Routing Video Mentor

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Dedication

I dedicate this Video Mentor product to my mother-in-law and father-in-law (whom I prefer to think of as my "in-loves" rather than "in-laws"), Lelia and Willie Hargus Gordon. You have my undying gratitude for raising the girl that would one day become my wife. You guys did a nice job.

Acknowledgments

When I write acknowledgments for a book, I find myself trying to be eloquent in my wording. However, as I write these words, I find myself in a sleep-deprived state. So I'm going to speak from the heart. First, I send a thank you to Brett Bartow at Pearson for his continuing faith in me and allowing me to live out my life's purpose of teaching others. Countless people have crossed my path in the IT world who shaped my understanding and appreciation of routing technologies. I am grateful for your influences on me.

On a personal note, I always want to acknowledge God's blessings on my life. In fact, He promised that if we acknowledge Him in all our ways, He will direct our paths. So I don't want to pass up a deal like that.

Also, those who have been most impacted by my hours of seclusion while writing and recording this product are of course my family members. I continue to be amazed at how my wife Vivian is so understanding that this is time well spent. My daughters Stacie and Sabrina have even gotten used to my writing projects, and even though they wouldn't tell you so, I think they might be proud of their dad.

Contents at a Glance

Contents

Introduction

Routing Video Mentor helps those who configure or maintain Cisco routers. Additionally, this Video Mentor product helps candidates of any Cisco exam that focuses on routing content, at both the associate and professional levels, but especially for the CCNP certification. Each Routing Video Mentor video presents a unique lab scenario, with both visual references and audio explanations of what you should expect to happen in a particular lab. The videos also show the command-line interface (CLI) commands used to implement the features described in each lab video, along with running commentary. The end result is a set of lab videos that explain some of the most important routing topics, with thorough explanations from a trusted mentor.

Routing Video Mentor was created out of a need for something more than just the static written word of a typical book. Cisco Press already offers many books that cover the wide breadth of routing. However, many people learn better in a classroom setting, with an instructor explaining the concepts while showing details as projected on the wall. Many customers of Cisco Press' book products asked for a product closer to what you might get in a class, and the Video Mentor series of products is the result.

Goals and Methods

Routing Video Mentor has a very specific set of goals. First, this product seeks to help its viewers more completely and more thoroughly understand the most popular routing protocols in use today and many of the configuration options available for those routing protocols. Although you might have already read about these routing protocols in other books, or heard about them in classes, the *Routing Video Mentor* helps you master these particular routing concepts. Using the *Routing Video Mentor* in addition to a book or attending a course should help solidify your knowledge, help you see how to apply the knowledge, and better prepare you for the application of knowledge in real-world deployments or on a Cisco exam.

Note that *Routing Video Mentor* does not attempt to cover all aspects of each routing protocol. Rather, the *Routing Video Mentor* seeks to introduce the fundamentals of each routing protocol or concept addressed, and then expand on those fundamentals to assist the viewer in relating how the protocol or concept might be deployed in their (or in a customer's) environment.

Each of the 15 lab videos follows the same basic approach, including these basic steps:

1. The video begins with a description of the goals of the lab.
2. The lab scenario steps are listed, giving a general outline of what the viewer should expect to see and hear during the video.
3. The lab topology used in the video is described.
4. The video shows the CLI commands used to configure the routing protocol or concept being addressed in a particular lab.

Routing Video Mentor Contents

The *Routing Video Mentor* product package contains two components: a DVD and a booklet. The DVD contains the 15 lab videos, plus a PDF of the booklet. The DVD has been optimized for viewing on a computer with a 1024 X 768 minimum pixel grid. When the DVD starts, it will display a menu, from which you can start one of the 15 lab videos or view a PDF copy of the booklet.

The booklet is intended to be used for reference when watching the videos, as opposed to being a standalone tool. The booklet has a section corresponding to each of the 15 *Routing Video Mentor* labs and includes the following:

- The list of objectives for the lab
- The list of scenario steps
- A high-level overview of concepts demonstrated in the lab
- The beginning configuration on each device
- Configurations added to each device during the lab
- A diagram of the topology used in the lab

Who Should Use the *Routing Video Mentor*?

The *Routing Video Mentor* is primarily intended for people using self-study books as their main method of preparing to configure or maintain Cisco routers, or to pass routing protocol-related Cisco exams. Additionally, this product should be useful to anyone who is studying routing topics, either by reading books or when taking classes.

How the *Routing Video Mentor* Is Organized

The *Routing Video Mentor* DVD menu gives you access to each of the 15 labs. The menu also gives you access to a PDF of the booklet included with the DVD.

The booklet itself simply contains 15 sections, each referencing one of the 15 lab videos. The 15 lab videos are as follows:

- **Lab 1, "Configuring Static Routes"** This lab introduces the concept of routing, discusses administrative distance, identifies when static routes might be used, and demonstrates the configuration of static routes.
- **Lab 2, "Configuring and Verifying RIPv1 and RIPv2"** This lab contrasts the RIPv1 and the RIPv2 routing protocol, discusses how RIPv1 and RIPv2 can coexist in the same network, and illustrates how to configure RIPv1, RIPv2, and authentication for the RIPv2 portion of the network.
- **Lab 3, "Configuring and Verifying EIGRP"** This lab introduces EIGRP, describes the metric used by EIGRP, demonstrates a basic EIGRP configuration, illustrates how to disable EIGRP's auto-summarization feature, and shows how to load balance across unequal cost paths.
- **Lab 4, "Configuring and Verifying Single-Area OSPF"** This lab introduces OSPF, describes the function of a *designated router*, illustrates how to configure OSPF in a single area, and demonstrates how to influence the election of a designated router.
- **Lab 5, "Configuring OSPF for Multiple Areas and Frame Relay Nonbroadcast"** This lab describes the *nonbroadcast* OSPF network type, identifies characteristics of a multi-area OSPF network, demonstrates the configuration of a multi-area OSPF network, and shows how to logically join a discontiguous OSPF area with the OSPF backbone area using a *virtual link*.

- **Lab 6, "Configuring and Verifying OSPF Route Summarization for Interarea and External Routes"** This lab discusses the benefits of route summarization, contrasts types of OSPF route summarization, shows how to summarize routes between OSPF areas, and illustrates how to summarize routes that did not originate in OSPF as those routes are redistributed into OSPF.
- **Lab 7, "Configuring Route Redistribution"** This lab explains the need for route redistribution, discusses the function of a boundary router, introduces the concept of a seed metric, configures a portion of the topology for EIGRP, configures a portion of the topology for OSPF, and configures mutual route redistribution between OSPF and EIGRP.
- **Lab 8, "Configuring Integrated IS-IS Routing"** This lab introduces the IS-IS routing protocol, explains IS-IS NSAP addressing, and configures IS-IS to use both area authentication and domain authentication.
- **Lab 9, "Configuring and Verifying Policy-Based Routing"** This lab introduces the concept of policy-based routing, discusses route maps, configures the topology with the OSPF routing protocol, and configures policy-based routing to influence how OSPF makes its routing decisions.
- **Lab 10, "Configuring Multihome BGP"** This lab introduces the BGP routing protocol, discusses how BGP makes its path selection, configures a portion of the topology for OSPF, configures a portion of the topology for BGP, demonstrates how to create a default route advertisement from the topology's backbone routers, redistributes OSPF into BGP, and verifies multihome BGP operation by creating a link failure and verifying that traffic reroutes across an alternate link.
- **Lab 11, "Using Route Maps for BGP Path Selection"** This lab explains BGP's *local preference* attribute, introduces BGP's *ASPATH* attribute, configures a route map to influence outbound path selection using the local preference attribute, and configures a route map to influence inbound path selection using the ASPATH attribute.
- **Lab 12, "Implementing Multicast Routing"** This lab reviews multicast theory, enables multicast support throughout the lab topology, configures a router to join a multicast group, verifies dense mode operation, configures a rendezvous point, and confirms sparse mode operation.
- **Lab 13, "Configuring IPv6 Addressing"** This lab introduces IP version 6 (IPv6), illustrates IPv6 addressing, globally configures IPv6 on a router, and adds IPv6 addressing to router interfaces.
- **Lab 14, "Configuring IPv6 OSPF Routing"** This lab identifies options for routing between IPv6 networks, introduces OSPF version 3 (OSPFv3), and configures OSPFv3 to route between the IPv6 networks configured in Lab 13 "Configuring IPv6 Addressing".
- **Lab 15, "Tunneling IPv6 via IPv4"** This lab identifies options for IPv4 and IPv6 to coexist on the same network, discusses the operation of an IPv6-over-IPv4 tunnel, removes the IPv6 and OSPFv3 configuration from a portion of the topology (making that portion of the topology IPv4-only), creates a tunnel to span the IPv4 region of the network, and configures the tunnel to encapsulate IPv6 packets for transmission through the IPv4 network.

Lab 1

Configuring Static Routes

This *Routing Video Mentor* lab introduces the concept and need for routing. Various approaches to routing are identified, one which is to statically configure routes. The lab then demonstrates the creation of two static routes, one of which acts as a default route. Specifically, the objectives of this lab are as follows:

- Introduce routing
- Describe administrative distance
- Understand when a static route might be used
- Introduce the *Routing Video Mentor* topology
- Show the syntax for static routing
- Configure static routes
- Verify static routes
- Save configuration

Scenario

This lab contains two main steps, as follows:

Step 1 Configure and verify a static route pointing to a stub network.

Step 2 Configure and verify a default route.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 1-1, 1-2, 1-3, and 1-4 illustrate these initial configurations.

Example 1-1 Initial Configuration for R1

```
hostname R1
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
```

continues

Example 1-1 Initial Configuration for R1 continued

```
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 1-2 Initial Configuration for R2

```
hostname R2
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
```

Example 1-3 Initial Configuration for BB1

```
hostname BB1
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 1-4 Initial Configuration for BB2

```
hostname BB2
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

Initial Routing Tables

Without any routing (static or dynamic) configured on the routers, the routers are only aware of directly connected networks. You can use the **show ip route** command to display known routes. Examples 1-5, 1-6, 1-7, and 1-8 show the initial routing tables of the routers. Notice the "C" next to the routes in the routing tables. The "C" indicates that the route entry was made because the specified network is directly connected to the router.

Example 1-5 Initial Routing Table for R1

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/30 is subnetted, 2 subnets
C       172.16.1.0 is directly connected, Serial0/0.1
C       172.16.2.0 is directly connected, Serial0/0.2
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, FastEthernet0/0
```

Example 1-6 Initial Routing Table for R2

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 1 subnets
C       10.1.2.0 is directly connected, FastEthernet0/1
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, FastEthernet0/0
```

Example 1-7 Initial Routing Table for BB1

```
BB1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/30 is subnetted, 1 subnets
C       172.16.1.0 is directly connected, Serial0/0.2
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Serial0/0.1
```

Example 1-8 Initial Routing Table for BB2

```
BB2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/30 is subnetted, 1 subnets
C       172.16.2.0 is directly connected, Serial0/0.2
     10.0.0.0/30 is subnetted, 1 subnets
C       10.1.1.0 is directly connected, Serial0/0.1
```

Ending Configurations

This lab initially adds a static route to router R1 which points to the stub network of 10.1.2.0/24. This network is referred to as a stub network, because no traffic flows through that network traveling to or from another network. Example 1-9 shows the configuration of router R1 after the addition of the static route.

Example 1-9 R1 Configuration After the Addition of a Static Route

```
hostname R1
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
!
ip route 10.1.2.0 255.255.255.0 192.168.1.2
```

Example 1-10 shows R1's routing table after the addition of the static route. Notice the "S" adjacent to network 10.1.2.0 in the routing table. The "S" indicates the route was statically configured.

Example 1-10 R1's Routing Table After Configuring a Static Route

```
R1#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/30 is subnetted, 2 subnets
C       172.16.1.0 is directly connected, Serial0/0.1
C       172.16.2.0 is directly connected, Serial0/0.2
     10.0.0.0/24 is subnetted, 1 subnets
S       10.1.2.0 [1/0] via 192.168.1.2
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, FastEthernet0/0
```

From the perspective of router R2, any route not locally connected could only be accessible via its upstream router R1. Router R1 is accessible via R2's FastEthernet 0/0 interface. Therefore, a static default route is configured to route traffic for any unknown network out of FastEthernet 0/0. Example 1-11 shows R2's configuration after the addition of the static default route.

Example 1-11 R2's Configuration after Configuring a Static Default Route

