ZebOS-XP®
Network Platform

Version 1.4
Extended Performance

Unicast Configuration Guide

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IP Infusion Inc. Proprietary

IP Infusion Inc.
3965 Freedom Circle, Suite 200
Santa Clara, CA 95054
+1 408-400-1900
http://www.ipinfusion.com/

For support, questions, or comments via E-mail, contact:
support@ipinfusion.com

Contents

Preface

This guide describes how to configure unicast protocols such as RIP, OSPF, IS-IS, and BGP in ZebOS-XP.

Audience

This guide is intended for network administrators and other engineering professionals who configure unicast protocols.

Conventions

Table P-1 shows the conventions used in this guide.

Table P-1: Conventions

Convention	Description
Italics	Emphasized terms; titles of books
Note:	Special instructions, suggestions, or warnings
`monospaced type`	Code elements such as commands, functions, parameters, files, and directories

Contents

This guide contains these chapters and appendices:

Related Documents

Use this guide with these command references for details about the commands used in the configurations.

- *Unicast Routing Information Base Command Reference*
- *Routing Information Protocol Command Reference*
- *Open Shortest Path First Command Reference*
- *Intermediate System to Intermediate System Command Reference*
- *Border Gateway Protocol Command Reference*
- *Layer 2 Command Reference*
- *Network Services Module Command Reference*

Note: All ZebOS-XP technical manuals are available to licensed customers at http://www.ipinfusion.com/support/document_list.

Chapter Organization

The chapters in this guide are organized into these major sections:

- An overview that explains a configuration in words
- Topology with a diagram that shows the devices and connections used in the configuration
- Configuration steps in a table for each device where the left-hand side shows the commands you enter and the right-hand side explains the actions that the commands perform
- Validation which shows commands and their output that verify the configuration

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CHAPTER 1 Static Routes

This chapter contains basic static routing configuration examples.

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

For details about the commands used in these examples, see the *Unicast Routing Information Base Command Reference*.

Topology

Router R1 is configured with these static routes:

- The remote network 10.10.12.0/24
- The loopback address (host addresses) of router R2
- The loopback address of router R3

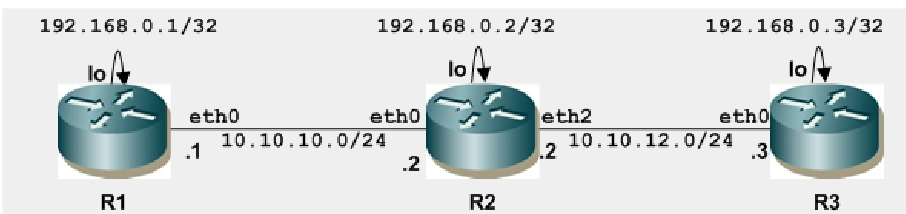

Figure 1-1: Basic Static Route

In all three routes, interface `eth0` of router R2 is the gateway. Router R3 is configured with a default static route that 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

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Enter interface mode.
`(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.
`(config-if)#exit`	Exit interface mode.

`(config)#ip route 10.10.12.0/24 10.10.10.2`
`(config)#ip route 192.168.0.2/32 10.10.10.2`
`(config)#ip route 192.168.0.3/32 10.10.10.2`
	Specify the destination prefix and mask for the network and a gateway.
	Because 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

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Enter interface mode.
`(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.
`(config-if)#exit`	Exit Interface mode.
`(config)#ip route 192.168.0.1/32 10.10.10.1` `(config)#ip route 192.168.0.3/32 10.10.12.3`	Specify the destination and mask for the network and a gateway.

R3

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Enter interface mode.
`(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.
`(config-if)#exit`	Exit Interface mode.
`(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. Because 10.10.12.2 is the only available route, you can specify it as the default gateway instead of specifying it as the gateway for an individual network or host address.

CHAPTER 2 RIP

This chapter contains basic Router Information Protocol (RIP) configuration examples.

For details about the commands used in these examples, see the *Routing Information Protocol Command Reference*.

Enable RIP

This example shows the minimum configuration required to enable 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, then associate a network with the routing process.

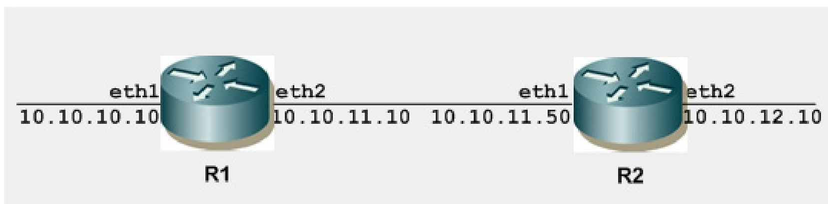

Figure 2-2: Enable RIP Topology

R1

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

R2

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

Validation

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

Specify RIP Version

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

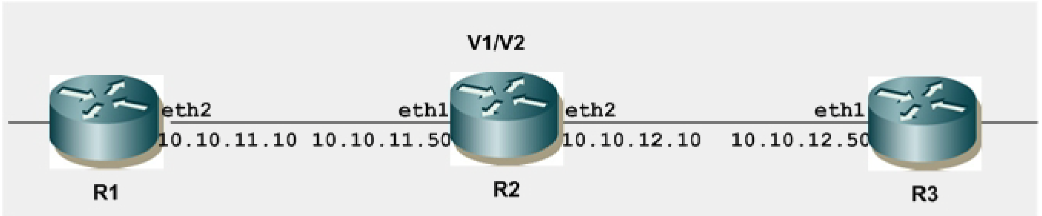

Figure 2-3: RIP Version Topology

R2

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

Validation

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

Authentication with a Single Key

ZebOS-XP RIP provides a choice of configuring authentication with a single key or with multiple keys. This example shows authenticating routing information exchange using a single key.

Topology

Routers R1 and R2 are running RIP and exchanging routing updates. To configure single-key authentication on R1, specify an interface, 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 the password. For an exchange of updates between R1 and R2, define the same password and authentication mode on R2.

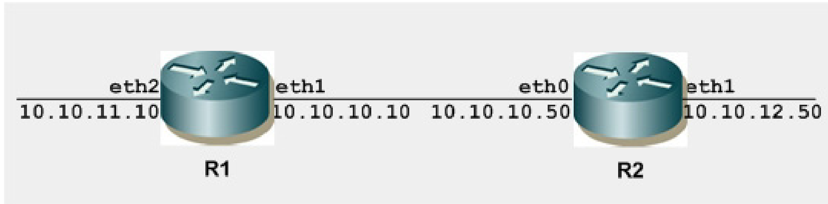

Figure 2-4: Single-key Topology

R1

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

R2

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

Validation

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

Text Authentication with 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, then define the authentication string or passwords to use 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 set of keys) that will be used for authentication on each interface, and the authentication mode to use.

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 accommodate different time setup on machines. However, the send lifetime is not required to overlap, and IP Infusion Inc. recommends configuring no overlapping for the send lifetime.

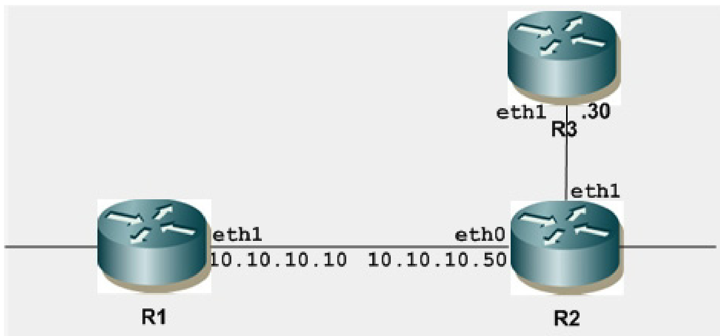

Figure 2-5: Multiple-key Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#router rip`	Define a RIP routing process, and enter Router mode.
`(config-router)#network 10.10.10.0/24`	Associate network `10.10.10.0/24` with the RIP process.
`(config-router)#redistribute connected`	Enable redistributing from connected routes.
`(config-router)#exit`	Quit Router mode, and return to Configure mode.
`(config)#key chain SUN`	Enter Keychain management mode to add keys to the key chain `SUN`.
`(config-keychain)#key 10`	Add authentication key ID (`10`) to the key chain `SUN`.
`(config-keychain-key)#key-string IPI`	Specify a password (`IPI`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 2 to noon of March 7, 2003.
`(config-keychain-key)#exit`	Exit Keychain-Key mode, and return to Keychain mode.
`(config-keychain)#key 20`	Add another authentication key (`20`) to the key chain `SUN`.

`(config-keychain-key)#key-string Earth`	Specify a password (`Earth`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 7 to noon of March 12, 2003.
`(config-keychain-key)#end`	Enter Privileged Exec mode.
`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify interface `eth1` as the interface you want to configure.
`(config-if)#ip rip authentication key chain SUN`	Enable RIPv2 authentication on `eth1` interface and specify the key chain `SUN` to use for authentication.
`(config-if)#ip rip authentication mode text`	Specify text authentication mode to use for RIP packets. This step is optional, because text is the default mode.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router rip`	Define a RIP routing process, and enter Router mode.
`(config-router)#network 10.10.10.0/24`	Associate network `10.10.10.0/24` with the RIP process.
`(config-router)#redistribute connected`	Enable redistributing from connected routes.
`(config-router)#exit`	Quit Router mode, and return to Configure mode.
`(config)#key chain MOON`	Enter Keychain management mode to add keys to the key chain `MOON`.
`(config-keychain)#key 30`	Add authentication key ID (`30`) to the key chain `MOON`.
`(config-keychain-key)#key-string IPI`	Specify a password (`IPI`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 2 to noon of March 7, 2003.
`(config-keychain)#key 40`	Add another authentication key (`40`) to the key chain `MOON`.
`(config-keychain-key)#key-string Earth`	Specify a password (`Earth`) to use by the specified key.
`(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.

`(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 sent. In this case, key string `IPI` can be sent from noon of March 7 to noon of March 12, 2003.
`(config-keychain-key)#end`	Enter Privileged Exec mode.
`#configure terminal`	Enter Configure mode.
`(config)#interface eth0`	Specify interface `eth0` as the interface you want to configure.
`(config-if)#ip rip authentication key chain MARS`	Enable RIPv2 authentication on the `eth1` interface, and specify the key chain `MARS` to use for authentication.
`(config-if)#ip rip authentication mode text`	Specify the authentication mode to use for RIP packets. This step is optional, because text is the default mode.

Validation

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

MD5 Authentication with 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 exchanging routing updates. To configure authentication on R1, define a key chain, specify keys in the key chain, then define the authentication string or passwords to use 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 use. Configure R2 and R3 to have the same key ID and key string as R1 for the time that updates are 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 lifetimes should be configured to overlap; however, the send lifetime should not overlap.

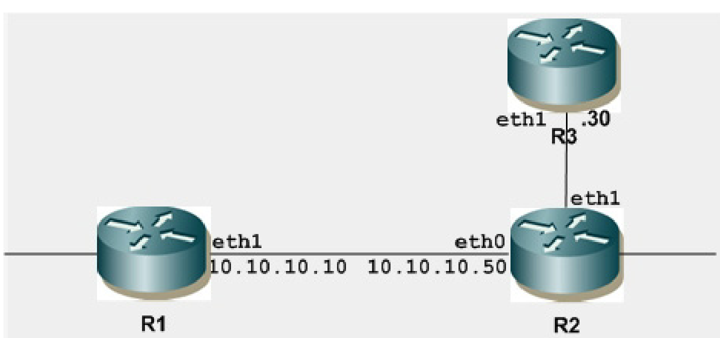

Figure 2-6: MD5 Multiple-key Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#router rip`	Define a RIP routing process, and enter Router mode.
`(config-router)#network 10.10.10.0/24`	Associate network `10.10.10.0/24` with the RIP process.
`(config-router)#redistribute connected`	Enable redistributing from connected routes.
`(config-router)#exit`	Quit Router mode, and return to Configure mode.
`(config)#key chain SUN`	Enter Keychain management mode to add keys to the key chain `SUN`.
`(config-keychain)#key 1`	Add authentication key ID (`1`) to the key chain `SUN`.
`(config-keychain-key)#key-string IPI`	Specify a password (`IPI`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 2 to noon of March 7, 2003.
`(config-keychain-key)#exit`	Exit Keychain-Key mode, and return to Keychain mode.
`(config-keychain)#key 2`	Add another authentication key (`2`) to the key chain `SUN`.
`(config-keychain-key)#key-string Earth`	Specify a password (`Earth`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 7 to noon of March 12, 2003.
`(config-keychain-key)#end`	Enter Privileged Exec mode.
`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify interface `eth1` as the interface you want to configure.
`(config-if)#ip rip authentication key chain SUN`	Enable RIPv2 authentication on the `eth1` interface, and specify the key chain `SUN` to use for authentication.
`(config-if)#ip rip authentication mode md5`	Specify MD5 authentication mode to use for RIP packets.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router rip`	Define a RIP routing process, and enter Router mode.
`(config-router)#network 10.10.10.0/24`	Associate network `10.10.10.0/24` with the RIP process.
`(config-router)#redistribute connected`	Enable redistributing from connected routes.
`(config-router)#exit`	Quit Router mode, and return to Configure mode.
`(config)#key chain MOON`	Enter Keychain management mode to add keys to the key chain `MOON`.
`(config-keychain)#key 1`	Add authentication key ID (`1`) to the key chain `MOON`.
`(config-keychain-key)#key-string IPI`	Specify a password (`IPI`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 2 to noon of March 7, 2003.
`(config-keychain)#key 2`	Add another authentication key (`2`) to the key chain `MARS.`
`(config-keychain-key)#key-string Earth`	Specify a password (`Earth`) to use by the specified key.
`(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.
`(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 sent. In this case, key string `IPI` can be sent from noon of March 7 to noon of March 12, 2003.
`(config-keychain-key)#end`	Enter Privileged Exec mode.
`#configure terminal`	Enter Configure mode.
`(config)#interface eth0`	Specify interface `eth0` as the interface you want to configure.
`(config-if)#ip rip authentication key chain MARS`	Enable RIPv2 authentication on the `eth1` interface, and specify the key chain `MARS` to use for authentication.
`(config-if)#ip rip authentication mode md5`	Specify the authentication mode to use for RIP packets.

Validation

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

CHAPTER 3 # RIPng

This chapter contains a basic RIPng configuration example.

For details about the commands used in these examples, see the *Routing Information Protocol Command Reference*.

Topology

The diagram shows the minimum configuration required to enable RIPng on an interface. R1 and R2 are two routers connected to network 3ffe:11::/64. To enable RIPng, first define the RIPng routing process, then enable RIPng on each interface.

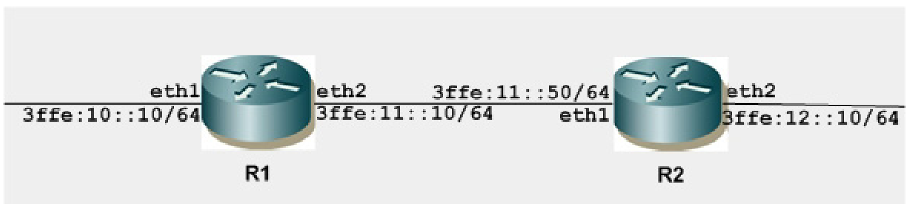

Figure 3-7: RIPng Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ipv6 router rip`	Enable RIPng routing on interface `eth1`.
`(config-if)#exit`	Exit Interface mode, and enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ipv6 router rip`	Enable RIPng routing on interface `eth2`.
`(config-if)#exit`	Exit Interface mode, and enter Configure mode.
`(config)#router ipv6 rip`	Define a RIPng routing process, and enter Router mode.

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ipv6 router rip`	Enable RIPng routing on interface `eth1`.
`(config-if)#exit`	Exit Interface mode, and enter Configure mode.

`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ipv6 router rip`	Enable RIPng routing on interface `eth2`.
`(config-if)#exit`	Exit Interface mode, and enter Configure mode.
`(config)#router ipv6 rip`	Define a RIPng routing process, and enter Router mode.

Validation

show ipv6 rip

CHAPTER 4 **OSPF**

This chapter contains basic OSPF (Open Shortest Path First) configuration examples.

For details about the commands used in these examples, see the *Open Shortest Path First Command Reference*.

Enable OSPF on an Interface

The diagram shows the minimum configuration required to enable 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. It is possible, however, to configure different interfaces on a router to belong to different areas.

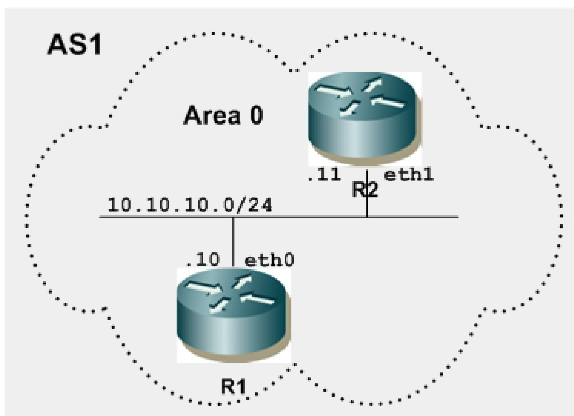

Figure 4-8: Basic OSPF Topology

R1

`#configure terminal`	Enter configure mode
`(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.
`(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

`#configure terminal`	Enter configure mode

`(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.
`(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.

Validation

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

Set Priority

This example shows how to set the 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, which is higher than the default priority (1) of R1 and R2; making it the DR.

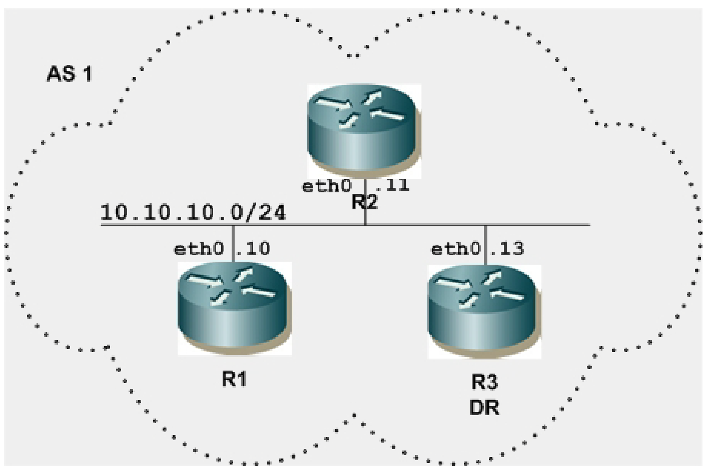

Figure 4-9: Set OSPF Priority

R3

(config)#`interface eth1`	Specify the interface (`eth1`) to configure.
(config-if)#`ip ospf priority 10`	Specify the router priority to a higher priority (10) to make R3 the Designated Router (DR).
(config-if)#`exit`	Exit interface mode.
(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.
(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

`#configure terminal`	Enter configure mode
`(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.
`(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

`(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.
`(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.

Validation

show ip ospf neighbor, show ip ospf interface

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 Area 1.

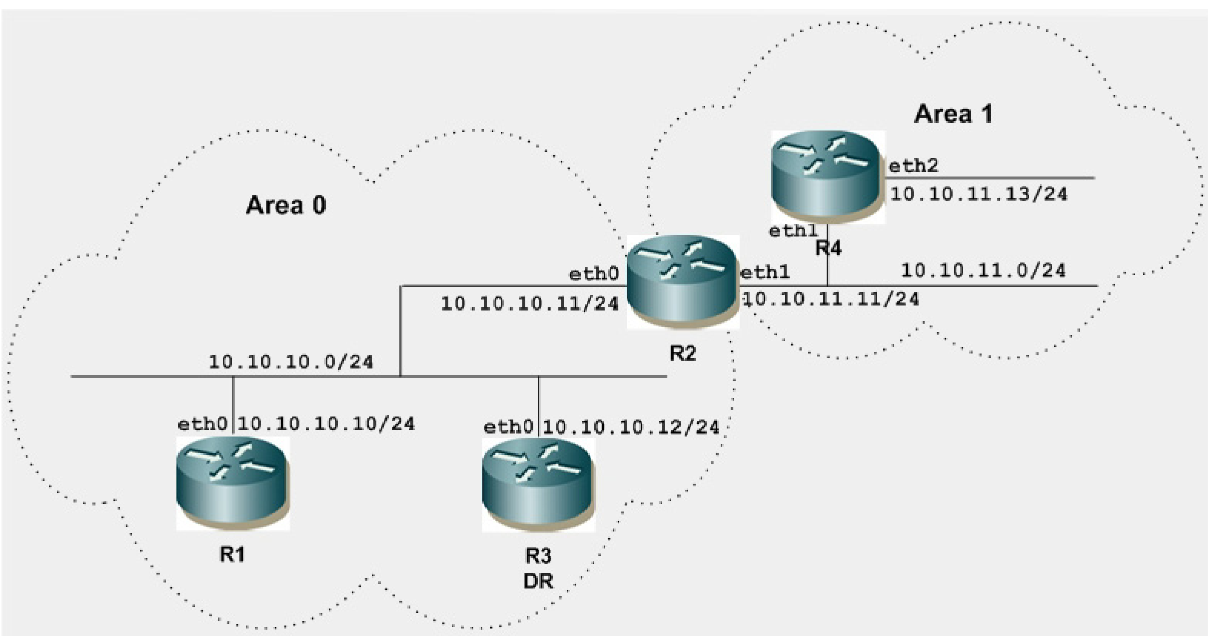

Figure 4-10: OSPF ABR Topology

R2

`#configure terminal`	Enter configure mode
`(config)#router ospf 100`	Configure the routing process, and specify the Process ID (`100`). The Process ID should be a unique positive integer.
`(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.
`(config-router)#network 10.10.11.0/24 area 1`	Define the other interface `(10.10.11.0/24)` on which OSPF runs, and associate the area ID `(1)` with the interface.

Validation

show ip ospf, show ip ospf interface

Redistribute 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.

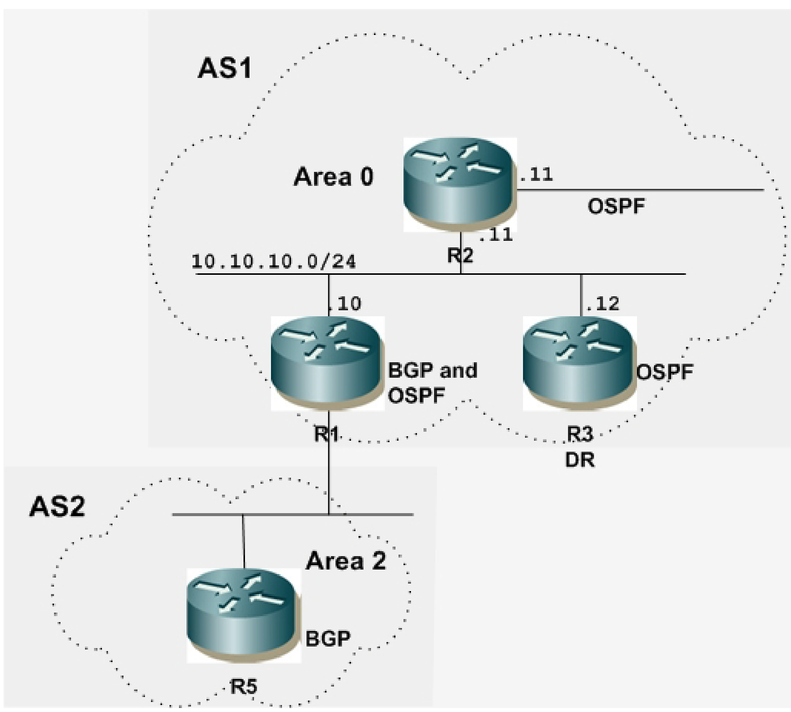

Figure 4-11: Redistribute Routes

R1

`#configure terminal`	Enter configure mode.
`(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.
`(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).
`(config-router)#redistribute bgp`	Specify redistributing routes from other routing protocol (BGP) into OSPF.

Validation

show ip ospf database external

Cost

A route can be made the preferred route by changing its cost. In this example, cost has been configured to make R2 the next hop for R1.

The default cost for 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 is computed as follows:

R2: 10+100 = 110

R3: 10+150 = 160

Therefore, R1 chooses R2 as its next hop to destination 10.10.14.0/24 because it has the lower cost.

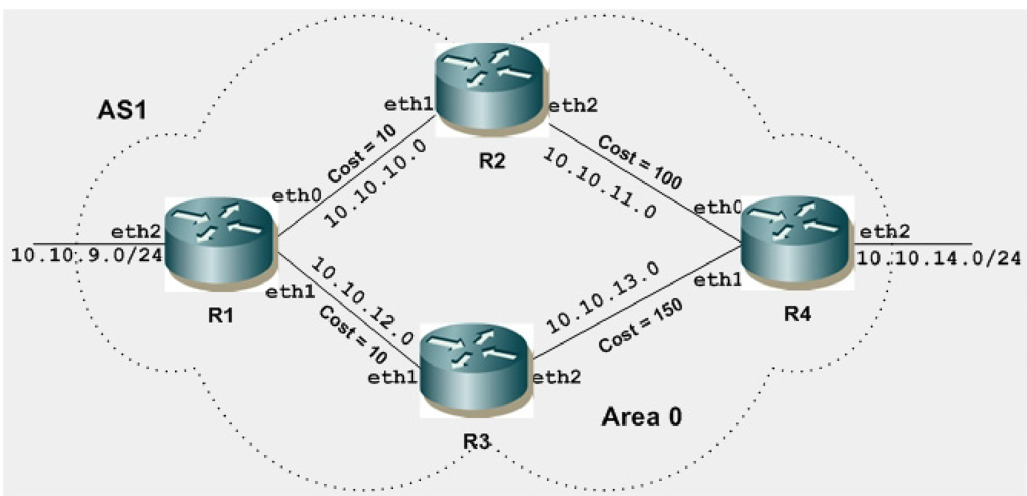

Figure 4-12: Configure Cost Topology

R1

`#configure terminal`	Enter configure mode.
`(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.

`(config-router)#network 10.10.9.0/24 area 0`
`(config-router)#network 10.10.10.0/24 area 0`
`(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

`(config)#interface eth2`	Specify the interface (`eth2)` to configure.
`(config-if)#ip ospf cost 100`	Set the OSPF cost of this link to `100`.
`(config-if)#exit`	Exit interface mode.
`(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.
`(config-router)#network 10.10.10.0/24 area 0` `(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

`(config)#interface eth2`	Specify the interface (`eth2)` to configure.
`(config-if)#ip ospf cost 150`	Set the OSPF cost of this link to `100`.
`(config-if)#exit`	Exit interface mode.
`(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.
`(config-router)#network 10.10.12.0/24 area 0` `(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

`(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.

`(config-router)#network 10.10.11.0/24 area 0`
`(config-router)#network 10.10.13.0/24 area 0`
`(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.

Validation

show ip ospf route

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, in turn, 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.

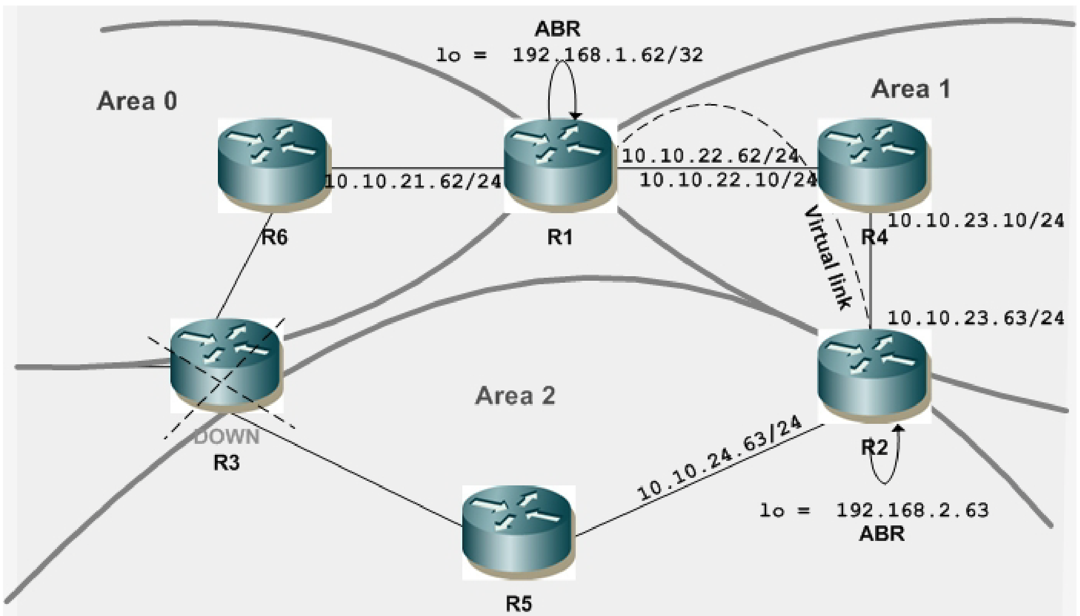

Figure 4-13: Virtual Links Topology

R1

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Specify loopback as the interface you want to configure.
`(config-if)#ip address 192.168.1.62/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit interface mode.
`(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.
`(config-router)#ospf router-id 192.168.1.62`	Configure the OSPF Router ID (`192.168.1.62`) for this router.
`(config-router)#network 10.10.21.0/24 area 0` `(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.
`(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

`(config)#interface lo`	Specify loopback as the interface you want to configure.
`(config-if)#ip address 192.168.2.63/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit interface mode.
`(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.
`(config-router)#ospf router-id 192.168.2.63`	Configure the OSPF Router ID (`192.168.1.63`) for this router.

`(config-router)#network 10.10.23.0/24 area 1`
`(config-router)#network 10.10.24.0/24 area 2`
`(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.

`(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`.

Validation

show ip ospf virtual-links, show ip ospf neighbor, show ip ospf, show ip ospf route

OSPF Authentication

There are three types of OSPF authentications--Null (Type 0), Simple Text (Type 1), and MD5 (Type 2). With Null authentication, routing exchanges over the network are not authenticated. In Simple Text authentication, the authentication type is the same for all routers that communicate using OSPF in a network. For MD5 authentication, 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 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 the Area authentication type, the 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.

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.

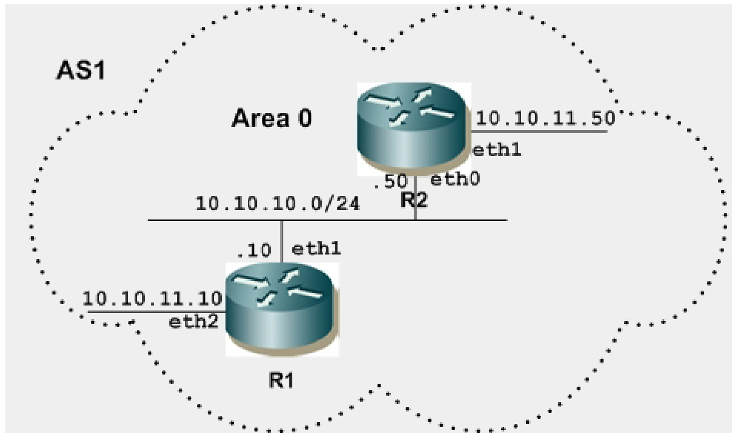

Figure 4-14: OSPF Authentication Topology

R1

`#configure terminal`	Enter configure mode.
`(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.
`(config-router)#network 10.10.10.0/24 area 0` `(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).
`(config-router)#area 0 authentication message-digest`	Enable MD5 authentication on area 0.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure.
`(config-if)#ip ospf message-digest-key 1 md5 test`	Register the MD5 key test for OSPF authentication. The key ID is 1.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode
`(config)#interface eth2`	Specify the interface (`eth2`) to configure.
`(config-if)#ip ospf authentication`	Enable the OSPF packet to use text authentication on the current interface (`eth2`).
`(config-if)#ip ospf authentication-key test`	Specify an OSPF authentication password (`test`) for the neighboring routers.

R2

`#configure terminal`	Enter configure mode.
`(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.
`(config-router)#network 10.10.10.0/24 area 0` `(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).

`(config-router)#area 0 authentication message-digest`	Enable MD5 authentication on area 0.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#interface eth0`	Specify the interface (`eth0`) to configure.
`(config-if)#ip ospf message-digest-key 1 md5 test`	Register MD5 key test for OSPF authentication. The key ID is 1.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth1`	Specify the interface (`eth2`) to configure.
`(config-if)#ip ospf authentication`	Enable the OSPF packet to use text authentication on the current interface (`eth1`).
`(config-if)#ip ospf authentication-key test`	Specify an OSPF authentication password `test` for the neighboring routers.

Validation

show run, show ip ospf neighbor

Multiple OSPF Instances

By using multiple OSPF instances, OSPF routes can be segregated, based on their instance number. Routes of one instance are stored differently from routes of another instance running in the same router.

To configure multiple OSPF instances, perform the following procedures referring to the topology diagram below:

1. Enable OSPF on an interface.
2. Enable multiple instances.
3. Configure redistribution among multiple instances.

   Note: Optionally, redistribution can be configured with the metric, type or route-map options.

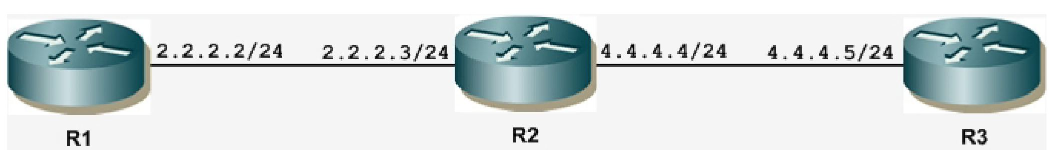

Figure 4-15: Multiple OSPF Instances

Enable OSPF on an Interface

R1 and R2 are two routers in Area 0 connecting to network 2.2.2.0/24.

R1

`(config)#int eth1`	Specify the interface on which OSPF is to be enabled.
`(config-if)#no shutdown`	Activate the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 10`	Configure an OSPF instance with an instance ID of `10`.

(config-router)#router-id 5.5.5.5	Configure the router ID to use on this instance.
(config-router)#network 2.2.2.0/24 area 0	Advertise the network with the area ID.

R2

(config)#int eth1	Specify the interface on which OSPF is to be enabled.
(config-if)#no shutdown	Activate the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 10	Configure an OSPF instance with an instance ID of 10.
(config-router)#router-id 6.6.6.6	Configure the router ID to use on this instance.
(config-router)#network 2.2.2.0/24 area 0	Advertise the network with the area ID.

Enable Multiple OSPF Instances on a Router

In this example, routers R1, R2, and R3 are in Area 0, and all run OSPF.

R1

(config)#int eth1	Enter the Interface mode for eth1.
(config-if)#no shutdown	Activate the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 10	Configure an OSPF instance with an instance ID of 10.
(config-router)#router-id 5.5.5.5	Configure the router ID to use on this instance.
(config-router)#network 2.2.2.0/24 area 0	Advertise the network with the area ID.

R2

(config)#int eth1	Enter the Interface mode for eth1.
(config-if)#no shutdown	Activate the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 10	Configure an OSPF instance with an instance ID of 10.
(config-router)#router-id 6.6.6.6	Configure the router ID to use on this instance.
(config-router)#network 2.2.2.0/24 area 0	Advertise the network with the area ID.
(config-router)#exit	Exit router mode.
(config)#int eth2	Enter the Interface mode for eth2.
(config-if)#ip address 4.4.4.4/24	Configure the IP address.
(config-if)#no shutdown	Activate the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 15	Configure an OSPF instance with an instance ID of 15.
(config-router)#router-id 8.8.8.8	Configure the router ID to use on this instance.
(config-router)#network 4.4.4.0/24 area 0	Advertise the network with the area ID.

R3

(config)#int eth1	Enter the Interface mode for eth1.
(config-if)#ip address 4.4.4.5/24	Configure the IP address.
(config-if)#no shutdown	Activate the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 15	Configure an OSPF instance with an instance ID of 15.
(config-router)#router-id 7.7.7.7	Configure the router ID to use on this instance.
(config-router)#network 4.4.4.0/24 area 0	Advertise the network with the area ID.

Redistribute among Multiple Instances

In this example, routes of one instance are redistributed to another instance to enable ping from R1 to R3 or vice versa; and R2 redistributes routes from one instance to another.

R2

(config)#router ospf 15	Configure an OSPF instance with instance ID 15.
(config-router)#router-id 7.7.7.7	Configure the router ID.
(config-router)#redistribute ospf 10	Redistribute instance 10 routes.
(config-router)#redistribute connected	Redistribute connected routes to instance 15.
(config-router)#exit	Exit Router mode, and return to Configure mode.
(config)#router ospf 10	Configure an OSPF instance with instance ID 10.
(config-router)#router-id 6.6.6.6	Configure the router ID.
(config-router)#redistribute ospf 15	Redistribute instance 15 routes.
(config-router)#redistribute connected	Redistribute connected routes to instance 10.

Redistribution with the Metric Option

In this example, on R3, R1 and R2 have each other's routes with a metric of 100.

R2

(config)#router ospf 15	Configure an OSPF instance with instance ID 15.
(config-router)#router-id 8.8.8.8	Configure the router ID.
(config-router)#redistribute ospf 10 metric 100	Redistribute instance 10 routes with metric 100.
(config-router)#redistribute connected	Redistribute connected routes to instance 15.
(config-router)#exit	Exit Router mode, and return to Configure mode.
(config)#router ospf 10	Configure an OSPF instance with instance ID 10.
(config-router)#router-id 6.6.6.6	Configure the router ID.
(config-router)#redistribute ospf 15 metric 100	Redistribute instance 15 routes with metric 100.
(config-router)#redistribute connected	Redistribute connected routes to instance 10.

Redistribution with the Type Option

In this example, on R3, R1 has R3 routes as type 2, and R2 has R1 routes as type 1.

R2

(config)#router ospf 15	Configure an OSPF instance with instance ID 15.
(config-router)#router-id 8.8.8.8	Configure the router ID.
(config-router)#redistribute ospf 10 metric-type 1	Redistribute instance 10 routes with metric-type 1.
(config-router)#redistribute connected	Redistribute connected routes to instance 15.
(config-router)#exit	Exit Router mode, and return to Configure mode.
(config)#router ospf 10	Configure an OSPF instance with instance ID 10.
(config-router)#router-id 6.6.6.6	Configure the router ID.
(config-router)#redistribute ospf 15 metric-type 2	Redistribute instance 15 routes with type 2.
(config-router)#redistribute connected	Redistribute connected routes to instance 10.

Redistribution with the Route-Map Option

R2

(config)#router ospf 15	Configure an OSPF instance with instance ID 15.
(config-router)#router-id 8.8.8.8	Configure the router ID.
(config-router)#redistribute ospf 10 route-map map 1	Redistribute instance 10 routes with route map 1.
(config-router)#redistribute connected	Redistribute connected routes to instance 15.
(config-router)#exit	Exit Router mode, and return to Configure mode.
(config)#router ospf 10	Configure an OSPF instance with instance ID 10.
(config-router)#router-id 6.6.6.6	Configure the router ID.
(config-router)#redistribute ospf 15 route-map 2	Redistribute instance 15 routes with route map 2.
(config-router)#redistribute connected	Redistribute connected routes to instance 10.

Validation

show ip ospf neighbor, show ip route, show ip ospf route

Multiple OSPF Instances on Same Subnet

Multiple OSPF instances can be configured on the same subnet. The OSPF instance ID supports separate OSPFv2 protocol instances. With this feature, an adjacency is formed only if the received packet’s instance ID is the same as the instance ID configured for that interface.

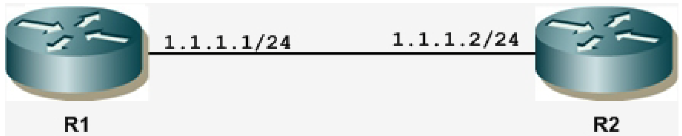

Figure 4-16: Multiple Instances on the Same Subnet

R1

`#configure terminal`	Enter configure mode.
`(config)#enable ext-ospf-multi-inst`	Enable multiple-instance capability.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 1.1.1.0/24 area 0 instance-id 1`	Advertise the network in Area 0 with an instance ID of `1`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 2`	Configure an OSPF instance with an instance ID of `2`.
`(config-router)#network 1.1.1.0/24 area 0 instance-id 2`	Advertise the network in Area 0 with an instance ID of `2`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

R2

`#configure terminal`	Enter configure mode.
`(config)#enable ext-ospf-multi-inst`	Enable multiple-instance capability.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 1.1.1.0/24 area 0 instance-id 1`	Advertise the network in Area 0 with an instance ID of `1`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 2`	Configure an OSPF instance with an instance ID of `2`.
`(config-router)#network 1.1.1.0/24 area 0 instance-id 2`	Advertise the network in Area 0 with an instance ID of `2`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

Validation

show ip ospf interface, show ip ospf neighbor

Remove a Multiple-Instance Configuration

R1

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Identify OSPF instance 1.
`(config-router)#no network 1.1.1.0/24 area 0 instance-id 1`	Disable OSPF for instance ID 1.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 2`	Identify OSPF instance 2.
`(config-router)#no network 1.1.1.0/24 area 0 instance-id 2`	Disable OSPF for instance ID 2.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#no enable ext-ospf-multi-inst`	Disable multiple-instance capability.

R2

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Identify OSPF instance 1.
`(config-router)#no network 1.1.1.0/24 area 0 instance-id 1`	Disable OSPF for instance ID 1.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 2`	Identify OSPF instance 2.
`(config-router)#no network 1.1.1.0/24 area 0 instance-id 2`	Disable OSPF for instance ID 2.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#no enable ext-ospf-multi-inst`	Disable multiple-instance capability.

Same Subnet in Multiple OSPF Areas

Multiple OSPF areas for a same subnet can be configured between two routers. In the diagram below, OSPF is enabled between R2 and R3 under area 0 and area 1, though there is only one link available between these two routers. Multi-area adjacency allows establishing adjacency on multiple areas between the Area Border Routers (ABRs). The specified interface of the ABR is associated with multiple areas.

Each multi-area-adjacency internally implements point-to-point functionality, once the adjacency reaches the FULL state. This point-to-point link provides a topological path for that area. Like a virtual link, there is no restriction for multi-area adjacency that the packets always go through the backbone.

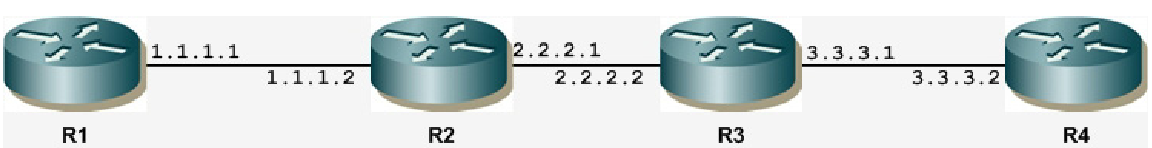

Figure 4-17: One Subnet with Multiple OSPF Areas

R1

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 1.1.1.0/24 area 1`	Configure OSPF between R1 and R2 under area `1`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

R2

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 1.1.1.0/24 area 1`	Configure OSPF between R1 and R2 under area `1`.
`(config-router)#network 2.2.2.0/24 area 0`	Configure OSPF between R2 and R3 under area `0`.
`(config-router)#area 1 multi-area-adjacency eth1 neighbor 2.2.2.2`	Configure area 1 on a link where area 0 is already configured.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

R3

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 2.2.2.0/24 area 0`	Configure OSPF between R2 and R3 under area `0`.
`(config-router)#network 3.3.3.0/24 area 1`	Configure OSPF between R3 and R4 under area `1`.
`(config-router)#area 1 multi-area-adjacency eth1 neighbor 2.2.2.1`	Configure area 1 on a link where area 0 is already configured.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

R4

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure an OSPF instance with an instance ID of `1`.
`(config-router)#network 3.3.3.0 area 1`	Configure OSPF between R3 and R4 under area `1`.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

Validation

show ip ospf multi-area-adjacencies

Virtual Router for Management Debugging

ZebOS-XP can enable debugging per Virtual Router (VR) for several protocol modules, including OSPF. Debugging output is visible only within that VR, except for the PVR (Privileged VR).

Note: VR/VRF is supported only for 3.X kernel on hardware platforms.

For details, see the *Integrated Module Interface Command Reference*.

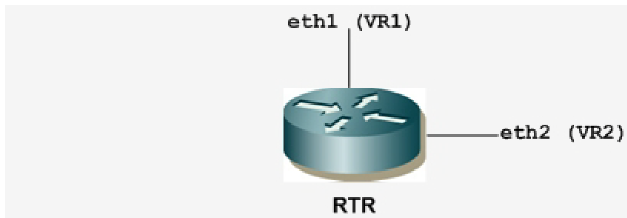

Figure 4-18: VR for Management Debugging

`#configure terminal`	Enter the Configure mode.
`(config)#virtual-router vr1`	Create a virtual router VR1 context.
`(config-vr)#load ospf`	Enter VR mode and enable OSPF for VR1 context.
`(config-vr)#exit`	Exit VR mode and return to Configure mode.
`(config)#virtual-router vr2`	Enter VR mode and create a virtual router VR2 context.
`(config-vr)#load ospf`	Enable OSPF for VR2 context.
`(config-vr)#exit`	Exit VR mode and return to Configure mode.
`(config)#interface eth1`	Enter the interface mode for `eth1`.
`(config-if)#virtual-router forwarding vr1`	Attach the `eth1` interface to VR1 context.
`(config-if)#exit`	Exit Interface mode and return to Configure mode.
`(config)#interface eth2`	Enter the interface mode for `eth2`.
`(config-if)#virtual-router forwarding vr2`	Attach the `eth2` interface to VR2 context.
`(config-if)#exit`	Exit to PVR mode.
`(config-if)#exit`	Exit Interface mode and return to Configure mode.
`(config)exit`	Exit Configure mode.
`#login virtual-router vr1`	Login to VR1 context.
`#configure terminal`	Enter the Configure mode in VR1 context.
`(config)#interface eth1`	Enter the interface mode in VR1.
`(config-if)#ip address 10.1.1.1/24`	Assign IP address `10.1.1.1/24` to `eth1`.
`(config-if)#exit`	Exit Interface mode and return to Configure mode.
`(config)#router ospf 100`	Enter Configure Router mode and create an OSPF routing process.
`(config-router)#network 10.1.1.0/24 area 0`	Attach network `10.1.1.1/24 t`o area 0.
`(config-router)#exit`	Exit Configure Router mode and return to Configure mode.
`(config)#debug ospf all`	Enable debugging for OSPF.
`(config)#log file`	Enable logging to default file.
`(config)#exit`	Exit configure mode

`#exit`	Exit PVR mode.
`#login virtual-router vr2`	Login to VR2 context.
`#configure terminal`	Enter the Configure mode in VR2 context.
`(config)#interface eth2`	Enter the interface mode in VR2.
`(config-if)#ip address 20.1.1.1/24`	Assign IP address `20.1.1.1.1/24` to `eth2`.
`(config-if)#exit`	Exit Interface mode and return to Configure mode.
`(config)#router ospf 200`	Create an OSPF routing process.
`(config-router)#network 20.1.1.0/24 area 0`	Attach the network `20.1.1.1/24` to area 0.
`(config-router)#exit`	Exit Configure Router mode and return to Configure mode.
`(config)#debug ospf all`	Enable debugging for OSPF.
`(config)#log file vr2.log`	Enable logging to user-assigned file name `vr2.log`.
`(config)#exit`	Exit configure mode
`#exit`	Exit to PVR mode.

Validation

The following commands are used to verify logging and are available only to privileged VR (PVR) users.

- show vlog all
- show vlog clients
- show vlog virtual-routers
- show vlog terminals

Debug messages can be viewed on the terminal by entering the following command:

```
terminal monitor
```

Viewing of debug messages on the terminal can be stopped by entering the following command:

```
no terminal monitor
```

LSA Throttling

This section contains basic OSPF LSA throttling configuration examples.

The OSPF Link-State Advertisement (LSA) throttling feature provides a mechanism to dynamically slow down link-state advertisement (LSA) updates in OSPF during times of network instability. It also allows faster OSPF convergence by providing LSA rate limiting in milliseconds, when network is stable.

How OSPF LSA Throttling Works

The `timers throttle lsa all` command controls the generation (sending) of LSAs. The first LSA is always generated immediately upon an OSPF topology change, and the next LSA generated is controlled by the minimum start interval. The subsequent LSAs generated for the same LSA are rate-limited until the maximum interval is reached. The “same LSA” is defined as an LSA instance that contains the same LSA ID number, LSA type, and advertising router ID.

The `timers lsa arrival` command controls the minimum interval for accepting the same LSA. If an instance of the same LSA arrives sooner than the interval that is set, the LSA is dropped. It is recommended that the arrival interval be less than or equal to the hold-time interval of the `timers throttle lsa all` command.

Topology

The diagram shows the minimum configuration required to enable OSPF LSA Throttling Timers feature. 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. It is possible, however, to configure different interfaces on a router to belong to different areas.

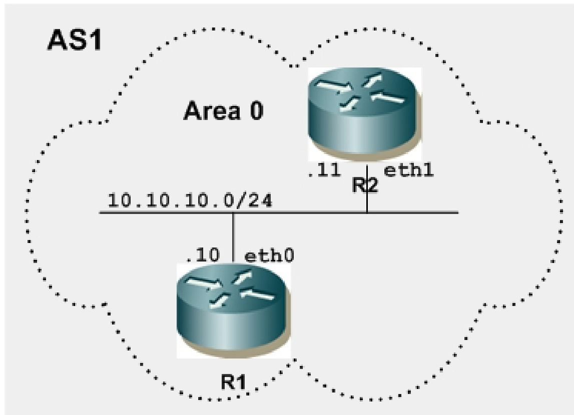

Figure 4-19: Basic OSPF Topology

R1

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Specify the interface loopback to configure.
`(config-if)#ip address 1.1.1.1/32`	Configure the ip address (1.1.1.1) to interface loopback.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`(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).
`(config-router)#network 1.1.1.1/32 area 0`	Define the interface (`1.1.1.1/32`) on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)#timers throttle lsa all 10000 20000 45000`	Configure LSA Throttling timers (Starting interval : <0-600000>, Min Hold Interval : <1-600000> and Max Wait Interval :< 1-600000>) in milliseconds. The Default value for corresponding timers are: Starting interval: 0, Min Hold Interval: 5 sec and Max Wait Interval: 5 sec.
`(config-router)#end`	Exit router mode

R2

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID `(1)`. The Process ID should be a unique positive integer identifying the routing process.
`(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.

Validation

R1

Check the output of `show ip ospf` and verify the initial throttle delay, minimum hold time for LSA throttle and maximum wait time for LSA throttle.

```
#show ip ospf 1
 Routing Process "ospf 1" with ID 4.1.1.1
 Process uptime is 1 minute
 Process bound to VRF default
 Conforms to RFC2328, and RFC1583 Compatibility flag is disabled
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Graceful Restart
 This router is an ASBR (injecting external routing information)
 SPF schedule delay min 0 secs 500 msecs
 SPF schedule delay max 50 secs 0 msecs
 Refresh timer 10 secs
 Number of incomming current DD exchange neighbors 0/5
 Number of outgoing current DD exchange neighbors 0/5
 Initial LSA throttle delay 10 secs 0 msecs
 Minimum hold time for LSA throttle 20 secs 0 msecs
 Maximum wait time for LSA throttle 45 secs 0 msecs
 Minimum LSA arrival 1 secs 0 msecs
 Number of external LSA 5. Checksum 0x010632
 Number of opaque AS LSA 0. Checksum 0x000000
 Number of non-default external LSA 5
 External LSA database is unlimited.
 Number of LSA originated 6
 Number of LSA received 0
 Number of areas attached to this router: 1
    Area 0 (BACKBONE)
        Number of interfaces in this area is 1(1)
        Number of fully adjacent neighbors in this area is 0
        Area has no authentication
        SPF algorithm last executed 00:00:47.558 ago
        SPF algorithm executed 2 times
        Number of LSA 1. Checksum 0x0041e0
```

Check the output of `show ip ospf` and verify that OSPF adjacency is up.

```
#sh ip ospf neighbor

OSPF process 1:
Neighbor ID     Pri   State           Dead Time   Address         Interface Inst
ance ID
10.12.49.102      1   Full/DR         00:00:38    10.10.10.10     eth2       0
```

Enable `ospf database-timer rate-limit` debugging to verify the LSA refresh being sent according to configured LSA throttling timers.

```
#debug ospf database-timer rate-limit
#show debugging ospf
OSPF debugging status:
  OSPF rate limit timer events debugging is on
```

Perform shut/no shut based on LSA throttling timers and check if the LSA refresh are sent accordingly.

```
(config)#int lo
(config-if)#shutdown
<pvr> : 2012/06/07 03:16:52 OSPF[ 2050]: Starting Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: with 10000 msec delay

(config-if)#
<pvr> : 2012/06/07 03:17:02 OSPF[ 2050]: Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: expired
<pvr> : 2012/06/07 03:17:02 OSPF[ 2050]: For Next Instance of
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: generation wait 20000 msec

(config-if)#no shutdown
<pvr> : 2012/06/07 03:17:05 OSPF[ 2050]: Starting Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: with 17107 msec delay

(config-if)#
<pvr> : 2012/06/07 03:17:22 OSPF[ 2050]: Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: expired
<pvr> : 2012/06/07 03:17:22 OSPF[ 2050]: For Next Instance of
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: generation wait 40000 msec

(config-if)#shutdown
<pvr> : 2012/06/07 03:17:25 OSPF[ 2050]: Starting Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: with 36873 msec delay

(config-if)#no shutdown
<pvr> : 2012/06/07 03:18:03 OSPF[ 2050]: Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: expired
<pvr> : 2012/06/07 03:18:03 OSPF[ 2050]: For Next Instance of
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: generation wait 45000 msec
<pvr> : 2012/06/07 03:18:04 OSPF[ 2050]: Starting Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: with 43332 msec delay

(config-if)#
<pvr> : 2012/06/07 03:18:48 OSPF[ 2050]: Rate Limit Timer for
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: expired
<pvr> : 2012/06/07 03:18:48 OSPF[ 2050]: For Next Instance of
LSA[0.0.0.0:Type1:4.1.1.1:(self)]: generation wait 45000 msec
```

R2

Check the output of "show ip ospf neighbor" and verify that OSPF adjacency is up.

```
#show ip ospf neighbor

OSPF process 1:
Neighbor ID     Pri   State           Dead Time   Address         Interface Inst
ance ID
4.1.1.1           1   Full/Backup     00:00:36    10.10.10.11     eth1        0
```

Check the output of `show ip ospf database` and verify that LSA (router LSA in this example) is updated according to the configured LSA throttling timers configured on its neighbor.

```
#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1           76 0x80000002 0x8ee5 2
10.12.49.102    10.12.49.102      77 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1           85 0x80000002 0x8ee5 2
10.12.49.102    10.12.49.102      83 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1            1 0x80000003 0x945d 1
10.12.49.102    10.12.49.102      84 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1           20 0x80000003 0x945d 2
10.12.49.102    10.12.49.102     104 0x80000002 0x6d39 1
```



```
#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1            1 0x80000004 0x8ae7 2
10.12.49.102    10.12.49.102     105 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1           40 0x80000004 0x8ae7 2
10.12.49.102    10.12.49.102     144 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1            1 0x80000005 0x905f 1
10.12.49.102    10.12.49.102     145 0x80000002 0x6d39 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1           45 0x80000005 0x905f 1
10.12.49.102    10.12.49.102     190 0x80000002 0x6d39 1
```

Configure OSPF LSA Arrival Timers

The diagram shows the minimum configuration required to enable OSPF Minimum LSA Arrival Timers feature. 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. It is possible, however, to configure different interfaces on a router to belong to different areas.

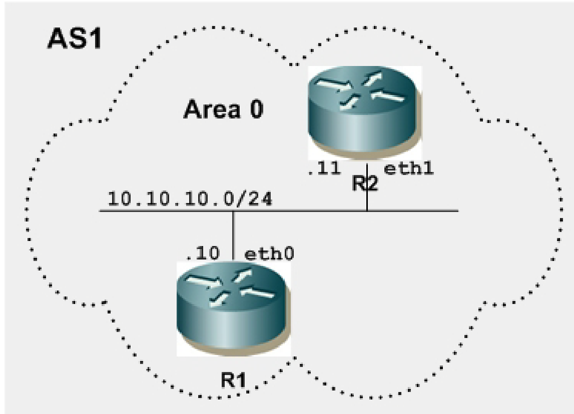

Figure 4-20: Basic OSPF Topology

R1

`#configure terminal`	Enter configure mode.
`(config)#interface lo`	Specify the interface loopback to configure.
`(config-if)#ip address 1.1.1.1/32`	Configure the ip address (1.1.1.1) to interface loopback.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`(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).
`(config-router)#network 1.1.1.1/32 area 0`	Define the interface (`1.1.1.1/32`) on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)#end`	Exit router mode

R2

`#configure terminal`	Enter configure mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID `(1)`. The Process ID should be a unique positive integer identifying the routing process.
`(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.
`(config-router)#timers lsa arrival 100000`	Configure Minimum LSA Arrival timers (Minimum LSA arrival Interval :< 0-600000>) in milliseconds. The Default value for Minimum LSA Arrival timer is: 1 sec.

Validation

R1:

Check the output of `show ip ospf` and verify that the minimum LSA arrival timer by default is set to 1 sec.

```
#show ip ospf
 Routing Process "ospf 1" with ID 4.1.1.1
 Process uptime is 2 hours 26 minutes
 Process bound to VRF default
 Conforms to RFC2328, and RFC1583 Compatibility flag is disabled
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
 Supports Graceful Restart
 SPF schedule delay min 0 secs 500 msecs
 SPF schedule delay max 50 secs 0 msecs
 Refresh timer 10 secs
 Number of incomming current DD exchange neighbors 0/5
 Number of outgoing current DD exchange neighbors 0/5
 Initial LSA throttle delay 0 secs 0 msecs
 Minimum hold time for LSA throttle 5 secs 0 msecs
 Maximum wait time for LSA throttle 5 secs 0 msecs
 Minimum LSA arrival 1 secs 0 msecs
 Number of external LSA 0. Checksum 0x000000
 Number of opaque AS LSA 0. Checksum 0x000000
 Number of non-default external LSA 0
 External LSA database is unlimited.
 Number of LSA originated 3
 Number of LSA received 24
 Number of areas attached to this router: 1
    Area 0 (BACKBONE)
        Number of interfaces in this area is 5(5)
        Number of fully adjacent neighbors in this area is 1
        Area has no authentication
        SPF algorithm last executed 02:23:11.479 ago
        SPF algorithm executed 8 times
        Number of LSA 7. Checksum 0x04136d
```

Check the output of `show ip ospf neighbor` and verify that OSPF adjacency is up.

```
#show ip ospf neighbor

OSPF process 1:
Neighbor ID     Pri   State           Dead Time   Address         Interface Inst
ance ID
10.12.49.102      1   Full/DR         00:00:39    10.10.10.10     eth2       0
```

R2:

Check the output of `show ip ospf` and verify that the minimum LSA arrival timer is set to 100 sec.

```
#show ip ospf
 Routing Process "ospf 1" with ID 10.12.49.102
 Process uptime is 2 hours 28 minutes
 Process bound to VRF default
 Conforms to RFC2328, and RFC1583 Compatibility flag is disabled
 Supports only single TOS(TOS0) routes
 Supports opaque LSA
```

```
 Supports Graceful Restart
 SPF schedule delay min 0 secs 500 msecs
 SPF schedule delay max 50 secs 0 msecs
 Refresh timer 10 secs
 Number of incomming current DD exchange neighbors 0/5
 Number of outgoing current DD exchange neighbors 0/5
 Initial LSA throttle delay 0 secs 0 msecs
 Minimum hold time for LSA throttle 5 secs 0 msecs
 Maximum wait time for LSA throttle 5 secs 0 msecs
 Minimum LSA arrival 100 secs 0 msecs
 Number of external LSA 0. Checksum 0x000000
 Number of opaque AS LSA 0. Checksum 0x000000
 Number of non-default external LSA 0
 External LSA database is unlimited.
 Number of LSA originated 6
 Number of LSA received 29
 Number of areas attached to this router: 1
    Area 0 (BACKBONE)
        Number of interfaces in this area is 1(1)
        Number of fully adjacent neighbors in this area is 1
        Area has no authentication
        SPF algorithm last executed 02:25:31.431 ago
        SPF algorithm executed 11 times
        Number of LSA 7. Checksum 0x04116e
```

Check the output of show ip ospf neighbor and verify that OSPF adjacency is up.

```
#show ip ospf neighbor

OSPF process 1:
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
4.1.1.1           1   Full/Backup     00:00:37    10.10.10.11     eth1       0
```

Check the output of “show ip ospf database” and verify that LSA is accepted only after a time difference of 100 sec between two consecutive LSAs.

```
#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
4.1.1.1         4.1.1.1          120 0x8000000b 0x8465 1
10.12.49.102    10.12.49.102     621 0x80000003 0x6b3a 1

#sh ip ospf database

            OSPF Router with ID (10.12.49.102) (Process ID 1)

                Router Link States (Area 0.0.0.0)

Link ID         ADV Router      Age  Seq#       CkSum  Link count
```

```
4.1.1.1         4.1.1.1         121 0x8000000c 0x7aef 5
10.12.49.102    10.12.49.102    621 0x80000003 0x6b3a 1
#
```

Loop-Free Alternate Fast Reroute

This section contains basic OSPF Loop-Free Alternate Fast Reroute (LFA-FRR) configuration examples.

Overview

The goal of (LFA-FRR) is to reduce failure reaction time to 10s of milliseconds by using a pre-computed alternate next-hop in the event that the currently selected primary next-hop fails, so that the alternate can be rapidly used when the failure is detected. A network with this feature experiences less traffic loss and less micro-looping of packets than a network without LFA-FRR.

