config-router)#** network 10.10.24.0/24 area 2 **ZebOS(config-router)#** network 192.168.2.63/32 area 2	Define interfaces on which OSPF runs and associate the area IDs (1 and 2) with the interface.
ZebOS(config-router)# area 1 virtual-link 192.168.1.62	Configure a virtual link between this router R2 and R1(Router ID 192.168.2.62) through transit area 1.

Names of Commands Used

area virtual-link, network area

Validation Commands

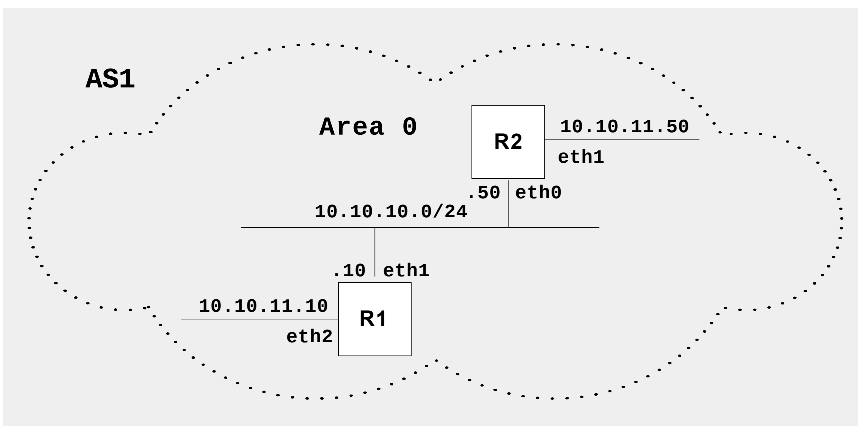
show ip ospf virtual link, show ip ospf neighbor, show ip ospf

OSPF Authentication

In the ZebOS implementation there are three types of OSPF authentications--Null authentication (Type 0), Simple Text (Type 1) authentication and MD5 (Type 2) authentication. Null authentication means that routing exchanges over the network are not authenticated. In Simple Text authentication, configure the authentication type to be the same for all routers that are to communicate using OSPF in a network. For MD5 authentication, you configure a key and a key-id on each router. The router generates a message digest on the basis of the key, key ID and the OSPF packet and adds it to the OSPF packet.

The Authentication type can be configured on a per-interface basis or a per area basis. Additionally, Interface and Area authentication can be used together. Area authentication is used for an area and interface authentication is used for a specific interface in the area. If the Interface authentication type is different from area authentication type, interface authentication type overrides the area authentication type. If the authentication type is not specified for an interface, the authentication type for the area is used. The authentication command descriptions contain details of each type of authentication. Refer to the *OSPF Command Reference* for OSPF authentication commands.

In the example below, `R1` and `R2` are configured for both the interface and area authentications.The authentication type of interface `eth1` on `R1` and interface `eth0` on `R2` is md5 mode and is defined by the `area authentication` command; however, the authentication type of interface `eth2` on `R1` and interface `eth1` on `R2` is plain text mode and is defined by the `ip ospf authentication` command. This interface command overrides the area authentication command.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 10.10.11.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID `(0)` with the interface (area ID 0 specifies the backbone area).
ZebOS(config-router)# area 0 authentication message-digest	Enable MD5 authentication on area 0.
ZebOS(config-router)# exit	Exit the `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth1	Specify the interface (`eth1`)to be configured.
ZebOS(config-if)# ip ospf message-digest-key 1 md5 test	Register MD5 key `test` for OSPF authentication. The Key ID is 1.

ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode
ZebOS(config)# interface eth2	Specify the interface (`eth2`)to be configured.
ZebOS(config-if)# ip ospf authentication	Enable OSPF packet to use text authentication on the current interface (`eth2`).
ZebOS(config-if)# ip ospf authentication-key test	Specify an OSPF authentication password `test` for the neighboring routers.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ospf 100	Configure the Routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 10.10.11.0/24 area 0	Define interfaces on which OSPF runs and associate the area ID `(0)` with the interface (area ID 0 specifies the backbone area).
ZebOS(config-router)# area 0 authentication message-digest	Enable MD5 authentication on area 0.
ZebOS(config-router)# exit	Exit the `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured.
ZebOS(config-if)# ip ospf message-digest-key 1 md5 test	Register MD5 key `test` for OSPF authentication. The Key ID is 1.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to `Configure` mode
ZebOS(config)# interface eth1	Specify the interface (`eth2`)to be configured.
ZebOS(config-if)# ip ospf authentication	Enable OSPF packet to use text authentication on the current interface (`eth1`).
ZebOS(config-if)# ip ospf authentication-key test	Specify an OSPF authentication password `test` for the neighboring routers.

Names of Commands Used

ip ospf authentication, ip ospf authentication-key, network area, area authentication message-digest

Validation Commands

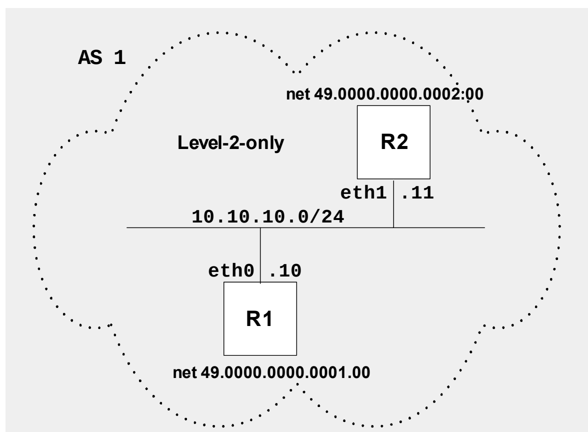
show run, show ip ospf neighbor

CHAPTER 6 IS-IS (IPv4) Configuration

This chapter contains basic IS-IS configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *IS-IS Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Enabling IS-IS on an interface

This example shows the minimum configuration required for enabling IS-IS on an interface. R1 and R2 are two routers in `ipi` instance connecting to the network `10.10.10.0/24`. After enabling IS-IS on an interface, create a routing instance and specify the Network Entity Title (NET). IS-IS explicitly specifies a NET to begin routing. NET is comprised of the area address and the system ID of the router.



R1

ZebOS# `configure terminal`	Enter the `Configure` mode.
ZebOS(config)# `interface eth0`	Specify the interface (`eth0`) to be configured and enter the Interface mode.
ZebOS(config-if)# `ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
ZebOS(config-if)# `exit`	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# `router isis ipi`	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# `is-type level-2-only`	Configure instance `ipi` as `Level-2-only` routing.
ZebOS(config-router)# `net 49.0000.0000.0001.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS# `configure terminal`	Enter the `Configure` mode.
ZebOS(config)# `interface eth0`	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.

ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

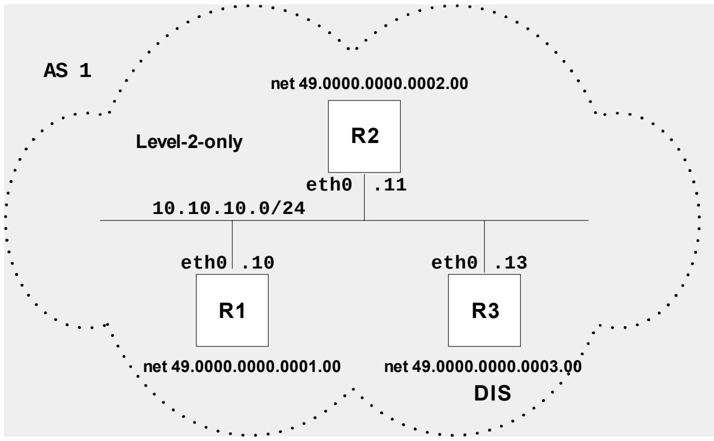
ip router isis, net, router isis

Validation Commands

show clns neighbors, show isis database, show isis topology

Setting priority

This example shows the configuration for setting the priority for an interface. Set a high priority for a router to make it the Designated IS (DIS). Router R3 is configured to have a priority of 70, this is higher than the default priority (default priority is 60) of R1 and R2. This makes R3 the DIS.



R3

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (`ipi`).
ZebOS(config-if)# isis priority 70	Specify the router priority to a higher priority (`70`) to make R3 the designated IS (DIS).
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Configure instance `ipi` as `Level-2-only` routing.
ZebOS(config-router)# net 49.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R1

ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (`ipi`).
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Configure instance `ipi` as `Level-2-only` routing.
ZebOS(config-router)# net 49.0000.0000.0000.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

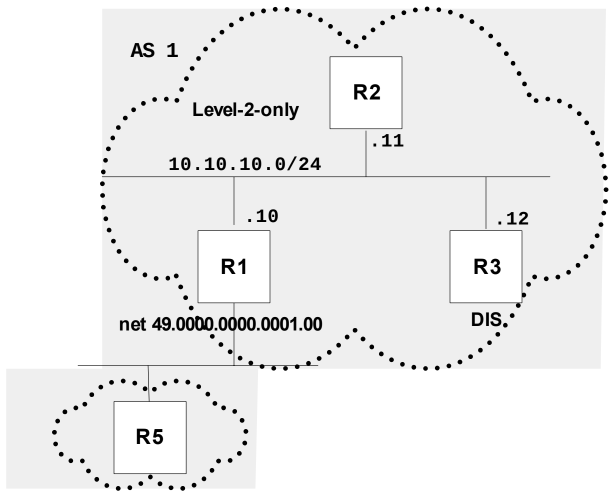
ip router isis, net, router isis, isis priority

Validation Commands

show clns neighbors, show isis database, show isis topology

Redistributing routes into IS-IS

In this example the configuration causes BGP routes to be imported into the IS-IS routing table and advertised into the `ipi` instance.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (`ipi`).
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (`ipi`) as `Level-2-only`.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# redistribute bgp	Specify redistributing routes from other routing protocol (BGP) into IS-IS.

Names of Commands Used

ip router isis, redistribute, is-type, router isis

Validation Commands

show clns neighbors, show isis database, show isis topology, show ip isis route, show ip route

Configuring Metric

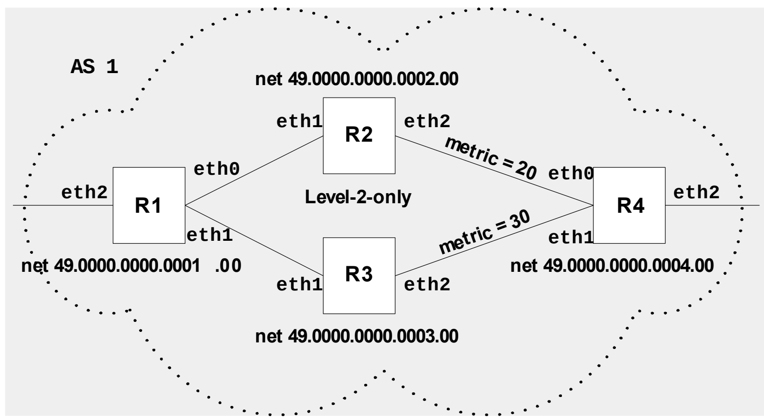
You can make a route the preferred route by changing its metric. In this example, the cost has been configured to make R3 the next hop for R1.

The default metric on each interface is 10. Interface eth2 on R2 has a metric of 20 and Interface eth2 on R3 has a metric of 30. The total cost to reach 10.10.14.0/24 (R4) through R2 and R3:

R2: 10+20 = 30

R3: 10+30 = 40

In this topology, R1 chooses R2 as its next hop for destination 10.10.14.0/24.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# isis metric 20	Set the value of IS-IS metric (on eth2) to 20.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# isis metric 30	Set the value of IS-IS metric (on eth2) to 30.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

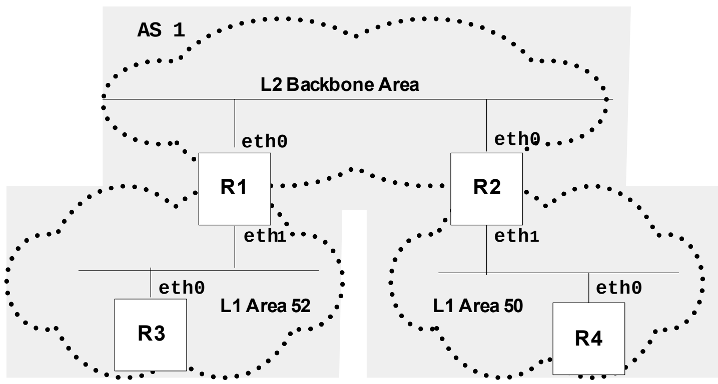
ip router isis, net, isis metric, router isis

Validation Commands

show clns neighbors, show isis database, show isis topology, show ip isis route, show ip route

L1 L2 Area Routing with Single Instance

IS-IS supports a two-level hierarchy for handling and scaling the functionality of large networks. The Level-1 (L1) area is mainly for `Leaf` networks and the Level-2 (L2) area is the backbone area connecting Level-1 areas. In this example, R3 and R4 are configured as Level-1 routers and sit in the Level-1 area. R1 and R2 are configured as Level-1-2 routers and connect these two Level-1 areas with a backbone Level-2 area. You can configure Level-1-2 routers with single or multiple instances. This configuration shows the single instance version of the Level-1-2 router.



R1

ZebOS# `configure terminal`	Enter the `Configure` mode.
ZebOS(config)# `interface eth0`	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# `ip router isis abc`	Enable IS-IS routing on the interface `eth0` for area `abc.`
ZebOS(config-if)# `isis circuit-type level-2-only`	Set the circuit type for the interface `eth0`.
ZebOS(config-if)# `exit`	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# `interface eth1`	Specify the interface (`eth1`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# `ip router isis abc`	Enable IS-IS routing on the interface `eth1` for area `abc.`
ZebOS(config-if)# `isis circuit-type level-1`	Set the circuit type for the interface `eth1`.
ZebOS(config-if)# `exit`	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# `router isis abc`	Create an IS-IS routing instance for area `abc`.
ZebOS(config-router)# `net 52.0000.0000.0001.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# `interface eth0`	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# `ip router isis bb`	Enable IS-IS routing on the interface `eth0` for area `bb.`
ZebOS(config-if)# `isis circuit-type level-2-only`	Set the circuit type for the interface `eth0`.
ZebOS(config-if)# `exit`	Exit `Interface` mode and return to `Configure` mode.

ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis bb	Enable IS-IS routing on the interface eth1 for area bb.
ZebOS(config-if)# isis circuit-type level-1	Set the circuit type for the interface eth1.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis bb	Create an IS-IS routing instance for area bb.
ZebOS(config-router)# net 50.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis xyz	Enable IS-IS routing on the interface eth0 for area xyz.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis xyz	Create an IS-IS routing instance for area xyz.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (xyz) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis aa	Enable IS-IS routing on the interface eth0 for area aa.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis aa	Create an IS-IS routing instance for area aa.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (aa) as Level-1.
ZebOS(config-router)# net 50.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

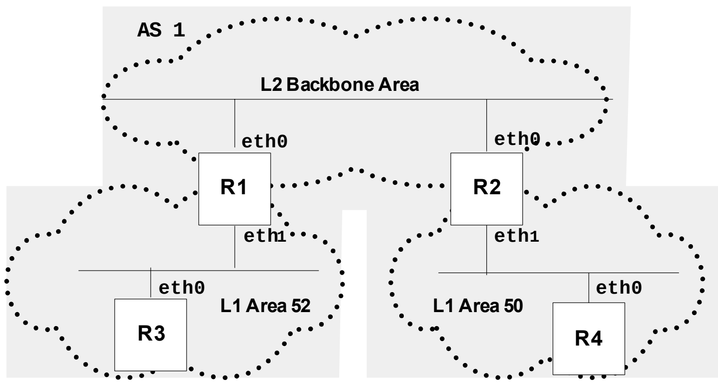
Names of Commands Used

isis circuit-type, is-type, ip router isis, net

Validation Commands

L1 L2 Area Routing with Multiple Instances

IS-IS supports a two-level hierarchy for handling and scaling the functionality of large networks. The Level-1 (L1) area is mainly for Leaf networks and the Level-2 (L2) area is the backbone area connecting Level-1 areas. In this example, R3 and R4 are configured as Level-1 routers and sit in the Level-1 area. R1 and R2 are configured as Level-1-2 routers and connect these two Level-1 areas with a backbone Level-2 area. You can configure Level-1-2 routers with single or multiple instances. This configuration shows the multiple instance version of the Level-1-2 router.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0) to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis aaa	Enable IS-IS routing on the interface eth0 for area aaa.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis aaa	Create an IS-IS routing instance for area aaa.
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (aaa) as Level-2-only.
ZebOS(config-router)# net bb.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis ccc	Enable IS-IS routing on the interface eth1 for area ccc.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ccc	Create an IS-IS routing instance for area ccc.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (ccc) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth0	Specify the interface (eth0) to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis bb	Enable IS-IS routing on the interface eth0 for area bb.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.

ZebOS(config)# router isis bb	Create an IS-IS routing instance for area bb.
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (bb) as Level-2-only.
ZebOS(config-router)# net bb.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis abc	Enable IS-IS routing on the interface eth1 for area abc.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis abc	Create an IS-IS routing instance for area abc.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (abc) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis xyz	Enable IS-IS routing on the interface eth0 for area xyz.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis xyz	Create an IS-IS routing instance for area xyz.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (xyz) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ip router isis aa	Enable IS-IS routing on the interface eth0 for area aa.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis aa	Create an IS-IS routing instance for area aa.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (aa) as Level-1.
ZebOS(config-router)# net 50.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

isis circuit-type, is-type, ip router isis, net

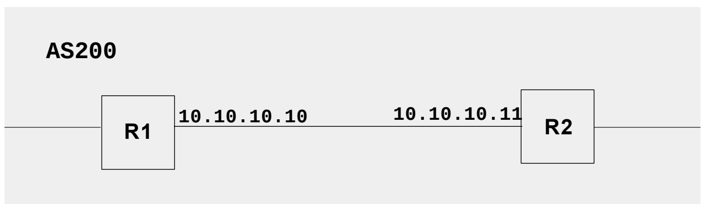
Validation Commands

CHAPTER 7 BGP Configuration

This chapter contains basic BGP configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *BGP Command Reference*. To avoid repetition, some Common commands, such as `configure terminal`, have not been listed under the *Commands Used* section. These common Commands are explained in the *NSM Command Reference*.

Enabling BGP (routers in the same AS)

This example shows the minimum configuration required for enabling BGP on an interface. R1 and R2 are two routers belonging to the same Autonomous System, AS10, connecting to network 10.10.10.0/24. First, define the routing process and the AS number to which the routers belong. Then, define BGP neighbors to start exchanging routing updates.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R1.
ZebOS(config-router)# neighbor 10.10.10.11 remote-as 200	Define BGP neighbors and establish a TCP session. `10.10.10.11` is the IP address of the neighbor (R2) and `200` is the neighbor's AS number.