```
hostname R2
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
 no keepalive
!
ip route 0.0.0.0 0.0.0.0 FastEthernet0/0
```

Example 1-12 shows R2's routing table after the addition of the static default route. In addition to the "S" adjacent to the default route of 0.0.0.0, also notice the asterisk. The asterisk identifies this route as a candidate default route.

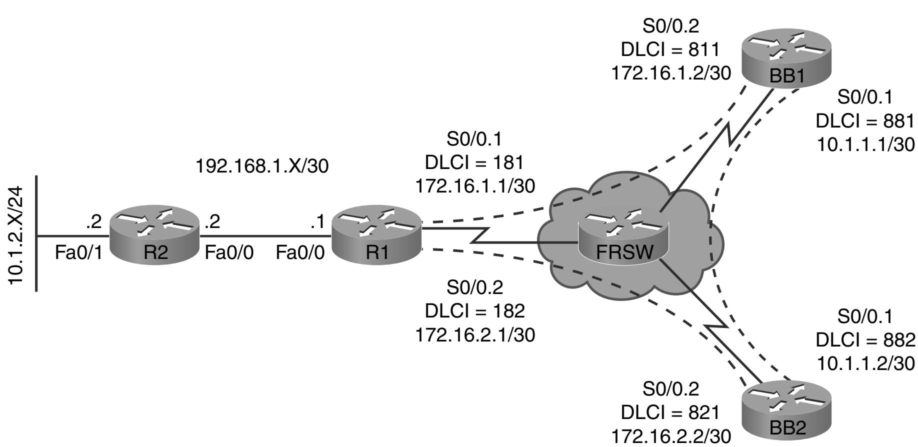
Example 1-12 R2's Routing Table after Configuring a Static Default Route

```
R2#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 0.0.0.0 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 1 subnets
C       10.1.2.0 is directly connected, FastEthernet0/1
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, FastEthernet0/0
S*   0.0.0.0/0 is directly connected, FastEthernet0/0
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 1-1.

Figure 1-1 Static Routing Topology



The following IOS command is demonstrated in the lab to configure static routes:

Router(config)#**ip route** *network* [*mask*] {*address* | *interface*} [*distance*] [**permanent**]

Table 1-1 offers a reference for the command parameters.

Table 1-1 IOS Command Reference for Lab 1

Parameter	Description
network	Destination network
mask	Subnet mask of destination network
address	IP address of next-hop router
interface	Local interface used to reach the specified network
distance	Administrative distance
permanent	Keeps the route in the routing table even if the associated local interface is down

Lab 2

Configuring and Verifying RIPv1 and RIPv2

This *Routing Video Mentor* lab introduces the *Routing Information Protocol* (RIP). The characteristics of RIP are discussed, in addition to the distinctions between RIP version 1 and RIP version 2.

The lab demonstrates the configuration of RIPv1. RIPv2 is then added to a portion of the lab topology, making RIPv1 and RIPv2 coexist in the same network. RIPv2's authentication configuration is then added for selected routers in the network. Specifically, the objectives of this lab are as follows:

- Introduce RIP
- Contrast RIPv1 and RIPv2
- Show the syntax for RIP configuration
- Configure RIPv1
- Configure RIPv2
- Configure support for a mixed RIPv1 and RIPv2 network
- Add authentication support for RIPv2
- Verify RIP operation

Scenario

This lab contains three main steps, as follows:

Step 1 Configure and verify RIPv1 on all routers in the topology.

Step 2 Add RIPv2 to selected routers in the topology.

Step 3 Add authentication between the RIPv2 routers.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 2-1, 2-2, 2-3, and 2-4 illustrate these initial configurations.

Example 2-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
```

continues

Example 2-1 Initial Configuration for R1 continued

```
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 2-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
```

Example 2-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 2-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.2 255.255.255.252
 snmp trap link-status
 frame-relay interface-dlci 821
```

RIPv1 Configuration

The lab begins without any static routes or dynamic routing protocols configured. Each router is then configured for RIPv1. Even though specific subnets could be specified with the **network** command in router-rip configuration mode, RIP automatically changes the specified subnet address to its classful address.

Examples 2-5, 2-6, 2-7, and 2-8 show the RIPv1 configuration commands added to the routers.

Example 2-5 RIPv1 Configuration for R1

```
router rip
 network 1.0.0.0
 network 172.16.0.0
 network 192.168.1.0
```

Example 2-6 RIPv1 Configuration for R2

```
router rip
 network 2.0.0.0
 network 10.0.0.0
 network 192.168.1.0
```

Example 2-7 RIPv1 Configuration for BB1

```
router rip
 network 3.0.0.0
 network 10.0.0.0
 network 172.16.0.0
```

Example 2-8 RIPv1 Configuration for BB2

```
router rip
 network 4.0.0.0
 network 10.0.0.0
 network 172.16.0.0
```

The scenario presented in this lab requires router R2 to be a RIPv1 router, whereas the backbone routers (that is, BB1 and BB2) should be configured for RIPv2. Therefore, router R1, which sits between router R2 and the backbone routers, needs to be configured for RIPv2. However, router R1 needs to simultaneously transmit and receive RIPv1 information on its FastEthernet 0/0 interface, which connects router R1 to router R2.

Examples 2-9 and 2-10 illustrate the commands entered on the backbone routers to configure those routers for RIPv2 and to disable RIPv2's default behavior of automatically performing route summarization.

Example 2-9 RIPv2 Configuration for BB1

```
router rip
 version 2
 no auto-summary
```

Example 2-10 RIPv2 Configuration for BB2

```
router rip
 version 2
 no auto-summary
```

Example 2-11 not only shows the commands entered on router R1 to configure R1 for RIPv2, but it also shows the commands entered for R1's FastEthernet 0/0 interface, which tells that interface to send and receive RIPv1 formatted packets.

Example 2-11 R1's Configuration for RIPv2 with RIPv1 Compatibility

```
interface FastEthernet0/0
 ip rip send version 1
 ip rip receive version 1
!
router rip
 version 2
 no auto-summary
```

After router R1 has been configured for RIPv2 with RIPv1 compatibility, the lab demonstrates that router R1 still does not have reachability to network 10.1.2.0/24, which is connected to router R2's FastEthernet 0/1 interface. The reason for this lack of reachability is determined to be the advertisements for the 10.0.0.0/8 classful network being sourced by the backbone routers, in addition to router R2. To remedy this symptom, a static route was added to router R1 to route packets destined for the 10.1.2.0/24 network to a next-hop IP address of 192.168.1.2, which is the IP address of router R2's FastEthernet 0/0 interface. This static route was created on router R1 by issuing the following command in global configuration mode: **ip route 10.1.2.0 255.255.255.0 192.168.1.2**.

This lab scenario also specifies a requirement for using RIPv2 authentication between R1 and the backbone routers, and also between the backbone routers.

RIPv2 Authentication Configuration

RIPv2 authentication is supported using either clear text or a *Message Digest 5* (MD5) hash value. This lab demonstrates the MD5 approach, which is more secure. Examples 2-12, 2-13, and 2-14 illustrate the RIPv2 authentication commands entered on routers R1, BB1, and BB2, respectively.

Example 2-12 RIPv2 Authentication Configuration for R1

```
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
interface Serial0/0.1 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
!
interface Serial0/0.2 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
```

Example 2-13 RIPv2 Authentication Configuration for BB1

```
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
key chain KEYCHAIN2
 key 1
   key-string CISCO
!
interface Serial0/0.1 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN2
!
interface Serial0/0.2 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
```

Example 2-14 RIPv2 Authentication Configuration for BB2

```
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
key chain KEYCHAIN2
 key 1
   key-string CISCO
!
interface Serial0/0.1 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN2
!
interface Serial0/0.2 point-to-point
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
```

Final Configuration

As a reference, Examples 2-15, 2-16, 2-17, and 2-18 provide the final configurations for routers R1, R2, BB1, and BB2 respectively.

Example 2-15 Final Configuration for R1

```
hostname R1
!
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 ip rip send version 1
 ip rip receive version 1
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
```

continues

Example 2-15 Final Configuration for R1 continued

```
!
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
 frame-relay interface-dlci 182
!
router rip
 version 2
 network 1.0.0.0
 network 172.16.0.0
 network 192.168.1.0
 no auto-summary
!
ip route 10.1.2.0 255.255.255.0 192.168.1.2
```

Example 2-16 Final Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
!
router rip
 network 2.0.0.0
 network 10.0.0.0
 network 192.168.1.0
```

Example 2-17 Final Configuration for BB1

```
hostname BB1
!
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
key chain KEYCHAIN2
 key 1
   key-string CISCO
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.1 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN2
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 ip address 172.16.1.2 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
 frame-relay interface-dlci 811
!
router rip
 version 2
 network 3.0.0.0
 network 10.0.0.0
 network 172.16.0.0
 no auto-summary
```

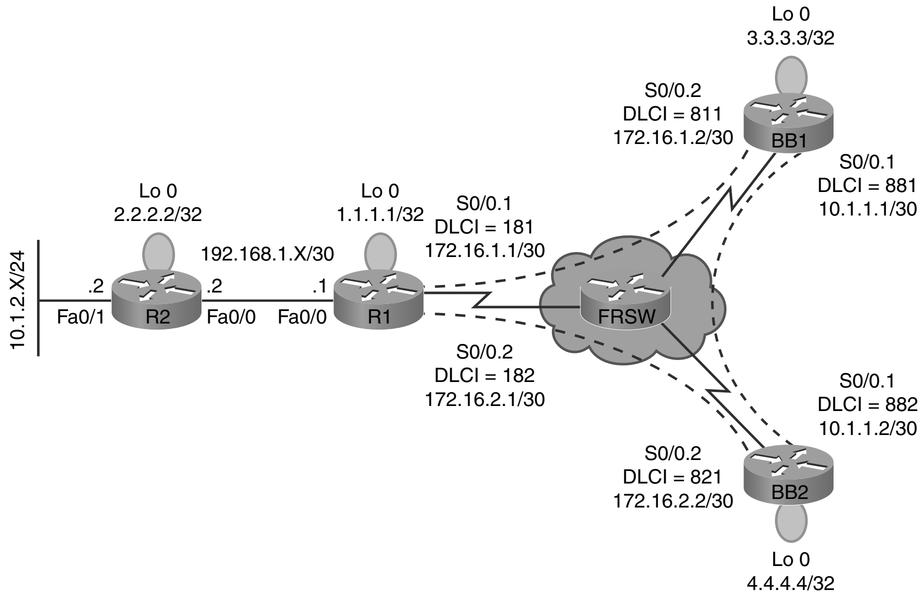
Example 2-18 Final Configuration for BB2

```
hostname BB2
!
key chain KEYCHAIN1
 key 1
   key-string CISCO
!
key chain KEYCHAIN2
 key 1
   key-string CISCO
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.2 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN2
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.2 255.255.255.252
 ip rip authentication mode md5
 ip rip authentication key-chain KEYCHAIN1
 frame-relay interface-dlci 821
!
router rip
 version 2
 network 4.0.0.0
 network 10.0.0.0
 network 172.16.0.0
 no auto-summary
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 2-1.

Figure 2-1 RIP Routing Topology



This lab also illustrates the use of several RIP-related IOS commands. The syntax for these commands is presented in Table 2-1.