After enabling LFA-FRR on routers, routers calculate a backup path for each primary path to reach the destination.The backup path is calculated based on the attributes such as node protecting, link protecting, and broadcast link protecting. If there is an ECMP route to a primary link, no backup is calculated.

Topology

The diagram shows the configuration required to enable the OSPF LFA feature.

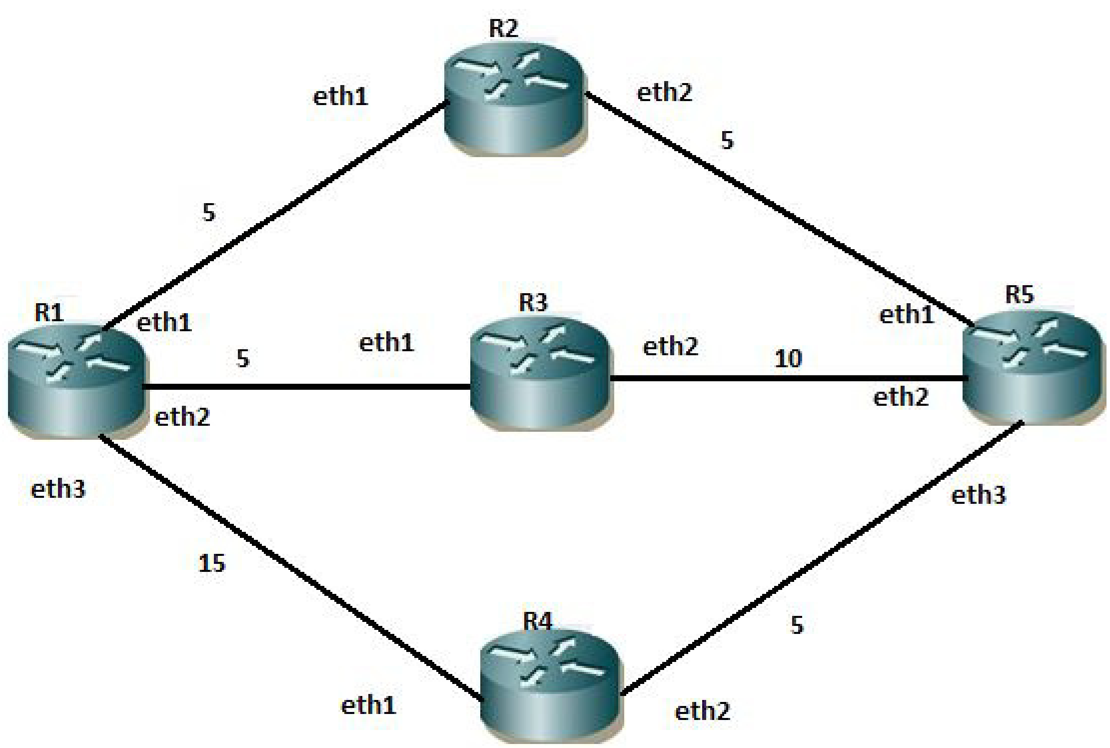

Figure 4-21: Basic OSPF-LFA Topology

R1

#configure terminal	Enter configure mode.
(config)#int eth1	Enter interface mode.
(config-if)#ip address 10.1.1.1/24	Configure the IP address of the interface.
(config-if)#exit	Exit interface mode.
(config)#int eth2	Enter interface mode.
(config-if)#ip address 20.1.1.1/24	Configure the IP address of the interface.
(config-if)#exit	Exit interface mode.
(config)#int eth3	Enter interface mode.
(config-if)#ip address 30.1.1.1/24	Configure the IP address of the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 1	Configure the routing process and specify the Process ID (1).
(config-router)#network 10.1.1.0/24 area 0	Define the interface (10.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
(config-router)#network 20.1.1.0/24 area 0	Define the interface (20.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
(config-router)#network 30.1.1.0/24 area 0	Define the interface (30.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
(config-router)#fast-reroute keep-all-paths	Configure LFA-FRR to calculate the available backup path.
(config-router)#end	Exit router mode.

R2

#configure terminal	Enter configure mode.
(config)#int eth1	Enter interface mode.
(config-if)#ip address 10.1.1.2/24	Configure the IP address of the interface.
(config-if)#exit	Exit interface mode.
(config)#int eth2	Enter interface mode.
(config-if)#ip address 40.1.1.1/24	Configure the IP address of the interface.
(config-if)#exit	Exit interface mode.
(config)#router ospf 1	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
(config-router)#network 10.1.1.0/24 area 0	Define the interface (20.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
(config-router)#network 40.1.1.0/24 area 0	Define the interface (40.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
(config-router)#end	Exit router mode.

R3

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ip address 20.1.1.2/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ip address 50.1.1.1/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`(config-router)#network 20.1.1.0/24 area 0`	Define the interface (`20.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#network 50.1.1.0/24 area 0`	Define the interface (`50.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#end`	Exit router mode.

R4

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ip address 30.1.1.2/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ip address 60.1.1.1/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`(config-router)#network 30.1.1.0/24 area 0`	Define the interface (`30.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#network 60.1.1.0/24 area 0`	Define the interface (`60.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#end`	Exit router mode.

R5

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ip address 40.1.1.2/24`	Configure the IP address of the interface.

`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ip address 50.1.1.1/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth3`	Enter interface mode.
`(config-if)#ip address 60.1.1.2/24`	Configure the IP address of the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#router ospf 1`	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
`(config-router)#network 40.1.1.0/24 area 0`	Define the interface (30.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#network 50.1.1.0/24 area 0`	Define the interface (30.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#network 60.1.1.0/24 area 0`	Define the interface (60.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`(config-router)#end`	Exit router mode.

Validation

R1:

Check OSPF neighborship.

```
#sh ip ospf neighbor

OSPF process 100 VRF(default):
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
2.2.2.2           1   Full/DR         00:00:33    10.1.1.2        eth1       0
3.3.3.3           1   Full/DR         00:00:33    20.1.1.2        eth2       0
4.4.4.4           1   Full/DR         00:00:39    30.1.1.2        eth3       0
#
```

Check the OSPF route installation and LFA-FRR backup path for the primary path.

```
#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
C       10.1.1.0/24 is directly connected, eth1
C       20.1.1.0/24 is directly connected, eth2
C       30.1.1.0/24 is directly connected, eth3
O       40.1.1.0/24 [110/10] via 10.1.1.2, eth1, 00:16:43
O       50.1.1.0/24 [110/15] via 20.1.1.2, eth2, 00:16:43
```



```
O IA    60.1.1.0/24 [110/15] via 10.1.1.2, eth1, 00:16:43
O E2    70.1.1.0/24 [110/20] via 30.1.1.2, eth3, 00:16:43
O E2    80.1.1.0/24 [110/20] via 10.1.1.2, eth1, 00:16:43
C       127.0.0.0/8 is directly connected, lo
C       192.168.100.0/24 is directly connected, eth0

Gateway of last resort is not set
#sh ip route fast-reroute
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
O       50.1.1.0/24 [110/20] via 10.1.1.2, eth1 inactive, 00:16:43
O       60.1.1.0/24 [110/20] via 20.1.1.2, eth2 inactive, 00:16:43
O       70.1.1.0/24 [110/20] via 10.1.1.2, eth1 inactive, 00:16:43
O       80.1.1.0/24 [110/15] via 20.1.1.2, eth2 inactive, 00:16:43
#
```

Not mandatory that for all primary path, there exists an LFA backup path only if inequality equation satisfies according to attributes configured on routers, backup path will be calculated.

To prohibit an interface from being used as a repair path, disable fast reroute calculation on the interface.

```
(config)#int eth2
(config-if)#ip ospf fast-reroute per-prefix candidate disable
(config-if)#end
```

Verify that the `eth3` interface is not used for backup path calculation.

```
#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
O       10.1.1.0/24 [110/10] via 20.1.1.1, eth1, 00:34:04
C       20.1.1.0/24 is directly connected, eth1
O       30.1.1.0/24 [110/20] via 20.1.1.1, eth1, 00:34:04
O       40.1.1.0/24 [110/15] via 20.1.1.1, eth1, 00:34:04
                    [110/15] via 50.1.1.2, eth2, 00:34:04
C       50.1.1.0/24 is directly connected, eth2
O IA    60.1.1.0/24 [110/15] via 50.1.1.2, eth2, 01:08:29
O E2    70.1.1.0/24 [110/20] via 20.1.1.1, eth1, 00:34:03
O E2    80.1.1.0/24 [110/20] via 50.1.1.2, eth2, 01:11:17
C       127.0.0.0/8 is directly connected, lo
C       192.168.100.0/24 is directly connected, eth0
```

```
Gateway of last resort is not set
#sh ip route fast-reroute
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
O       10.1.1.0/24 [110/20] via 50.1.1.2, eth2 inactive, 00:00:51
O       30.1.1.0/24 [110/35] via 50.1.1.2, eth2 inactive, 00:00:51
O       60.1.1.0/24 [110/20] via 20.1.1.1, eth1 inactive, 00:00:51
O       70.1.1.0/24 [110/30] via 50.1.1.2, eth2 inactive, 00:00:51
O       80.1.1.0/24 [110/15] via 20.1.1.1, eth1 inactive, 00:00:51
#
```

Now the LFA backup paths have been changed, `eth3` is not used.

Tie-Breaking Configuration:

By default, LFA backup path is calculated based on link protection. Other supported attributes are:

- Node-protecting
- Broadcast-link protecting
- Primary path

```
(config)#router ospf 100
(config-router)#fast-reroute tie-break broadcast-interface-disjoint index 1
(config-router)#fast-reroute tie-break node-protecting index 2
(config-router)#
```

Verify `show ip route` and `show ip route fast-reroute` for backup path calculated according to attributes configured above.

```
#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
C       10.1.1.0/24 is directly connected, eth1
C       20.1.1.0/24 is directly connected, eth2
C       30.1.1.0/24 is directly connected, eth3
O       40.1.1.0/24 [110/10] via 10.1.1.2, eth1, 01:07:26
O       50.1.1.0/24 [110/15] via 20.1.1.2, eth2, 01:07:26
O IA    60.1.1.0/24 [110/15] via 10.1.1.2, eth1, 01:07:26
O E2    70.1.1.0/24 [110/20] via 30.1.1.2, eth3, 01:07:26
O E2    80.1.1.0/24 [110/20] via 10.1.1.2, eth1, 01:07:26
C       127.0.0.0/8 is directly connected, lo
C       192.168.100.0/24 is directly connected, eth0
```



```
Gateway of last resort is not set
#sh ip route fast-reroute
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

IP Route Table for VRF "default"
O       50.1.1.0/24 [110/20] via 10.1.1.2, eth1 inactive, 00:00:15
O       60.1.1.0/24 [110/20] via 20.1.1.2, eth2 inactive, 00:00:15
O       70.1.1.0/24 [110/20] via 10.1.1.2, eth1 inactive, 00:00:15
O       80.1.1.0/24 [110/15] via 20.1.1.2, eth2 inactive, 00:00:15
#
```

OSPFv2 Flood Reduction

This section contains basic OSPF Flood reduction configuration examples.

By design, OSPF requires link-state advertisements (LSAs) to be refreshed as they expire after 3600 sec. Some implementations improve flooding by reducing the frequency of refresh timers from 30-50. This method reduces the refresh traffic but requires at least one refresh time before the LSA expires.

The OSPF Flood Reduction feature works by reducing unnecessary refreshing and flooding of already known and unchanged information. To achieve this reduction, the LSAs are flooded with the higher bit set, thus making them DoNotAge (DNA) LSAs.

Topology

The diagram shows the configuration required to enable the OSPF Flood reduction feature.

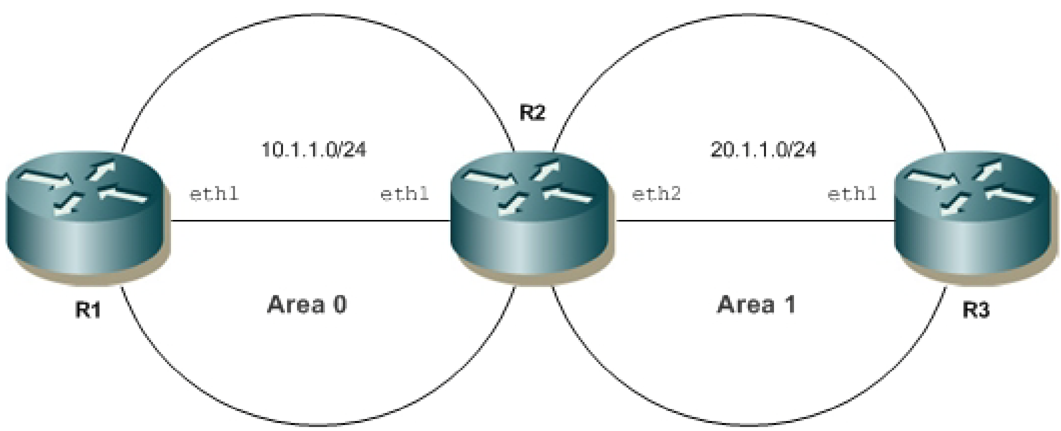

Figure 4-22: OSPF Flood-Reduction Topology

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ip address 10.1.1.1/24`	Configure the IP address of the interface.
`R1(config-if)#exit`	Exit interface mode.
`R1(config)#router ospf 1`	Configure the routing process and specify the Process ID (`1`).
`R1(config-router) #network 10.1.1.0/24 area 0`	Define the interface (`10.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`R1(config-router)#ospf flood-reduction`	Configure ospf flood reduction ,to make LSAs Do not age and wont be refreshed
`R1(config-router)#end`	Exit router mode.

R2

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ip address 10.1.1.2/24`	Configure the IP address of the interface.
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#int eth2`	Enter interface mode.
`R2(config-if)#ip address 20.1.1.1/24`	Configure the IP address of the interface.
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`R2(config-router)#network 10.1.1.0/24 area 0`	Define the interface (`20.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`R2(config-router)#network 20.1.1.0/24 area 1`	Define the interface (`20.1.1.0/24`) on which OSPF runs, and associate the area ID (1) with the interface
`R2(config-router)#ospf flood-reduction`	Configure ospf flood reduction ,to make LSAs Do not age and wont be refreshed
`R2(config-router)#end`	Exit router mode.

R3

`R3#configure terminal`	Enter configure mode.
`R3(config)#int eth1`	Enter interface mode.
`R3(config-if)#ip address 20.1.1.2/24`	Configure the IP address of the interface.
`R3(config-if)#exit`	Exit interface mode.

`R3(config)#router ospf 1`	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
`R3(config-router)#network 20.1.1.0/24 area 1`	Define the interface (20.1.1.0/24) on which OSPF runs, and associate the area ID (1) with the interface
`R3(config-router)#ospf flood-reduction`	Configure ospf flood reduction ,to make LSAs Do not age and wont be refreshed
`R3(config-router)#end`	Exit router mode.

Validation 1

R1:

```
#sh ip ospf neighbor
OSPF process 0 VRF(default):
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
192.168.100.46    1   Full/Backup     00:00:34    10.1.1.2        eth1       0
```

Check OSPF Database to verify DNA bit has set for LSA

The DNA bit is set for a remote device and the DNA bit is not set for a self-originated LSA.

```
#sh ip ospf database

            OSPF Router with ID (192.168.100.55) (Process ID 0 VRF default)

                Router Link States (Area 0.0.0.0)
Link ID         ADV Router      Age       Seq#       CkSum  Link count
192.168.100.46  192.168.100.46    1(DNA)  0x80000007 0x38e0 1
192.168.100.55  192.168.100.55  465       0x80000006 0x9871 1

                Net Link States (Area 0.0.0.0)
Link ID         ADV Router      Age       Seq#       CkSum
10.1.1.1        192.168.100.55  465       0x80000002 0xed38

                Summary Link States (Area 0.0.0.0)
Link ID         ADV Router      Age       Seq#       CkSum  Route
20.1.1.0        192.168.100.46    1(DNA)  0x80000001 0x9792 20.1.1.0/24

                Area-Local Opaque-LSA (Area 0.0.0.0)
Link ID         ADV Router      Age       Seq#       CkSum  Opaque ID
1.0.0.1         192.168.100.46    1(DNA)  0x80000002 0x2a0c 1
1.0.0.1         192.168.100.55  463       0x80000002 0x4ed5 1
1.0.0.8         192.168.100.46    1(DNA)  0x80000002 0x211a 8
1.0.0.8         192.168.100.55  463       0x80000002 0xcc66 8
#
```

R2:

```
#sh ip ospf neighbor

OSPF process 0 VRF(default):
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
```

```
192.168.100.55    1   Full/DR         00:00:36    10.1.1.1        eth1       0
192.168.100.50    1   Full/DR         00:00:36    20.1.1.2        eth2       0
#sh ip ospf database

            OSPF Router with ID (192.168.100.46) (Process ID 0 VRF default)

                Router Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Link count
192.168.100.46  192.168.100.46  1480      0x80000007 0x38e0 1
192.168.100.55  192.168.100.55     1(DNA) 0x80000006 0x9871 1

                Net Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum
10.1.1.1        192.168.100.55     1(DNA) 0x80000002 0xed38


                Summary Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Route
20.1.1.0        192.168.100.46  1621      0x80000001 0x9792 20.1.1.0/24

                Area-Local Opaque-LSA (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Opaque ID
1.0.0.1         192.168.100.46  1483      0x80000002 0x2a0c 1
1.0.0.1         192.168.100.55     1(DNA) 0x80000002 0x4ed5 1
1.0.0.8         192.168.100.46  1483      0x80000002 0x211a 8
1.0.0.8         192.168.100.55     1(DNA) 0x80000002 0xcc66 8

                Router Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Link count
192.168.100.46  192.168.100.46  1471      0x80000007 0xe81c 1
192.168.100.50  192.168.100.50     1(DNA) 0x80000006 0xb548 1

                Net Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum
20.1.1.2        192.168.100.50     1(DNA) 0x80000001 0x4fd6

                Summary Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Route
10.1.1.0        192.168.100.46   444      0x80000002 0x181b 10.1.1.0/24

                Area-Local Opaque-LSA (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Opaque ID
1.0.0.1         192.168.100.46  1474      0x80000002 0x2a0c 1
1.0.0.1         192.168.100.50     1(DNA) 0x80000002 0x3af3 1
1.0.0.8         192.168.100.50     1(DNA) 0x80000002 0xec35 8
1.0.0.10        192.168.100.46  1474      0x80000002 0xd252 10
#
```

Validation 2

To disable flood reduction on a particular interface, use the below command

On disabling flood reduction DNA bit should be removed from database and LSA refresh should take place at regular intervals.

```
#conf ter
Enter configuration commands, one per line.  End with CNTL/Z.
(config)#int eth2
(config-if)#no ip ospf flood-reduction
(config-if)#end
#sh ip ospf database

            OSPF Router with ID (192.168.100.46) (Process ID 0 VRF default)
                Router Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Link count
192.168.100.46  192.168.100.46   248      0x80000004 0x3edd 1
192.168.100.55  192.168.100.55   252      0x80000004 0x9c6f

                Net Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum
10.1.1.1        192.168.100.55   252      0x80000001 0xef37

                Summary Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Route
20.1.1.0        192.168.100.46   294      0x80000001 0x9792 20.1.1.0/24

                Area-Local Opaque-LSA (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Opaque ID
1.0.0.1         192.168.100.46   249      0x80000001 0x2c0b 1
1.0.0.1         192.168.100.55   250      0x80000001 0x50d4 1
1.0.0.8         192.168.100.46   249      0x80000001 0x2319 8
1.0.0.8         192.168.100.55   250      0x80000001 0xce65 8

                Router Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Link count
192.168.100.46  192.168.100.46   246      0x80000004 0xee19 1
192.168.100.50  192.168.100.50     1(DNA) 0x80000004 0xb946 1

                Net Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum
20.1.1.2        192.168.100.50     1(DNA) 0x80000001 0x4fd6

                Summary Link States (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Route
10.1.1.0        192.168.100.46   294      0x80000001 0x1a1a 10.1.1.0/24

                Area-Local Opaque-LSA (Area 0.0.0.1)
Link ID         ADV Router       Age      Seq#       CkSum  Opaque ID
1.0.0.1         192.168.100.46   244      0x80000001 0x2c0b 1
1.0.0.1         192.168.100.50     1(DNA) 0x80000001 0x3cf2 1
1.0.0.8         192.168.100.50     1(DNA) 0x80000001 0xee34 8
1.0.0.10        192.168.100.46   244      0x80000002 0xd252 10
#
```

Validation 3

When there is demand circuit incapable router, Indication LSA will be generated by an ABR to other areas, so that other routers which are demand circuit and DNA capable will stop sending DNA bit set LSAs and LSA will be refreshed at regular intervals.

In ASBR-Summary link states for Link-ID 6.6.6.6 the term 'I LSA' indicates that the Indication LSA is received from an ABR and that the DNA bit should be cleared

Show output for Indication LSA:

```
#sh ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 0 VRF default)

                Router Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Link count
1.1.1.1         1.1.1.1         1041      0x80000112 0xd9e4 2
2.2.2.2         2.2.2.2          169      0x8000011e 0x296c 2
4.4.4.4         4.4.4.4         1058      0x800000c0 0xb657 1
6.6.6.6         6.6.6.6          856      0x800000fd 0xeee5 1

                Net Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum
10.1.1.2        2.2.2.2          499      0x800000b4 0xc49f
20.1.1.2        6.6.6.6          606      0x800000b5 0x50e8
30.1.1.2        4.4.4.4         1448      0x800000b3 0xfb41

                Summary Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Route
40.1.1.0        4.4.4.4         1298      0x800000b3 0x9eaf 40.1.1.0/24
40.1.1.0        6.6.6.6         1256      0x800000b4 0x56ef 40.1.1.0/24
50.1.1.0        4.4.4.4          988      0x800000b8 0x0838 50.1.1.0/24
50.1.1.0        6.6.6.6          816      0x800000b3 0xdf5c 50.1.1.0/24

                ASBR-Summary Link States (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum
6.6.6.6         6.6.6.6          466      0x800000b3 0x2e4bI LSA

                Area-Local Opaque-LSA (Area 0.0.0.0)
Link ID         ADV Router       Age      Seq#       CkSum  Opaque ID
1.0.0.1         1.1.1.1           80      0x800000b3 0xcaa9 1
1.0.0.1         2.2.2.2         1209      0x800000c4 0xacae 1
1.0.0.1         4.4.4.4          918      0x800000bb 0xc68d 1
1.0.0.1         6.6.6.6         1526      0x800000b3 0xde6d 1
1.0.0.8         1.1.1.1         1671      0x800000b2 0x7909 8
1.0.0.8         2.2.2.2          869      0x800000bb 0x670d 8
1.0.0.8         4.4.4.4         1018      0x800000bb 0xc67d 8
1.0.0.8         6.6.6.6          376      0x800000b2 0xce8a 8
1.0.0.10        1.1.1.1          460      0x800000b3 0x313a 10
1.0.0.10        2.2.2.2          999      0x800000ba 0xd279 10
```


Demand Circuit

This section contains basic OSPFv2 Demand Circuit configuration examples.

Demand circuits are network segments whose costs vary with usage; charges can be based both on connect time and on bytes/packets transmitted. Examples of demand circuits include ISDN circuits, X.25 SVCs, and dial-up lines.The periodic nature of OSPF routing traffic has until now required a demand circuit's underlying data-link connection to be constantly open, resulting in unwanted usage charges. With the modifications described herein, OSPF Hellos and the refresh of OSPF routing information are suppressed on demand circuits, allowing the underlying data-link connections to be closed when not carrying application traffic.

Demand circuits and regular network segments (e.g., leased lines) are allowed to be combined in any manner. In other words, there are no topological restrictions on the demand circuit support. However, while any OSPF network segment can be defined as a demand circuit, only point-to-point networks receive the full benefit. When broadcast and NBMA networks are declared demand circuits, routing update traffic is reduced but the periodic sending of Hellos is not, which in effect still requires the data-link connections remain constantly open.

Point-to-Point network

The diagram shows the configuration required to enable the OSPF Demand Circuit feature at the interface level in a P2P network

Note: There is no global level configuration for demand circuits.

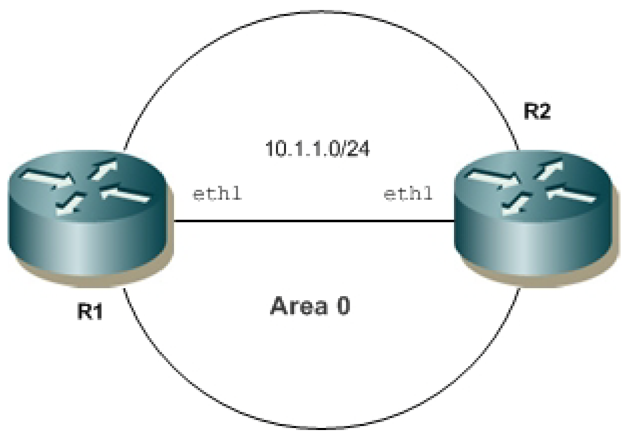

Figure 4-23: OSPF Demand Circuit Topology

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ip address 10.1.1.1/24`	Configure the IP address of the interface.
`R1(config-if)#ip ospf demand-circuit`	Enable demand circuit on the interface
`R1(config-if)#ip ospf network point-point`	Enable the network type as point to point
`R1(config-if)# exit`	Exit interface mode.
`R1(config)#router ospf 1`	Configure the routing process and specify the Process ID (1).

R1(config-router) #network 10.1.1.0/24 area 0	Define the interface (10.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
R1(config-router)#end	Exit router mode.

R2

R2#configure terminal	Enter configure mode.
R2(config)#int eth1	Enter interface mode.
R2(config-if)#ip address 10.1.1.2/24	Configure the IP address of the interface.
R2(config-if)#ip ospf demand-circuit	Enable demand circuit on the interface
R2(config-if)#ip ospf network point-point	Enable the network type as point to point
R2(config-if)#exit	Exit interface mode.
R2(config)#router ospf 1	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
R2(config-router)#network 10.1.1.0/24 area 0	Define the interface (10.1.1.0/24) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
R2(config-router)#end	Exit router mode.

Validation1

Verify in the neighbor output the dead timer should be inactive after enabling demand-circuit. Hence, hello's will be suppressed.

R2:

```
rtr2#show ip ospf neighbor
Total number of full neighbors: 1
OSPF process 1 VRF(default):
Neighbor ID     Pri   State            Dead Time   Address         Interface Instance ID
1.1.1.1           1   Full/ -          inactive    20.10.10.49     eth1                0
```

Validation 2

DNA bit will be set for remote device LSA's and DNA bit will not be set for a self-originated LSA

```
rtr2#sh ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 1 VRF default)

                Router Link States (Area 0.0.0.0)
Link ID         ADV Router       Age       Seq#       CkSum  Link count
1.1.1.1         1.1.1.1            1(DNA)  0x80000002 0x028e 2
2.2.2.2         2.2.2.2          621       0x80000002 0x6926 2

                Area-Local Opaque-LSA (Area 0.0.0.0)
Link ID         ADV Router       Age       Seq#       CkSum  Opaque ID
1.0.0.1         1.1.1.1            1(DNA)  0x80000001 0x30f6 1
```

```
1.0.0.1         2.2.2.2         619      0x80000001 0x34ea 1
1.0.0.8         1.1.1.1           1(DNA) 0x80000001 0xadd2 8
1.0.0.8         2.2.2.2         619      0x80000001 0x552b 8
rtr2#
```

Validation 3

The demand circuit bit will be set in Hello options field.

R2:

```
#sh ip ospf neighbor detail
rtr2#sh ip ospf neighbor detail
 Neighbor 1.1.1.1, interface address 20.10.10.49
    In the area 0.0.0.0 via interface eth1
    Neighbor priority is 1, State is Full, 5 state changes
    Hello is suppressed
    DR is 0.0.0.0, BDR is 0.0.0.0
    Options is 0x62 (-|O|DC|-|-|-|E|-)
    Dead timer due in inactive
    Neighbor is up for 00:13:13
    Database Summary List 0
    Link State Request List 0
    Link State Retransmission List 0
    Crypt Sequence Number is 0
    Thread Inactivity Timer off
    Thread Database Description Retransmission off
    Thread Link State Request Retransmission off
    Thread Link State Update Retransmission off
```

Validation 4

Hello is suppressed for one neighbor according to the above configuration.

```
rtr2#sh ip ospf interface
eth1 is up, line protocol is up
  Internet Address 20.10.10.46/24, Area 0.0.0.0, MTU 1500
  Process ID 1, VRF (default), Router ID 2.2.2.2, Network Type POINTTOPOINT, Cost: 1
  Reduce LSA flooding.
  Transmit Delay is 1 sec,  State Point-To-Point, TE Metric 1
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in inactive
  Neighbor Count is 1, Adjacent neighbor count is 1
  Suppress hello for 1 neighbor(s)
  Hello received 4 sent 4, DD received 4 sent 3
  LS-Req received 1 sent 1, LS-Upd received 4 sent 4
  LS-Ack received 3 sent 3, Discarded 0
  No authentication
```

Point-toMultipoint network

The diagram shows the configuration required to enable the OSPF Demand Circuit feature on an interface level, in P2MP and P2MP non-broadcast network

Note: There is no global level configuration command for the demand circuit feature.

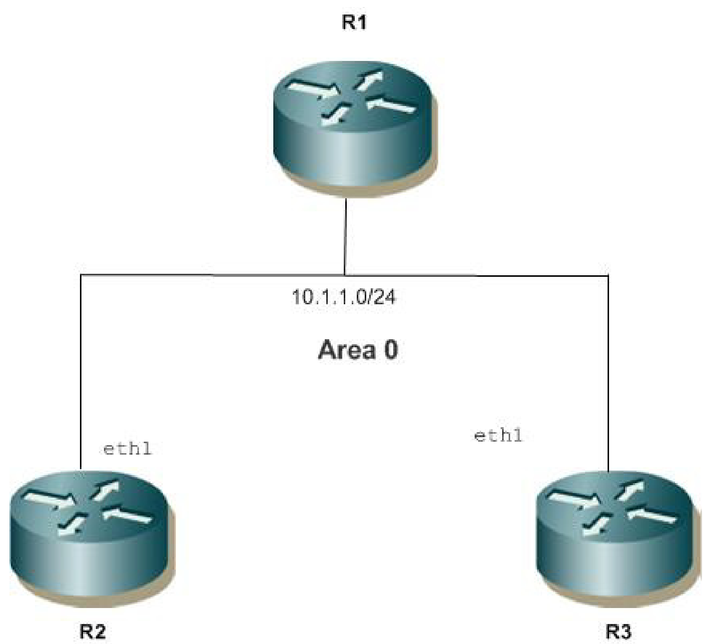

Figure 4-24: OSPF Demand Circuit Topology

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ip address 10.1.1.1/24`	Configure the IP address of the interface.
`R1(config-if)#ip ospf demand-circuit`	Enable demand circuit on the interface
`R1(config-if)#ip ospf network point-to-multipoint`	Enable the network type as point to multipoint network
`R1(config-if)# exit`	Exit interface mode.
`R1(config)#router ospf 1`	Configure the routing process and specify the Process ID (`1`).
`R1(config-router)#network 10.1.1.0/24 area 0`	Define the interface (`10.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`R1(config-router)#router-id 1.1.1.1`	Configure unique router-id for each router.
`R1(config-router)# end`	Exit router mode.

R2

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ip address 10.1.1.2/24`	Configure the IP address of the interface.
`R2(config-if)#ip ospf network point-to-multipoint non-broadcast`	Enable the network type as point to multipoint network
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`R2(config-router)#network 10.1.1.0/24 area 0`	Define the interface (`10.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`R2(config-router)#router-id 2.2.2.2`	Configure unique router-id
`R2(config-router)#end`	Exit router mode.

R3

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ip address 10.1.1.3/24`	Configure the IP address of the interface.
`R1(config-if)#ip ospf network point-to-multipoint non-broadcast`	Enable the network type as point to multipoint network
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`R2(config-router)#network 10.1.1.0/24 area 0`	Define the interface (`10.1.1.0/24`) on which OSPF runs, and associate the area ID (0) with the interface (area ID 0 specifies the backbone area).
`R2(config-router)#router-id 3.3.3.3`	Configure unique router-id
`R2(config-router)#end`	Exit router mode.

Validation 1

Hello's are suppressed only between rtr2 and rtr1 since demand circuit is enabled only on rtr2 and it is non-broadcast P2MP. rtr3 and rtr1 exchange hellos periodically.

R2:

```
rtr2#show ip ospf neighbor
Total number of full neighbors: 1
OSPF process 1 VRF(default):
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
1.1.1.1           1   Full/ -         inactive    10.10.10.46     eth1                0
rtr2#
```

```
rtr1#show ip ospf neighbor
Total number of full neighbors: 2
OSPF process 1 VRF(default):
Neighbor ID     Pri   State           Dead Time   Address         Interface Instance ID
2.2.2.2           1   Full/ -         inactive    10.10.10.49     eth1                 0
3.3.3.3           1   Full/ -         00:01:44    10.10.10.51     eth1                 0
```

Validation 2

In the interface details of rtr2. It shows the number of neighbors whose hello's have been suppressed.

```
rtr2#show ip ospf interface eth1
eth1 is up, line protocol is up
  Internet Address 10.10.10.49/24, Area 0.0.0.0, MTU 1500
  Process ID 1, VRF (default), Router ID 2.2.2.2, Network Type P2MP-NBMA, Cost: 1
  Reduce LSA flooding.
  Transmit Delay is 1 sec,  State Point-To-Point, TE Metric 1
  Timer intervals configured, Hello 30, Dead 120, Wait 120, Retransmit 5
    Hello due in 00:00:06
  Neighbor Count is 1, Adjacent neighbor count is 1
  Suppress hello for 1 neighbor(s)
  Hello received 5 sent 3, DD received 4 sent 3
  LS-Req received 1 sent 1, LS-Upd received 13 sent 4
  LS-Ack received 0 sent 7, Discarded 1
  No authentication
rtr2#
```


CHAPTER 5 OSPFv3

This chapter contains basic OSPFv3 configuration examples.

For details about the commands used in these examples, see the *Open Shortest Path First Command Reference*.

Enable 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.

Note: You must explicitly specify a Router ID for the OSPFv3 process to be activated.

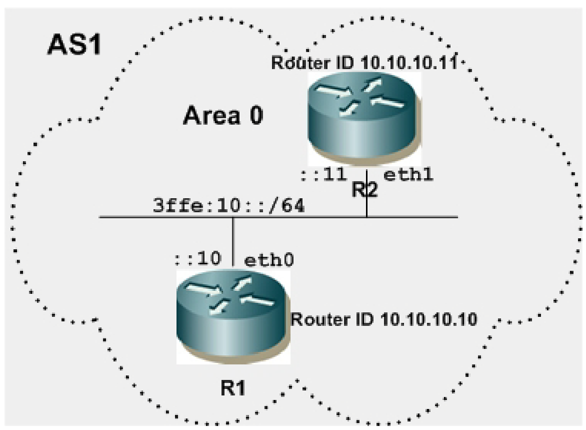

Figure 5-25: Basic OSPFv3 Topology

R1

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

R2

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf`	Create an OSPFv3 routing instance.

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

Validation

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospfv3 topology

Set Priority

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

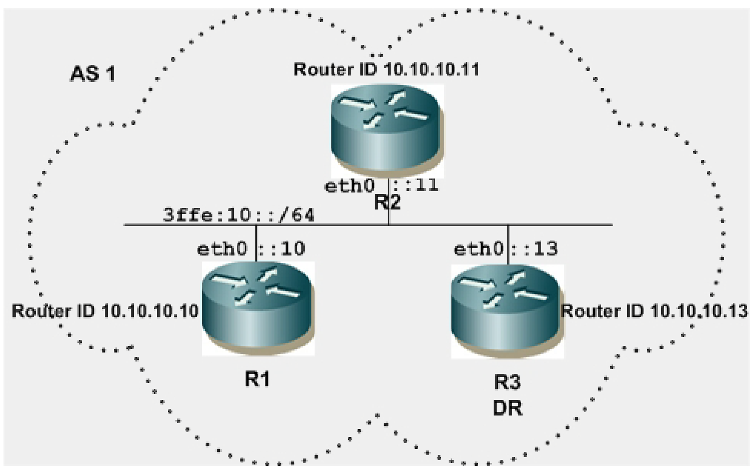

Figure 5-26: OSPFv3 Set Priority

R3

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

R1

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

R2

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

Validation

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospfv3 topology

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 Area 1.

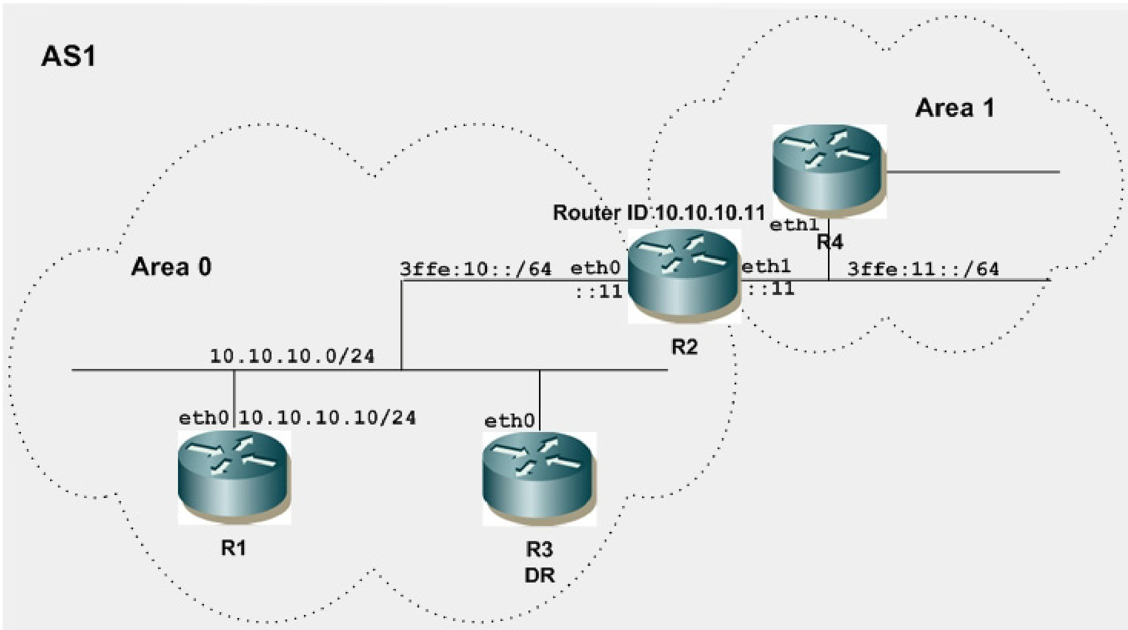

Figure 5-27: OSPFv3 Area Border Router

R2

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

Validation

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospfv3 topology, show ipv6 route, show ipv6 ospf route

Redistribute Routes into OSPFv3

In this example, the BGP routes are imported into the OSPF routing table, and advertised as Type 5 External LSAs into Area 0.

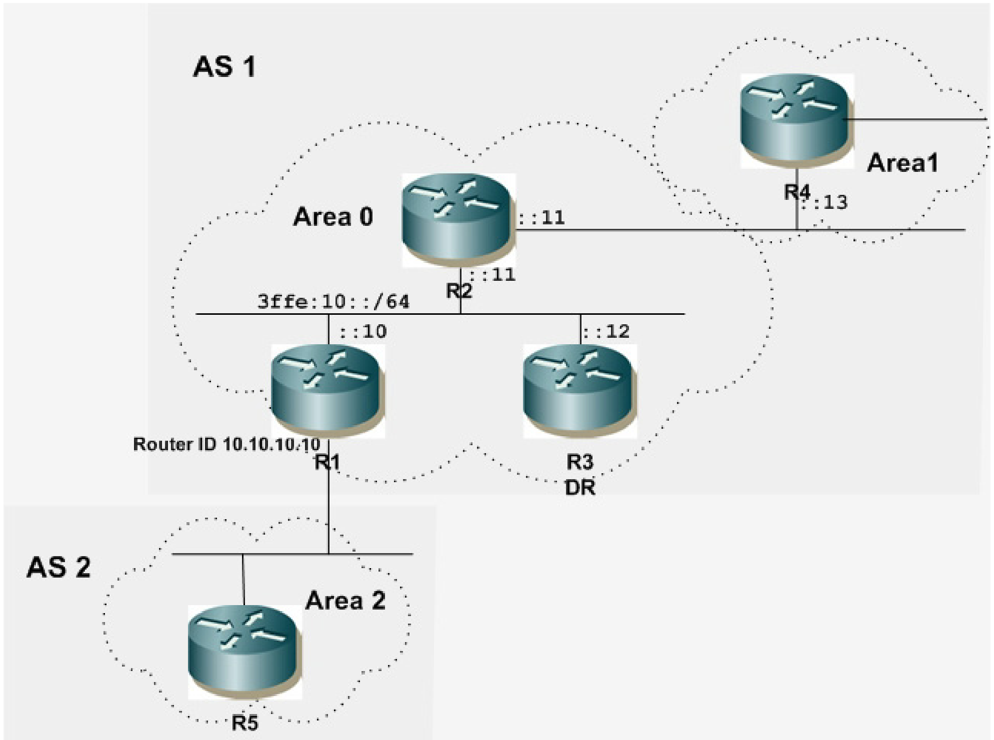

Figure 5-28: OSPFv3 Redistribute Routes

R1

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

Validation

show ipv6 ospf neighbor, show ipv6 ospf database, show ipv6 ospfv3 topology, show ipv6 ospf route, show ipv6 route

Cost

Make a route the preferred route by changing its cost. In this example, cost has been configured to make R2 the next hop for R1.

The default cost for 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 is computed as follows:

R2: 10+100 = 110

R3: 10+150 = 160

For this reason, R1 chooses R2 as its next hop to destination 10.10.14.0/24, because it has the lower cost.

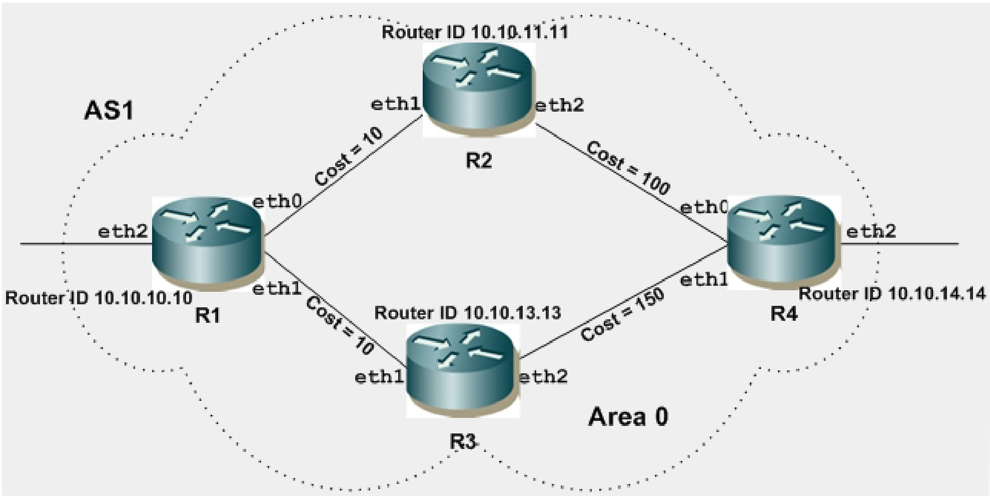

Figure 5-29: Configure Cost OSPFv3

R1

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

R2

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

R3

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

R4

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

`(config-if)# exit`	Exit interface mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 0`	Enable OSPFv3 routing on an interface, and assign the Area ID `(0)`.

Validation

show ipv6 ospf neighbor, show ipv6 ospfv3 topology, show ipv6 ospf database, show ipv6 ospf route, show ipv6 route

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, in turn 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.

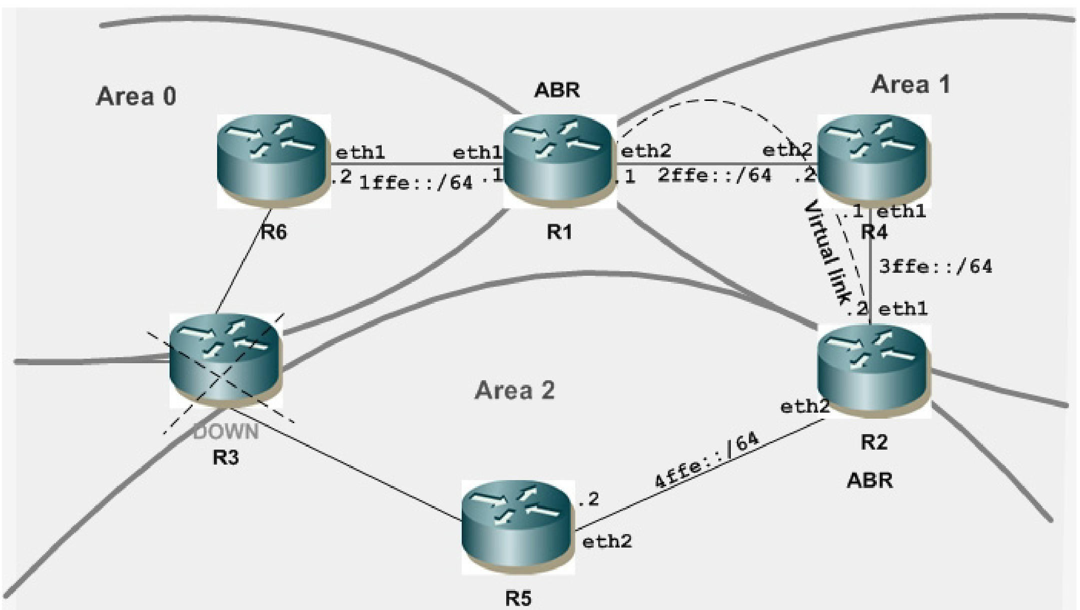

Figure 5-30: OSPFv3 Virtual Links

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 0`	Enable OSPFv3 routing on this interface, and assign the Area ID `(0)`.
`(config-if)# exit`	Exit interface mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.

`(config-if)# ipv6 router ospf area 1`	Enable OSPFv3 routing on this interface, and assign the Area ID `(1)`.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf`	Create an OSPFv3 routing instance.
`(config-router)# router-id 1.1.1.1`	Specify a Router ID (`1.1.1.1`) for the OSPFv3 routing process.
`(config-router)# area 1 virtual-link 2.2.2.2`	Configure a virtual link between this router R1 and R2 (Router ID `2.2.2.2`) through transit area 1.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 1`	Enable OSPFv3 routing on this interface, and assign the Area ID `(1)`.
`(config-if)# exit`	Exit interface mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 2`	Enable OSPFv3 routing on this interface, and assign the Area ID `(2)`.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf`	Create an OSPFv3 routing instance.
`(config-router)# router-id 2.2.2.2`	Specify a Router ID (`2.2.2.2`) for the OSPFv3 routing process.
`(config-router)# area 1 virtual-link 1.1.1.1`	Configure a virtual link between this router R1 and R2 (Router ID `1.1.1.1`) through transit area 1.

R4

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 1`	Enable OSPFv3 routing on this interface, and assign the Area ID `(1)`.
`(config-if)# exit`	Exit interface mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 1`	Enable OSPFv3 routing on this interface, and assign the Area ID `(1)`.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf`	Create an OSPFv3 routing instance.
`(config-router)# router-id 4.4.4.4`	Specify a Router ID (`4.4.4.4`) for the OSPFv3 routing process.

R5

`# configure terminal`	Enter Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 2`	Enable OSPFv3 routing on this interface, and assign the Area ID `(2)`.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf`	Create an OSPFv3 routing instance.
`(config-router)# router-id 5.5.5.5`	Specify a Router ID (`5.5.5.5`) for the OSPFv3 routing process.

R6

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router ospf area 0`	Enable OSPFv3 routing on this interface, and assign the Area ID `(0)`.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf`	Create an OSPFv3 routing instance.
`(config-router)# router-id 6.6.6.6`	Specify a Router ID (`6.6.6.6`) for the OSPFv3 routing process.

Validation

show ipv6 ospf virtual-links, show ipv6 ospf neighbor, show ipv6 ospf, show ipv6 ospf route

Multiple Instances

By using multiple OSPFv3 instances, OSPFv3 routes can be segregated, based on their instance number. Routes of one instance are stored differently from routes of another instance running in the same router.

To configure multiple OSPFv3 instances, refer to the topology diagram and follow the procedures below.

1. Enable OSPFv3 on an interface.
2. Enable multiple instances.
3. Configure redistribution among multiple instances.

   Note: Optionally, redistribution can be configured with the metric, type, or route-map options.

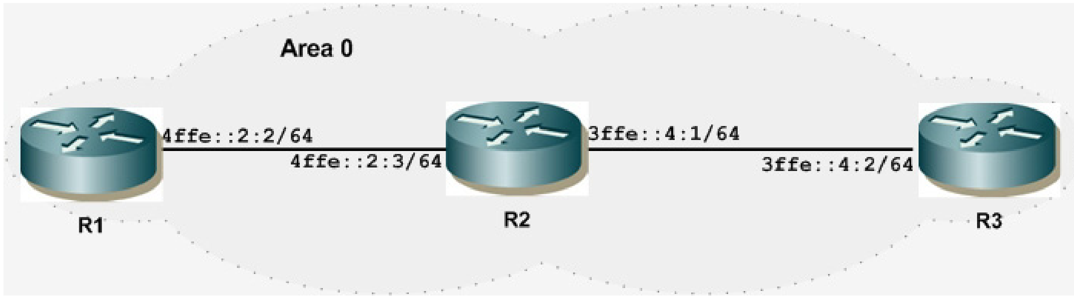

Figure 5-31: Multiple OSPFv3 Instances

Enable OSPFv3 on an Interface

This example shows how to enable OSPFv3 on an interface. R1 and R2 are two routers in Area 0 connecting to network 4ffe::2:/64.

R1

`(config)# router ipv6 ospf 10`	Configure an OSPFv3 instance with an instance ID of `10`.
`(config-router)# router-id 151.151.151.151`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth1`	Specify the interface on which OSPFv3 is to be enabled.
`(config-if)# ipv6 address 4ffe::2:2/64`	Configure the IPv6 address.
`(config-if)# ipv6 router ospf area 0 tag 10`	Configure the area number and instance value: match the instance ID with the instance ID created previously.
`(config-if)# no shutdown`	Activate the interface.

R2

`(config)# router ipv6 ospf 10`	Configure an OSPFv3 instance with an instance ID of `10`.
`(config-router)# router-id 152.152.152.152`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth1`	Specify the interface on which OSPFv3 is to be enabled.
`(config-if)# ipv6 address 4ffe::3:3/64`	Configure the IPv6 address.
`(config-if)# ipv6 router ospf area 0 tag 10`	Configure the area number and instance value: match the instance ID with the instance ID created previously.
`(config-if)# no shutdown`	Activate the interface.

Validation

show ipv6 interface brief, show ipv6 ospf route, show ipv6 ospf neighbor

Enable Multiple OSPFv3 Instances on a Router

In this example, routers R1, R2, and R3 are in Area 0, and all run OSPFv3.

R1

`(config)# router ipv6 ospf 5`	Configure an OSPFv3 instance with an instance ID of 5.
`(config-router)# router-id 5.5.5.5`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth1`	Specify the interface on which OSPFv3 is to be enabled.
`(config-if)# ipv6 address 4ffe::2:2/64`	Configure the IPv6 address.
`(config-if)# ipv6 router ospf area 0 tag 5`	Configure the area number and instance value: match the instance ID with the instance ID created previously.
`(config-if)# no shutdown`	Activate the interface.

R2

`(config)# router ipv6 ospf 5`	Configure an OSPFv3 instance with an instance ID of 5.
`(config-router)# router-id 149.149.149.149`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth1`	Configure the interface to connect to R1.
`(config-if)# ipv6 address 4ffe::3:3/64`	Configure the IPv6 address.
`(config-if)# ipv6 router ospf area 0 tag 5`	Configure the area number and instance value: match the instance ID with the instance ID created previously.
`(config-if)# no shutdown`	Activate the interface.
`(config)# router ipv6 ospf 15`	Configure an OSPFv3 instance with an instance ID of 15.
`(config-router)# router-id 159.159.159.159`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth2`	Configure the interface to connect to R3.
`(config-if)# ipv6 address 4ffe::4:1/64`	Configure the IPv6 address.
`(config-if)# no shutdown`	Activate the interface.
`(config-if)# ipv6 router ospf area 0 tag 15`	Configure the area number and instance value: match the instance ID with the instance ID created previously.

R3

`(config)# router ipv6 ospf 15`	Configure an OSPFv3 instance with an instance ID of 15.
`(config-router)# router-id 152.152.152.152`	Configure the router ID to use on this instance.
`(config-router)# exit`	Exit Router mode, and return to Interface mode.
`(config)# int eth1`	Specify the interface on which OSPFv3 is to be enabled.
`(config-if)# ipv6 address 3ffe::2:1/64`	Configure the IPv6 address.
`(config-if)# ipv6 router ospf area 0 tag 15`	Configure the area number and instance value: match the instance ID with the instance ID created previously.
`(config-if)# no shutdown`	Activate the interface.

Validation

show ipv6 ospf route, show ipv6 ospf neighbor

Redistribute among Multiple Instances

In this example, routes of one instance are redistributed to another instance to enable ping from R1 to R3 or vice versa; and R2 redistributes routes from one instance to another.

R2

(config)# router ipv6 ospf 15	Configure an OSPFv3 instance with instance ID 15.
(config-router)# router-id 159.159.159.159	Configure the router ID.
(config-router)# redistribute ospf 5	Redistribute instance 5 routes.
(config-router)# redistribute connected	Redistribute co routes to instance 15.
(config-router)# exit	Exit Router mode, and return to Configure mode.
(config)# router ipv6 ospf 5	Configure an OSPFv3 instance with instance ID 5.
(config-router)# router-id 149.149.149.149	Configure the router ID.
(config-router)# redistribute ospf 15	Redistribute instance 15 routes.
(config-router)# redistribute connected	Redistribute connected routes to instance 5.

Validation

Use the following validation commands on R1 and R3:

show ipv6 ospf route, show ipv6 ospf neighbor

Redistribute with Metric Option

In this example, on R3, R1 and R2 have each other's routes with a metric of 100.

R2

(config)# router ipv6 ospf 15	Configure an OSPFv3 instance with instance ID 15.
(config-router)# router-id 149.149.149.149	Configure the router ID.
(config-router)# redistribute ospf 15 metric 100	Redistribute instance 15 routes with metric 100.
(config-router)# redistribute connected	Redistribute connected routes to instance 15.
(config-router)# exit	Exit Router mode, and return to Configure mode.
(config)# router ipv6 ospf 5	Redistribute routes into instance 5.
(config-router)# router-id 149.149.149.149	Configure the router ID.
(config-router)# redistribute ospf 15 metric 100	Redistribute instance 15 routes with metric 100.
(config-router)# redistribute connected	Redistribute connected routes to instance 5.

Validation

Use the following validation commands on R1 and R3:

show ipv6 ospf route, show ipv6 ospf neighbor

Redistribute with Type Option

In this example, on R3, R1 has R3 routes as type 2, and R2 has R1 routes as type 1.

R2

(config)# router ipv6 ospf 15	Configure an OSPFv3 instance with instance ID 15.
(config-router)# router-id 159.159.159.159	Configure the router ID.
(config-router)# redistribute ospf 15 metric-type 1	Redistribute instance 15 routes as type 1.
(config-router)# redistribute connected	Redistribute connected routes to instance 15.
(config-router)# exit	Exit Router mode, and return to Configure mode.
(config)# router ipv6 ospf 5	Redistribute routes into instance 5.
(config-router)# router-id 149.149.149.149	Configure the router ID.
(config-router)# redistribute ospf 15 metric-type 2	Redistribute instance 15 routes with type 2.
(config-router)# redistribute connected	Redistribute instance 15 as type 2.

Validation

Use the following validation commands on R1 and R3:

show ipv6 ospf route, show ipv6 ospf neighbor

Redistribute with Route-Map Option

R2

(config)# router ipv6 ospf 15	Configure an OSPFv3 instance with instance ID 15.
(config-router)# router-id 159.159.159.159	Configure the router ID.
(config-router)# redistribute ospf 5 route-map 1	Redistribute instance 5 routes with route map 1.
(config-router)# redistribute connected	Redistribute connected routes to instance 15.
(config-router)# exit	Exit Router mode, and return to Configure mode.
(config)# router ipv6 ospf 5	Redistribute routes into instance 5.
(config-router)# router-id 149.149.149.149	Configure the router ID.
(config-router)# redistribute ospf 15 route-map 1	Redistribute instance 15 routes with route map 1.
(config-router)# redistribute connected	Redistribute connected routes to instance 15.

Validation

Use the following validation commands on R1 and R3:

show ipv6 ospf route, show ipv6 ospf neighbor

Graceful Restart

The possibility of maintaining a router's data forwarding capability while the router's control software restarts is called graceful restart or non-stop forwarding. After the router restarts and reloads, it must change its OSPF processing until it re-establishes full adjacencies with all its former fully adjacent neighbors. The time period between the restart/reload and re-establishment of adjacencies is called the grace period.

Essentially, the OSPF enhancements for graceful restart are as follows:

- The router attempting a graceful restart originates link-local Opaque-LSAs, called Grace-LSAs, announcing its intention to perform a graceful restart within a specified amount of time (grace period).
- During the grace period, neighbors continue to announce the restarting router in their LSAs as if it were fully adjacent (OSPF neighbor state Full), but only if the network topology remains static (the contents of the LSAs in the link-state database that have LS types 1-5 and 7 remain unchanged, and periodic refreshes are allowed).

Figure 5-32: OSPFv3 Graceful Restart

Configure Router as Helper

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 address 5ffe::112/64`	Assign the IPv6 address to the interface.
`(config-if)# ipv6 router ospf area 0 tag 1`	Configure the interface for OSPFv3 on area 0.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf 1`	Create an OSPFv3 routing instance.
`(config-router)# router-id 1.1.1.1`	Specify a Router ID (`1.1.1.1`) for the OSPFv3 routing process.
`(config-router)# capability restart graceful`	Enable graceful restart capability.
`(config-router)# end`	Exit Configure mode and enter Privilege Exec mode.
`# write`	Save the configuration.
`# restart ipv6 ospf graceful grace-period 200`	Restart OSPFv3 with a 200-second grace period, so that the neighbor maintains adjacency and preserves the routes for 200 seconds.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 address 5ffe::113/64`	Assign the IPv6 address to the interface.
`(config-if)# ipv6 router ospf area 0 tag 1`	Configure the interface for OSPFv3 on area 0.
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf 1`	Create an OSPFv3 routing instance.
`(config-router)# router-id 2.2.2.2`	Specify a Router ID (`2.2.2.2`) for the OSPFv3 routing process.
`(config-router)# exit`	Exit Router mode and enter Configure mode.
`(config)# ipv6 ospf restart helper max-grace-period 300`	Configure R2 to act as the helper when the grace period is less than 300.

Remove Helper Configuration

R2

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 1`	Create an OSPFv3 routing instance.
`(config-router)# router-id 1.1.1.1`	Specify a Router ID (`1.1.1.1`) for the OSPFv3 routing process.
`(config-router)# exit`	Exit Router mode and enter Configure mode.
`(config)# ipv6 ospf restart helper never`	Configure R2 to not work as the helper.

Router as Helper when Restart Reason is Reload

R2

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 1`	Create an OSPFv3 routing instance.
`(config-router)# router-id 1.1.1.1`	Specify a Router ID (`1.1.1.1`) for the OSPFv3 routing process.
`(config-router)# exit`	Exit Router mode and enter Configure mode.
`(config)# ipv6 ospf restart helper only-reload`	Configure R2 to work as the helper only when the restart reason is reload.

Router as Helper when Restart Reason is Upgrade

R2

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 1`	Create an OSPFv3 routing instance.
`(config-router)# router-id 1.1.1.1`	Specify a Router ID (`1.1.1.1`) for the OSPFv3 routing process.
`(config-router)# exit`	Exit Router mode and enter Configure mode.
`(config)# ipv6 ospf restart helper only-upgrade`	Configure R2 to work as the helper only when the restart reason is upgrade.

Validation

show ipv6 ospf neighbor, show ipv6 ospf route, show ipv6 route, show ipv6 ospf database grace

Not-So-Stubby Area

This section contains OSPFv3 NSSA (Not-So-Stubby Area) configuration examples.

An NSSA allows external routes to be advertised into the OSPF autonomous system while retaining the characteristics of a stub area to the rest of the autonomous system. To do this, the ASBR in an NSSA will originate type 7 LSAs to advertise the external destinations. These NSSA external LSAs are flooded throughout the NSSA but are blocked at the ABR.

The NSSA external LSA has a flag in its header known as the P-bit. The NSSA ASBR has the option of setting or clearing the P-bit. If an NSSA's ABR receives a type 7 LSA with the P-bit set to one, it translates the type 7 LSA into a type 5 LSA and floods it throughout the other areas. If the P-bit is set to zero, no translation takes place and the destination in the type 7 LSA is not advertised outside of the NSSA.