R2

ZebOS# configure terminal	Enter the `Configure` mode
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R2.
ZebOS(config-router)# neighbor 10.10.10.10 remote-as 200	Define BGP neighbors and establish a TCP session. `10.10.10.10` is the IP address of the neighbor (R1) and `200` is the neighbor's AS number.

Names of Commands Used

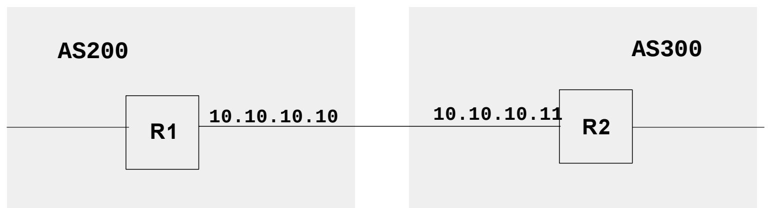
router bgp, neighbor remote-as

Validation Commands

show ip bgp summary, show ip bgp neighbors

Enabling BGP (routers in different ASs)

This example shows the minimum configuration required for enabling BGP on an interface when the routers belong to different Autonomous Systems. R1 and R2 are two routers in different ASs, AS10 and AS11 connecting to network 10.10.10.0/24.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R1.
ZebOS(config-router)# neighbor 10.10.10.11 remote-as 300	Define BGP neighbors and establish a TCP session. `10.10.10.11` is the IP address of the neighbor (R2) and `300` is the neighbor's AS number.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 300	Define the routing process. The number `300` specifies the AS number of R2.
ZebOS(config-router)# neighbor 10.10.10.10 remote-as 200	Define BGP neighbors and establish a TCP session. `10.10.10.10` is the IP address of the neighbor (R1) and `200` is the neighbor's AS number.

Names of Commands Used

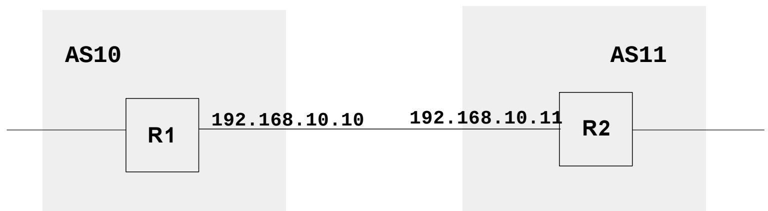
router bgp, neighbor remote-as

Validation Commands

show ip bgp summary, show ip bgp neighbors

Route-Map

Use route-maps to filter incoming updates from a BGP peer. In this example, a prefix-list `ipi` on R1 is configured to deny entry of any routes with the IP address `1.1.1.0/M (M = 26,27,28)`. To test the filter, R2 is configured to generate network addresses `1.1.1.0/27` and `1.1.2.0/24`. To verify, use the `show ip bgp` command on R1; it displays R1 receiving updates from only `1.1.2.0/24`.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# ip prefix-list ipi seq 5 deny 1.1.1.0/24 ge 26 le 28 **ZebOS(config)#** ip prefix-list ipi seq 10 permit any	Create an entry in the prefix-list. `ipi` is the name of the map that is created above. 5 specifies the sequence number or position of this specific route map. `deny` specifies the packets are to be rejected. `26` and `28` are the minimum and maximum prefix lengths to be matched.
ZebOS(config)# route-map ipi permit 1	Enter the route-map mode to set the match operation.
ZebOS(config-route-map)# match ip address prefix-list ipi	Set the match criteria. In this case, if the route-map name matches `ipi`, the packets from the first sequence will be denied.
ZebOS(config-route-map)# exit	Exit the `Route-map` mode and return to `Configure` mode.
ZebOS(config)# router bgp 10	Define the routing process and establish a TCP session. The number `10` specifies the AS number of R1.
ZebOS(config-router)# neighbor 192.168.10.11 remote-as 11	Define BGP neighbors and establish a TCP session. `192.168.10.11` is the IP address of the neighbor (R2) and `11` is the neighbor's AS number.
ZebOS(config-router)# neighbor 192.168.10.11 route-map ipi in	Apply a route-map to routes. `192.168.10.11` specifies the IP address of BGP neighbor. `ipi` is the name of the route-map and `in` specifies that the access list will apply to incoming advertisements.

R2

ZebOS(config)# router bgp 11	Define the routing process and establish a TCP session. The number `11` specifies the AS number of R2.
ZebOS(config-router)# neighbor 192.168.10.10 remote-as 10	Define BGP neighbors and establish a TCP session. `192.168.10.10` is the IP address of the neighbor (R1) and `10` is the neighbor's AS number.
ZebOS(config-router)# network 1.1.1.0/27	Specify the network to be advertised by the BGP routing process.
ZebOS(config-router)# network 1.1.2.0/24	Specify the network to be advertised by the BGP routing process.

Names of Commands Used

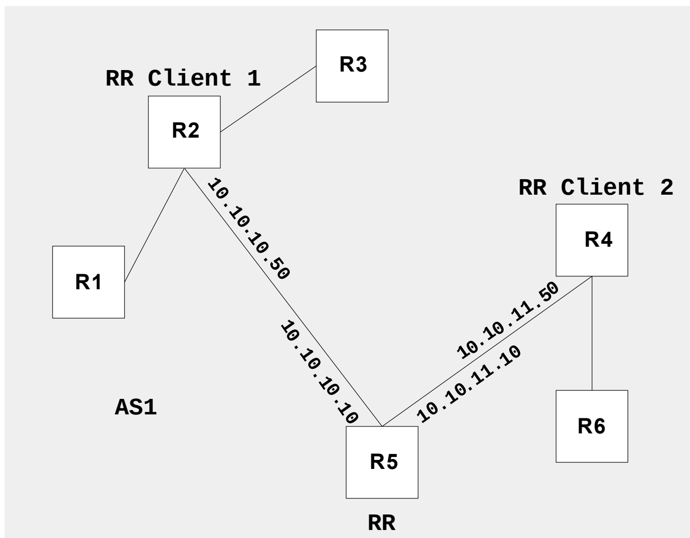
ip prefix-list (*NSM Command Reference*), neighbor remote-as, route-map, match ip address, network and network backdoor.

Validation Commands

show ip bgp

Route Reflector

Use Route Reflectors to reduce the IBGP mesh inside an AS. In this example, R2, R5 and R4 would have to maintain a full mesh among themselves but by making R5 the Route Reflector, R2 (Client1) has IBGP session with RR only and not with R4 (Client 2). The routes learned from R2 are advertised to the other clients and to IBGP peers outside the cluster; the IBGP routes learned from IBGP peers outside the cluster are advertised to the R2. This reduces the IBGP peer connections in AS1.



RR (R5)

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 1	Define the routing process. The number `1` specifies the AS number of R5.
ZebOS(config-router)# neighbor 10.10.10.50 remote-as 1	Define BGP neighbor and establish a TCP session. `10.10.10.50` is the IP address of one of the neighbors (R2) and `1` is the neighbor's AS number.
ZebOS(config-router)# neighbor 10.10.10.50 route-reflector client	Configure R5 as the Route-Reflector (RR) and neighbor R2 as its client.
ZebOS(config-router)# neighbor 10.10.11.50 remote-as 1	Define BGP neighbor and establish a TCP session. `10.10.11.50` is the IP address of one of the neighbors (R4) and `1` is the neighbor's AS number.
ZebOS(config-router)# neighbor 10.10.11.50 route-reflector client	Configure R5 as the Route-Reflector (RR) and neighbor R4 as its client.

RR Client 1 (R2)

ZebOS(config)# router bgp 1	Define the routing process. The number `1` specifies the AS number of R2.
ZebOS(config-router)# neighbor 10.10.10.10 remote-as 1	Define BGP neighbor and establish a TCP session. `10.10.10.10` is the IP address of the neighbor (R5) and `1` is the neighbor's AS number.

RR Client 2 (R4)

ZebOS(config)# router bgp 1	Define the routing process. The number 1 specifies the AS number of R4.
ZebOS(config-router)# neighbor 10.10.11.10 remote-as 1	Define BGP neighbor and establish a TCP session. 10.10.11.10 is the IP address of the neighbor (R5) and 1 is the neighbor's AS number.

Names of Commands Used

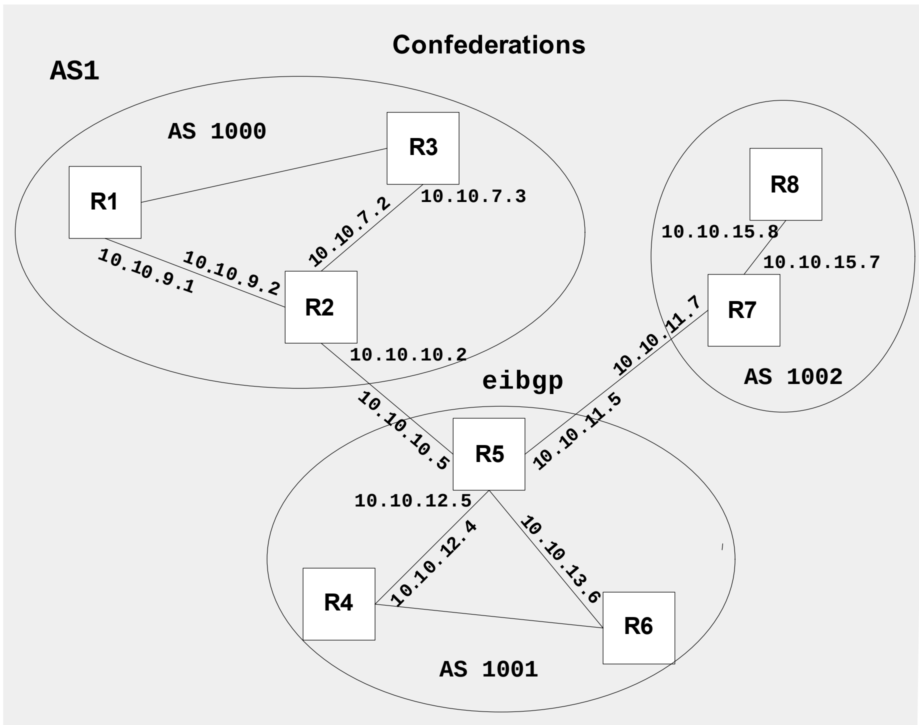
neighbor remote-as, neighbor route-reflector-client

Validation Commands

show ip bgp, show ip bgp neighbors

Confederations

In this example, AS1 contains three Confederation Autonomous Systems--AS 1000, AS 1001 and AS 1002. To any outside AS, the Confederation is a single Autonomous System AS1. Confederation eIBGP is run between R2 and R5, and between R5 and R7. R2 is configured so that its local AS is 1000. Its peer connection to R5 is set up like any other eBGP session. The `bgp confederation identifier` command tells the router that it is a member of a Confederation and the Confederation ID. The `bgp confederation peers` command lists the member autonomous system to which R2 is connected. The command tells the BGP process that the eBGP connection is a Confederation eBGP rather than normal eBGP.



R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 1000	Define the routing process. The number `1000` specifies the AS number of R2.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier, to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1001 1002	Specify AS `1001` and `1002` to become members of the Confederation.
ZebOS(config-router)# neighbor 10.10.10.5 remote-as 1001 **ZebOS(config-router)#** neighbor 10.10.9.1 remote-as 1000 **ZebOS(config-router)#** neighbor 10.10.7.3 remote-as 1000	Define BGP neighbors for R2 and establish a TCP session by specifying the IP addresses and the AS numbers of neighbors.

R5

ZebOS(config)# router bgp 1001	Define the routing process. The number `1001` specifies the AS number of R5.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier, to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1000 1002	Specify AS `1000` and `1002` to become members of the Confederation.
ZebOS(config-router)# neighbor 10.10.10.2 remote-as 1000 **ZebOS(config-router)#** neighbor 10.10.11.7 remote-as 1002 **ZebOS(config-router)#** neighbor 10.10.13.6 remote-as 1001 **ZebOS(config-router)#** neighbor 10.10.12.4 remote-as 1001	Define BGP neighbors for R5 and establish a TCP session by specifying the IP addresses and the AS numbers of neighbors.

R7

ZebOS(config)# router bgp 1002	Define the routing process. The number `1001` specifies the AS number of R5.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier, to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1000 1001	Specify AS `1000` and `1001` to become members of the Confederation.
ZebOS(config-router)# neighbor 10.10.11.5 remote-as 1001 **ZebOS(config-router)#** neighbor 10.10.15.8 remote-as 1002	Define BGP neighbors for R7 and establish a TCP session by specifying the IP addresses and the AS numbers of neighbors.

Names of Commands Used

neighbor remote-as, bgp confederation peer, bgp confederation identifier

Validation Commands

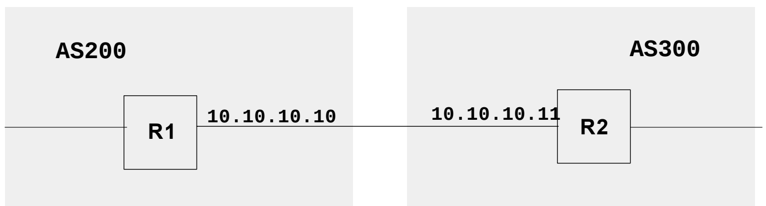
show ip bgp, show ip bgp neighbors

BGP Authentication

BGP authentication allows users to receive selected routing information enhancing security of their network traffic. When BGP authentication is enabled on a router, the router verifies routing packet it receives by exchanging a password that is configured on both the sending and the receiving routers.

Note: To enable BGP authentication on TCP/IP you need to apply a kernel patch and specific MD5 libraries. Refer to the *Installation Guide* for detailed information on how to apply the MD5 authentication patch (*Install Linux* chapter) and the required libraries (*Appendix*).

In this example, both R1 and R2 have `ipi` as the password. Configure the same password on all routers that are to communicate using BGP in a network



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R1.
ZebOS(config-router)# neighbor 10.10.10.11 remote-as 200	Define BGP neighbors and establish a TCP session. `10.10.10.11` is the IP address of the neighbor (R2) and `200` is the neighbor's AS number.
ZebOS(config-router)# neighbor 10.10.10.11 password 1 ipi	Specify the encryption type and the password.

R2

ZebOS# configure terminal	Enter the `Configure` mode
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R2.
ZebOS(config-router)# neighbor 10.10.10.10 remote-as 200	Define BGP neighbors and establish a TCP session. `10.10.10.10` is the IP address of the neighbor (R1) and `200` is the neighbor's AS number.
ZebOS(config-router)# neighbor 10.10.10.10 password 1 ipi	Specify the encryption type and the password.

Names of Commands Used

neighbor remote-as, neighbor password

Validation Commands

show ip bgp, show ip bgp neighbors

CHAPTER 8 LDP Configuration

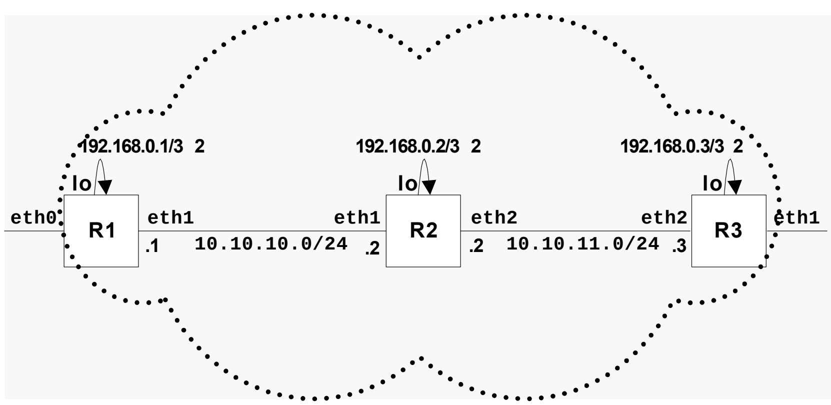
This chapter contains basic LDP configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *LDP Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. These Common commands are explained in the *NSM Command Reference*.

Protocol names mentioned in the samples (for example, LDP), indicate the protocol daemons on which the configuration is performed. ZebOS SRS users and other VTY Shell users view a common CLI for all protocol daemons and can follow this configuration without having to go from one protocol to the other. Users not using VTY Shell must make sure they are in the correct daemon when configuring. For commands used to enter each command mode see the `Command Modes` section in the *Introduction* chapter.

Enabling Label Switching

To run LDP on a system, requires the following tasks:

- Enabling label-switching on the interface on NSM.
- Enabling LDP on an interface in the LDP daemon.
- Running an IGP (for example, OSPF) to distribute reachability information within the MPLS cloud.
- Configuring the transport address.



R1(NSM)

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth1	Specify the interface `(eth1)` to be configured.
ZebOS(config-if)# label-switching	Enable label switching on interface `eth1`.
ZebOS(config-if)# exit	Exit the `Interface` mode and return to the `Configure` mode.
ZebOS(config)# interface lo	Specify the loopback (`lo`) interface to be configured.
ZebOS(config-if)# ip address 192.168.0.1/32	Set the IP address of the loopback interface to `192.168.0.1/32`.

R1(LDP)

ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured.
ZebOS(config-if)# enable-ldp	Enable LDP on a specified interface eth1.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router ldp	Enter Router mode.
ZebOS(config-router)# router-id 192.168.0.1	Set the router ID for IP address 192.168.0.1.
ZebOS(config-router)# transport-address 192.168.0.1	Configure the transport address that will be used for a TCP session over which LDP will run. Preferably use the loopback address as transport address.
ZebOS(config-router)# exit	Exit the Router mode and return to the Configure mode.

R1(OSPF)

ZebOS(config)# router ospf 100	Configure the routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying hte routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 192.168.0.1/32 area 0	Define the interface on which OSPF runs and associate the area ID (0) with the interface.

R2(NSM)

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface lo	Specify the loopback (lo) interface to be configured.
ZebOS(config-if)# ip address 192.168.0.2/32	Set the IP address of the loopback interface to 192.168.0.2/32.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured.
ZebOS(config-if)# label-switching	Enable label switching on interface eth1.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured.
ZebOS(config-if)# label-switching	Enable label switching on interface eth2.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.

R2(LDP)

ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured.
ZebOS(config-if)# enable-ldp	Enable LDP on a specified interface eth1.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured.
ZebOS(config-if)# enable-ldp	Enable LDP on a specified interface eth2.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router ldp	Enter Router mode.