Table 2-1 IOS Command Reference for Lab 2

Command	Description
Router(config)# **router rip**	Starts the RIP routing process
Router(config-router)# **network** *ip-address*	Identifies a network to advertise via RIP
Router(config-router)# **version 2**	Enables RIPv2
Router(config-router)# **no auto-summary**	Disables automatic summarization for RIPv2 (RIPv1 always uses automatic summarization)
Router(config-if)# **ip rip send version** {**1** | **2**}	Specifies the version of RIP advertisements to send out of an interface
Router(config-if)# **ip rip receive version** {**1** | **2**}	Specifies the version of RIP advertisements an interface can receive
Router(config-if)# **ip rip authentication mode** {**text** | **md5**}	Specifies the type of authentication used by RIPv2 (RIPv1 does not support authentication)
Router(config)# **key chain** *name*	Defines a key chain used for authentication by a routing protocol
Router(config-keychain)# **key** *number*	Creates a key and enters keychain key configuration mode
Router(config-keychain-key)# **key-string** *string*	Identifies the string of characters that comprise the key

Lab 3

Configuring and Verifying EIGRP

This *Routing Video Mentor* lab examines the theory and configuration of *Enhanced Interior Gateway Routing Protocol* (EIGRP). EIGRP was originally developed by Cisco Systems, and it is categorized as a balanced hybrid routing protocol.

The objectives of this lab are as follows:

- Introduce EIGRP
- Describe the EIGRP metric
- Show the syntax for EIGRP configuration
- Configure EIGRP
- Disable auto-summarization
- Load balance using the *variance* feature
- Verify EIGRP operation

Scenario

This lab contains three main steps, as follows:

Step 1 Configure and verify EIGRP on all routers in the topology.

Step 2 Disable auto-summarization on all routers in the topology.

Step 3 Load balance across unequal cost paths using the *variance* feature.

Previous routing protocol configurations have been removed from the routers in the topology. Also, since EIGRP can consider bandwidth when making its routing decisions, be aware that the bandwidth of the link between router R1 and router BB1 is 128 kbps, and the bandwidth of the link between router R1 and router BB2 is 64 kbps.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 3-1, 3-2, 3-3, and 3-4 illustrate these initial configurations.

Example 3-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
```

continues

Example 3-1 Initial Configuration for R1 continued

```
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 3-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
```

Example 3-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 3-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.2 255.255.255.252
 snmp trap link-status
 frame-relay interface-dlci 821
```

EIGRP Configuration

This lab begins by configuring each router to use EIGRP as a routing protocol. Unlike RIP, the EIGRP process uses a specified *autonomous system number*. This autonomous system number must be configured identically for neighboring routers to exchange EIGRP routing updates.

Examples 3-5, 3-6, 3-7, and 3-8 show the initial EIGRP configuration commands added to the routers. Notice that each router uses an autonomous system number of 1.

Example 3-5 EIGRP Configuration for R1

```
router eigrp 1
 network 1.1.1.1 0.0.0.0
 network 172.16.1.0 0.0.0.3
 network 172.16.2.0 0.0.0.3
 network 192.168.1.0 0.0.0.3
```

Example 3-6 EIGRP Configuration for R2

```
router eigrp 1
 network 2.2.2.2 0.0.0.0
 network 10.1.2.0 0.0.0.255
 network 192.168.1.0 0.0.0.3
```

Example 3-7 EIGRP Configuration for BB1

```
router eigrp 1
 network 3.3.3.3 0.0.0.0
 network 10.1.1.0 0.0.0.3
 network 172.16.1.0 0.0.0.3
```

Example 3-8 EIGRP Configuration for BB2

```
router eigrp 1
 network 4.4.4.4 0.0.0.0
 network 10.1.1.0 0.0.0.3
 network 172.16.2.0 0.0.0.3
```

After the initial EIGRP configuration, the lab demonstrates that, by default, EIGRP advertises networks at their classful boundary. Specifically, in this lab, the 10.1.1.0/30 network, interconnecting routers BB1 and BB2, and the 10.1.2.0/24 network connected to router R2 are both advertised to router R1 as network 10.0.0.0/8. This is because a Class A IP address has an 8 bit classful subnet mask.

Therefore, given the FastEthernet link's more favorable EIGRP metric, router R1 always uses the FastEthernet link to Router R2 to reach any destination located in the 10.0.0.0/8 address space. As a result, network 10.1.1.0/30 becomes unreachable.

To overcome this default behavior, this lab disables EIGRP auto-summarization on all routers. Examples 3-9, 3-10, 3-11, and 3-12 illustrate the disabling of the auto-summarization feature.

Example 3-9 Disabling Auto-Summarization on R1

```
router eigrp 1
 no auto-summary
```

Example 3-10 Disabling Auto-Summarization on R2

```
router eigrp 1
 no auto-summary
```

Example 3-11 Disabling Auto-Summarization on BB1

```
router eigrp 1
 no auto-summary
```

Example 3-12 Disabling Auto-Summarization on BB2

```
router eigrp 1
 no auto-summary
```

In this lab, router R1 can access the backbone network (that is 10.1.1.0/30) via its Frame Relay link to BB1 operating at rate of 128 kbps or via its Frame Relay link to BB2 operating at a rate of 64 kbps. By default, EIGRP uses the link with the most attractive metric, which, by default, is based on bandwidth and delay. Therefore, router R1 uses its link to BB1 to reach network 10.1.1.0/30.

To increase throughput to the backbone network, enable the EIGRP variance feature. The variance feature allows EIGRP to load balance across unequal-cost paths. However, the cost (that is, the metric) must vary by no more than a specific factor, as configured with the **variance** command.

This lab uses a variance of 2. The variance parameter is a multiplier applied to the best metric, which creates a range of metrics across which EIGRP will route traffic. Example 3-13 illustrates the configuration of the variance feature on router R1.

Example 3-13 Configuring the Variance Feature on R1

```
router eigrp 1
 variance 2
```

Final Configuration

As a reference, Examples 3-14, 3-15, 3-16, and 3-17 provide the final configurations for routers R1, R2, BB1, and BB2, respectively.

Example 3-14 Final Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
!
router eigrp 1
 variance 2
 network 1.1.1.1 0.0.0.0
 network 172.16.1.0 0.0.0.3
 network 172.16.2.0 0.0.0.3
 network 192.168.1.0 0.0.0.3
 no auto-summary
```

Example 3-15 Final Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
!
router eigrp 1
 network 2.2.2.2 0.0.0.0
 network 10.1.2.0 0.0.0.255
 network 192.168.1.0 0.0.0.3
 no auto-summary
```

Example 3-16 Final Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
!
router eigrp 1
 network 3.3.3.3 0.0.0.0
 network 10.1.1.0 0.0.0.3
 network 172.16.1.0 0.0.0.3
 no auto-summary
```

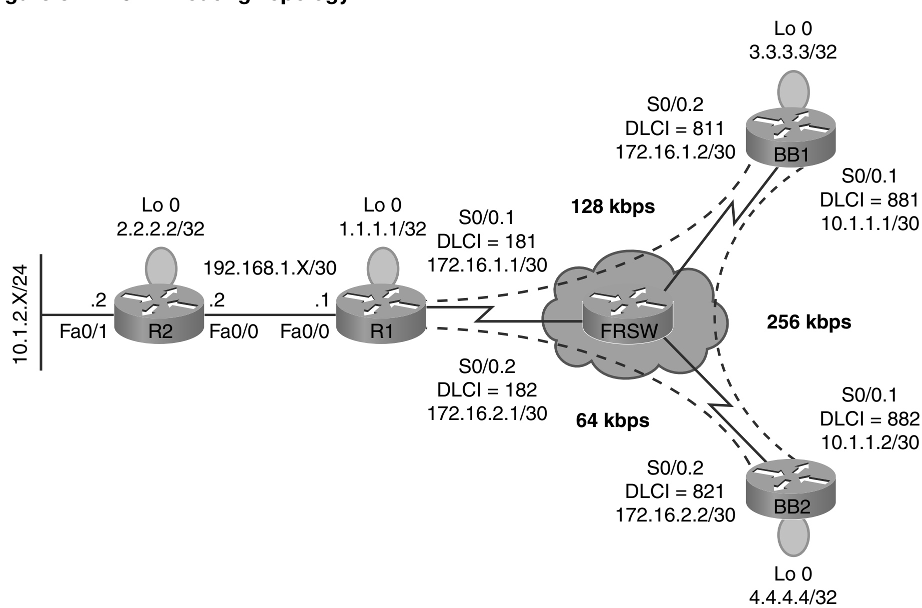
Example 3-17 Final Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
!
router eigrp 1
 network 4.4.4.4 0.0.0.0
 network 10.1.1.0 0.0.0.3
 network 172.16.2.0 0.0.0.3
 no auto-summary
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 3-1.

Figure 3-1 EIGRP Routing Topology



This lab also illustrates the use of several EIGRP-related IOS commands. The syntax for these commands is presented in Table 3-1.

Table 3-1 IOS Command Reference for Lab 3

Command	Description
Router(config)# **router eigrp** *autonomous-system-number*	Starts the EIGRP routing process (NOTE: All routers that exchange EIGRP routing information must use the same autonomous system number)
Router(config-router)# **network** *network* [*wildcard-mask*]	Specifies a connected network that will participate in the EIGRP routing process
Router(config-router)# **no auto-summary**	Disables automatic network summarization
Router(config-router)# **variance** *multiplier*	Determines the metric values over which EIGRP will load balance traffic

Lab 4

Configuring and Verifying Single-Area OSPF

This *Routing Video Mentor* lab examines the theory and configuration of the *Open Shortest Path First* (OSPF) routing protocol. While additional labs in the *Routing Video Mentor* will also address OSPF, this initial OSPF lab discusses the fundamentals of OSPF and illustrates a simple configuration with a single OSPF area.

The objectives of this lab are as follows:

- Introduce OSPF
- Describe Designated Router (DR)
- Enumerate OSPF network types
- Show the syntax for OSPF configuration
- Configure OSPF
- Manipulate the IP OSPF priority for an interface
- Verify OSPF operation

Scenario

This lab contains two main steps, as follows:

Step 1 Configure and verify OSPF on all routers in the topology.

Step 2 Influence the DR election.

Previous routing protocol configurations have been removed from the routers in the topology. Also, for this lab, all routers are considered to be in the same OSPF area, Area 0.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 4-1, 4-2, 4-3, and 4-4 illustrate these initial configurations.

Example 4-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
```

continues

Example 4-1 Initial Configuration for R1 continued

```
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 4-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
```

Example 4-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 4-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 ip address 172.16.2.2 255.255.255.252
 snmp trap link-status
 frame-relay interface-dlci 821
```

OSPF Configuration

This lab begins by configuring each router to use OSPF as a routing protocol. Unlike EIGRP, which used an autonomous system number, OSPF uses a process ID. The process ID is locally significant (that is, process IDs do not need to match on neighboring routers).

The syntax used by the **network** command used by OSPF specifies that a wildcard mask is used, as opposed to a subnet mask. However, this lab demonstrates that as a shortcut, you can specify the subnet mask, and it is automatically converted to the corresponding wildcard mask.

As another shortcut, this lab demonstrates that you can use a single **network** command to have all interfaces on a router participate in the same OSPF network. For example, you could use the **network 0.0.0.0 255.255.255.255 area 0** command to tell a router that all of its interfaces were to be associated with OSPF area 0.

Examples 4-5, 4-6, 4-7, and 4-8 show the initial OSPF configuration commands added to the routers. Notice that in the configuration for R2, a subnet mask was specified (rather than a wildcard mask). However, the resulting running configuration showed the corresponding wildcard mask.

Example 4-5 OSPF Configuration for R1

```
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 4-6 OSPF Configuration for R2

```
router ospf 1
 network 10.1.2.0 0.0.0.255 area 0
 network 192.168.1.0 255.255.255.252 area 0
 network 2.2.2.2 0.0.0.0 area 0
```

Example 4-7 OSPF Configuration for BB1

```
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 4-8 OSPF Configuration for BB2

```
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

On a multi-access network (such as the FastEthernet link between routers R1 and R2), rather than having all routers form adjacencies with all other routers, OSPF can elect a designated router (DR). All other routers on that multi-access network then form an adjacency with that DR. Also, a backup designated router (BDR) can be elected. All other routers would also form adjacencies with the BDR.

OSPF Priority Configuration

In this lab, to illustrate how the DR election could be influenced, the goal is to prevent router R2 from becoming the DR. Initially, this lab demonstrates that router R2 is the DR, due to router R2 having the highest IP address on its loopback interface. However, to influence router R1 to become the DR, this lab applies an OSPF priority of 0 to the FastEthernet 0/0 interface of router R2, thus preventing it from participating in a DR election.