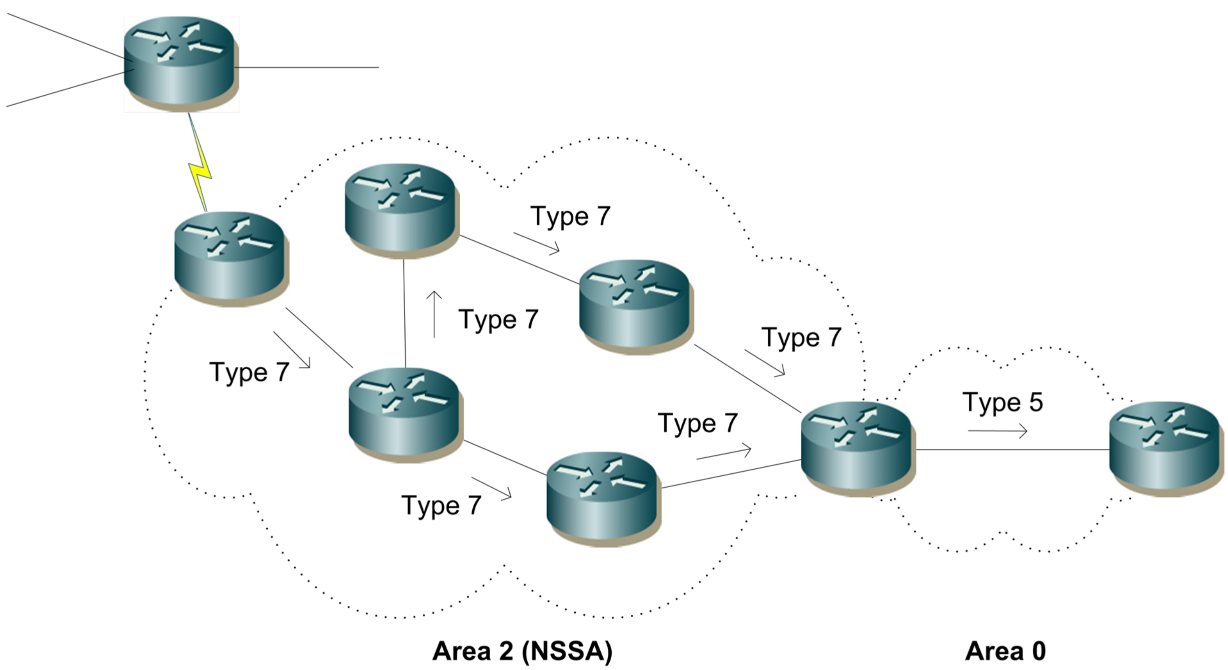

Figure 5-33: Translating Type 7 LSAs into Type 5 LSAs

NSSA with Route Options

This example shows the configuration to enable NSSA and to configure different route options for NSSA. There are three `area nssa` command options for originating default Type-3 LSA and default Type-7 LSA, and for blocking redistribution of Type-7 LSA into an NSSA:

- `no-summary`: The NSSA ABR blocks all type-3 and type-4 LSAs into the NSSA area and sends a single type-3 LSA into the area to advertise a default route
- `default-information-originate`: The NSSA ABR advertises a default route into the NSSA as a type-7 LSA.
- `no-redistribution`: The NSSA ABR bocks type-7 LSA from being redistributed into the NSSA area.

In Figure 5-34, R2 is an NSSA ABR as well as an NSSA ASBR that maps the router interfaces to two different areas and redistributes the connected routes of the loopback interface. Also, this example sets the `no-summary`, `no-redistribution`, and `default-information-originate` options on R2 to originate default Type-3 LSAs and default Type-7 LSAs into the NSSA and to block Type-7 LSAs.

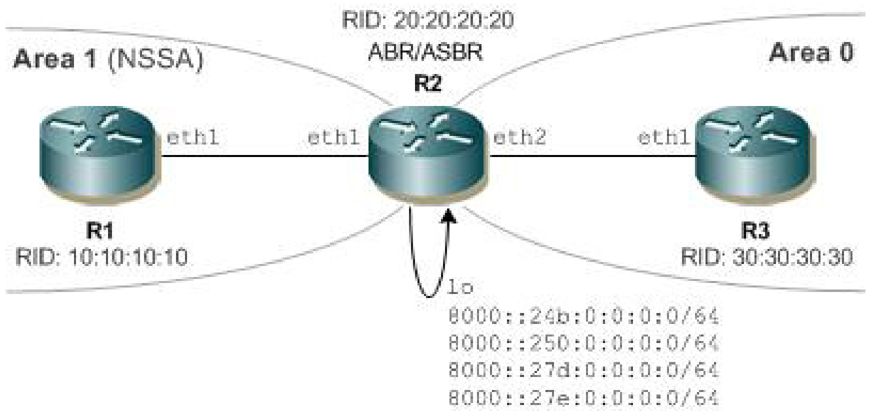

Figure 5-34: NSSA with Route Options

R1

`(config)#int eth1`	Enter interface mode for `eth1`.
`(config-if)#ipv6 router ospf tag 100 area 1`	Configure interface in an area assigned with the area ID (1).
`(config-if)#exit`	Exit interface mode.
`(config)#router ipv6 ospf 100`	Configure the routing process and specify the tag (`100`).
`(config-router)#router-id 10.10.10.10`	Configure the router ID to use on this instance (100)
`(config-router)#area 1 nssa`	Configure area as NSSA
`(config-router)#exit`	Exit interface mode

R2

`(config)#int eth1`	Enter interface mode for `eth1`.
`(config-if)#ipv6 router ospf tag 100 area 1`	Configure interface in an area assigned with the area ID (1).
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode for `eth2`
`(config-if)#ipv6 router ospf tag 100 area 0`	Configure interface in backbone
`(config-if)#interface lo`	Enter interface mode for Loopback

(config-if)#ipv6 address 8000::24b:0:0:0:0/64	Assign IPv6 address to loopback interface
(config-if)#ipv6 address 8000::250:0:0:0:0/64	Assign IPv6 address to loopback interface
(config-if)#ipv6 address 8000::27d:0:0:0:0/64	Assign IPv6 address to loopback interface
(config-if)#ipv6 address 8000::27e:0:0:0:0/64	Assign IPv6 address to loopback interface
(config-if)#exit	Exit interface mode.
(config)#router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)#router-id 20.20.20.20	Configure the router ID to use on this instance (100)
(config-router)#redistribute connected	Redistribute the configured loopback network into the NSSA
(config-router)#area 1 nssa no-redistribution default-information-originate no-summary	Configure the Router to originate default Type-3 LSAs and default Type-7 LSAs, and to block Type-7 LSAs into the NSSA
(config-router)#exit	Exit interface mode

R3

(config)#int eth1	Enter interface mode for eth1.
(config-if)#ipv6 router ospf tag 100 area 0	Configure interface in an area assigned with the area ID (1).
(config-if)#exit	Exit interface mode.
(config)#router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)#router-id 30.30.30.30	Configure the router ID to use on this instance (100)
(config-router)#exit	Exit interface mode

Validation 1

In the output of `show ipv6 ospf neighbor` below, verify that OSPFv3 adjacency is in state “full” for both R1 and R2 under the process identifier 100.

```
R1#sh ipv6 ospf neighbor
OSPFv3 Process (100)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
20.20.20.20       1   Full/DR         00:00:34    eth2       0

R2#sh ipv6 ospf neighbor
OSPFv3 Process (100)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
10.10.10.10       1   Full/Backup     00:00:38    eth1       0
```

Validation 2

The output below shows originating default Type-3 LSAs into the NSSA with the no-summary option. The advertising router identifier is for R2 (20.20.20.20, the NSSA-ABR). Also, the prefix is ::/0 and the LS-Type is Inter-Area-Prefix-LSA for the default Type-3 LSA route into the NSSA.

```
R1#sh ipv6 ospf database inter-prefix

            OSPFv3 Router with ID (10.10.10.10) (Process 100)
```

```
                Inter-Area-Prefix-LSA (Area 0.0.0.1)

  LS age: 1234
  LS Type: Inter-Area-Prefix-LSA
  Link State ID: 0.0.0.6
  Advertising Router: 20.20.20.20
  LS Seq Number: 0x80000001
  Checksum: 0x17D0
  Length: 28
    Metric: 1
    Prefix: ::/0
    Prefix Options: 0
```

Validation 3

The output below shows originating default type-7 LSAs alone after setting the no-redistribution and default-information originate options. The advertising router identifier is for R2 (20.20.20.20, the NSSA-ABR). Also, the prefix is ::/0 and LS-Type is NSSA-external-LSA for the default Type-7 LSA route into the NSSA

```
R1#sh ipv6 ospf database nssa-external

            OSPFv3 Router with ID (10.10.10.10) (Process 100)

                NSSA-external-LSA (Area 0.0.0.1)

  LS age: 1758
  LS Type: NSSA-external-LSA
  Link State ID: 0.0.0.20
  Advertising Router: 20.20.20.20
  LS Seq Number: 0x80000002
  Checksum: 0x6468
  Length: 32
    Metric Type: 2 (Larger than any link state path)
    Metric: 1
    Prefix: ::/0
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0
```

NSSA with the Summary Address Option

Figure 5-35 shows the configuration to originate external LSAs (Type-7) and translate them into external LSAs (Type-5):

- R1 is an NSSA-ASBR configured with loopback IPv6 addresses that are redistributed into OSPFv3
- R2 is an NSSA-ABR
- R3 is backbone router

R1 originates Type-7 LSAs which are summarized into a single Type-7 into the NSSA by the `summary-address` option and this summarized Type-7 is converted to Type-5 LSA by R2.

Also, the summarized route can be tagged using the `tag` command and the advertisement of summarized routes can be suppressed by the `not-advertise` option.

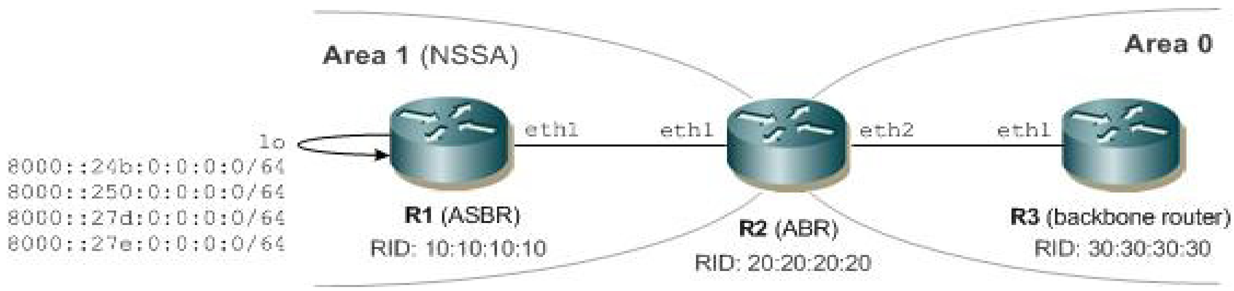

Figure 5-35: Using the summary-address Option

R1

`(config)# int eth1`	Enter interface mode for `eth1`.
`(config-if)# ipv6 router ospf tag 100 area 1`	Configure interface in an area assigned with the area ID (1).
`(config-if)# exit`	Exit interface mode.
`(config-if)# interface lo`	Enter interface mode for loopback
`(config-if)# ipv6 address 8000::24b:0:0:0:0/64`	Assign IPv6 address to loopback interface
`(config-if)# ipv6 address 8000::250:0:0:0:0/64`	Assign IPv6 address to loopback interface
`(config-if)# ipv6 address 8000::27d:0:0:0:0/64`	Assign IPv6 address to loopback interface
`(config-if)# ipv6 address 8000::27e:0:0:0:0/64`	Assign IPv6 address to loopback interface
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf 100`	Configure the routing process and specify the tag (`100`).
`(config-router)# router-id 10.10.10.10`	Configure the router ID to use on this instance (100)
`(config-router)# area 1 nssa`	Configure the area as NSSA.
`(config-router)# redistribute connected`	Redistribute the configured loopback network into OSPFv3 NSSA. Note: Connected networks can be redistributed by setting the metric and metric type.
`(config-router)# summary-address 8000::/48 tag 10`	Summarize the address range and tag the summarized route
`(config-router)# exit`	Exit interface mode

R2

`(config)# int eth1`	Enter interface mode for `eth1`.
`(config-if)# ipv6 router ospf tag 100 area 1`	Configure interface in an area assigned with the area ID (1).
`(config-if)#exit`	Exit interface mode.
`(config)# int eth2`	Enter interface mode for `eth2`
`(config-if)# ipv6 router ospf tag 100 area 0`	Configure interface in backbone area (0)
`(config-if)# exit`	Exit interface mode.
`(config)# router ipv6 ospf 100`	Configure the routing process and specify the tag (`100`).

(config-router)# router-id 20.20.20.20	Configure the router ID to use on this instance (100)
(config-router)# area 1 nssa	Configure the Router in NSSA
(config-router)# exit	Exit interface mode

R3

(config)# int eth1	Enter interface mode for `eth1`.
(config-if)# ipv6 router ospf tag 100 area 0	Configure interface in backbone area (0)
(config-if)# exit	Exit interface mode.
(config)# router ipv6 ospf 100	Configure the routing process and specify the tag (`100`).
(config-router)# router-id 30.30.30.30	Configure the router ID to use on this instance (100)
(config-router)# exit	Exit interface mode

In the configurations above, you can suppress the external route summarization by NSSA-ASBR by specifying the `not-advertise` parameter as shown below:

```
(config-router)#summary-address 8000::/48 not-advertise
```

Also, connected networks can be redistributed by setting the metric and metric type as shown below:

```
(config-router)#redistribute connected metric 20 metric-type 1
```

Validation 1

The output below shows the summarized route generated by NSSA-ASBR (R1) with a tag. The output has the LS Type as NSSA-external-LSA with advertising router identifier (10.10.10.10) of the NSSA-ASBR (R1). Also, check the Prefix which is summarized route and external route tag as configured.

```
R1#sh ipv6 ospf database nssa-external

            OSPFv3 Router with ID (10.10.10.10) (Process 100)

                NSSA-external-LSA (Area 0.0.0.1)

  LS age: 90
  LS Type: NSSA-external-LSA
  Link State ID: 0.0.0.11
  Advertising Router: 10.10.10.10
  LS Seq Number: 0x80000003
  Checksum: 0x69B3
  Length: 40
    Metric Type: 2 (Larger than any link state path)
    Metric: 21
    Prefix: 8000::/48
    Prefix Options: 8 (P|-|-|-)
    External Route Tag: 10
```

Validation 2

The output below on the NSSA-ABR that is translating Type-7 LSAs to Type-5 LSAs shows summarized address in Type-7 and Type-5 LSA. Check for the same prefix, external route tag in both Type7 and Type-5 LSA.

```
R2#sh ipv6 ospf database nssa-external
```

```
            OSPFv3 Router with ID (20.20.20.20) (Process 100)

                NSSA-external-LSA (Area 0.0.0.1)

  LS age: 241
  LS Type: NSSA-external-LSA
  Link State ID: 0.0.0.11
  Advertising Router: 10.10.10.10
  LS Seq Number: 0x80000003
  Checksum: 0x69B3
  Length: 40
    Metric Type: 2 (Larger than any link state path)
    Metric: 21
    Prefix: 8000::/48
    Prefix Options: 8 (P|-|-|-)
    External Route Tag: 10

R2#sh ipv6 ospf database external

            OSPFv3 Router with ID (20.20.20.20) (Process 100)

                AS-external-LSA

  LS age: 245
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.3
  Advertising Router: 20.20.20.20
  LS Seq Number: 0x80000003
  Checksum: 0x8660
  Length: 40
    Metric Type: 2 (Larger than any link state path)
    Metric: 21
    Prefix: 8000::/48
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 10
```

Validation 3

The output below on the backbone router shows the summarized address in the translated Type-5 LSA. The prefix and external route tag are the same as the summarized Type-7 LSA originated by R1.

```
R3#sh ipv6 ospf database external

            OSPFv3 Router with ID (30.30.30.30) (Process 100)

                AS-external-LSA

  LS age: 409
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.3
  Advertising Router: 20.20.20.20
```



```
LS Seq Number: 0x80000003
Checksum: 0x8660
Length: 40
  Metric Type: 2 (Larger than any link state path)
  Metric: 21
  Prefix: 8000::/48
  Prefix Options: 0 (-|-|-|-)
  External Route Tag: 10
```

NSSA with the Translator Role Option

Type-7 to Type-5 translation is done by an NSSA-ABR. If an NSSA has multiple NSSA-ABRs, only one will perform the translation. The NSSA-ABR translator role options are:

- Candidate (default)
- Always

In the topology in Figure 5-36:

- R1 is NSSA-ASBR
- R2 and R3 are NSSA-ABRs
- R4 is a backbone router

In this example, the NSSA translator role `candidate` is configured on both NSSA-ABRs (R2 and R3). The Type-7 to Type-5 translation is done by the router with the higher router identifier (R3).

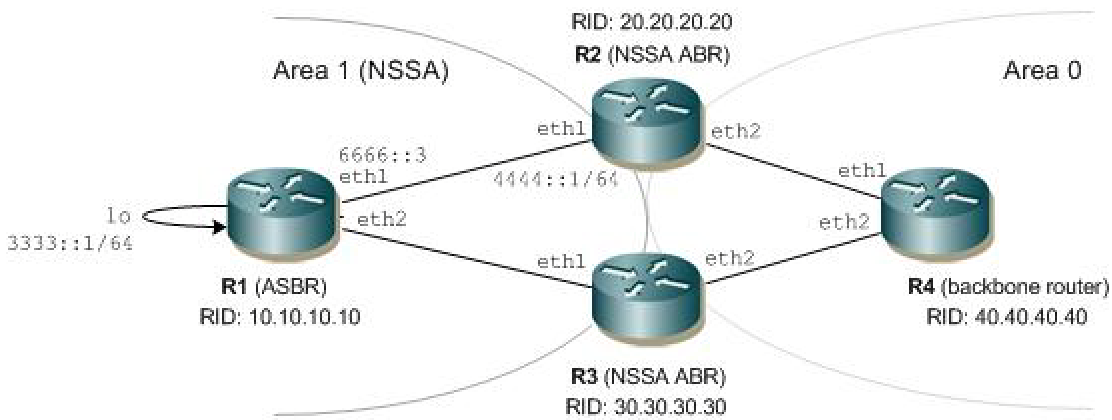

Figure 5-36: Using the translator-role Option

When one NSSA-ABR is configured with the translator role as `always` and the other as `candidate`, then translation is done by the router configured as `always`. In this scenario, the translation can be biased by setting the translator role to `always` on the router that has the lower router identifier.

R1

(config)# int eth1	Enter interface mode for eth1.
(config-if)# ipv6 router ospf tag 100 area 1	Configure interface in an area assigned with the area ID (1).
(config-if)#exit	Exit interface mode.
(config)# int eth2	Enter interface mode for eth2.
(config-if)# ipv6 router ospf tag 100 area 1	Configure interface in an area assigned with the area ID (1).

(config-if)# exit	Exit interface mode.
(config-if)# interface lo	Enter interface mode for Loopback
(config-if)# ipv6 address 3333::1/64	Assign IPv6 address to loopback interface
(config-if)# exit	Exit interface mode.
(config)# router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)# router-id 10.10.10.10	Configure the router ID to use on this instance (100)
(config-router)# area 1 nssa	Configure the area as NSSA.
(config-router)# redistribute static	Redistribute the static route configured into the OSPF NSSA
(config-router)# redistribute connected	Redistribute the connected network into OSPF NSSA
(config-router)# exit	Exit interface mode
(config)# ipv6 route 4444::1/64 6666::3	Configure the static route with the nexthop address as R2's eth1 IPv6 address
(config)# exit	Exit interface mode.

R2

(config)# int eth1	Enter interface mode for eth1.
(config-if)# ipv6 router ospf tag 100 area 1	Configure interface in an area assigned with the area ID (1).
(config-if)#exit	Exit interface mode.
(config)# int eth2	Enter interface mode for eth2
(config-if)# ipv6 router ospf tag 100 area 0	Configure interface in backbone area (0)
(config-if)# exit	Exit interface mode.
(config)# router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)# router-id 20.20.20.20	Configure the router ID to use on this instance (100)
(config-router)# area 1 nssa translator-role candidate	Configure the NSSA-ABR with the translator role candidate.
(config-router)# exit	Exit interface mode

R3

(config)# int eth1	Enter interface mode for eth1.
(config-if)# ipv6 router ospf tag 100 area 1	Configure interface in an area assigned with the area ID (1).
(config-if)#exit	Exit interface mode.
(config)# int eth2	Enter interface mode for eth2
(config-if)# ipv6 router ospf tag 100 area 0	Configure interface in backbone area (0)
(config-if)# exit	Exit interface mode.
(config)# router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)# router-id 30.30.30.30	Configure the router ID to use on this instance (100)
(config-router)# area 1 nssa translator-role candidate	Configure the NSSA-ABR with the translator role candidate.
(config-router)# exit	Exit interface mode

R4

(config)# int eth1	Enter interface mode for eth1.
(config-if)# ipv6 router ospf tag 100 area 0	Configure interface in backbone area (0)
(config)# int eth2	Enter interface mode for eth2
(config-if)# ipv6 router ospf tag 100 area 0	Configure interface in backbone area (0)
(config-if)# exit	Exit interface mode.
(config)# router ipv6 ospf 100	Configure the routing process and specify the tag (100).
(config-router)# router-id 40.40.40.40	Configure the router ID to use on this instance (100)
(config-router)# exit	Exit interface mode

The command to configure the NSSA-Translator role as `always` is:

```
(config-router)# area 1 nssa translator-role always
```

The NSSA-ABR can continue to perform translation after its services are no longer required for the stability interval which is set using the command below on the NSSA-ABR.

```
(config-router)#area 1 nssa stability-interval 7777
```

Validation 1

The translation is done by the NSSA-ABR with the higher router identifier. In the output below, check the router identifier of the NSSA-ABR. Also, check the router which is elected and the router which is disabled.

```
R2#sh ipv6 ospf
 Routing Process "OSPFv3 (100)" with ID 20.20.20.20
 Process uptime is 21 minutes
 SPF schedule delay min 0.500 secs, SPF schedule delay max 50.0 secs
 Minimum LSA interval 5 secs, Minimum LSA arrival 1 secs
 Number of incomming current DD exchange neighbors 0/5
 Number of outgoing current DD exchange neighbors 0/5
 Number of external LSA 4. Checksum Sum 0x1F816
 Number of AS-Scoped Unknown LSA 0
 Number of LSA originated 28
 Number of LSA received 58
 Number of areas in this router is 2
    Area BACKBONE(0)
        Number of interfaces in this area is 1(1)
        SPF algorithm executed 7 times
        Number of LSA 19.  Checksum Sum 0x7454D
        Number of Unknown LSA 0
    Area 0.0.0.1 (NSSA)
        Number of interfaces in this area is 1(1)
        SPF algorithm executed 14 times
        Number of LSA 19.  Checksum Sum 0xA4D18
        Number of Unknown LSA 0
        NSSA Translator State is disabled
R3#sh ipv6 ospf
 Routing Process "OSPFv3 (100)" with ID 30.30.30.30
 Process uptime is 19 minutes
```

```
SPF schedule delay min 0.500 secs, SPF schedule delay max 50.0 secs
Minimum LSA interval 5 secs, Minimum LSA arrival 1 secs
Number of incomming current DD exchange neighbors 0/5
Number of outgoing current DD exchange neighbors 0/5
Number of external LSA 4. Checksum Sum 0x1F816
Number of AS-Scoped Unknown LSA 0
Number of LSA originated 31
Number of LSA received 69
Number of areas in this router is 2
   Area BACKBONE(0)
       Number of interfaces in this area is 1(1)
       SPF algorithm executed 15 times
       Number of LSA 19.  Checksum Sum 0x7454D
       Number of Unknown LSA 0
   Area 0.0.0.1 (NSSA)
       Number of interfaces in this area is 1(1)
       SPF algorithm executed 10 times
       Number of LSA 19.  Checksum Sum 0xA4D18
       Number of Unknown LSA 0
       NSSA Translator State is elected
```

Validation 2

The translated Type-5 LSA in R4 in area 0 has the advertising router identifier of R3. In the output below, the LS Type is AS-External-LSA and the advertising router has the higher router identifier.

```
R4#sh ipv6 ospf database external

            OSPFv3 Router with ID (40.40.40.40) (Process 100)

                AS-external-LSA

  LS age: 885
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.7
  Advertising Router: 30.30.30.30
  LS Seq Number: 0x80000001
  Checksum: 0xD3FE
  Length: 40
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 3333::/64
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 18
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.8
  Advertising Router: 30.30.30.30
  LS Seq Number: 0x80000003
  Checksum: 0x7457
```

```
Length: 56
  Metric Type: 2 (Larger than any link state path)
  Metric: 20
  Prefix: 4444::/64
  Prefix Options: 0 (-|-|-|-)
  Forwarding Address: 6666::3
  External Route Tag: 0
```

Link LSA Suppression

If link LSA suppression is enabled and the interface type is not broadcast or NBMA, the router will not originate a link-LSA for the link. This implies that other routers on that link will determine the router's next hop address using a mechanism other than the link LSA.

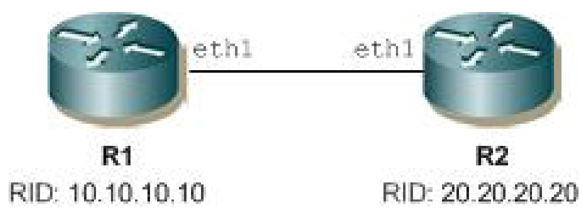

Figure 5-37: LSA Suppression

R1

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#router-id 10.10.10.10`	Configure the router ID to use on this instance (100-IPI)
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf tag 100-IPI area 1`	Configure interface in an area assigned with the area ID (1). The tag uniquely identifies the routing process.
`(config-if)# ipv6 ospf network point-to-point`	Configure the OSPF interface network type as point to point
`(config-if)# ipv6 ospf link-lsa-suppression enable`	Enable the link LSA suppression mechanism
`(config-if)# exit`	Exit interface mode

R2

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#router-id 20.20.20.20`	Configure the router ID to use on this instance (100-IPI)
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode

`(config-if)#ipv6 router ospf tag 100-IPI area 1`	Configure interface in an area assigned with the area ID (1). The tag uniquely identifies the routing process.
`(config-if)# ipv6 ospf network point-to-point`	Configure the OSPF interface network type as point to point
`(config-if)# ipv6 ospf link-lsa-suppression enable`	Enable the link LSA Suppression Mechanism
`(config-if)# exit`	Exit interface mode

Note: This is not applicable for broadcast and NBMA networks.

Validation 1

Verify that adjacency has been established.

```
R1#sh ipv6 ospf neighbor
OSPFv3 Process (100)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
20.20.20.20       1   Full/ -         00:00:37    eth2       0
```

Validation 2

Verify that DUT should not have the Link LSA in the Link state database.

Note: The output below is captured after link lsa suppression enabled which has not Link LSA in the LSDB.

```
DUT#sh ipv6 ospf database

            OSPFv3 Router with ID (10.10.10.10) (Process 100)

                Router-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         10.10.10.10       15 0x80000004 0x3264      1
0.0.0.0         20.20.20.20       15 0x80000002 0xdbba      1

                Intra-Area-Prefix-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.12        10.10.10.10       14 0x80000004 0xaab4      1  Router-LSA
0.0.0.13        20.20.20.20       15 0x80000002 0x8f7f      1  Router-LSA

                Intra-Area-Te-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.4         10.10.10.10       15 0x80000004 0xa326
0.0.0.3         20.20.20.20       15 0x80000002 0xffec
R1#sh ipv6 ospf database link

            OSPFv3 Router with ID (10.10.10.10) (Process 100)
```

Address Family IPv4 Unicast Configuration

This chapter contains basic OSPFv3 address family IPv4 unicast configuration examples.

The address family feature lets OSPFv3 IPv6 networks support both IPv6 and IPv4 unicast traffic. It uses multiple instance identifiers to support multiple address families. By default OSPFv3 supports only IPv6 unicast traffic.

The purpose of supporting address families in OSPFv3 is to advertise IPv4 unicast address family routes in OSPFv3 by assigning different instance identifier ranges to different address families. With this feature, users may have two router processes per interface, but only one process per address family. Each instance identifier implies a separate OSPFv3 instance with its own neighbor adjacencies, link state database, and SPF computation. A single IPv4 or IPv6 OSPFv3 process running multiple instances on the same interface is not supported.

Enable Address Family IPv4 Unicast

The diagram below shows the minimum configuration required to enable the OSPFv3 address family feature and to establish the adjacency between R1 and R2 to support the IPv4 address family.

Note: To enable the IPv4 unicast address family in an OSPFv3 router, you need to configure an IPv4 address on the OSPFv3 enabled interface.

Figure 5-38: IPv4 Address Family on OSPFv3

R1

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#router-id 10.12.49.123`	Configure the router ID to use for this process (100-IPI)
`(config-router)# address-family ipv4 unicast`	Enable the ipv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)# ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in area 0. The tag uniquely identifies the routing process and the instance identifier is 64-95 for the IPv4 address family
`(config-if)#exit`	Exit interface mode

R2

`# configure terminal`	Enter Configure mode.
`(config)# router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#router-id 10.12.49.124`	Configure the router ID to use on this tag (100-IPI)
`(config-router)# address-family ipv4 unicast`	Enable the ipv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode

`(config)#interface eth1`	Enter interface configuration mode
`(config-if)# ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in area 0. The tag uniquely identifies the routing process and the instance identifier is 64-95 for the IPv4 address family
`(config-if)#end`	Exit interface mode

Note: Use the process identifier to tag the interface, The instance identifier should be same on R1 and R2. In the above example, the process identifiers (`100-IPI`) and the instance identifiers are the same (64).

Validation

Verify that adjacency has been established with the configured instance identifier.

```
R2#sh ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State           Dead Time   Interface Instance ID
10.12.49.123      1   Full/DR         00:00:37    eth1           64

R2#sh ipv6 ospf interface eth1
eth1 is up, line protocol is up
  Interface ID 3
  IPv6 Prefixes
    fe80::5054:ff:fe4e:32d1/64 (Link-Local Address)
  OSPFv3 Process (1), Area 0.0.0.0, Instance ID 64
    Router ID 10.12.49.124, Network Type BROADCAST, Cost: 1, TE Metric: 0
    Transmit Delay is 1 sec, State Backup, Priority 1
    Designated Router (ID) 10.12.49.123
      Interface Address fe80::5054:ff:fe7e:3466
    Backup Designated Router (ID) 10.12.49.129
      Interface Address fe80::5054:ff:fe4e:32d1
    Timer interval configured, Hello 10, Dead 40, Wait 40, Retransmit 5
      Hello due in 00:00:04
    Neighbor Count is 1, Adjacent neighbor count is 1
```

Originate Type-7 LSAs and Translate to Type-5

Figure 5-39 shows the configuration to originate Type-7 LSAs and translate them into Type-5 LSAs. R3 is an NSSA-ASBR that originates Type-7 LSAs into the NSSA which are converted to Type-5 LSAs by R2 which is an NSSA-ABR. R1 is a backbone router.

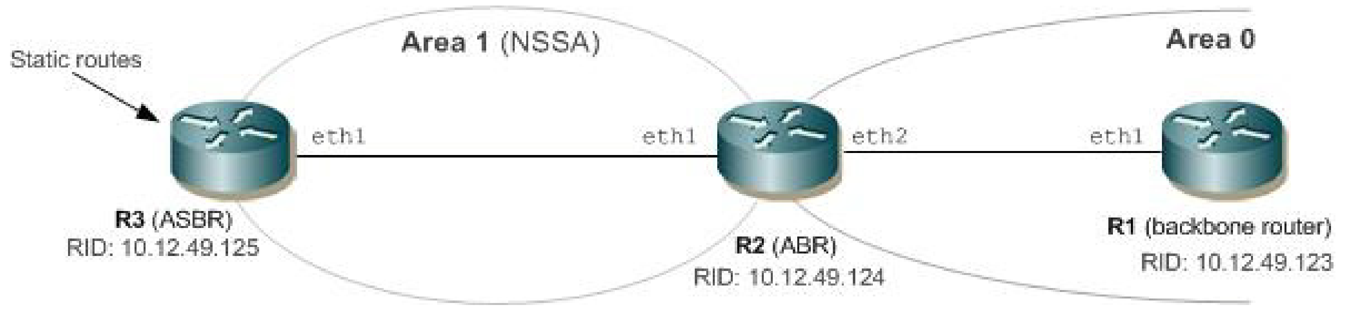

Figure 5-39: Originate Type-7 LSAs and Translate to Type-5 under Address Family IPv4

R1

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process
`(config-router)#router-id 10.12.49.123`	Configure the router ID to use on this tag (100-IPI)
`(config-router)#address-family ipv4 unicast`	Enable the IPv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#ip route 15.15.15.0/24 null`	Configure the static route with the nexthop address set to null
`(config-router)#router-id 10.12.49.124`	Configure the router ID to use for this process (100-IPI)
`(config-router)#area 1 nssa`	Configure the area 1 as NSSA.
`(config-router)#address-family ipv4 unicast`	Enable the ipv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.
`(config-if)#ipv6 router ospf area 1 tag 100-IPI instance-id 65`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.
`(config-if)#exit`	Exit interface mode

R3

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process.
`(config-router)#router-id 10.12.49.125`	Configure the router ID to use for this process (100-IPI)
`(config-router)#area 1 nssa`	Configure the area 1 as NSSA.
`(config-router)#address-family ipv4 unicast`	Enable the ipv4 address family

`(config-router-af)#redistribute static`	Redistribute the static routes configured into the OSPF NSSA
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 1 tag 100-IPI instance-id 65`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.

Validation 1

Verify that adjacency has been established with the configured instance identifier.

```
DUT#sh ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State           Dead Time   Interface   Instance ID
10.12.49.123      1   Full/DR         00:00:31       eth1           95
10.12.49.124      1   Full/Backup     00:00:38    eth2           94
```

Validation 2

Verify that the ABR has External LSA Type 5 in its Database.

Note: Check that R3 has generated a Type 7 LSA.

```
R3#sh ipv6 ospf database external

            OSPFv3 Router with ID (10.12.49.129) (Process 1)

                AS-external-LSA

  LS age: 1517
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.1
  Advertising Router: 10.12.49.124
  LS Seq Number: 0x80000003
  Checksum: 0x597D
  Length: 36
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 10.12.49.0/24
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 991
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.11
  Advertising Router: 10.12.49.124
  LS Seq Number: 0x80000001
  Checksum: 0x4C60
  Length: 36
    Metric Type: 2 (Larger than any link state path)
```

```
    Metric: 21
    Prefix: 33.33.33.0/29
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 442
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.13
  Advertising Router: 10.12.49.129
  LS Seq Number: 0x80000001
  Checksum: 0x376B
  Length: 36
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 33.33.33.1/32
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 442
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.14
  Advertising Router: 10.12.49.129
  LS Seq Number: 0x80000001
  Checksum: 0x3B65
  Length: 36
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 33.33.33.2/32
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 442
  LS Type: AS-External-LSA
  Link State ID: 0.0.0.15
  Advertising Router: 10.12.49.129
  LS Seq Number: 0x80000001
  Checksum: 0x3F5F
  Length: 36
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 33.33.33.3/32
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0


  LS age: 442
  LS Type: AS-External-LSA
```

```
  Link State ID: 0.0.0.16
  Advertising Router: 10.12.49.129
  LS Seq Number: 0x80000001
  Checksum: 0x4359
  Length: 36
    Metric Type: 2 (Larger than any link state path)
    Metric: 20
    Prefix: 33.33.33.4/32
    Prefix Options: 0 (-|-|-|-)
    External Route Tag: 0
```

Validation 3

Verify that FIB of backbone router has External Route as “O E2”.

```
R3#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

Gateway of last resort is 10.12.49.1 to network 0.0.0.0

K*      0.0.0.0/0 via 10.12.49.1, eth0
C       10.12.49.0/24 is directly connected, eth0
C       11.11.11.0/24 is directly connected, eth1
C       11.13.11.0/24 is directly connected, eth3
C       11.14.11.0/24 is directly connected, eth4
C       11.15.11.0/24 is directly connected, eth5
C       12.12.12.0/24 is directly connected, eth1
O IA    30.30.30.0/24 [110/2] via 12.12.12.12, eth1
O E2    33.33.33.0/29 [110/21] via 12.12.12.12, eth1
O E2    33.33.33.1/32 [110/20] via 12.12.12.12, eth1
O E2    33.33.33.2/32 [110/20] via 12.12.12.12, eth1
O E2    33.33.33.3/32 [110/20] via 12.12.12.12, eth1
O E2    33.33.33.4/32 [110/20] via 12.12.12.12, eth1
C       127.0.0.0/8 is directly connected, lo
K       169.254.0.0/16 is directly connected, eth0
```

Summarize Intra-Area and External Routes

Figure 5-40 shows the configuration to enable intra-area and external route summarization. The IPv4 address family is enabled on R1. R2 summarizes the internal OSPF routes which R3 redistributes.

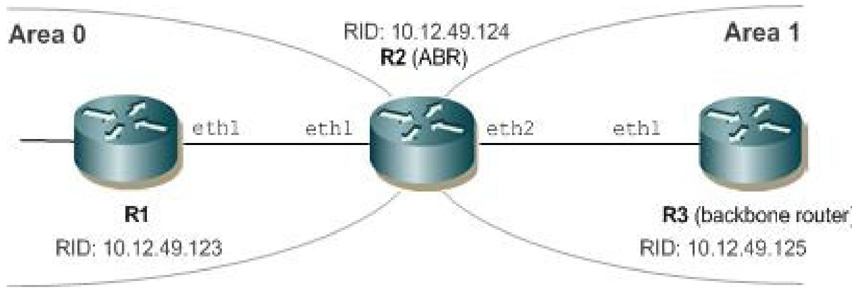

Figure 5-40: Enabling Intra-Area and External Route Summarization

R1

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process
`(config-router)#router-id 10.12.49.123`	Configure the router ID to use for this process (100-IPI)
`(config-router)#address-family ipv4 unicast`	Enable the IPv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router ipv6 ospf 100-IPI`	Configure the routing process and specify the tag (`100-IPI`) which uniquely identifies the routing process
`(config-router)#router-id 10.12.49.124`	Configure the router ID to use for this process (100-IPI)
`(config-router)#address-family ipv4 unicast`	Enable the IPv4 address family
`(config-router-af)#exit-address-family`	Exit Router AF configuration mode
`(config-router)#exit`	Exit Router configuration mode
`(config)#interface eth1`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 0 tag 100-IPI instance-id 64`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.
`(config)#interface eth2`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 1 tag 100-IPI instance-id 65`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.
`(config)#interface lo`	Enter interface configuration mode
`(config-if)#ipv6 router ospf area 1 tag 101 instance-id 65`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.

(config-router-af)#area 1 range 11.11.11.11/29 advertise	Summarize the internal OSPF routes.
(config-if)#exit	Exit interface mode

R3

#configure terminal	Enter Configure mode.
(config)#router ipv6 ospf 100-IPI	Configure the routing process and specify the tag (100-IPI) which uniquely identifies the routing process.
(config-router)#router-id 10.12.49.125	Configure the router ID to use for this process (100-IPI)
(config-router)#address-family ipv4 unicast	Enable the IPv4 address family
(config-router-af)#exit-address-family	Exit Router AF configuration mode
(config-router)#exit	Exit Router configuration mode
(config)#interface eth1	Enter interface configuration mode
(config-if)#ipv6 router ospf area 1 tag 100-IPI instance-id 65	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process and the instance identifier which is 64-95 for the IPv4 address family.
(config-router)#address-family ipv4 unicast	Enable the IPv4 address family
(config-router-af)#redistribute connected	Redistribute the connected route to generate external LSAs
(config-router-af)#summary address 51.51.51.51/29	Summarize the external route at the ASBR.

Inter Area Route Aggregation Validation

Validation 1: Verify that adjacency has been established with the configured instance identifier.

```
DUT#sh ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State           Dead Time   Interface Instance ID
10.12.49.123      1   Full/DR         00:00:34    eth1       95
10.12.49.124      1   Full/DR         00:00:36    eth2       94
```

Validation 2: Verify that a single aggregated OSPF IA route is available in FIB of R1.

```
R1#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

Gateway of last resort is 10.12.49.1 to network 0.0.0.0

K*      0.0.0.0/0 via 10.12.49.1, eth0
C       10.12.49.0/24 is directly connected, eth0
C       11.11.11.0/24 is directly connected, eth1
C       11.13.11.0/24 is directly connected, eth3
C       11.14.11.0/24 is directly connected, eth4
C       11.15.11.0/24 is directly connected, eth5
```

```
C       12.12.12.0/24 is directly connected, eth1
O IA    33.33.33.0/29 [110/2] via 12.12.12.12, eth1
C       127.0.0.0/8 is directly connected, lo
K       169.254.0.0/16 is directly connected, eth0
```

Validation 3: Verify that the Inter-Area-Prefix-LSA has one prefix in the R1 Link State Database.

```
R1#sh ipv6 ospf database

            OSPFv3 Router with ID (10.12.49.123) (Process 1)

                Link-LSA (Interface eth1)

Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.3         10.12.49.123      88 0x8000008b 0xe531      2
0.0.0.3         10.12.49.129    1406 0x8000008a 0xfc61      1

                Router-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         10.12.49.123    1409 0x80000006 0x1f6e      1
0.0.0.0         10.12.49.129    1411 0x80000004 0x087e      1

                Network-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         10.12.49.123    1409 0x80000002 0xe4f0

                Inter-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.7         10.12.49.129     112 0x80000001 0xc722

                Intra-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         10.12.49.123    1409 0x80000002 0xfb99      3  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         10.12.49.123    1409 0x80000005 0x9cdb
0.0.0.3         10.12.49.129    1411 0x80000003 0x7cf7
```

External Route Summarization Validation:

Note: External route summarization is done at the ASBR.

Validation 1: Verify that single summarized external route in the ABR.

```
R2#sh ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
```



```
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

Gateway of last resort is 10.12.49.1 to network 0.0.0.0

K*       0.0.0.0/0 via 10.12.49.1, eth0
C        10.12.49.0/24 is directly connected, eth0
O        11.11.11.0/24 [110/1] is directly connected, eth1
C        12.12.12.0/24 is directly connected, eth1
C        30.30.30.0/24 is directly connected, eth2
O E2     33.33.33.0/29 [110/21] via 30.30.30.1, eth2
C        127.0.0.0/8 is directly connected, lo
K        169.254.0.0/16 is directly connected, eth0
```

Validation 2: Verify that a single Type 5 LSA is in the ABR's Link State Data Base.

```
R2#sh ipv6 ospf database

            OSPFv3 Router with ID (10.12.49.129) (Process 1)

                Link-LSA (Interface eth1)

Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.3         10.12.49.123    1161 0x8000008e 0xdf34      2
0.0.0.3         10.12.49.129     675 0x8000008e 0xf465      1

                Link-LSA (Interface eth2)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.3         10.12.49.124     785 0x80000001 0xc0d5      1
0.0.0.4         10.12.49.129     759 0x80000001 0xc4c9      1

                Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         10.12.49.123     674 0x8000000a 0x1772      1
0.0.0.0         10.12.49.129     759 0x80000008 0xf98a      1

                Network-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         10.12.49.123     674 0x80000006 0xdcf4

                Inter-Area-Prefix-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.8         10.12.49.129     759 0x80000001 0x2ec8

                Inter-Area-Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.2         10.12.49.129     699 0x80000001 0x4056

                Intra-Area-Prefix-LSA (Area 0.0.0.0)
```

```
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         10.12.49.123     674 0x80000006 0xf39d      3  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         10.12.49.123     674 0x80000009 0x94df
0.0.0.3         10.12.49.129     680 0x80000007 0x74fb

                Router-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         10.12.49.124     719 0x80000004 0xb9cb      1
0.0.0.0         10.12.49.129     714 0x80000004 0xa6d9      1

                Network-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.4         10.12.49.129     719 0x80000001 0xae20

                Inter-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.38        10.12.49.129     754 0x80000002 0x50c0
0.0.0.39        10.12.49.129     754 0x80000002 0x6aa2

                Intra-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.5         10.12.49.129     713 0x80000001 0x6c12      2  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         10.12.49.124     715 0x80000004 0x2f42
0.0.0.4         10.12.49.129     719 0x80000003 0x0963

                AS-external-LSA
Link State ID   ADV Router      Age  Seq#       CkSum          Tag
0.0.0.11        10.12.49.124      40 0x80000001 0x4c60 E2      0
```

Flood Reduction

This section contains basic OSPFv3 flood reduction configuration examples.

By design, OSPFv3 requires link-state advertisements (LSAs) to be refreshed as they expire after 3600 sec. Some implementations improve flooding by reducing the frequency of refresh timers from 30-50 seconds. This method reduces the refresh traffic but requires at least one refresh time before the LSA expires.

ZebOS-XP can handle DoNotAge (DNA) LSAs received from other routers. As their name suggests, DNA LSAs do not age out in the database

When there is demand circuit incapable router, Indication LSA will be generated by an ABR to other areas, so that other routers which are demand circuit and DNA capable will stop sending DNA bit set LSAs and LSA will be refreshed at regular intervals

Topology

Figure 5-42 shows the configuration to enable flood-reduction on a global level.

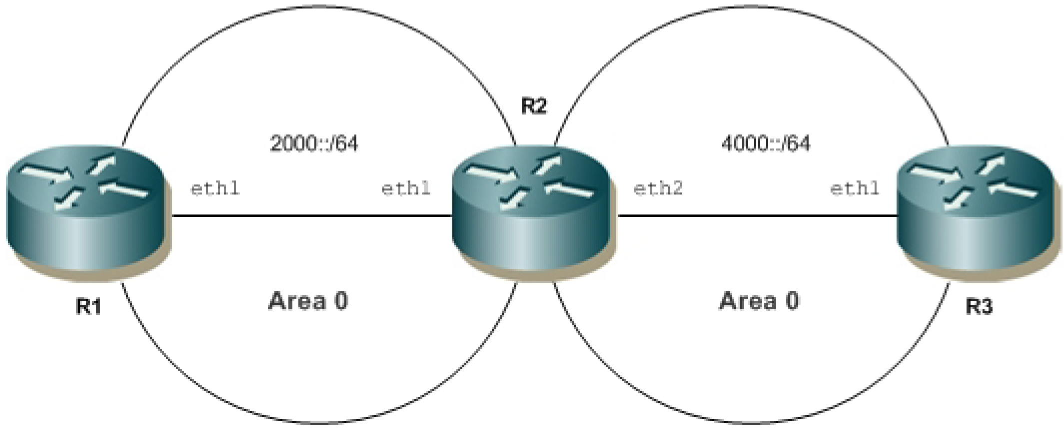

Figure 5-41: Basic Topology for OSPFv3 Flood Reduction

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ipv6 address 2000::49/64`	Configure the IP address of the interface.
`R1(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R1(config-if)#exit`	Exit interface mode.
`R1(config)#router ipv6 ospf`	Configure the routing process
`R1(config-router)#router-id 1.1.1.1`	Configure router-id to uniquely identify the router
`R1(config-router)#ospfv3 flood-reduction`	Configure flood reduction
`R1(config-router)#end`	Exit router mode.

R2

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ipv6 address 2000::46/64`	Configure the IP address of the interface.
`R2(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#int eth2`	Enter interface mode.
`R2(config-if)#ipv6 address 4000::46/64`	Configure the IP address of the interface.
`R2(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process

`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ipv6 ospf 1`	Configure the routing process
`R2(config-router)#router-id 2.2.2.2`	Configure router-id to uniquely identify the router
`R2(config-router)#ospfv3 flood-reduction`	Configure flood reduction
`R2(config-router)#end`	Exit router mode.

R3

`R3#configure terminal`	Enter configure mode.
`R3(config)#int eth1`	Enter interface mode.
`R3(config-if)#ipv6 address 4000::51/64`	Configure the IP address of the interface.
`R3(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process
`R3(config-if)#exit`	Exit interface mode.
`R3(config)#router ipv6 ospf 1`	Configure the routing process
`R3(config-router)#router-id 3.3.3.3`	Configure router-id to uniquely identify the router
`R3(config-router)#ospfv3 flood-reduction`	Configure flood reduction
`R3(config-router)#end`	Exit router mode.

Validation 1

Check OSPFv3 Database to verify DNA bit has set for LSA. DNA bit will be set for remote device and DNA bit will not be set for a self-originated LSA

R1

```
rtr2#show ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State            Dead Time   Interface  Instance ID
1.1.1.1           1   Full/Backup      00:00:38    eth1       0
3.3.3.3           1   Full/DR          00:00:35    eth2       0
rtr2#
rtr2#sh ipv6 ospf database

            OSPFv3 Router with ID (2.2.2.2) (Process 1)

                Link-LSA (Interface eth1)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix
0.0.0.3         1.1.1.1           41(DNA)   0x80000001 0x233f      2
0.0.0.3         2.2.2.2          285        0x80000001 0x5442      2

                Link-LSA (Interface eth2)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix
0.0.0.4         2.2.2.2          285        0x80000001 0xd23b      1
0.0.0.3         3.3.3.3           41(DNA)   0x80000001 0xa51e      1
```

```
                Router-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum    Link
0.0.0.0         1.1.1.1            1(DNA)  0x80000003 0x0fda      1
0.0.0.0         2.2.2.2          240       0x80000004 0xf1f1      1

                Network-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         2.2.2.2          245       0x80000001 0x12de

                Inter-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.2         2.2.2.2          285       0x80000001 0xf1b9

                Intra-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix  Reference
0.0.0.3         2.2.2.2          239       0x80000001 0xd3e7      2  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         1.1.1.1            1(DNA)  0x80000003 0x0483
0.0.0.3         2.2.2.2          245       0x80000002 0x93f2

                Router-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age       Seq#       CkSum    Link
0.0.0.0         2.2.2.2          240       0x80000003 0x548b      1
0.0.0.0         3.3.3.3            1(DNA)  0x80000003 0x25b8      1

                Network-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         3.3.3.3            1(DNA)  0x80000001 0x489c

                Inter-Area-Prefix-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         2.2.2.2          280       0x80000002 0x8445
0.0.0.4         2.2.2.2          280       0x80000002 0x154d

                Intra-Area-Prefix-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix  Reference
0.0.0.3         3.3.3.3            1(DNA)  0x80000001 0xe87e      1  Network-LSA
```

```
                Intra-Area-Te-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.4         2.2.2.2          244       0x80000002 0x7b9e
0.0.0.3         3.3.3.3           10(DNA)  0x80000002 0x8f7c
```

Validation 2

To disable flood reduction on a particular interface, use the below command. On disabling flood reduction DNA bit should be removed from database and LSA refresh should take place at regular intervals.

```
#conf ter
Enter configuration commands, one per line.End with CNTL/Z.
(config)#int eth2
(config-if)#no ipv6 ospf flood-reduction
(config-if)#end

rtr2#sh ipv6 ospf database

            OSPFv3 Router with ID (2.2.2.2) (Process 1)

                Link-LSA (Interface eth1)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix
0.0.0.3         1.1.1.1           41  0x80000001 0x233f      2
0.0.0.3         2.2.2.2          285       0x80000001 0x5442      2

                Link-LSA (Interface eth2)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix
0.0.0.4         2.2.2.2          285       0x80000001 0xd23b      1
0.0.0.3         3.3.3.3           41  0x80000001 0xa51e      1

                Router-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum    Link
0.0.0.0         1.1.1.1            1  0x80000003 0x0fda      1
0.0.0.0         2.2.2.2          240       0x80000004 0xf1f1      1

                Network-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         2.2.2.2          245       0x80000001 0x12de

                Inter-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.2         2.2.2.2          285       0x80000001 0xf1b9

                Intra-Area-Prefix-LSA (Area 0.0.0.0)
```

```
Link State ID   ADV Router      Age        Seq#       CkSum  Prefix  Reference
0.0.0.3         2.2.2.2          239        0x80000001 0xd3e7      2  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age        Seq#       CkSum
0.0.0.3         1.1.1.1            1   0x80000003 0x0483
0.0.0.3         2.2.2.2          245        0x80000002 0x93f2

                Router-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age        Seq#       CkSum    Link
0.0.0.0         2.2.2.2          240        0x80000003 0x548b      1
0.0.0.0         3.3.3.3            1   0x80000003 0x25b8      1

                Network-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age        Seq#       CkSum
0.0.0.3         3.3.3.3            1   0x80000001 0x489c

                Inter-Area-Prefix-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age        Seq#       CkSum
0.0.0.3         2.2.2.2          280        0x80000002 0x8445
0.0.0.4         2.2.2.2          280        0x80000002 0x154d

                Intra-Area-Prefix-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age        Seq#       CkSum  Prefix  Reference
0.0.0.3         3.3.3.3            1   0x80000001 0xe87e      1  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.1)

Link State ID   ADV Router      Age        Seq#       CkSum
0.0.0.4         2.2.2.2          244        0x80000002 0x7b9e
0.0.0.3         3.3.3.3           10   0x80000002 0x8f7c
```

0

Indication LSA Generation

Figure 5-42 shows the configuration for Indication LSA Generation when a demand circuit incapable router is present.

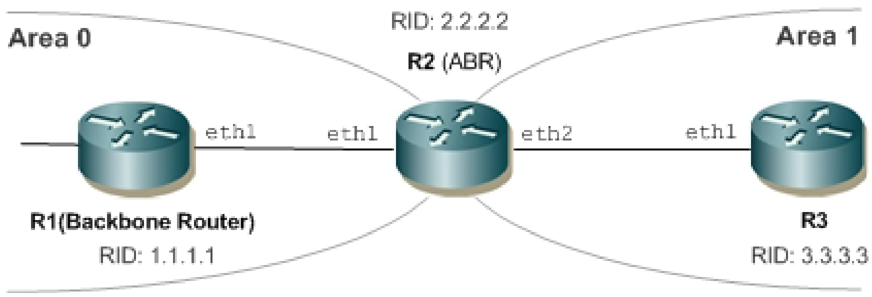

Figure 5-42: Basic Topology for Indication LSA Generation

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ipv6 address 2000::1/64`	Configure the IP address of the interface.
`R1(config-if)#ipv6 router ospf area 0`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R1(config-if)#exit`	Exit interface mode.
`R1(config)#router ipv6 ospf`	Configure the routing process
`R1(config-router)#router-id 1.1.1.1`	Configure router-id to uniquely identify the router
`R1(config-router)#end`	Exit router mode.

R2

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ipv6 address 2000::2/64`	Configure the IP address of the interface.
`R2(config-if)#ipv6 router ospf area 0`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#int eth2`	Enter interface mode.
`R2(config-if)#ipv6 address 4000::1/64`	Configure the IP address of the interface.
`R2(config-if)#ipv6 router ospf area 1`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ipv6 ospf`	Configure the routing process
`R2(config-router)#router-id 2.2.2.2`	Configure router-id to uniquely identify the router
`R2(config-router)#end`	Exit router mode.

R3

`R3#configure terminal`	Enter configure mode.
`R3(config)#int eth1`	Enter interface mode.
`R3(config-if)#ipv6 address 4000::2/64`	Configure the IP address of the interface.

`R3(config-if)#ipv6 router ospf area 1`	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process
`R3(config-if)#exit`	Exit interface mode.
`R3(config)#router ipv6 ospf`	Configure the routing process
`R3(config-router)#router-id 3.3.3.3`	Configure router-id to uniquely identify the router
`R3(config-router)#end`	Exit router mode.

Validation

Verify R2 Area Border Router has generated an Indication LSA (I LSA) for area 0 and no indication LSA should be generated for area1 since demand circuit incapable router is in area1.

In the Inter-area Router LSA. the term 'I LSA' indicates that R2 (2.2.2.2) has generated Indication LSA for R1.

R1:

```
#sh ipv6 ospf neighbor
OSPFv3 Process (*null*)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
2.2.2.2           1   Full/DR         00:00:31    eth1       0

#sh ipv6 ospf database
            OSPFv3 Router with ID (1.1.1.1) (Process *null*)
                Link-LSA (Interface eth1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.3         1.1.1.1           69 0x80000002 0xc6cf      1
0.0.0.3         2.2.2.2         1800 0x80000001 0xc7fb      1

                Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         1.1.1.1         1570 0x80000004 0x0ddb      1
0.0.0.0         2.2.2.2         1570 0x80000004 0xf1f1      1

                Network-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         2.2.2.2         1571 0x80000001 0x12de

                Inter-Area-Prefix-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2         1795 0x80000002 0xf9b1

                Inter-Area-Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2         1553 0x80000001 0xbf69 I LSA

                Intra-Area-Prefix-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         2.2.2.2         1570 0x80000001 0x5fef      2  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         1.1.1.1         1570 0x80000002 0x2659
```

```
0.0.0.3         2.2.2.2         1570 0x80000002 0x3a40
```

R2:

```
#sh ipv6 ospf neighbor
OSPFv3 Process (*null*)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
1.1.1.1           1   Full/Backup     00:00:38    eth1       0
3.3.3.3           1   Full/DR         00:00:37    eth2       0
#sh ipv6 ospf database
            OSPFv3 Router with ID (2.2.2.2) (Process *null*)
                Link-LSA (Interface eth1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.3         1.1.1.1          635 0x80000002 0xc6cf      1
0.0.0.3         2.2.2.2          563 0x80000002 0xc5fc      1

                Link-LSA (Interface eth2)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.4         2.2.2.2          563 0x80000002 0x9a50      1
0.0.0.3         3.3.3.3          489 0x80000002 0xe2ff      1

                Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         1.1.1.1          332 0x80000005 0x0bdc      1
0.0.0.0         2.2.2.2          331 0x80000005 0xeff2      1

                Network-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         2.2.2.2          331 0x80000002 0x10df

                Inter-Area-Prefix-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2          557 0x80000003 0xf7b2

                Inter-Area-Router-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2          311 0x80000002 0xbd6a I LSA

                Intra-Area-Prefix-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         2.2.2.2          331 0x80000002 0x5df0      2  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         1.1.1.1          332 0x80000003 0x245a
0.0.0.3         2.2.2.2          331 0x80000003 0x3841

                Router-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         2.2.2.2          308 0x80000005 0x508d      1
0.0.0.0         3.3.3.3          317 0x80000004 0x629a      1
```



```
                Network-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         3.3.3.3          317 0x80000002 0x469d

                Inter-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2          558 0x80000003 0x7581
0.0.0.2         2.2.2.2          318 0x80000004 0x8a3e

                Intra-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         3.3.3.3          312 0x80000002 0xf076      1  Network-LSA

                Intra-Area-Te-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.4         2.2.2.2          313 0x80000003 0xb2a2
0.0.0.3         3.3.3.3          317 0x80000003 0xd080
```

R3:

```
#sh ipv6 ospf neighbor
OSPFv3 Process (*null*)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
2.2.2.2           1   Full/Backup     00:00:40    eth1       0
#sh ipv6 ospf database

            OSPFv3 Router with ID (3.3.3.3) (Process *null*)
              Link-LSA (Interface eth1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix
0.0.0.4         2.2.2.2          649 0x80000002 0x9a50      1
0.0.0.3         3.3.3.3          573 0x80000002 0xe2ff      1

                Router-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum    Link
0.0.0.0         2.2.2.2          394 0x80000005 0x508d      1
0.0.0.0         3.3.3.3          401 0x80000004 0x629a      1

                Network-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.3         3.3.3.3          401 0x80000002 0x469d

                Inter-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.1         2.2.2.2          644 0x80000003 0x7581
0.0.0.2         2.2.2.2          404 0x80000004 0x8a3e

                Intra-Area-Prefix-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum  Prefix  Reference
0.0.0.2         3.3.3.3          396 0x80000002 0xf076      1  Network-LSA
```

```
                Intra-Area-Te-LSA (Area 0.0.0.1)
Link State ID   ADV Router      Age  Seq#       CkSum
0.0.0.4         2.2.2.2          399 0x80000003 0xb2a2
0.0.0.3         3.3.3.3          401 0x80000003 0xd080
```

Demand Circuit

This section contains basic OSPFv3 Demand Circuit configuration examples.

Demand circuits are network segments whose costs vary with usage; charges can be based both on connect time and on bytes/packets transmitted. Examples of demand circuits include ISDN circuits, X.25 SVCs, and dial-up lines.The periodic nature of OSPF routing traffic has until now required a demand circuit's underlying data-link connection to be constantly open, resulting in unwanted usage charges. With the modifications described herein, OSPF Hellos and the refresh of OSPF routing information are suppressed on demand circuits, allowing the underlying data-link connections to be closed when it is not carrying application traffic. Demand circuits and regular network segments (e.g., leased lines) are allowed to be combined in any manner. In other words, there are no topological restrictions on the demand circuit support. However, while any OSPF network segment can be defined as a demand circuit, only point-to-point networks receive the full benefit. When broadcast and NBMA networks are declared demand circuits, routing update traffic is reduced but the periodic sending of Hellos is not, which in effect still requires that the data-link connections remain constantly open.

Point-to-Point Network

The diagram shows the configuration to enable the OSPFv3 Demand Circuit feature at the interface level in a P2P network.

Note: There is no global level configuration command for demand circuits.

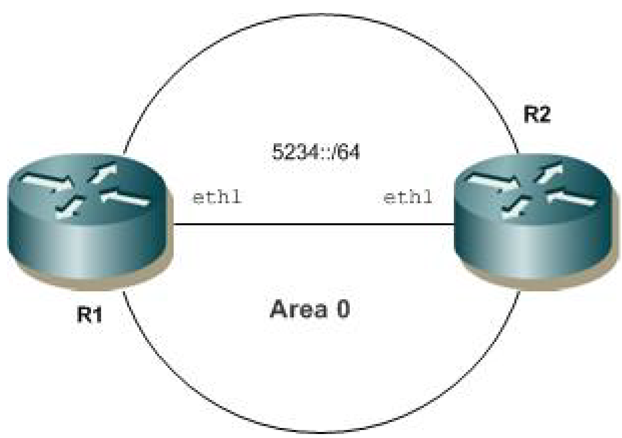

Figure 5-43: Basic Topology for OSPFv3 Demand Circuit Topology

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ipv6 address 5243::1/64`	Configure the IPv6 address of the interface.
`R1(config-if)#ipv6 ospf demand-circuit`	Enable Demand Circuit on the interface

R1(config-if)#ipv6 ospf network point-to-point	Enable network type as point-to-point network
R1(config-if)#ipv6 router ospf area 0 tag 1	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
R1(config-if)#exit	Exit interface mode.
R1(config)#router ipv6 ospf 1	Configure the routing process
R1(config-router)#router-id 1.1.1.1	Configure router-id to uniquely identify the router
R1(config-router)#end	Exit router mode.