ZebOS(config-router)# router-id 192.168.0.2	Set the router ID for IP address 192.168.0.2.
ZebOS(config-router)# transport-address 192.168.0.2	Configure the transport address that will be used for a TCP session over which LDP will run. Preferably use the loopback address as transport address.
ZebOS(config-router)# exit	Exit the Router mode and return to the Configure mode.

R2(OSPF)

ZebOS(config)# router ospf 100	Configure the routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying the routing process.
ZebOS(config-router)# network 10.10.10.0/24 area 0 **ZebOS(config-router)#** network 10.10.11.0/24 area 0 **ZebOS(config-router)#** network 192.168.0.2/32 area 0	Define the interface on which OSPF runs and associate the area ID (0) with the interface.

R3(NSM)

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface lo	Specify the loopback (lo) interface to be configured.
ZebOS(config-if)# ip address 192.168.0.3/32	Set the IP address of the loopback interface to 192.168.0.3/32.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured.
ZebOS(config-if)# label-switching	Enable label switching on interface eth2.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.

R3(LDP)

ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured.
ZebOS(config-if)# enable-ldp	Enable LDP on a specified interface eth2.
ZebOS(config-if)# exit	Exit the Interface mode and return to the Configure mode.
ZebOS(config)# router ldp	Enter Router mode.
ZebOS(config-router)# router-id 192.168.0.3	Set the router ID for IP address 192.168.0.3.
ZebOS(config-router)# transport-address 192.168.0.3	Configure the transport address that will be used for a TCP session over which LDP will run. Preferably use the loopback address as transport address.
ZebOS(config-router)# exit	Exit the Router mode and return to the Configure mode.

R3(OSPF)

ZebOS(config)# router ospf 100	Configure the routing process and specify the Process ID (100). The Process ID should be a unique positive integer identifying hte routing process.
ZebOS(config-router)# network 10.10.11.0/24 area 0 **ZebOS(config-router)#** network 192.168.0.3/32 area 0	Define the interface on which OSPF runs and associate the area ID (0) with the interface.

Names of Commands Used

label-switching, ip address *(NSM Command Reference)*

enable-ldp, router-id, transport-address *(LDP Command Reference)*

network area *(OSPF Command Reference)*

Validation Commands

LDP - show ldp adjacency, show ldp session, show ldp, show ldp interface

NSM - show mpls forwarding table

CHAPTER 9 IPv6 Configuration

IPv6 is a Layer 3 transport protocol superseding the IPv4 protocol. Two of the major changes from IPv4 are a different header and an increase in the size of address from 32 bits to 128 bits.

IPv6 Addresses

Basic Format

IPv6 addresses are 128 bits long. This number of bits generates high decimal numbers with up to 39 digits. Such numbers are hard to work with and memorize. To represent such big numbers, designers use the hexadecimal format. In hexadecimal, 4 bits are represented by a digit or character from `0-9` and `a-f (10-15)`. This format reduces the length of the IPv6 address to 32 characters. To avoid mix-up or loss of single hexadecimal digits, IPv6 designers chose a hexadecimal format with a colon separator after each block of 16 bits. An example of an IPv6 address:

`3ffe:ffff:0100:f101:0210:a4ff:fee3:9566`

Simplifying the Addresses

To make using the addresses simpler, leading zeros of each 16-bit block are omitted:

`3ffe:ffff:100:f101:210:a4ff:fee3:9566`

Sequences of 16 bit blocks containing only zeros are replaced with two colons`::` (not more than once per address). The new address looks like:

`3ffe:ffff:100:f101::1 (Basic--3ffe:ffff:0100:f101:0:0:0:1)`

Special Addresses

The initial part of the IPv6 address space is reserved and out of this prefix some special addresses have been defined:

Unspecified address

The unspecified address (similar to 0.0.0.0 in IPv4) for IPv6 is:

`0000:0000:0000:0000:0000:0000:0000:0000` (or `::`)

Localhost address

The special address for the loopback interface (similar to IPv4 localhost address 127.0.0.1) for IPv6 is:

`0000:0000:0000:0000:0000:0000:0000:0001` (or `::1`)

Link local address

The link local address is assigned automatically to an interface when IPv6 is enabled. It is used only on local links for link communication purposes. The link local addresses typically begin with `fe80`.

Site local address

The site local addresses typically start with `fec0` and are used within a site. They are not for global use.

Aggregatable Global Unicast addresses

Composed of 3-bit prefix `001` followed by four components: Top Level Aggregator (TLA), Next Level Aggregator (NLA), Site Local Aggregator, and an Interface Identifier. The Aggregatable Global Unicast Address must be globally unique over the whole Internet.

Multicasting Addresses

Multicast capability is formally added into the IPv6 protocol. The multicasting addresses begin with `ff0x`, where `x` is any hexadecimal number. An example of multicast address is `ff02::1`. This stands for all nodes of an address.

IPv6 Networking Utilities

Linux

When installing the standard Linux kernel version 2.4, the IPv6 protocol stack is enabled if IPv6 option is selected before building the kernel.

To make use of utilities for Linux, download and install the `net-tools` and `iputils` packages. The `net-tools` package includes utilities such as `ifconfig`, `netstat`, `route` and `hostname;` the `iputils` package contains `ping6`, `tracepath6` and `traceroute6`. For detailed information on how to install the utilities and compile the source code, go to `http://www.bieringer.de/linux/Ipv6/.`

The utilities to be used when working with IPv6 are similar to the IPv4 utilities. The Man pages and Help screens display the online help for all Linux utilities. They can be accessed by entering:

`man UTILITYNAME` (where `UTILITYNAME` is the name of the utility)

`parameter --help` (for example `ifconfig --help`)

ifconfig

Use this tool for general network configuration of the Linux box. Using the address family flag lets you switch between IPv4 and IPv6 address families. Use `ifconfig` to start and stop the interface and other statistics.

netstat

This tool provides options and statistics such as port information, routing table, and interface table.

ping6, traceroute6 and tracepath6

These are similar to the IPv4 utilities. Instead of using `ping` or `traceroute`, use `ping6` or `traceroute6`. The `tracepath6` tool displays the path and the MTU information.

Solaris

IPv6 Networking Utilities such as `ifconfig, netstat, route, ping, traceroute` also come with the IPv6 stack on Solaris2.8. They are very similar to IPv4 utilities. Use man pages to get instructions on how to use these utilities.

ifconfig

Configures network interface parameters. Use inet6 option for configuring an interface with IPv6 address.

netstat

Shows network status. Use `-f inet6` to show IPv6 network status.

ping

Sends `ICMP (ICMP6) ECHO_REQUEST` packets to network hosts. Use `-A inet6` to send `ICMP6 ECHO_REQUEST` packets to network hosts

traceroute

Traces the route that an IP packet follows to another internet host. Use `-A inet6` to trace the IPv6 packet.

Before Configuring IPv6 protocols

Linux

Before configuring the ZebOS SRS IPv6 protocols on Linux, make sure your current kernel supports IPv6.

1. To verify if your current kernel supports IPv6, check your `/proc-file-system`. The following entry must exist:

```
/proc/net/if_inet6
```

2. Then use `ping6` to check if the IPv6 communication can be established. Make sure you have root privileges to run `ping6`. An example of the ping6 command is:

```
ping6 -I <if-name> <ipv6-address>
```

   where `if-name` is the name of the interface and `ipv6-address` is a link-local IPv6 address, or a multicast address.

   For example, use the following command to check communication to all IPv6 enabled hosts on the same network:

```
ping6 -I eth0 ff02::1
```

Note: General information on enabling IPv6 for Redhat Linux OS is available online at:

`http://tldp.org/HOWTO/Linux+IPv6-HOWTO/systemcheck-kernel.html`

Solaris

IPv6 stack is available on Solaris 2.8 Operating environment. It is an integral part of Solaris 2.8.

To check if the IPv6 stack is enabled and if the IPv6 address is already configured type

```
ifconfig -a
```

If there is no IPv6 address defined for any interface, use the following command to enable the IPv6 stack:

```
ifconfig <ifname> inet6 plumb up
```

Type `ifconfig -a` again to verify the IPv6 link-local address in the configuration table. Check the IPv6 connection with the network by typing:

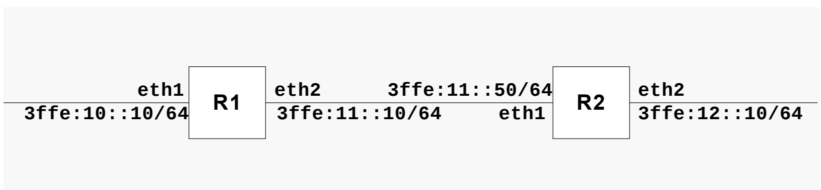
```
ping -s ff02::1
```

CHAPTER 10 RIPng Configuration

This chapter contains basic RIPng configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *RIP Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Enabling RIPng

This example shows the minimum configuration required for enabling RIPng on an interface. `R1` and `R2` are two routers connecting to network `3ffe:11::/64`. To enable RIPng, first define the RIPng routing process and then associate a network with the routing process.



R1

ZebOS# `configure terminal`	Enter the `Configure` mode.
ZebOS(config)# `router ipv6 rip`	Define a RIPng routing process and enter the `Router` mode.
ZebOS(config-router)# `network 3ffe:10::/64` **ZebOS(config-router)#** `network 3ffe:11::/64`	Associate networks with the RIPng process.

R2

ZebOS# `configure terminal`	Enter the `Configure` mode.
ZebOS(config)# `router ipv6 rip`	Define a RIPng routing process and enter the `Router` mode
ZebOS(config-router)# `network 3ffe:11::/64` **ZebOS(config-router)#** `network 3ffe:12::/64`	Associate networks with the RIPng process.

Names of Commands Used

router ipv6 rip, network

Validation Commands

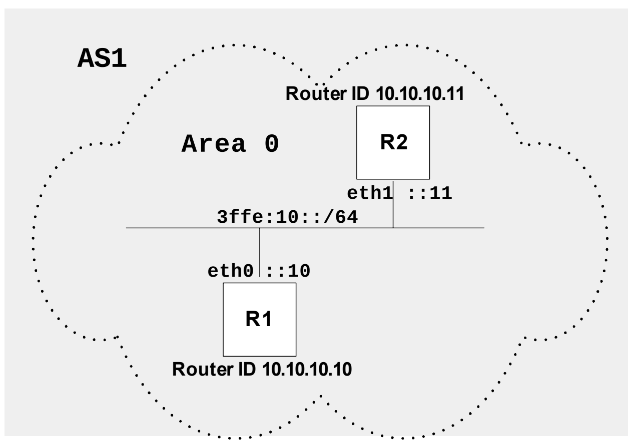
show ipv6 rip

CHAPTER 11 OSPFv3 Configuration

This chapter contains basic OSPFv3 configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *OSPF Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Enabling OSPFv3 on an interface

This example shows the minimum configuration required for enabling OSPFv3 on an interface. R1 and R2 are two routers in `Area 0` connecting to the network `3ffe:10::/64`. After enabling OSPFv3 on an interface, create a routing instance and specify the Router-ID. OSPFv3 explicitly specifies that a Router-ID to begin routing.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.10	Specify a Router ID for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID `0`.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.11	Specify a Router ID (`10.10.10.11`) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).

Names of Commands Used

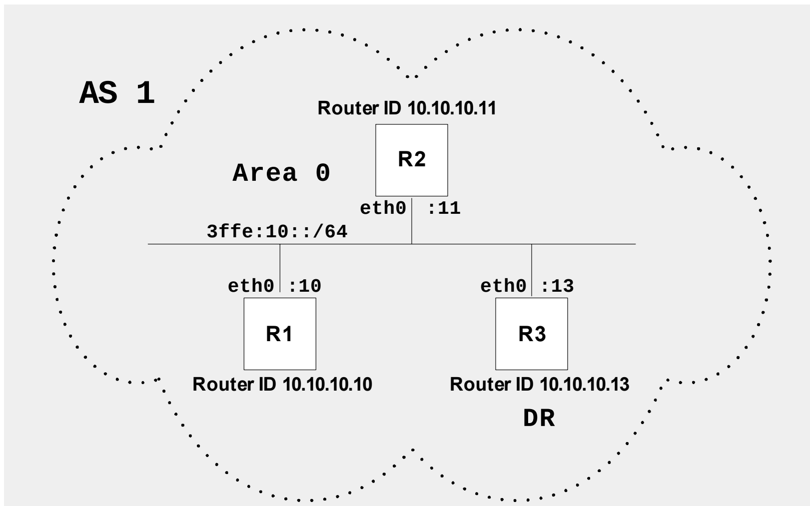
ipv6 router ospf area, router-id, router ipv6 ospf

Validation Commands

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospf topology

Setting priority

This example shows configuration for setting priority for an interface. Set a high priority for a router to make it the Designated Router (DR). Router R3 is configured to have a priority of 10; this is higher than the default priority (default priority is 1) of R1 and R2. This makes R3 the DR.



R3

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.13	Specify a Router ID (`10.10.10.13`) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (`0`).
ZebOS(config-if)# ipv6 ospf priority 10	Specify the router priority to a higher priority (10) to make R3 the Designated Router (DR).

R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.10	Specify a Router ID (`10.10.10.10`) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (`0`).

R2

ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.11	Specify a Router ID (10.10.10.11) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).

Names of Commands Used

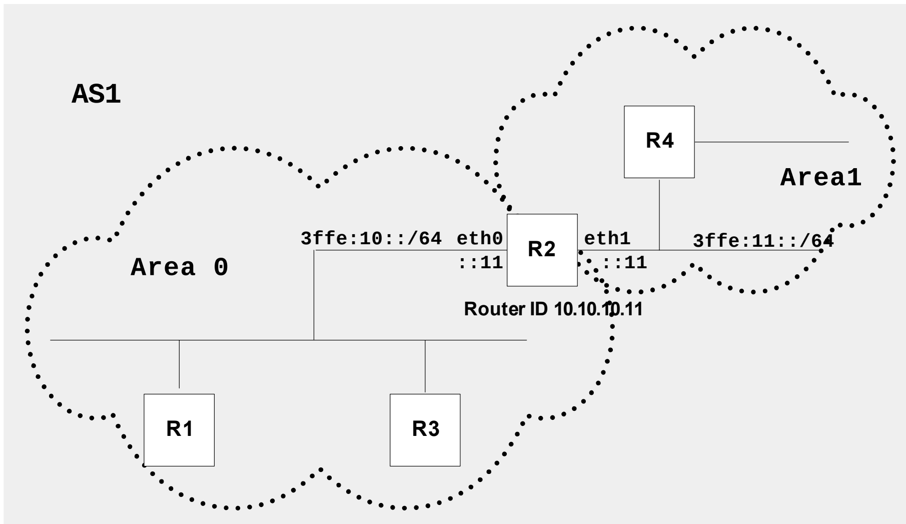
ipv6 ospf priority, ipv6 router ospf area, router-id, router ipv6 ospf

Validation Commands

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospf topology

Configuring an Area Border Router

This example shows configuration for an Area Border Router. Here, R2 is an Area Border Router (ABR). On R2, interface eth0 is in Area 0 and interface eth1 is in Area 1.



R2

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.11	Specify a Router ID (10.10.10.11) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 1	Enable OSPFv3 routing on the other interface and assign the other Area ID (1).

Names of Commands Used

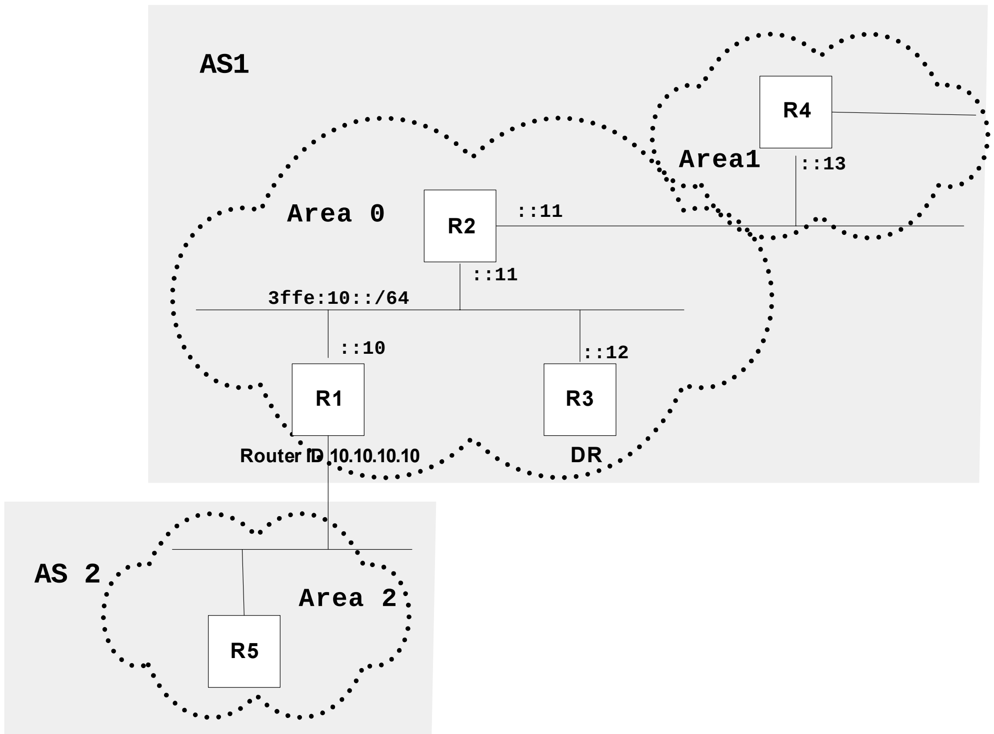
ipv6 router ospf area, router-id, router ipv6 ospf

Validation Commands

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospf topology, show ipv6 route, show ipv6 ospf route

Redistributing routes into OSPFv3

In this example the configuration causes BGP routes to be imported into the OSPF routing table and advertised as `Type 5` External LSAs into `Area 0`.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.10	Specify a Router ID (`10.10.10.10`) for the OSPFv3 routing process.
ZebOS(config-router)# redistribute bgp	Specify redistributing routes from other routing protocol (BGP) into OSPFv3.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (`0`).