Example 4-9 illustrates the configuration of an OSPF priority on router R2's FastEthernet 0/0 interface.

Example 4-9 Configuring an OSPF Priority on R2

```
interface FastEthernet0/0
 ip ospf priority 0
```

Final Configuration

As a reference, Examples 4-10, 4-11, 4-12, and 4-13 provide the final configurations for routers R1, R2, BB1, and BB2 respectively.

Example 4-10 Final Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
```

continues

Example 4-10 Final Configuration for R1 continued

```
bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 4-11 Final Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 ip ospf priority 0
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
!
router ospf 1
router ospf 1
 network 10.1.2.0 0.0.0.255 area 0
 network 192.168.1.0 0.0.0.3 area 0
 network 2.2.2.2 0.0.0.0 area 0
```

Example 4-12 Final Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

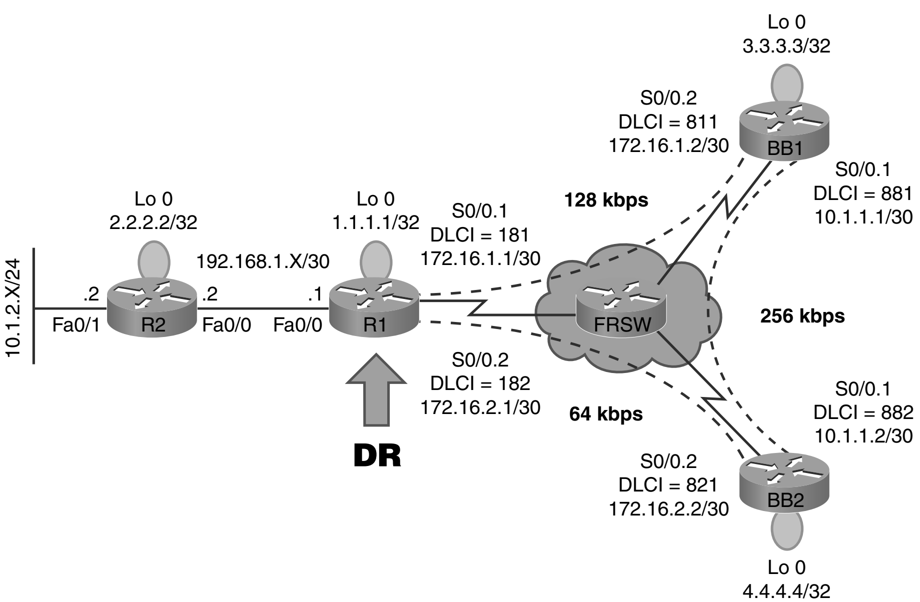
Example 4-13 Final Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 4-1.

Figure 4-1 OSPF Single-Area Routing Topology



This lab also illustrates the use of several OSPF-related IOS commands. The syntax for these commands is presented in Table 4-1.

Table 4-1 IOS Command Reference for Lab 4

Command	Description
Router(config)# **router ospf** *process-id*	Enables an OSPF process on a router
Router(config-router)# **network** *network* [*wildcard-mask*] **area** *number*	Identifies the networks participating in the OSPF process and the OSPF areas to which the networks belong
Router(config-if)# **ip ospf priority 0**	Prevents a router interface from participating in a DR election

Lab 5

Configuring OSPF for Multiple Areas and Frame Relay Nonbroadcast

This *Routing Video Mentor* lab builds on the theory of the OSPF routing protocol introduced in the previous lab. For example, this lab illustrates a nonbroadcast OSPF network type, which does not automatically learn neighboring routers. Also, this lab illustrates an OSPF topology with multiple areas, one of which is not contiguous with the OSPF backbone area of Area 0.

The objectives of this lab are as follows:

- Discuss the characteristics of a nonbroadcast OSPF network type
- Discuss the characteristics of multi-area OSPF networks
- Explain the need for a virtual link
- Show the syntax for OSPF configuration
- Configure OSPF for multiple areas
- Configure OSPF for a nonbroadcast OSPF network type
- Configure a virtual link
- Verify OSPF operation

Scenario

This lab contains three main steps, as follows:

Step 1 Configure OSPF on all routers in the topology.

Step 2 Specify neighboring OSPF routers for the Frame Relay network portion of the topology.

Step 3 Add a virtual link between Area 2 and Area 0.

This lab defines three OSPF areas: Area 0 (the backbone area), Area 1, and Area 2. Also, routers R1, BB1, and BB2 attach to the Frame Relay cloud via their serial interfaces, as opposed to the point-to-point subinterfaces demonstrated in the previous lab.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 5-1, 5-2, 5-3, and 5-4 illustrate these initial configurations.

Example 5-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 duplex auto
 speed auto
!
interface Serial0/0
 ip address 172.16.1.1 255.255.255.0
 encapsulation frame-relay
 frame-relay map ip 172.16.1.3 182 broadcast
 frame-relay map ip 172.16.1.2 181 broadcast
```

Example 5-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
```

Example 5-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 ip address 172.16.1.2 255.255.255.0
 encapsulation frame-relay
 frame-relay map ip 172.16.1.3 881 broadcast
 frame-relay map ip 172.16.1.1 811 broadcast
```

Example 5-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 ip address 172.16.1.3 255.255.255.0
 encapsulation frame-relay
 frame-relay map ip 172.16.1.1 821 broadcast
 frame-relay map ip 172.16.1.2 882 broadcast
```

OSPF Configuration

This lab begins by configuring each router to use OSPF as a routing protocol, with different networks participating in various OSPF areas. Examples 5-5, 5-6, 5-7, and 5-8 show the initial OSPF configuration commands added to the routers.

Example 5-5 Initial OSPF Configuration for R1

```
router ospf 1
 network 1.1.1.1 0.0.0.0 area 0
 network 172.16.1.0 0.0.0.255 area 0
 network 192.168.1.0 0.0.0.3 area 1
```

Example 5-6 Initial OSPF Configuration for R2

```
router ospf 1
 network 2.2.2.2 0.0.0.0 area 2
 network 10.1.2.0 0.0.0.255 area 2
 network 192.168.1.0 0.0.0.3 area 1
```

Example 5-7 Initial OSPF Configuration for BB1

```
router ospf 1
 network 3.3.3.3 0.0.0.0 area 0
 network 172.16.1.0 0.0.0.255 area 0
```

Example 5-8 Initial OSPF Configuration for BB2

```
router ospf 1
 network 4.4.4.4 0.0.0.0 area 0
 network 172.16.1.0 0.0.0.255 area 0
```

The default OSPF network type for a Frame Relay serial interface is *nonbroadcast*. Routers interconnecting via a nonbroadcast OSPF network type do not dynamically learn about one another. As a result, you need to use the **neighbor** command to tell a router at one end of a PVC about the router at the other end of the PVC. Also, be aware that only one of the two interconnected routers needs to be configured with the **neighbor** command. Examples 5-9 and 5-10 illustrate the neighbor configurations on routers R1 and BB2.

Example 5-9 Configuring OSPF Neighbors on R1

```
router ospf 1
 neighbor 172.16.1.2
 neighbor 172.16.1.3
```

Example 5-10 Configuring an OSPF Neighbor on BB2

```
router ospf 1
 neighbor 172.16.1.2
```

In a multiarea OSPF network, all networks must be adjacent to the backbone area (that is, Area 0). In this lab, Area 2 is not physically adjacent to Area 0. Therefore, a virtual link is configured to make Area 2 logically adjacent to Area 0. Examples 5-11 and 5-12 illustrate the configuration of the virtual link on routers R1 and R2.

Example 5-11 Configuring a Virtual Link on R1

```
router ospf 1
 area 1 virtual-link 2.2.2.2
```

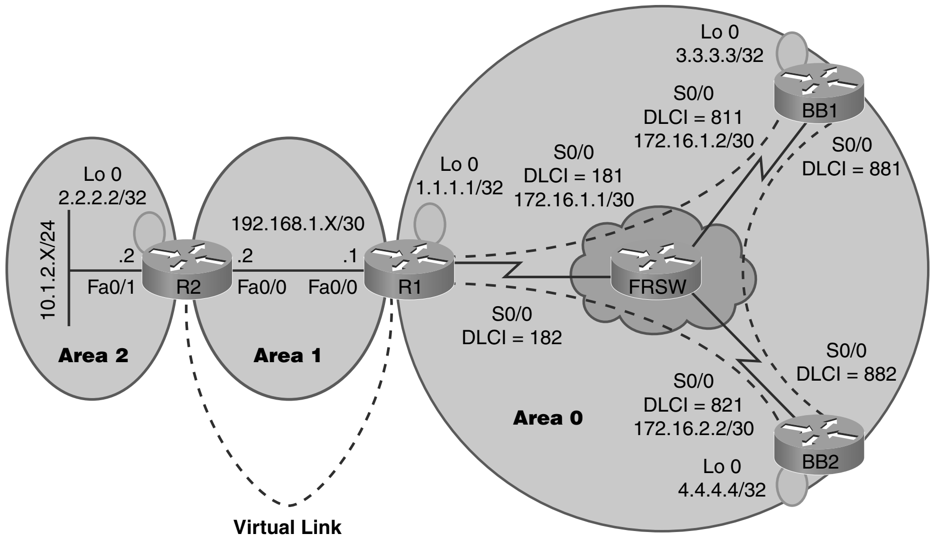
Example 5-12 Configuring a Virtual Link on R2

```
router ospf 1
 area 1 virtual-link 1.1.1.1
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 5-1.

Figure 5-1 OSPF Multi-Area Routing Topology



This lab also illustrates the use of several OSPF-related IOS commands. The syntax for these commands is presented in Table 5-1.

Table 5-1 IOS Command Reference for Lab 5

Command	Description
Router(config)# **router ospf** *process-id*	Enables an OSPF process on a router
Router(config-router)# **network** *network* [*wildcard-mask*] **area** *number*	Identifies the networks participating in the OSPF process and the OSPF areas to which the networks belong
Router(config-router)# **neighbor** *ip-address*	Statically configures a neighboring OSPF router in a nonbroadcast network
Router(config-router)# **area** *number* **virtual-link** *router-id*	Creates a virtual link between a router and Area 0 *number* = the area that is to be crossed to reach Area 0 *router-id* = the OSPF router ID of the router on the opposite end of the virtual link

Lab 6

Configuring and Verifying OSPF Route Summarization for Interarea and External Routes

This *Routing Video Mentor* lab continues to build on the theory of the OSPF routing protocol discussed in previous labs. Specifically, this lab demonstrates how to reduce the size of a routing table by summarizing contiguous network address spaces into a single route advertisement.

The objectives of this lab are as follows:

- Discuss the benefit of route summarization
- Explain how routes can be summarized between OSPF areas
- Describe how routes can be summarized into OSPF from another routing protocol
- Configure route summarization from connected routes into OSPF
- Configure route summarization from one OSPF area into another
- Verify OSPF route summarization

Scenario

This lab contains three main steps, as follows:

Step 1 Configure OSPF on all routers in the topology.

Step 2 Summarize routes originating outside of OSPF.

Step 3 Summarize routes originating in a different OSPF area.

This lab defines two OSPF areas: Area 0 (the backbone area) and Area 1. Note that the loopback interfaces on router R2 do not participate in any OSPF area.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 6-1, 6-2, 6-3, and 6-4 illustrate these initial configurations.