R2

R2#configure terminal	Enter configure mode.
R2(config)#int eth1	Enter interface mode.
R2(config-if)#ipv6 address 5234::2/64	Configure the IPv6 address of the interface.
R2(config-if)#ipv6 ospf demand-circuit	Enable Demand Circuit on the interface
R2(config-if)#ipv6 ospf network point-to-point	Enable network type as point-to-point network
R2(config-if)#ipv6 router ospf area 0 tag 1	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
R2(config-if)#exit	Exit interface mode.
R2(config)#int eth2	Enter interface mode.
R2(config-if)#ipv6 address 4000::1/64	Configure the IPv6 address of the interface.
R2(config-if)#ipv6 router ospf area 1	Configure the interface in an area assigned with the area ID (1) which uniquely identifies the routing process
R2(config-if)#exit	Exit interface mode.
R2(config)#router ipv6 ospf 1	Configure the routing process
R2(config-router)#router-id 2.2.2.2	Configure router-id to uniquely identify the router
R2(config-router)#end	Exit router mode.

Validation 1

The dead timer is inactive after enabling demand-circuit. Therefor, hello packets are suppressed

R2:

```
rtr2#show ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
1.1.1.1           1   Full/ -         inactive    eth1       0
rtr2#
```

Validation 2

The DNA bit is remote device LSA's but is not set for a self-originated LSA .

R2:

```
rtr2#sh ipv6 ospf database
```

```
            OSPFv3 Router with ID (2.2.2.2) (Process 1)

                Link-LSA (Interface eth1)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix
0.0.0.3         1.1.1.1            2(DNA)  0x80000001 0xf4da      1
0.0.0.3         2.2.2.2          857       0x80000001 0x26dd      1

                Router-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum    Link
0.0.0.0         1.1.1.1            1(DNA)  0x80000002 0x0ae1      1
0.0.0.0         2.2.2.2          852       0x80000002 0x9952      1

                Intra-Area-Prefix-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum  Prefix  Reference
0.0.0.2         1.1.1.1            1(DNA)  0x80000002 0x26c3      1  Router-LSA
0.0.0.3         2.2.2.2          851       0x80000002 0x528d      1  Router-LSA

                Intra-Area-Te-LSA (Area 0.0.0.0)

Link State ID   ADV Router      Age       Seq#       CkSum
0.0.0.3         1.1.1.1            1(DNA)  0x80000002 0x95d8
0.0.0.3         2.2.2.2          852       0x80000002 0x5716

rtr2#
```

Validation 3

The demand circuit bit is set in the hello option's field.

```
rtr2#sh ipv6 ospf neighbor detail
 Neighbor 1.1.1.1, interface address fe80::5054:ff:fed3:4132
    In the area 0.0.0.0 via interface eth1
    Neighbor priority is 1, State is Full, 5 state changes
    Hello is suppressed
    DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x000133 (AF|*|*|DC|R|-|-|E|V6)
    Dead timer due in inactive
    Database Summary List 0
    Link State Request List 0
    Link State Retransmission List 0
rtr2#
```

Validation 4

Hello is suppressed in one neighbor according to the above configurations.

```
rtr2#sh ipv6 ospf interface
eth1 is up, line protocol is up
  Interface ID 3
  IPv6 Prefixes
```



```
    fe80::5054:ff:fe55:1a9f/64 (Link-Local Address)
    5234::2/64
  OSPFv3 Process (1), Area 0.0.0.0, Instance ID 0
    Router ID 2.2.2.2, Network Type POINTTOPOINT, Cost: 1, TE Metric: 1
    Reduce LSA Flooding
    Transmit Delay is 1 sec, State Point-To-Point, Priority 1
    Timer interval configured, Hello 10, Dead 40, Wait 40, Retransmit 5
      Hello due in inactive
    Neighbor Count is 1, Adjacent neighbor count is 1
    Suppress hello for 1 neighbor(s)
    Hello received 3 sent 2, DD received 4 sent 3
    LS-Req received 1 sent 1, LS-Upd received 3 sent 4
    LS-Ack received 2 sent 2, Discarded 0
```

Point-to-Multipoint Network

The diagram shows the configuration required to enable the OSPFv3 Demand Circuit feature at the interface level between a P2MP network and a P2MP non-broadcast network.

Note: There is no global level configuration command for demand circuits.

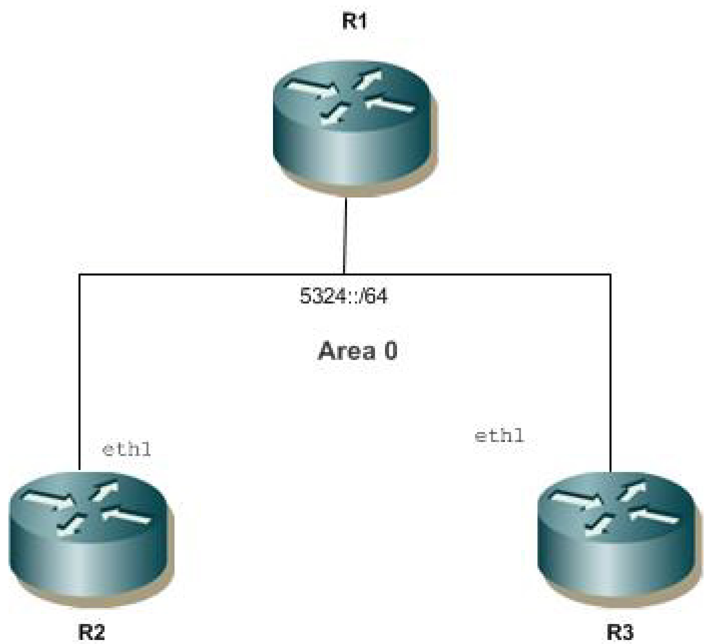

Figure 5-44: Basic Topology for OSPFv3 Demand Circuit Topology

R1

`R1#configure terminal`	Enter configure mode.
`R1(config)#int eth1`	Enter interface mode.
`R1(config-if)#ipv6 address 5243::1/64`	Configure the IPv6 address of the interface.
`R1(config-if)#ipv6 ospf demand-circuit`	Enable Demand Circuit on the interface
`R1(config-if)#ipv6 ospf network point-to-multipoint`	Enable network type as point-to-multipoint network

`R1(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R1(config-if)#exit`	Exit interface mode.
`R1(config)#router ipv6 ospf 1`	Configure the routing process
`R1(config-router)#router-id 1.1.1.1`	Configure router-id to uniquely identify the router
`R1(config-router)#end`	Exit router mode.

R2

`R2#configure terminal`	Enter configure mode.
`R2(config)#int eth1`	Enter interface mode.
`R2(config-if)#ipv6 address 5234::2/64`	Configure the IPv6 address of the interface.
`R2(config-if)#ipv6 ospf demand-circuit`	Enable Demand Circuit on the interface
`R2(config-if)#ipv6 ospf network point-to-multipoint non-broadcast`	Enable network type as point-to-multipoint network
`R2(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ipv6 ospf 1`	Configure the routing process
`R2(config-router)#router-id 2.2.2.2`	Configure router-id to uniquely identify the router
`R2(config-router)#end`	Exit router mode.

R3

`R3#configure terminal`	Enter configure mode.
`R3(config)#int eth1`	Enter interface mode.
`R3(config-if)#ipv6 address 5234::3/64`	Configure the IPv6 address of the interface.
`R3(config-if)#ipv6 ospf demand-circuit`	Enable Demand Circuit on the interface
`R3(config-if)#ipv6 ospf network point-to-multipoint non-broadcast`	Enable network type as point-to-multipoint network
`R3(config-if)#ipv6 router ospf area 0 tag 1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`R2(config-if)#exit`	Exit interface mode.
`R2(config)#router ipv6 ospf 1`	Configure the routing process
`R2(config-router)#router-id 3.3.3.3`	Configure router-id to uniquely identify the router
`R2(config-router)#end`	Exit router mode.

Validation 1

Verify hellos are suppressed between rtr1 to rtr2 and rtr1 to rtr3 since demand circuit enabled on rtr1 which is point-to-multipoint.

```
rtr2#show ipv6 ospf neighbor
Total number of full neighbors: 1
OSPF process 1 VRF(default):
Neighbor ID     Pri   State            Dead Time   Address         Interface Instance ID
```

```
1.1.1.1           1   Full/ -          inactive    10.10.10.46     eth1              0
rtr2#
```

R1:

```
rtr1#show ipv6 ospf neighbor
Total number of full neighbors: 2
OSPF process 1 VRF(default):
Neighbor ID     Pri   State            Dead Time   Address         Interface Instance ID
2.2.2.2           1   Full/ -          inactive    10.10.10.49     eth1              0
3.3.3.3           1   Full/ -          00:01:44    10.10.10.51     eth1              0
rtr1#show ipv6 ospf interface eth1
eth1 is up, line protocol is up
  Interface ID 3
  IPv6 Prefixes
    fe80::5054:ff:fed3:4132/64 (Link-Local Address)
    5234::1/64
  OSPFv3 Process (1), Area 0.0.0.0, Instance ID 0
    Router ID 1.1.1.1, Network Type POINTTOPOINT, Cost: 1, TE Metric: 1
    Reduce LSA Flooding
    Transmit Delay is 1 sec, State Point-To-Point, Priority 1
    Timer interval configured, Hello 10, Dead 40, Wait 40, Retransmit 5
      Hello due in inactive
    Neighbor Count is 1, Adjacent neighbor count is 1
    Suppress hello for 1 neighbor(s)
    Hello received 2 sent 3, DD received 3 sent 4
    LS-Req received 1 sent 1, LS-Upd received 4 sent 3
    LS-Ack received 2 sent 2, Discarded 0

rtr2#show ipv6 ospf neighbor detail
Neighbor 1.1.1.1, interface address fe80::5054:ff:fed3:4132
    In the area 0.0.0.0 via interface eth1
    Neighbor priority is 1, State is Full, 5 state changes
    Hello is suppressed
    DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x000133 (AF|*|*|DC|R|-|-|E|V6)
    Dead timer due in inactive
    Database Summary List 0
    Link State Request List 0
    Link State Retransmission List 0

rtr2#show ipv6 ospf database router adv-router 1.1.1.1

            OSPFv3 Router with ID (2.2.2.2) (Process 1)

                Router-LSA (Area 0.0.0.0)

  LS age(DNA): 1
  LS Type: Router-LSA
  Link State ID: 0.0.0.0
  Advertising Router: 1.1.1.1
```

```
LS Seq Number: 0x80000002
Checksum: 0x0AE1
Length: 40
Flags: 0x00 (-|-|-|-|-)
Options: 0x000133 (AF|*|*|DC|R|-|-|E|V6)

  Link connected to: another Router (point-to-point)
    Metric: 1
    Interface ID: 3
    Neighbor Interface ID: 3
    Neighbor Router ID: 2.2.2.2
```

Distribute List

To filter the routes that Open Shortest Path First Version 3 (OSPFv3) installs in the Routing Information Base (RIB), use the `distribute-list in` command in an appropriate configuration mode.

To filter the routes redistributed into Open Shortest Path First Version 3 (OSPFv3) from other routing protocols, use the `distribute-list out` command in an appropriate configuration mode.

Topology

Figure 5-45 shows the configuration to illustrate the distribute-list support for OSPFv3

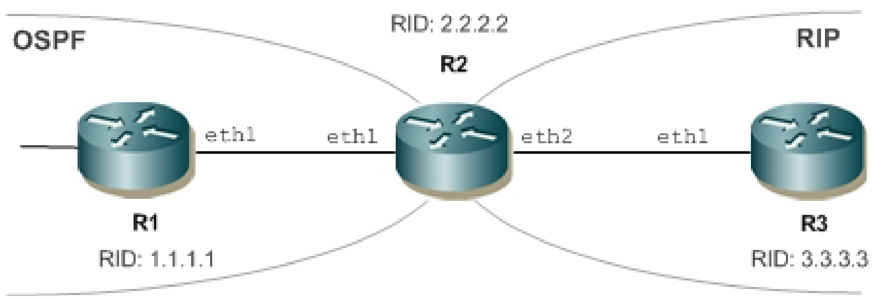

Figure 5-45: Basic Topology for Distribute-list

R1

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 2000::1/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag proc1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`(config-if)#exit`	Exit interface mode.
`(config)#router ipv6 ospf proc1`	Configure the routing process
`(config-router)#router-id 1.1.1.1`	Configure router-id to uniquely identify the router
`(config-router)#end`	Exit router mode.

R2

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 2000::50/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag proc1`	Configure the interface in an area assigned with the area ID (0) which uniquely identifies the routing process
`(config-if)# exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ipv6 address 4000::50/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag proc1`	Configure the interface in an area assigned with the area ID
`(config-if)# ipv6 router rip`	Configure rip instance under interface
`(config-if)#exit`	Exit interface mode.
`(config)#router ipv6 rip`	Configure the rip routing process
`(config-router)# neighbor fe80::5054:ff:fe85:19bc eth1`	Configure RIP neighbor peer
`(config-router)#exit`	Exit router mode.
`(config)#ipv6 access-list 1 permit 7777::/64`	Configure access list to permit 7777::/64 and deny 8888::/64
`(config)#router ipv6 ospf proc1`	Configure the routing process
`(config-router)#router-id 2.2.2.2`	Configure router-id to uniquely identify the router
`(config-router)# redistribute rip`	Redistribute rip routes
`(config-router)# distribute-list 1 out rip`	Configure distribute list to allow the permitted routes
`(config-router)#exit`	Exit router mode.
`(Config)# ipv6 access-list 1 permit 8888::/64`	Configure static route
`(config-router)#exit`	Exit router mode.

R3

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 4000::51/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router rip`	Configure rip instance under interface
`(config-if)#exit`	Exit interface mode.
`(config)# router ipv6 rip`	Configure the rip routing process

(config-router)# neighbor fe80::5054:ff:fec6:69f eth2	Configure rip neighbor peer
(config-router)#end	Exit router mode.
(config)# ipv6 route 7777::/64 eth2	Configure static route
(config)# ipv6 route 8888::/64 eth3	Configure static route
(config)# router ipv6 rip	Configure the rip routing process
(config-router)#redistribute static	Redistribute configured static routes
(config-router)#end	Exit router mode.

Validation 1

Verify OSPF neighborship is up between R1and R2

R2:

```
rtr2#show ipv6 ospf neighbor
OSPFv3 Process (Proc1)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
1.1.1.1           1   Full/Backup     00:00:38    eth1       0
rtr2#
```

Validation 2

Check if permitted route 7777::/64 is present in route table and denied route 8888::/64 is not present.

R1:

```
rtr1#show ipv6 ospf route
 OSPFv3 Process (Proc1)
 Codes: C - connected, D - Discard, O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2
    Destination     Metric          Next-hop
 C  2000::/64         1            directly connected, eth1, Area 0.0.0.0
 E2 7777::/64        1/20   via    fe80::5054:ff:fe1e:269d, eth1
rtr1#
```

Validation 3

Check both the routes 7777::/64 and 8888::/64 are present after 8888::/64 is permitted

R1:

```
rtr1#show ipv6 ospf route
OSPFv3 Process (Proc1)
Codes: C - connected, D - Discard, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2

   Destination    Metric    Next-hop
C  2000::/64        1      directly connected, eth1, Area 0.0.0.0
E2 7777::/64       1/20   via fe80::5054:ff:fe1e:269d, eth1
E2 8888::/64       1/20   via fe80::5054:ff:fe1e:269d, eth1
```



```
rtr1#
```

Loop Free Alternate

The diagram shows the configuration for the OSPFv3 Loop Free Alternate (LFA) feature.

Topology

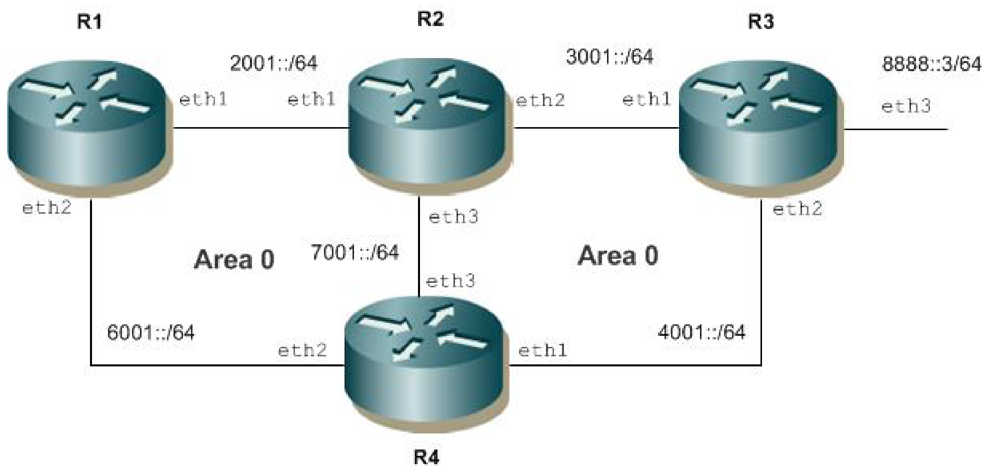

Figure 5-46: Basic OSPFv3 LFA Topology

R1

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 2001::1/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ipv6 address 6001::1/64`	Configure the IPv6address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 5`	Configure cost for the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#router ipv6 ospf 1`	Configure the routing process and specify the Process ID (1).
`(config)#router-id 1.1.1.1`	Configure the router-id
`(config-router)#fast-reroute keep-all-paths`	Configure LFA-FRR to calculate the available backup path.
`(config-router)#end`	Exit router mode.

R2

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 2001::2/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ipv6 address 3001::2/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth3`	Enter interface mode.
`(config-if)#ipv6 address 7001::2/64`	Configure the IP v6address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 2`	Configure cost for the interface.
`(config)#router ipv6 ospf 1`	Configure the routing process, and specify the Process ID (`1`). The Process ID should be a unique positive integer identifying the routing process.
`(config)#router-id 2.2.2.2`	Configure the router-id
`(config-router)#end`	Exit router mode.

R3

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 3001::3/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ipv6 address 4001::3/64`	Configure the IP v6address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 2`	Configure cost for the interface.
`(config)#int eth3`	Enter interface mode.
`(config-if)#ipv6 address 8888::3/64`	Configure the IP v6address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#exit`	Exit interface mode.

`(config)#router ipv6 ospf 1`	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
`(config)#router-id 3.3.3.3`	Configure the router-id
`(config-router)#end`	Exit router mode.

R4

`#configure terminal`	Enter configure mode.
`(config)#int eth1`	Enter interface mode.
`(config-if)#ipv6 address 5001::4/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 2`	Configure cost for the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth2`	Enter interface mode.
`(config-if)#ipv6 address 6001::4/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 5`	Configure cost for the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#int eth3`	Enter interface mode.
`(config-if)#ipv6 address 7001::4/64`	Configure the IPv6 address of the interface.
`(config-if)#ipv6 router ospf area 0 tag 1`	Enable OSPFv3 on the interface.
`(config-if)#ipv6 ospf cost 2`	Configure cost for the interface.
`(config)#router ipv6 ospf 1`	Configure the routing process, and specify the Process ID (1). The Process ID should be a unique positive integer identifying the routing process.
`(config)#router-id 4.4.4.4`	Configure the router-id.
`(config-router)#end`	Exit router mode.

Validation

Check OSPFv3 neighborship.

```
rtr1#show ipv6 ospf neighbor
OSPFv3 Process (1)
Neighbor ID     Pri   State           Dead Time   Interface  Instance ID
2.2.2.2           1   Full/DR         00:00:35    eth1       0
4.4.4.4           1   Full/DR         00:00:35    eth2       0
```

Check the OSPF route installation and LFA-FRR backup path for the primary path.

```
rtr1#show ipv6 route
IPv6 Routing Table
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
```

```
       IA - OSPF inter area, E1 - OSPF external type 1,
       E2 - OSPF external type 2, N1 - OSPF NSSA external type 1,
       N2 - OSPF NSSA external type 2, I - IS-IS, B - BGP
Timers: Uptime

IP Route Table for VRF "default"
C      ::1/128 via ::, lo, 1d18h11m
C      2001::/64 via ::, eth1, 01:33:09
O      3001::/64 [110/2] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
O      4001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
C      5001::/64 via ::, eth3, 1d18h01m
C      6001::/64 via ::, eth2, 17:06:18
O      7001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
O      8888::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
C      fe80::/64 via ::, eth2, 17:48:03
rtr1#show ipv6 route fast-reroute
IPv6 Fast-reroute Routing Table
Codes: R - RIP, O - OSPF,
       I - IS-IS, B - BGP
O      3001::/64 [110/8] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:00:59
O      4001::/64 [110/7] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:00:09
O      7001::/64 [110/7] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:00:59
O      8888::/64 [110/8] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:00:09
```

Not mandatory that for all primary path, there exists an LFA backup path only if inequality equation satisfies according to attributes configured on routers, backup path will be calculated.

To prohibit an interface from being used as a repair path, disable fast reroute calculation on the interface.

```
(config)#int eth2
(config-if)#ipv6 ospf fast-reroute per-prefix candidate disable
(config-if)#end
```

Verify that the `eth2` interface is not used for backup path calculation.

```
rtr1#show ipv6 route
IPv6 Routing Table
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       IA - OSPF inter area, E1 - OSPF external type 1,
       E2 - OSPF external type 2, N1 - OSPF NSSA external type 1,
       N2 - OSPF NSSA external type 2, I - IS-IS, B - BGP
Timers: Uptime

IP Route Table for VRF "default"
C      ::1/128 via ::, lo, 1d18h11m
C      2001::/64 via ::, eth1, 01:33:09
O      3001::/64 [110/2] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
O      4001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
C      5001::/64 via ::, eth3, 1d18h01m
C      6001::/64 via ::, eth2, 17:06:18
O      7001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
O      8888::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:00:34
C      fe80::/64 via ::, eth2, 17:48:03
rtr1#show ipv6 route fast-reroute
```


Now there is no LFA backup paths as we have disabled the interface from backup path calculation

Tie-Breaking Configuration:

By default, LFA backup path is calculated based on interface-disjoint. Other supported attributes are:

- Primary Path
- Broadcast-link protecting
- Node-protection

```
(config)#router ipv6 ospf 1
rtr1(config-router)#fast-reroute tie-break node-protecting index 1
```

Verify `show ipv6 route` and `show ipv6 route fast-reroute` for backup path calculated according to attributes configured above.

```
rtr1#show ipv6 route
IPv6 Routing Table
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       IA - OSPF inter area, E1 - OSPF external type 1,
       E2 - OSPF external type 2, N1 - OSPF NSSA external type 1,
       N2 - OSPF NSSA external type 2, I - IS-IS, B - BGP
Timers: Uptime

IP Route Table for VRF "default"
C      ::1/128 via ::, lo, 1d18h15m
C      2001::/64 via ::, eth1, 01:37:43
O      3001::/64 [110/2] via fe80::5054:ff:feed:dc42, eth1, 00:01:29
O      4001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:01:29
C      5001::/64 via ::, eth3, 1d18h06m
C      6001::/64 via ::, eth2, 17:10:52
O      7001::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:01:29
O      8888::/64 [110/3] via fe80::5054:ff:feed:dc42, eth1, 00:01:29
C      fe80::/64 via ::, eth2, 17:52:37
rtr1#show ipv6 route fast-reroute
IPv6 Fast-reroute Routing Table
Codes: R - RIP, O - OSPF,
       I - IS-IS, B - BGP
O      4001::/64 [110/7] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:01:28
O      7001::/64 [110/7] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:01:28
O      8888::/64 [110/8] via fe80::5054:ff:fe7b:921e, eth2 inactive, 00:01:28
```

CHAPTER 6 IS-IS IPv4

This chapter contains basic IS-IS (Intermediate System to Intermediate System) configuration examples.

For details about the commands used in these examples, see the *Intermediate System to Intermediate System Command Reference*.

Enable 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 the `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.

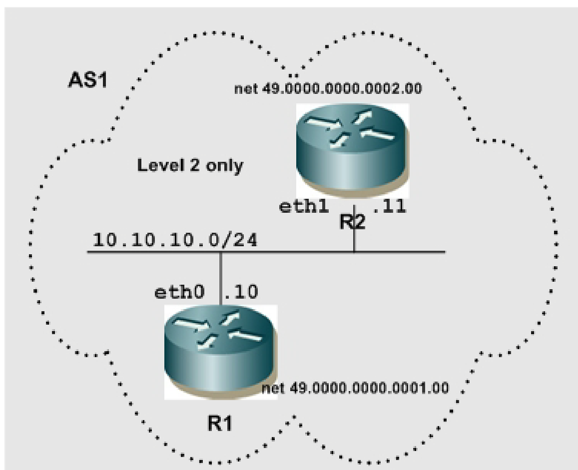

Figure 6-47: Basic IS-IS Topology

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area 49 (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

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

Validation

show clns neighbors, show isis database, show isis topology

Set Priority

This example describes how to set 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 (64) of R1 and R2. This makes R3 the DIS.

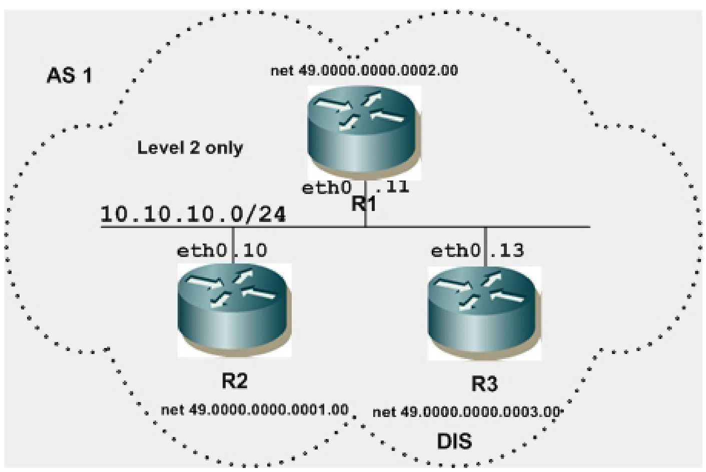

Figure 6-48: Set IS-IS Priority

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# isis priority 70`	Specify the router priority to a higher priority `(70)` to make R3 the designated IS (DIS).

`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

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

Validation

show clns neighbors, show isis database, show isis topology

Redistribute 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.

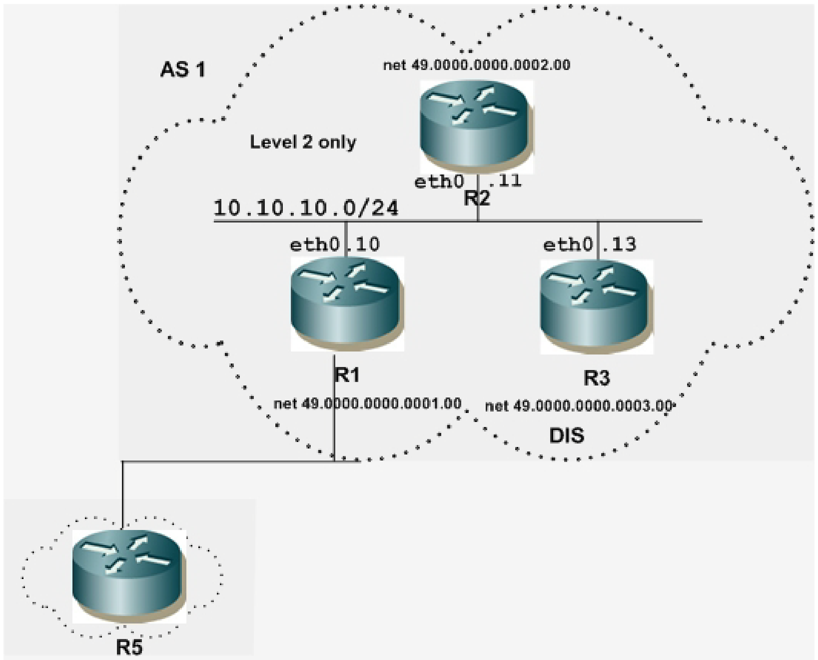

Figure 6-49: Redistribute Routes Into IS-IS

R1

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

Validation

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

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 for 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 is computed as follows:

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.

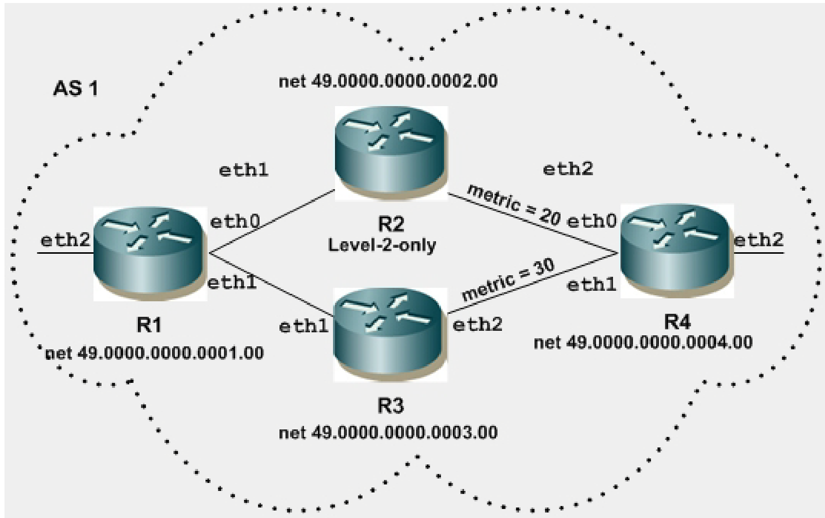

Figure 6-50: Configure IS-IS Metric

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# isis metric 20`	Set the value of IS-IS metric (on `eth2`) to `20`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# isis metric 30`	Set the value of IS-IS metric (on `eth2`) to `30`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.

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

Validation

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

L1-L2 Area Routing with a 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 reside 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.

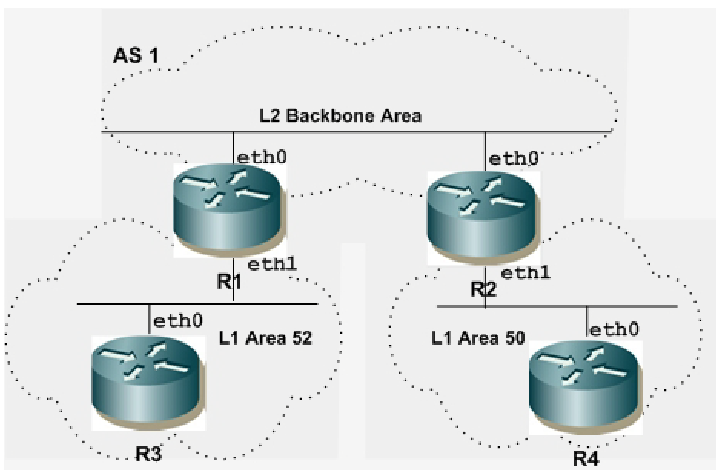

Figure 6-51: Single-Instance L1-L2 Area Routing

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis abc`	Enable IS-IS routing on the interface `eth0` for area `abc`.
`(config-if)# isis circuit-type level-2-only`	Set the circuit type for the interface `eth0`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.

`# configure terminal`	Enter Configure mode.
`(config-if)# ip router isis abc`	Enable IS-IS routing on the interface `eth1` for area `abc`.
`(config-if)# isis circuit-type level-1`	Set the circuit type for interface `eth1` to level 1.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis abc`	Create an IS-IS routing instance for area `abc`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis bb`	Enable IS-IS routing on the interface `eth0` for area `bb`.
`(config-if)# isis circuit-type level-2-only`	Set the circuit type for the interface `eth0` to level-2 only.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip router isis bb`	Enable IS-IS routing on interface `eth1` for area `bb`.
`(config-if)# isis circuit-type level-1`	Set the circuit type for interface `eth1` to level 1.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis bb`	Create an IS-IS routing instance for area `bb`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis xyz`	Enable IS-IS routing on the interface `eth0` for area `xyz`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis xyz`	Create an IS-IS routing instance for area `xyz`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`xyz`) as `level-1`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis aa`	Enable IS-IS routing on the interface `eth0` for area `aa`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis aa`	Create an IS-IS routing instance for area `aa`.

`(config-router)# is-type level-1`	Establish the IS level for this area (`aa`) as `level-1`.
`(config-router)# net 50.0000.0000.0004.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Validation

show ip isis route, show ip route

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 reside 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.

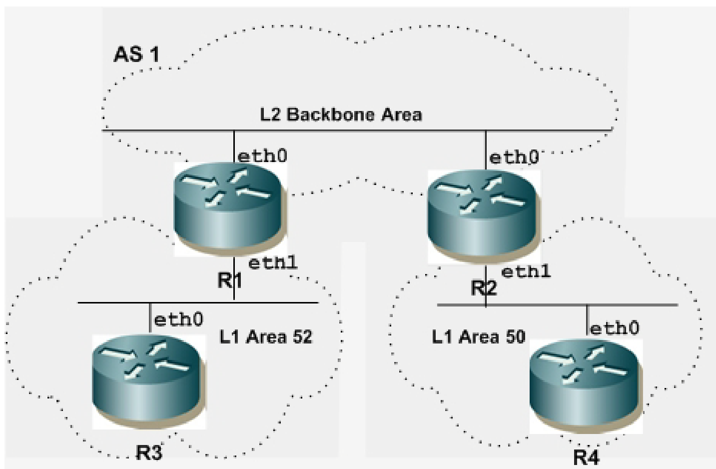

Figure 6-52: Multiple-Instance L1-L2 Area Routing

R1

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

`# configure terminal`	Enter Configure mode.
`(config-if)# ip router isis ccc`	Enable IS-IS routing on interface `eth1` for area `ccc`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ccc`	Create an IS-IS routing instance for area `ccc`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`ccc`) as `level-1`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis bb`	Enable IS-IS routing on interface `eth0` for area `bb`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis bb`	Create an IS-IS routing instance for area `bb`.
`(config-router)# is-type level-2-only`	Establish the IS level for this area (`bb`) as `level-2-only`.
`(config-router)# net bb.0000.0000.0002.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
`(config-router)# exit`	Exit Router mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip router isis abc`	Enable IS-IS routing on interface `eth1` for area `abc`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis abc`	Create an IS-IS routing instance for area `abc`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`abc`) as `level-1`.
`(config-router)# net 52.0000.0000.0002.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis xyz`	Enable IS-IS routing on interface `eth0` for area `xyz`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis xyz`	Create an IS-IS routing instance for area `xyz`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`xyz`) as `level-1`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ip router isis aa`	Enable IS-IS routing on interface `eth0` for area `aa`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis aa`	Create an IS-IS routing instance for area `aa`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`aa`) as `level-1`.
`(config-router)# net 52.0000.0000.0004.00`	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Validation

show ip isis route, show ip route

Route Leaking

Route leaking is defined in RFC 2966. For Level-1 (L1) routers, only level-1 routes are populated in the routing table. The L1 router has a default route to the nearest Level-1/Level-2 (L1/L2) router: This could result in sub-optimal routing in certain scenarios. Route leaking causes an L1/L2 router to advertise the level-2 routes in its database to the L1 router, thus allowing the L1 router to acknowledge the prefixes advertised by the Level-2 (L2) router. In this way, the L1 router has the ability to learn the true cost to reach other areas.

In the following example, R1 is the L1 router, R2 is the L1/L2 router doing the route leaking, and R3 is the L2 router. The following configuration is given only for R2, assuming that the adjacency with R1 and R3 are already up, and the route tables with appropriate routes are already populated.

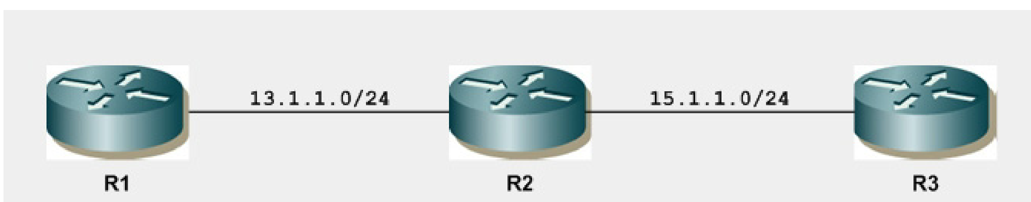

Figure 6-53: Route Leaking Topology

R2

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance for area `49 (1)`.
`(config-router)# redistribute isis level-2 into level-1`	Redistribute routes learned from level 2 into level 1 (route leaking).
`(config-router)# end`	Exit Router mode.

In the example, route, `i ia 3.3.3.0/24 [115/30] via 15.1.1.32, eth2, 00:00:02`, is the L2 route leaked by the L1/L2 router into the L1 router.

```
Router1#show ip route
```

```
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

Gateway of last resort is 15.1.1.32 to network 0.0.0.0

i*L1    0.0.0.0/0 [115/10] via 15.1.1.32, eth2, 00:00:59
i ia    3.3.3.0/24 [115/30] via 15.1.1.32, eth2, 00:00:02
C       10.1.2.0/24 is directly connected, eth0
K       10.10.0.0/16 via 10.1.2.1, eth0
K       10.10.3.0/24 is directly connected, eth0
C       13.1.1.0/24 is directly connected, eth1
C       15.1.1.0/24 is directly connected, eth2
C       31.31.31.31/32 is directly connected, lo
C       127.0.0.0/8 is directly connected, lo
K       169.254.0.0/16 is directly connected, eth0
```

Validation

show ip route

Route Summarization

Route summarization makes the routing table smaller, but still allows complete IP connectivity, if everything is configured properly.

The following example consists of a three-router topology, in which R2 is doing the summarization. In this example, R1 is the L1 router, R2 is the L1/L2 router doing the summarization, and R3 is the L2 router. The following configuration is given only for R2, assuming that the adjacencies with R1 and R3 are already up, and the route tables with the appropriate routes are already populated.

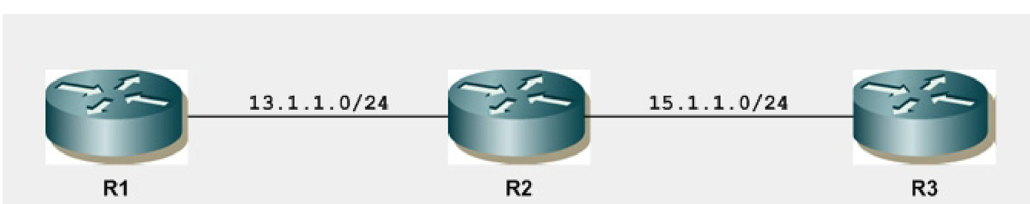

Figure 6-54: Route Summarization Topology

R2

`#configure terminal`	Enter Configure mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area `49 (1)`.
`(config-router)#summary-address 20.10.3.0/6 level-1 metric 1`	The prefixes, 20.10.3.0/8, 21.10.3.0/8, 22.10.3.0/8, and 23.10.3.0/8 are summarized to 20.10.3.0/6.
`(config-router)#end`	Exit Router mode.

Validation

show ip route

Graceful Restart

ISIS provides graceful restart, in which the adjacency and routes are maintained in the routing table for the grace period. In this way, the data flow is not affected, and there is no packet loss during the restart phase.

In the following example, R1 is the L1/L2 router, and R2 is the L1/L2 restart-helper router. The following configuration is given only for R2, assuming that the adjacency with R1 is already up, and the route tables with the appropriate routes are already populated.

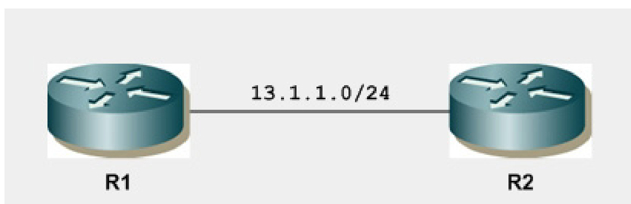

Figure 6-55: IS-IS Graceful Restart

R2

`#configure terminal`	Enter Configure mode.
`(config)#isis restart helper`	Configure this router as a restart helper.
`(config)#isis restart grace-period 100`	Set the grace period to 100 seconds. The restarting router should come up before 100 seconds, otherwise, the adjacency and routes will be deleted.

Note: The IS-IS daemon in the restarting router must be manually restarted: it does not restart automatically.

Validation

show ip route

IS-IS Distance

Administrative distance in IS-IS can be configured for a specified source ID or for all routes.

This example shows configuring the IS-IS administrative distance for the IPv4 address family.

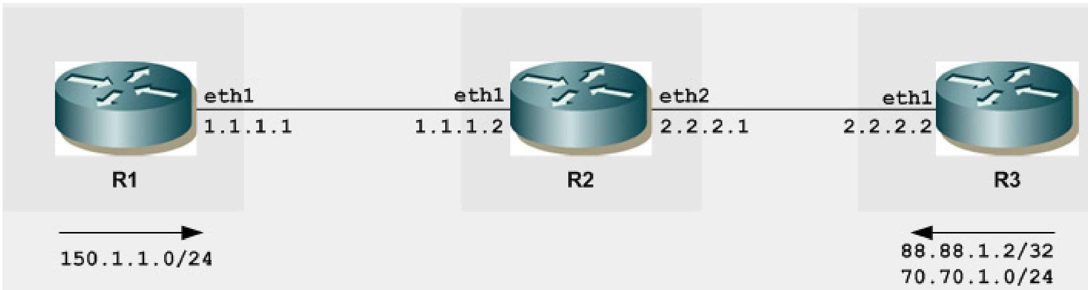

Figure 6-56: IS-IS Distance Topology

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip address 1.1.1.2/24`	Assign the IP address on this interface (`eth1`).
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0001.00`	Establish a Network Entity Title (NET) for this instance, specifying the address and the system ID.
`(config-router)# redistribute static`	Redistribute the static routes.

R2

`# configure terminal`	Enter Configure mode.
`(config)# access-list DIST permit 88.88.1.2/32`	Create an access list to permit the `88.88.1.2/32` route from R3.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip address 1.1.1.1/24`	Assign the IP address on this interface (`eth1`).
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ip address 2.2.2.1/24`	Assign the IP address on this interface (`eth2`).
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth2`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0002.00`	Specify the NET address.
`(config-router)# distance 100`	Configure the administrative distance for all routes received from R1 and R2.

`(config-router)# distance 20 0000.0000.0001`	Configure the administrative distance for all routes received from R1. This command overwrites the applied distance, 100, and will apply distance 20 for all routes received from R1.
`(config-router)# distance 30 0000.0000.0003 DIST`	Configure the distance, `30`, to the route, 88.88.1.2/32, received from R3. All other routes from R3 (for example, 70.70.1.0/24) will have the distance applied as 100. If the distance, 100, is not configured, all other routes will have a default distance of 115.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ip address 2.2.2.2/24`	Assign the IP address on this interface (`eth1`).
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0003.00`	Specify the NET address.
`(config-router)# redistribute static`	Redistribute the static routes.

Validation

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

Overload Bit

The expanded use of the overload bit in IS-IS is useful to Internet Service Providers (ISPs) who run both BGP and IS-IS to avoid certain black-hole scenarios. The overload bit feature allows configuration of a router to disable the overload bit automatically when BGP has converged.

IS-IS disables the overload bit if BGP is not converged in ten minutes, and the `wait-for-bgp` option is configured.

When the `set overload-bit wait-for-bgp` is configured after restart (for example, using the `set-overload-bit on-startup wait-for-bgp` or `set-overload-bit on-startup <5-86400>` commands), the IS-IS router advertises the overload bit to all its neighbors, informing them not to route traffic through this router, except for the traffic destined to directly-connected networks of this router.

Whenever an interface is configured as no set-overload-bit (using the `no set-overload-bit` command), the router does not advertise or set the overload bit on startup.

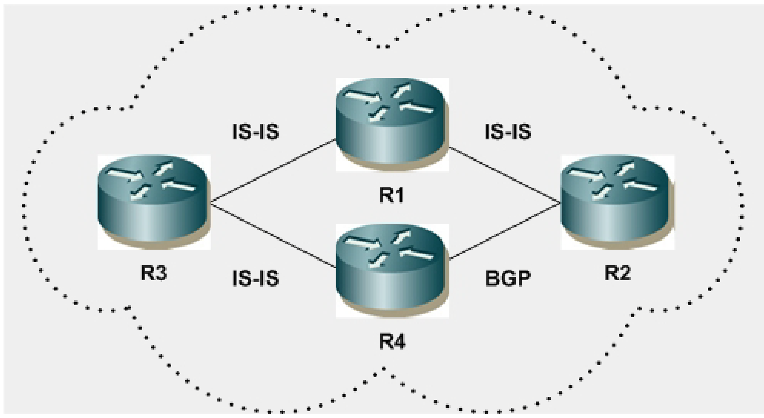

Figure 6-57: Configure Overload Bit

R1

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (1).
`(config-router)# net 49.0001.0000.0000.0001.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (eth1) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth1 (connected to R2).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# interface eth2`	Specify the interface (eth2) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth2 (connected to R3).
`(config-if)# isis metric 50`	Increase the value of IS-IS metric from R1-R3.

R2

`# configure terminal`	Enter Configure mode.
`(config)# router bgp 100`	Create a BGP routing instance (100).
`(config-router)# neighbor 1.1.1.2 remote-as 2`	Specify the neighbor's IP address (1.1.1.2) and the ASN value of the neighbor (2).
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (eth1) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth1 (connected to R1).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# interface eth2`	Specify the interface (eth2) to configure and enter Interface mode.

`# configure terminal`	Enter Configure mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth2` (connected to R4).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance `(1)`.
`(config-router)# net 49.0001.0000.0000.0002.00`	Define the NET address.
`(config-router)# set-overload-bit on-startup wait-for-bgp`	Configure IS-IS to set the overload bit until BGP is completely converged (maximum 600 seconds) only on restart.
`(config-router)# set-overload-bit on-startup wait-for-bgp suppress external`	Configure IS-IS to suppress external routes until the configured value (in seconds) only on startup.
`(config-router)# set-overload-bit on-startup wait-for-bgp suppress interlevel`	Configure IS-IS to suppress inter-level routes until the configured value (in seconds) only on startup.

R3

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance `(1)`.
`(config-router)# net 49.0001.0000.0000.0003.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1` (connected to R4).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth2` (connected to R1).

R4

`# configure terminal`	Enter Configure mode.
`(config)# router bgp 100`	Create a BGP routing instance `(100)`.
`(config-router)# neighbor 1.1.1.1 remote-as 1`	Specify the neighbor's IP address (`1.1.1.1`) and the ASN value of the neighbor (`1`).
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance `(1)`.
`(config-router)# net 49.0001.0000.0000.0004.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1` (connected to R3).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.

`# configure terminal`	Enter Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth2` (connected to R2).

Validation

Use the following commands to verify adjacency and protocol-related details:

show clns neighbors, show isis database, show ip bgp summary

Passive Interface

In ISP and large enterprise networks, many of the distribution routers have more than 200 interfaces. Before the Default Passive-Interface feature, there were two possibilities for obtaining routing information from tall of these interfaces:

- Configure a routing protocol on the backbone interfaces and redistribute connected interfaces.
- Configure the routing protocol on all interfaces and manually set most of them as passive, which was time consuming.

The solution to this problem was to configure the routing protocol on all interfaces and manually set the `passive-interface` command on the interfaces where adjacency was not desired. In certain networks, this meant coding 200 or more passive-interface statements. With the Default Passive Interface feature, this problem is solved by allowing all interfaces to be set as passive by default using a single `passive-interface` default command, then configuring individual interfaces in which adjacencies are desired using the `no passive-interface` command.

Usage

1. When a specific interface is configured as passive using the `passive-interface` command:
   - The interface loses its adjacency on that interface, for example, eth1.
   - The interface (eth1) is still advertised by other IS-IS speaking interfaces to their neighbors.
2. When a specific interface is configured as not passive using the `no passive-interface` command:
   - The interface is IS-IS disabled and must be enabled using the `ip router isis` command (for example, `ip router isis 1`).
   - The interface (for example, eth1) is not advertised by other IS-IS speaking interfaces to their neighbors.
3. When an interface is configured with the `passive interface` command:
   - All interfaces lose their adjacency, except the interface with the higher index number. (For example: If eth1, eth2, eth3, and eth4 are the router interfaces, eth4 has the highest index number.)
   - All interfaces are advertised by the active IS-IS speaking interface to its neighbors.
4. When an interface is configured with the `no passive interface` command:
   - All interfaces are IS-IS disabled, except the interface that was active, and all interfaces must enable IS-IS on these interfaces using the `ip router isis` command (for example, `ip router isis 1`).
   - All interfaces are not advertised by the active IS-IS speaking interface to its neighbors.

Topology

Figure 6-58 shows a passive-interface configuration example.

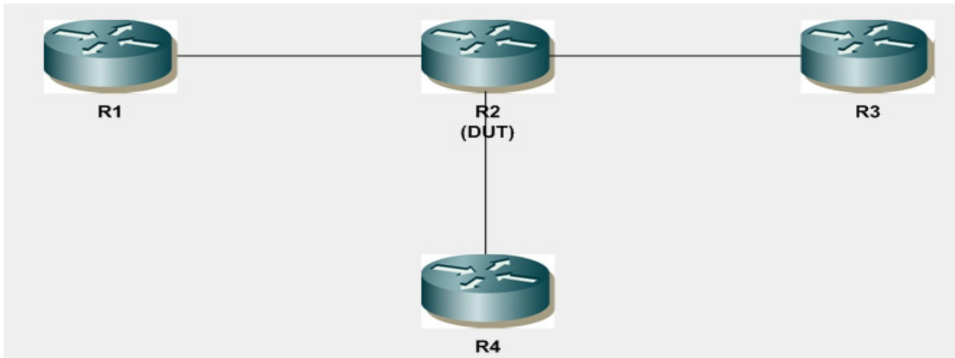

Figure 6-58: IS-IS Passive Interface

R1

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (1).
`(config-router)# net 49.0001.0000.0000.0001.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (eth1) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth1 (connected to R2).

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (eth1) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth1 (connected to R1).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# interface eth2`	Specify the interface (eth2) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth2 (connected to R3).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# interface eth3`	Specify the interface (eth3) to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface eth2 (connected to R4).
`(config-if)# exit`	Exit Interface mode and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (1).

`# configure terminal`	Enter Configure mode.
`(config-router)# net 49.0001.0000.0000.0002.00`	Define the NET address.
`(config-router)# passive-interface eth1`	Configure the `eth1` interface as passive.
`(config-router)# passive-interface`	Configure all interfaces as passive, except one (interface with the higher index number).

R3

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance `(1`).
`(config-router)# net 49.0001.0000.0000.0003.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1)` to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1` (connected to R2).

R4

`# configure terminal`	Enter Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance `(1`).
`(config-router)# net 49.0001.0000.0000.0004.00`	Define the NET address.
`(config-router)# exit`	Exit Router mode and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1)` to configure and enter Interface mode.
`(config-if)# ip router isis 1`	Enable IS-IS routing on interface `eth1` (connected to R2).

Validation

show clns neighbors, show isis database detail

CHAPTER 7 IS-IS IPv6

This chapter contains basic IS-IS (IPv6) configuration examples.

For details about the commands used in these examples, see the *Intermediate System to Intermediate System Command Reference*.

Enable IS-IS on an Interface

This example shows the minimum configuration required for enabling IS-IS (IPv6) on an interface. R1 and R2 are two routers in the `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.

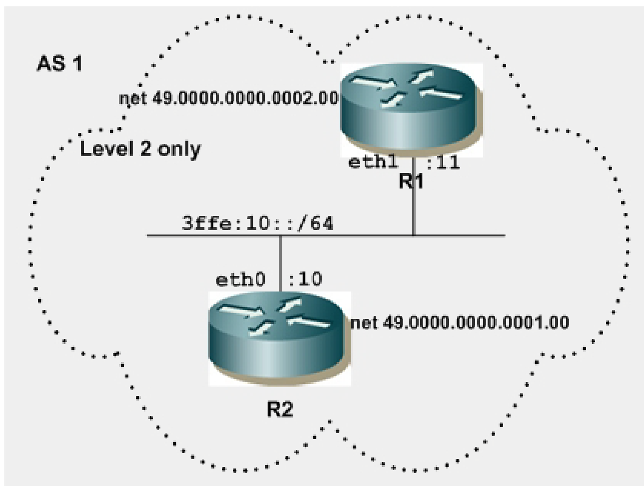

Figure 7-59: Enable IS-ISv6

R1

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

R2

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

Validation

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

Set Priority

This example shows 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 (60) of R1 and R2. This makes R3 the DIS.

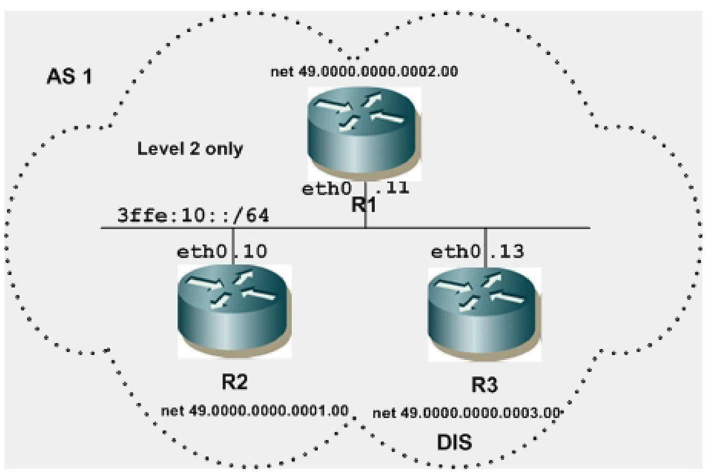

Figure 7-60: Set IS-ISv6 Priority

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# isis priority 70`	Specify the router priority to a higher priority `(70)` to make R3 the designated IS (DIS).

`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

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

Validation

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

Redistribute 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.

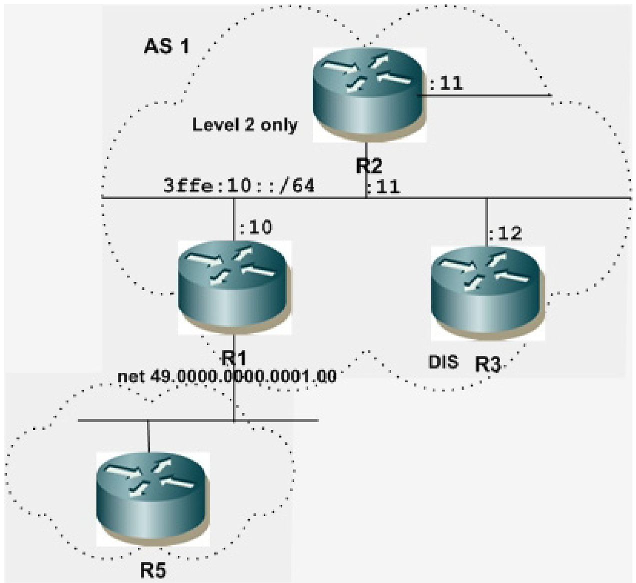

Figure 7-61: Redistribute Routes Into IS-ISv6

R1

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

Validation

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

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.

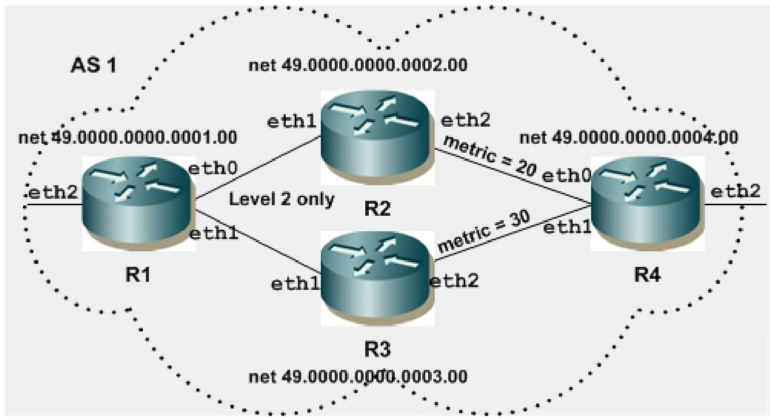

Figure 7-62: IS-ISv6 Metric

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49(ipi)`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.

`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49(ipi).`
`(config-if)# isis metric 20`	Set the value of IS-IS metric (on `eth2`) to `20`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# isis metric 30`	Set the value of IS-IS metric (on `eth2`) to `30`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).
`(config-router)# is-type level-2-only`	Configure instance `ipi` as `level-2-only` routing.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis ipi`	Enable IS-IS routing on an interface for area `49 (ipi).`
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis ipi`	Create an IS-IS routing instance for area `49` (`ipi`).

(config-router)# is-type level-2-only	Configure instance ipi as level-2-only routing.
(config-router)# net 49.0000.0000.0004.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

Validation

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

L1-L2 Area Routing with a 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 reside 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.

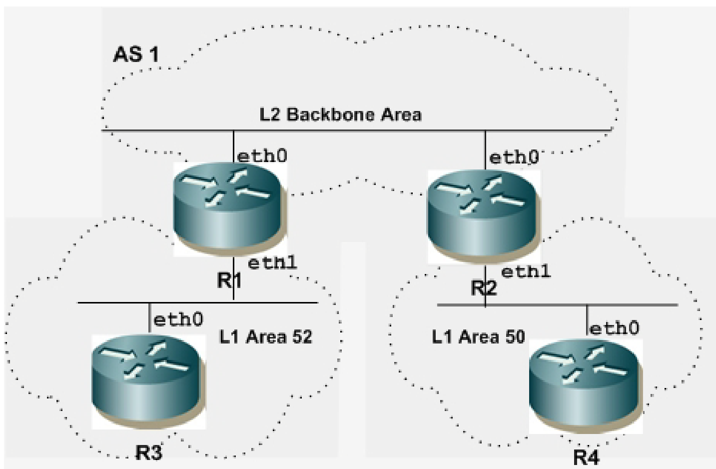

Figure 7-63: Single-Instance L1-L2 Area Routing

R1

# configure terminal	Enter Configure mode.
(config)# interface eth0	Specify the interface (eth0) to configure, and enter Interface mode.
(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface eth0 for area abc.
(config-if)# isis circuit-type level-2-only	Set the circuit type for the interface eth0.
(config-if)# exit	Exit Interface mode, and return to Configure mode.
(config)# interface eth1	Specify the interface (eth1) to configure, and enter Interface mode.
(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface eth1 for area abc.
(config-if)# isis circuit-type level-1	Set the circuit type for the interface eth1.
(config-if)# exit	Exit Interface mode, and return to Configure mode.

`# configure terminal`	Enter Configure mode.
`(config)# router isis abc`	Create an IS-IS routing instance for area `abc`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis bb`	Enable IS-IS routing on the interface `eth0` for area `bb`.
`(config-if)# isis circuit-type level-2-only`	Set the circuit type for the interface `eth0`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis bb`	Enable IS-IS routing on the interface `eth1` for area `bb`.
`(config-if)# isis circuit-type level-1`	Set the circuit type for the interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis bb`	Create an IS-IS routing instance for area `bb`.
`(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

`(config)# interface eth0`	Specify the interface (`eth0`) to configure, and enter Interface mode.
`(config-if)# ipv6 router isis xyz`	Enable IS-IS routing on the interface `eth0` for area `xyz`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis xyz`	Create an IS-IS routing instance for area `xyz`.
`(config-router)# is-type level-1`	Establish the IS level for this area (`xyz`) as `level-1`.
`(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

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

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 reside 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.

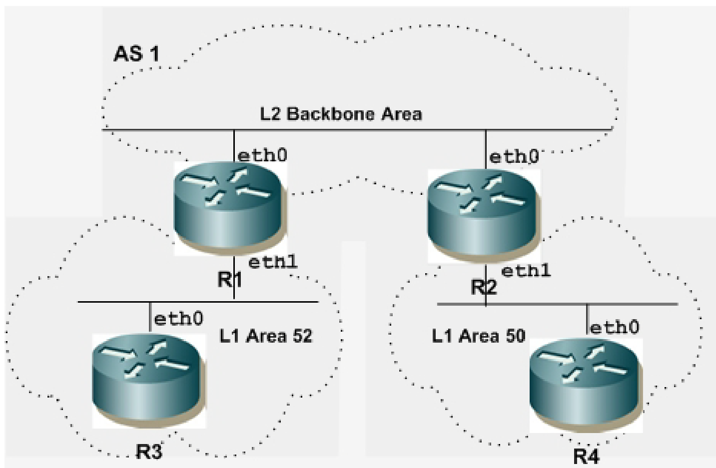

Figure 7-64: Multiple-Instance L1-L2 Area Routing

R1

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

(config)# interface eth0	Specify the interface (eth0) to configure, and enter Interface mode.
(config-if)# ipv6 router isis bb	Enable IS-IS routing on the interface eth0 for area bb.
(config-if)# exit	Exit Interface mode, and return to Configure mode.
(config)# router isis bb	Create an IS-IS routing instance for area bb.
(config-router)# is-type level-2-only	Establish the IS level for this area (bb) as level-2-only.
(config-router)# net bb.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.
(config-router)# exit	Exit Router mode, and return to Configure mode.
(config)# interface eth1	Specify the interface (eth1) to configure, and enter Interface mode.
(config-if)# ipv6 router isis abc	Enable IS-IS routing on the interface eth1 for area abc.
(config-if)# exit	Exit Interface mode, and return to Configure mode.
(config)# router isis abc	Create an IS-IS routing instance for area abc.
(config-router)# is-type level-1	Establish the IS level for this area (abc) as level-1.
(config-router)# net 52.0000.0000.0002.00	Establish a Network Entity Title for this instance, specifying the area address and the system ID.