Names of Commands Used

redistribute, ipv6 router ospf area, router-id, router ipv6 ospf

Validation Commands

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospf topology, show ipv6 ospf route, show ipv6 route

Configure Cost

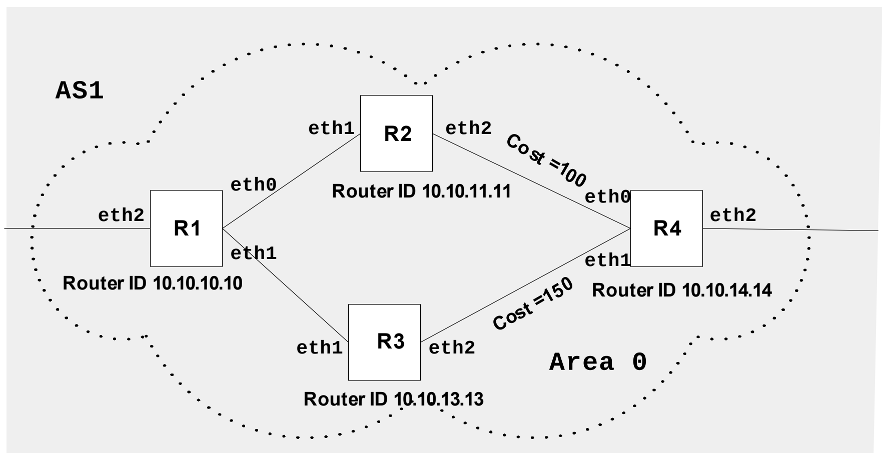
Make a route the preferred route by changing its cost. In this example, cost has been configured to make R3 the next hop for R1.

The default cost on each interface is 10. Interface eth2 on R2 has a cost of 100 and Interface eth2 on R3 has a cost of 150. The total cost to reach 10.10.14.0/24 (R4) through R2 and R3:

R2: 10+100 = 110

R3: 10+150 = 160

In this topology, R1 chooses R2 as its next hop for destination 10.10.14.0/24.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.10.10	Specify a Router ID (10.10.10.10) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).

R2

ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.11.11	Specify a Router ID (10.10.11.11) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# ipv6 ospf cost 100	Set the cost of link-state metric (on eth2) to 100

R3

ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.13.13	Specify a Router ID (10.10.13.13) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# ipv6 ospf cost 150	Set the cost of link-state metric to 150.

R4

ZebOS(config)# router ipv6 ospf	Create an OSPFv3 routing instance.
ZebOS(config-router)# router-id 10.10.14.14	Specify a Router ID (10.10.14.14) for the OSPFv3 routing process.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router ospf area 0	Enable OSPFv3 routing on an interface and assign the Area ID (0).

Names of Commands Used

ipv6 ospf cost, ipv6 router ospf area, router-id, router ipv6 ospf

Validation Commands

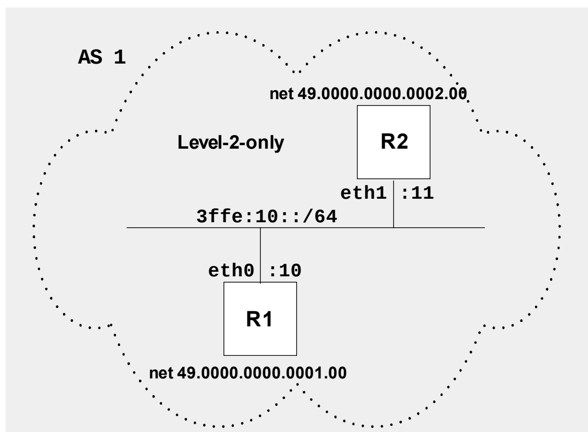
show ipv6 ospf neighbor, show ipv6 ospf topology, show ipv6 ospf database, show ipv6 ospf route, show ipv6 route

CHAPTER 12 IS-IS (IPv6) Configuration

This chapter contains basic IS-IS (IPv6) configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *IS-IS Command Reference*. To avoid repetition, some Common commands, like `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Enabling IS-IS on an interface

This example shows the minimum configuration required for enabling IS-IS on an interface. R1 and R2 are two routers in `ipi` instance connecting to the network `3ffe:10::/64`. After enabling IS-IS on an interface, create a routing instance and specify the Network Entity Title (NET). IS-IS explicitly specifies a NET to begin routing. NET is comprised of the area address and the system ID of the router.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 `(ipi).`
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Configure instance `ipi` as `Level-2-only` routing.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 `(ipi).`

ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Configure instance `ipi` as `Level-2-only` routing.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

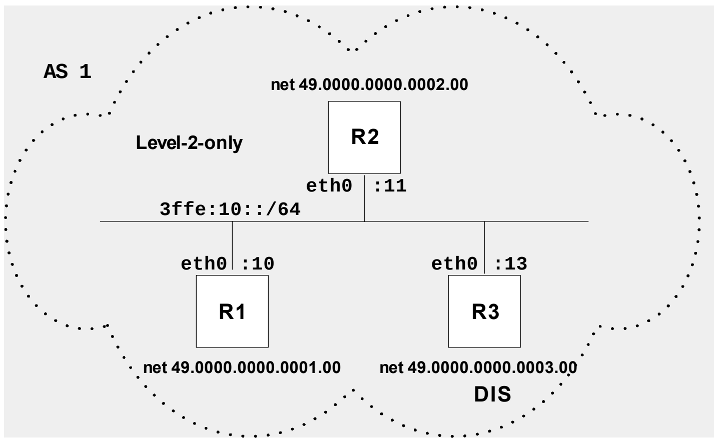
ipv6 router isis, net, router isis

Validation Commands

show clns neighbors, show isis database, show ipv6 isis topology

Setting priority

This example shows the configuration for setting the priority for an interface. Set a high priority for a router to make it the Designated IS (DIS). Router R3 is configured to have a priority of 70; this is higher than the default priority (default priority is 60) of R1 and R2. This makes R3 the DIS.



R3

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# isis priority 70	Specify the router priority to a higher priority (70) to make R3 the designated IS (DIS).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R1

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0000.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

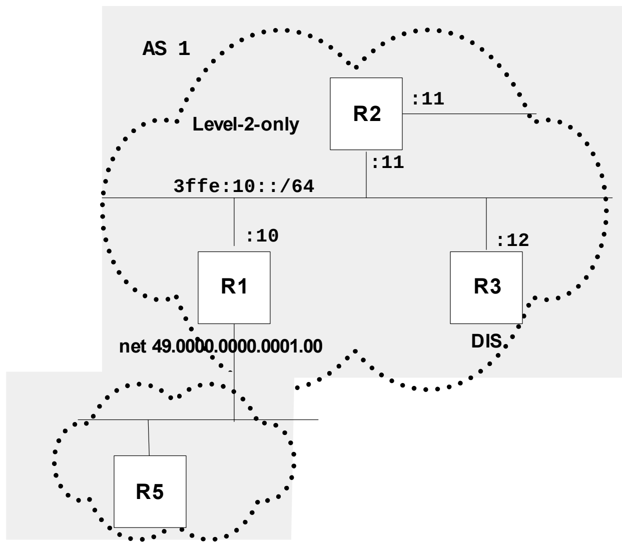
ipv6 router isis, net, router isis, isis priority

Validation Commands

show clns neighbors, show isis database, show ipv6 isis topology

Redistributing routes into IS-IS

In this example the configuration causes BGP routes to be imported into the IS-IS routing table and advertised into the `ipi` instance.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (`ipi`).
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (`ipi`).
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (`ipi`) as `Level-2-only`.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# address-family ipv6	Enter `address-family` mode.
ZebOS(config-router-af)# redistribute bgp	Specify redistributing routes from other routing protocol (BGP) into IS-IS.

Names of Commands Used

ipv6 router isis, redistribute, is-type, router isis, address-family

Validation Commands

show clns neighbors, show isis database, show ipv6 isis topology, show ipv6 isis route, show ipv6 route

Configuring Metric

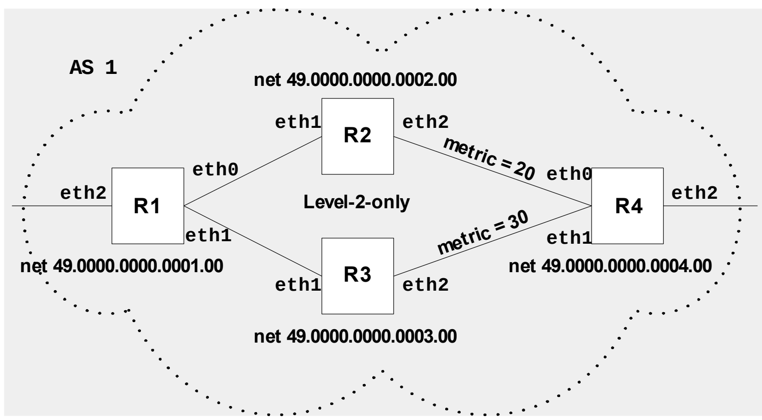
Make a route the preferred route by changing its metric. In this example, cost has been configured to make R3 the next hop for R1.

The default metric on each interface is 10. Interface eth2 on R2 has a metric of 20 and Interface eth2 on R3 has a metric of 30. The total cost to reach 3ffe:10::/64 (R4) through R2 and R3:

R2: 10+20 = 30

R3: 10+30 = 40

In this topology, R1 chooses R2 as its next hop for destination 10.10.14.0/24.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# isis metric 20	Set the value of IS-IS metric (on eth2) to 20.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth2	Specify the interface (eth2) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# isis metric 30	Set the value of IS-IS metric (on eth2) to 30.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1) to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis ipi	Enable IS-IS routing on an interface for area 49 (ipi).
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis ipi	Create an IS-IS routing instance for area 49 (ipi).
ZebOS(config-router)# is-type level-2-only	Configure instance ipi as Level-2-only routing.
ZebOS(config-router)# net 49.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

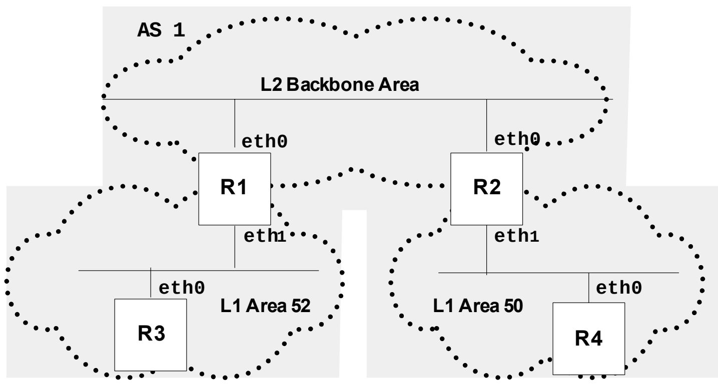
ipv6 router isis, net, isis metric, router isis

Validation Commands

show clns neighbors, show isis database, show ipv6 isis topology, show ipv6 isis route, show ipv6 route

L1 L2 Area Routing with Single Instance

IS-IS supports a two-level hierarchy for handling and scaling the functionality of large networks. The Level-1 (L1) area is mainly for `Leaf` networks and the Level-2 (L2) area is the backbone area connecting Level-1 areas. In this example, R3 and R4 are configured as Level-1 routers and sit in the Level-1 area. R1 and R2 are configured as Level-1-2 routers and connect these two Level-1 areas with a backbone Level-2 area. You can configure Level-1-2 routers with single or multiple instances. This configuration shows the single instance version of the Level-1-2 router.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface `eth0` for area `abc.`
ZebOS(config-if)# isis circuit-type level-2-only	Set the circuit type for the interface `eth0`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# interface eth1	Specify the interface (`eth1`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface `eth1` for area `abc.`
ZebOS(config-if)# isis circuit-type level-1	Set the circuit type for the interface `eth1`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis abc	Create an IS-IS routing instance for area `abc`.
ZebOS(config-router)# net 52.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis bb	Enable IS-IS routing on the interface `eth0` for area `bb.`
ZebOS(config-if)# isis circuit-type level-2-only	Set the circuit type for the interface `eth0`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.

ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis bb	Enable IS-IS routing on the interface eth1 for area bb.
ZebOS(config-if)# isis circuit-type level-1	Set the circuit type for the interface eth1.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis bb	Create an IS-IS routing instance for area bb.
ZebOS(config-router)# net 50.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis xyz	Enable IS-IS routing on the interface eth0 for area xyz.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis xyz	Create an IS-IS routing instance for area xyz.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (xyz) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis aa	Enable IS-IS routing on the interface eth0 for area aa.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis aa	Create an IS-IS routing instance for area aa.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (aa) as Level-1.
ZebOS(config-router)# net 50.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

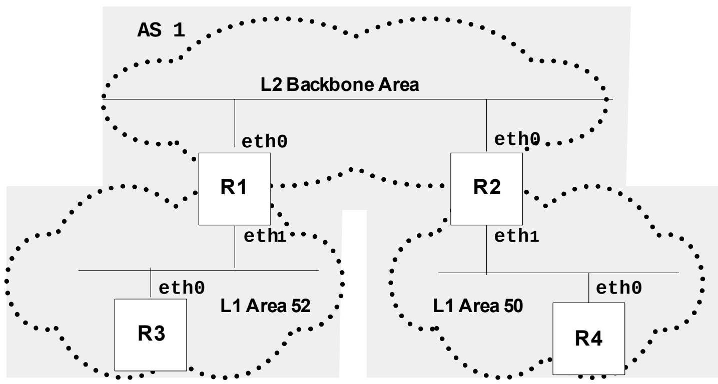
Names of Commands Used

isis circuit-type, is-type, ipv6 router isis, net

Validation Commands

L1 L2 Area Routing with Multiple Instances

IS-IS supports a two-level hierarchy for handling and scaling the functionality of large networks. The Level-1 (L1) area is mainly for `Leaf` networks and the Level-2 (L2) area is the backbone area connecting Level-1 areas. In this example, R3 and R4 are configured as Level-1 routers and sit in the Level-1 area. R1 and R2 are configured as Level-1-2 routers and connect these two Level-1 areas with a backbone Level-2 area. You can configure Level-1-2 routers with single or multiple instances. This configuration shows the multiple instance version of the Level-1-2 router.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis aaa	Enable IS-IS routing on the interface `eth0` for area `aaa`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis aaa	Create an IS-IS routing instance for area `aaa`.
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (`aaa`) as `Level-2-only`.
ZebOS(config-router)# net bb.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# exit	Exit `Router` mode and return to `Configure` mode.
ZebOS(config)# interface eth1	Specify the interface (`eth1`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis ccc	Enable IS-IS routing on the interface `eth1` for area `ccc`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.
ZebOS(config)# router isis ccc	Create an IS-IS routing instance for area `ccc`.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (`ccc`) as `Level-1`.
ZebOS(config-router)# net 52.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R2

ZebOS(config)# interface eth0	Specify the interface (`eth0`)to be configured and enter the `Interface` mode.
ZebOS(config-if)# ipv6 router isis bb	Enable IS-IS routing on the interface `eth0` for area `bb`.
ZebOS(config-if)# exit	Exit `Interface` mode and return to `Configure` mode.

ZebOS(config)# router isis bb	Create an IS-IS routing instance for area bb.
ZebOS(config-router)# is-type level-2-only	Establish the IS level for this area (bb) as Level-2-only.
ZebOS(config-router)# net bb.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
ZebOS(config-router)# exit	Exit Router mode and return to Configure mode.
ZebOS(config)# interface eth1	Specify the interface (eth1)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface eth1 for area abc.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis abc	Create an IS-IS routing instance for area abc.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (abc) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0001.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis xyz	Enable IS-IS routing on the interface eth0 for area xyz.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis xyz	Create an IS-IS routing instance for area xyz.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (xyz) as Level-1.
ZebOS(config-router)# net 52.0000.0000.0003.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R4

ZebOS(config)# interface eth0	Specify the interface (eth0)to be configured and enter the Interface mode.
ZebOS(config-if)# ipv6 router isis aa	Enable IS-IS routing on the interface eth0 for area aa.
ZebOS(config-if)# exit	Exit Interface mode and return to Configure mode.
ZebOS(config)# router isis aa	Create an IS-IS routing instance for area aa.
ZebOS(config-router)# is-type level-1	Establish the IS level for this area (aa) as Level-1.
ZebOS(config-router)# net 50.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Names of Commands Used

isis circuit-type, is-type, ipv6 router isis, net

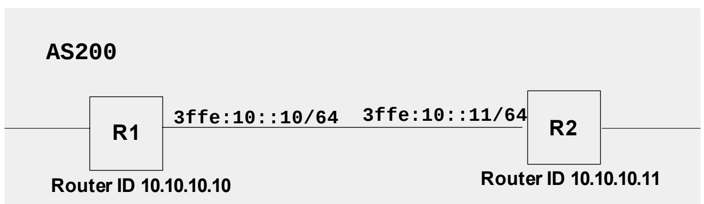
Validation Commands

CHAPTER 13 BGP4+ Configuration

This chapter contains basic BGP4+ configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *BGP Command Reference*. To avoid repetition, some Common commands, such as `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Enabling iBGP Peering (using global address)

This example shows the minimum configuration required to enable BGP on an interface. R1 and R2 are two routers belonging to the same Autonomous System, AS200, connecting to network `3ffe:10::/64`. First, define the routing process and the AS number to which the routers belong. Configure a fixed Router ID and then, define BGP neighbors to start exchanging routing updates.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R1.
ZebOS(config-router)# bgp router-id 10.10.10.10	Configure a fixed Router ID (`10.10.10.10`) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::11 remote-as 200	Define BGP neighbor R2 and establish a TCP session by specifying the global IPv6 address (`3ffe:10::11`) and the AS number(`200`)of neighbor R2.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::11 activate	Activate the neighbor R2(`3ffe:10::11`) and enable exchange of IPv6 address prefix types with this neighbor.

R2

ZebOS(config)# router bgp 200	Define the routing process. The number `200` specifies the AS number of R2.
ZebOS(config-router)# bgp router-id 10.10.10.11	Configure a fixed Router ID (`10.10.10.11`) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::10 remote-as 200	Define BGP neighbor (R1) and establish a TCP session by specifying the global IPv6 address (`3ffe:10::10`)and the AS number(`200`)of neighbor R1.

ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::10 activate	Activate the neighbor R1(3ffe:10::10) and enable exchange of IPv6 address prefix types with this neighbor.