Example 6-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
```

continues

Example 6-1 Initial Configuration for R1 continued

```
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 6-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 10.10.1.1 255.255.255.0
!
interface Loopback1
 ip address 10.10.2.1 255.255.255.0
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
```

Example 6-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 2.1.1.1 255.255.255.255
!
interface Loopback1
 ip address 2.1.1.2 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 6-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

OSPF Configuration

This lab begins by configuring each router to use OSPF as a routing protocol, with most networks participating either in OSPF Area 0 or Area 1. The loopback interfaces on router R2, however, do not participate in an OSPF area. Therefore, to make these routes known to the OSPF routing process, these *connected* routes are redistributed into the OSPF routing process. Examples 6-5, 6-6, 6-7, and 6-8 show the initial OSPF configuration commands added to the routers.

Example 6-5 Initial OSPF Configuration for R1

```
router ospf 1
 network 1.1.1.1 0.0.0.0 area 0
 network 172.16.1.0 0.0.0.3 area 0
 network 172.16.2.0 0.0.0.3 area 0
 network 192.168.1.0 0.0.0.3 area 0
```

Example 6-6 Initial OSPF Configuration for R2

```
router ospf 1
 redistribute connected subnets
 network 192.168.1.0 0.0.0.3 area 0
```

Example 6-7 Initial OSPF Configuration for BB1

```
router ospf 1
 network 2.1.1.1 0.0.0.0 area 1
 network 2.1.1.2 0.0.0.0 area 1
 network 10.1.1.0 0.0.0.3 area 1
 network 172.16.1.0 0.0.0.3 area 0
```

Example 6-8 Initial OSPF Configuration for BB2

```
router ospf 1
 network 4.4.4.4 0.0.0.0 area 1
 network 10.1.1.0 0.0.0.3 area 1
 network 172.16.2.0 0.0.0.3 area 0
```

Routes that are statically configured, directly connected, or known to a non-OSPF routing protocol can be redistributed into the OSPF routing process. This redistribution allows other routers participating in an OSPF network to reach these redistributed networks. In this lab, the networks of router R2's loopback interfaces are redistributed into the OSPF routing process using the **summary-address** command. Example 5-9 illustrates this configuration on router R2.

Example 5-9 Configuring Address Summarization on R2

```
router ospf 1
 summary-address 10.10.0.0 255.255.252.0
```

Routers participating in large multi-area OSPF networks can often benefit from summarizing routes between OSPF areas. Specifically, these interarea route summarizations can reduce the size of routing tables that need to be maintained by the OSPF routers. Examples 5-10 and 5-11 show how the **area range** command is used in this lab to summarize route advertisements exiting Area 1 (from routers BB1 and BB2) and entering Area 0.

Example 5-10 Configuring Route Summarization on BB1

```
router ospf 1
 area 1 range 2.1.1.0 255.255.255.252
```

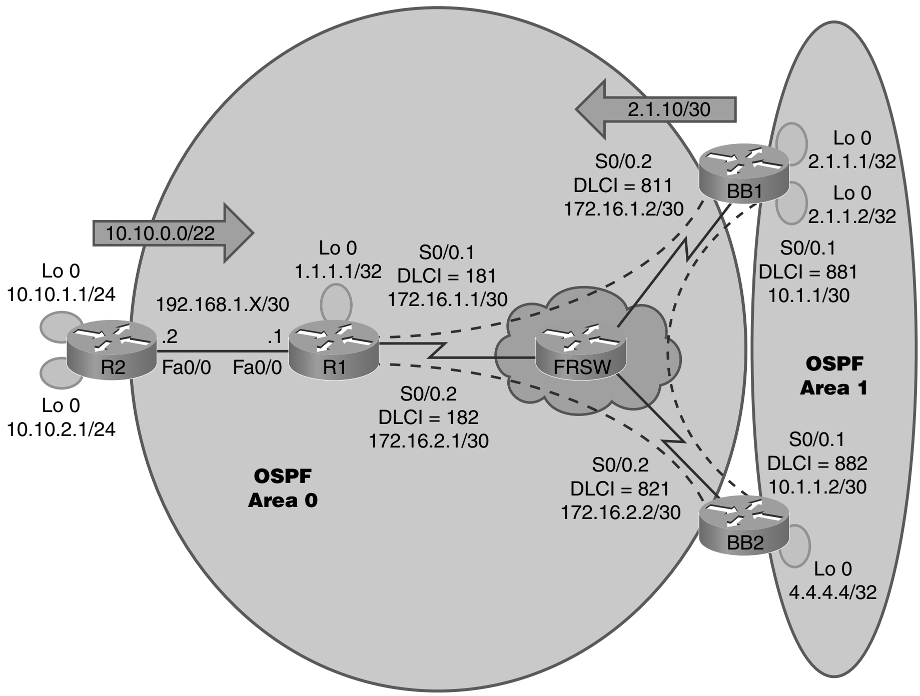
Example 5-11 Configuring Route Summarization on BB2

```
router ospf 1
 area 1 range 2.1.1.0 255.255.255.252
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 6-1.

Figure 6-1 OSPF Routing Topology



This lab also illustrates the use of several OSPF-related IOS commands. The syntax for these commands is presented in Table 6-1.

Table 6-1 IOS Command Reference for Lab 6

Command	Description
Router(config)# **router ospf** *process-id*	Enables an OSPF process on a router
Router(config-router)# **area** *area-number* **range** *summary-network-address subnet-mask*	Summarizes OSPF-advertised networks in an area into a summary address which can be advertised to a different area
Router(config-router)# **summary-address** *summary-network-address subnet-mask*	Summarizes routes from a non-OSPF routing protocol (including statically configured and directly connected networks) into an OSPF route advertisement

Lab 7

Configuring Route Redistribution

This *Routing Video Mentor* lab demonstrates how route information can be exchanged between dissimilar routing protocols, specifically OSPF and EIGRP. Because OSPF and EIGRP use different metrics, the autonomous system boundary router (that is, the router connecting to both the OSPF and EIGRP networks) needs to be configured to redistribute routes from each of the routing protocols into one another.

The objectives of this lab are as follows:

- Describe the need for route redistribution
- Explain the function of a boundary router
- Discuss the purpose of a seed metric
- Show the syntax for route redistribution
- Configure a portion of the lab topology for EIGRP
- Configure a portion of the lab topology for OSPF
- Configure route redistribution on the boundary router
- Verify route redistribution

Scenario

This lab contains two main steps, as follows:

Step 1 Configure routing protocols on all routers in the topology.

Step 2 Mutually redistribute routes in the OSPF and EIGRP domains.

This lab uses the EIGRP routing protocol for a portion of the topology and the OSPF routing protocol for the remainder of the topology. Router R1 sits between these two routing domains and is therefore configured for both EIGRP and OSPF.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 7-1, 7-2, 7-3, and 7-4 illustrate these initial configurations.

Example 7-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
```

continues

Example 7-1 Initial Configuration for R1 continued

```
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 7-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
```

Example 7-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 7-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

Routing Protocol Configuration

This lab begins by configuring each router for OSPF or EIGRP. The OSPF routing domain has a single area (Area 0). Examples 7-5, 7-6, 7-7, and 7-8 show the initial routing protocol configuration commands added to the routers.

Example 7-5 EIGRP and OSPF Configuration for R1

```
router eigrp 100
 network 192.168.1.0
 no auto-summary
!
router ospf 1
 network 1.1.1.1 0.0.0.0 area 0
 network 172.16.1.0 0.0.0.3 area 0
 network 172.16.2.0 0.0.0.3 area 0
```

Example 7-6 EIGRP Configuration for R2

```
router eigrp 100
 network 2.0.0.0
 network 10.0.0.0
 network 192.168.1.0
 no auto-summary
```

Example 7-7 OSPF Configuration for BB1

```
router ospf 1
 network 3.3.3.3 0.0.0.0 area 0
 network 10.1.1.0 0.0.0.3 area 0
 network 172.16.1.0 0.0.0.3 area 0
```

Example 7-8 OSPF Configuration for BB2

```
router ospf 1
 network 4.4.4.4 0.0.0.0 area 0
 network 10.1.1.0 0.0.0.3 area 0
 network 172.16.2.0 0.0.0.3 area 0
```

OSPF routes have a default seed metric of 20. Therefore, when EIGRP routes are redistributed into OSPF, those EIGRP routes begin with an OSPF metric of 20. Also, the **subnet** parameter was appended to the **redistribute eigrp 100** command to redistribute specific EIGRP subnets into OSFP, as opposed to redistributing classful routes originating in EIGRP.

EIGRP does not have a default seed metric. Therefore, the **default-metric** command is used to specify the bandwidth, delay, reliability, load, and MTU parameters associated with routes originating in OSPF. Example 7-9 illustrates the redistribution configuration commands issued on router R1.

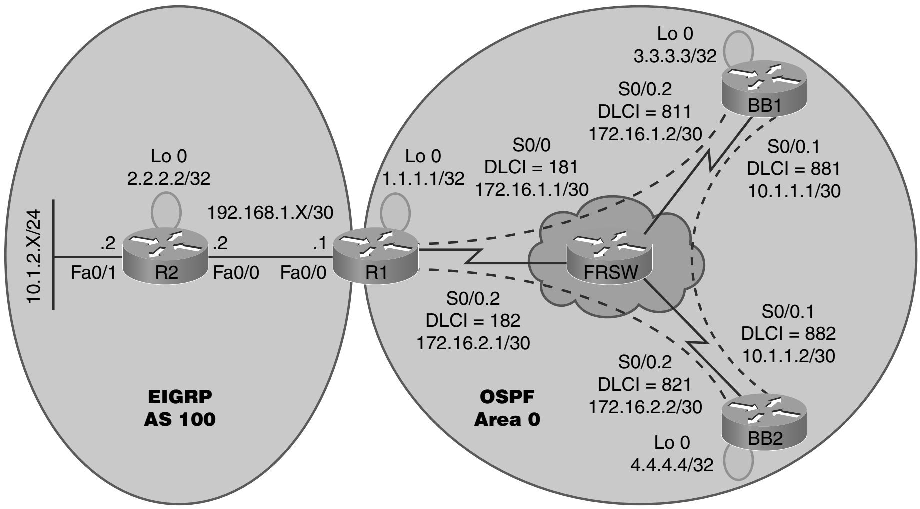
Example 7-9 Configuring Route Redistribution on R1

```
router eigrp 100
 redistribute ospf 1
 default-metric 100000 10 255 1 1500
!
router ospf 1
 redistribute eigrp 100 subnets
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 7-1.

Figure 7-1 Lab 7 Routing Topology



This lab also illustrates the use of several OSPF-related IOS commands. The syntax for these commands is presented in Table 7-1.

Table 7-1 IOS Command Reference for Lab 7

Command	Description
Router(config)# **router ospf** *process-id*	Enables an OSPF process on a router
Router(config-router)# **redistribute eigrp** *autonomous-system-number* **subnets**	Redistributes routes, including subnetted routes, from a specified EIGRP autonomous system into OSPF
Router(config)# **router eigrp** *autonomous-system-number*	Enables an EIGRP routing process on a router
Router(config-router)# **redistribute ospf** *process-id bandwidth delay reliability load mtu*	Redistributes routes from a specified OSPF process ID into EIGRP
Router(config-router)# **default-metric** *bandwidth delay reliability load mtu*	Specifies the parameters used to calculate the seed metric for routes being redistributed into EIGRP, using the following EIGRP metric parameters: *bandwidth* (in kbps) *delay* (in tens of microseconds) *reliability* (maximum of 255) *load* (minimum of 1) *mtu* (in bytes)

Lab 8

Configuring Integrated IS-IS Routing

This *Routing Video Mentor* lab illustrates the configuration of the IS-IS routing protocol. Specifically, *Integrated IS-IS* is configured, which supports the routing of IP traffic. Integrated IS-IS has some similarities to the OSPF routing protocol, in that it is a link-state routing protocol; it can divide the network into areas; and it uses the Dijkstra algorithm.

This lab also demonstrates IS-IS authentication. Specifically, within Area 100, neighbor authentication is configured on the interfaces interconnecting Area 100 routers. The routers that are members of Area 100 are configured with an area password. Additionally, the Layer 1-2 routers in Areas 100 and 200 (that is, routers R1 and R2, respectively) are configured for domain authentication.

The objectives of this lab are as follows:

- Introduce IS-IS
- Discuss lab topology
- Explain IS-IS NSAP addressing
- Show the syntax for IS-IS routing
- Configure the lab topology for the IS-IS routing protocol
- Configure IS-IS area authentication
- Configure IS-IS domain authentication
- Verify operation of the IS-IS routing protocol

Scenario

This lab contains two main steps, as follows:

Step 1 Configure Integrated IS-IS on all routers in the topology.

Step 2 Configure Integrated IS-IS neighbor authentication, area authentication, and domain authentication.