R3

(config)# interface eth0	Specify the interface (eth0) to configure, and enter Interface mode.
(config-if)# ipv6 router isis xyz	Enable IS-IS routing on the interface eth0 for area xyz.
(config-if)# exit	Exit Interface mode, and return to Configure mode.
(config)# router isis xyz	Create an IS-IS routing instance for area xyz.
(config-router)# is-type level-1	Establish the IS level for this area (xyz) as level-1.
(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

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

Validation

show ipv6 isis route, show ipv6 route

Configure IS-IS IPv6 Distance

Administrative distance can be configured for an IS-IS IPv6 address family.

This example shows configuring the IS-IS administrative distance for the IPv6 address family.

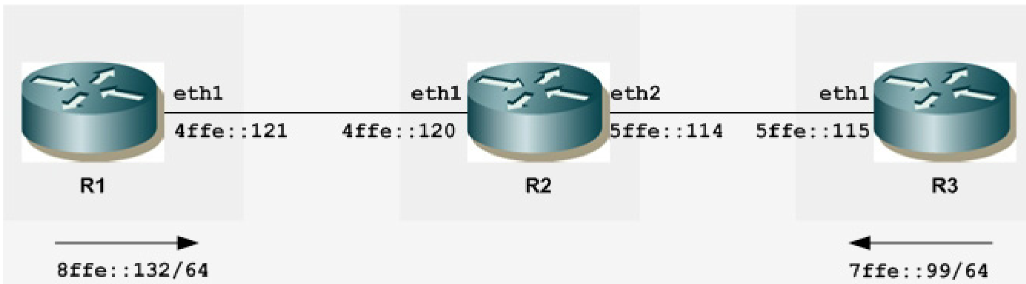

Figure 7-65: IS-ISv6 Distance

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 address 4ffe::121/24`	Assign the IPv6 address on this interface (`eth1`).
`(config-if)# ipv6 router isis 1`	Enable IS-ISv6 routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0001.00`	Establish a Network Entity Title (NET) for this instance, specifying the address and the system ID.
`(config-router)# address-family ipv6`	Enter IPv6 Address-Family mode.
`(config-router-af)# redistribute static`	Redistribute the static routes.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 address 4ffe::120/24`	Assign the IPv6 address on this interface (`eth1`).
`(config-if)# ipv6 router isis 1`	Enable IS-ISv6 routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.

`(config-if)# ipv6 address 5ffe::114/24`	Assign the IPv6 address on this interface (`eth2`).
`(config-if)# ipv6 router isis 1`	Enable IS-ISv6 routing on interface `eth2`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0002.00`	Specify the NET address.
`(config-router)# address-family ipv6`	Enter IPv6 Address-Family mode.
`(config-router)# distance 60`	Configure the administrative distance in IPv6 Address-Family mode.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)# ipv6 address 5ffe::115/24`	Assign the IPv6 address on this interface (`eth1`).
`(config-if)# ipv6 router isis 1`	Enable IS-ISv6 routing on interface `eth1`.
`(config-if)# exit`	Exit Interface mode, and return to Configure mode.
`(config)# router isis 1`	Create an IS-IS routing instance (`1`).
`(config-router)# net 49.0001.0000.0003.00`	Specify the NET address.
`(config-router)# address-family ipv6`	Enter IPv6 Address-Family mode.
`(config-router)# redistribute static`	Redistribute the static routes.

Validation

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

CHAPTER 8 IS-IS-TE IPv4

This chapter contains basic IS-IS TE configuration examples.

For details about the commands used in these examples, see the *Intermediate System to Intermediate System Command Reference*.

A TE link represents an IS-IS/OSPF link state advertisement and a link state database of certain physical resources and their properties between two GMPLS nodes. Typically, a TE link is advertised as an adjunct to a “regular” OSPF or IS-IS link. That is, an adjacency is brought up on the link. When the link is up, both the regular IGP properties of the link (for example, the SPF metric) and the TE properties of the link are then advertised.

Enable MPLS-TE in Level-1 and Level-2 on L1-L2 IS

In the following example, R1 is the L1 router, R2 is the L1/L2 router enabling MPLS-TE for both Level-1 and Level-2 IS, and R3 is the L2 router. The following configuration is given for R1, R2 and R3.

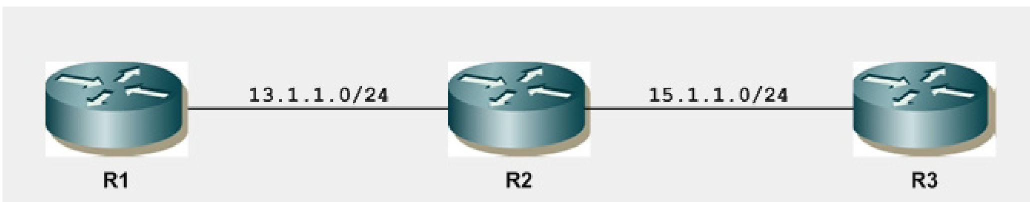

Figure 8-66: MPLS-TE Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#interface eth2`	Enter Interface eth2 configure mode.
`(config-if)#ip address 15.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth2.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2.
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#mpls traffic-eng router-id 2.2.2.2`	Configure MPLS-TE unique router-id TLV.

`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0002.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0002.
`(config-router)#end`	Exit Router mode.

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (eth1) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-1`	Configure IS-Type as Level-1 router.
`(config-router)#mpls traffic-eng router-id 1.1.1.1`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0001.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0001.
`(config-router)#end`	Exit Router mode.

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2)` to configure, and enter Interface mode.
`(config-if)#ip address 15.1.1.3/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-2`	Configure IS-Type as Level-1 router.
`(config-router)#mpls traffic-eng router-id 3.3.3.3`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0003.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0003.
`(config-router)#end`	Exit Router mode.

Validation

R2

Check the output of "show clns neighbors" to verify that ISIS adjacency is up.

```
#show clns neighbors
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0001 eth2        5254.00bb.5e85      Up     24        L1   IS-IS
0000.0000.0003 eth4        5254.00ac.f960      Up     9         L2   IS-IS
#
```

Check the output of "show isis database level-1 verbose" to verify that LSP does have correct router-id.

```
#sh isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00  0x0000000C   0x3129        1055              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.03
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00* 0x00000014   0x3CE9        1192              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.03
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.03-00* 0x00000005   0x685B        1028              0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00

#
```

Check the output of "show isis database level-2 verbose" to verify that LSP does have correct router-id.

```
#sh isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00* 0x0000000F   0x8C9B        939               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.2
```

```
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00  0x0000000C   0x8470       1193              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.3
    Maximum Link Bandwidth: 125000000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.01-00  0x00000004   0x8D36       1015              0/0/0
  Metric:   0          IS-Extended 0000.0000.0003.00
  Metric:   0          IS-Extended 0000.0000.0002.00
#
```

R1

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.00f6.4ae7      Up     7         L1   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have correct router-id.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00* 0x0000000C   0x3129        877               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.03
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00  0x00000014   0x3CE9       1014              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.03
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 12500000.00
```



```
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.03-00  0x00000005   0x685B        851               0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00
#
```

R3

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#sh clns  neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.0062.3ea6      Up     21        L2   IS-IS
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have correct router-id.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00  0x0000000F   0x8C9B        819               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00* 0x0000000C   0x8470        1073              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.3
    Maximum Link Bandwidth: 125000000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.01-00* 0x00000004   0x8D36        895               0/0/0
  Metric:   0          IS-Extended 0000.0000.0003.00
  Metric:   0          IS-Extended 0000.0000.0002.00
#
```

Maximum Link Bandwidth and Reservable Bandwidth

In the following example, R1 is the L1 router, R2 is the L1/L2 router enabling MPLS-TE for both Level-1 and Level-2 IS, and R3 is the L2 router. The following configuration is given for R1, R2 & R3.

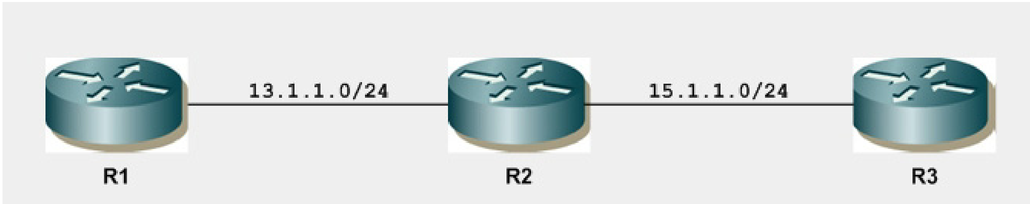

Figure 8-67: MPLS-TE Topology

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#interface eth2`	Enter Interface eth2 configure mode.
`(config-if)#ip address 15.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#`	ip router isis 1Enable ISIS on interface eth2.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2.
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#mpls traffic-eng router-id 2.2.2.2`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0002.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0002.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth2`	Enter the interface configure mode.
`(config-if)#bandwidth 1g`	Configure Maximum link Bandwidth as 1g bits per second.
`(config-if)#reservable-bandwidth 100m`	Specify the maximum reservable bandwidth per interface.
`(config-if)#exit`	Exit interface configure mode.
`(config)#interface eth4`	Enter the interface configure mode.
`(config-if)#bandwidth 500m`	Configure Maximum link Bandwidth as 500m bits per second.
`(config-if)#reservable-bandwidth 200m`	Specify the maximum reservable bandwidth per interface.
`(config-if)#`	Exit interface configure mode.

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-1`	Configure IS-Type as Level-1 router.
`(config-router)#mpls traffic-eng router-id 1.1.1.1`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0001.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0001.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#bandwidth 1g`	Configure Maximum link Bandwidth as 1g bits per second.
`(config-if)#reservable-bandwidth 100m`	Specify the maximum reservable bandwidth per interface.
`(config-if)#exit`	Exit interface configure mode.

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 15.1.1.3/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-2`	Configure IS-Type as Level-2 router.
`(config-router)#mpls traffic-eng router-id 3.3.3.3`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0003.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0003.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.

`(config-if)#bandwidth 1g`	Configure Maximum link Bandwidth as 1g bits per second.
`(config-if)#reservable-bandwidth 100m`	Specify the maximum reservable bandwidth per interface.
`(config-if)#exit`	Exit interface configure mode.

Validation

R2

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

#show clns neighbors

```
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0001 eth2        5254.00bb.5e85      Up     23        L1   IS-IS
0000.0000.0003 eth4        5254.00ac.f960      Up     9         L2   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured Max Link Bandwidth and Reservable Bandwidth.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00  0x00000009   0x53C9        554               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00* 0x0000000B   0x36A2        1185              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.01
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
```



```
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.01-00* 0x00000007   0x7251        825               0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured Max Link Bandwidth and Reservable Bandwidth.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00* 0x0000000B   0xA332        1160              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00  0x0000000B   0xA65F        1099              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.3
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
```

```
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.01-00  0x00000007   0x8739        795               0/0/0
    Metric:   0          IS-Extended 0000.0000.0003.00
    Metric:   0          IS-Extended 0000.0000.0002.00

  #
```

R1

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.00f6.4ae7      Up     9         L1   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured Max Link Bandwidth and Reservable Bandwidth.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00* 0x00000009   0x53C9        392               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00  0x0000000B   0x36A2        1023              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.01
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
```

```
        Unreserved Bandwidth at priority 2: 0.00
        Unreserved Bandwidth at priority 3: 0.00
        Unreserved Bandwidth at priority 4: 0.00
        Unreserved Bandwidth at priority 5: 0.00
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 13.1.1.0/24
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0002.01-00  0x00000007   0x7251        663                0/0/0
    Metric:   0          IS-Extended 0000.0000.0002.00
    Metric:   0          IS-Extended 0000.0000.0001.00

  #
```

R3

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.0062.3ea6      Up     26        L2   IS-IS
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured Max Link Bandwidth and Reservable Bandwidth.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00  0x0000000B   0xA332        1068              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00* 0x0000000B   0xA65F        1007              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
```

```
    IPv4 Interface Address: 15.1.1.3
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.01-00* 0x00000007   0x8739       703               0/0/0
  Metric:   0          IS-Extended 0000.0000.0003.00
  Metric:   0          IS-Extended 0000.0000.0002.00

#
```

Administrative Group Constraints

To configure administrative group constraints (also known as color constraints) in Level-1 and Level-2 on L1-L2 IS:

- Configure support for required admin groups in NSM on all participating routers
- Configure required administrative groups on all participating interfaces

The configuration in this example forces the primary LSP to be setup through links that belong either to admin group A or C. A link that does not belong to either of these admin groups will not be used for setting up the LSP.

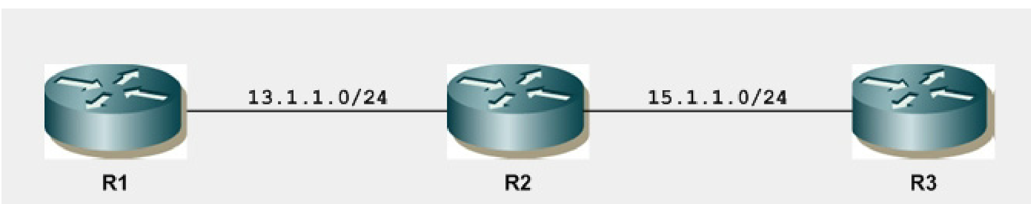

Figure 8-68: MPLS-TE Topology

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config)#interface eth2`	Enter Interface eth2 configure mode.
`(config-if)#ip address 15.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth2.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2.

`(config-if)#exit`	Exit from interface configuration mode.
`(config)#mpls admin-group a 0`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#mpls admin-group b 1`	
`(config)#mpls admin-group c 2`	
`(config)#mpls admin-group d 3`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#mpls traffic-eng router-id 2.2.2.2`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0002.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0002.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth2`	Enter the interface configure mode.
`(config-if)#admin-group a`	Add administrative groups to the links. When used in the interface mode, this command adds a link between an Interface and a group. The name is the name of the group Previously configured. You can have multiple groups per Interface.
`(config-if)#admin-group c`	
`(config-if)#exit`	Exit interface configure mode.
`(config)#interface eth4`	Enter the interface configure mode.
`(config-if)#admin-group b`	Add administrative groups to the links. When used in the interface mode, this command adds a link between an Interface and a group. The name is the name of the group previously configured. You can have multiple groups per Interface.
`(config-if)#admin-group d`	
`(config-if)#end`	Exit interface configure mode.

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit interface configure mode.
`(config)#mpls admin-group a 0`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#mpls admin-group c 2`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-1`	Configure IS-Type as Level-1 router.

`(config-router)#mpls traffic-eng router-id 1.1.1.1`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0001.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0001.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#admin-group a` `(config-if)#admin-group c`	Add administrative groups to the links. When used in the interface mode, this command adds a link between an Interface and a group. The name is the name of the group Previously configured. You can have multiple groups per Interface.
`(config-if)#end`	Exit interface configure mode.

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 15.1.1.3/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit interface configure mode.
`(config)#mpls admin-group b 1` `(config)#mpls admin-group d 3`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-2`	Configure IS-Type as Level-2 router.
`(config-router)#mpls traffic-eng router-id 3.3.3.3`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0003.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0003.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#admin-group b` `(config-if)#admin-group d`	Add administrative groups to the links. When used in the interface mode, this command adds a link between an Interface and a group. The name is the name of the group Previously configured. You can have multiple groups per Interface.
`(config-if)#end`	Exit interface configure mode.

Validation

R2

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0001 eth2        5254.00bb.5e85      Up     24        L1   IS-IS
0000.0000.0003 eth4        5254.00ac.f960      Up     9         L2   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured admin-group constraints in Level-1.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00  0x00000053   0x7B3F        1034              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00* 0x00000054   0xC9AD        595               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
```

```
        Unreserved Bandwidth at priority 2: 0.00
        Unreserved Bandwidth at priority 3: 0.00
        Unreserved Bandwidth at priority 4: 0.00
        Unreserved Bandwidth at priority 5: 0.00
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 13.1.1.0/24
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0002.01-00* 0x0000004F   0xE199       800               0/0/0
    Metric:   0          IS-Extended 0000.0000.0002.00
    Metric:   0          IS-Extended 0000.0000.0001.00
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured admin-group constraints in Level-2.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00* 0x00000054   0x115E        988               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
      Group 3
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00  0x00000054   0xC2DC        1079              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
      Group 3
    IPv4 Interface Address: 15.1.1.3
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
```



```
        Unreserved Bandwidth at priority 1: 0.00
        Unreserved Bandwidth at priority 2: 0.00
        Unreserved Bandwidth at priority 3: 0.00
        Unreserved Bandwidth at priority 4: 0.00
        Unreserved Bandwidth at priority 5: 0.00
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.01-00  0x0000004F   0xF681        788                 0/0/0
    Metric:   0          IS-Extended 0000.0000.0003.00
    Metric:   0          IS-Extended 0000.0000.0002.00

  #
```

R1

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.00f6.4ae7      Up     7         L1   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured admin-group constraints in Level-1.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00* 0x00000053   0x7B3F        1089              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00  0x00000054   0xC9AD        650               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
```

```
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
      Unreserved Bandwidth at priority 6: 0.00
      Unreserved Bandwidth at priority 7: 0.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.01-00  0x0000004F   0xE199        855               0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00
#
```

R3

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.0062.3ea6      Up     28        L2   IS-IS
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured admin-group constraints in Level-2.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00  0x00000054   0x115E        1104              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
      Group 3
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 0.00
      Unreserved Bandwidth at priority 1: 0.00
      Unreserved Bandwidth at priority 2: 0.00
      Unreserved Bandwidth at priority 3: 0.00
      Unreserved Bandwidth at priority 4: 0.00
      Unreserved Bandwidth at priority 5: 0.00
```

```
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 13.1.1.0/24
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.00-00* 0x00000054   0xC2DC       1195              0/0/0
    Area Address: 49.0001
    NLPID:        0xCC
    IP Address:   15.1.1.3
    Router ID:    3.3.3.3
    Metric:   10         IS-Extended 0000.0000.0003.01
      Admin-Group:
        Group 1
        Group 3
      IPv4 Interface Address: 15.1.1.3
      Maximum Link Bandwidth: 62500000.00
      Reservable Bandwidth: 25000000.00
      Unreserved Bandwidth:
        Unreserved Bandwidth at priority 0: 0.00
        Unreserved Bandwidth at priority 1: 0.00
        Unreserved Bandwidth at priority 2: 0.00
        Unreserved Bandwidth at priority 3: 0.00
        Unreserved Bandwidth at priority 4: 0.00
        Unreserved Bandwidth at priority 5: 0.00
        Unreserved Bandwidth at priority 6: 0.00
        Unreserved Bandwidth at priority 7: 0.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.01-00* 0x0000004F   0xF681       904               0/0/0
    Metric:   0          IS-Extended 0000.0000.0003.00
    Metric:   0          IS-Extended 0000.0000.0002.00
  #
```

Bandwidth Group Constraints

To configure Bandwidth group constraints in Level-1 and Level-2 on L1-L2 IS:

- Configure support for required mpls dste groups in NSM on all participating routers
- Configure required Bandwidth groups constraints on all participating interfaces

This configuration assumes that basic mpls configuration for dste is done prior to this configuration.

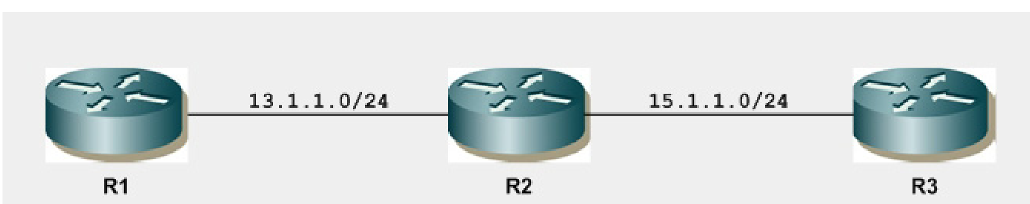

Figure 8-69: MPLS-TE Topology

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1)` to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config)#interface eth2`	Enter Interface eth2 configure mode.
`(config-if)#ip address 15.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth2.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2.
`(config-if)#exit`	Exit from interface configuration mode.
Note: The `mpls class-type` command is not supported by harware platforms.	
`(config)#mpls class-type ct0 default`	Define class type names, and enable class types.
`(config)#mpls class-type ct1 a1`	
`(config)#mpls class-type ct2 a2`	
`(config)#mpls class-type ct3 a3`	
`(config)#mpls class-type ct4 a4`	
`(config)#mpls class-type ct5 a5`	
`(config)#mpls class-type ct6 a6`	
`(config)#mpls class-type ct7 a7`	
Note: The `mpls te-class` command is not supported by harware platforms.	
`(config)#mpls te-class te0 a2 5`	Define the DiffServ TE class, class type name, and preemption priority.
`(config)#mpls te-class te1 a2 4`	
`(config)#mpls te-class te2 default 2`	
`(config)#mpls te-class te3 default 4`	
`(config)#mpls te-class te4 default 5`	
`(config)#mpls te-class te5 default 0`	
`(config)#mpls te-class te6 default 3`	
`(config)#mpls te-class te7 default 7`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#mpls traffic-eng router-id 2.2.2.2`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0002.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0002.
`(config-router)#exit`	Exit Router mode.

`(config)#interface eth2`	Enter the interface configure mode.
`(config-if)#bandwidth 1g`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 100m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	
`(config-if)#exit`	Exit interface configure mode.
`(config)#interface eth4`	Enter the interface configure mode.
`(config-if)#bandwidth 500m`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 200m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	
`(config-if)#end`	Exit interface configure mode.

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.1/24`	Configure ip address to the interface eth1.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
Note: The `mpls class-type` command is not supported by harware platforms.	
`(config)#mpls class-type ct0 default`	Define class type names, and enable class types.
`(config)#mpls class-type ct1 a1`	
`(config)#mpls class-type ct2 a2`	
`(config)#mpls class-type ct3 a3`	

`(config)#mpls class-type ct4 a4`	
`(config)#mpls class-type ct5 a5`	
`(config)#mpls class-type ct6 a6`	
`(config)#mpls class-type ct7 a7`	
Note: The `mpls te-class` command is not supported by harware platforms.	
`(config)#mpls te-class te0 a2 5`	Define the DiffServ TE class, class type name, and preemption priority.
`(config)#mpls te-class te1 a2 4`	
`(config)#mpls te-class te2 default 2`	
`(config)#mpls te-class te3 default 4`	
`(config)#mpls te-class te4 default 5`	
`(config)#mpls te-class te5 default 0`	
`(config)#mpls te-class te6 default 3`	
`(config)#mpls te-class te7 default 7`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-1`	Configure IS-Type as Level-1 router.
`(config-router)#mpls traffic-eng router-id 1.1.1.1`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0001.00`	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0001.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#bandwidth 1g`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 100m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 15.1.1.3/24`	Configure ip address to the interface eth1.

(config-if)#ip router isis 1	Enable ISIS on interface eth1.
(config-if)#isis circuit-type level-2	Configure ISIS circuit-type as Level-2
(config-if)#exit	Exit from interface configuration mode.
Note: The `mpls class-type` command is not supported by harware platforms.	
(config)#mpls class-type ct0 default	Define class type names, and enable class types.
(config)#mpls class-type ct1 a1	
(config)#mpls class-type ct2 a2	
(config)#mpls class-type ct3 a3	
(config)#mpls class-type ct4 a4	
(config)#mpls class-type ct5 a5	
(config)#mpls class-type ct6 a6	
(config)#mpls class-type ct7 a7	
Note: The `mpls te-class` command is not supported by harware platforms.	
(config)#mpls te-class te0 a2 5	Define the DiffServ TE class, class type name, and preemption priority.
(config)#mpls te-class te1 a2 4	
(config)#mpls te-class te2 default 2	
(config)#mpls te-class te3 default 4	
(config)#mpls te-class te4 default 5	
(config)#mpls te-class te5 default 0	
(config)#mpls te-class te6 default 3	
(config)#mpls te-class te7 default 7	
(config)#router isis 1	Create an IS-IS routing instance for area 49 (1).
(config-router)#metric-style wide	Configure the new style of metric type as wide.
(config-router)#is-type level-2	Configure IS-Type as Level-2 router.
(config-router)#mpls traffic-eng router-id 3.3.3.3	Configure MPLS-TE unique router-id TLV.
(config-router)#mpls traffic-eng level-2	Enable MPLS-TE in is-type Level-1.
(config-router)#net 49.0001.0000.0000.0003.00	Configure the ISIS net address with area id as: 49.0001 and system-id as: 0000.0000.0003.
(config-router)#exit	Exit Router mode.
(config)#interface eth1	Enter the interface configure mode.
(config-if)#bandwidth 500m	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth1 interface.
(config-if)#reservable-bandwidth 200m	
(config-if)#bandwidth-constraint default 100m	
(config-if)#bandwidth-constraint a1 100m	
(config-if)#bandwidth-constraint a2 100m	
(config-if)#bandwidth-constraint a3 100m	
(config-if)#bandwidth-constraint a4 100m	
(config-if)#bandwidth-constraint a5 100m	

`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	
`(config-if)#end`	Exit interface configure mode.

Validation

R2

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors

Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0001 eth2        5254.00bb.5e85      Up     25        L1   IS-IS
0000.0000.0003 eth4        5254.00ac.f960      Up     8         L2   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured Unreserved Bandwidth constraints in Level-1.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00  0x00000058   0x651D        1161              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 12500000.00
      Unreserved Bandwidth at priority 1: 12500000.00
      Unreserved Bandwidth at priority 2: 12500000.00
      Unreserved Bandwidth at priority 3: 12500000.00
      Unreserved Bandwidth at priority 4: 12500000.00
      Unreserved Bandwidth at priority 5: 12500000.00
      Unreserved Bandwidth at priority 6: 12500000.00
      Unreserved Bandwidth at priority 7: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00* 0x0000005A   0xB18C        1113              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
```



```
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 12500000.00
      Unreserved Bandwidth at priority 1: 12500000.00
      Unreserved Bandwidth at priority 2: 12500000.00
      Unreserved Bandwidth at priority 3: 12500000.00
      Unreserved Bandwidth at priority 4: 12500000.00
      Unreserved Bandwidth at priority 5: 12500000.00
      Unreserved Bandwidth at priority 6: 12500000.00
      Unreserved Bandwidth at priority 7: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.01-00* 0x00000052   0xDB9C        711               0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured Unreserved Bandwidth constraints in Level-2

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00* 0x00000059   0xFA3C        1119              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
      Group 3
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 12500000.00
      Unreserved Bandwidth at priority 1: 12500000.00
      Unreserved Bandwidth at priority 2: 12500000.00
      Unreserved Bandwidth at priority 3: 12500000.00
      Unreserved Bandwidth at priority 4: 12500000.00
      Unreserved Bandwidth at priority 5: 12500000.00
      Unreserved Bandwidth at priority 6: 12500000.00
      Unreserved Bandwidth at priority 7: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0003.00-00  0x0000005C   0xA6BD        1166              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   15.1.1.3
  Router ID:    3.3.3.3
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
```

```
        Group 3
      IPv4 Interface Address: 15.1.1.3
      Maximum Link Bandwidth: 62500000.00
      Reservable Bandwidth: 25000000.00
      Unreserved Bandwidth:
        Unreserved Bandwidth at priority 0: 12500000.00
        Unreserved Bandwidth at priority 1: 12500000.00
        Unreserved Bandwidth at priority 2: 12500000.00
        Unreserved Bandwidth at priority 3: 12500000.00
        Unreserved Bandwidth at priority 4: 12500000.00
        Unreserved Bandwidth at priority 5: 12500000.00
        Unreserved Bandwidth at priority 6: 12500000.00
        Unreserved Bandwidth at priority 7: 12500000.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.01-00  0x00000052   0xF084        693               0/0/0
    Metric:   0          IS-Extended 0000.0000.0003.00
    Metric:   0          IS-Extended 0000.0000.0002.00

  #
```

R1

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.00f6.4ae7      Up     9         L1   IS-IS
```

Check the output of “show isis database level-1 verbose” to verify that LSP does have configured Unreserved Bandwidth constraints in Level-1.

```
#show isis database level-1 verbose
Area 1:
IS-IS Level-1 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0001.00-00* 0x00000058   0x651D        1001              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.1
  Router ID:    1.1.1.1
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.1
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 12500000.00
      Unreserved Bandwidth at priority 1: 12500000.00
      Unreserved Bandwidth at priority 2: 12500000.00
      Unreserved Bandwidth at priority 3: 12500000.00
      Unreserved Bandwidth at priority 4: 12500000.00
      Unreserved Bandwidth at priority 5: 12500000.00
      Unreserved Bandwidth at priority 6: 12500000.00
      Unreserved Bandwidth at priority 7: 12500000.00
    TE-Default Metric: 1
```



```
  Metric:   10         IP-Extended 13.1.1.0/24
0000.0000.0002.00-00  0x0000005A   0xB18C        953               0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0002.01
    Admin-Group:
      Group 0
      Group 2
    IPv4 Interface Address: 13.1.1.2
    Maximum Link Bandwidth: 125000000.00
    Reservable Bandwidth: 12500000.00
    Unreserved Bandwidth:
      Unreserved Bandwidth at priority 0: 12500000.00
      Unreserved Bandwidth at priority 1: 12500000.00
      Unreserved Bandwidth at priority 2: 12500000.00
      Unreserved Bandwidth at priority 3: 12500000.00
      Unreserved Bandwidth at priority 4: 12500000.00
      Unreserved Bandwidth at priority 5: 12500000.00
      Unreserved Bandwidth at priority 6: 12500000.00
      Unreserved Bandwidth at priority 7: 12500000.00
    TE-Default Metric: 1
  Metric:   10         IP-Extended 13.1.1.0/24
  Metric:   10         IP-Extended 15.1.1.0/24
0000.0000.0002.01-00  0x00000052   0xDB9C        551               0/0/0
  Metric:   0          IS-Extended 0000.0000.0002.00
  Metric:   0          IS-Extended 0000.0000.0001.00
```

R3

Check the output of “show clns neighbors” to verify that ISIS adjacency is up.

```
#show clns neighbors
Area 1:
System Id      Interface   SNPA                State  Holdtime  Type Protocol
0000.0000.0002 eth1        5254.0062.3ea6      Up     26        L2   IS-IS
#
```

Check the output of “show isis database level-2 verbose” to verify that LSP does have configured Unreserved Bandwidth constraints in Level-2.

```
#show isis database level-2 verbose
Area 1:
IS-IS Level-2 Link State Database:
LSPID                 LSP Seq Num  LSP Checksum  LSP Holdtime      ATT/P/OL
0000.0000.0002.00-00  0x00000059   0xFA3C        1020              0/0/0
  Area Address: 49.0001
  NLPID:        0xCC
  IP Address:   13.1.1.2
  Router ID:    2.2.2.2
  Metric:   10         IS-Extended 0000.0000.0003.01
    Admin-Group:
      Group 1
      Group 3
    IPv4 Interface Address: 15.1.1.2
    Maximum Link Bandwidth: 62500000.00
    Reservable Bandwidth: 25000000.00
    Unreserved Bandwidth:
```

```
        Unreserved Bandwidth at priority 0: 12500000.00
        Unreserved Bandwidth at priority 1: 12500000.00
        Unreserved Bandwidth at priority 2: 12500000.00
        Unreserved Bandwidth at priority 3: 12500000.00
        Unreserved Bandwidth at priority 4: 12500000.00
        Unreserved Bandwidth at priority 5: 12500000.00
        Unreserved Bandwidth at priority 6: 12500000.00
        Unreserved Bandwidth at priority 7: 12500000.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 13.1.1.0/24
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.00-00* 0x0000005C   0xA6BD        1066              0/0/0
    Area Address: 49.0001
    NLPID:        0xCC
    IP Address:   15.1.1.3
    Router ID:    3.3.3.3
    Metric:   10         IS-Extended 0000.0000.0003.01
      Admin-Group:
        Group 1
        Group 3
      IPv4 Interface Address: 15.1.1.3
      Maximum Link Bandwidth: 62500000.00
      Reservable Bandwidth: 25000000.00
      Unreserved Bandwidth:
        Unreserved Bandwidth at priority 0: 12500000.00
        Unreserved Bandwidth at priority 1: 12500000.00
        Unreserved Bandwidth at priority 2: 12500000.00
        Unreserved Bandwidth at priority 3: 12500000.00
        Unreserved Bandwidth at priority 4: 12500000.00
        Unreserved Bandwidth at priority 5: 12500000.00
        Unreserved Bandwidth at priority 6: 12500000.00
        Unreserved Bandwidth at priority 7: 12500000.00
      TE-Default Metric: 1
    Metric:   10         IP-Extended 15.1.1.0/24
  0000.0000.0003.01-00* 0x00000052   0xF084        593               0/0/0
    Metric:   0          IS-Extended 0000.0000.0003.00
    Metric:   0          IS-Extended 0000.0000.0002.00
```

Establish RSVP Trunks Using CSPF

CSPF ((Constraint-based Shortest Path First) is used to calculate the path for an RSVP trunk. The RSVP daemon (rsvpd) sends a request to the CSPF server to compute a path through the network to reach the destination. CSPF returns a hop-by-hop path called the Explicit Route to the RSVP daemon to use in the Explicit Route Object (ERO). Each router along the path sends a Path message only to the nexthop specified in the ERO.

In ZebOS-XP, CSPF is enabled by default and the trunk is CSPF-enabled automatically. This configuration assumes that basic mpls configuration is done prior to this configuration.There are two rsvp trunks are configured : one is from L1-2 IS to L1 IS and another is from L1-2 IS to L2 IS.

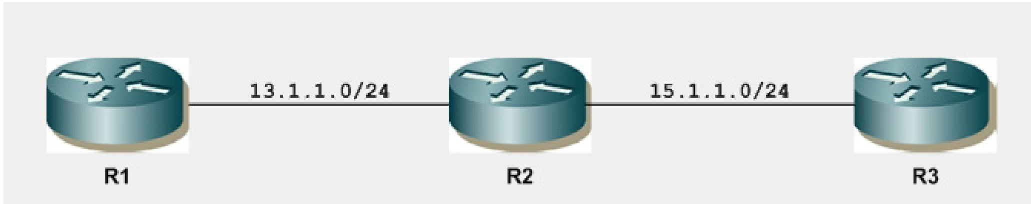

Figure 8-70: MPLS-TE Topology

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the interface (`lo`) to configure, and enter Interface mode.
`(config-if)#ip address 2.2.2.2/32`	Configure ip address to the interface eth1.
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config)#interface eth2`	Enter Interface eth2 configure mode.
`(config-if)#ip address 15.1.1.2/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth2.
`(config-if)#isis circuit-type level-2`	Configure ISIS circuit-type as Level-2.
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#mpls admin-group a 0`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#mpls admin-group b 1`	
`(config)#mpls admin-group c 2`	
`(config)#mpls admin-group d 3`	
Note: The `mpls class-type` command is not supported by harware platforms.	
`(config)#mpls class-type ct0 default`	Define class type names, and enable class types.
`(config)#mpls class-type ct1 a1`	
`(config)#mpls class-type ct2 a2`	
`(config)#mpls class-type ct3 a3`	
`(config)#mpls class-type ct4 a4`	
`(config)#mpls class-type ct5 a5`	
`(config)#mpls class-type ct6 a6`	
`(config)#mpls class-type ct7 a7`	
Note: The `mpls te-class` command is not supported by harware platforms.	
`(config)#mpls te-class te0 a2 5`	Define the DiffServ TE class, class type name, and preemption priority.
`(config)#mpls te-class te1 a2 4`	

`(config)#mpls te-class te2 default 2`	
`(config)#mpls te-class te3 default 4`	
`(config)#mpls te-class te4 default 5`	
`(config)#mpls te-class te5 default 0`	
`(config)#mpls te-class te6 default 3`	
`(config)#mpls te-class te7 default 7`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#capability cspf`	Enable CSPF capability on ISIS.
`(config-router)#mpls traffic-eng router-id 2.2.2.2`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-2.
`(config-router)#net 49.0001.0000.0000.0002.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0002.
`(config-router)#exit`	Exit Router mode.
`(config)#router rsvp`	Configure router rsvp.
`(config-router)#from 2.2.2.2`	Configure ingress trunk source address.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#label-switching`	Enable label switching on interface eth1.
`(config-if)#enable-rsvp`	Enable rsvp on interface eth1.
`(config-if)#admin-group a`	Add new administrative groups and specify their names and assign bit values to them.
`(config-if)#admin-group c`	
`(config-if)#bandwidth 1g`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 100m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	
`(config-if)#exit`	Exit interface configure mode.
`(config)#interface eth2`	Enter the interface configure mode.
`(config-if)#label-switching`	Enable label switching on interface eth1.
`(config-if)#enable-rsvp`	Enable rsvp on interface eth1.
`(config-if)#admin-group b`	Add new administrative groups and specify their names and assign bit values to them.
`(config-if)#admin-group d`	

`(config-if)#bandwidth 500m`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#bandwidth 500m`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 200m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	
`(config-if)#bandwidth-constraint a7 100m`	
`(config-if)#exit`	Exit interface configure mode.
`(config)#rsvp-trunk L1-T1-CSPF`	Configure rsvp trunk L1-T1-CSPF.
`(config-trunk)#to 13.1.1.1`	Configure Destination Address of L1 RSVP trunk.
`(config-trunk)#exit`	Exit trunk configure mode.
`(config)#rsvp-trunk L2-T2-CSPF`	Configure rsvp trunk L2-T2-CSPF.
`(config-trunk)#to 15.1.1.3`	Configure Destination Address of L2 RSVP trunk.
`(config-trunk)#exit`	Exit trunk configure mode

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the interface (`lo`) to configure, and enter Interface mode.
`(config-if)#ip address 1.1.1.1/32`	Configure ip address to the interface eth1.
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 13.1.1.1/24`	Configure ip address to the interface eth2.
`(config-if)#ip router isis 1`	Enable ISIS on interface eth1.
`(config-if)#isis circuit-type level-1`	Configure ISIS circuit-type as Level-1
`(config-if)#exit`	Exit from interface configuration mode.
`(config)#mpls admin-group a 0`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#mpls admin-group c 2`	
Note: The `mpls class-type` command is not supported by harware platforms.	
`(config)#mpls class-type ct0 default`	Define class type names, and enable class types.
`(config)#mpls class-type ct1 a1`	
`(config)#mpls class-type ct2 a2`	
`(config)#mpls class-type ct3 a3`	

`(config)#mpls class-type ct4 a4`	
`(config)#mpls class-type ct5 a5`	
`(config)#mpls class-type ct6 a6`	
`(config)#mpls class-type ct7 a7`	
Note: The `mpls te-class` command is not supported by harware platforms.	
`(config)#mpls te-class te0 a2 5`	Define the DiffServ TE class, class type name, and preemption priority.
`(config)#mpls te-class te1 a2 4`	
`(config)#mpls te-class te2 default 2`	
`(config)#mpls te-class te3 default 4`	
`(config)#mpls te-class te4 default 5`	
`(config)#mpls te-class te5 default 0`	
`(config)#mpls te-class te6 default 3`	
`(config)#mpls te-class te7 default 7`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-1`	Configure IS-Type as Level-1 router.
`(config-router)#capability cspf`	Enable CSPF capability on ISIS.
`(config-router)#mpls traffic-eng router-id 1.1.1.1`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-1`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0001.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0001.
`(config-router)#exit`	Exit Router mode.
`(config)#router rsvp`	Configure router rsvp.
`(config-router)#from 2.2.2.2`	Configure ingress trunk source address.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#label-switching`	Enable label switching on interface eth1.
`(config-if)#enable-rsvp`	Enable rsvp on interface eth1.
`(config-if)#admin-group a`	Add new administrative groups and specify their names and assign bit values to them.
`(config-if)#admin-group c`	
`(config-if)#bandwidth 1g`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 100m`	
`(config-if)#bandwidth-constraint default 100m`	
`(config-if)#bandwidth-constraint a1 100m`	
`(config-if)#bandwidth-constraint a2 100m`	
`(config-if)#bandwidth-constraint a3 100m`	
`(config-if)#bandwidth-constraint a4 100m`	
`(config-if)#bandwidth-constraint a5 100m`	
`(config-if)#bandwidth-constraint a6 100m`	

(config-if)#bandwidth-constraint a7 100m	
(config-if)#exit	Exit interface configure mode.
(config)#interface eth2	Enter the interface configure mode.
(config-if)#label-switching	Enable label switching on interface eth1.
(config-if)#enable-rsvp	Enable rsvp on interface eth1.
(config-if)#admin-group b	Add new administrative groups and specify their names and assign bit values to them.
(config-if)#admin-group d	
(config-if)#bandwidth 500m	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
(config-if)#bandwidth 500m	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
(config-if)#reservable-bandwidth 200m	
(config-if)#bandwidth-constraint default 100m	
(config-if)#bandwidth-constraint a1 100m	
(config-if)#bandwidth-constraint a2 100m	
(config-if)#bandwidth-constraint a3 100m	
(config-if)#bandwidth-constraint a4 100m	
(config-if)#bandwidth-constraint a5 100m	
(config-if)#bandwidth-constraint a6 100m	
(config-if)#bandwidth-constraint a7 100m	
(config-if)#exit	Exit interface configure mode.
(config)#rsvp-trunk L1-T1-CSPF	Configure rsvp trunk L1-T1-CSPF.
(config-trunk)#to 13.1.1.1	Configure Destination Address of L1 RSVP trunk.
(config-trunk)#exit	Exit trunk configure mode.
(config)#rsvp-trunk L2-T2-CSPF	Configure rsvp trunk L2-T2-CSPF.
(config-trunk)#to 15.1.1.3	Configure Destination Address of L2 RSVP trunk.
(config-trunk)#exit	Exit trunk configure mode

R3

#configure terminal	Enter Configure mode.
(config)#interface lo	Specify the interface (lo) to configure, and enter Interface mode.
(config-if)#ip address 3.3.3.3/32	Configure ip address to the interface eth1.
(config-if)#exit	Exit from interface configuration mode.
(config)#interface eth2	Specify the interface (eth2) to configure, and enter Interface mode.
(config-if)#ip address 15.1.1.3/24	Configure ip address to the interface eth2.
(config-if)#ip router isis 1	Enable ISIS on interface eth1.
(config-if)#isis circuit-type level-2	Configure ISIS circuit-type as Level-1
(config-if)#exit	Exit from interface configuration mode.

`(config)#mpls admin-group b 1`	Add new administrative groups and specify their names and assign bit values to them.
`(config)#mpls admin-group d 3`	
Note: The `mpls class-type` command is not supported by harware platforms.	
`(config)#mpls class-type ct0 default`	Define class type names, and enable class types.
`(config)#mpls class-type ct1 a1`	
`(config)#mpls class-type ct2 a2`	
`(config)#mpls class-type ct3 a3`	
`(config)#mpls class-type ct4 a4`	
`(config)#mpls class-type ct5 a5`	
`(config)#mpls class-type ct6 a6`	
`(config)#mpls class-type ct7 a7`	
Note: The `mpls te-class` command is not supported by harware platforms.	
`(config)#mpls te-class te0 a2 5`	Define the DiffServ TE class, class type name, and preemption priority.
`(config)#mpls te-class te1 a2 4`	
`(config)#mpls te-class te2 default 2`	
`(config)#mpls te-class te3 default 4`	
`(config)#mpls te-class te4 default 5`	
`(config)#mpls te-class te5 default 0`	
`(config)#mpls te-class te6 default 3`	
`(config)#mpls te-class te7 default 7`	
`(config)#router isis 1`	Create an IS-IS routing instance for area 49 (1).
`(config-router)#metric-style wide`	Configure the new style of metric type as wide.
`(config-router)#is-type level-2`	Configure IS-Type as Level-1 router.
`(config-router)#capability cspf`	Enable CSPF capability on ISIS.
`(config-router)#mpls traffic-eng router-id 3.3.3.3`	Configure MPLS-TE unique router-id TLV.
`(config-router)#mpls traffic-eng level-2`	Enable MPLS-TE in is-type Level-1.
`(config-router)#net 49.0001.0000.0000.0003.00`	Configure the ISIS net address with area id as: 49.0001 and system id as: 0000.0000.0003.
`(config-router)#exit`	Exit Router mode.
`(config)#router rsvp`	Configure router rsvp.
`(config-router)#from 3.3.3.3`	Configure ingress trunk source address.
`(config-router)#exit`	Exit Router mode.
`(config)#interface eth1`	Enter the interface configure mode.
`(config-if)#label-switching`	Enable label switching on interface eth1.
`(config-if)#enable-rsvp`	Enable rsvp on interface eth1.
`(config-if)#bandwidth 500m`	Reserve the bandwidth, and configure the bandwidth Constraint for each class type on the eth2 interface.
`(config-if)#reservable-bandwidth 200m`	
`(config-if)#bandwidth-constraint default 100m`	

(config-if)#bandwidth-constraint a1 100m	
(config-if)#bandwidth-constraint a2 100m	
(config-if)#bandwidth-constraint a3 100m	
(config-if)#bandwidth-constraint a4 100m	
(config-if)#bandwidth-constraint a5 100m	
(config-if)#bandwidth-constraint a6 100m	
(config-if)#bandwidth-constraint a7 100m	
(config-if)#end	Exit interface configure mode.

Validation

R2

Check the output of “show rsvp session” to verify that RSVP trunks are up in both Level-1 and Level-2.

```
#show rsvp session
Ingress RSVP:
To               From             State  Pri  Rt  Style  Labelin  Labelout  LSPName
 DSType
13.1.1.1         2.2.2.2          Up     Yes   1   1 SE       -        3 L1-T1-CSPF
DEFAULT
15.1.1.3         2.2.2.2          Up     Yes   1   1 SE       -        3 L2-T2-CSPF
DEFAULT
Total 2 displayed, Up 2, Down 0.

#
```

Check the output of “show cspf lsp” to verify the LSP properties for both Level-1 and Level-2.

```
#show cspf lsp
Lsp Id              : 0x650065
   Client ID        : 1
   State            : 3
   Ingress          : 2.2.2.2
   Egress           : 13.1.1.1
   Setup Priority   : 7
   Hold Priority    : 0
   Hop Limit        : 65
   Include Mask     : 0x0
   Exclude Mask     : 0x0
   LSP Metric       : 0
   Computed ERO     :
       13.1.1.1

Lsp Id              : 0x660066
   Client ID        : 1
   State            : 3
   Ingress          : 2.2.2.2
   Egress           : 15.1.1.3
   Setup Priority   : 7
   Hold Priority    : 0
   Hop Limit        : 65
   Include Mask     : 0x0
   Exclude Mask     : 0x0
```

```
       LSP Metric      : 0
       Computed ERO    :
           15.1.1.3

    #
```

Check the output of `show rsvp trunk` to verify the RSVP trunks configured in both Level-1 and Level-2.

```
    #show rsvp trunk
    Trunk Name      Trunk ID  Type  #Sess  Egress Address(es)
    L1-T1-CSPF      101       P2P   1       13.1.1.1
    L2-T2-CSPF      102       P2P   1       15.1.1.3
    Total trunks configured: 2.
```

R1

Check the output of `show rsvp session` to verify that RSVP trunks are up in Level-1.

```
    #show rsvp session
    Egress RSVP:
    To              From            State Pri Rt Style Labelin Labelout LSPName
     DSType
    13.1.1.1        2.2.2.2         Up    Yes  1  1 SE       3        - L1-T1-CSPF
     ELSP_CON
    Total 1 displayed, Up 1, Down 0.
```

R3

Check the output of `show rsvp session` to verify that RSVP trunks are up in Level-2.