Names of Commands Used

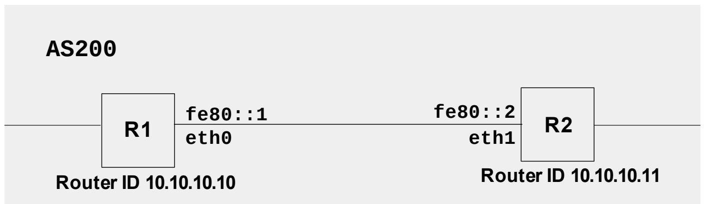
router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors

Enabling iBGP peering (using link-local address)

This example shows the minimum configuration required to enable BGP on an interface. R1 and R2 are two routers belonging to the same Autonomous System, AS200, connecting to network fe80::/10. First, define the routing process and the AS number to which the routers belong. Configure a fixed Router ID for BGP4+ routing process and then, define BGP neighbors to start exchanging routing updates.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router bgp 200	Define the routing process. The number 200 specifies the AS number of R1.
ZebOS(config-router)# bgp router-id 10.10.10.10	Configure a fixed Router ID (10.10.10.10) for the BGP4+ routing process.
ZebOS(config-router)# neighbor fe80::2 remote-as 200	Define BGP neighbor (R2) and establish a TCP session by specifying the link-local address (fe80::2)and the AS number(200)of neighbor R2.
ZebOS(config-router)# neighbor fe80::2 interface eth0	To specify a link-local neighbor, configure the interface name of the neighbor fe80::2.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor fe80::2 activate	Activate the neighbor R2(fe80::2) and enable exchange of IPv6 address prefix types with this neighbor.

R2

ZebOS(config)# router bgp 200	Define the routing process. The number 200 specifies the AS number of R2.
ZebOS(config-router)# bgp router-id 10.10.10.11	Configure a fixed Router ID (10.10.10.11) for the BGP4+ routing process.
ZebOS(config-router)# neighbor fe80::1 remote-as 200	Define BGP neighbor (R1) and establish a TCP session by specifying the link-local address R1(fe80::1) and the AS number(200)of neighbor R1.
ZebOS(config-router)# neighbor fe80::1 interface eth1	To specify a link-local neighbor, configure the interface name of the neighbor fe80::1.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor fe80::1 activate	Activate the neighbor R1(fe80:1) and enable exchange of IPv6 address prefix types with this neighbor.

Names of Commands Used

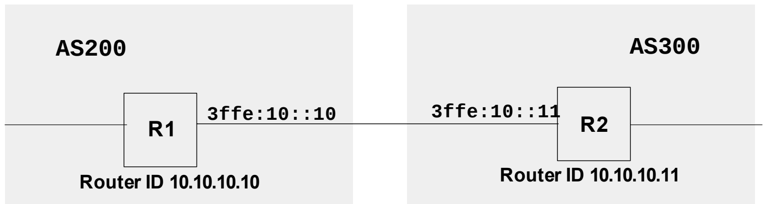
router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors

Enabling eBGP Peering (routers in different ASs)

This example shows the minimum configuration required to enable BGP on an interface when the routers belong to different Autonomous Systems. R1 and R2 are two routers in different Autonomous Systems, AS200 and AS300 connecting to network 3ffe:10::/64.



R1

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# router bgp 200	Define the routing process. The number 200 specifies the AS number of R1.
ZebOS(config-router)# bgp router-id 10.10.10.10	Configure a fixed Router ID (10.10.10.10) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::11 remote-as 300	Define BGP neighbor (R2) and establish a TCP session by specifying the IPv6 address (3ffe:10::11) and the AS number(300)of neighbor R2.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::11 activate	Activate the neighbor R2(3ffe:10::11) and enable exchange of IPv6 address prefix types with this neighbor.

R2

ZebOS(config)# router bgp 300	Define the routing process. The number 300 specifies the AS number of R2.
ZebOS(config-router)# bgp router-id 10.10.10.11	Configure a fixed Router ID (10.10.10.11) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::10 remote-as 200	Define BGP neighbor (R1) and establish a TCP session by specifying the IPv6 address (3ffe:10::10) and the AS number(200)of neighbor R1.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::10 activate	Activate the neighbor R1(3ffe:10::10) and enable exchange of IPv6 address prefix types with this neighbor.

Names of Commands Used

router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors

Route-Map

Use route-maps to filter incoming updates from a BGP peer. In this example, a prefix-list `ipi` on R1 is configured to deny entry of any routes with the IP address `3ffe:12::/32`. To test the filter, R2 is configured to generate network prefixes `3ffe:11::/48` and `3ffe:12::/48`. To verify, use the `show ipv6 bgp` command on R1; it displays R1 receiving `3ffe:11::/48` network prefix only.

R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# ipv6 prefix-list ipi seq 5 deny 3ffe:12::/32 ge 48 le 64 **ZebOS(config)#** ipv6 prefix-list ipi seq 10 permit any	Create an entry in the prefix-list. `ipi` is the name of the map that is created. `5` and `10` specify the sequence number or position of this specific route map. `deny` specifies the packets are to be rejected. `permit` specifies the packets are to be allowed. `48` and `64` are the minimum and maximum prefix lengths, respectively, to be matched.
ZebOS(config)# route-map ipi permit 1	Enter the `Route-map` mode.
ZebOS(config-route-map)# match ipv6 address prefix-list ipi	Set the match criteria. In this case, if the route-map name matches `ipi`, the packets from the first sequence will be denied.
ZebOS(config-route-map)# exit	Exit `Route-map` mode and return to `Configure` mode.
ZebOS(config)# router bgp 10	Define the routing process. The number `10` specifies the AS number of R1.
ZebOS(config-router)# bgp router-id 192.168.10.10	Configure a fixed Router ID (`192.168.10.10`) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10:11 remote-as 11	Define BGP neighbor (R2) and establish a TCP session by specifying the IPv6 address (`3ffe:10::11`)and the AS number(`11`)of neighbor R2.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::11 route-map ipi in	Apply a route-map `ipi` to all incoming routes.
ZebOS(config-router-af)# neighbor 3ffe:10::11 activate	Activate the neighbor R2(`3ffe:10::11`) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# exit-address-family	Exit `Address Family` mode and return to the `Router` mode.
ZebOS(config-router)# exit	Exit the `Router` mode and return to `Configure` mode.

R2

ZebOS(config)# router bgp 11	Define the routing process. The number 11 specifies the AS number of R2.
ZebOS(config-router)# bgp router-id 192.168.10.11	Configure a fixed Router ID (192.168.10.11) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::10 remote-as 10	Define BGP neighbor (R1) and establish a TCP session by specifying the IPv6 address (3ffe:10::10)and the AS number(10)of neighbor R1.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# network 3ffe:11::/48	Announce the IPv6 network prefix (3ffe:11::/48).
ZebOS(config-router-af)# network 3ffe:12::/48	Announce the IPv6 network prefix (3ffe:12::/48).
ZebOS(config-router-af)# neighbor 3ffe:10::10 activate	Activate the neighbor R1(3ffe:10::10) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# exit-address-family	Exit Address Family mode and return to Router mode.

Names of Commands Used

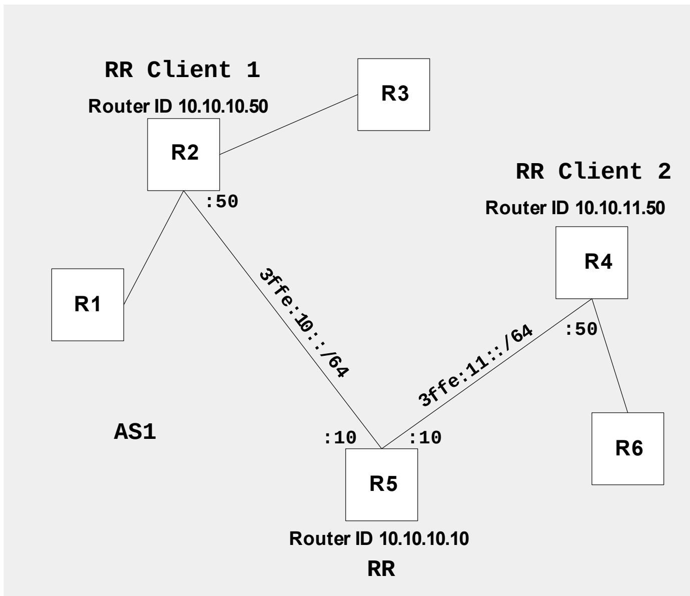
neighbor route-map, ipv6 prefix-list, route-map, match ipv6 address, network and network backdoor, router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors, show ipv6 bgp, show ipv6 bgp prefix-list

Route Reflector

Use Route Reflectors to reduce the iBGP mesh inside an AS. In this example, R2, R5 and R4 would have to maintain a full mesh among themselves but by making R5 the Route Reflector, R2 (Client1) has iBGP session with RR only and not with R4 (Client 2). The routes learned from R2 are advertised to the other clients and to iBGP peers outside the cluster; the iBGP routes learned from iBGP peers outside the cluster are advertised to the R2. This reduces the iBGP peer connections in AS1.



RR (R5)

ZebOS# configure terminal	Enter the `Configure` mode
ZebOS(config)# router bgp 1	Define the routing process. The number `1` specifies the AS number of R5 (RR).
ZebOS(config-router)# bgp router-id 10.10.10.10	Configure a fixed Router ID (`10.10.10.10`) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::50 remote-as 1	Define BGP neighbor (R2) and establish a TCP session by specifying the IPv6 address (`3ffe:10::50`)and the AS number(`1`)of neighbor R2.
ZebOS(config-router)# neighbor 3ffe:11::50 remote-as 1	Define BGP neighbor (R4) and establish a TCP session by specifying the IPv6 address (`3ffe:11::50`)and the AS number(`1`) of neighbor R4.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::50 route-reflector-client	Configure R5 as the Route-Reflector (RR) and neighbor R2 as its client.
ZebOS(config-router-af)# neighbor 3ffe:10::50 activate	Activate the neighbor R2(`3ffe:10::50`) and enable exchange of IPv6 address prefix types with this neighbor.

ZebOS(config-router-af)# neighbor 3ffe:11::50 route-reflector-client	Configure R5 as the Route-Reflector (RR) and neighbor R4 as its client.
ZebOS(config-router-af)# neighbor 3ffe:11::50 activate	Activate the neighbor R4(3ffe:11::50) and enable exchange of IPv6 address prefix types with this neighbor.

RR Client 1 (R2)

ZebOS(config)# router bgp 1	Define the routing process. The number 1 specifies the AS number of R2 (RR Client 1).
ZebOS(config-router)# bgp router-id 10.10.10.50	Configure a fixed Router ID (10.10.10.50) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:10::10 remote-as 1	Define BGP neighbor (R5) and establish a TCP session by specifying the IPv6 address (3ffe:10::10) and the AS number(1) of neighbor R5.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::10 activate	Activate the neighbor (3ffe:10::10) and enable exchange of IPv6 address prefix types with this neighbor.

RR Client 2 (R4)

ZebOS(config)# router bgp 1	Define the routing process. The number 1 specifies the AS number of R4 (RR Client 2).
ZebOS(config-router)# bgp router-id 10.10.11.50	Configure a fixed Router ID (10.10.11.50) for the BGP4+ routing process.
ZebOS(config-router)# neighbor 3ffe:11::10 remote-as 1	Define BGP neighbor (R5) and establish a TCP session by specifying the IPv6 address (3ffe:11::10) and the AS number(1) of the neighbor .
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:11::10 activate	Activate the neighbor (3ffe:11::10) and enable exchange of IPv6 address prefix types with this neighbor.

Names of Commands Used

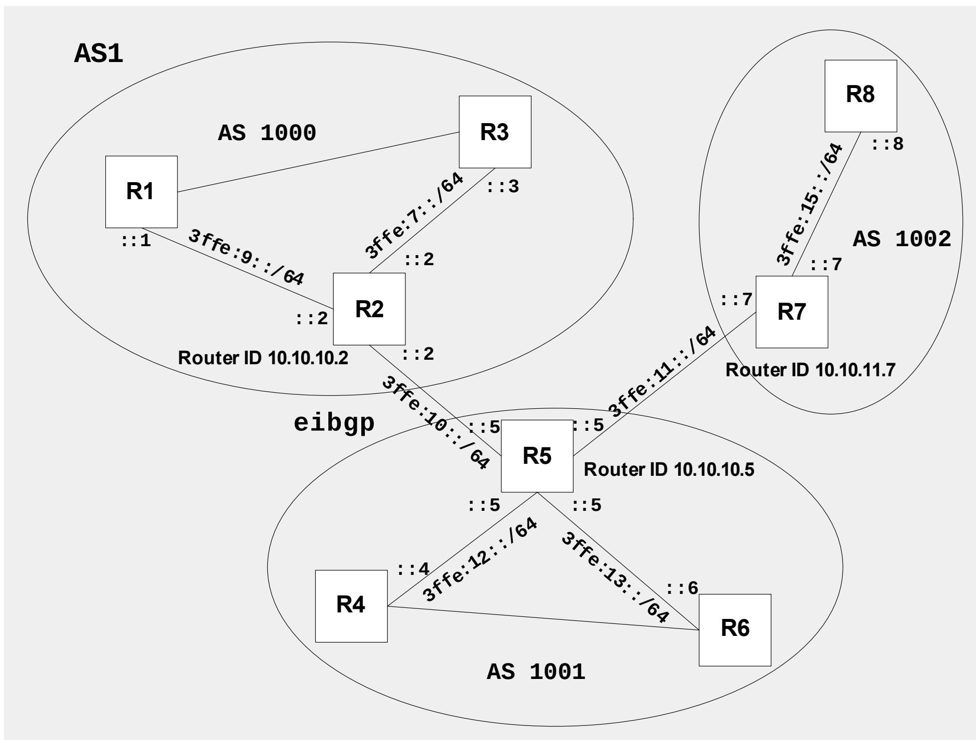
neighbor route-reflector-client, router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors

Confederations

In this example, AS1 contains three Confederation Autonomous Systems--AS 1000, AS 1001 and AS 1002. To any outside AS, the Confederation is a single Autonomous System AS1. Confederation eBGP is run between R2 and R5, and between R5 and R7. R2 is configured so that its local AS is 1000. Its peer connection to R5 is set up like any other eBGP session. The `bgp confederation identifier` command tells the router that it is a member of a Confederation and the Confederation ID. The `bgp confederation peers` command lists the member autonomous system to which R2 is connected. The command tells the BGP process that the eBGP connection is a Confederation eBGP rather than normal eBGP.



R2

ZebOS# configure terminal	Enter the `Configure` mode
ZebOS(config)# router bgp 1000	Define the routing process. The number `1000` specifies the AS number of R2.
ZebOS(config-router)# bgp router-id 10.10.10.2	Configure a fixed Router ID (`10.10.10.2`) for the BGP4+ routing process.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier (1), to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1001 1002	Specify Autonomous Systems `1001` and `1002` as confederation peers making them members of the Confederation.
ZebOS(config-router)# neighbor 3ffe:10::5 remote-as 1001	Define BGP neighbor (R5) and establish a TCP session by specifying the IPv6 address (`3ffe:10::5`) and the AS number(`1001`)of neighbor R5.

ZebOS(config-router)# neighbor 3ffe:9::1 remote-as 1000	Define BGP neighbor (R1) and establish a TCP session by specifying the IPv6 address (3ffe:9::1) and the AS number(1000)of neighbor R1.
ZebOS(config-router)# neighbor 3ffe:7::3 remote-as 1000	Define BGP neighbor (R3) and establish a TCP session by specifying the IPv6 address (3ffe:7::3)and the AS number(1000)of neighbor R3.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::5 activate	Activate neighbor R5(3ffe:10::5) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:9::1 activate	Activate neighbor R1(3ffe:9::1) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:7::3 activate	Activate neighbor R3(3ffe:7::3) and enable exchange of IPv6 address prefix types with this neighbor.

R5

ZebOS(config)# router bgp 1001	Define the routing process. The number 1001 specifies the AS number of R5.
ZebOS(config-router)# bgp router-id 10.10.10.5	Configure a fixed Router ID (10.10.10.5) for the BGP4+ routing process.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier (1), to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1000 1002	Specify Autonomous Systems 1001 and 1002 as confederation peers making them members of the Confederation.
ZebOS(config-router)# neighbor 3ffe:10::2 remote-as 1000	Define BGP neighbor (R2) and establish a TCP session by specifying the IPv6 address (3ffe:10::2)and the AS number(1000)of neighbor R2.
ZebOS(config-router)# neighbor 3ffe:11::7 remote-as 1002	Define BGP neighbor (R7) and establish a TCP session by specifying the IPv6 address (3ffe:11::7)and the AS number(1002)of neighbor R7.
ZebOS(config-router)# neighbor 3ffe:12::4 remote-as 1001	Define BGP neighbor (R4) and establish a TCP session by specifying the IPv6 address (3ffe:12::4)and the AS number(1001)of neighbor R4.
ZebOS(config-router)# neighbor 3ffe:13::6 remote-as 1001	Define BGP neighbor (R6) and establish a TCP session by specifying the IPv6 address (3ffe:13::6)and the AS number(1001)of neighbor R6.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:10::2 activate	Activate the neighbor R2(3ffe:10::2) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:11::7 activate	Activate the neighbor R7(3ffe:11::7) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:12::4 activate	Activate the neighbor R4(3ffe:12::4) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:13::6 activate	Activate the neighbor R6(3ffe:13::6) and enable exchange of IPv6 address prefix types with this neighbor.

R7

ZebOS(config)# router bgp 1002	Define the routing process. The number 1002 specifies the AS number of R7.
ZebOS(config-router)# bgp router-id 10.10.11.7	Configure a fixed Router ID (10.10.11.7) for the BGP4+ routing process.
ZebOS(config-router)# bgp confederation identifier 1	Specify BGP Confederation Identifier (1), to others the group will appear as a single AS and the identifier as its AS number.
ZebOS(config-router)# bgp confederation peers 1000 1001	Specify Autonomous Systems 1000 and 1001 as confederation peers making them members of the Confederation.
ZebOS(config-router)# neighbor 3ffe:11::5 remote-as 1001	Define BGP neighbor (R5) and establish a TCP session by specifying the IPv6 address (3ffe:11::5)and the AS number(1001)of neighbor R5.
ZebOS(config-router)# neighbor 3ffe:15::8 remote-as 1002	Define BGP neighbor (R8) and establish a TCP session by specifying the IPv6 address (3ffe:15::8)and the AS number(1002)of neighbor R8.
ZebOS(config-router)# address-family ipv6	Enter the Address Family mode for configuring routing sessions that use IPv6 address prefixes.
ZebOS(config-router-af)# neighbor 3ffe:11::5 activate	Activate the neighbor R5(3ffe:11::5) and enable exchange of IPv6 address prefix types with this neighbor.
ZebOS(config-router-af)# neighbor 3ffe:15::8 activate	Activate the neighbor R8(3ffe:15::8) and enable exchange of IPv6 address prefix types with this neighbor.

Names of Commands Used

bgp confederation identifier, bgp confederation peer, router bgp, bgp router-id, neighbor remote-as, address-family, neighbor activate

Validation Commands

show ipv6 bgp summary, show ipv6 bgp neighbors

CHAPTER 14 PIM-SM Configuration

The Protocol Independent Multicasting-Sparse Mode (PIM-SM) is a multicast routing protocol designed to operate efficiently across Wide Area Networks (WANs) with sparsely distributed groups. It helps network nodes that are geographically dispersed to conserve bandwidth and to reduce traffic by simultaneously delivering a single stream of information to multiple locations.