This lab divides the topology into two Integrated IS-IS areas. Routers R1, BB1, and BB2 are members of Area 100, while router R2 is a member of Area 200.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 8-1, 8-2, 8-3, and 8-4 illustrate these initial configurations.

Example 8-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 8-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
```

Example 8-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 8-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

Basic Integrated IS-IS Configuration

This lab begins by configuring each router for Integrated IS-IS. Notice the structure of the NSAP address, as specified by the **net** command. The first portion of the NSAP address reflects the *Authority and Format Identifier* (AFI), which is a 49 for a locally administered AFI. The *Area ID* is represented by four digits (for example, Area 100 is represented as 0100). The *System ID* is represented by twelve digits uniquely identifying the router. This lab used the IP address of a router's Loopback 0 interface for this unique System ID. For example, a loopback IP address of 1.1.1.1 would translate into a System ID of 0010.0100.1001. Finally, the *NSAP Selector* (that is, the NSEL) is always 00 for a router. Therefore, as an example, for router R1 (with an Area ID of 100 and a loopback IP address of 1.1.1.1), an NSAP address of 49.0100.0010.0100.1001.00 is used. Examples 8-5, 8-6, 8-7, and 8-8 show the initial Integrated IS-IS configuration commands added to the routers.

Example 8-5 Integrated IS-IS Configuration for R1

```
router isis
 net 49.0100.0010.0100.1001.00
!
interface Loopback0
 ip router isis
!
interface FastEthernet0/0
 ip router isis
!
interface Serial0/0.1
 ip router isis
!
interface Serial0/0.2
 ip router isis
```

Example 8-6 Integrated IS-IS Configuration for R2

```
router isis
 net 49.0200.0020.0200.2002.00
!
interface Loopback0
 ip router isis
!
interface FastEthernet0/0
 ip router isis
!
interface FastEthernet0/1
 ip router isis
!
```

Example 8-7 Integrated IS-IS Configuration for BB1

```
router isis
 net 49.0100.0030.0300.3003.00
 is-type level-1
!
interface Loopback0
 ip router isis
!
interface Serial0/0.1
 ip router isis
!
interface Serial0/0.2 point-to-point
 ip router isis
```

Example 8-8 Integrated IS-IS Configuration for BB2

```
router isis
 net 49.0100.0040.0400.4004.00
 is-type level-1
!
interface Loopback0
 ip router isis
!
interface Serial0/0.1
 ip router isis
!
interface Serial0/0.2
 ip router isis
```

To prevent any unwanted Integrated IS-IS adjacencies from forming between routers in Area 100, neighbor authentication is configured on each of the interfaces interconnecting routers R1, BB1, and BB2. Also, to authenticate information being exchanged between Area 100 routers, area authentication is configured in router configuration mode. Additionally, to authenticate Integrated IS-IS information exchanged between Area 100 and Area 200, the Level 1-2 routers from those areas (that is, routers R1 and R2) are configured for domain authentication, in router configuration mode. Examples 8-9, 8-10, 8-11, and 8-12 show these authentication commands.

Example 8-9 Configuring Integrated IS-IS Authentication on R1

```
interface Serial0/0.1
 isis password ciscopress1
!
interface Serial0/0.2
 isis password ciscopress1
!
router isis
 domain-password ciscopress3
 area-password ciscopress2
```

Example 8-10 Configuring Integrated IS-IS Authentication on R2

```
router isis
 domain-password ciscopress3
```

Example 8-11 Configuring Integrated IS-IS Authentication on BB1

```
interface Serial0/0.1
 isis password ciscopress1
!
interface Serial0/0.2
 isis password ciscopress1
!
router isis
 area-password ciscopress2
```

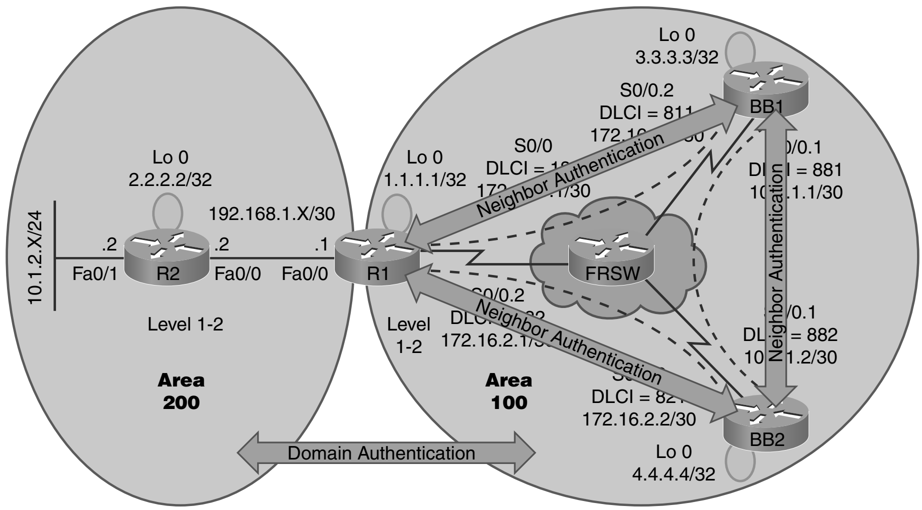
Example 8-12 Configuring Integrated IS-IS Authentication on BB2

```
interface Serial0/0.1
 isis password ciscopress1
!
interface Serial0/0.2
 isis password ciscopress1
!
router isis
 area-password ciscopress2
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 8-1.

Figure 8-1 Lab 8 Routing Topology



This lab also illustrates the use of several Integrated IS-IS IOS commands. The syntax for these commands is presented in Table 8-1.

Table 8-1 IOS Command Reference for Lab 8

Command	Description
Router(config)# **router isis**	Starts an IS-IS routing process on a router
Router(config-router)# **net** *nsap-address*	Specifies the NSAP address used by a router's IS-IS routing process
Router(config-router)# **is-type** {**level-1** | **level-1-2** | **level-2**}	Identifies a router as a particular IS-IS router type (defaults to level-1-2)
Router(config-router)# **domain-password** *password*	Configures a password that is inserted into Level 2 LSPs, to provide authentication between different IS-IS areas
Router(config-router)# **area-password** *password*	Configures a password to be configured on all routers in an IS-IS area to provide area authentication
Router(config-if)# **ip router isis**	Instructs an interface to participate in the IS-IS routing process
Router(config-if)# **isis password** *password* **level-1**	Prevents unwanted IS-IS adjacencies from forming with an interface by enabling an authentication password for an interface

Lab 9

Configuring and Verifying Policy-Based Routing

This *Routing Video Mentor* lab offers an example of how policy-based routing (PBR) can be used to influence the path of traffic through a network. Specifically, even though a routing protocol dictates that a packet take one path to a destination, PBR can influence the packet to take an alternate path to its destination.

With OSPF configured on all routers, this lab observes that traffic flowing from router R2's FastEthernet 0/0 interface to router BB1's loopback interface flows from router R1 directly to router BB1, due to the OSPF metric of that route. However, this lab demonstrates how PBR can be configured to cause this traffic to exit router R1 with router BB2 as its next-hop. The traffic then flows from router BB2 to router BB1. While this path is suboptimal from OSPF's perspective, there might be some sort of traffic engineering requirement for traffic to flow over such an alternate path.

The objectives of this lab are as follows:

- Introduce policy-based routing
- Discuss route maps
- Examine lab topology diagram
- Show the syntax for policy-based routing
- Configure the lab topology for the OSPF routing protocol
- Determine how OSPF routes traffic to a specific destination
- Configure policy-based routing
- Verify policy-based routing alters the path of traffic through the network

Scenario

This lab contains two main steps, as follows:

Step 1 Configure OSPF on all routers in the topology.

Step 2 Configure PBR on router R1 to influence the next-hop IP address of specific traffic.

This lab groups all routers into a single OSPF area, Area 0. Recall that OSPF uses a metric of *cost*, which is based on calculated bandwidth.

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 9-1, 9-2, 9-3, and 9-4 illustrate these initial configurations.

Example 9-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 9-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
```

Example 9-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 9-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

OSPF Configuration

This lab begins by configuring each router for OSPF, and the interfaces of all routers participate in OSPF Area 0. When configuring OSPF, a **network** command is typically issued for each interface on a router participating in a specific OSPF area. However, as a shortcut, if all interfaces on a router participate in a single OSPF area, a single **network** command can be issued. In this lab all interfaces on all routers participate in OSPF Area 0. Therefore, in router configuration mode for OSPF, the command **network 0.0.0.0 0.0.0.0 area 0** is issued on each router. (Note that the subnet mask of 0.0.0.0 is automatically converted into the corresponding wildcard mask of 255.255.255.255 in the IOS configuration. However, 0.0.0.0 is quicker to type), This single **network** statement causes all interfaces on the router to participate in OSPF Area 0. Examples 9-5, 9-6, 9-7, and 9-8 show the initial OSPF configuration commands added to the routers.

Example 9-5 OSPF Configuration for R1

```
router ospf 1
 network 0.0.0.0 0.0.0.0 area 0
```

Example 9-6 OSPF Configuration for R2

```
router ospf 1
 network 0.0.0.0 0.0.0.0 area 0
```

Example 9-7 OSPF Configuration for BB1

```
router ospf 1
 network 0.0.0.0 0.0.0.0 area 0
```

Example 9-8 OSPF Configuration for BB2

```
router ospf 1
 network 0.0.0.0 0.0.0.0 area 0
```

The goal of this lab it to cause traffic originating from 192.168.1.2 (that FastEthernet 0/0 interface on router R2) to be forwarded out of router R1 with a next-hop IP address of 172.16.2.2, rather than 172.16.1.2 (which is the next-hop IP address determined by OSPF). First, an access list is configured to match traffic sourced from an IP address of 192.168.1.2. Example 9-9 shows the configuration of this access list on router R1.

Example 9-9 Configuring an Access List on R1

```
access-list 1 permit 192.168.1.2
```

Next, a route map is configured to set the next-hop IP address for traffic matching access list 1. Example 9-10 illustrates this route map configuration.

Example 9-10 Configuring a Route Map on R1

```
route-map PBR-TEST permit 10
 match ip address 1
 set ip next-hop 172.16.2.2
```

Finally, the route map is applied to interface FastEthernet 0/0 on router R1, because traffic sourced from 192.168.1.2 enters router R1 on this interface. Example 9-11 demonstrates the application of the route map to interface FastEthernet 0/0.

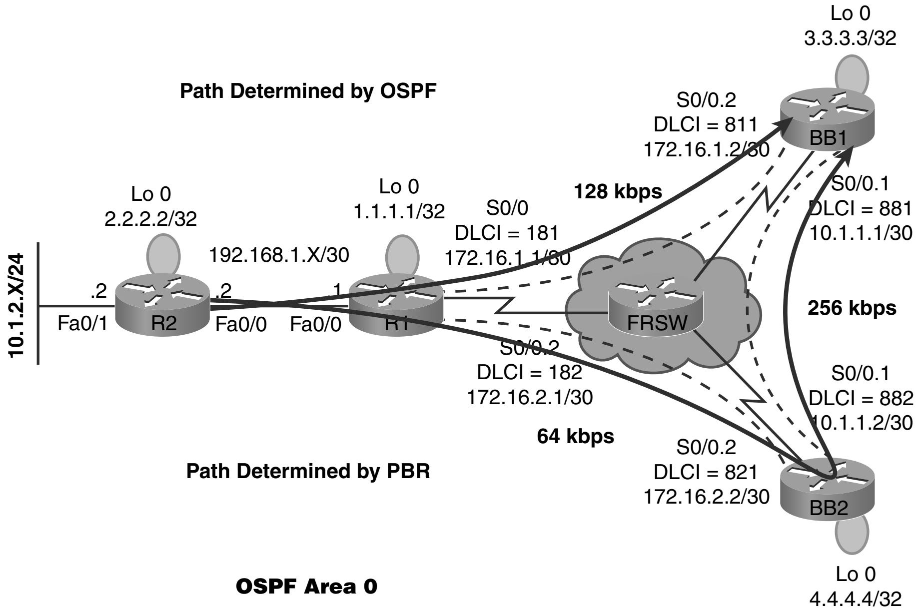
Example 9-11 Applying a Route Map to an Interface on R1