```
    #show rsvp session
    Egress RSVP:
    To              From            State Pri Rt Style Labelin Labelout LSPName
     DSType
    15.1.1.3        2.2.2.2         Up    Yes  1  1 SE       3        - L2-T2-CSPF
     ELSP_CON
    Total 1 displayed, Up 1, Down 0.
```

CHAPTER 9 BGP

This chapter contains basic Border Gateway Protocol configuration examples.

For details about the commands used in these examples, see the *Border Gateway Protocol Command Reference*.

Enable BGP Routers in the Same Autonomous System

Figure 9-71 shows the minimum configuration required to enable BGP on an interface. R1 and R2 are two routers belonging to the same AS, AS200, 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.

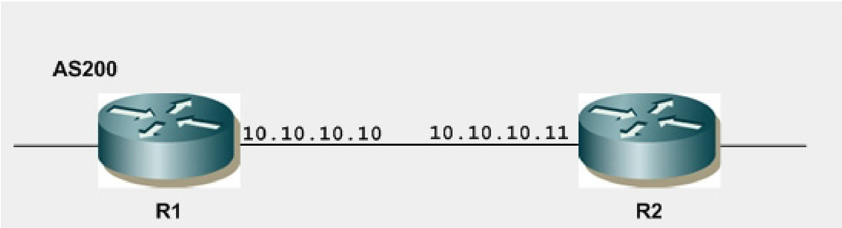

Figure 9-71: Routers in the Same Autonomous System

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(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

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of `R2`.
`(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.

Validation

show ip bgp summary, show ip bgp neighbors

Enable BGP Between Different Autonomous Systems

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 autonomous system, AS200 and AS300, connecting to network 10.10.10.0/24.

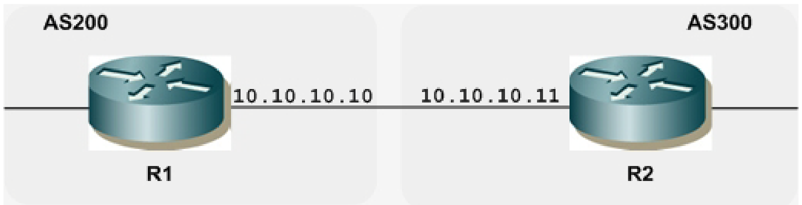

Figure 9-72: Routers in Different Autonomous Systems

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(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

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 300`	Define the routing process. The number `300` specifies the AS number of `R2`.
`(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.

Validation

show ip bgp summary, show ip bgp neighbors

Route-Map

Use route maps to filter incoming updates from a BGP peer. In this example, the 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.

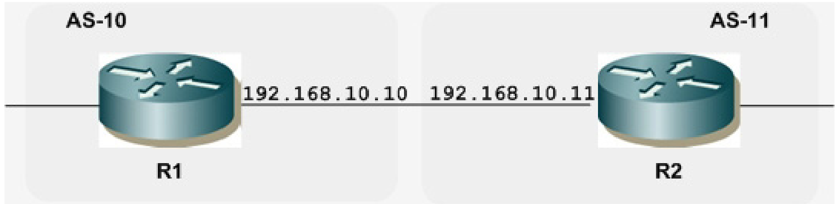

Figure 9-73: Configure Route-Map

R1

`#configure terminal`	Enter Configure mode.
`(config)#ip prefix-list ipi seq 5 deny 1.1.1.0/24 ge 26 le 28`	Create an entry in the prefix-list. The `ipi` parameter 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.
`(config)#ip prefix-list ipi seq 10 permit any`	Create another entry in the `ipi` map. `10` specifies the sequence number or position of this specific route map. The `permit` parameter `any` specifies accept all packets of any length.
`(config)#route-map ipi permit 1`	Enter Route-map mode to set the match operation.
`(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 are denied.
`(config-route-map)#exit`	Exit Route-map mode, and return to Configure mode.
`(config)#router bgp 10`	Define the routing process, and establish a TCP session. The number `10` specifies the AS number of R1.
`(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.
`(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. The `ipi` parameter is the name of the route map, and `in` specifies that the access list applies to incoming advertisements.

R2

`(config)#router bgp 11`	Define the routing process, and establish a TCP session. The number `11` specifies the AS number of R2.
`(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.
`(config-router)#network 1.1.1.0/27`	Specify the network to be advertised by the BGP routing process.
`(config-router)#network 1.1.2.0/24`	Specify the network to be advertised by the BGP routing process.

Validation

show ip bgp

Route Reflector

The configurations in this section apply to BGP Route Reflectors (RR).

Reduce the iBGP Mesh Inside an Autonomous System

Use Route Reflectors to reduce the iBGP mesh inside an Autonomous System (AS).

Topology

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 an iBGP session with the RR only, but 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 R2. This reduces the iBGP peer connections in AS1.

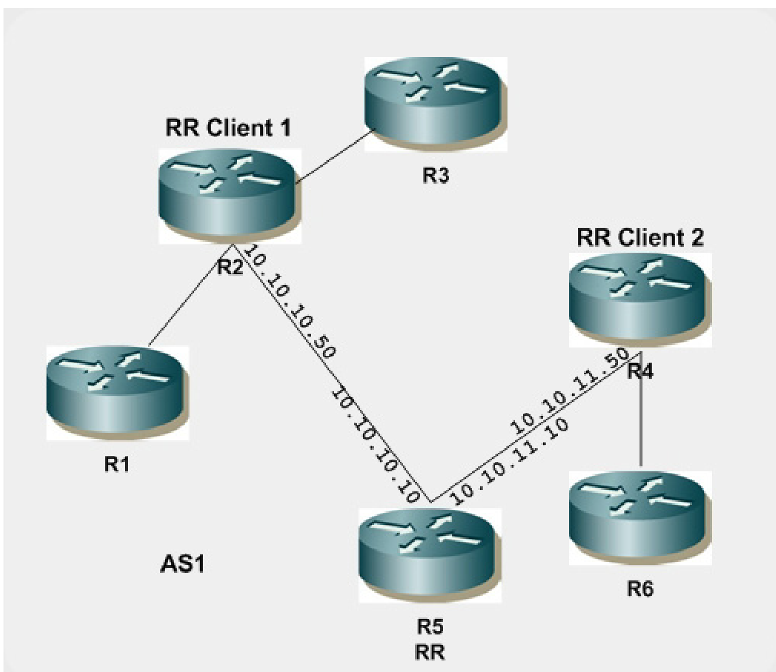

Figure 9-74: BGP Route Reflector

RR (R5)

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 1`	Define the routing process. The number `1` identifies the AS number of R5.
`(config-router)#neighbor 10.10.10.50 remote-as 1`	Define the 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.

`(config-router)#neighbor 10.10.10.50 route-reflector client`	Configure `R5` as the Route-Reflector (RR) and neighbor R2 as its client.
`(config-router)#neighbor 10.10.11.50 remote-as 1`	Define the 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.
`(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)

`(config)#router bgp 1`	Define the routing process. The number `1` specifies the AS number of R2.
`(config-router)#neighbor 10.10.10.10 remote-as 1`	Define the 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)

`(config)#router bgp 1`	Define the routing process. The number `1` identifies the AS number of `R4`.
`(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.

Validation

show ip bgp, show ip bgp neighbors

Make Route Reflector Transparent to Clients

The basic rule of BGP is that a BGP speaker cannot advertise a route to an iBGP neighbor if that route was learned from another iBGP neighbor. Configuring a route reflector provides a means to circumvent this rule. The entire route reflector process is transparent to the clients, and no configuration is necessary on these clients.

Whenever an iBGP-speaking router receives a route update, it forwards the route to the neighbor without changing the nexthop IP address, thus making it an unreachable route, unless verified by an iGP (for example, neighbor x.x.x.x route-reflector-client).

- If a router is configured as a Route Reflector, it forwards the routes received by changing the nexthop address as itself, thus making the nexthop reachable.
- If a route is received from a client, the route is forwarded to the clients.
- If a route is received from a non-client, the route is forwarded to the clients and non-clients.

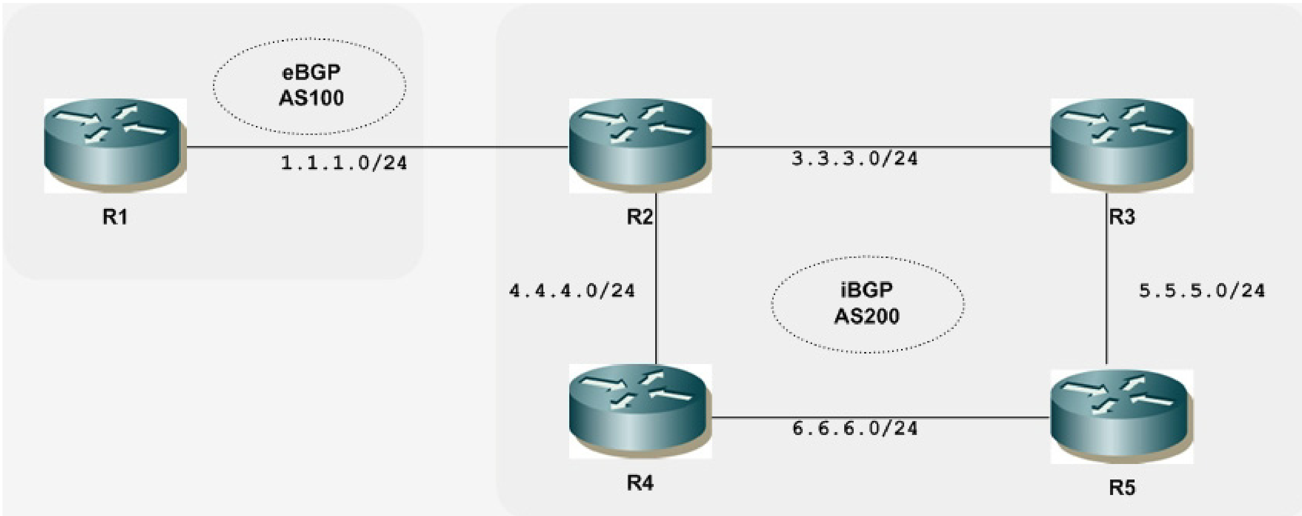

Figure 9-75: eBGP and iBGP Route Reflector Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Define the routing process with AS number `100`.
`(config-router)#neighbor 1.1.1.2 remote-as 200`	Define the eBGP neighbor (R2).
`(config-router)#network 100.100.100.100/32`	Advertise a route via eBGP connection to R2.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Define the eBGP neighbor (R1).
`(config-router)#neighbor 4.4.4.1 remote-as 200`	Define the iBGP neighbor (R4).
`(config-router)#neighbor 3.3.3.1 remote-as 200`	Define the iBGP neighbor (R3).
`(config-router)#bgp cluster-id 4`	Define a cluster ID (`4`) when multiple Route Reflectors exist.
`(config-router)#neighbor 3.3.3.1 route-reflector client`	Configure `R3` as the Route-Reflector and neighbor R2 as its client.
`(config-router)#neighbor 4.4.4.1 route-reflector client`	Configure `R4` as the Route-Reflector and neighbor R2 as its client.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.

(config-router)#neighbor 3.3.3.2 remote-as 200	Define the iBGP neighbor (R2).
(config-router)#neighbor 5.5.5.2 remote-as 200	Define the iBGP neighbor (R5).

R4

#configure terminal	Enter Configure mode.
(config)#router bgp 200	Define the routing process with AS number 200.
(config-router)#neighbor 4.4.4.2 remote-as 200	Define the iBGP neighbor (R2).
(config-router)#neighbor 6.6.6.2 remote-as 200	Define the iBGP neighbor (R5).

R5

#configure terminal	Enter Configure mode.
(config)#router bgp 200	Define the routing process with AS number 200.
(config-router)#neighbor 5.5.5.1 remote-as 200	Define the iBGP neighbor (R3).
(config-router)#neighbor 6.6.6.1 remote-as 200	Define the iBGP neighbor (R4).

Validation

show ip bgp, show ip bgp summary, show ip route

Route Server

At an Internet exchange point, many ISPs are connected to each other by external BGP peering. Normally, these external BGP connections are done by full mesh. As with internal BGP full-mesh formation, this method has a scaling issue.

Route Server is a method to resolve the problem; it is very similar to Route Reflector functionality, except it uses eBGP connections, in practice. Each ISP's BGP router only peers to the Route Server. Route Server serves as BGP information exchange to other BGP routers. By applying this method, numbers of BGP connections are reduced to O(n). Route Server also takes care of inbound and out-bound filtering policies for many-to-many eBGP connections, as they would have appeared if each router were connected to no other routers.

A BGP daemon can work as a normal BGP router, a Route Server, or as both.

A ZebOS-XP Route Server is set up using BGP views. ZebOS-XP does not guarantee support of Route Server over a BGP-MPLS-VPN link. However, ZebOS-XP Route Server can support IPv4 and IPv6 prefix services to different client routers through single-hop or multi-hop eBGP.

ZebOS-XP Route Server offers transparency of next-hop, MED, and AS-number while serving the routes from one client to another. It also supports a limited route-filtering capability for inbound and outbound control messages.

Note: When a BGP daemon is configured in Route-Server mode for a particular BGP view, it does not install any routes in the kernel for that view.

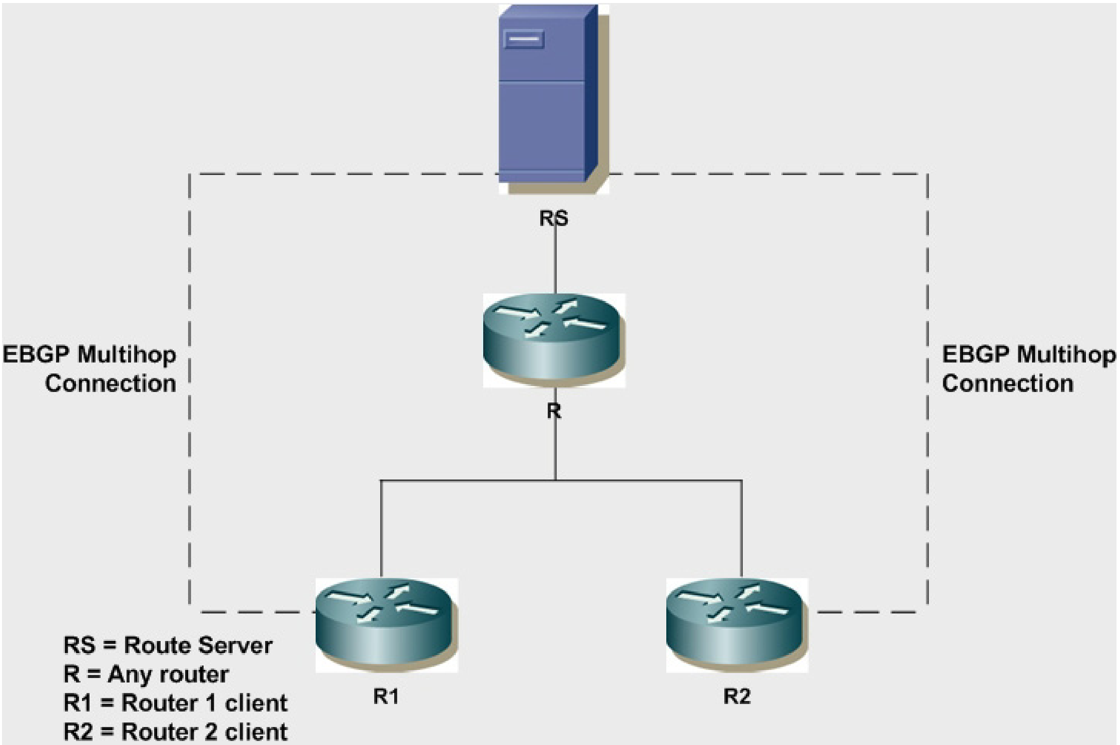

Figure 9-76: Route Server Topology

RS

`#configure terminal`	Enter Configure mode.
`(config)#router ospf`	Enter router mode to configure an OSPF routing process
`(config-router)#network 50.1.1.0/24 area 0`	Define the interface (`50.1.1.0/24`) on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)#network 144.144.144.144/32 area 0`	Define the interface (`144.144.144.144/32`) on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router bgp 5 view a`	Specify a BGP routing view name.
`(config-router)#neighbor 60.60.60.60 remote-as 2`	Define the BGP neighbor, and establish a TCP session. `60.60.60.60` is the IP address of the neighbor, and `2` is the neighbor's AS number.
`(config-router)#neighbor 60.60.60.60 ebgp-multihop 255`	Define the neighbor `60.60.60.60` can be `255` hops away.
`(config-router)#neighbor 60.60.60.60 update-source lo`	Specify the loopback interface BGP sessions use for the TCP connection.
`(config-router)#neighbor 60.60.60.60 route-server-client`	Configure the router as a BGP Route Server, and specify the `60.60.60.60` neighbor as its client.
`(config-router)#neighbor 77.77.77.77 remote-as 1`	Define the BGP neighbor, and establish a TCP session. `77.77.77.77` is the IP address of the neighbor, and `1` is the neighbor's AS number.

`#configure terminal`	Enter Configure mode.
`(config-router)#neighbor 77.77.77.77 ebgp-multihop 255`	Define the neighbor `77.77.77.77` can be `255` hops away.
`(config-router)#neighbor 77.77.77.77 update-source lo`	Specify the loopback interface BGP sessions use for the TCP connection.
`(config-router)#neighbor 77.77.77.77 route-server-client`	Configure the router as a BGP Route Server, and specify the `77.77.77.77` neighbor as its client.
`(config-router)#neighbor 77.77.77.77 route-map to_R1 out`	Apply a route map to the `to_R1` outgoing route.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#access-list lan02 permit 100.100.100.0/24`	Specify permit route `100.100.100.0/24` for access list `lan02`.
`(config)#access-list r2_NH permit 60.60.60.60/32`	Specify permit route `60.60.60.60/32` for access list `r2_NH`.
`(config)#route-map to_R1 permit 1`	Enter Route-Map mode, and permit route `to_R1`, sequence `1`.
`(config-route-map)#match ip address lan02`	Specify match address `lan02`.
`(config-route-map)#set ip next-hop 60.60.60.60`	Specify `60.60.60.60` as the address of the nexthop.

Validation

show ip bgp view

Route Server with Multiple Views

The following is a Route Server configuration example for a BGP router to transfer all capabilities of BGP routes to all clients and distribute routes with advanced dynamic policies.

Usage

When configuring BGP using the `bgp multiple-instance` command:

- It enables the router to run multiple BGP instances.
- Before enabling or disabling this feature, all BGP instances must be deleted.
- When using this feature, a specific peer cannot be a member of multiple instances.
- By enabling this feature, a normal BGP instance and multiple views can be run.

When configuring BGP using the `bgp multiple-instance allow-same peer` command:

- It enables the router to run multiple BGP instances only in views.
- Before enabling or disabling this feature, all BGP instances must be deleted.
- When using this feature, a specific peer can be a member of multiple instances.
- By enabling this feature, a normal BGP instance cannot be run, but multiple BGP views can be run.

When configuring BGP using the `neighbor x.x.x.x route-server client` command, the x.x.x.x neighbor is treated as a Route-Server client.

Topology

In the following example, R1 is a member of View 1, R2 runs two views, R3 is a member of View 2, and R4 is a member of both View 1 and 2.

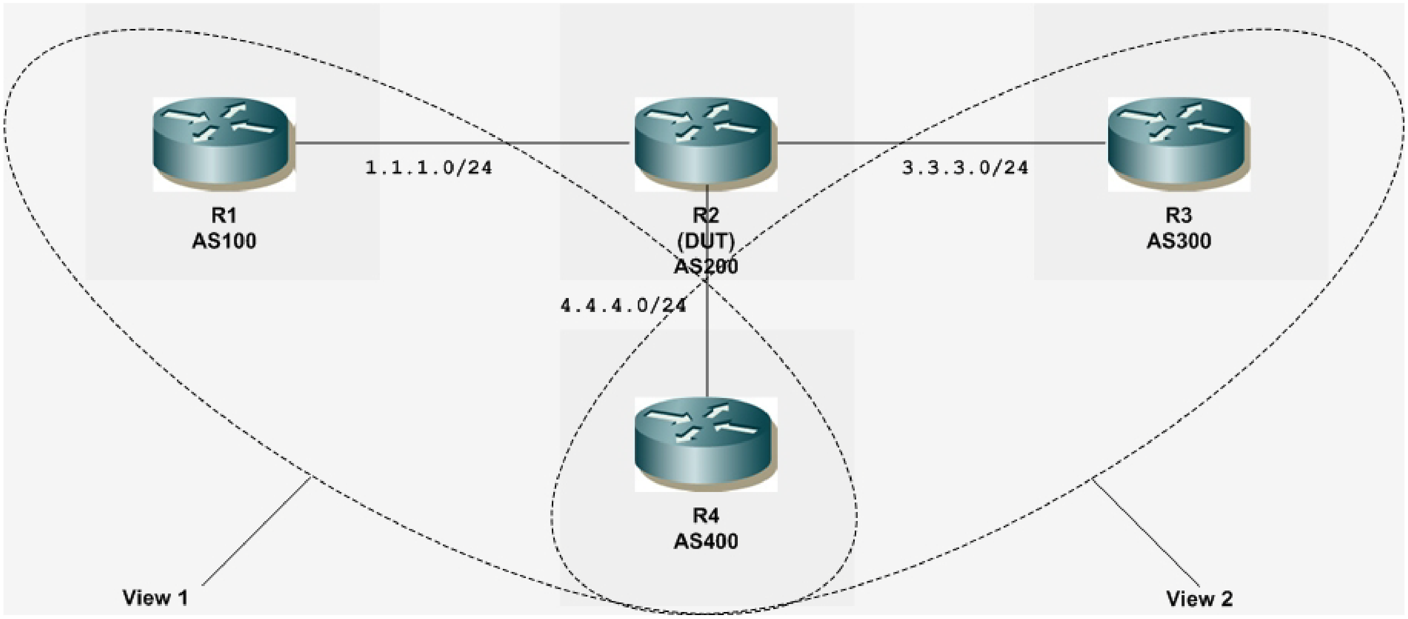

Figure 9-77: Route Server with Multiple Views

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Define the routing process with AS number `100`.
`(config-router)#neighbor 1.1.1.2 remote-as 200`	Define an eBGP neighbor (R2).

R2

`#configure terminal`	Enter Configure mode.
`(config)#bgp multiple-instance allow-same-peer`	Create only BGP views in which the same peers can be members of multiple views. A normal BGP instance is not created.
`(config)#router bgp 230 view one`	Create a BGP view.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Define an eBGP neighbor.
`(config-router)#neighbor 1.1.1.1 route-server-client`	Configure a Route-Server client on R2.
`(config-router)#neighbor 4.4.4.4 remote-as 400`	Define an eBGP neighbor.
`(config-router)#neighbor 4.4.4.4 route-server-client`	Configure a Route-Server client on R2.
`(config-router)#exit`	Exit Router mode and enter Configure mode.
`(config)#router bgp 230 view two`	Create a BGP view.

`#configure terminal`	Enter Configure mode.
`(config-router)#neighbor 3.3.3.1 remote-as 300`	Define an eBGP neighbor.
`(config-router)#neighbor 3.3.3.1 route-server-client`	Configure a Route-Server client on R2.
`(config-router)#neighbor 4.4.4.1 remote-as 400`	Define an eBGP neighbor.
`(config-router)#neighbor 4.4.4.1 route-server-client`	Configure a Route-Server client on R2.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 300`	Define the routing process with AS number `300`.
`(config-router)#neighbor 3.3.3.2 remote-as 230`	Define an eBGP neighbor (R2).

R4

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 400`	Define the routing process with AS number `400`.
`(config-router)#neighbor 4.4.4.2 remote-as 230`	Define an eBGP neighbor (R2).

Validation

show ip bgp, show ip bgp summary, show ip bgp view one, show ip bgp view one summary

BGP Confederations

In BGP, nodes running iBGP protocols must be interconnected forming a full mesh. Confederation solves the iBGP full-mesh network complexity and inefficiency by splitting a large autonomous system domain into smaller autonomous system domains, called member autonomous systems. Member autonomous systems can form eBGP connections among themselves, to prevent full-mesh connections among each iBGP-running node.

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 AS to which the router is connected.

In the following example, R1, R2, and R3 are members of the same confederation with different AS numbers.

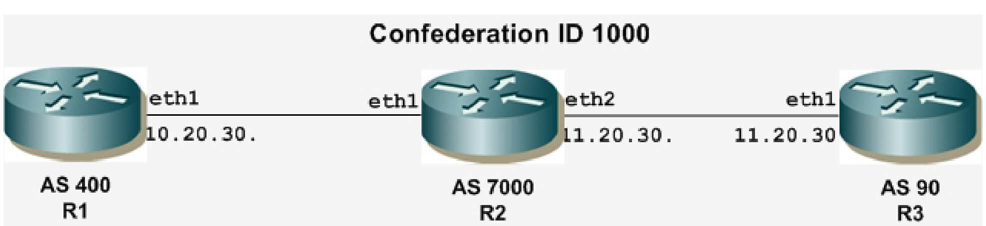

Figure 9-78: BGP Confederation

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 400`	Assign the ASN value (`400`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID, the externally visible autonomous system number that identifies the BGP confederation as a whole.
`(config-router)#bgp confederation peers 7000`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 10.20.30.2 remote-as 7000`	Specify the neighbor's IP address (`10.20.30.2`) and the ASN value of the neighbor (`7000`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 7000`	Assign the ASN value (`7000`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 400 90`	Specify the neighbor ASN values for confederation membership.
`(config-router)#neighbor 10.20.30.1 remote-as 400`	Specify the neighbor's IP address (`10.20.30.1`) and the ASN value of the neighbor (`400`).
`(config-router)#neighbor 11.20.30.30 remote-as 90`	Specify the neighbor's IP address (`11.20.30.30`) and the ASN value of the neighbor (`90`).

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 90`	Assign the ASN value (`90`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 7000`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 11.20.30.20 remote-as 7000`	Specify the neighbor's IP address (`11.20.30.20`) and the ASN value of the neighbor (`7000`).

Multiple Autonomous Systems

In the following example, R1 and R2 are members of the same confederation with the same AS numbers, and R3 is a member of the same confederation with a different AS number.

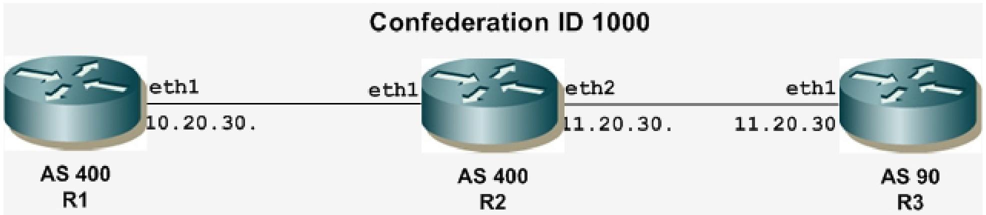

Figure 9-79: BGP Confederation with Multiple AS

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 90`	Assign the ASN value (`90`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#neighbor 10.20.30.2 remote-as 400`	Specify the neighbor's IP address (`10.20.30.2`) and the ASN value of the neighbor (`400`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 11.20.30.20/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 400`	Assign the ASN value (`400`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 90`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 10.20.30.1 remote-as 400`	Specify the neighbor's IP address (`10.20.30.1`) and the ASN value of the neighbor (`400`).
`(config-router)#neighbor 11.20.30.30 remote-as 90`	Specify the neighbor's IP address (`11.20.30.30`) and the ASN value of the neighbor (`90`).

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 90`	Assign the ASN value (`90`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 400`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 11.20.30.20 remote-as 400`	Specify the neighbor's IP address (`11.20.30.20`) and the ASN value of the neighbor (`400`).

Outside Autonomous System

In the following example, R1 and R2 are members of the same confederation with different AS numbers, and R3 is a member outside the confederation.

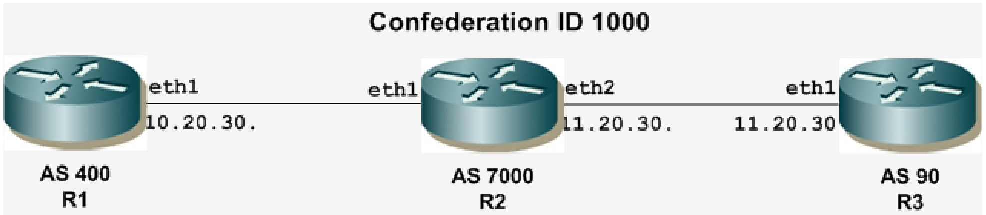

Figure 9-80: Single Confederation with Outside AS

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 400`	Assign the ASN value (`400`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 7000`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 10.20.30.2 remote-as 7000`	Specify the neighbor's IP address (`10.20.30.2`) and the ASN value of the neighbor (`7000`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 11.20.30.20/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 7000`	Assign the ASN value (`7000`) to the router.
`(config)#bgp confederation identifier 1000`	Specify the BGP confederation ID.
`(config-router)#bgp confederation peers 400`	Specify the neighbor ASN value for confederation membership.
`(config-router)#neighbor 10.20.30.1 remote-as 400`	Specify the neighbor's IP address (`10.20.30.1`) and the ASN value of the neighbor (`400`).
`(config-router)#neighbor 11.20.30.30 remote-as 90`	Specify the neighbor's IP address (`11.20.30.30`) and the ASN value of the neighbor (`90`).

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 90`	Assign the ASN value (`90`) to the router.
`(config-router)#neighbor 11.20.30.20 remote-as 100`	Specify the neighbor's IP address (`11.20.30.20`) and the ASN value of the neighbor (`100`).

Validation

show ip bgp summary, show ip bgp neighbors

Multiple Autonomous Systems

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 AS, 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 AS to which R2 is connected. The command tells the BGP process that the eBGP connection is a Confederation eBGP, rather than a normal eBGP.

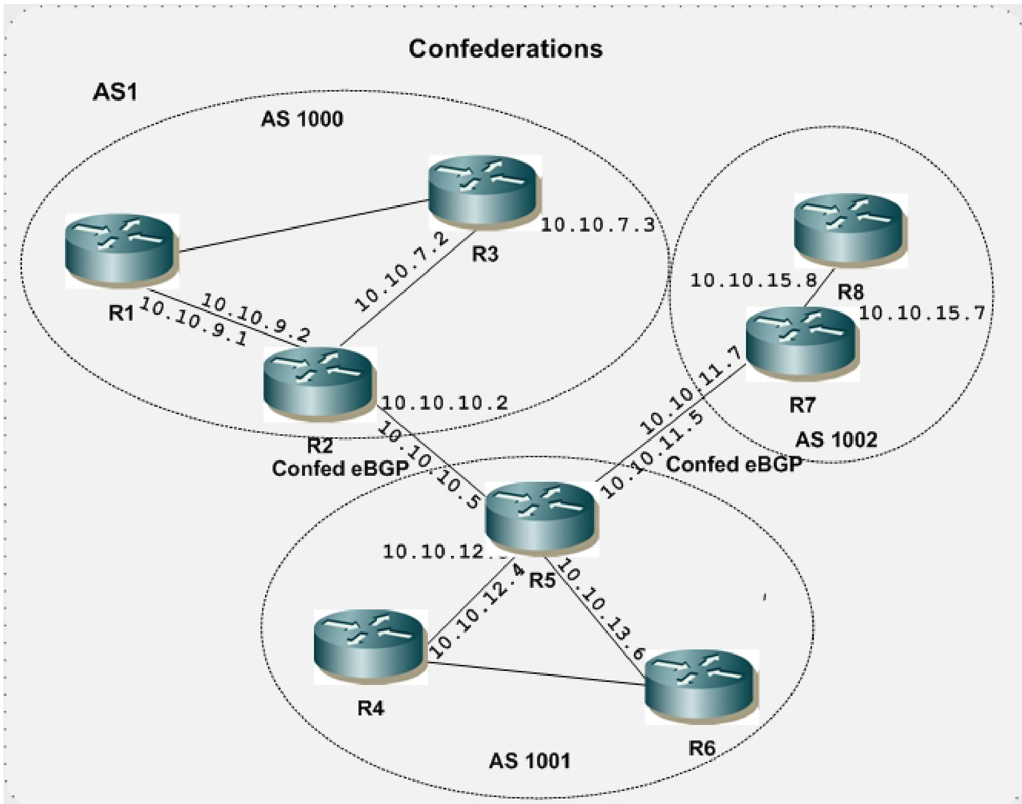

Figure 9-81: Multiple Confederations and Multiple AS

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 1000`	Define the routing process. The number `1000` specifies the AS number of R2.
`(config-router)#bgp confederation identifier 1`	Specify the BGP Confederation Identifier. To others, the group appears as a single AS, and the identifier as an AS number.
`(config-router)#bgp confederation peers 1001 1002`	Specify autonomous system `1001` and `1002` to become members of the Confederation.

`(config-router)#neighbor 10.10.10.5 remote-as 1001`
`(config-router)#neighbor 10.10.9.1 remote-as 1000`
`(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

(config)#router bgp 1001	Define the routing process. The number 1001 specifies the AS number of R5.
(config-router)#bgp confederation identifier 1	Specify the BGP Confederation Identifier. To others, the group appears as a single AS, and the identifier as an AS number.
(config-router)#bgp confederation peers 1000 1002	Specify autonomous systems 1000 and 1002 to become members of the Confederation.
(config-router)#neighbor 10.10.10.2 remote-as 1000 (config-router)#neighbor 10.10.11.7 remote-as 1002 (config-router)#neighbor 10.10.13.6 remote-as 1001 (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

(config)#router bgp 1002	Define the routing process. The number 1001 specifies the AS number of R5.
(config-router)#bgp confederation identifier 1	Specify the BGP Confederation Identifier. To others, the group appears as a single AS, and the identifier as an AS number.
(config-router)#bgp confederation peers 1000 1001	Specify autonomous systems1000 and 1001 to become members of the Confederation.
(config-router)#neighbor 10.10.11.5 remote-as 1001 (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.

Validation

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 packets it receives by exchanging a password that is configured on both the sending and receiving routers.

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

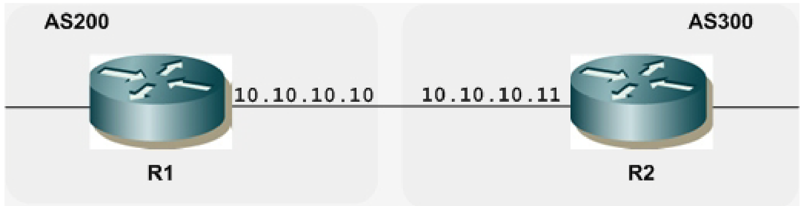

Figure 9-82: BGP Authentication

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(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.
`(config-router)#neighbor 10.10.10.11 password 1 ipi`	Specify the encryption type and the password.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R2.
`(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.
`(config-router)#neighbor 10.10.10.10 password 1 ipi`	Specify the encryption type and the password.

Validation

show ip bgp, show ip bgp neighbors

Enable eBGP Multihop

This example shows the minimum configuration required for enabling eBGP multihop on peers speaking BGP. eBGP multihop is used for routers that are not directly connected to each other. Typically, eBGP peers are directly connected, but if there is a requirement that necessitates this scenario, this configuration can be used.

Note: The IP addresses used in the configuration should be accessible through an IGP or static routing.

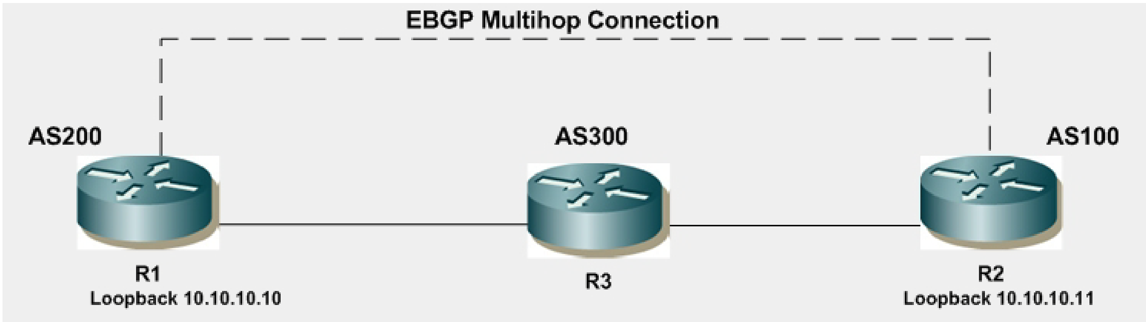

Figure 9-83: eBGP Multihop Connection

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of `R1`.
`(config-router)#neighbor 10.10.10.11 remote-as 100`	Define BGP neighbors, and establish a TCP session. `10.10.10.11` is the IP address of the neighbor (R2), and `100` is the neighbor's AS number.
`(config-router)#neighbor 10.10.10.11 ebgp-multihop 10`	Define the neighbor `10.10.10.11` can be `10` hops away.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Define the routing process. The number `100` specifies the AS number of `R2`.
`(config-router)#neighbor 10.10.10.11 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.
`(config-router)#neighbor 10.10.10.10 ebgp-multihop 10`	Defines the neighbor `10.10.10.10` can be 10 hops away.

Validation

show ip bgp, show ip bgp neighbors

Enable Peer Groups

A BGP speaker might have the same update policies for a set of its peers. This is very useful if you have to change the update policies for all of the peers: Changing individual routers for separate policies can be very time-consuming, thus, peer groups play an important role in creating and assigning policies to a group of routers.

In the following scenario, R1, R2, and R3 belong to the same peer group. R4 and R1 are eBGP peers. R1 is the route reflector (configuration not shown), and R2 and R3 are in AS 200. R4 is in AS 100.

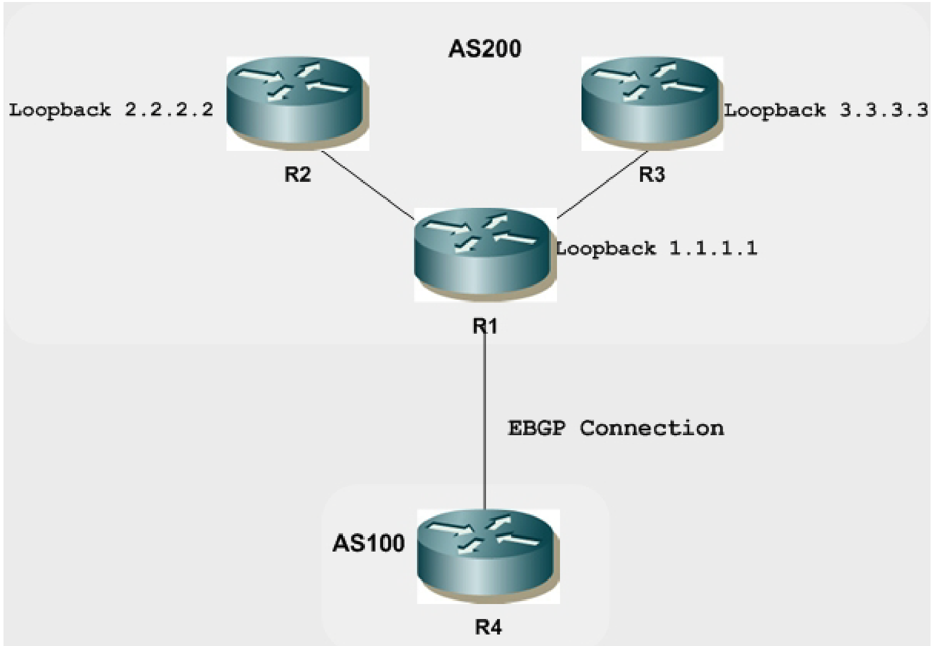

Figure 9-84: BGP Peer Groups

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(config-router)#neighbor ipi peer-group`	Create a peer group named `ipi`.
`(config-router)#neighbor ipi remote-as 200`	Assign options to the peer group named `ipi`.
`(config-router)#neighbor 2.2.2.2 peer-group ipi`	Define neighbor `2.2.2.2` (`R2`) as a peer group member.
`(config-router)#neighbor 3.3.3.3 peer-group ipi`	Define neighbor `3.3.3.3` (`R3`) as a peer group member.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(config-router)#neighbor 1.1.1.1 remote-as 200`	Create a TCP connection with neighbor `1.1.1.1` of AS `200`.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of R1.
`(config-router)#neighbor 1.1.1.1 remote-as 200`	Create a TCP connection with neighbor `1.1.1.1` of AS `200`.

Validation

show ip bgp, show ip bgp neighbors

Redistribute with OSPF

If there are routers that run both OSPF and BGP, certain OSPF routes might have to be sent to other eBGP peers. This can be achieved using the redistribution feature. Consider the following topology, in which R1 and R2 are eBGP peers, and R2 and R3 are OSPF peers. R2 is redistributing OSPF routes into BGP. The OSPF routes are sent to the R1 BGP routing table. This configuration assumes that all OSPF and eBGP sessions are up and running, and that only the redistribution must be configured.

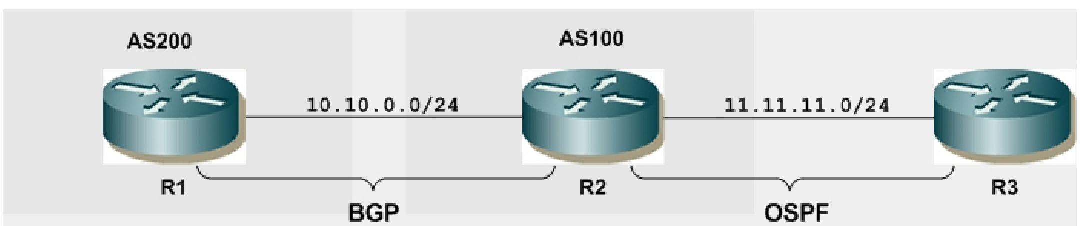

Figure 9-85: Redistribute with OSPF

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Define the routing process. The number `100` specifies the AS number of R2.
`(config-router)#redistribute ospf`	Redistribute OSPF routes in the R2 routing table into the R1 BGP routing table.
`(config-router)#exit`	Exit Router-BGP mode.

Validation

show ip bgp

Add Multiple Instances of the Same Autonomous System

BGP supports adding the same AS number multiple times to influence the route selection process. This can be done using route maps, as described below.

Under normal circumstances, any route advertised by R1 is sent to R4 via two different routes, and then R4 selects the path from R2. This decision can be influenced by adding multiple instances of AS number 200 at R2.

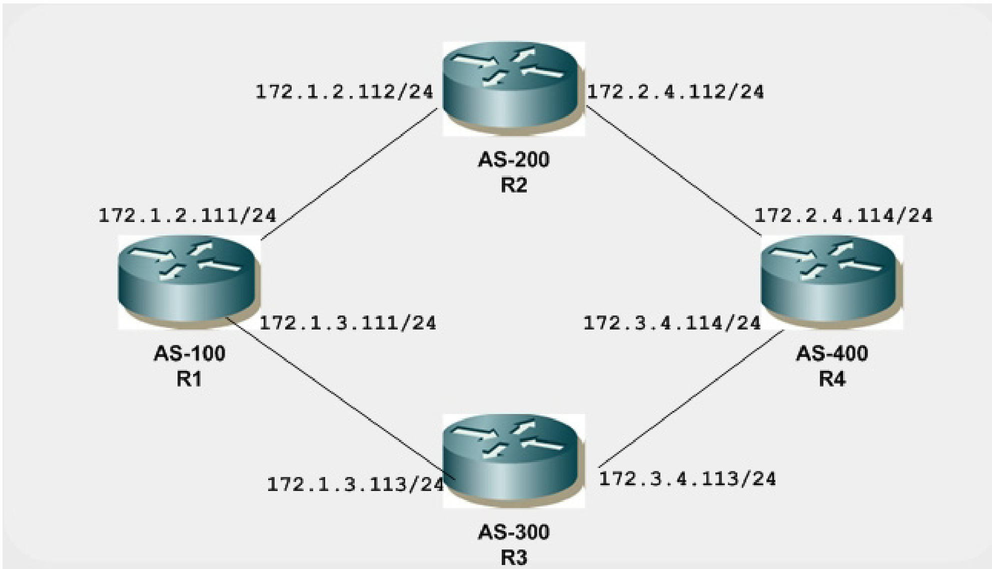

Figure 9-86: Multiple Instances of Same AS

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Define the routing process with AS number `100`.
`(config-router)#neighbor 172.1.2.112 remote-as 200`	Define neighbor R2. `172.1.2.112` is the IP address of R2, and `200` is the AS number.
`(config-router)#neighbor 172.1.3.113 remote-as 300`	Define neighbor R3. `172.1.3.113` is the IP address of R2, and `300` is the AS number.
`(config-router)#network 44.44.44.0/24`	Advertise network `44.44.44.0/24` through BGP. This route reaches R4 via R2 and R3.

R2

`#configure terminal`	Enter Configure mode.
`(config)#route-map mul_inst permit 10`	Define the route-map multiple instance with permit definition sequence number `10`.
`(config)#set as-path prepend 200 200`	Prepend AS number `200` two times to the AS_PATH attribute in the BGP Update message.
`(config-route-map)#exit`	Exit Route-map mode, and return to Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.
`(config-router)#neighbor 172.1.2.111 remote-as 100`	Define neighbor R1. `172.1.2.111` is the IP address of R1, and `100` is the AS number.
`(config-router)#neighbor 172.2.4.114 remote-as 400`	Define neighbor R4. `172.2.4.114` is the IP address of R2, and `400` is the AS number.
`(config-router)#neighbor 172.2.4.114 route-map mul_inst out`	Apply route-map `multi_inst` to all outbound routes to R4.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 300`	Define the routing process with AS number `300`.
`(config-router)#neighbor 172.1.3.111 remote-as 100`	Define neighbor R1. `172.1.3.111` is the IP address of R1, and `100` is the AS number.
`(config-router)#neighbor 172.3.4.114 remote-as 400`	Define neighbor R4. `172.3.4.114` is the IP address of R4, and `400` is the AS number.

R4

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 400`	Define the routing process with AS number `400`.
`(config-router)#neighbor 172.2.4.112 remote-as 200`	Define neighbor R2. `172.2.4.112` is the IP address of R2, and `200` is the AS number.
`(config-router)#neighbor 172.3.4.113 remote-as 300`	Define neighbor R3. `172.3.4.113` is the IP address of R3, and `300` is the AS number.

Validation

show ip bgp

Remove the Multi-Exit Disc Attribute from Update Messages

You can remove the Multi-Exit Disc (MED) attribute values from received update messages.

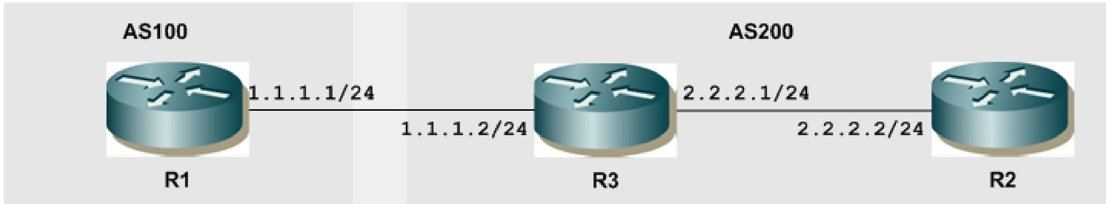

Figure 9-87: Remove MED Attribute

R1

`#configure terminal`	Enter Configure mode.
`(config)#route-map med permit 1`	Define the route-map MED with permit definition sequence number `1`.
`(config-route-map)#exit`	Exit Route-map mode, and return to Configure mode.
`(config)#router bgp 100`	Define the routing process with AS number `100`.
`(config-router)#neighbor 1.1.1.2 remote-as 200`	Define neighbor R2. `1.1.1.2` is the IP address of R2, and `200` is the AS number.
`(config-router)#neighbor 1.1.1.2 route-map med out`	Apply the route-map MED to all outbound routes to R2.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.
`(config-router)#neighbor 2.2.2.1 remote-as 200`	Define neighbor R2. `2.2.2.1` is the IP address of R2, and `200` is the AS number.

Removing Sent and Received MED values

The following describes how to remove the received and sent MED values, respectively.

R2 - Remove Received MED Value

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Define neighbor R1. `1.1.1.1` is the IP address of R1, and `100` is the AS number.
`(config-router)#neighbor 2.2.2.2 remote-as 200`	Define neighbor R3. `2.2.2.2` is the IP address of R3, and `200` is the AS number.
`(config-router)#bgp bestpath med remove-recv-med`	Enable the remove received MED value option.

R2 - Remove Send MED Value

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process with AS number `200`.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Define neighbor R1. `1.1.1.1` is the IP address of R1, and `100` is the AS number.
`(config-router)#neighbor 2.2.2.2 remote-as 200`	Define neighbor R3. `2.2.2.2` is the IP address of R3, and `200` is the AS number.
`(config-router)#bgp bestpath med remove-send-med`	Enable the remove sent MED value option.

Validation

show ip bgp

BGP Four-Byte Autonomous System

Extended AS numbers can be mapped to 2-byte AS numbers if the value is less than, or equal to, 65535. If the AS number is higher than 65535, it cannot be mapped to a 2-byte AS number. Therefore, if a BGP speaker is configured with a non-mappable AS number, it must enable the BGP extended ASN capability in ZebOS-XP.

Note: Autonomous System number 23456 is a reserved IANA number for AS transition; thus, it is recommended that no system be configured with 23456 as its AS number.

The extended ASN capability is disabled by default. However, when it is enabled, it is able to interoperate with a 2-byte AS-numbered speaker, in compliance with RFC 4893.

If a 4-byte AS number is configured in the provider’s network using BGP MPLS VPN or standard IPv4/IPv6 BGP, it is recommended that the PE routers be 4-byte AS-enabled before connecting to 4-byte AS-enabled customer networks. For implications related to AS number transition issues, refer to RFC 4893.

You can also set up 4-byte AS-specific extended communities and route distinguishers (RDs) with limited capabilities. However, it is recommended that 2-byte AS-specific RDs and extended communities be used for regular deployment.

BGP encodes an ASN into four octets, so that more autonomous systems can be supported. Extended ASN capability is advertised in the Open message capabilities when the 4-octet ASN capability is enabled. When the 4-octet ASN capability is enabled, the valid ASN value range is <1-4294967295>, with the exception discussed in the first Note, above.

Note: Four-octet capability is disabled by default.

4-Octet ASN Capability Enabled on R1 and R2

In this example, 4-Octet ASN capability is enabled on BGP speakers R1 and R2.

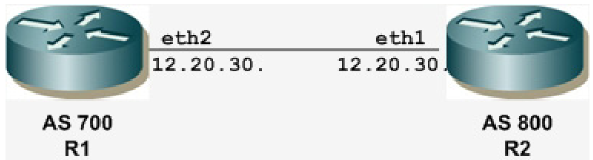

Figure 9-88: 4-Octet ASN on Both Routers

R1

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 400000`	Assign the ASN value (`400000`) to the router.
`(config-router)#neighbor 10.20.30.2 remote-as 7000`	Specify the neighbor's IP address (`10.20.30.2`) and the ASN value of the neighbor (`7000`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 7000`	Assign the ASN value (`7000`) to the router.
`(config-router)#neighbor 10.20.30.1 remote-as 400000`	Specify the neighbor's IP address (`10.20.30.1`) and the ASN value of the neighbor (`400000`).

4-Octet ASN Capability Enabled on R1 and Disabled on R2

In the following two examples, 4-Octet ASN capability is enabled on BGP speaker R1 and disabled on R2.

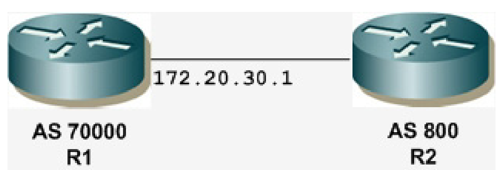

Figure 9-89: 4-Octet ASN on One Router

R1

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 70000`	Assign the ASN value (`70000`) to the router.
`(config-router)#neighbor 172.20.30.20 remote-as 800`	Specify the neighbor's IP address (`172.20.30.20`) and the ASN value of the neighbor (`800`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#no bgp extended-asn-cap`	Disable 4-octet ASN capability.
`(config)#router bgp 800`	Assign the ASN value (`800`) to the router.
`(config-router)#neighbor 172.20.30.10 remote-as 23456`	Specify the neighbor's IP address (`172.20.30.10`) and the ASN value of the neighbor (`23456`).

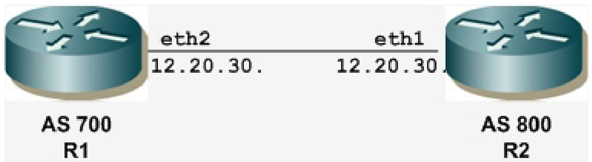

Figure 9-90: 4-Octet ASN

R1

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 700`	Assign the ASN value (`700`) to the router.
`(config-router)#neighbor 172.20.30.20 remote-as 800`	Specify the neighbor's IP address (`172.20.30.20`) and the ASN value of the neighbor (`800`).

R2

`#configure terminal`	Enter Configure mode.
`(config)#no bgp extended-asn-cap`	Disable 4-octet ASN capability.
`(config)#router bgp 800`	Assign the ASN value (`800`) to the router.
`(config-router)#neighbor 172.20.30.10 remote-as 700`	Specify the neighbor's IP address (`172.20.30.10`) and the ASN value of the neighbor (`700`).

Validation

show ip bgp summary, show ip bgp neighbors

BGP Extended Community Attribute

The Extended Community Attribute provides a mechanism for labeling information carried in BGP.

Configure Extended Community with a 2-Byte ASN

In the following example, CE1, PE1, PE2, and CE2 are 2-byte-ASN capable, and do not support 4-byte-ASN capability.

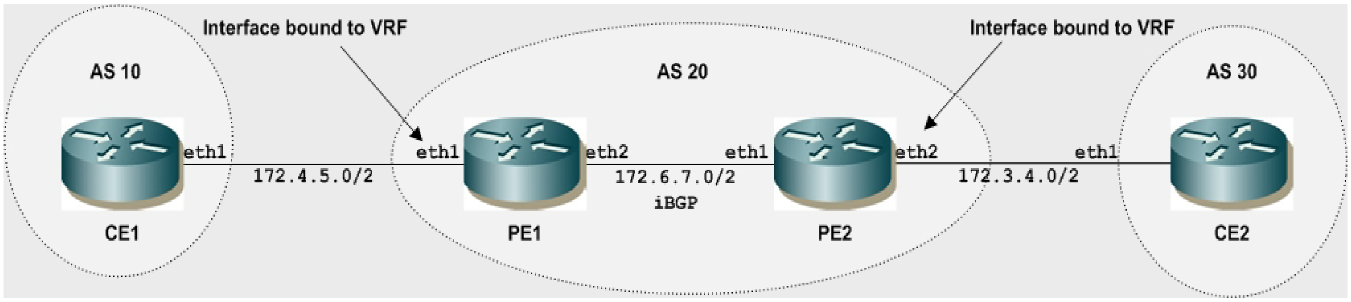

Figure 9-91: Extended Communities — 2-Byte ASN

CE1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 172.4.5.115/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router. The ASN range is <1-65535>.
`(config-router)#neighbor 172.4.5.116 remote-as 200`	Specify the neighbor's IP address (`172.4.5.116`) and the ASN value of the neighbor (`200`).

PE1

`#configure terminal`	Enter Configure mode.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 100:10`	Assign a route distinguisher (RD) for the VRF, which is a unique value on the router. The RD value can be in ASN:NN or A.B.C.D:NN format.
`(config-vrf)#route-target both 100:200`	Specify the 2-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (eth1) to the VRF (`VRF1`).
`(config-if)#ip address 172.4.5.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 172.6.7.117 remote-as 200`	Specify the neighbor's (PE2) IP address (`172.6.7.117`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.117 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.4.5.115 remote-as 100`	Specify the neighbor's (CE1) IP address and ASN value.
`(config-router-af)#neighbor 172.4.5.115 soo 1800:300`	Enable site-of-origin (SOO). The SOO value can be in ASN:NN or A.B.C.D:NN format. If the customer AS (CE1) is multi-homed to ISP, this command ensures that the PE does not advertise the routes back to the same AS/IP address. This command is for a route-origin extended community.

PE2

`#configure terminal`	Enter Configure mode.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 500:50`	Assign a route distinguisher (RD) for the VRF.
`(config-vrf)#route-target both 100:200`	Specify the 2-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (eth2) to the VRF (`VRF1`).
`(config-if)#ip address 172.3.4.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 172.6.7.116 remote-as 200`	Specify the neighbor's (PE1) IP address (`172.6.7.116`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.116 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.3.4.114 remote-as 30`	Specify the neighbor's (CE2) IP address and ASN value.

Configure Extended Community with a 2-Byte ASN

In the following example, CE1, PE1, PE2, and CE2 support 4-byte ASN capability.

Note: PE1 and PE2 should both either be 4-byte-ASN capable or 2-byte-ASN capable. Support for the combination of one 4-byte-ASN capable PE with one 2-byte-ASN-capable PE is currently unavailable.

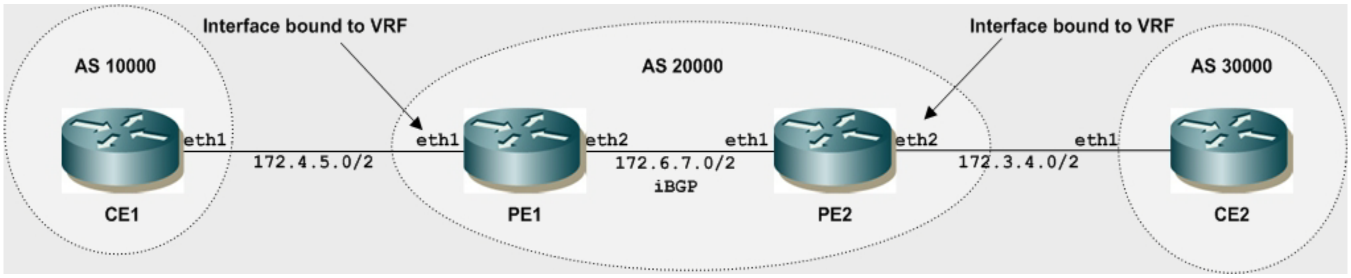

Figure 9-92: Extended Communities — 4-Byte ASN

CE1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1)` to configure, and enter Interface mode.
`(config-if)#ip address 172.4.5.115/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 100000`	Assign the ASN value (`100`) to the router. The ASN range is <1-65535>.
`(config-router)#neighbor 172.4.5.116 remote-as 200000`	Specify the neighbor's IP address (`172.4.5.116`) and the ASN value of the neighbor (`200000`).

PE1

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability. Dynamic change from 2-byte to 4-byte capability, or vice versa, is not allowed, unless the VRF is removed.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 700000:10`	Assign a 4-byte route distinguisher (RD) for the VRF, which is a unique value on the router. The RD value can be in ASN:NN or A.B.C.D:NN format.
`(config-vrf)#route-target both 800000:200`	Specify the 4-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (eth1) to the VRF (`VRF1`).
`(config-if)#ip address 172.4.5.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200000`	Assign the ASN value (`200000`) to the router.
`(config-router)#neighbor 172.6.7.117 remote-as 200`	Specify the neighbor's (PE2) IP address (`172.6.7.117`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.117 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.4.5.115 remote-as 100000`	Specify the neighbor's (CE1) IP address and ASN value.
`(config-router-af)#neighbor 172.4.5.115 soo 1800000:300`	Enable site-of-origin (SOO). The SOO value can be in ASN:NN or A.B.C.D:NN format. If the customer AS (CE1) is multi-homed to ISP, this command ensures that the PE does not advertise the routes back to the same AS/IP address. This command is for route-origin extended community.

PE2

`#configure terminal`	Enter Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability. Dynamic change from 2-byte to 4-byte capability, or vice versa, is not allowed, unless the VRF is removed.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 500000:50`	Assign a 4-byte route distinguisher (RD) for the VRF.
`(config-vrf)#route-target both 800000:200`	Specify the 4-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth2)` to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (eth1) to the VRF (`VRF1`).
`(config-if)#ip address 172.3.4.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth1)` to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200000`	Assign the ASN value (`200000`) to the router.
`(config-router)#neighbor 172.6.7.116 remote-as 200000`	Specify the neighbor's (PE2) IP address (`172.6.7.116`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.116 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.3.4.114 remote-as 300000`	Specify the neighbor's (CE1) IP address and ASN value.

CE2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1)` to configure, and enter Interface mode.
`(config-if)#ip address 172.3.4.114/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#bgp extended-asn-cap`	Enable 4-octet ASN capability.
`(config)#router bgp 300000`	Assign the ASN value (`300000`) to the router.
`(config-router)#neighbor 172.3.4.117 remote-as 200000`	Specify the neighbor's IP address (`172.3.4.117`) and the ASN value of the neighbor (`200000`).

Validation

show ip bgp, show ip bgp neighbors, show ip bgp vpnv4 all

IPv6 Route Refresh

Route-Refresh capability in BGP allows the dynamic exchange of route refresh request between BGP speakers and subsequent re-advertisement of the respective Adj-RIB-Out. To advertise Route Refresh capability to a peer, a BGP speaker uses BGP Capabilities Advertisement [BGP-CAP]. By advertising the Route Refresh capability to a peer, a BGP speaker conveys to the peer that the speaker is capable of receiving, and properly handling. the ROUTE-REFRESH message from the peer.

The following example is for Route-Refresh capability for the IPv6 address family.

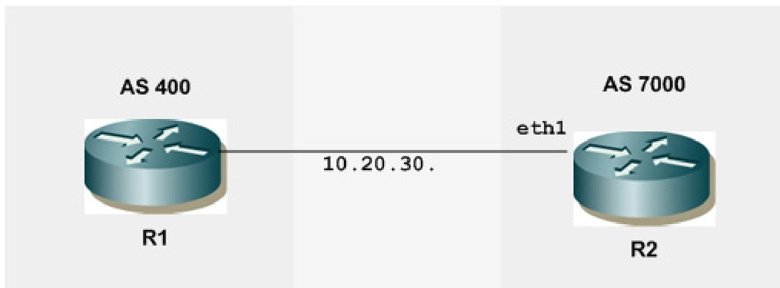

Figure 9-93: IPv6 Route Refresh

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 10.20.30.1/24`	Configure the IP address on this interface
`(config-if)#ipv6 address 3ffe::114/64`	Configure the IPv6 address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 400`	Assign the ASN value (`400`) to the router.
`(config-router)#neighbor 3ffe::115 remote-as 7000`	Specify the neighbor's IPv6 address (`3ffe::115`) and the ASN value of the neighbor (`7000`).
`(config-router)#address-family ipv6 unicast`	Exchange IPv6 capabilities, and enter IPv6 mode.
`(config-router-af)#neighbor 3ffe::115 activate`	Activate the IPv6 peer.
`(config-router-af)#redistribute static`	Advertise the static routes.

R2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 10.20.30.2/24`	Configure the IP address on this interface
`(config-if)#ipv6 address 3ffe::115/64`	Configure the IPv6 address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 7000`	Assign the ASN value (`7000`) to the router.
`(config-router)#neighbor 3ffe::114 remote-as 400`	Specify the neighbor's IPv6 address (`3ffe::114`) and the ASN value of the neighbor (`400`).
`(config-router)#address-family ipv6 unicast`	Exchange IPv6 capabilities, and enter IPv6 mode.
`(config-router-af)#neighbor 3ffe::114 activate`	Activate the IPv6 peer.
`(config-router-af)#redistribute static`	Advertise the static routes.
`(config-router-af)#exit`	Exit twice.
`#clear ip bgp 3ffe::115 in`	Send the Route-Refresh message to the IPv6 peer.
`#clear ip bgp * in`	Send the Route-Refresh message to all IPv4 and IPv6 peers
`#clear ip bgp 400 in`	Send the Route-Refresh message to all IPv4 and IPv6 peers in the ASN-400.

Validation

show ip bgp summary, show ip bgp neighbors, show bgp ipv6, show ipv6 route

Nexthop Tracking

Nexthop tracking is used to notify the BGP process asynchronously whenever there is any change in the IGP routes. It reduces the convergence time of BGP routes when IGP routes are changed.

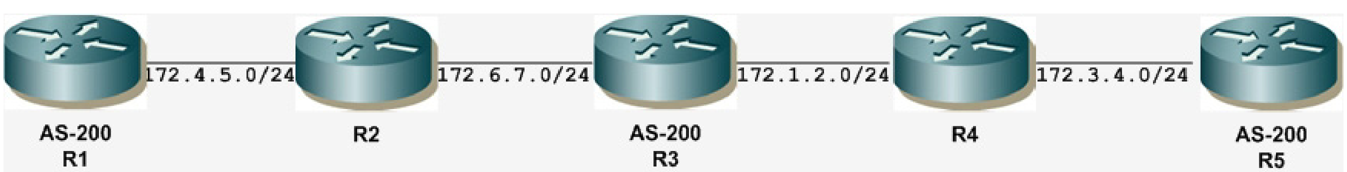

Figure 9-94: BGP Nexthop Tracking

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 100.100.100.100/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router. The ASN range is <1-65535>.
`(config-router)#neighbor 200.200.200.200 remote-as 200`	Specify the neighbor's IP address (`200.200.200.200`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 200.200.200.200 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.4.5.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.4.5.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#network 172.6.7.0/24 area 0`	Advertise the network in Area `0`.

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 200.200.200.200/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 100.100.100.100 remote-as 200`	Specify the neighbor's IP address (`100.100.100.100`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 100.100.100.100 update-source lo`	Specify the routing update source.
`(config-router)#neighbor 300.300.300.300 remote-as 200`	Specify the neighbor's IP address (`300.300.300.300`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 300.300.300.300 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.6.7.0/24 area 0`	Advertise the network in Area `0`.

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 200.200.200.200/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config-router)#network 172.1.2.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#bgp nexthop-trigger enable`	Enable Nexthop tracking.

R4

`#configure terminal`	Enter Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.1.2.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#network 172.3.4.0/24 area 0`	Advertise the network in Area `0`.

R5

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 300.300.300.300/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 200.200.200.200 remote-as 200`	Specify the neighbor's IP address (`200.200.200.200`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 200.200.200.200 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.3.4.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.

Validation

show ip bgp summary, show ip bgp neighbors, show ip bgp, show bgp nexthop-tracking, show ip bgp scan

Nexthop Tracking Delay Timer

The delay interval between routing table walks can be configured for nexthop delay tracking. This time determines how long BGP waits before it starts walking the full BGP routing table after receiving notification from NSM about a next-hop change.

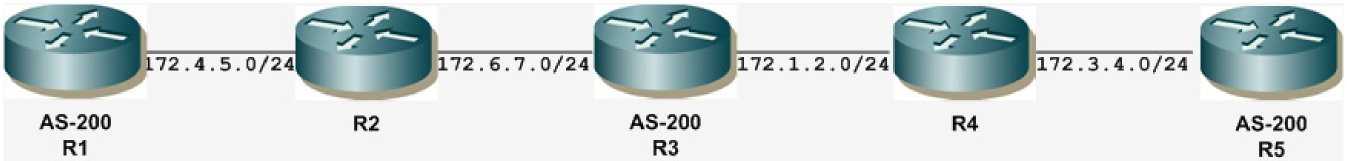

Figure 9-95: Topology for Nexthop Tracking Delay Timer

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 100.100.100.100/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router. The ASN range is <1-65535>.
`(config-router)#neighbor 200.200.200.200 remote-as 200`	Specify the neighbor's IP address (`200.200.200.200`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 200.200.200.200 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.4.5.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.4.5.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#network 172.6.7.0/24 area 0`	Advertise the network in Area `0`.

R3

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 200.200.200.200/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 100.100.100.100 remote-as 200`	Specify the neighbor's IP address (`100.100.100.100`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 100.100.100.100 update-source lo`	Specify the routing update source.

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 200.200.200.200/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config-router)#neighbor 300.300.300.300 remote-as 200`	Specify the neighbor's IP address (`300.300.300.300`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 300.300.300.300 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.6.7.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#network 172.1.2.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#bgp nexthop-trigger enable`	Enable nexthop tracking.
`(config)#bgp nexthop-trigger delay 20`	Configure the nexthop trigger-delay time interval.

R4

`#configure terminal`	Enter Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.1.2.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#network 172.3.4.0/24 area 0`	Advertise the network in Area `0`.

R5

`#configure terminal`	Enter Configure mode.
`(config)#interface lo`	Specify the loopback interface, and enter Interface mode.
`(config-if)#ip address 300.300.300.300/32`	Configure the IP address on this interface.
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 200.200.200.200 remote-as 200`	Specify the neighbor's IP address (`200.200.200.200`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 200.200.200.200 update-source lo`	Specify the routing update source.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.
`(config)#router ospf 1`	Configure the OSPF process (`1`).
`(config-router)#network 172.3.4.0/24 area 0`	Advertise the network in Area `0`.
`(config-router)#redistribute connected`	Redistribute the connected routes.

Validation

show ip bgp summary, show ip bgp neighbors, show ip bgp, show bgp nexthop-tracking, show ip bgp scan

BGP Graceful Restart

Using BGP graceful restart, the data-forwarding plane of a router can continue to process and forward packets, even if the control plane (which is responsible for determining best paths) fails.

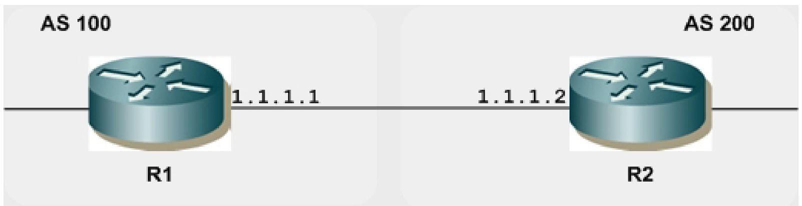

Figure 9-96: Graceful Restart Topology

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart restart-time 180`	Configure the maximum time (`180`) required for neighbor(s) to restart.
`(config-router)#bgp graceful-restart stalepath-time 150`	Configure the maximum time (`150`) to retain stale paths from the restarting neighbor(s).
`(config-router)#bgp update-delay 120`	Configure the maximum time to defer initial route selection.
`(config-router)#neighbor 1.1.1.2 remote-as 200`	Specify the neighbor's IP address (`1.1.1.2`) and the ASN value of the neighbor (`200`).
`(config-router)#neighbor 1.1.1.2 capability graceful-restart`	Specify the neighbor's IP address (`1.1.1.2`) for which the graceful restart capability is supports.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support. If the restart and stale-path timers are not configured, the defaults are 90 seconds and 360 seconds, respectively.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Specify the neighbor's IP address (`1.1.1.1`) and the ASN value of the neighbor (`100`).

`#configure terminal`	Enter Configure mode.
`(config-router)#neighbor 1.1.1.1 capability graceful-restart`	Specify the neighbor's IP address (`1.1.1.1`) for which the graceful restart capability supports.
`(config-router)#neighbor 1.1.1.1 restart-time 160`	Configure the maximum time (`160`) required for the neighbor to restart. This overwrites the configured restart time for that neighbor. For example, the configured restart-time for all neighbors is 90 seconds (default). With this command, the neighbor, 1.1.1.1, has a 160 second restart-time (overwrites 90 seconds).

Validation

show ip bgp summary, show ip bgp neighbors, show ip bgp, show ip route database bgp, show ip route database, show ip route

BGP-MPLS Graceful Restart

BGP-MPLS graceful restart provides a mechanism to save necessary MPLS forwarding-state information in NSM and synchronize with the VRF table when BGP goes offline in the control plane.

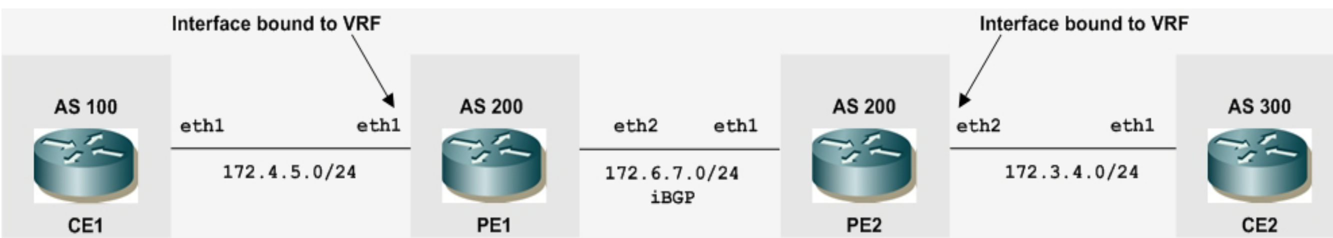

Figure 9-97: BGP-MPLS Graceful Restart

CE1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip address 172.4.5.115/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router. The ASN range is <1-65535>.
`(config-router)#neighbor 172.4.5.116 remote-as 200`	Specify the neighbor's IP address (`172.4.5.116`) and the ASN value of the neighbor (`200`).

PE1

`#configure terminal`	Enter Configure mode.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 100:10`	Assign a route distinguisher (RD) for the VRF, which is a unique value on the router. The RD value can be in ASN:NN or A.B.C.D:NN format.
`(config-vrf)#route-target both 100:200`	Specify the 2-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (`eth1`) to the VRF (`VRF1`).
`(config-if)#ip address 172.4.5.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.116/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart restart-time 180`	Configure the maximum time (`180`) required for neighbor(s) to restart.
`(config-router)#bgp graceful-restart stalepath-time 150`	Configure the maximum time (`150`) to retain stale paths from the restarting neighbor(s).
`(config-router)#bgp update-delay 120`	Configure the maximum time to defer initial route selection.
`(config-router)#neighbor 172.6.7.117 remote-as 200`	Specify the neighbor's (PE2) IP address (`172.6.7.117`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.117 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#neighbor 172.6.7.117 capability graceful-restart`	Specify the neighbor's IP address (`172.6.7.117`) for which the graceful restart capability supports.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.4.5.115 remote-as 100`	Specify the neighbor's (CE1) IP address and ASN value.

PE2

`#configure terminal`	Enter Configure mode.
`(config)#ip vrf VRF1`	Specify the name of the VRF (`VRF1`) to be created.
`(config-vrf)#rd 500:50`	Assign a route distinguisher (RD) for the VRF.
`(config-vrf)#route-target both 100:200`	Specify the 2-Octet AS specific or IPv4 specific Transitive Route-Target extended community attribute.
`(config-vrf)#exit`	Exit VRF mode, and return to Configure mode.
`(config)#interface eth1`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip vrf forwarding VRF1`	Bind the interface (`eth2`) to the VRF (`VRF1`).
`(config-if)#ip address 172.3.4.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#interface eth2`	Specify the interface (`eth2`) to configure, and enter Interface mode.
`(config-if)#ip address 172.6.7.117/24`	Configure the IP address on this interface
`(config-if)#exit`	Exit Interface mode, and return to Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart restart-time 180`	Configure the maximum time (`180`) required for neighbor(s) to restart.
`(config-router)#bgp graceful-restart stalepath-time 150`	Configure the maximum time (`150`) to retain stale paths from the restarting neighbor(s).
`(config-router)#neighbor 172.6.7.116 remote-as 200`	Specify the neighbor's (PE1) IP address (`172.6.7.116`) and the ASN value of the neighbor (`200`). In this case, it is an iBGP connection, so both PE1 and PE2 are in the same AS.
`(config-router)#address-family vpnv4 unicast`	Enable the exchange of VPNv4 routing information among ISP PE-routers, and enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 172.6.7.116 activate`	Enable the exchange of routing information with a peer router.
`(config-router-af)#neighbor 172.6.7.116 capability graceful-restart`	Specify the neighbor's IP address (`172.6.7.116`) for which the graceful restart capability supports.
`(config-router-af)#exit`	Exit Address-Family-VPNv4 mode.
`(config-router)#address-family ipv4 vrf VRF1`	Enable the exchange of VRF routing information among ISP PE-routers, and enter Address-Family-VRF mode.
`(config-router-af)#neighbor 172.3.4.114 remote-as 300`	Specify the neighbor's (CE2) IP address and ASN value.

CE1

#configure terminal	Enter Configure mode.
(config)#interface eth1	Specify the interface (eth1) to configure, and enter Interface mode.
(config-if)#ip address 172.3.4.114/24	Configure the IP address on this interface
(config-if)#exit	Exit Interface mode, and return to Configure mode.
(config)#router bgp 300	Assign the ASN value (300) to the router.
(config-router)#neighbor 172.3.4.117 remote-as 200	Specify the neighbor's IP address (172.3.4.117) and the ASN value of the neighbor (200).

Validation

show ip bgp summary, show ip bgp neighbors, show ip bgp vpnv4 all, show mpls ilm-table, show mpls vrf-table, show ip route vrf database, show ip route vrf

BGP Graceful Reset

The graceful restart mechanism for BGP session reset (the BGP daemon is not restarted) is used so that any changes in network configuration do not affect packet forwarding. The bgp graceful-restart graceful-reset CLI invokes graceful restart when a configuration change forces a peer reset. Graceful restart is invoked only when these CLI configuration changes force a peer reset.

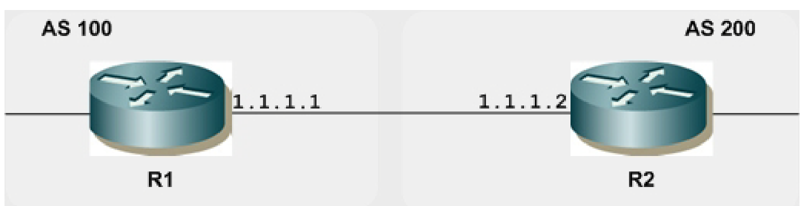

Figure 9-98: BGP Graceful Reset

R1

#configure terminal	Enter Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to the router.
(config-router)#bgp graceful-restart	Enable BGP graceful restart support.
(config-router)#bgp graceful-restart graceful-reset	Configure to invoke graceful restart when a configuration change forces a peer reset.
(config-router)#neighbor 1.1.1.2 remote-as 200	Specify the neighbor's IP address (1.1.1.2) and the ASN value of the neighbor (200).
(config-router)#neighbor 1.1.1.2 capability graceful-restart	Specify the neighbor's IP address (1.1.1.2) for which the graceful restart capability supports.

R2

#configure terminal	Enter Configure mode.
(config)#router bgp 200	Assign the ASN value (200) to the router.
(config-router)#bgp graceful-restart	Enable BGP graceful restart support.

`#configure terminal`	Enter Configure mode.
`(config-router)#bgp graceful-restart graceful-reset`	Configure to invoke graceful restart when a configuration change forces a peer reset.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Specify the neighbor's IP address (`1.1.1.1`) and the ASN value of the neighbor (`100`).
`(config-router)#neighbor 1.1.1.1 capability graceful-restart`	Specify the neighbor's IP address (`1.1.1.1`) for which the graceful restart capability supports.

Validation

show ip bgp summary, show ip bgp neighbors, show ip bgp, show ip route database bgp, show ip route database, show ip route

BGP Distance

Administrative distance in BGP can be configured for a specific address family.

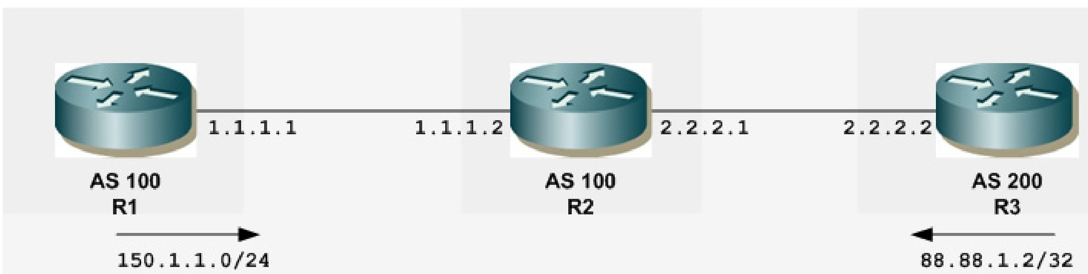

Figure 9-99: Administrative Distance for IPv4 BGP

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#network 150.1.1.0/24`	Specify the network to be advertised by the BGP routing process.
`(config-router)#neighbor 1.1.1.2 remote-as 100`	Specify the neighbor's IP address and ASN value.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#neighbor 2.2.2.2 remote-as 200`	Specify the neighbor's IP address and ASN value.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Specify the neighbor's IP address and the ASN value of another neighbor.
`(config-router)#distance 12 13 120`	Configure the administrative distance for external, internal, and local routes received.
`(config-router)#aggregate-address 50.50.0.0/16 summary-only`	Configure a non-AS-set aggregate route on R2. The local distance is applied to this route.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#network 88.88.1.2/32`	Specify the network to be advertised by the BGP routing process.
`(config-router)#neighbor 2.2.2.1 remote-as 100`	Specify the neighbor's IP address and ASN value.

Validation

show ip bgp summary, show ip bgp neighbors, show ip route database bgp, show ip route database, show ip route, show ip bgp

BGP Weight per Peer

A different weight can be assigned per address family of a peer. For example, a system can be configured to prefer VPN4 routes from peer A and IPv4 routes from peer B.

If the neighbor weight command is given under a specific address-family mode, the peer weight is set for that specific address family. If the address family is not specifically set, the weight is updated for the default address-family.

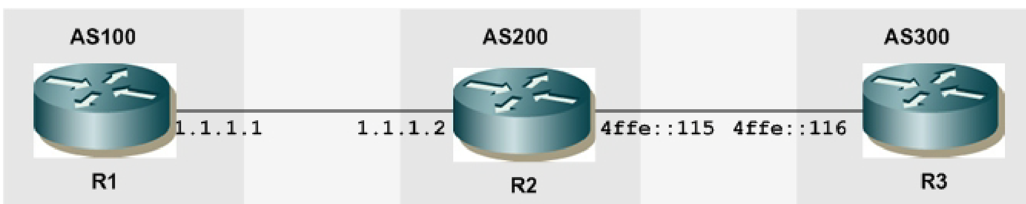

Figure 9-100: BGP Weight Per Peer

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#neighbor 1.1.1.2 remote-as 200`	Specify the neighbor's IP address and ASN value.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#neighbor 1.1.1.1 remote-as 100`	Specify the neighbor's IP address and ASN value.
`(config-router)#neighbor 1.1.1.1 weight 500`	Add a weight of `500` to all the routes coming from the neighbor, `1.1.1.1` (only IPv4 routes).
`(config-router)#neighbor 4ffe:116 remote-as 300`	Specify the IPv6 neighbor's address and ASN value.

(config-router)#address-family ipv6 unicast	Enter the IPv6 Address-Family mode.
(config-router-af)#neighbor 4ffe::116 activate	Activate the peer in IPv6 Address-Family mode.
(config-router-af)#neighbor 4ffe::116 weight 700	Add a weight of 700 to all routes coming from R3 (only IPv6 routes).
(config-router)#address-family ipv6 labeled-unicast	Enter 6PE address-family mode.
(config-router-af)#neighbor 1.1.1.1 activate	Activate the IPv4 neighbor to send IPv6 routes.
(config-router-af)#neighbor 1.1.1.1 weight 3000	Add a weight of 3000 to all 6PE routes coming from R1.

R3

#configure terminal	Enter Configure mode.
(config)#router bgp 300	Assign the ASN value (300) to the router.
(config-router)#neighbor 4ffe::115 remote-as 200	Define the IPv6 neighbor (R2).
(config-router)#address-family ipv6 unicast	Enter the IPv6 Address-Family mode.
(config-router-af)#neighbor 4ffe::115 activate	Activate the peer in Address-Family mode.

Validation

show ip bgp summary, show ip bgp neighbors, show bgp ipv6 neighbors, show ip bgp, show bgp ipv6, show ip route, show ipv6 route

OSPF as PE-CE Protocol for VPNs

In an MPLS VPN environment, customer networks are connected to an MPLS VPN-enabled provider backbone. As shown in Figure 9-101, Customer A areas, Areas 0 and 1, are connected to an MPLS VPN–enabled provider network. Area 0 and Area 1 have routers CE1 and CE2 running OSPF. MP-iBGP is used between PE1 and PE2 to propagate routes between Site 1 (Area 0) and Site 2 (Area 1). Traditional OSPF-BGP redistribution is performed at PE routers, PE1 and PE2. In this case, routes distributed by CE1 into the MP-iBGP cloud are sent to CE2 as external routes, even though both CE1 and CE2 belong to the same customer.

This behavior can be changed with the additional domain ID configuration. Each VRF should be configured a domain ID on the PE routers. If a PE router gets a route through the MP-iBGP cloud and has to send to any customer site, it checks the domain ID value against the list of stored domain ID values. If the incoming domain ID matches any of the stored IDs, that route is inserted into the customer site with the same type, as it was inserted into the MP-BGP cloud; otherwise, it is inserted as external route.

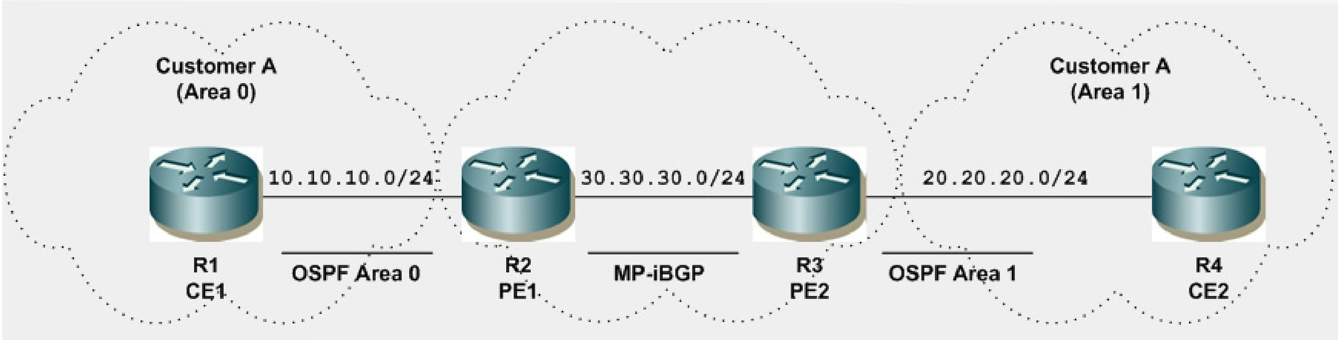

Figure 9-101: OSPF as PE-CE Protocol

CE1

`#configure terminal`	Enter Configure mode.
`(config)#router ospf 1`	Configure the routing process and specify the Process ID (`1`).
`(config-router)#network 10.10.10.0/24 area 0`	Advertise the network in OSPF.

PE1

`#configure terminal`	Enter Configure mode.
`(config)#ip vrf IPI`	Specify the name of the VRF (`IPI`) to be created.
`(config)#interface eth1`	Specify the interface (`eth1`) to configure.
`(config-if)#ip vrf forwarding`	Remove interface `eth1` from passive mode.
`(config-if)#exit`	Exit Interface mode and return to Configure mode.
`(config)#router ospf 1 IPI`	Configure OSPF for VRF.
`(config-router)#network 10.10.10.0/24 area 0`	Advertise the network for OSPF adjacency with CE1.
`(config-router)#domain-id 1.1.1.1`	Configure the primary domain ID.
`(config-router)#domain-id 2.2.2.2 secondary`	Configure a secondary domain ID.
`(config-router)#domain-id 3.3.3.3 secondary`	Configure a secondary domain ID.
`(config-router)#exit`	Exit Router mode and return to Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the BGP router.
`(config-router)#neighbor 30.30.30.2 remote-as 100`	Configure neighbor `30.30.30.2` for iBGP.
`(config-router)#address-family vpnv4 unicast`	Enter Address-Family-VPNv4 mode.
`(config-router-af)#neighbor 30.30.30.2 activate`	Activate neighbor `30.30.30.2`.
`(config-router-af)#exit-address-family`	Exit Address Family mode and return to Router mode.
`(config-router)#address-family ipv4 vrf IPI`	Enter Address-Family-VRF mode.
`(config-router)#redistribute ospf`	Specify redistributing routes from OSPF into BGP.
`(config-router-af)#exit-address-family`	Exit Address Family mode and return to Router mode.

PE2

#configure terminal	Enter Configure mode.
(config)#interface eth1	Specify the interface (eth1) to configure.
(config-if)#ip vrf forwarding	Remove interface eth1 from passive mode.
(config-if)#exit	Exit Interface mode and return to Configure mode.
(config)#router ospf 1 IPI	Configure OSPF for VRF.
(config-router)#network 20.20.20.0/24 area 0	Advertise the network for OSPF adjacency with CE1.
(config-router)#domain-id 1.1.1.1	Configure the primary domain ID.
(config-router)#domain-id 2.2.2.2 secondary	Configure a secondary domain ID.
(config-router)#domain-id 3.3.3.3 secondary	Configure a secondary domain ID.
(config-router)#exit	Exit Router mode and return to Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to the BGP router.
(config-router)#neighbor 30.30.30.1 remote-as 100	Configure neighbor 30.30.30.1 for iBGP.
(config-router)#address-family vpnv4 unicast	Enter Address-Family-VPNv4 mode.
(config-router-af)#neighbor 30.30.30.2 activate	Activate neighbor 30.30.30.2.
(config-router-af)#exit-address-family	Exit Address Family mode and return to Router mode.
(config-router)#address-family ipv4 vrf IPI	Enter Address-Family-VRF mode.
(config-router)#redistribute ospf	Specify redistributing routes from OSPF into BGP.
(config-router-af)#exit-address-family	Exit Address Family mode and return to Router mode.

CE2

#configure terminal	Enter Configure mode.
(config)#router ospf 1	Configure the routing process, and specify the Process ID (1).
(config-router)#network 20.20.20.0/24 area 0	Advertise the network in OSPF.

Validation

show ip bgp vpnv4 all

BGP Multipath for IPv4 and IPv6

BGP support for multipath supports both IPv4 and IPv6 prefixes. BGP Multipath allows load-balancing traffic among multiple BGP routes. It supports both iBGP and eBGP routes. In case of eBGP, the routes should arrive from same AS number.

Multipath iBGP

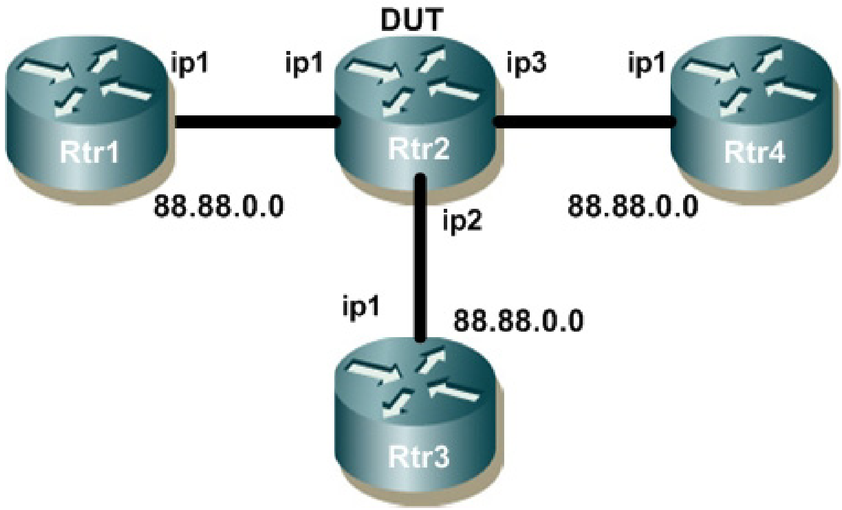

Figure 9-102: Multipath iBGP for IPv4

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 2.2.2.2`	Configure a fixed Router ID (2.2.2.2).
`(config-router)#redistribute static`	Redistribute the static routes.
`(config-router)#neighbor 30.30.30.9 remote-as 100`	Configure neighbor 30.30.30.9 for iBGP.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ip route 88.88.0.0/16 eth3`	Configure the IP address on eth3 interface.

Rtr3

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 4.4.4.4`	Configure a fixed Router ID (4.4.4.4).
`(config-router)#redistribute static`	Redistribute the static routes.
`(config-router)#neighbor 40.40.40.9 remote-as 100`	Configure neighbor 40.40.40.9 for iBGP.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ip route 88.88.0.0/16 eth3`	Configure the IP address on eth3 interface.

Rtr4

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 6.6.6.6`	Configure a fixed Router ID (6.6.6.6).

(config-router)#redistribute static	Redistribute the static routes.
(config-router)#neighbor 50.50.50.9 remote-as 100	Configure neighbor 50.50.50.9 for iBGP.
(config)#exit	Exit the BGP Router mode and return to the Configure mode.
(config)#ip route 88.88.0.0/16 eth3	Configure the IP address on eth3 interface.

DUT

#configure terminal	Enter the Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to the BGP router.
(config-router)#max-paths ibgp 2	Configure iBGP max-paths (2).
(config)#bgp router-id 9.9.9.9	Configure a fixed Router ID (9.9.9.9).
(config-router)#neighbor 30.30.30.2 remote-as 100	Configure neighbor 30.30.30.2 for iBGP.
(config-router)#neighbor 40.40.40.4 remote-as 100	Configure neighbor 40.40.40.4 for iBGP.
(config-router)#neighbor 50.50.50.6 remote-as 100	Configure neighbor 50.50.50.6 for iBGP.
(config-router)#exit	Exit the Router mode and return to Configure mode.

Validation