PIM-SM uses the IP multicast model of receiver-initiated membership, supporting both shared and shortest-path trees and using soft-state mechanisms to adapt to changing network conditions. It relies on a topology-gathering protocol to populate a multicast routing table with routes.

References

The ZebOS PIM-SM module is based on the following IETF draft:

`draft-ietf-pim-sm-v2-new-05`

Terminology

Following is a brief description of some of the terms and concepts used to describe the PIM-SM protocol:

Rendezvous Point (RP)

A Rendezvous Point (RP) router is configured as the root of the non-source-specific distribution tree for a multicast group. Join messages from receivers for a group are sent towards the RP. Data from senders is sent to the RP so that receivers can discover who the senders are, and start to receive traffic destined for the group.

Multicast Routing Information Base (MRIB)

The MRIB is a multicast topology table derived from the unicast routing table. In PIM-SM, the MRIB is used to decide where to send Join/Prune messages. It also provides routing metrics for destination addresses. These metrics are used when sending and processing Assert messages.

Reverse Path Forwarding

Reverse Path Forwarding (RPF) is a concept of an optimized form of flooding, where the router accepts a packet from `SourceA` through Interface `IF1` only if `IF1` is the interface the router would use in order to reach `SourceA`. It determines whether the interface is correct by consulting its unicast routing tables. The packet that arrives through interface `IF1` is forwarded because the routing table lists this interface as the shortest path to the network. The router's unicast routing table determines the shortest path for the multicast packets. Because a router accepts a packet from only one neighbor, it floods the packet only once, meaning that (assuming point-to-point links) each packet is transmitted over each link once in each direction.

Tree Information Base (TIB)

The TIB is the collection of state at a PIM router storing the state of all multicast distribution trees at that router. It is created by receiving Join/Prune messages, Assert messages, and IGMP information from local hosts.

Upstream

Towards the root of the tree. The root of the tree might be either the Source or the RP.

Downstream

Away from the root of the tree. The root of tree might be either the Source or the RP.

Source-Based Trees

In the Source-Based Trees concept, the forwarding paths are based on the shortest unicast path to the source. If the unicast routing metric is `hop counts`, then the branches of the multicast Source-Based Trees are minimum hop. If the metric is `delay`, the branches are minimum delay.

For every multicast source, there is a corresponding multicast tree that directly connects the source to all receivers. All traffic to the members of an associated group passes along the tree made for their source. Source-Based Trees have two entries with a list of outgoing interfaces-- the source address and the multicast group.

Shared Trees

Shared trees or the RP trees (RPT) rely on a central router called the Rendezvous Point (RP) that receives all the traffic from the sources and forwards that traffic to the receivers. All hosts might not be receivers. There is a single tree for each multicast group, regardless of the number of sources. Only the routers on the tree know about the group and information is sent only to interested receivers. With an RP, receivers have a place to join even if no source exists.

The shared tree is unidirectional, and information flows only from the RP to the receivers. If a host other than the RP has to send data on the tree, the data must first be tunneled to the RP and then multicast to the members. This means that even if a receiver is also a source, it can only use the tree to receive packets from the RP and not to send packets to the RP (unless the source is located between the RP and the receivers).

Bootstrap Router (BSR)

When a new multicast sender starts sending data packets or a new receiver starts sending Join message towards the RP for that multicast group, it needs to know the next hop router towards the RP. The BSR provides group-to-RP mapping information to all the PIM routers in a domain allowing them to be able to map to the correct RP address.

Data Flow from Source to Receivers

1. Sending out Hello Messages

PIM routers periodically send Hello messages to discover neighboring PIM routers. Hello messages are multicast using the address 224.0.0.13 (`ALL-PIM-ROUTERS` group).

Routers do not send any acknowledgement that a Hello message was received. A `holdtime` value determines the length of time for which the information is valid. In PIM-SM, a downstream receiver must join a group before traffic is forwarded on the interface.

2. Electing a Designated Router

In a multi-access network with multiple routers connected, one of them is selected to act as a designated router (DR) for a given period of time. The DR is responsible for sending Join/Prune messages to the RP for local members.

3. Determining the RP

PIM-SM uses a BootStrap Router (BSR) to originate Bootstrap messages and to disseminate RP information. The messages are multicast to the group on each link. If the BSR is not apparent, the routers flood the domain with advertisements. The router with the highest priority (if priorities are same then the higher IP address) is selected to be the RP. Routers receive and store Bootstrap messages originated by the BSR. When a Designated Router (DR) gets a membership indication from IGMP for (or a data packet from) a directly connected host, for a group for which it has no entry, the DR maps the group address to one of the candidate RPs that can service that group. The DR then sends a Join/Prune message towards that RP.

In a small domain, the RP can also be configured statically.

4. Joining the Shared Tree

To join a multicast group, a host sends an IGMP message to its upstream router after which the router can begin to accept multicast traffic for that group. The router sends a Join message to its upstream PIM neighbor in the direction of the RP. When a router receives a Join from a downstream router, it checks to see if a state exists for the group in its multicast routing table. If a state already exists, then the Join message has reached the shared tree and the interface from which the message was received is entered in the Outgoing Interface list. If no state exists, an entry is created, the interface is entered in the Outgoing Interface list, and the Join message is again sent towards the RP.

5. Registering with the RP

A DR can begin receiving traffic from a source without having a Source or a Group state for that source. In this case the DR has no information on how to get multicast traffic to the RP through a tree. When the source DR receives the initial multicast packet, it encapsulates it in a Register message and unicasts it to the RP for that group. The RP de-encapsulates each Register message and forwards the extracted data packet to downstream members on the RPT. Once the path is established from the source to the RP, the DR begins sending traffic to the RP as standard IP multicast packets as well as encapsulated within Register messages. The RP temporarily receives packets twice. When the RP detects the normal multicast packets, it sends a Register-Stop message to the source DR, meaning it should stop sending register packets.

6. Sending Register-Stop Messages

When the RP begins receiving traffic from the source, both as Register messages and as unencapsulated IP packets, it sends a Register-Stop message to the DR. This notifies the DR that the traffic is now being received as standard IP multicast packets on the SPT. When the DR receives this message, it stops encapsulating traffic in Register messages.

7. Pruning the Interface

Routers attached to receivers send Prune messages to the RP to disassociate the source from the RP. When an RP receives a Prune message, it no longer forwards traffic from the source indicated in the Prune message. If all members of a multicast group are pruned, the IGMP state of the DR is deleted and the interface is removed from the Source and Group lists of the group.

8. Forwarding Multicast Packets

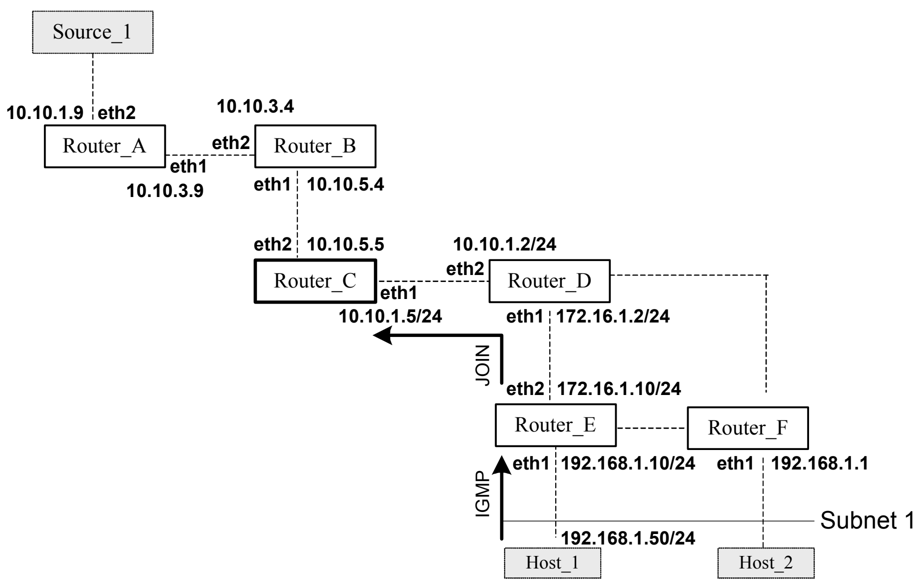
PIM-SM routers forward multicast traffic onto all interfaces that lead to receivers that have explicitly joined a multicast group. Messages are sent to a group address in the local subnetwork and have an Time to Live (TTL) of 1. The router performs a RPF check and forwards the packet. Traffic that arrives on the correct interface is sent onto all outgoing interfaces that lead to downstream receivers if the downstream router has sent a join to this router or is a member of this group.

PIM-SM Configuration

PIM-SM is a soft-state protocol. The main requirement is to enable PIM-SM on desired interfaces and configure the RP information correctly, through static or dynamic methods. All multicast group states are maintained dynamically as the result of IGMP `Report/Leave` and PIM `Join/Prune` messages. Currently, IPI supports only one RP for all multicast groups (224.0.0.0/4).

This section provides PIM-SM configuration examples for two relevant scenarios. The following graphic displays the network topology used in these examples:

Note: For details on the commands used in the following examples refer to the *PIM-SM Command Reference.*



Configuring RP statically

In this example using the above topology, `Router_C` is the Rendezvous Point (RP) and all routers are statically configured with RP information. Host_1 and Host_2 join group 224.0.1.3 for all the sources. They send IGMP membership report to Subnet 1. Two routers are attached to Subnet 1--`Router_E` and `Router_F`, both have default DR priority on `eth1`. The `Router_E` having a higher IP address on the `eth1`, becomes the Designated Router (DR) and is responsible to send Join messages to the RP (`Router_C`). While configuring the RP, make sure that:

- Every router includes the `ip pim rp-address 10.10.1.5` statement even if it does not have any source or group member attached to it.
- There is only one RP address for a group scope in the PIM domain.
- All interfaces running PIM-SM need to have sparse-mode enabled. In the configuration sample below, notice that both `eth1` and `eth2` are `pim sparse-mode` enabled.

Here is a sample configuration at `Router_D`:

```
hostname Router_D
!
interface eth0
!
interface eth1
```

```
 ip pim sparse-mode
!
interface eth2
 ip pim sparse-mode
!
interface lo
!
!
ip multicast-routing
ip pim rp-address 10.10.1.5
!
```

Configure all the routers with the same `ip pim rp-address 10.10.1.5` command as shown above.

Use the following commands to verify the RP configuration, interface details, and the multicast routing table.

RP details

At `Router_D`, the `show ip pim rp-hash` command shows that 10.10.1.5 is the RP for all multicast groups 224.0.0.0/4. All other routers will have a similar output:

```
Router_D# show ip pim rp-hash
Group(s): 224.0.0.0/4
    RP: 10.10.1.5
```

Interface details

The `show ip pim interface` command displays the interface details. This output displays the interface details on `Router_E` and shows that `Router_E` is the Designated Router on `Subnet 1`.

```
Router_E# show ip pim interface
Address          Interface VIFindex Ver/   Nbr    Query  DR     DR
                                    Mode   Count  Intvl  Prior
192.168.1.10      eth1      0       v2/S   1      125    1      192.168.1.10
172.16.1.10       eth2      2       v2/S   1      125    1      172.16.1.10
```

IP multicast routing table

Note the different displays in the Multicast Routing Tables of an RP router and other routers.

1. The `show ip mroute` command displays the IP multicast routing table. In this table:

```
RPF nbr Displays the unicast next-hop to reach RP.
RPF idx Displays the incoming interface for this (*, G) state.
RP Displays the IP address for the RP router
The leading dots .... Stand for VIF index
Router_E# show ip mroute
IP Multicast Routing Table

(*,*,RP) Entries: 0
(*,G) Entries: 1
(S,G) Entries: 0
(S,G,rpt) Entries: 0
(*, 224.0.1.3)
RP: 10.10.1.5
RPF nbr: 172.16.1.2
RPF idx: eth2
```

```
Upstream State: JOINED
 Local     ................................
 Joined    j...............................
 Asserted  ................................
 Outgoing  o...............................
```

At Router_E, eth2 is the incoming interface of the (*, G) entry and eth1 is on the outgoing interface list of the (*, G) entry. This means that there is group member through eth1 and RP is reachable through eth2.

The 0 position on this 32-bit index is for eth1 (as illustrated in the interface display above). The j on the 0 index indicates that the Join has come from eth1.

2. Since Router_C is the RP and the root of this multicast tree, the show ip mroute command on Router_C shows RPF nbr as 0.0.0.0 and RPF idx as none.

```
Router_C# show ip mroute
IP Multicast Routing Table

(*,*,RP) Entries: 0
(*,G) Entries: 1
(S,G) Entries: 0
(S,G,rpt) Entries: 0
(*, 224.0.1.3)
RP: 10.10.1.5
RPF nbr: 0.0.0.0
RPF idx: None
Upstream State: JOINED
 Local     ................................
 Joined    j...............................
 Asserted  ................................
 Outgoing  o...............................
```

Configuring RP dynamically

A static configuration of RP works for a small, stable PIM domain; however, it is not practical for a large and not-so-stable internetwork. In such a network, if the RP fails, the network administrator might have to change the static configurations on all PIM routers. Another reason for choosing dynamic configuration is a higher routing traffic leading to a change in the RP.

We use the BSR mechanism to dynamically maintain the RP information. For configuring RP dynamically in the above scenario, Router_C on eth1 and Router_D on eth1 are configured as Candidate RP using the ip pim rp-candidate command. Router_D on eth1 is also configured as Candidate BSR. Since no other router has been configured as Candidate BSR, the Router_D becomes the BSR router and is responsible for sending group-to-RP mapping information to all other routers in this PIM domain.

The following output displays the complete configuration at Router_C and Router_D:

```
Router_D# show run
!
interface eth0
!
interface eth1
 ip pim sparse-mode
!
interface eth2
 ip pim sparse-mode
!
```

```
interface lo
!
ip multicast-routing
ip pim bsr-candidate eth1
ip pim rp-candidate eth1 2
!

Router_C# show run
interface eth0
!
interface eth1
 ip pim sparse-mode
!
interface eth2
 ip pim sparse-mode
!
interface lo
!
!
ip multicast-routing
ip pim rp-candidate eth1
```

The highest priority router is chosen as the RP. If two or more routers have the same priority, a hash function in the BSR mechanism is used to choose the RP to make sure that all routers in the PIM-domain have the same RP for the same group.

Use the `ip pim rp-candidate IFNAME PRIORITY` command, to change the default priority of any candidate RP. At `Router_D`, the `show ip pim rp-hash` command shows that `Router_C` has been chosen as the RP.

PIM group-to-RP mappings

Use the `show ip pim rp mapping` command to display the group-to-RP mapping details. The output displays information about RP candidates. There are two RP candidates for the group range 224.0.0.0/4. RP Candidate 10.10.1.5 has a default priority of 192, whereas, RP Candidate 172.16.1.2 has been configured to have a priority of 2. Since RP candidate 172.16.1.2 has a higher priority, it is selected as RP for the multicast group 224.0.0.0/4.

```
ZebOS# show ip pim rp mapping
This system is the Bootstrap Router (v2)
Group(s): 224.0.0.0/4
  RP: 10.10.1.5
    Info source: 172.16.1.2, via bootstrap, priority 192
         Uptime: 00:00:13, expires: 00:02:29
  RP: 172.16.1.2
    Info source: 172.16.1.2, via bootstrap, priority 2
         Uptime: 00:34:42, expires: 00:01:49
```

RP details

To display information about the RP router, use the following command. This output displays that 172.16.1.2 has been chosen as the RP for the multicast group 224.0.0.0/24.

```
Router_D# show ip pim rp-hash
Group(s): 224.0.0.0/4
    RP: 172.16.1.2
    Info source: 172.16.1.2, via bootstrap
```

After RP information reaches all PIM routers in the domain, various state machines maintain all routing states as the result of Join/Prune from group membership. To display information on interface details and the multicast routing table, refer to the *Configuring RP Statically* section above.

CHAPTER 15 VRRP Configuration

This chapter provides an overview of Virtual Router Redundancy Protocol (VRRP) and its implementation with ZebOS.

VRRP eliminates the risk of a single point of failure inherent in a static default routing environment. It specifies an election protocol that dynamically assigns responsibility for a virtual router to one of the VRRP routers on a LAN. One of the major advantages of VRRP is that it makes default path available without requiring configuration of dynamic routing on every end-host.

Reference

The ZebOS VRRP module is based on:

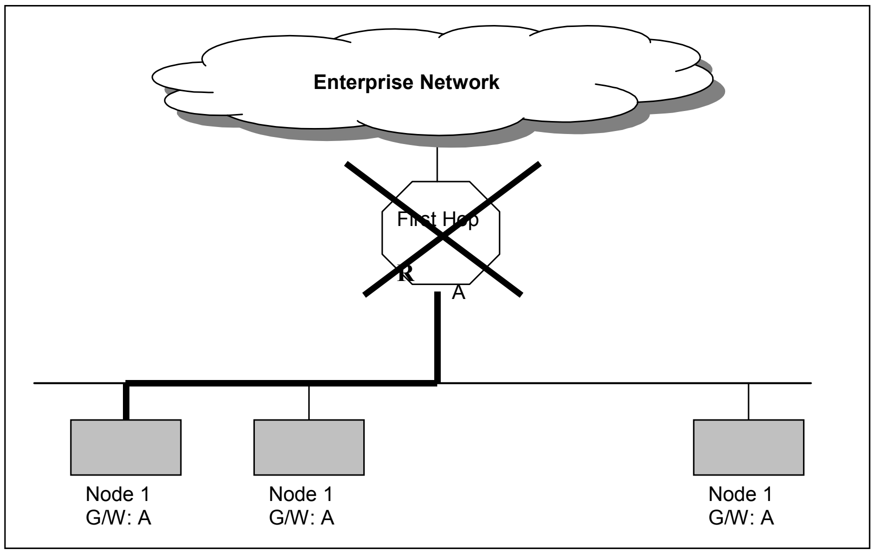
RFC 2338 (VRRP) Knight, S., et.al "Virtual Router Redundancy Protocol (VRRP)".