```
interface FastEthernet0/0
 ip policy route-map PBR-TEST
```

Video Presentation Reference

This lab presented a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 9-1.

Figure 9-1 Lab 9 Routing Topology



This lab also illustrates the use of several PBR-related commands. The syntax for these commands is presented in Table 9-1.

Table 9-1 IOS Command Reference for Lab 9

Command	Description
Router(config)# **router ospf** *process-id*	Enables an OSPF process on a router
Router(config-router)# **network 0.0.0.0 0.0.0.0 area** *number*	Configures all of a router's connected interfaces to participate in the specified OSPF area
Router(config)# **route-map** *tag* [**permit** | **deny**] [*seq-num*]	Creates a route map
Router(config-route-map)# **match ip address** *acl-number*	Causes the route map to match traffic which matches a specified access control list (ACL)
Router(config-route-map)# **set ip next-hop** *ip-address*	Sets the next-hop IP address for traffic matched by a route map
Router(config-if)# **ip policy route-map** *tag*	Applies a route map to an interface

Lab 10

Configuring Multihome BGP

This *Routing Video Mentor* lab introduces Border Gateway Protocol (BGP) as a solution for routing between autonomous systems (that is, networks under different administrative controls). BGP is commonly used to route between Internet service providers (ISPs), and if a corporate network connects to more than one ISP (for redundancy purposes as an example), that corporate network might also benefit by running BGP on its Internet router and peering with each of its service providers. Such a configuration is called *multihome BGP*.

BGP is considered to be an exterior gateway protocol (EGP), whereas interior gateway protocols (IGPs), such as OSPF and EIGRP, are used to route traffic within an autonomous system. This lab mirrors a real-world application, where the corporate routers run OSPF as their IGP, but the corporate Internet router also runs BGP to peer with each of its ISPs.

Also, similar to a real-world deployment, the corporate network (represented by routers R1 and R2 in this lab) runs OSPF as the routing protocol, while R1 interconnects with the ISP routers (that is routers BB1 and BB2) via BGP. Also, because R1 is multihomed to the Internet (represented by network 10.1.1.0/30 in this lab), if R1 were to lose its link with BB1 or BB2, R1 should still be able to reach the Internet via the alternate path. This redundancy feature is verified by shutting down the primary link being used by R1 to access the Internet and confirming reconvergence over the backup link.

The objectives of this lab are as follows:

- Introduce Border Gateway Protocol (BGP)
- Discuss how BGP selects paths
- Examine lab topology diagram
- Show the syntax for BGP configuration
- Configure a portion of the lab topology for OSPF
- Configure a portion of the lab topology for BGP
- Configure a default route advertisement on the backbone BGP routers
- Redistribute OSPF-learned routes into BGP
- View the IP routing table and the BGP forwarding table on Router R1
- Cause a link failure and then verify that BGP reroutes around the failure

Scenario

This lab contains three main steps, as follows:

Step 1 Configure the OSPF domain in the topology.

Step 2 Configure the BGP domain of the topology.

Step 3 Originate a default route from the ISP routers, and propagate the default route into the OSPF domain.

This lab defines OSPF Area 0 as containing all interfaces on router R2 and the FastEthernet 0/0 interface on router R1. OSPF represents the IGP being used by the corporate network in this example, while BGP represents the EGP being used between the corporate network and the ISP routers (that is, routers BB1 and BB2).

Initial Configurations

All routers in the topology begin with hostnames, IP addressing, and Layer 2 encapsulation (where required). Examples 10-1, 10-2, 10-3, and 10-4 illustrate these initial configurations.

Example 10-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 64
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 10-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
```

Example 10-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 10-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

OSPF Configuration

This lab begins by configuring the OSPF domain of the topology. Examples 10-5 and 10-6 illustrate this initial OSPF configuration on routers R2 and R1.

Example 10-5 OSPF Configuration for R2

```
router ospf 1
 network 0.0.0.0 0.0.0.0 area 0
```

Example 10-6 OSPF Configuration for R1

```
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
```

Router R1 acts as a boundary router, between the OSPF and BGP domains. Therefore, router R1 has a BGP configuration in addition to an OSPF configuration. Examples 10-7, 10-8, and 10-9 show BGP configurations applied to routers R1, BB1, and BB2.

Example 10-7 BGP Configuration for R1

```
router bgp 65001
 network 1.1.1.1 mask 255.255.255.255
 network 172.16.1.0 mask 255.255.255.252
 network 172.16.2.0 mask 255.255.255.252
 neighbor 172.16.1.2 remote-as 65002
 neighbor 172.16.2.2 remote-as 65003
```

Example 10-8 BGP Configuration for BB1

```
router bgp 65002
 network 3.3.3.3 mask 255.255.255.255
 network 10.1.1.0 mask 255.255.255.252
 network 172.16.1.0 mask 255.255.255.252
 neighbor 10.1.1.2 remote-as 65003
 neighbor 172.16.1.1 remote-as 65001
```

Example 10-9 BGP Configuration for BB2

```
router bgp 65003
 network 4.4.4.4 mask 255.255.255.255
 network 10.1.1.0 mask 255.255.255.252
 network 172.16.2.0 mask 255.255.255.252
 neighbor 10.1.1.1 remote-as 65002
 neighbor 172.16.2.1 remote-as 65001
```

This lab simulates a real-world scenario where ISPs send default route information out to their customers. In this lab, routers BB1 and BB2 originate default route information and send that default route information to router R1. Router R1 then sends that default route information to the corporate network (that is, router R2 in this lab) via OSPF. Examples 10-10, 10-11, and 10-12 illustrate the configuration on the routers in the topology to make default route information from ISPs available to customer routers.

Example 10-10 Default Route Configuration on BB1

```
ip route 0.0.0.0 0.0.0.0 null 0
!
router bgp 65002
 network 0.0.0.0
```

Example 10-11 Default Route Configuration on BB2

```
ip route 0.0.0.0 0.0.0.0 null 0
!
router bgp 65003
 network 0.0.0.0
```

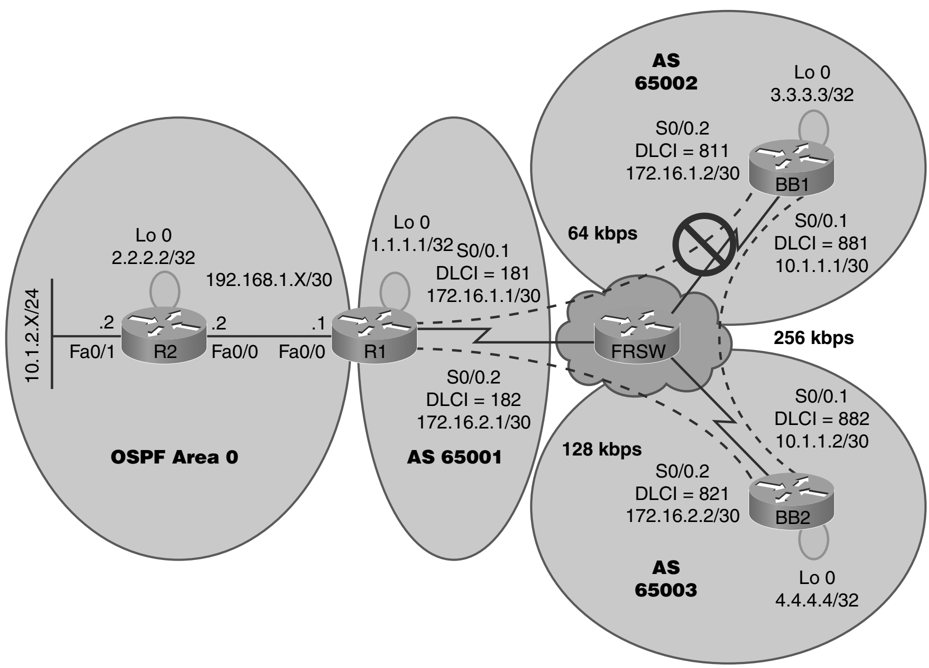
Example 10-12 Default Route Injection into OSPF on R1

```
router ospf 1
 default-information originate
```

Video Presentation Reference

This lab presented a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 10-1.

Figure 10-1 Lab 10 Routing Topology



This lab also illustrates the use of several BGP-related commands. The syntax for these commands is presented in Table 10-1.

Table 10-1 IOS Command Reference for Lab 10

Command	Description
Router(config)# **router bgp** *as-number*	Enables the BGP process for a specific autonomous system
Router(config-router)# **network** *network-address* [**mask** *subnet-mask*]	Specifies a network to be advertised by the BGP routing process
Router(config-router)# **neighbor** *ip-address* **remote-as** *as-number*	Forms a BGP neighborship with a BGP peer located at the specified IP address, belonging to the specified autonomous system

Lab 11

Using Route Maps for BGP Path Selection

This *Routing Video Mentor* lab builds on the previous lab (Lab 10, "Configuring Multihome BGP"). Specifically, Lab 10 illustrated the configuration of BGP to interconnect a corporate network (that is, routers R1 and R2) with two Internet service providers (ISPs). Routers BB1 and BB2 acted as the two ISP routers, and network 10.1.1.0/30 represented the Internet.

During Lab 10, the observation was made that traffic flowing from the corporate network to the Internet used the link between R1 and BB1 (a link configured for 64 kbps), rather than the link between R1 and BB2 (a link configured for 128 kbps). The reason R1 chose the link to BB1 was due to BB1 having a lower BGP router ID than BB2. The lowest BGP router ID is used as the decision-making criterion, if all other BGP path selection parameters (enumerated in Lab 10) are equal.

In this lab, a couple of BGP path selection parameters are configured on R1 to influence both outbound and inbound routing paths. The objectives of this lab are as follows:

- Discuss BGPs local preference attribute
- Show how local preference attributes will be used in the lab topology
- Discuss BGPs ASPATH attribute
- Show how an ASPATH attribute will be used in the lab topology
- Show the syntax for using route maps to configure BGP attributes
- Configure route maps to set local preference attributes
- Verify outgoing path selection
- Configure a route map to set an ASPATH attribute
- Verify incoming path selection

Scenario

This lab contains two main steps, as follows:

Step 1 Configure local preference values to influence outbound path selection on R1.

Step 2 Configure the ASPATH attribute to influence inbound path selection on R1.

The initial lab configuration is fully functional. However, the 64 kbps link between R1 and BB1 is being used (as opposed to the 128 kbps link between R1 and BB2) for sending traffic to the Internet, and some return traffic from the Internet also uses the suboptimal 64 kbps link.

Therefore, this lab manipulates the local preference and ASPATH attributes to influence BGP to use the 128 kbps link for traffic flowing between the corporate network (that is, routers R1 and R2) and the Internet (that is, network 10.1.1.0/30).

Initial Configurations

This lab begins with the ending configuration of Lab 10. Therefore, BGP and OSPF are already configured. OSPF routes are being redistributed into BGP, and a default route is being injected into OSPF. Examples 11-1, 11-2, 11-3, and 11-4 illustrate these initial configurations.