```
#show ip bgp 88.88.0.0
BGP routing table entry for 88.88.0.0/16
Paths: (3 available, best #3, table Default-IP-Routing-Table)
  Not advertised to any peer
  Local
    40.40.40.4 from 40.40.40.4 (4.4.4.4)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate,
installed
      Last update: Sat Jan  3 00:50:38 1970

  Local
    50.50.50.6 from 50.50.50.6 (6.6.6.6)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate
      Last update: Sat Jan  3 00:50:28 1970

  Local
    30.30.30.2 from 30.30.30.2 (2.2.2.2)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate,
installed, best
      Last update: Sat Jan  3 00:50:20 1970

#show ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default
```

```
C       30.30.30.0/24 is directly connected, ge3
C       40.40.40.0/24 is directly connected, ge5
C       50.50.50.0/24 is directly connected, ge7
B       88.88.0.0/16 [200/0] via 30.30.30.2, ge3, 00:00:44
                     [200/0] via 40.40.40.4, ge5, 00:00:44
C       90.90.90.90/32 is directly connected, lo
C       127.0.0.0/8 is directly connected, lo
#
```

Multipath eBGP

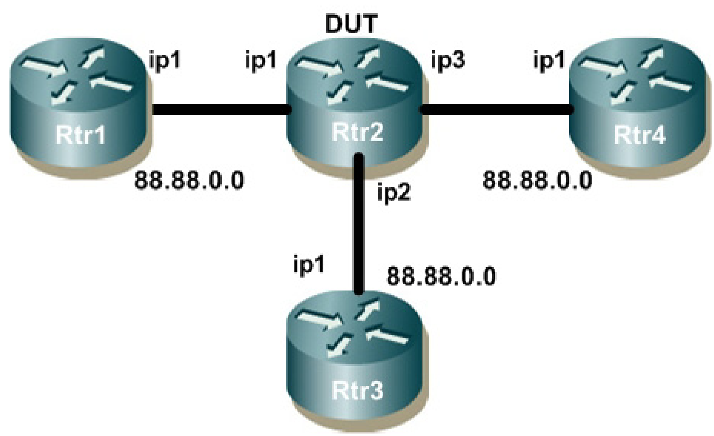

Figure 9-103: Multipath eBGP for IPv4

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 2.2.2.2`	Configure a fixed Router ID (2.2.2.2).
`(config-router)#redistribute static`	Redistribute the static routes.
`(config-router)#neighbor 30.30.30.9 remote-as 100`	Configure neighbor 30.30.30.9 for iBGP.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ip route 88.88.0.0/16 eth3`	Configure the IP address on eth3 interface.

Rtr3

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 4.4.4.4`	Configure a fixed Router ID (4.4.4.4).
`(config-router)#redistribute static`	Redistribute the static routes.
`(config-router)#neighbor 40.40.40.9 remote-as 100`	Configure neighbor 40.40.40.9 for iBGP.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ip route 88.88.0.0/16 eth3`	Configure the IP address on eth3 interface.

Rtr4

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#bgp router-id 6.6.6.6`	Configure a fixed Router ID (6.6.6.6).
`(config-router)#redistribute static`	Redistribute the static routes.
`(config-router)#neighbor 50.50.50.9 remote-as 100`	Configure neighbor 50.50.50.9 for iBGP.
`(config)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ip route 88.88.0.0/16 eth3`	Configure the IP address on eth3 interface.

DUT

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router.
`(config-router)#max-paths ebgp 2`	Configure eBGP max-paths (2).
`(config)#bgp router-id 9.9.9.9`	Configure a fixed Router ID (9.9.9.9).
`(config-router)#neighbor 30.30.30.2 remote-as 200`	Configure neighbor 30.30.30.2 for eBGP.
`(config-router)#neighbor 40.40.40.4 remote-as 200`	Configure neighbor 40.40.40.4 for eBGP.
`(config-router)#neighbor 50.50.50.6 remote-as 200`	Configure neighbor 50.50.50.6 for eBGP.
`(config-router)#exit`	Exit the Router mode and return to Configure mode.

Validation

```
#show ip bgp 88.88.0.0

BGP routing table entry for 88.88.0.0/16
Paths: (3 available, best #3, table Default-IP-Routing-Table)
  Advertised to non peer-group peers:
  30.30.30.2 50.50.50.6
  200
    30.30.30.2 from 30.30.30.2 (2.2.2.2)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate,
installed
      Last update: Sat Jan  3 02:06:25 1970

  200
    50.50.50.6 from 50.50.50.6 (6.6.6.6)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate
      Last update: Sat Jan  3 02:05:39 1970

  200
    40.40.40.4 from 40.40.40.4 (4.4.4.4)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate,
installed, best
      Last update: Sat Jan  3 02:05:11 1970
```

```
#show ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

C        30.30.30.0/24 is directly connected, ge3
C        40.40.40.0/24 is directly connected, ge5
C        50.50.50.0/24 is directly connected, ge7
B        88.88.0.0/16 [20/0] via 30.30.30.2, ge3, 00:00:11
                      [20/0] via 40.40.40.4, ge5, 00:00:11
C        90.90.90.90/32 is directly connected, lo
C        127.0.0.0/8 is directly connected, lo
#

#show run router bgp
!
router bgp 100
 bgp router-id 9.9.9.9
 max-paths ebgp 2
 neighbor 30.30.30.2 remote-as 200
 neighbor 40.40.40.4 remote-as 200
 neighbor 50.50.50.6 remote-as 200
!
```

Multipath iBGP for IPv6

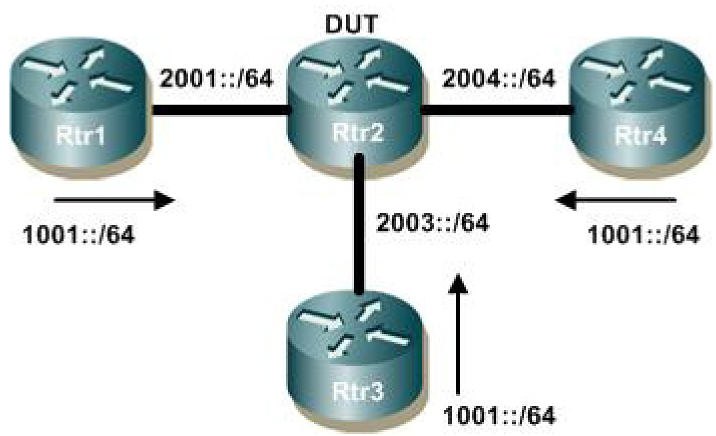

Figure 9-104: Multipath iBGP for IPv6

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to BGP router.
`(config-router)#bgp router-id 1.1.1.1`	Configure a fixed Router ID (1.1.1.1).

(config-router)#neighbor 2001::2 remote-as 100	Configure neighbor 2001::2 for iBGP.
(config-router)#address-family ipv6	Enter the IPv6 Address-Family mode.
(config-router-af)#redistribute static	Redistribute the IPv6 static routes.
(config-router-af)#neighbor 2001::2 activate	Activate neighbor 2001::2.
(config-router-af)#exit-address-family	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
(config-router)#exit	Exit the BGP Router mode and return to the Configure mode.
(config)#ipv6 route 1001::/64 null	Configure IPv6 static route with next-hop as NULL interface.

Rtr3

#configure terminal	Enter the Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to BGP router.
(config-router)#bgp router-id 3.3.3.3	Configure a fixed Router ID (3.3.3.3).
(config-router)#neighbor 2003::2 remote-as 100	Configure neighbor 2003::2 for iBGP.
(config-router)#address-family ipv6	Enter the IPv6 Address-Family mode.
(config-router-af)#redistribute static	Redistribute the IPv6 static routes.
(config-router-af)#neighbor 2003::2 activate	Activate neighbor 2003::2.
(config-router-af)#exit-address-family	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
(config-router)#exit	Exit the BGP Router mode and return to the Configure mode.
(config)#ipv6 route 1001::/64 null	Configure IPv6 static route with next-hop as NULL interface.

Rtr4

#configure terminal	Enter the Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to BGP router.
(config-router)#bgp router-id 4.4.4.4	Configure a fixed Router ID (4.4.4.4).
(config-router)#neighbor 2004::2 remote-as 100	Configure neighbor 2004::2 for iBGP.
(config-router)#address-family ipv6	Enter the IPv6 Address-Family mode.
(config-router-af)#redistribute static	Redistribute the IPv6 static routes.
(config-router-af)#neighbor 2004::2 activate	Activate neighbor 2004::2.
(config-router-af)#exit-address-family	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
(config-router)#exit	Exit the BGP Router mode and return to the Configure mode.
(config)#ipv6 route 1001::/64 null	Configure IPv6 static route with next-hop as NULL interface.

DUT

#configure terminal	Enter the Configure mode.
(config)#router bgp 100	Assign the ASN value (100) to BGP router.

`(config-router)#bgp router-id 2.2.2.2`	Configure a fixed Router ID (2.2.2.2).
`(config-router)#max-paths ibgp 2`	Configure iBGP maximum paths (2).
`(config-router)#neighbor 2001::1 remote-as 100`	Configure neighbor 2001::1 for iBGP.
`(config-router)#neighbor 2003::3 remote-as 100`	Configure neighbor 2003::3 for iBGP.
`(config-router)#neighbor 2004::4 remote-as 100`	Configure neighbor 2004::4 for iBGP.
`(config-router)#address-family ipv6`	Enter the IPv6 Address-Family mode.
`(config-router-af)#neighbor 2001::1 activate`	Activate neighbor 2001::1.
`(config-router-af)#redistribute static`	Redistribute the IPv6 static routes.
`(config-router-af)#neighbor 2004::2 activate`	Activate neighbor 2004::2.
`(config-router-af)#neighbor 2003::3 activate`	Activate neighbor 2003::3.
`(config-router-af)#neighbor 2004::4 activate`	Activate neighbor 2004::4.
`(config-router-af)#exit-address-family`	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.

Validation

```
#show bgp ipv6 1001::/64

BGP routing table entry for 1001::/64
Paths: (3 available, best #2, table Default-IP-Routing-Table)
  Not advertised to any peer
  Local
    2004::4(fe80::5054:ff:feae:1f85) from 2004::4 (4.4.4.4)
     (fe80::5054:ff:feae:1f85)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate
      Last update: Wed Oct 17 12:52:46 2012

  Local
    2001::1(fe80::5054:ff:fe76:f9a2) from 2001::1 (1.1.1.1)
     (fe80::5054:ff:fe76:f9a2)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate,
installed, best
      Last update: Wed Oct 17 12:36:57 2012

  Local
    2003::3(fe80::5054:ff:fe62:253a) from 2003::3 (3.3.3.3)
     (fe80::5054:ff:fe62:253a)
      Origin incomplete metric 0, localpref 100, valid, internal, multipath-candidate,
installed
      Last update: Wed Oct 17 12:25:27 2012
#

#show ipv6 route
IPv6 Routing Table
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       IA - OSPF inter area, E1 - OSPF external type 1,
```

```
       E2 - OSPF external type 2, I - IS-IS, B - BGP
Timers: Uptime

C      ::1/128 via ::, lo, 01:12:53
B      1001::/64 [200/0] via fe80::5054:ff:fe76:f9a2, eth1, 00:19:09
                 [200/0] via fe80::5054:ff:fe62:253a, eth3, 00:19:09
C      2001::/64 via ::, eth1, 01:12:48
C      2003::/64 via ::, eth3, 01:12:48
C      2004::/64 via ::, eth4, 01:12:48
C      fe80::/64 via ::, eth0, 01:12:53
K      ff00::/8 via ::, virbr0, 01:12:53
#

#show bgp summary
BGP router identifier 2.2.2.2, local AS number 100
BGP table version is 5
1 BGP AS-PATH entries
0 BGP community entries
1  Configured ebgp ECMP multipath: Currently set at 1
2  Configured ibgp ECMP multipath: Currently set at 2

Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001::1         4   100      79      78        5    0    0 00:31:29        1
2003::3         4   100     169     171        5    0    0 00:32:31        1
2004::4         4   100      80      79        5    0    0 00:33:13        1

Total number of neighbors 3
#
```

Multipath eBGP for IPv6

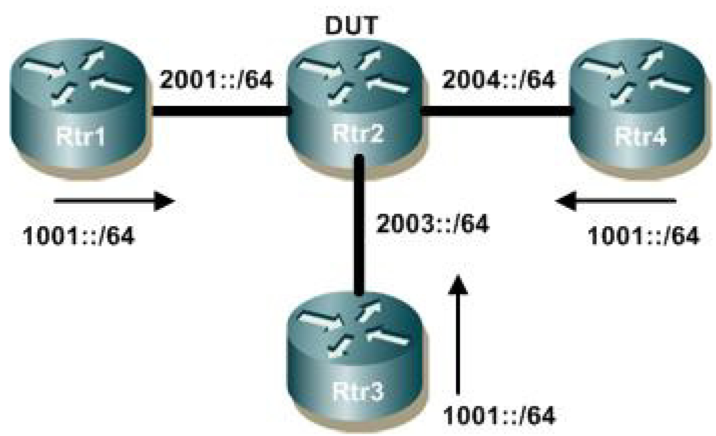

Figure 9-105: Multipath eBGP for IPv6

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to BGP router.

`(config-router)#bgp router-id 1.1.1.1`	Configure a fixed Router ID (1.1.1.1).
`(config-router)#neighbor 2001::2 remote-as 200`	Configure neighbor 2001::2 for eBGP in AS: 200.
`(config-router)#address-family ipv6`	Enter the IPv6 Address-Family mode.
`(config-router-af)#redistribute static`	Redistribute the IPv6 static routes.
`(config-router-af)#neighbor 2001::2 activate`	Activate neighbor 2001::2.
`(config-router-af)#exit-address-family`	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ipv6 route 1001::/64 null`	Configure IPv6 static route with next-hop as NULL interface.

Rtr3

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to BGP router.
`(config-router)#bgp router-id 3.3.3.3`	Configure a fixed Router ID (3.3.3.3).
`(config-router)#neighbor 2003::2 remote-as 200`	Configure neighbor 2003::2 for eBGP in AS: 200.
`(config-router)#address-family ipv6`	Enter the IPv6 Address-Family mode.
`(config-router-af)#redistribute static`	Redistribute the IPv6 static routes.
`(config-router-af)#neighbor 2003::2 activate`	Activate neighbor 2003::2.
`(config-router-af)#exit-address-family`	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ipv6 route 1001::/64 null`	Configure IPv6 static route with next-hop as NULL interface.

Rtr4

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to BGP router.
`(config-router)#bgp router-id 4.4.4.4`	Configure a fixed Router ID (4.4.4.4).
`(config-router)#neighbor 2004::2 remote-as 200`	Configure neighbor 2004::2 for eBGP in AS: 200.
`(config-router)#address-family ipv6`	Enter the IPv6 Address-Family mode.
`(config-router-af)#redistribute static`	Redistribute the IPv6 static routes.
`(config-router-af)#neighbor 2004::2 activate`	Activate neighbor 2004::2.
`(config-router-af)#exit-address-family`	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.
`(config)#ipv6 route 1001::/64 null`	Configure IPv6 static route with next-hop as NULL interface.

DUT

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 200`	Assign the ASN value (200) to BGP router.
`(config-router)#bgp router-id 2.2.2.2`	Configure a fixed Router ID (2.2.2.2).
`(config-router)#max-paths ebgp 2`	Configure eBGP maximum paths (2).
`(config-router)#neighbor 2001::1 remote-as 100`	Configure neighbor 2001::1 for eBGP in AS: 100.
`(config-router)#neighbor 2003::3 remote-as 100`	Configure neighbor 2003::3 for eBGP in AS: 100.
`(config-router)#neighbor 2004::4 remote-as 100`	Configure neighbor 2004::4 for eBGP in AS: 100.
`(config-router)#address-family ipv6`	Enter the IPv6 Address-Family mode.
`(config-router-af)#neighbor 2001::1 activate`	Activate neighbor 2001::1.
`(config-router-af)#neighbor 2003::3 activate`	Activate neighbor 2003::3.
`(config-router-af)#neighbor 2004::4 activate`	Activate neighbor 2004::4.
`(config-router-af)#exit-address-family`	Exit the IPv6 Address-Family mode and return to the BGP Router mode.
`(config-router)#exit`	Exit the BGP Router mode and return to the Configure mode.

Validation

```
#show bgp 1001::/64

BGP routing table entry for 1001::/64
Paths: (3 available, best #3, table Default-IP-Routing-Table)
  Advertised to non peer-group peers:
  2001::1 2003::3
  100
    2001::1(fe80::5054:ff:fe76:f9a2) from 2001::1 (1.1.1.1)
    (fe80::5054:ff:fe76:f9a2)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate
      Last update: Wed Oct 17 13:17:58 2012

  100
    2003::3(fe80::5054:ff:fe62:253a) from 2003::3 (3.3.3.3)
    (fe80::5054:ff:fe62:253a)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate, 
installed
      Last update: Wed Oct 17 13:17:50 2012

  100
    2004::4(fe80::5054:ff:feae:1f85) from 2004::4 (4.4.4.4)
    (fe80::5054:ff:feae:1f85)
      Origin incomplete metric 0, localpref 100, valid, external, multipath-candidate, 
installed, best
      Last update: Wed Oct 17 13:16:57 2012
#
```



```
#show ipv6 route
IPv6 Routing Table
Codes: K - kernel route, C - connected, S - static, R - RIP, O - OSPF,
       IA - OSPF inter area, E1 - OSPF external type 1,
       E2 - OSPF external type 2, I - IS-IS, B - BGP
Timers: Uptime

C      ::1/128 via ::, lo, 03:18:43
B      1001::/64 [20/0] via fe80::5054:ff:fe62:253a, eth3, 01:44:06
                 [20/0] via fe80::5054:ff:feae:1f85, eth4, 01:44:06
C      2001::/64 via ::, eth1, 03:18:38
C      2003::/64 via ::, eth3, 03:18:38
C      2004::/64 via ::, eth4, 03:18:38
C      fe80::/64 via ::, eth0, 03:18:43
K      ff00::/8 via ::, virbr0, 03:18:43
#
```

```
#show bgp summary
BGP router identifier 2.2.2.2, local AS number 200
BGP table version is 1
1 BGP AS-PATH entries
0 BGP community entries
2  Configured ebgp ECMP multipath: Currently set at 2
1  Configured ibgp ECMP multipath: Currently set at 1

Neighbor        V     AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
2001::1         4    100     262     265        1    0    0 01:44:49        1
2003::3         4    100     282     284        1    0    0 01:45:20        1
2004::4         4    100     273     274        1    0    0 01:45:50        1

Total number of neighbors 3
#
```

BGP Graceful Shutdown

This section contains BGP graceful shutdown configuration examples.

BGP graceful shutdown reduces and avoid packets loss during maintenance shutdown by keeping the path undisturbed even after shutdown by lowering local preference so that routers of an AS can use this until they become aware of new path. If there is no alternate path available in the AS, the same path is used until forwarding failure occurs.

BGP graceful shutdown is supported for both BGP-IPv4 and BGP-IPv6 configurations.

Configure BGP Graceful Shutdown on an Interface

Figure 9-106 shows the minimum configuration required to enable graceful shutdown on an interface. R1, R2, and R3 are three routers in three different ASs. R4 is another router in another AS forming an alternate path – R1 R4 R3 to the primary path.

Note: BGP graceful shutdown is only supported for eBGP configurations. It is not supported for iBGP configurations.

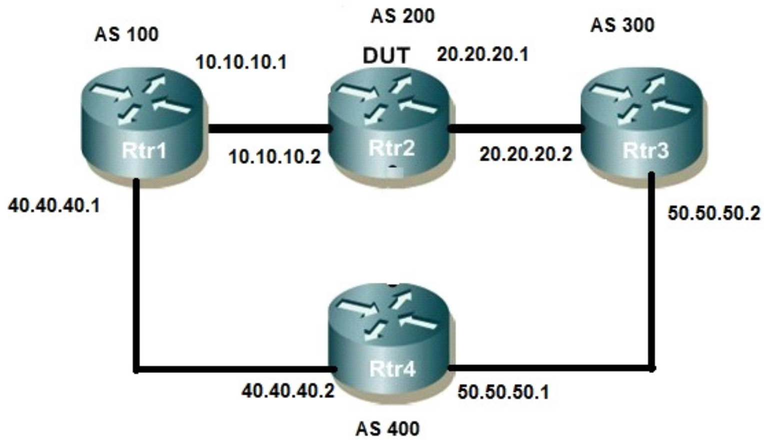

Figure 9-106: BGP Graceful Shutdown Topology 1

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 10.10.10.2 remote-as 200`	Establish eBGP neighborship with R2.
`(config-router)#neighbor 40.40.40.2 remote-as 400`	Establish eBGP neighborship with R4.

Rtr2

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 200`	Assign the ASN value (200) to BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 10.10.10.1 remote-as 100`	Establish eBGP neighborship with R1.
`(config-router)#neighbor 20.20.20.2 remote-as 300`	Establish eBGP neighborship with R3.
`(config-router)#bgp g-shut-capable`	Enable the graceful shutdown capability on the DUT.
`(config-router)#neighbor 10.10.10.1 g-shut`	Enable graceful shutdown functionality on the connected interface to R1.

(config-router)#neighbor 10.10.10.1 g-shut-timer 70	Configure the value of the graceful shutdown timer. After the timer expires, the BGP session initiated for graceful shutdown is shut down. The supported range for the graceful shutdown timer value is from 10 to 65535, in seconds. The default value is 60 seconds.
(config-router)#network 6.6.6.0/24	Specify the network to be advertised by the BGP routing process from DUT.

Rtr3

#configure terminal	Enter the Configure mode.
(config)#router bgp 300	Assign the ASN value (300) to BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
(config-router)#neighbor 20.20.20.1 remote-as 200	Establish eBGP neighborship with R2
(config-router)#neighbor 50.50.50.1 remote-as 400	Establish eBGP neighborship with R4.

Rtr4

#configure terminal	Enter the Configure mode.
(config)#router bgp 400	Assign the ASN value (400) to the BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
(config-router)#neighbor 40.40.40.1 remote-as 100	Establish eBGP neighborship with R1.
(config-router)#neighbor 50.50.50.2 remote-as 300	Establish eBGP neighborship with R3.

Validation

Checking for BGP Graceful Shutdown Community Tag on R2:

```
R2#show ip bgp 6.6.6.0
BGP routing table entry for 6.6.6.0/24
Paths: (1 available, best #1, table Default-IP-Routing-Table)
  Not advertised to any peer
  Local
    0.0.0.0 from 0.0.0.0 (20.20.20.1)
      Origin IGP, localpref 100, weight 32768, valid, sourced, local, best
Community: 0:65535 <<<<<<< community tagged (The community value 65535 is used
for the graceful shutdown)
Last update: Wed Apr 18 15:37:18 2012
Checking for BGP Graceful Shutdown Community Tag on DUT
```

Configure BGP Graceful Shutdown on a Router

Figure 9-107 shows the minimum configuration required to enable graceful shutdown at the router level. R1, R2, and R3 are three routers in three different ASs. R4 is another router in another AS forming an alternate path – R1 R4 R3 to the primary path.

Note: BGP graceful shutdown at the router level is used to bring down all the BGP sessions on the DUT. If there is still an alternate path for the data traffic, it takes that path.

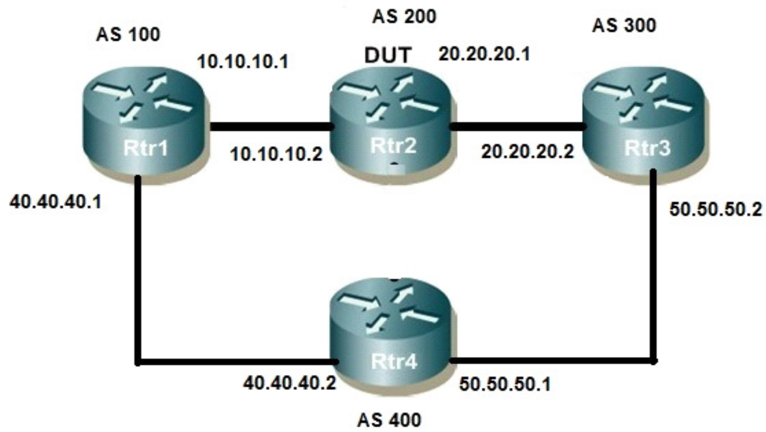

Figure 9-107: BGP Graceful Shutdown Topology 2

Rtr1

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 100`	Assign the ASN value (100) to the BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 10.10.10.2 remote-as 200`	Establish eBGP neighborship with R2.
`(config-router)#neighbor 40.40.40.2 remote-as 400`	Establish eBGP neighborship with R4.

Rtr2

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 200`	Assign the ASN value (200) to the BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 10.10.10.1 remote-as 100`	Establish eBGP neighborship with R1.
`(config-router)#neighbor 20.20.20.2 remote-as 300`	Establish eBGP neighborship with R3.
`(config-router)#bgp g-shut-capable`	Enabling the graceful shutdown capability on the DUT.
`(config-router)#bgp g-shut`	Enable BGP graceful shutdown functionality at the router level.

`(config-router)#bgp g-shut-local-preference 100`	Configure the local preference value of the routes to be used during graceful shutdown. This local reference is different from the BGP local preference value and is set in order to make the alternative path a preferred one in the case of graceful shutdown. The supported range of the local preference value is from 0 to 4294967295.
`(config-router)#network 70.70.70.0/24`	Specify the network to be advertised by the BGP routing process from DUT.

Rtr3

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 300`	Assign the ASN value (300) to the BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 20.20.20.1 remote-as 200`	Establish eBGP neighborship with R2.
`(config-router)#neighbor 50.50.50.1 remote-as 400`	Establish eBGP neighborship with R4.

Rtr4

`#configure terminal`	Enter the Configure mode.
`(config)#router bgp 400`	Assign the ASN value (400) to the BGP router. The AS number should be a unique positive integer identifying the Autonomous System.
`(config-router)#neighbor 40.40.40.1 remote-as 100`	Establish eBGP neighborship with R1.
`(config-router)#neighbor 50.50.50.2 remote-as 300`	Establish eBGP neighborship with R3.

Validation

```
    R2#show ip bgp 70.70.70.0
    BGP routing table entry for 70.70.70.0/24
    Paths: (1 available, best #1, table Default-IP-Routing-Table)
      Advertised to non peer-group peers:
      20.20.20.2
      Local
        0.0.0.0 from 0.0.0.0 (20.20.20.1)
          Origin IGP, localpref 100, weight 32768, valid, sourced, local, bestBGP
    routing table entry for 70.70.70.0/24
    Paths: (1 available, best #1, table Default-IP-Routing-Table)
    Community: 0:65535 <<<<<<< community tagged (The community value 65535 is used
    for the graceful shutdown)
Last update: Wed Apr 20 11:21:17 2012
```

CHAPTER 10 BGP4+

This chapter contains basic BGP4+ configuration examples.

For details about the commands used in these examples, see the *Border Gateway Protocol Command Reference*.

Enable iBGP Peering Using a 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 (AS), AS200, connecting to network 3ffe:10::/48. First, specify the IPv6 global address, then define the routing process and AS number to which the routers belong. Configure a fixed Router ID, then, define BGP neighbors to start exchanging routing updates.

Figure 10-108: iBGP Peering

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)#ipv6 address 3ffe:10::10/48`	Specify the IPv6 global address.
`(config-if)#exit`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of `R1`.
`(config-router)#bgp router-id 10.10.10.10`	Configure a fixed Router ID (`10.10.10.10`) for the BGP4+ routing process.
`(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.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.
`(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

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)#ipv6 address 3ffe:10::11/48`	Specify the IPv6 global address.
`(config-if)#exit`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of `R2`.
`(config-router)#bgp router-id 10.10.10.11`	Configure a fixed Router ID (`10.10.10.11`) for the BGP4+ routing process.
`(config-router)#neighbor 3ffe:10::10 remote-as 200`	Define the 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`.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.
`(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.

Validation

show bgp ipv6 summary, show bgp ipv6 neighbors

Enable iBGP Peering Using Link-local Address

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

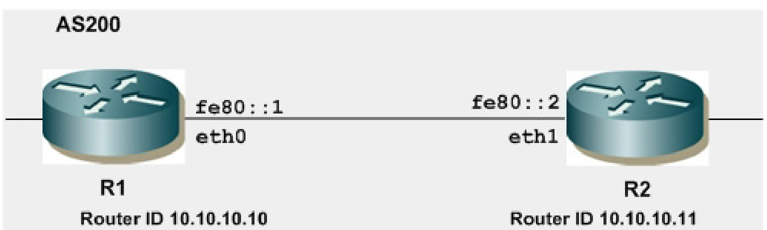

Figure 10-109: iBGP Peering Link-Local Address

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Define the routing process. The number `200` specifies the AS number of `R1`.
`(config-router)#bgp router-id 10.10.10.10`	Configure a fixed Router ID (`10.10.10.10`) for the BGP4+ routing process.

`#configure terminal`	Enter Configure mode.
`(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`.
`(config-router)#neighbor fe80::2 interface eth0`	To specify a link-local neighbor, configure the interface name of the neighbor `fe80::2`.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.
`(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

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

Validation

show bgp ipv6 summary, show bgp ipv6, show bgp ipv6 neighbors

Enable eBGP Peering Between Different Autonomous Systems

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

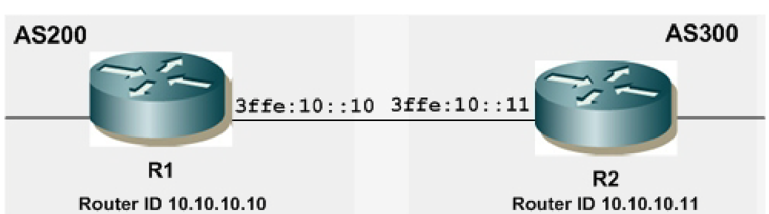

Figure 10-110: BGP Peering - Different AS

R1

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

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

Validation

show bgp ipv6 summary, show bgp ipv6 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 bgp ipv6` command on R1; it displays R1 receiving only the 3ffe:11::/48 network prefix.

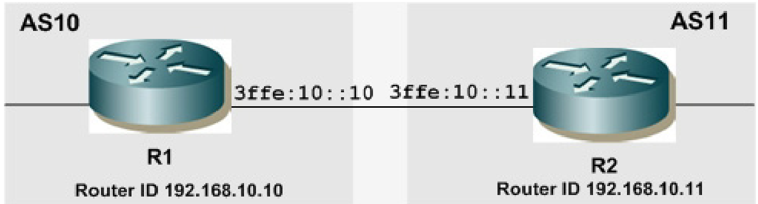

Figure 10-111: Route-Map

R1

`#configure terminal`	Enter Configure mode.
`(config)#ipv6 prefix-list ipi seq 5 deny 3ffe:12::/32 ge 48 le 64`	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.
`(config)#ipv6 prefix-list ipi seq 10 permit any`	Create another entry in the `ipi` map. `10` specifies the sequence number or position of this specific route map. `permit any` specifies accept all packets of any length.
`(config)#route-map ipi permit 1`	Enter Route-map mode.
`(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.
`(config-route-map)#exit`	Exit Route-map mode, and return to Configure mode.
`(config)#router bgp 10`	Define the routing process. The number `10` specifies the AS number of `R1`.
`(config-router)#bgp router-id 192.168.10.10`	Configure a fixed Router ID (`192.168.10.10`) for the BGP4+ routing process.
`(config-router)#neighbor 3ffe:10:11 remote-as 11`	Define the BGP neighbor (R2), and establish a TCP session by specifying the IPv6 address (`3ffe:10::11`) and the AS number `(11)` of neighbor `R2`.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.
`(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.
`(config-router-af)#neighbor 3ffe:10::11 route-map ipi in`	Apply the route-map `ipi` to all incoming routes.
`(config-router-af)#exit-address-family`	Exit Address Family mode, and return to Router mode.
`(config-router)#exit`	Exit Router mode, and return to Configure mode.

R2

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

Validation

show bgp ipv6 summary, show bgp ipv6 neighbors, show bgp ipv6, show bgp ipv6 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 an 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.

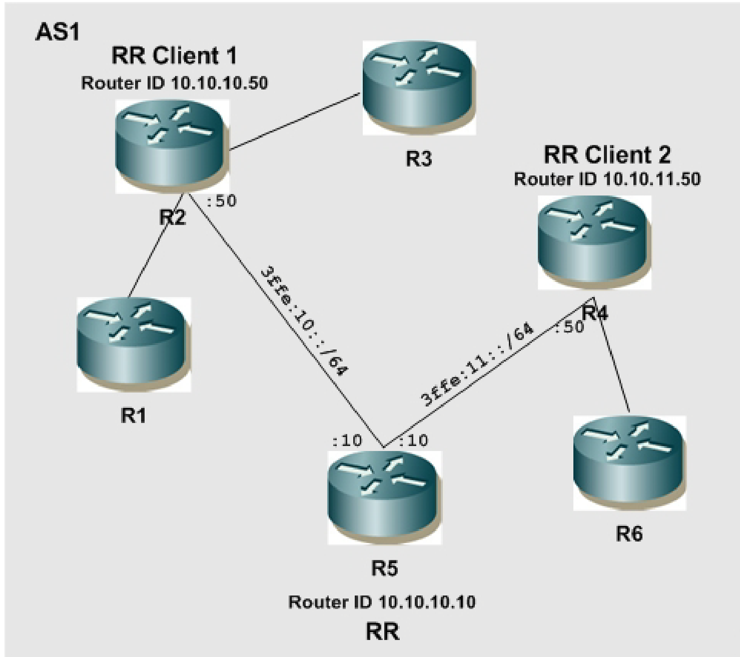

Figure 10-112: BGP4+ Route Reflector

RR (R5)

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

RR Client 1 (R2)

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

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

Validation

show bgp ipv6 summary, show bgp ipv6 neighbors

Confederations

In this example, AS1 contains three Confederated Autonomous Systems--AS 1000, AS 1001 and AS 1002. To any outside AS, the overall Confederation is a single AS, 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 informs the router that it is a member of a Confederation and passes the Confederation ID. The `bgp confederation peers` command lists the member AS to which R2 is connected. The same command tells the BGP process that the eBGP connection is a Confederation eBGP, rather than a normal eBGP.

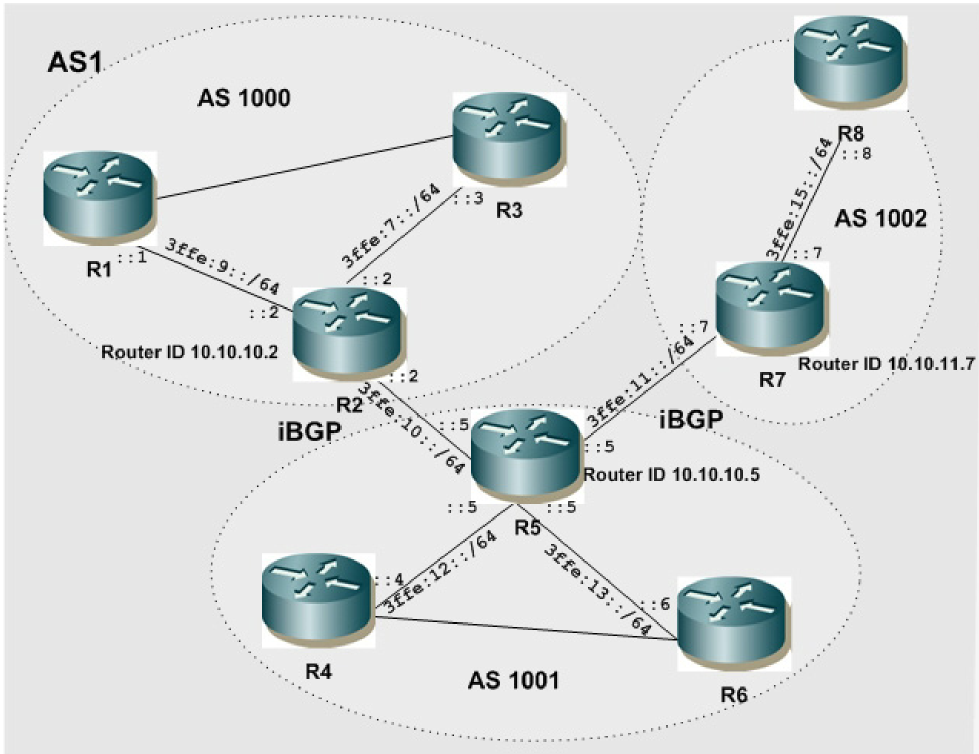

Figure 10-113: BGP4+ Confederations

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 1000`	Define the routing process. The number `1000` specifies the AS number of `R2`.
`(config-router)#bgp router-id 10.10.10.2`	Configure a fixed Router ID (`10.10.10.2`) for the BGP4+ routing process.
`(config-router)#bgp confederation identifier 1`	Specify the BGP Confederation Identifier (1). To others, the group will appear as a single AS, and the identifier as its AS number.
`(config-router)#bgp confederation peers 1001 1002`	Specify ASs `1001` and `1002` as confederation peers, making them members of the Confederation.
`(config-router)#neighbor 3ffe:10::5 remote-as 1001`	Define the BGP neighbor (R5), and establish a TCP session by specifying the IPv6 address (`3ffe:10::5`) and the AS number (`1001`) of neighbor `R5`.
`(config-router)#neighbor 3ffe:9::1 remote-as 1000`	Define the BGP neighbor (`R1`), and establish a TCP session by specifying the IPv6 address (`3ffe:9::1`) and the AS number (`1000`) of neighbor `R1`.
`(config-router)#neighbor 3ffe:7::3 remote-as 1000`	Define the BGP neighbor (`R3`), and establish a TCP session by specifying the IPv6 address (`3ffe:7::3`) and the AS number (`1000`) of neighbor `R3`.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.

(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.
(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.
(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

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

(config)#router bgp 1002	Define the routing process. The number 1002 specifies the AS number of R7.
(config-router)#bgp router-id 10.10.11.7	Configure a fixed Router ID (10.10.11.7) for the BGP4+ routing process.

`(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.
`(config-router)#bgp confederation peers 1000 1001`	Specify ASs `1000` and `1001` as confederation peers, making them members of the Confederation.
`(config-router)#neighbor 3ffe:11::5 remote-as 1001`	Define the BGP neighbor (`R5`), and establish a TCP session by specifying the IPv6 address (`3ffe:11::5`) and the AS number `(1001)` of neighbor R5.
`(config-router)#neighbor 3ffe:15::8 remote-as 1002`	Define the BGP neighbor (`R8`), and establish a TCP session by specifying the IPv6 address (`3ffe:15::8`) and the AS number `(1002)` of neighbor `R8`.
`(config-router)#address-family ipv6`	Enter Address Family mode for configuring routing sessions that use IPv6 address prefixes.
`(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.
`(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.

Validation

show bgp ipv6 summary, show bgp ipv6 neighbors

BGP4+ Graceful Restart

Using BGP+ graceful restart, the data-forwarding plane of a router can continue to process and forward packets, even if the control plane (which is responsible for determining best paths) fails.

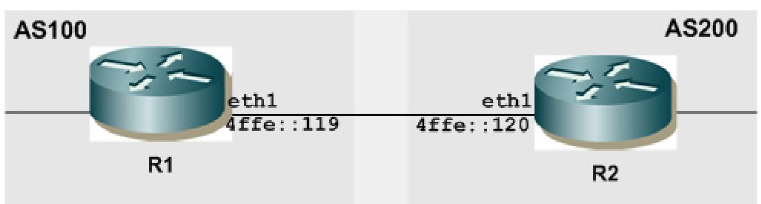

Figure 10-114: BGP4+ Graceful Restart

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#neighbor 4ffe::120 remote-as 200`	Specify the neighbor’s IP address (`4ffe::120`) and the ASN value of the neighbor (`200`).
`(config-router)#address-family ipv6 unicast`	Exchange the IPv6 capabilities, and switch the mode to the IPv6 address family.

`#configure terminal`	Enter Configure mode.
`(config-router-af)#neighbor 4ffe::120 activate`	Specify the neighbor's IPv6 address (`4ffe::120`), and activate the neighbor.
`(config-router-af)#neighbor 4ffe::120 capability graceful-restart`	Specify the neighbor's IPv6 address (`4ffe::120`) for which the graceful restart capability is supported.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart restart-time 120`	Configure the maximum time (`120`) required for neighbor(s) to restart.
`(config-router)#bgp graceful-restart stalepath-time 120`	Configure the maximum time (`120`) to retain stale paths from the restarting neighbor(s).
`(config-router)#neighbor 4ffe::119 remote-as 100`	Specify the neighbor's IP address (`4ffe::119`) and the ASN value of the neighbor (`100`).
`(config-router)#address-family ipv6 unicast`	Exchange the IPv6 capabilities, and switch the mode to the IPv6 address family.
`(config-router-af)#neighbor 4ffe::119 activate`	Specify the neighbor's IPv6 address (`4ffe::119`), and activate the neighbor.
`(config-router-af)#neighbor 4ffe::119 capability graceful-restart`	Specify the neighbor's IPv6 address (`4ffe::119`) for which the graceful restart capability is supported.

Validation

show bgp ipv6 summary, show ip bgp neighbors, show bgp ipv6, show ipv6 route database bgp, show ipv6 route database, show ipv6 route

Configure BGP4+ Distance

Administrative distance in BGP+ can be configured for a specific address family.

This example shows configuring the BGP administrative distance for the IPv6 address family.

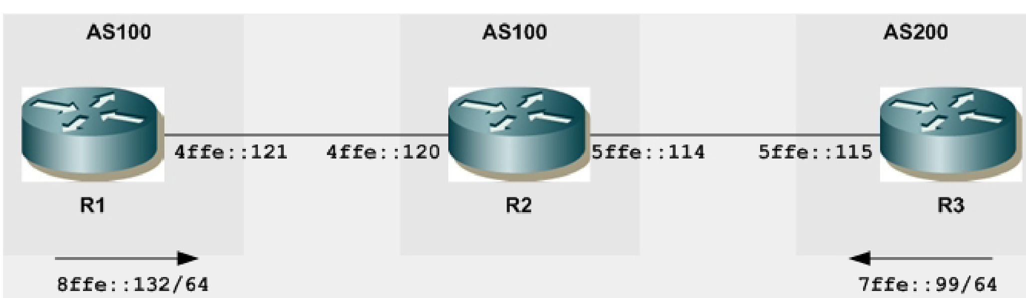

Figure 10-115: BGP4+ Distance

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#network 8ffe::132/64`	Specify the network to be advertised by the BGP routing process.
`(config-router)#neighbor 4ffe::120 remote-as 100`	Specify the neighbor's IP address and ASN value.
`(config-router)#address-family ipv6 unicast`	Enter IPv6 Address-Family mode.
`(config-router-af)#neighbor 4ffe::120 activate`	Activate the IPv6 neighbor.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#neighbor 4ffe::121 remote-as 100`	Specify the neighbor's IP address and ASN value.
`(config-router)#neighbor 5ffe::115 remote-as 200`	Specify the neighbor's IP address and the ASN value of another neighbor.
`(config-router)#address-family ipv6 unicast`	Enter IPv6 Address-Family mode.
`(config-router-af)#aggregate-address 2ffe::102/64 summary-only`	Configure an IPv6 non-AS-set aggregate route on R2. The local distance will be applied to this route.
`(config-router-af)#neighbor 4ffe::121 activate`	Activate the IPv6 neighbor.
`(config-router-af)#neighbor 5ffe::115 activate`	Activate the IPv6 neighbor.
`(config-router-af)#distance 12 13 11`	Configure the administrative distance for external, internal, and local routes received in IPv6 Address-Family mode.

R3

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#network 7ffe::99/64`	Specify the network to be advertised by the BGP routing process.
`(config-router)#neighbor 5ffe::114 remote-as 100`	Specify the neighbor's IP address and ASN value.
`(config-router)#address-family ipv6 unicast`	Enter IPv6 Address-Family mode.
`(config-router-af)#neighbor 5ffe::114 activate`	Activate the IPv6 neighbor.

Validation

show bgp ipv6 summary, show ip bgp neighbors, show ipv6 route database bgp, show ipv6 route database, show ipv6 route, show bgp ipv6

BGP4+ Graceful Reset

The graceful restart mechanism for BGP+ session reset (the BGP+ daemon is not restarted) is used so that any changes in network configuration do not affect packet forwarding. The `bgp graceful-restart graceful-reset` CLI invokes graceful restart when a configuration change forces a peer reset. Graceful restart is invoked only when these CLI configuration changes force a peer reset.

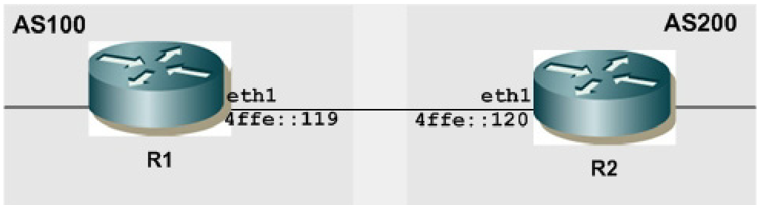

Figure 10-116: BGP4+ Graceful Reset

R1

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 100`	Assign the ASN value (`100`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart graceful-reset`	Configure to invoke graceful restart when a configuration change forces a peer reset.
`(config-router)#neighbor 4ffe::120 remote-as 200`	Specify the neighbor's IP address (`4ffe::120`) and the ASN value of the neighbor (`200`).
`(config-router)#address-family ipv6 unicast`	Exchange the IPv6 capabilities, and switch the mode to the IPv6 address family.
`(config-router-af)#neighbor 4ffe::120 activate`	Specify the neighbor's IPv6 address (`4ffe::120`), and activate the neighbor.
`(config-router-af)#neighbor 4ffe::120 capability graceful-restart`	Specify the neighbor's IPv6 address (`4ffe::120`) for which the graceful restart capability is supported.

R2

`#configure terminal`	Enter Configure mode.
`(config)#router bgp 200`	Assign the ASN value (`200`) to the router.
`(config-router)#bgp graceful-restart`	Enable BGP graceful restart support.
`(config-router)#bgp graceful-restart graceful-reset`	Configure to invoke graceful restart when a configuration change forces a peer reset.
`(config-router)#neighbor 4ffe::119 remote-as 100`	Specify the neighbor's IP address (`4ffe::119`) and the ASN value of the neighbor (`100`).

`#configure terminal`	Enter Configure mode.
`(config-router)#address-family ipv6 unicast`	Exchange the IPv6 capabilities, and switch the mode to the IPv6 address family.
`(config-router-af)#neighbor 4ffe::119 activate`	Specify the neighbor's IPv6 address (`4ffe::119`), and activate the neighbor.
`(config-router-af)#neighbor 4ffe::119 capability graceful-restart`	Specify the neighbor's IPv6 address (`4ffe::119`) for which the graceful restart capability is supported.

Validation

show bgp ipv6 summary, show ip bgp neighbors, show bgp ipv6, show ipv6 route database bgp, show ipv6 route database, show ipv6 route

CHAPTER 11 Forwarding Plane Load Balancing

ZebOS-XP uses Forwarding Plane Load Balancing when the kernel supports Equal Cost Multipath (ECMP). ZebOS-XP installs the maximum number of ECMP routes supported by the kernel. This allows for load balancing to be performed with more than one nexthop to reach a destination. If the router receives and installs multiple paths with the same administrative distance and cost to a destination, load-balancing is possible.

Ideally, multiple nexthops have different interfaces to the destination, but this is not mandatory. The algorithm for distributing traffic across ECMP routes is dependent on the kernel, and typically based on the protocol, source address, destination address, and port.

Enable Load Balancing

The following example illustrates how to enable Equal Cost Multipath (ECMP), and configure a routing protocol (OSPF is used in this example) for load balancing. However, this example will not work if the kernel does not support load balancing. In this topology, R1, R2, and R3 are three Linux routers connected to each other. R1 can reach R3 through two links available to R2.

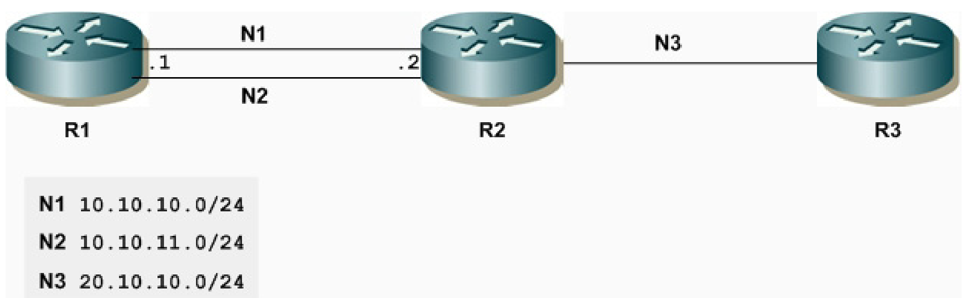

Figure 11-117: Load Balancing Topology

R1 - NSM

1. Enable multipath support and set the maximum number of paths to be installed in the Forwarding Information Base (FIB):

```
#configure terminal
(config)#maximum-paths 2
```

R1 - OSPF

1. Configure OSPF on all interfaces on R1, R2, and R3.

   R1 learns about R3 through 2 nexthops (both networks N1 and N2).

Validation

R1 - OSPF

Run the `show ip ospf route` command on R1. The OSPF routing table displays that it can reach R3 through both of the nexthops:

```
R1#show ip ospf route
   O  10.10.10.0/24 [10] is directly connected, eth1, Area 0.0.0.0
   O  10.10.11.0/24 [10] is directly connected, eth2, Area 0.0.0.0
   O  20.10.10.0/24 [20] via 10.10.10.2, eth1, Area 0.0.0.0
                         via 10.10.11.2, eth2, Area 0.0.0.0
```

Run the `show ip route` command on R1. It displays that R1 has installed both nexthops to reach R3 in the NSM routing table:

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
      i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default

K       10.10.0.0/24 via 10.70.0.1, eth0
C       10.10.10.0/24 is directly connected, eth1
C       10.10.11.0/24 is directly connected, eth2
C       10.70.0.0/24 is directly connected, eth0
O       20.10.10.0/24 [110/20] via 10.10.10.2, eth1, 00:12:40
                      [110/20] via 10.10.11.2, eth2, 00:12:40
C       127.0.0.0/8 is directly connected, lo
S       192.16.1.0/24 [1/0] is directly connected, eth1
```

R1- Kernel

Run the `ip route` command on the R1 kernel. The kernel routing table displays that R1 can reach R3 through both the nexthops.

```
R1#ip route
20.10.10.0/24  proto zebra  metric 20
        nexthop via 10.10.10.2  dev eth1 weight 1
        nexthop via 10.10.11.2  dev eth2 weight 1
10.70.0.0/24 dev eth0  scope link
10.10.0.0/24 via 10.70.0.1 dev eth0
10.10.10.0/24 dev eth1  proto kernel  scope link  src 10.10.10.1
10.10.11.0/24 dev eth2  proto kernel  scope link  src 10.10.11.1
127.0.0.0/8 dev lo scope link
```

These three show outputs display the two routes (N1 and N2) in the OSPF, NSM, and kernel routing tables. They illustrates that two routes are reaching R3, and load balancing is occurring.