Terminology

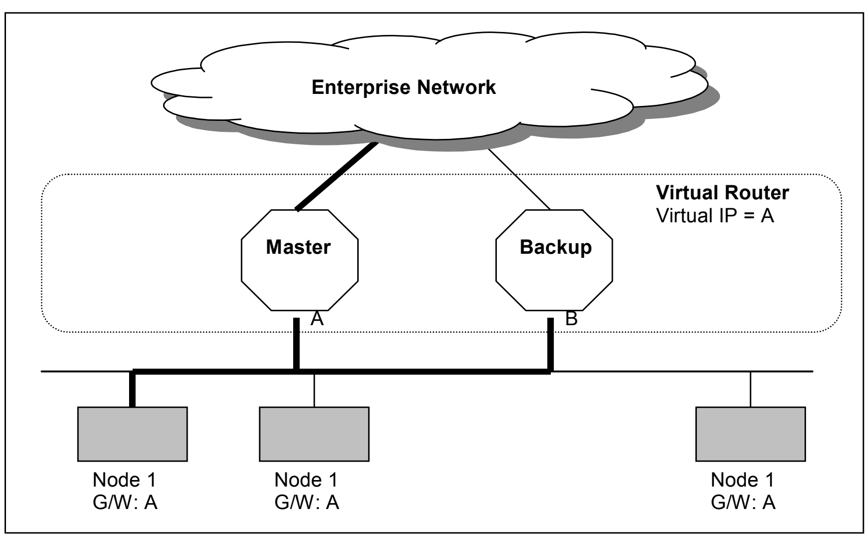
Backup Router	The VRRP router that is backing up an IP address. It assumes forwarding responsibility for the virtual IP address if the Master fails.
Critical IP	The IP address that a VRRP router sends/receives messages on for a particular session.
IP Address Owner	The VRRP Router that has the virtual router's IP address(es) as real interface address(es). This is the router that, when up, will respond to packets addressed to one of these IPaddresses for ICMP pings, TCP connections, etc.
Master Router	The VRRP router that owns the IP address (i.e., is being backed up), and which is the default router for forwarding for that IP address.
Virtual IP	The IP address that is being backed up by a VRRP session.
Virtual Router	A router managed by VRRP that acts as a default router for hosts on a shared LAN. It consists of a Virtual Router Identifier and a set of associated IP addresses across a common LAN. A VRRP Router might backup one or more virtual routers.
VRRP Router	A router running the Virtual Router Redundancy Protocol. It might participate in one or more virtual routers.

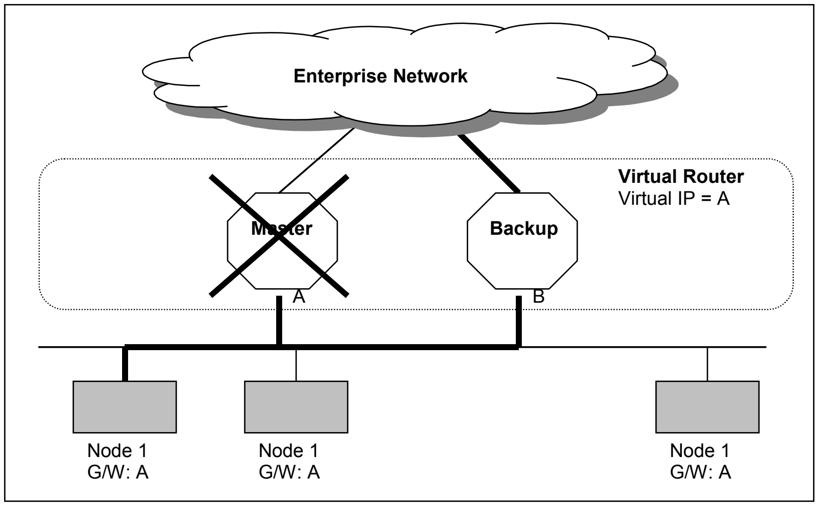
VRRP Process

Typically, end hosts are connected to the enterprise network through a single router (first hop router) that is in the same Local Area Network (LAN) segment. The most popular method of configuration is for the end hosts to statically configure this router as their default gateway. This minimizes configuration and processing overhead. The main problem with this configuration method is that it produces a single point of failure if this first hop router fails.



The Virtual Router Redundancy Protocol attempts to solve this problem by introducing the concept of a virtual router, composed of two or more VRRP routers on the same subnet. The concept of a virtual IP address is also introduced, which is the address that end hosts configure as their default gateway. Only one of the routers (called the Master) forwards packets on behalf of this IP address. In the event that the Master router fails, one of the other routers (Backup) assumes forwarding responsibility for it .





At first glance, the configuration outlined in might not seem very useful, as it doubles the cost and leaves one router idle at all times. This, however, can be avoided by creating two virtual routers and splitting the traffic between them.

Limitations

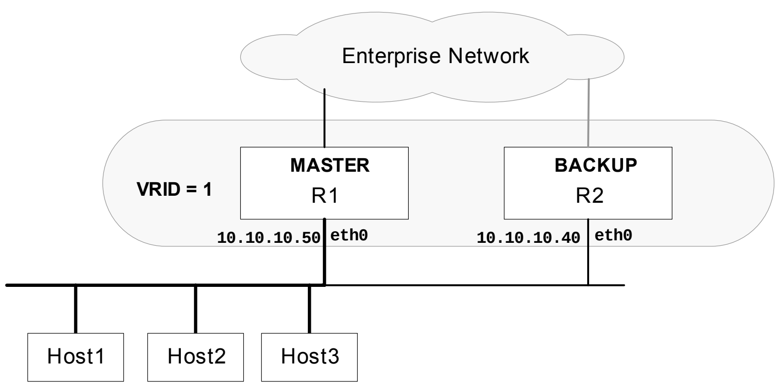
- The VRRP RFC specifies that the `master-down-timer` is a fraction that is always <1. The Linux operating system supports only timers that are multiples of 1 second. This might result in increasing the length of time the system takes in stabilizing the master, after master fails in the network with multiple backups.
- MD5 authentication is not yet supported for ZebOS VRRP.

VRRP Configuration

This section contains basic VRRP configuration examples. To see details on the commands used in these examples, or to see the outputs of the Validation commands, refer to the *VRRP Command Reference*. To avoid repetition, some Common commands, such as `configure terminal`, have not been listed under the *Commands Used* section. The *NSM Command Reference* explains these Common Commands.

Configuring VRRP (one Virtual Router)

In this configuration the end-hosts install a default route to the IP address of virtual router 1(VRID = 1) and both routers R1 and R2 run VRRP. R1 is configured to be the Master for virtual router 1 (VRID = 1) and R2 as a Backup for virtual router 1. If R1 fails, R2 will take over virtual router 1 and its IP addresses, and provide uninterrupted service for the hosts. Configuring only one virtual router, doubles the cost and leaves R2 idle at all times.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# vrrp create 1	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 1 10.10.10.50 master	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 1 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 1 255	Configure the priority to 255 as R1 is the master router. The priority value for the VRRP router that owns the IP address(es) associated with the virtual router must be 255. VRRP routers backing up a virtual router must use priority values between 1-254.
ZebOS(config)# vrrp preempt 1 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 1 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 1	Enable the VRRP session on the router.

R2

ZebOS# configure terminal	Enter the Configure mode.
ZebOS(config)# vrrp create 1	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 1 10.10.10.50 backup	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 1 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 1 200	Configure the priority to 200 (less than 255) as R2 is the Backup router.
ZebOS(config)# vrrp preempt 1 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 1 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 1	Enable the VRRP session on the router.

Names of Commands Used

vrrp create, vrrp virtualip, vrrp interface, vrrp priority, vrrp preempt, vrrp advtint, vrrp enable

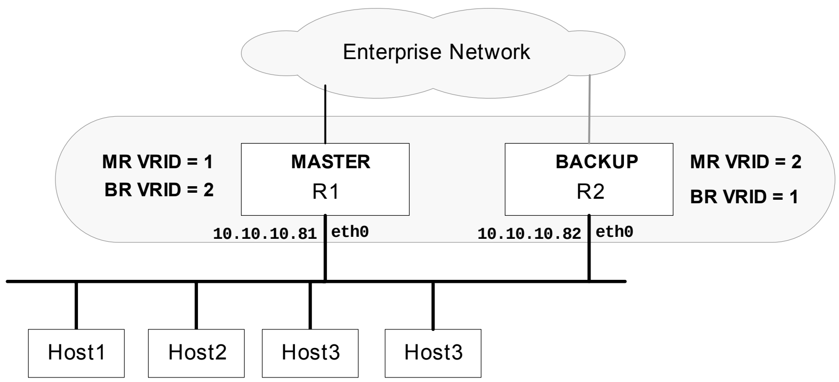
Validation Commands

show vrrp

Configuring VRRP (two Virtual Routers)

In the one virtual router example earlier, R2 is not backed up by R1. This example illustrates how to backup R2 by configuring a second virtual router.

In this configuration, R1 and R2 are two virtual routers and the hosts split their traffic between R1 and R2. R1and R2 function as backups for each other.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# vrrp create 1	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 1 10.10.10.81 master	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 1 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 1 255	Configure the priority to 255 as R1 is the master router. The priority value for the VRRP router that owns the IP address(es) associated with the virtual router must be 255. VRRP routers backing up a virtual router must use priority values between 1-254.
ZebOS(config)# vrrp preempt 1 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 1 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 1	Enable the VRRP session 1 on the router.
ZebOS(config)# vrrp create 2	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 2 10.10.10.82 backup	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 2 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 2 200	Configure the priority to 200 (less than 255) as R2 is the Backup router.

ZebOS(config)# vrrp preempt 2 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 2 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 2	Enable the VRRP session 2 on the router.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# vrrp create 1	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 1 10.10.10.81 backup	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 1 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 1 200	Configure the priority to 200 (less than 255) as R2 is the Backup router.
ZebOS(config)# vrrp preempt 1 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 1 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 1	Enable the VRRP session 1 on the router.
ZebOS(config)# vrrp create 1	Create a new VRRP session on the router and specify the VRID for the session.
ZebOS(config)# vrrp virtualip 2 10.10.10.82 master	Set the virtual IP address for the VRRP session. Define the default state (master or backup) of the VRRP router within the virtual router.
ZebOS(config)# vrrp interface 2 eth0	Specify the physical interface that will participate in virtual routing.
ZebOS(config)# vrrp priority 2 255	Configure the priority to 255 as R1 is the master router. The priority value for the VRRP router that owns the IP address(es) associated with the virtual router must be 255. VRRP routers backing up a virtual router must use priority values between 1-254.
ZebOS(config)# vrrp preempt 2 true	Set the preempt mode to specify that the highest priority will function as a backup to master when master is unavailable.
ZebOS(config)# vrrp advtint 2 5	Configure the advertisement interval to 5 seconds.
ZebOS(config)# vrrp enable 2	Enable the VRRP session 2 on the router.

Names of Commands Used

vrrp create, vrrp virtualip, vrrp interface, vrrp priority, vrrp preempt, vrrp advtint, vrrp enable

Validation Commands

show vrrp

Outputs

The following outputs on R1and R2 display the complete configuration for each session on R1 and R2. In session one R1 is the master router and in session 2 R2 is the master router.

```
R1#  show vrrp 1
----------Configuration----------
```

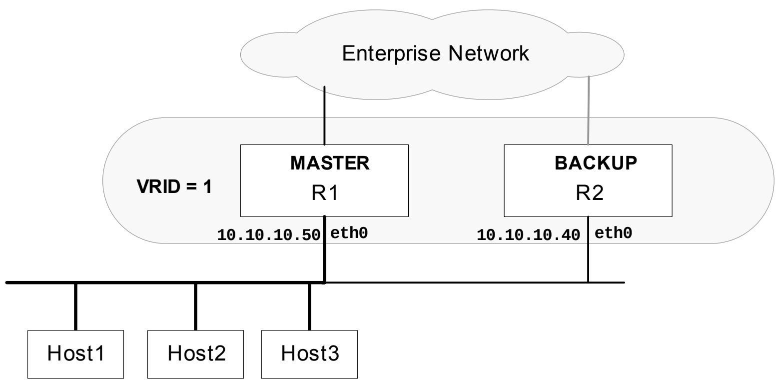
```
  VRID:           1
  state:       MASTER
  Virtual IP:       10.10.10.81
  IP Owner:       YES
  VR Interface:       eth2
  Priority:       255
  Advt Interval:   1 sec
  Preempt Mode:       TRUE
---------------------------------
R1# show vrrp 2
----------Configuration----------
  VRID:           2
  state:       BACKUP
  Virtual IP:       10.10.10.82
  IP Owner:       NO
  VR Interface:       eth2
  Priority:       200
  Advt Interval:   1 sec
  Preempt Mode:       TRUE
---------------------------------
R2# show vrrp 1
----------Configuration----------
  VRID:           1
  state:       BACKUP
  Virtual IP:       10.10.10.81
  IP Owner:       NO
  VR Interface:       eth2
  Priority:       200
  Advt Interval:   1 sec
  Preempt Mode:       TRUE
-------------------------------------
R2# show vrrp 2
----------Configuration----------
  VRID:           2
  state:       MASTER
  Virtual IP:       10.10.10.82
  IP Owner:       YES
  VR Interface:       eth2
  Priority:       255
  Advt Interval:   1 sec
  Preempt Mode:       TRUE
--------------------------------------
```

Authentication

The ZebOS VRRP implementation allows authentication using the plain text mode only. MD5 authentication is not yet supported.

Using text type authentication means that VRRP protocol exchanges are authenticated by a clear text password. A string of characters is specified for authentication. There is no default password. The receiver checks that the string in the packet matches its configured authentication string. Packets that do not match are discarded.

You must configure both the master and the backup routers to have the same authentication string and mode. If the authentication string (password) is not the same on both the routers, they will not talk to each other. In this example, if R1 and R2 have different passwords, R2 will not know about R1 and both will work as Master routers.



R1

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`) to be configured.
ZebOS(config-if)# ip vrrp authentication mode text	Specify the type of authentication to be used for VRRP packets.
ZebOS(config)# ip vrrp authentication string guest	Specify the authentication string or password used by a key.

R2

ZebOS# configure terminal	Enter the `Configure` mode.
ZebOS(config)# interface eth0	Specify the interface (`eth0`) to be configured.
ZebOS(config-if)# ip vrrp authentication mode text	Specify the type of authentication to be used for VRRP packets.
ZebOS(config)# ip vrrp authentication string guest	Specify the authentication string or password used by a key.

Names of Commands Used

ip vrrp authentication mode, ip vrrp authentication string

Validation Commands

CHAPTER 16 MPLS Layer-3 VPN Configuration

This chapter introduces the ZebOS MPLS Layer-3 VPN (Virtual Private Network) concept and describes the MPLS-VPN routing process.

The ZebOS MPLS Layer-3 VPN solution provides address space and routing separation through the use of per-VPN Routing and Forwarding tables (VRFs) and MPLS switching in the core and on the edge. VPN customer routing information is imported into the VRFs utilizing the Route Target BGP extended community. This VPN routing information is identified uniquely through the use of a Route Distinguisher (RD) and is distributed among Provider Edge (PE) routers using Multiprotocol BGP extensions.

Requirements

To fully implement the ZebOS MPLS Layer-3 VPN solution, the following ZebOS modules are required:

1. ZebOS Network Services Module
2. ZebOS BGP Protocol Module with the optional VPN extensions
3. ZebOS LDP Module
4. ZebOS MPLS Forwarder Module
5. ZebOS OSPFv2
6. ZebOS RIP

MPLS VPN Terminology

Service Provider The organization that owns the infrastructure that provides leased lines to customers offering them a Virtual Private Network Service. In the illustration below, CConnect is the service provider providing services to clients ComA and ComB.

Customer Edge (CE) Router A router at a customer's site that connects to the Service Provider via one or more Provider Edge routers. In the illustration below, CE1, CE2, CE3 and CE4 are all CE routers connected directly to the CConnect network.

Provider Edge (PE) Router A provider's router connected to the CE router through a leased line or dial up connection. In the illustration below, PE1 and PE2 are the PE routers as they link the CConnect service provider to its clients.

Provider Core Router (P) The devices in the core of the service provider network, which are generally themselves not Provider Edge routers. In the illustration below the P router is the Provider device, not connected to any customer and is the core of the CConnect network.

Site A contiguous part of the customer network. A site connects to the provider network through transmission lines, using a CE and PE router. In the illustration below R1, R2 and CE3 comprise a Customer network and are seen as a single site by the CConnect network.

Customer Router In the following illustration R1 and R2 are the Customer routers and are not directly connected to the CConnect network.

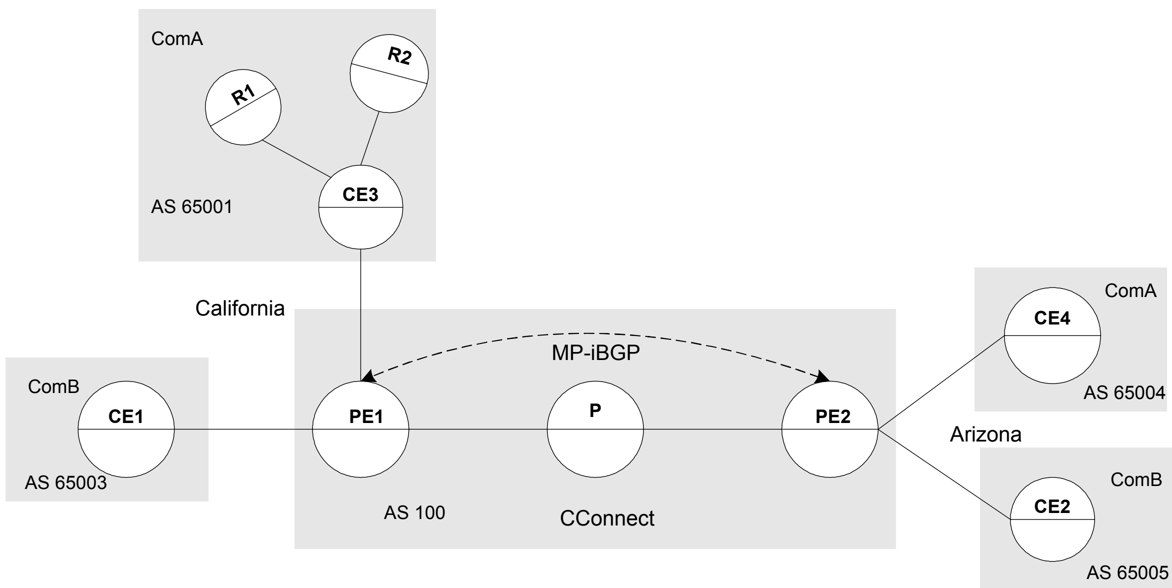


Figure 1: Virtual Private Network in CConnect Service Provider Network

The VPN Routing Process

The ZebOS MPLS-VPN Routing process involves the following steps:

1. Service Providers provide VPN services from PE routers that communicate directly with CE routers via Ethernet Link.
2. Each PE router maintains a Routing and Forwarding table (VRF) for each customer. This guarantees isolation and allows the usage of uncoordinated private addresses. When a packet is received from the CE the VRF that is mapped to that site is used to determine the routing for the data. If a PE has multiple connections to the same site, a single VRF is mapped to all of those connections.
3. After the PE router learns of the IP prefix, it converts it into a VPN-IPv4 prefix by prepending it with an 8-byte Route Distinguisher (RD). The RD ensures that even if two customers have the same address, two separate routes to that address can be maintained. These VPN-IPv4 addresses are exchanged between the PE routers through MP-BGP.
4. A unique Router ID (usually the loopback address) is used to allocate a label and to enable VPN packet forwarding across the backbone.
5. Based on routing information stored in the VRF table, packets are forwarded to their destination using MPLS. Each PE router allocates a unique label to every route in each VRF (even if they have the same next hop) and propagates these labels together with 12-byte VPN-IPv4 addresses through multiprotocol BGP.
6. Ingress PE routers prepend a two-level label stack to the VPN packet, which is forwarded across the Provider network. This label stack contains a BGP-specific label from the VRF table (associated with the incoming interface) specifying the BGP next hop and an LDP-specific label from the global FTN table specifying the IP next hop.
7. The Provider router in the network switches the VPN packet based on the top label or the LDP-specific label in the stack. This top label is used as the key to lookup in the incoming interface's Incoming Labels Mapping table (ILM). If there is an outbound label, the label is swapped and the packet is forwarded to the next hop, if not, then the router is the penultimate router and it pops the LDP-specific label and forwards the packet with only the BGP-specific label to the egress PE router.
8. The egress PE router pops the BGP-specific label, performs a single label lookup in the outbound interface and sends the packet to the appropriate CE router.