CHAPTER 12 VLAN Interfaces

This chapter contains examples for configuring VLAN interfaces.

For details about the commands used in these examples, see the *Layer 2 Command Reference*.

Overview

Several Virtual LAN (VLAN) interfaces can be configured on a single Ethernet interface. Once created, a VLAN interface functions the same as any physical interface.

NSM recognizes VLAN interfaces as physical interfaces. Once VLAN interfaces are created in the kernel, and IP addresses are assigned to them, ZebOS-XP commands can be used to configure and display VLAN interfaces the same was as any physical interface. ZebOS-XP routing protocols, such as RIP, OSPF and BGP, can run across networks using VLAN interfaces.

Two systems with physical connectivity (either directly connected or connected through a switch), can communicate with each other via VLAN interfaces that have the same VLAN IDs and belong to the same network.

If the physical interfaces are not directly connected to a switch, the corresponding ports on the switch must be configured as trunks, and should not be associated to any VLANs in the switch. The commands to configure switch ports as trunks depend on the type of the switch, and are beyond the scope of this document.

Topology

Figure 12-118 is used to describe VLAN interface configuration. In this example, there are two routers, R1 and R2, and the eth1 interface of R1 is connected directly to eth2 using a crossover ethernet cable.

Figure 12-118: VLAN Connections

The `eth1.10` VLAN interface is created on R1, and `eth2.10` is created on R2. The VLAN interfaces are configured in the same network: R1 and R2 can reach each other using the VLAN connection.

Note: A VLAN ID of both VLAN interfaces is the same (10). Two systems with different VLAN IDs cannot communicate, even if they are in the same network, since a VLAN ID tags packets sent on a VLAN interface.

Create a VLAN Interface

Use the `vconfig` utility to add a VLAN interface. The `vconfig` utility can be used to create or delete VLAN interfaces to or from a physical interface. The VLAN interface identifier has two parts separated by a period, the first of which is the identifier of the physical interface (such as, `eth1`, `eth2`...). The second part is the VLAN ID (on Linux, this number can be any number from `2-4095`). In this example, `eth1.10` denotes that the physical interface is `eth1`, and the VLAN ID is `1`.

```
[root]#vconfig add eth1 10
Added VLAN with VID == 10 to IF -:eth1:-
```

Configure an IP Address

Once a VLAN interface is created, configure an IP address on it. Use the `ipconfig` command to configure the IP address of the VLAN interface, then use the same command to display information about the VLAN interface.

```
[root]#ifconfig eth1.10 inet 1.1.1.145 netmask 255.255.255.0 broadcast 1.1.1.255 up
[root]#ifconfig eth1.10
eth1.10    Link encap:Ethernet  HWaddr 00:0E:0C:01:48:4D
          inet addr:1.1.1.145  Bcast:1.1.1.255  Mask:255.255.255.0
          inet6 addr: fe80::20e:cff:fe01:484d/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:0 errors:0 dropped:0 overruns:0 frame:0
          TX packets:2 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:0 (0.0 b)  TX bytes:172 (172.0 b)
```

Add IP Addresses to VLAN Interface

In NSM, you can add or remove IP addresses from VLAN interfaces, like normal interfaces. Using IMISH type:

```
#configure terminal
(config)#interface eth1.10
(config-if)#no ip address 1.1.1.145/24
(config-if)#ip address 192.168.1.50/24
```

Display VLAN Interfaces

In ZebOS-XP, VLAN interfaces appear as any physical interfaces, in the `show run` or the `show ip interface brief` outputs, and can be configured as any other interface.

The following is a sample output of the `show ip interface brief` command on R1.

Note: The IP address of interface `eth1.1` has correctly been changed by NSM:

```
#show ip interface brief
Interface          IP-Address      Status                   Protocol
lo                 127.0.0.1       up                       up
gre0               unassigned      administratively down    down
eth0               10.70.0.77      up                       up
....
sit0               unassigned      administratively down    down
eth1.10            192.168.1.50    up                       up
tunl0              unassigned      administratively down    down
```

Below is the NSM routing table, which shows the connected network `192.168.1.0/24` of `eth1.10`. These interfaces will now act as any physical interfaces, and all routing protocols will run across this network.

```
#show ip route
Codes: K - kernel, C - connected, S - static, R - RIP, B - BGP
       O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
```

```
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default
Gateway of last resort is 10.70.0.1 to network 0.0.0.0
K*      0.0.0.0/0 via 10.70.0.1, eth0
B       2.2.2.0/24 [200/0] via 192.168.1.145, eth4.2, 01:14:38
....
C       127.0.0.0/8 is directly connected, lo
K       169.254.0.0/16 is directly connected, eth4
C       192.168.1.0/24 is directly connected, eth1.10
```

Delete VLAN Interfaces

Use the `vconfig` utility to delete VLAN interfaces.

To remove the `eth1.10` interface on R1:

```
[root]#vconfig rem eth1.10
Removed VLAN -:eth1.10:-
```

Now, if you use the `ifconfig` command to try to display information about the `eth1.10` interface:

```
[root]#ifconfig eth1.10
eth1.10: error fetching interface information: Device not found
```

This shows that VLAN interfaces were successfully removed.

Using ZebOS-XP commands, when you try to configure this interface, a message is displayed, showing that the interface does not exist:

```
#configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
(config)#interface eth1.10
% No such interface
```

CHAPTER 13 Tunneling and Transitioning

This chapter contains basic IPv4 and IPv6 Transition Tunneling configuration examples.

Overview

Typically, tunneling is used to transmit private data over a public network, such as the Internet. Tunnels enable carrying of incompatible data over an existing network. For example, IPv6 data can be transmitted over IPv4 networks. Secure tunneling protocols can be used for transferring sensitive data over public networks.

Tunneling is achieved by encapsulating IP packets of private networks within IP packets of public networks. This allows packets destined for one IP address to be wrapped and redirected to another IP address. To encapsulate an IP packet, an outer IP header is inserted before the packet's existing header. The source and destination addresses in the inner IP header specify the original sender and recipient of the packet.

IPv4 Tunnel

The ZebOS-XP IPv4 Tunneling implementation supports Generic Routing Encapsulation (GRE) and IP in IP (IPIP) Tunneling. This section includes the configuration of GRE tunneling, only. For configuring IPIP tunnels, use the same configuration, but, specify the tunnel mode as `ipip`, instead of `gre`.

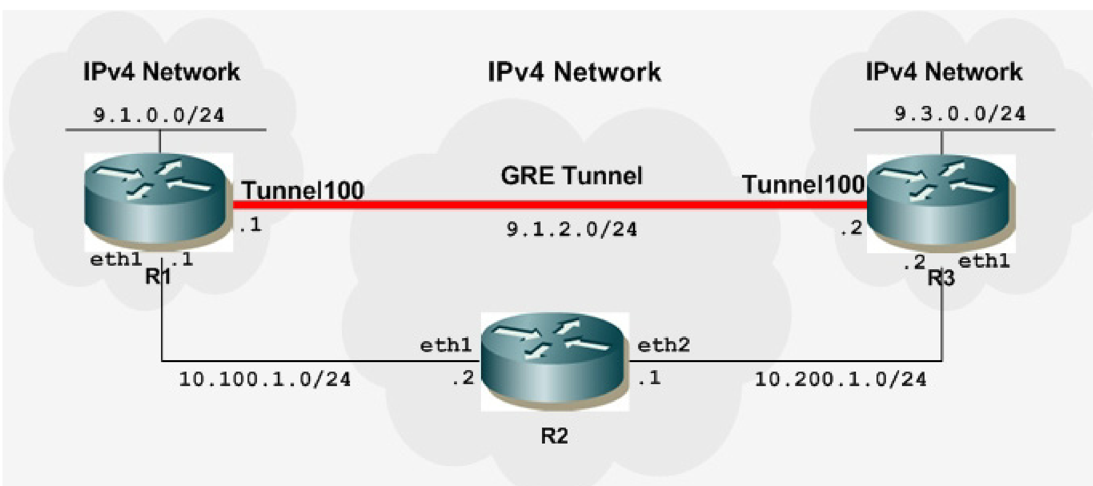

Figure 13-119: IPv4 Tunnel Configuration

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.100.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.

`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode gre`	Set the tunnel mode.
`(config-if)# tunnel source 10.100.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# tunnel destination 10.200.1.2`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ip address 9.1.2.1/24`	Set the IP address of the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.57`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 10.100.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# exit`	Exit Router mode, and enter Configure mode.
`(config)# ip route 9.3.0.0/24 Tunnel100`	Configure a static route for the tunnel interface.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.100.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.200.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.58`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 10.200.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# network 10.100.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.200.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode gre`	Set the tunnel mode.
`(config-if)# tunnel source 10.200.1.2`	Define the IPv4 address to use as the source address for the tunnel interface.

`(config-if)# tunnel destination 10.100.1.1`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ip address 9.1.2.2/24`	Set the IP address of the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.59`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 10.200.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# exit`	Exit Router mode, and enter Configure mode.
`(config)# ip route 9.1.0.0/24 Tunnel100`	Configure a static route for the tunnel interface.

Validation

show interface, show ip route

IPv6 Transition Tunnel

In this method of IPv6 transition, tunnels are enabled and configured statically. IPv4 and IPv6 addresses are manually assigned on both sides of the tunnel interface. To configure a tunnel interface, assign:

- an IPv4 address for reaching the local dual-stack router over the IPv4 network. For example, IPv4 address `192.168.1.1` is assigned on R1 as the tunnel source.
- an IPv4 address for reaching the dual-stack router at the other end of the tunnel over the IPv4 network. For example, `192.168.2.2` is assigned on R1 as tunnel the destination.
- an IPv6 address locally on the tunnel interface. For example, the IPv6 address `3ffe:b00:ffff:2::1/64` is assigned on R1.

R3 is configured similarly to allow forwarding of IPv6 packets over the IPv4 network.

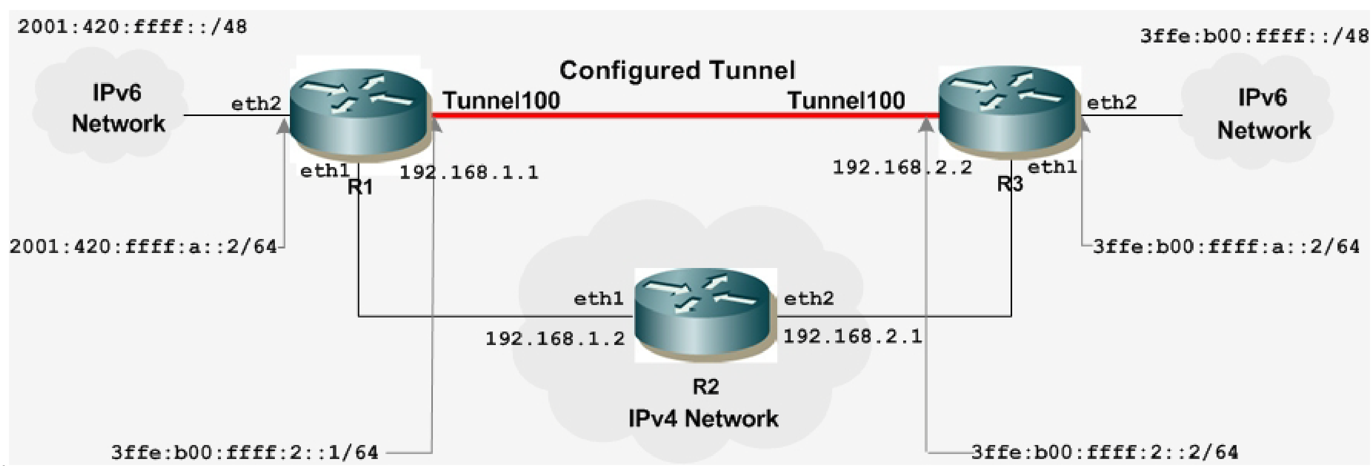

Figure 13-120: IPv6 Transition Tunnel

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure.
`(config-if)# ip address 192.168.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure.
`(config-if)# ipv6 address 2001:420:ffff:a::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# tunnel destination 192.168.2.2`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ipv6 address 3ffe:b00:ffff:2::1/64`	Set the IPv6 address on the Tunnel 100 interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 3ffe:b00:ffff::/48 Tunnel100`	Specify a static route to the network via a configured tunnel.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.58`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure.
`(config-if)# ip address 192.168.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface (`eth2`) to configure.
`(config-if)# ip address 192.168.2.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.59`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.2.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 3ffe:b00:ffff:a::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.2.2`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# tunnel destination 192.168.1.1`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ipv6 address 3ffe:b00:ffff:2::2/64`	Set the IPv6 address on the Tunnel 100 interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 2001:420:ffff::/48 Tunnel100`	Specify a static route to the network via a configured tunnel.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.57`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

Validation

show interface, show ipv6 route

IPv6 Transition - GRE Tunnel

Configuring the GRE (Generic Routing Encapsulation) Tunnel for IPv6 transition is similar to configuring the configured tunnel (described previously).To configure a GRE Tunnel, a route is statically configured between two routers to enable forwarding of IPv6 packets over an IPv4 network. To configure a GRE tunnel, assign:

- an IPv4 address for reaching the local dual-stack router over the IPv4 network. For example, IPv4 address `192.168.1.1` is assigned on R1 as the tunnel source.
- an IPv4 address for reaching the dual-stack router at the other end of the tunnel over the IPv4 network. For example, `192.168.2.2` is assigned on R1 as the tunnel destination.
- an IPv6 address locally on the tunnel interface. For example, the IPv6 address `3ffe:b00:ffff:2::1/64` is assigned on R1.

R3 is configured similarly to allow forwarding of IPv6 packets over the IPv4 network.

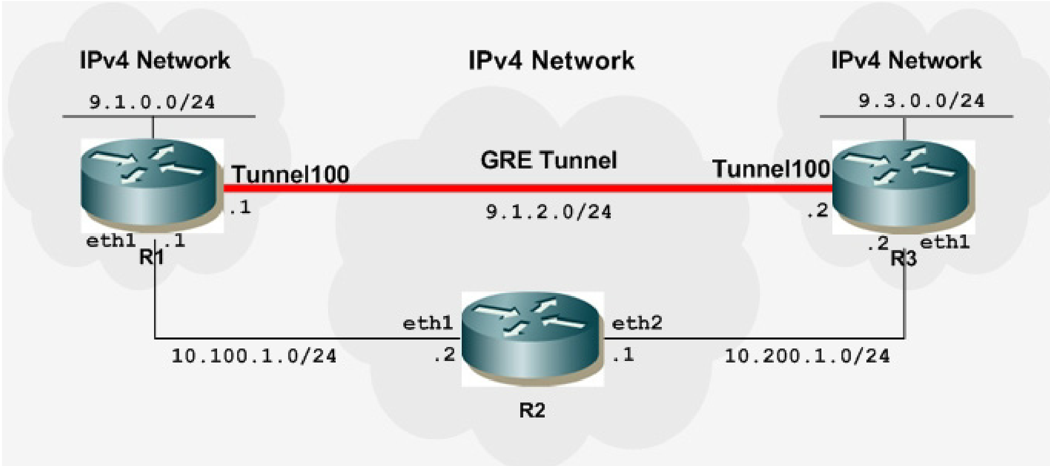

Figure 13-121: IPv4 GRE Transition Tunnel

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2001:420:ffff:a::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode gre`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# tunnel destination 192.168.2.2`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ipv6 address 3ffe:b00:ffff:2::1/64`	Set the IPv6 address on the Tunnel 100.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 3ffe:b00:ffff::/48 Tunnel100`	Specify a static route to the network via a configured tunnel.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.58`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 192.168.2.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.59`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.2.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 3ffe:b00:ffff:a::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode gre`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.2.2`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# tunnel destination 192.168.1.1`	Specify the destination IPv4 address of the tunnel interface.
`(config-if)# ipv6 address 3ffe:b00:ffff:2::2/64`	Set the IPv6 address on the Tunnel 100 interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 2001:420:ffff::/48 Tunnel100`	Specify a static route to the network via a configured tunnel.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.57`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

Validation

show interface, show ipv6 route

IPv6 Transition - 6to4 Automatic Tunnel

IPv6 transition is required for migrating from IPv4 to IPv6. One method to connect to the global IPv6 network over the IPv4 existing network is called 6to4 automatic tunneling. Using this method, it is not required to specify the destination address of the tunnel endpoint, instead, the destination IPv6 address, itself, contains the destination IPv4 address to use for the tunnel encapsulation. ZebOS-XP allows automatic creation of 6to4 global IPv6 address, which is derived from the configured tunnel source address.

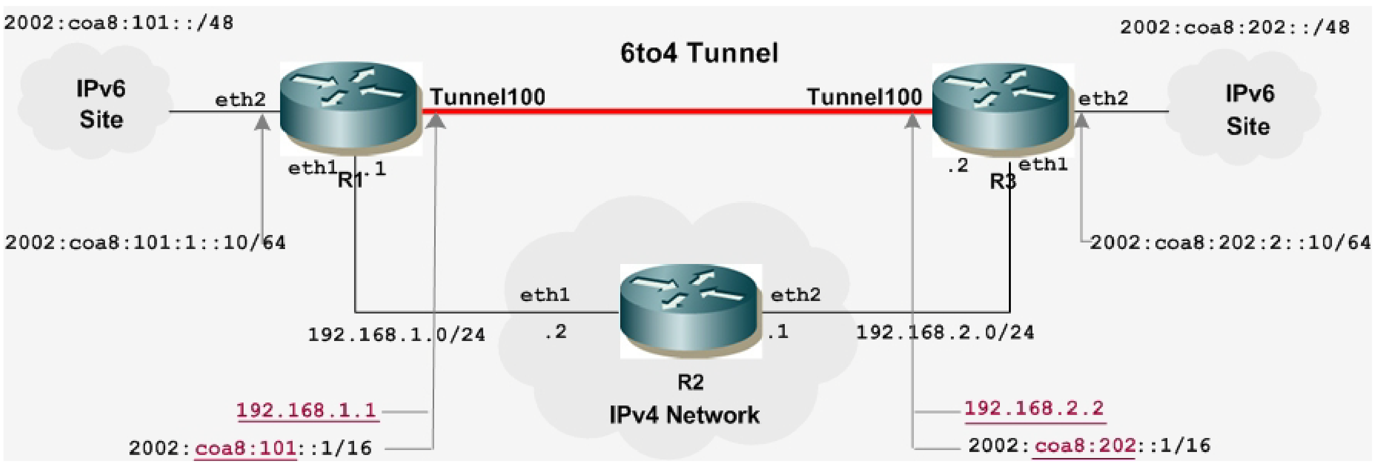

Figure 13-122: 6to4 Automatic Tunnel

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002:c0a8:101:1::10/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip 6to4`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.

`(config-router)# router-id 10.70.0.57`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 192.168.2.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.58`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.2.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002:c0a8:202:2::10/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip 6to4`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.2.2`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.76`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

Validation

show interface, show ipv6 route

IPv6 Transition - 6to4 Relay

The 6to4 Relay method is used to enable the sending of IPv6 packets to destinations that have other prefixes than 2002::/16. To make these prefixes reachable, one of the 6to4 routers on the IPv4 network must act as a gateway, and forward 6to4 traffic to the IPv6 Internet. This router is called the 6to4 relay. Typically, the 6to4 relay is at the border of the IPv4 and IPv6 Internet.

In this example, R3 is the 6to4 Relay, forwarding IPv6 packets received from 6to4 networks to the IPv6 Internet, and receiving routes from the IPv6 Internet. To configure a 6to4 relay, a default route (::/0) is added on R1, which points to R3. This allows all prefixes (other than 2002::/16) to be forwarded to the IPv6 Internet.

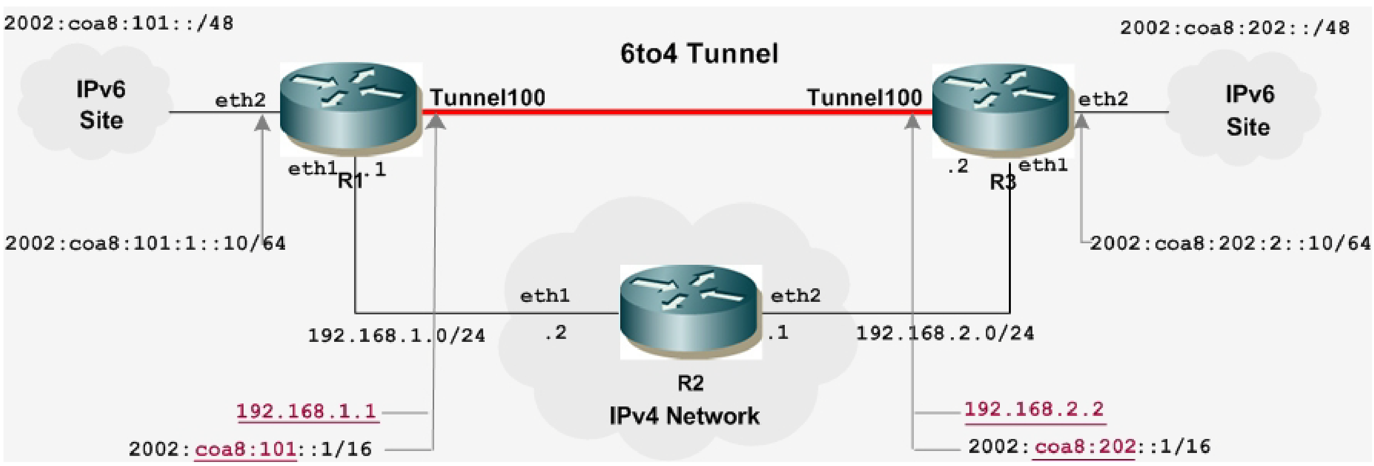

Figure 13-123: 6to4 Relay Tunnel

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002:c0a8:101:1::10/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip 6to4`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route ::/0 ::192.168.2.2 Tunnel100`	Specify the IPv6 default route to the 6to4 Relay router.

`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.59`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.1.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 192.168.2.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.
`(config-router)# router-id 10.70.0.58`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.1.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 192.168.2.2/24`	Set the IP address of the `eth1` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 3ffe:b00:ffff:a::1/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 100`	Create a tunnel interface.
`(config-if)# tunnel mode ipv6ip 6to4`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.2.2`	Define the IPv4 address to use as the source address for the tunnel interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# router ospf`	Create an OSPF routing instance.

`(config-router)# router-id 10.70.0.76`	Specify a Router ID for the OSPF routing process.
`(config-router)# network 192.168.2.0/24 area 0`	Define the interface on which OSPF runs, and associate the area ID (`0`) with the interface (area ID `0` specifies the backbone area).

Validation

show interface, show ipv6 route

IPv6 Transition - ISATAP Automatic Tunnel

ISATAP (Intra-Site Automatic Tunnel Address Protocol) is typically used for a site that does not have a fully native IPv6 network. Every ISATAP router and ISATAP host can talk to each other through the ISATAP automatic tunnel over the existing IPv4 network.

The difference between the ISATAP and 6to4 tunnel is that ISATAP tunnel interface treats underlying IPv4 as an NBMA (Non Broadcast Multi Access) network. Thus, each ISATAP interface has the same IPv6 prefix. The Router Advertisement (RA) functionality is used to automatically assign prefixes.

In this IPv6 transition method, the IPv6 address is manually configured on a tunnel interface of the ISATAP Router. On the ISATAP host, the IPv4 address is manually configured using the `tunnel destination` command. Once the ISATAP host receives RA from the ISATAP Router, it automatically generates the IPv6 address.

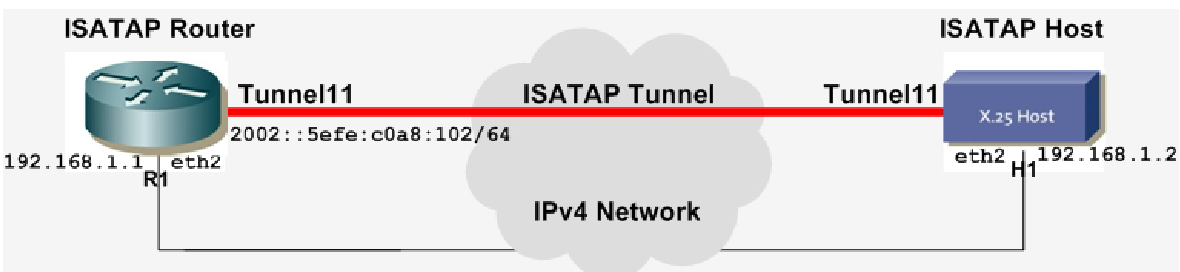

Figure 13-124: ISATAP Automatic Tunnel

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 192.168.1.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# interface tunnel 11`	Create a tunnel interface.
`(config-if)# ip address 2002::5efe:c0a8:101/64`	Assign the link local tunnel address in the ISATAP addressing format, Linklocal Prefix:0:5efe:w.x.y.z, where `w.x.y.z` is the IPv4 address assigned to the ISATAP router.
`(config-if)# tunnel mode ipv6ip isatap`	Set the tunnel mode.
`(config-if)# tunnel source 192.168.1.1`	Define the IPv4 address to use as the source address for the tunnel interface.

(config-if)# no ipv6 nd suppress-ra	Enable Router Advertisement (RA).
(config-if)# ipv6 address 2002::5efe:c0a8:101/64	Assign IPv6 address to tunnel interface. Assign the unicast address in the ISATAP addressing format, Unicast Prefix:0:5efe:w.x.y.z, where `w.x.y.x` is the IPv4 address assigned to the ISATAP router.

H1

# configure terminal	Enter Configure mode.
(config)# no ipv6 forwarding	Turn off IPv6 forwarding. Because H1 is a host, it does not require packet forwarding.
(config)# interface eth2	Specify the interface `(eth2)` to configure.
(config-if)# ip address 192.168.1.2	Set the IP address of the `eth2` interface.
(config-if)# exit	Exit Interface mode, and enter Configure mode.
(config)# interface tunnel 11	Create a tunnel interface.
(config-if)# ip address fe80::5efe:c0a8:102/64	Assign the link local tunnel address in the ISATAP addressing format, Linklocal Prefix:0:5efe:w.x.y.z, where w.x.y.z is the IPv4 address assigned to the ISATAP host.
(config-if)# tunnel mode ipv6ip isatap	Set the tunnel mode.
(config-if)# exit	Exit Interface mode and return to Configure mode.

Validation

R1

```
R1# show running-config interface eth2
!
interface eth2
 ip address 192.168.1.1/24
 ipv6 address fe80::20e:cff:fe62:c86b/64
 no shutdown
!
R1# show running-config interface Tunnel11
!
interface Tunnel22
 mac-address 0000.0000.0000
 tunnel source 192.168.1.1
 tunnel mode ipv6ip isatap
 ipv6 address fe80::5efe:c0a8:101/64
 ipv6 address 2002::5efe:c0a8:101/64
 no shutdown
 no multicast
 no ipv6 nd suppress-ra
!
```

H1

```
H1# show running-config interface eth2
!
```

```
interface eth2
 ip address 192.168.1.2/24
 ipv6 address fe80::20e:cff:fe62:c85c/64
 no shutdown
!
H1# show running-config interface Tunnel11
!
interface Tunnel22
 mac-address 0000.0000.0000
 tunnel source 192.168.1.2
 tunnel destination 192.168.1.1
 tunnel mode ipv6ip isatap
 ipv6 address fe80::5efe:c0a8:102/64
 ipv6 address 2002::5efe:c0a8:102/64
 no shutdown
 no multicast
!
```

CHAPTER 14 Internet Protocol Security

This chapter contains a complete sample Internet Protocol Security (IPSec) configuration.

Overview

IPsec is framework of open standards that ensures secure private communications over the internet. You can use IPSec to support Virtual Private Network (VPN), firewalls, and other applications that must transfer data across a public or insecure network. IPSec provides privacy, integrity, and authentication at the IP layer. IPSec also includes cryptographic techniques to support key management.

Topology

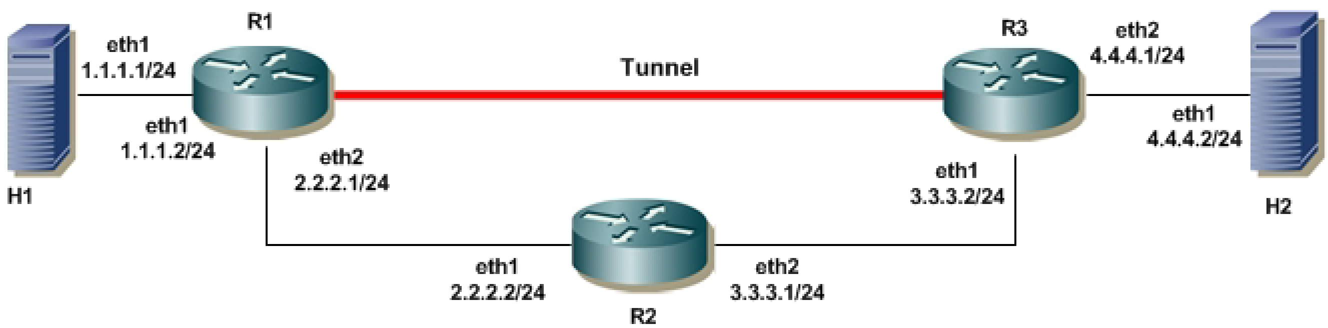

Figure 14-125: IPsec Topology

IPv4 Pre-Share Key

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ip address 1.1.1.2/24`	Assign an IP address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ip address 2.2.2.1/24`	Assign an IP address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#access-list 101 permit any 1.1.1.0/24 4.4.4.0/24`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.

`(config)#crypto map MAP1 1 ipsec-isakmp`	Create a crypto map.
`(config-crypto)#match address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set peer 3.3.3.2`	Set an IPsec peer.
`(config-crypto)# set transform-set t1`	Set the transform set.
`(config-crypto)# set security-association lifetime seconds 10000`	Set the lifetime of the security association.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth2`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)# crypto isakmp policy 1`	Create an IKE policy.
`(config-isakmp)#address 3.3.3.2`	Set the IP address of the peer.
`(config-isakmp)# authentication pre-share`	Set the authentication method to pre-shared keys.
`(config-isakmp)#encryption 3des`	Set the encryption algorithm to 3DES.
`(config-isakmp)# hash md5`	Set the hash algorithm to MD5.
`(config-isakmp)#lifetime 1000`	Set the lifetime of the security association.
`(config-isakmp)#psk key v+NkxY9LLZvwj4qCC2o/gGrWDF2d21jL`	Set the pre-shared key value
`(config-isakmp)# crypto isakmp enable`	Enable IKE.
`(config-isakmp)#exit`	Exit ISAKMP policy configuration mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 3.3.3.0/24 2.2.2.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 2.2.2.2`	Create a static route to direct traffic to the destination over the specified interface.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)# ip address 2.2.2.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ip address 3.3.3.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 2.2.2.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 3.3.3.2`	Create a static route to direct traffic to the destination over the specified interface.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)# ip address 3.3.3.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ip address 4.4.4.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#access-list 101 permit any 4.4.4.0/24 1.1.1.0/24`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)# crypto map MAP1 1 ipsec-isakmp`	Create a crypto map.
`(config-crypto)# match address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set peer 2.2.2.1`	Set an IPsec peer.
`(config-crypto)#set transform-set t1`	Set the transform set.
`(config-crypto)#set security-association lifetime seconds 10000`	Set the lifetime of the security association.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth1`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)# crypto isakmp policy 1`	Create an IKE policy.
`(config-isakmp)#address 2.2.2.1`	Set the IP address of the peer.
`(config-isakmp)# authentication pre-share`	Set the authentication method to pre-shared keys.
`(config-isakmp)#encryption 3des`	Set the encryption algorithm to 3DES.
`(config-isakmp)#hash md5`	Set the hash algorithm to MD5.
`(config-isakmp)#lifetime 1000`	Set the lifetime of the security association.
`(config-isakmp)#psk key v+NkxY9LLZvwj4qCC2o/gGrWDF2d21jL`	Set the pre-shared key value.
`(config-isakmp)# crypto isakmp enable`	Enable IKE.
`(config-isakmp)#exit`	Exit ISAKMP policy configuration mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 3.3.3.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 2.2.2.0/24 3.3.3.1`	Create a static route to direct traffic to the destination over the specified interface.

H1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# ip address 1.1.1.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 2.2.2.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 3.3.3.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.

H2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# ip address 4.4.4.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 2.2.2.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 3.3.3.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.

IPv4 Manual Key

This section shows how to set up an IPSec tunnel between R1 and R3 using a manual key.

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ip address 1.1.1.2/24`	Assign an IP address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ip address 2.2.2.1/24`	Assign an IP address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#access-list 101 permit any 1.1.1.0/24 4.4.4.0/24`	Create an access list.

`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)#crypto map MAP1 1 ipsec-manual`	Create a crypto map.
`(config-crypto)#match address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set peer 3.3.3.2`	Set an IPsec peer.
`(config-crypto)# set transform-set t1`	Set the transform set.
`(config-crypto)# set session-key inbound esp 1000 cipher 0123456789012345678909870123456789012345678909 87 authenticator 000011112222abcd`	Define IPsec keys.
`(config-crypto)#set session-key outbound esp 4000 cipher abcdefabcdefabcdeabcdabcabcdefabcdefabcdeabcdabc authenticator 999988887777edcb`	Define IPsec keys.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth2`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 3.3.3.0/24 2.2.2.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 2.2.2.2`	Create a static route to direct traffic to the destination over the specified interface.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)# ip address 2.2.2.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ip address 3.3.3.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 2.2.2.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 3.3.3.2`	Create a static route to direct traffic to the destination over the specified interface.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.

`(config-if)# ip address 3.3.3.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ip address 4.4.4.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#access-list 101 permit any 4.4.4.0/24 1.1.1.0/24`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)# crypto map MAP1 1 ipsec-manual`	Create a crypto map.
`(config-crypto)# match address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set peer 2.2.2.1`	Set an IPsec peer.
`(config-crypto)#set transform-set t1`	Set the transform set.
`(config-crypto)#set session-key inbound esp 4000 cipher abcdefabcdefabcdeabcdabcabcdefabcdefabcdeabcdabc authenticator 999988887777edcb`	Define IPsec keys.
`(config-crypto)#set session-key outbound esp 1000 cipher 0123456789012345678909870123456789012345678909 87 authenticator 000011112222abcd`	Define IPsec keys.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth1`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 3.3.3.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 2.2.2.0/24 3.3.3.1`	Create a static route to direct traffic to the destination over the specified interface.

H1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# ip address 1.1.1.1/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 2.2.2.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 3.3.3.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 4.4.4.0/24 1.1.1.2`	Create a static route to direct traffic to the destination over the specified interface.

H2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# ip address 4.4.4.2/24`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ip route 1.1.1.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 2.2.2.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ip route 3.3.3.0/24 4.4.4.1`	Create a static route to direct traffic to the destination over the specified interface.

IPv6 Pre-Share Key

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 1001::2/64`	Assign an IPv6 address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ipv6 address 2001::1/64`	Assign an IPv6 address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#ipv6 access-list 101 permit any 1001::/64 4001::/64`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)#crypto map MAP1 1 ipsec-isakmp`	Create a crypto map.
`(config-crypto)#match ipv6-address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set ipv6 peer 3001::2`	Set an IPsec peer.
`(config-crypto)# set transform-set t1`	Set the transform set.
`(config-crypto)# set security-association lifetime seconds 10000`	Set the lifetime of the security association.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth2`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)# crypto isakmp policy 1`	Create an IKE policy.
`(config-isakmp)#ipv6-address 3001::2`	Set the IPv6 address of the peer.
`(config-isakmp)# authentication pre-share`	Set the authentication method to pre-shared keys.

`(config-isakmp)#encryption 3des`	Set the encryption algorithm to 3DES.
`(config-isakmp)# hash md5`	Set the hash algorithm to MD5.
`(config-isakmp)#lifetime 1000`	Set the lifetime of the security association.
`(config-isakmp)#psk key v+NkxY9LLZvwj4qCC2o/gGrWDF2d21jL`	Set the pre-shared key value
`(config-isakmp)# crypto isakmp enable`	Enable IKE.
`(config-isakmp)#exit`	Exit ISAKMP policy configuration mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 3001::/64 2001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 2001::2`	Create a static route to direct traffic to the destination over the specified interface.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 2001::2/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ipv6 address 3001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 2001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 3001::2`	Create a static route to direct traffic to the destination over the specified interface.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 3001::2/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ipv6 address 4001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 access-list 101 permit any 4001::/64 1001::/64`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.

`(config)# crypto map MAP1 1 ipsec-isakmp`	Create a crypto map.
`(config-crypto)# match ipv6-address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set ipv6 peer 2001::1`	Set an IPsec peer.
`(config-crypto)#set transform-set t1`	Set the transform set.
`(config-crypto)#set security-association lifetime seconds 10000`	Set the lifetime of the security association.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth1`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)# crypto isakmp policy 1`	Create an IKE policy.
`(config-isakmp)#ipv6-address 2001::1`	Set the IPv6 address of the peer.
`(config-isakmp)# authentication pre-share`	Set the authentication method to pre-shared keys.
`(config-isakmp)#encryption 3des`	Set the encryption algorithm to 3DES.
`(config-isakmp)#hash md5`	Set the hash algorithm to MD5.
`(config-isakmp)#lifetime 1000`	Set the lifetime of the security association.
`(config-isakmp)#psk key v+NkxY9LLZvwj4qCC2o/gGrWDF2d21jL`	Set the pre-shared key value.
`(config-isakmp)# crypto isakmp enable`	Enable IKE.
`(config-isakmp)#exit`	Exit ISAKMP policy configuration mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 3001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 2001::/64 3001::1`	Create a static route to direct traffic to the destination over the specified interface.

H1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 1001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 2001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 3001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.

H2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 4001::2/64`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 2001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 3001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.

IPv6 Manual Key

R1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 1001::2/64`	Assign an IPv6 address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ipv6 address 2001::1/64`	Assign an IPv6 address to the interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)#ipv6 access-list 101 permit any 1001::/64 4001::/64`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)#crypto map MAP1 1 ipsec-manual`	Create a crypto map.
`(config-crypto)#match ipv6-address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set ipv6 peer 3001::2`	Set an IPsec peer.
`(config-crypto)#set transform-set t1`	Set the transform set.
`(config-crypto)#set session-key inbound esp 1000 cipher 0123456789012345678909870123456789012345678909 87 authenticator 000011112222abcd`	Define IPsec keys.
`(config-crypto)#set session-key outbound esp 4000 cipher abcdefabcdefabcdeabcdabcabcdefabcdefabcdeabcdabc authenticator 999988887777edcb`	Define IPsec keys.
`(config-crypto)#exit`	Exit crypto map configuration mode.

`(config)#crypto map MAP1 local-address eth2`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 3001::/64 2001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 2001::2`	Create a static route to direct traffic to the destination over the specified interface.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 2001::2/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)#ipv6 address 3001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 2001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 3001::2`	Create a static route to direct traffic to the destination over the specified interface.

R3

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 3001::2/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#interface eth2`	Enter interface mode.
`(config-if)# ipv6 address 4001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 access-list 101 permit any 4001::/64 1001::/64`	Create an access list.
`(config)#crypto ipsec transform-set t1 esp-auth esp-md5 esp-enc esp-3des`	Create a transform set.
`(config)# crypto map MAP1 1 ipsec-manual`	Create a crypto map.
`(config-crypto)# match ipv6-address 101`	Assign an extended access list for a crypto map entry which is used by IPsec to determine which traffic should be protected.
`(config-crypto)#set ipv6 peer 2001::1`	Set an IPsec peer.
`(config-crypto)#set transform-set t1`	Set the transform set.

`(config-crypto)#set session-key inbound esp 4000 cipher abcdefabcdefabcdeabcdabcabcdefabcdefabcdeabcdabc authenticator 999988887777edcb`	Define IPsec keys.
`(config-crypto)#set session-key outbound esp 1000 cipher 0123456789012345678909870123456789012345678909 87 authenticator 000011112222abcd`	Define IPsec keys.
`(config-crypto)#exit`	Exit crypto map configuration mode.
`(config)#crypto map MAP1 local-address eth1`	Set the interface for the crypto map to identify itself to a remote peer.
`(config)#interface eth1`	Enter interface mode.
`(config-if)# crypto map MAP1`	Apply the crypto map to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 3001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 2001::/64 3001::1`	Create a static route to direct traffic to the destination over the specified interface.

H1

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 1001::1/64`	Assign an IPv6 address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 2001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 3001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 4001::/64 1001::2`	Create a static route to direct traffic to the destination over the specified interface.

H2

`#configure terminal`	Enter Configure mode.
`(config)#interface eth1`	Enter interface mode.
`(config-if)#ipv6 address 4001::2/64`	Assign an IP address to the interface.
`(config-if)#exit`	Exit interface mode.
`(config)#ipv6 route 1001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 2001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.
`(config)#ipv6 route 3001::/64 4001::1`	Create a static route to direct traffic to the destination over the specified interface.

Validation

```
R1#show ipsec status
Security Associations (1 up, 0 connecting):
        MAP1-1[3]: ESTABLISHED 19 seconds ago,
2.2.2.1[2.2.2.1]...3.3.3.2[3.3.3.2]
        MAP1-1{2}: INSTALLED, TUNNEL, reqid 2, ESP SPIs: c2f67ecd_i c280e5be_o
        MAP1-1{2}: 2.2.2.1/32 === 3.3.3.2/32
R1#


R1#show crypto isakmp policy
Protection suite priority 1
  encryption algorithm:   3DES - Data Encryption Standard
  hash algorithm:   Message Digest 5
  authentication method:   preshared Key
  Diffie-Hellman Group: #14 (modp2048)
  lifetime: 1000
 psk key: v+NkxY9LLZvwj4qCC2o/gGrWDF2d21jL
 peer address: 3.3.3.2
R1#


R1#show crypto-map interface eth2
Interface eth2
Crypto-map MAP1
Crypto-spi 0
Crypto-access-list-id 101
Crypto-Transform set t1
Crypto-map peer: 3.3.3.2
R1#


R1#show crypto ipsec transform-set t1
Transform set t1
  Mode is Tunnel
  Algorithm esp-3des esp-md5
R1#
```


CHAPTER 15 Unicast Reverse Path Forwarding

This chapter contains basic IPv4 and IPv6 Unicast Reverse Path Forwarding examples.

For details about the commands used in these examples, see the *Network Services Module Command Reference*.

Overview

In an ISP or network usage, under Denial of Service attack from outside the network, often the packets carry spoofed source addresses. The spoofed source address maybe generated at random or may belong to any of the interior network addresses. By examining the source address in all the incoming packets a system may be able to filter these spoofed packets, unicast RPF check feature does exactly the same. It drops the packets whose source address does not fit in legitimately within the customers assigned source addresses. It also drops packets with addresses which are invalid, example 0.0.0.0/8, 10.0.0.0/8, 127.0.0.0/8 etc.

With this approach the malicious traffic effect can be suppressed, and attacks can be legitimately traced back to the source.There are several variations of applying Ingress filtering, each with its own merits and de-merits. Applying ingress filtering has an effect on Multi-homing feature if enabled.

The proposed ways to Implement Ingress Filtering are;

- Ingress Access Lists
- Strict Reverse Path forwarding.
- Feasible Path Reverse Path forwarding
- Loose Reverse Path forwarding

Loose uRPF for IPv4

When administrators use Unicast RPF in loose mode, the source address must appear in the routing table. R1 and R2 are connected through two Ethernet connections.

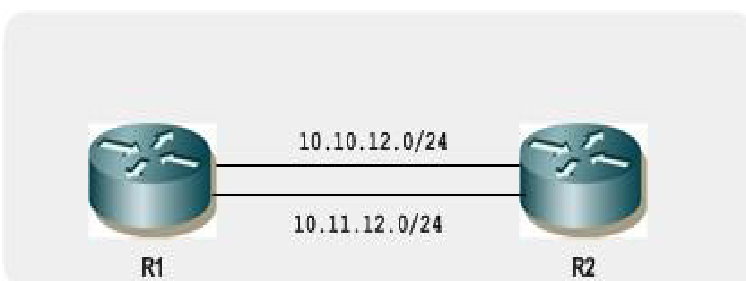

Figure 15-126: Loose uRPF for IPv4

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.10.12.1/24`	Set the IP address of the `eth1` interface.

`(config-if)# ip verify unicast source reachable-via any`	Configure loose uRPF on eth1 of R1.
`(config-if)# interface eth2`	Specify the interface (`eth2`) to configure.
`(config-if)# ip address 10.11.12.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# ip verify unicast source reachable-via any`	Configure loose uRPF on eth2 of R1.
`(config-if)# interface lo`	Specify the interface (`loopback`) to configure.
`(config-if)# ip address 1.1.1.1/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 2.2.2.0 255.255.255.0 10.10.12.2`	Configure static route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface (`eth1`) to configure.
`(config-if)# ip address 10.10.12.2/24`	Set the IP address of the `eth1` interface.
`(config-if)#ip verify unicast source`	Configure loose uRPF with allow default option on eth1 of R2.
`(config-if)# interface eth2`	Specify the interface (`eth2`) to configure.
`(config-if)# ip address 10.11.12.2/24`	Set the IP address of the `eth2` interface.
`(config-if)#ip verify unicast source`	Configure loose uRPF with allow default option on eth2 of R2.
`(config-if)# interface lo`	Specify the interface (`loopback`) to configure.
`(config-if)# ip address 2.2.2.2/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 0.0.0.0 0.0.0.0 10.11.12.1`	Configure default static route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

Loose uRPF with allow-default for IPv4

When administrators use Unicast RPF in loose with default option mode, the source address must appear in the routing table and it allows the use of the default route in the source verification process. R1 and R2 are connected through two Ethernet connections.

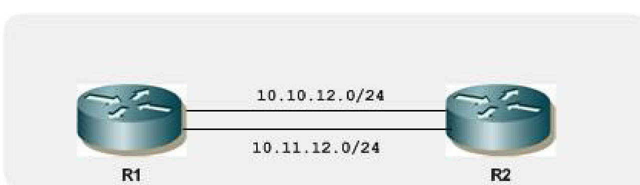

Figure 15-127: Loose uRPF with allow-default

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.10.12.1/24`	Set the IP address of the `eth1` interface.
`(config-if)# ip verify unicast source reachable-via any allow-default`	Configure loose uRPF with allow-default option on eth1 of R1.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 10.11.12.1/24`	Set the IP address of the `eth2` interface.
`(config-if)# ip verify unicast source reachable-via any allow-default`	Configure loose uRPF with allow-default option on eth2 of R1.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ip address 1.1.1.1/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 0.0.0.0 0.0.0.0 10.10.12.2`	Configure default static route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.10.12.2/24`	Set the IP address of the `eth1` interface.
`(config-if)#ip verify unicast source`	Configure loose uRPF with allow default option on eth1 of R2.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 10.11.12.2/24`	Set the IP address of the `eth2` interface.
`(config-if)#ip verify unicast source`	Configure loose uRPF with allow default option on eth2 of R2.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ip address 2.2.2.2/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 0.0.0.0 0.0.0.0 10.11.12.1`	Configure default static route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

Strict uRPF for IPv4

When administrators use Unicast RPF in strict mode, the packet must be received on the interface that the router would use to forward the return packet. Unicast RPF configured in strict mode may drop legitimate traffic that is received on an interface that was not the router's choice for sending return traffic.

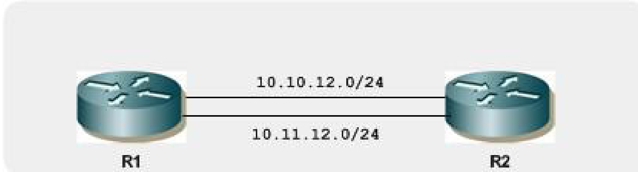

Figure 15-128: Strict uRPF for IPv4

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.10.12.1/24`	Set the IP address of the `eth1` interface.
`(config-if)#ip verify unicast source`	Configure strict uRPF on eth1 of R1.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 10.11.12.1/24`	Set the IP address of the `eth2` interface.
`(config-if)#ip verify unicast source`	Configure strict uRPF on eth2 of R1.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ip address 1.1.1.1/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 2.2.2.0 255.255.255.0 10.10.12.2`	Configure static route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ip address 10.10.12.2/24`	Set the IP address of the `eth1` interface.
`(config-if)#ip verify unicast source`	Configure strict uRPF on eth1 of R2.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ip address 10.11.12.2/24`	Set the IP address of the `eth2` interface.
`(config-if)#ip verify unicast source reachable-via rx`	Configure strict uRPF on eth2 of R2.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ip address 2.2.2.2/24`	Set the IP address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ip route 1.1.1.0 255.255.255.0 10.11.12.1`	Configure static route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

Loose uRPF for IPv6

When administrators use Unicast RPF in loose mode, the source address must appear in the routing table. R1 and R2 are connected through two Ethernet connections.

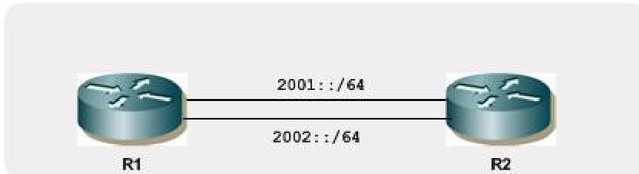

Figure 15-129: Loose uRPF for IPv6

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ipv6 address 2001::1/64`	Set the IPv6 address of the `eth1` interface.
`(config-if)# ipv6 verify unicast source reachable-via any`	Configure loose uRPF on eth1 of R1.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002::1/24`	Set the IPv6 address of the `eth2` interface.
`(config-if)# ipv6 verify unicast source reachable-via any`	Configure loose uRPF on eth2 of R1.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ipv6 address 5001::1/64`	Set the IPv6 address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 6001::/64 2001::2`	Configure ipv6 static route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ipv6 address 2001::2/64`	Set the IPv6 address of the `eth1` interface.
`(config-if)#ipv6 verify unicast source`	Configure loose uRPF on eth1 of R2.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)#ipv6 verify unicast source reachable-via any`	Configure loose uRPF on eth2 of R2.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ipv6 address 6001::2/64`	Set the IPv6 address of the `loopback` interface.

(config-if)# exit	Exit Interface mode, and enter Configure mode.
(config)# ipv6 route 5001::/64 2002::1	Configure ipv6 static route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

Loose uRPF with allow-default for IPv6

When administrators use Unicast RPF in loose with default option mode, the source address must appear in the routing table and it allows the use of the default route in the source verification process. R1 and R2 are connected through two Ethernet connections.

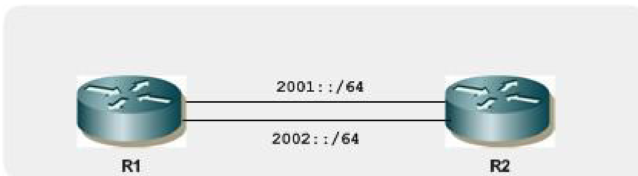

Figure 15-130: loose URPF with allow default for IPv6

R1

# configure terminal	Enter Configure mode.
(config)# interface eth1	Specify the interface (eth1) to configure.
(config-if)# ipv6 address 2001::1/64	Set the IPv6 address of the eth1 interface.
(config-if)#ipv6 verify unicast source	Configure loose uRPF with allow-default option on eth1 of R1.
(config-if)# interface eth2	Specify the interface (eth2) to configure.
(config-if)# ipv6 address 2002::1/24	Set the IPv6 address of the eth2 interface.
(config-if)#ipv6 verify unicast source	Configure loose uRPF with allow-default option on eth2 of R1.
(config-if)# interface lo	Specify the interface (loopback) to configure.
(config-if)# ipv6 address 5001::1/64	Set the IPv6 address of the loopback interface.
(config-if)# exit	Exit Interface mode, and enter Configure mode.
(config)# ipv6 route ::/0 2001::2	Configure ipv6 default route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

# configure terminal	Enter Configure mode.
(config)# interface eth1	Specify the interface (eth1) to configure.
(config-if)# ipv6 address 2001::2/64	Set the IPv6 address of the eth1 interface.
(config-if)#ipv6 verify unicast source	Configure loose uRPF on eth1 of R2.
(config-if)# interface eth2	Specify the interface (eth2) to configure.

`(config-if)# ipv6 address 2002::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# ipv6 verify unicast source reachable-via any`	Configure loose uRPF on eth2 of R2.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ipv6 address 6001::2/64`	Set the IPv6 address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route ::/0 2002::1`	Configure ipv6 default route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

Strict uRPF for IPv6

When administrators use Unicast RPF in strict mode, the packet must be received on the interface that the router would use to forward the return packet. Unicast RPF configured in strict mode may drop legitimate traffic that is received on an interface that was not the router's choice for sending return traffic.

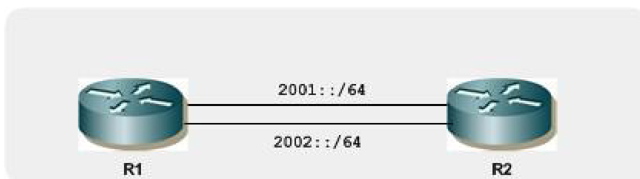

Figure 15-131: Strict URPF for IPv6

R1

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ipv6 address 2001::1/64`	Set the IPv6 address of the `eth1` interface.
`(config-if)# ipv6 verify unicast source reachable-via rx`	Configure strict uRPF on eth1 of R1.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002::1/24`	Set the IPv6 address of the `eth2` interface.
`(config-if)# ipv6 verify unicast source reachable-via rx`	Configure strict uRPF on eth2 of R1.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ipv6 address 5001::1/64`	Set the IPv6 address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 6001::/64 2001::2`	Configure ipv6 static route to reach loopback interface of R2 with next-hop as eth1 of R2.

R2

`# configure terminal`	Enter Configure mode.
`(config)# interface eth1`	Specify the interface `(eth1)` to configure.
`(config-if)# ipv6 address 2001::2/64`	Set the IPv6 address of the `eth1` interface.
`(config-if)# ipv6 verify unicast source reachable-via rx`	Configure strict uRPF on eth1 of R2.
`(config-if)# interface eth2`	Specify the interface `(eth2)` to configure.
`(config-if)# ipv6 address 2002::2/64`	Set the IPv6 address of the `eth2` interface.
`(config-if)# ipv6 verify unicast source reachable-via any`	Configure strict uRPF on eth2 of R2.
`(config-if)# interface lo`	Specify the interface `(loopback)` to configure.
`(config-if)# ipv6 address 6001::2/64`	Set the IPv6 address of the `loopback` interface.
`(config-if)# exit`	Exit Interface mode, and enter Configure mode.
`(config)# ipv6 route 5001::/64 2002::1`	Configure ipv6 static route to reach loopback interface of R1 with next-hop as eth2 of R1.

Validation

`show running-config interface, show ip interface brief, ping`

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