VPN Configuration

The MPLS Layer-3 VPN configuration process can be divided into the following steps:

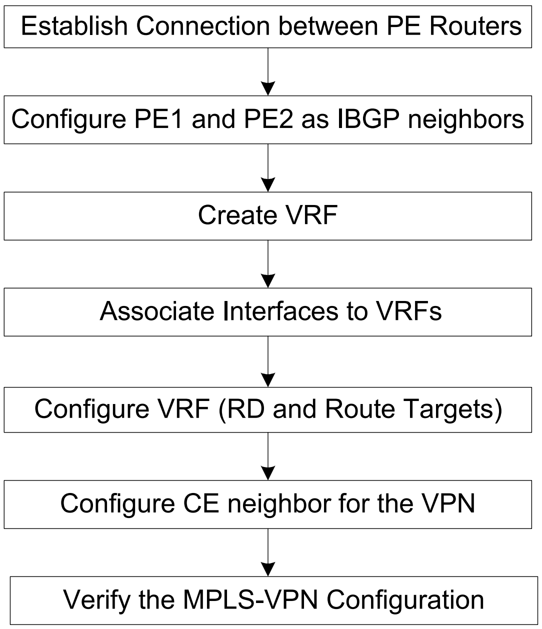


Figure 2: MPLS-VPN Configuration Flow Chart

A sample network is used in the explanation of the configuration steps throughout this section. In this sample the CConnect MPLS-VPN backbone has two customers--ComA and ComB. Both customers have sites in California and Arizona.

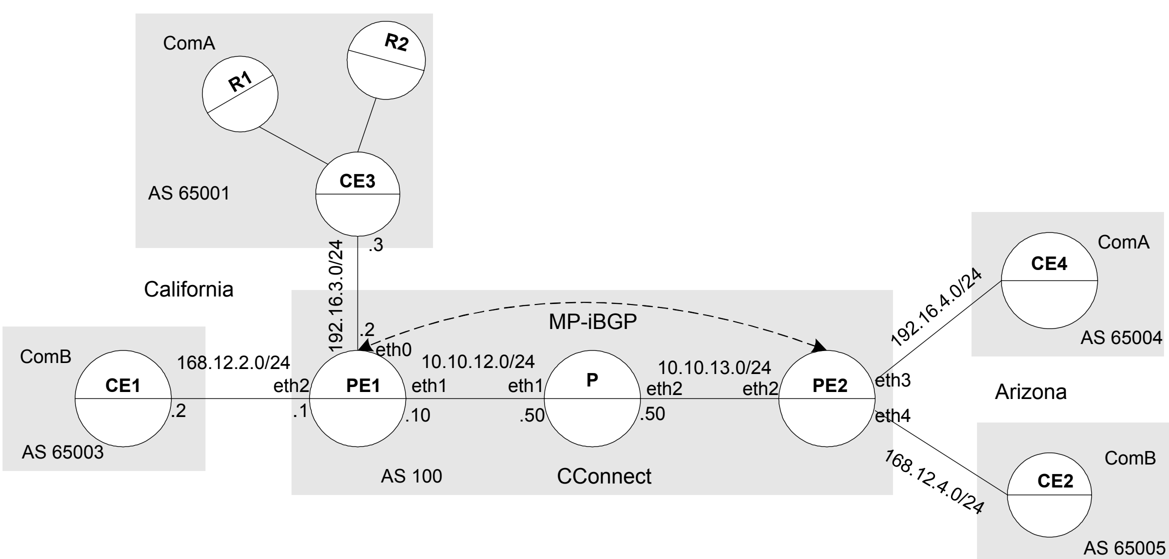


Figure 3: BGP4 address assignment between PE and CE routers

These steps provision a customer VPN service across the MPLS-VPN backbone:

Establish Connection between PE Routers

Establishing this connection involves two steps:

1. Enabling IGP

A sample configuration for establishing connection between the two Provider Edge routers PE1 and PE2:

Note: For details on OSPF commands, refer to the *OSPF Command Reference*.

PE1

```
PE1(config)# router ospf 100
PE1(config-router)# network 10.10.12.0/24 area 0
!
```

P

```
P(config)# router ospf 100
P(config-router)# network 10.10.12.0/24 area 0
P(config-router)# network 10.10.13.0/24 area 0
!
```

PE2

```
PE2(config)# router ospf 100
PE2(config-router)# network 10.10.13.0/24 area 0
!
```

2. Enabling LDP

A sample configuration for enabling LDP on the whole path between PE1 and PE2 (see figure 3):

Note: For details on LDP commands, refer to the *LDP Command Reference*.

PE1

```
PE1(config)# interface eth1
PE1(config-if)# enable-ldp
!
PE1(config)# router ldp
PE1(config-router)# advertisement-mode downstream-on-demand
PE1(config-router)# multicast-hellos
!
```

P

```
P(config)# interface eth1
P(config-if)# enable-ldp
P(config)# interface eth2
P(config-if)# enable-ldp
!
!
P(config)# router ldp
P(config-router)# advertisement-mode downstream-on-demand
P(config-router)# multicast-hellos
!
```

PE2

```
PE2(config)# interface eth2
PE2(config-if)# enable-ldp
!
!
PE2(config)# router ldp
PE2(config-router)# advertisement-mode downstream-on-demand
PE2(config-router)# multicast-hellos
!
```

Configure PEs as BGP Neighbors

BGP is the preferred protocol to transport VPN routes because of its multiprotocol capability and its scalability. Its ability to exchange information between indirectly connected routers, supports keeping VPN routing information out of the P routers. The P routers carry information as an optional BGP attribute. Any additional attributes are transparently forwarded by any P router. The MPLS-VPN forwarding model does not require the P routers to make routing decisions based on VPN addresses. They just forward packets based on label value attached to the packet. The P routers do not require enabling VPN.

Note: For details on BGP commands, refer to the *BGP Command Reference*.

PE1

```
PE1(config)# interface lo
PE1(config-if)# ip address 2.2.2.2/32
```

PE2

```
PE2(config)# interface lo
PE2(config-if)# ip address 3.3.3.3/32
!
```

PE1

```
PE1# configure terminal
PE1(config)# router bgp 100
PE1(config-router)# neighbor 3.3.3.3 remote-as 100
PE1(config-router)# neighbor 3.3.3.3 update-source 2.2.2.2
!
PE1(config-router)# address-family vpnv4 unicast
PE1(config-router-af)# neighbor 3.3.3.3 activate
!
```

PE2

```
PE2(config)# router bgp 100
PE2(config-router)# neighbor 2.2.2.2 remote-as 100
PE2(config-router)# neighbor 2.2.2.2 update-source 3.3.3.3
!
!
PE2(config-router)# address-family vpnv4 unicast
PE2(config-router-af)# neighbor 2.2.2.2 activate
!
```

Create VRF

Each PE router in the MPLS-VPN backbone is attached to a site that receives routes from a specific VPN, so the PE router must have the relevant Virtual Routing and Forwarding (VRF) configuration for that VPN. Use the following command in `Configure` mode to create the VRF (see *BGP Command Reference* for details):

```
(no) ip vrf VRF-NAME
```

`VRF-NAME` a name used to identify the VRF.

This command creates a VRF RIB, assigns a VRF-ID, and switches command mode to `vrf` mode on the ZebOS daemon. The following example shows the use of this command to create a VRF named `ComB`.

```
zebos(config)# ip vrf ComB
zebos(config-vrf)#
```

Associate Interfaces to VRFs

After the VRFs are defined on the PE router, the PE router needs to recognize which interfaces belong to which VRF. The VRF is populated with routes from connected sites. More than one interface can belong to the same VRF. To associate the interfaces (connected to the CE routers) to the VRFs, use the following command in the `Interface` mode (see *BGP Command Reference* for details):

```
(no) ip vrf forwarding VRF-NAME
```

`VRF-NAME` description.

In the following example, interface `eth1` is associated with the VRF named `ComB`.

```
zebos(config)# interface eth1
zebos(config-if)# ip vrf forwarding ComB
```

Configure VRF (RD and Route Targets)

After the VRF is created, configure the Router Distinguisher and the Route Targets.

1. Configuring Route Distinguishers

Route Distinguishers (RDs) make all customer routes unique. The routes need to be unique so that multiprotocol BGP treats the same prefix from two different VPNs as non-comparable routes. To configure RDs, a sequence of 64 bits is prepended to the IPv4 address in the multiprotocol BGP update. BGP considers two IPv4 addresses with different RDs as non-comparable even if they have the same address and mask.

Assign a particular value to the RD for each VRF on the PE router. Using the following command in the `Configure vrf` mode (see *BGP Command Reference*):

`rd RD-VALUE`

`RD-VALUE` = `ASN|IPID`

`ASN` = `AS Number:NN` Specifies a 16-bit AS number and an arbitrary number (for example 100:1)

`IPID` = `A.B.C.D|NN` Specifies a 32-bit IP address and an arbitrary number (for example 192.34.23.1:1)

To display the routing table for this VRF, use the `show ip route vrf` command.

The following example shows the addition of RD:

```
bgpd(config)# ip vrf ComB
bgpd(config-vrf)# rd 1:1
```

2. Configuring Route Targets

Any routes learned from customers are advertised across the network through the multiprotocol BGP, and any routes learned through multiprotocol BGP are added into the appropriate VRFs. The route target helps PE routers identify which VRFs should receive the routes. Use the following command to configure the route targets in the `Configure vrf` mode (see *BGP Command Reference*):

`(no) route-target [export|import|both] RT-VALUE`

`export` add route-target to the exporting routing information from the VRF

`import` import routing information which have this route-target

`both` Specify both import and export

`RT-VALUE` = `ASN|IPID`

`ASN` = `ASN:NN` 16-bit Specifies a AS number and an arbitrary number (for example 100:1)

`IPID` = `A.B.C.D|NN` Specifies a 32-bit IP address and an arbitrary number (for example 192.34.23.1:1)

The `route-target` command creates lists of import and export route-target extended communities for the VRF. It specifies a target VPN extended community. Execute the command once for each community. All routes with the specific route-target extended community are imported into all VRFs with the same extended community as an import route-target.

The following example shows the route-target configuration for `ComB`.

```
bgpd(config)# ip vrf ComB
bgpd(config-vrf)# route-target both 100:1
```

Configure CE neighbor for the VPN

The BGP sessions between PE and CE routers can carry different types of routes (VPN-IPv4, IPv4 routes). Address families are used to control the type of BGP session. Configure a BGP address family for each VRF on the PE router and a separate address family to carry VPN-IPv4 routes between PE routers. All non-VPN BGP neighbors are defined using the `IPv4 address` mode. Each VPN BGP neighbor is defined under its associated `Address Family` mode. To enter the address-family mode use the following command (see *BGP Command Reference* for details):

`address-family ipv4 vrf VRF-NAME`

`VRF-NAME` a name used to identify a VRF

A separate address family entry is used for every VRF and each address family entry could have multiple CE routers within the VRF.

The PE and CE routers must be directly connected for BGP4 sessions; BGP multihop is not supported between PE and CE routers

The following example places the router in address family mode and specifies company names ComA and ComB as the names of the VRF instance to associate with subsequent IPv4 address family configuration mode commands:

PE1

```
PE1(config)# router bgp 100
PE1(config-router)# address-family ipv4 vrf ComA
PE1(config-router-af)# neighbor 192.16.3.3 remote-as 65001
PE1(config-router-af)# neighbor 192.16.3.3 as-override
!
PE1(config-router)# address-family ipv4 vrf ComB
PE1(config-router-af)# neighbor 168.12.0.2 remote-as 65003
PE1(config-router-af)# neighbor 168.12.0.2 as-override
!
```

Verify the MPLS-VPN Configuration

Use the `show ip bgp neighbor` command to validate the neighbor session between the CE and the PE routers. Use the `show ip bgp vpnv4 all` command (see *BGP Command Reference* for details) to display all the VRFs and the routes associated with them.

The following is a sample output for the `show running-config` command, on the PE1, CE1 and P routers showing complete configuration (see *Figure 3*).

```
!
hostname CE1
password zebra
log stdout
!
interface lo
!
interface eth0
!
interface eth1
!
interface sit0
!
interface ppp0
!
interface eth2
 ip address 168.12.2.2/24
!
interface eth3
!
router bgp 65003
 bgp router-id 10.10.10.10
 redistribute connected
 neighbor 168.12.2.1 remote-as 100
!
---------------------------------------------------------------------------
!
hostname PE1
password zebra
log stdout
!
```

```
ip vrf ComB
 rd 1:1
 route-target both 100:1
!
ip vrf ComA
 rd 1:2
 route-target both 100:2
!
interface lo
 ip address 2.2.2.2/32
!
interface eth0
 ip address 192.16.3.2/24
 ip vrf forwarding ComA
!
interface eth1
 ip address 10.10.12.10/24
 enable-ldp
!
interface eth2
 ip address 168.12.2.1/24
 ip vrf forwarding ComB
!
interface sit0
!
interface ppp0
!
router bgp 100
 neighbor 3.3.3.3  remote-as 100
 neighbor 3.3.3.3  update-source 2.2.2.2
!
 address-family vpnv4 unicast
 neighbor 3.3.3.3  activate
 exit-address-family
!
 address-family ipv4 vrf ComB
 neighbor 168.12.2.2 remote-as 65003
 no neighbor 168.12.2.2  send-community extended
 neighbor 168.12.2.2 as-override
 exit-address-family
!
 address-family ipv4 vrf ComA
 neighbor 192.16.3.3 remote-as 65001
 no neighbor 192.16.3.3 send-community extended
 neighbor 192.16.3.3 as-override
 exit-address-family
!
router ldp
 advertisement-mode downstream-on-demand
 loop-detection
```

```
!
router ospf 100
 redistribute connected
 network 10.10.12.0/24 area 0
!
---------------------------------------------------------------------
!
hostname P
password zebra
log stdout
!
interface lo
!
interface eth0
!
interface eth1
 ip address 10.10.12.50/24
 enable-ldp
!
interface eth2
 ip address 10.10.13.50/24
 enable-ldp
!
interface eth3
!
interface eth4
!
interface sit0
!
interface ppp0
!
router ldp
 advertisement-mode downstream-on-demand
 loop detection
!
router ospf 100
 redistribute connected
 network 10.10.12.0/24 area 0
 network 10.1.13.0/24 area 0
```

VPN Commands

The MPLS layer-3 VPN commands are available from the ZebOS NSM and BGP daemons. This chapter includes an alphabetized list of all the VPN commands. Refer to the related Command References for details about the commands listed here.

Command Name	Use this command to:	Command Reference
address-family ipv4 vrf	exchange VRF routing information and to enter the address family mode	ZebOS BGP Command Reference
address-family vpnv4 unicast	exchange VPNv4 routing information and to enter the address family vpnv4 mode	ZebOS BGP Command Reference
bgp inbound route-filter	control installation of routing information into the BGP table	ZebOS BGP Command Reference
clear ip bgp	reset a VPNv4 BGP connection	ZebOS BGP Command Reference
debug bgp mpls	enable the display of MPLS related information	ZebOS BGP Command Reference
exit-address-family	exit address family-vrf or address family-vpnv4 mode	ZebOS BGP Command Reference
import map	assign a route map to the VRF and to import routing information from another PE	ZebOS BGP Command Reference
ip vrf	create a VRF RIB, assign a VRF ID and enter the Configure VRF mode	ZebOS NSM Command Reference
ip route vrf	create a new static entry for the VRF	ZebOS NSM Command Reference
ip vrf forwarding	associate an interface with VRF	ZebOS NSM Command Reference
neighbor activate	exchange routing information with a peer router	ZebOS BGP Command Reference
neighbor allowas-in	allow re-advertisement of all prefixes containing duplicate ASNs	ZebOS BGP Command Reference
neighbor as-override	override the ASN of a site with the ASN of a provider	ZebOS BGP Command Reference
neighbor description	associate a description with a neighbor	ZebOS BGP Command Reference
neighbor remote-as	establish BGP peering with a CE router	ZebOS BGP Command Reference
neighbor send-community-extend	send extended-community attributes to a CE router	ZebOS BGP Command Reference
neighbor shutdown	administratively disable a neighbor	ZebOS BGP Command Reference
neighbor soo	enable site-of-origin feature	ZebOS BGP Command Reference
redistribute	redistribute routes between routing domains	ZebOS BGP Command Reference
route distinguisher	assign a RD for the VRF	ZebOS BGP Command Reference
route-target	add a list of extended-communities to the VRF	ZebOS BGP Command Reference
set vpnv4 nexthop	set the IP address of the VPNv4 next hop router	ZebOS BGP Command Reference
show ip bgp vpnv4	display routing information about all VPNv4, VRF or an RD	ZebOS BGP Command Reference
show ip route vrf	display VRF routing table	ZebOS NSM Command Reference
show ip vrf	display VRF routing information	ZebOS NSM Command Reference

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