Example 11-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 64
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
!
router ospf 1
 network 192.168.1.0 0.0.0.3 area 0
 default-information originate
!
router bgp 65001
 network 1.1.1.1 mask 255.255.255.255
 network 172.16.1.0 mask 255.255.255.252
 network 172.16.2.0 mask 255.255.255.252
 redistribute ospf 1
 neighbor 172.16.1.2 remote-as 65002
 neighbor 172.16.2.2 remote-as 65003
```

Example 11-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 11-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
  frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 64
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
!
router bgp 65002
 network 0.0.0.0
 network 3.3.3.3 mask 255.255.255.255
 network 10.1.1.0 mask 255.255.255.252
 network 172.16.1.0 mask 255.255.255.252
 neighbor 10.1.1.2 remote-as 65003
 neighbor 172.16.1.1 remote-as 65001

!
ip route 0.0.0.0 0.0.0.0 null 0
```

Example 11-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
!
router bgp 65003
 network 0.0.0.0
 network 4.4.4.4 mask 255.255.255.255
 network 10.1.1.0 mask 255.255.255.252
 network 172.16.2.0 mask 255.255.255.252
 neighbor 10.1.1.1 remote-as 65002
 neighbor 172.16.2.1 remote-as 65001
!
ip route 0.0.0.0 0.0.0.0 null 0
```

Local Preference Configuration

This lab influences BGP path selection through configuration on router R1, rather than routers BB1 or BB2. The reason the configuration is confined to R1 is to simulate a real-world scenario where a network administrator would have administrative control over their own corporate network (that is, R1 and R2 in this lab) but would not have administrative control over ISP routers (that is, BB1 and BB2 in this scenario).

Initially, this lab influences outbound path selection, such that R1 prefers the 128 kbps link to BB2, rather than the 64 kbps link to BB1, to get out to the Internet. Specifically, local preference values are configured for incoming route advertisements from BB1 and BB2.

BGP prefers routes with higher local preference values. Routes advertised from BB1 are assigned a local preference of 100, while routes advertised from BB2 are assigned a local preference of 200. Example 11-5 shows this configuration.

Example 11-5 Local Preference Configuration for R1

```
route-map LOCALPREF-BB1
 set local-preference 100
!
route-map LOCALPREF-BB2
 set local-preference 200
!
router bgp 65001
 neighbor 172.16.1.2 route-map LOCALPREF-BB1 in
 neighbor 172.16.2.2 route-map LOCALPREF-BB2 in
```

Configuring the local preference values makes R1 prefer the 128 kbps link to BB2 rather than the 64 kbps link to BB1. However, that configuration only impacts outbound route selection from BB1. To influence incoming route selection (that is, for traffic coming into R1 from the Internet), R1 is configured to prepend two additional instances of its autonomous system to the autonomous system path (ASPATH) attribute assigned to routes advertised by R1 to BB1. Therefore, from the perspective of BB1, routes available via R1 appear to be two additional autonomous system hops away. This less attractive autonomous system path causes BB1 to prefer to route traffic destined for R1 via BB1s 256 kbps link to BB2 and then over BB2s 128 kbps link to R1. Example 11-6 illustrates this autonomous system path prepend configuration.

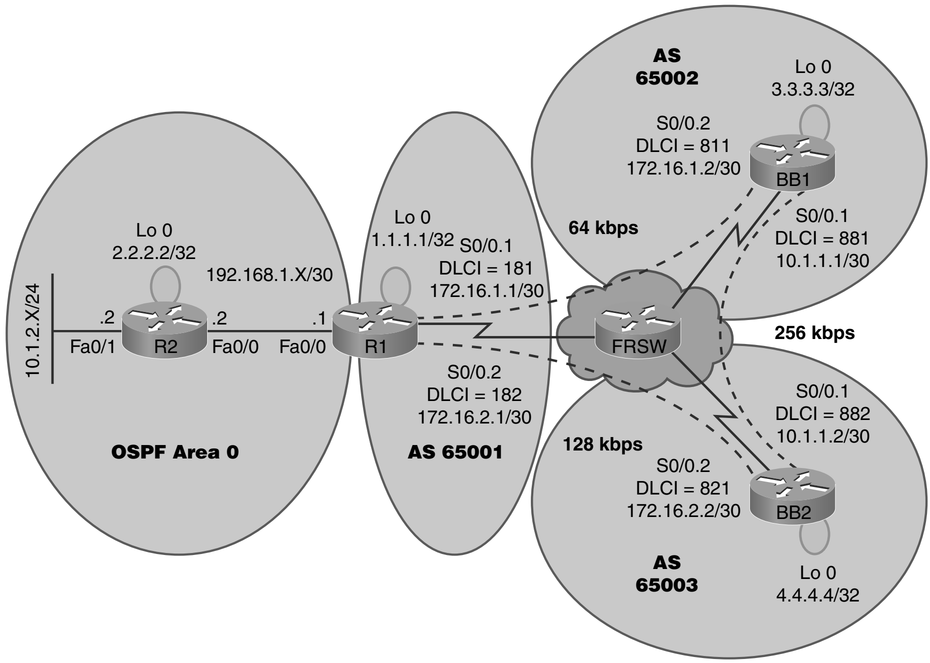
Example 11-6 Autonomous System Path Prepend Configuration for R1

```
route-map ASPATH permit 10
 set as-path prepend 65001 65001
!
router bgp 65001
 neighbor 172.16.1.2 route-map ASPATH out
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 11-1.

Figure 11-1 Lab 11 Routing Topology



This lab also illustrates the use of several BGP-related commands. The syntax for these commands is presented in Table 11-1.

Table 11-1 IOS Command Reference for Lab 11

Command	Description
Router(config)# **route-map** *tag* [**permit** | **deny**] [*seq-num*]	Creates a route map
Router(config-route-map)# **set local-preference** *local-preference*	Sets the local preference BGP attribute for routes matched by a route map
Router(config-route-map)# **set as-path prepend** *autonomous-system-number-1* [*…autonomous-system-number-n*]	Defines an autonomous system path to prepend to an autonomous system path known by the BGP forwarding table
Router(config)# **router bgp** *as-number*	Enables the BGP process for a specific autonomous system
Router(config-router)# **neighbor** *ip-address* **route-map** *route-map-name* [**in** | **out**]	Applies a specified route map to routes received from or advertised to a specified BGP neighbor

Lab 12

Implementing Multicast Routing

This *Routing Video Mentor* lab introduces the theory and configuration of multicast routing. With IP multicast, a source can send traffic destined for a Class D IP address. Through the proper multicast configuration of switches and routers, the traffic destined for the Class D IP address is replicated as needed, such that members of the multicast group receive the traffic, while non-members do not receive the traffic. While some Cisco switches can use the *IGMP Snooping* feature to determine the switch interfaces that should be forwarding multicast traffic, this lab primarily focuses on Protocol Independent Multicast (PIM). PIM serves as a multicast routing protocol configured on routers, and this lab discusses two modes of PIM: *dense mode* and *sparse mode*.

The objectives of this lab are as follows:

- Review multicast theory
- Show the syntax for configuring multicast
- Enable multicast on routers and router interfaces
- Verify multicast configurations
- Configure a router to join a multicast group
- Verify dense mode multicast operation
- Configure a rendezvous point
- Verify sparse mode multicast operation

Scenario

This lab contains three main steps, as follows:

Step 1 Enable all routers in the topology for IP multicast routing.

Step 2 Configure a router interface to join a multicast group.

Step 3 Configure the topology for PIM sparse mode operation.

The initial lab configuration is fully functional, and OSPF is being used as the routing protocol. Also, unlike previous labs, the link speed between routers R1 and BB1 and between routers R1 and BB2 are identical, 128 kbps. As a result, these paths have an equal cost.

Initial Configurations

As its name suggests, Protocol Independent Multicast is independent of the underlying Layer 3 routing protocol. As previously mentioned, this lab begins with OSPF configured on all routers. In the OSPF configuration, all interfaces on all routers are members of OSPF Area 0. Examples 12-1, 12-2, 12-3, and 12-4 illustrate these initial configurations.

Example 12-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 12-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 12-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
```

continues

Example 12-3 Initial Configuration for BB1 continued

```
 frame-relay interface-dlci 811
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Example 12-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
!
router ospf 1
 network 0.0.0.0 255.255.255.255 area 0
```

Basic Multicast Configuration

This lab begins by enabling the routers in this topology, and their physical interfaces, for IP multicast. Specifically, the routers are globally enabled for IP multicast, and the interfaces are configured for PIM *sparse-dense* mode, meaning that the interfaces will run in PIM sparse mode if a rendezvous point is available and in dense mode if a rendezvous point is not available. Examples 12-5, 12-6, 12-7, and 12-8 show this basic multicast configuration.

Example 12-5 Basic Multicast Configuration for R1

```
ip multicast-routing
!
interface FastEthernet0/0
 ip pim sparse-dense-mode
!
interface Serial0/0.1 point-to-point
 ip pim sparse-dense-mode
!
interface Serial0/0.2 point-to-point
 ip pim sparse-dense-mode
```

Example 12-6 Basic Multicast Configuration for R2

```
ip multicast-routing
!
interface FastEthernet0/0
 ip pim sparse-dense-mode
!
interface FastEthernet0/1
 ip pim sparse-dense-mode
```

Example 12-7 Basic Multicast Configuration for BB1

```
ip multicast-routing
!
interface Serial0/0.1 point-to-point
 ip pim sparse-dense-mode
!
interface Serial0/0.2 point-to-point
 ip pim sparse-dense-mode
```

Example 12-8 Basic Multicast Configuration for BB2

```
ip multicast-routing
!
interface Serial0/0.1 point-to-point
 ip pim sparse-dense-mode
!
interface Serial0/0.2 point-to-point
 ip pim sparse-dense-mode
```

Configuration for Joining a Multicast Group

This lab uses the FastEthernet 0/0 interface in router R2 to act as a multicast receiver for group 239.1.1.1. Router BB1 acts as the multicast source by sending ping packets destined for the multicast group of 239.1.1.1. Example 12-9 illustrates how to make a router interface join a multicast group.

Example 12-9 Configuring an Interface to Join a Multicast Group on R2

```
interface FastEthernet0/0
 ip igmp join-group 239.1.1.1
```

Sparse Mode Configuration

This lab initially demonstrates PIM dense mode operation, which uses a flood and prune behavior. However, PIM sparse mode avoids the flood and prune behavior while still achieving an optimal path between the multicast sender and receiver. The topology can be configured for sparse mode operation by going into global configuration mode in each router and specifying the IP address of the rendezvous point, which in this lab is an IP address of 10.1.1.2 (that is, the IP address of router

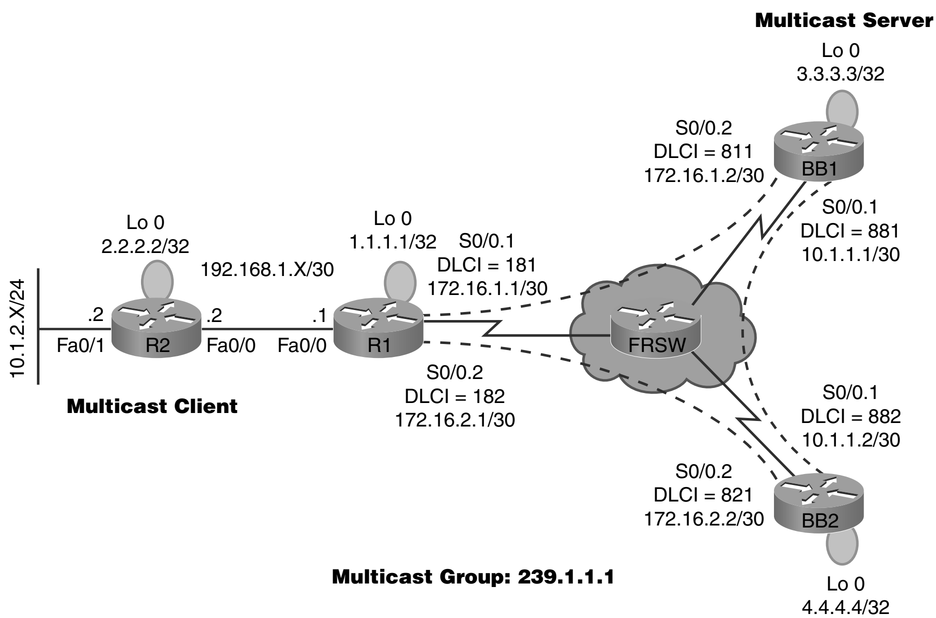
BB2s Serial 0/0.1 subinterface). Specifically, the following command is entered in global configuration mode on all routers in the topology to configure the rendezvous point:

```
ip pim rp-address 10.1.1.2
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 12-1.

Figure 12-1 Lab 12 Routing Topology



This lab also illustrates the use of several multicast-related commands. The syntax for these commands is presented in Table 12-1.

Table 12-1 IOS Command Reference for Lab 12

Command	Description
Router(config)# **ip multicast-routing**	Enables multicast routing on a router
Router(config-if)# **ip pim sparse-dense-mode**	Instructs an interface to run in PIM sparse mode if a rendezvous point is available and to run in PIM dense mode if a rendezvous point is not available
Router(config-if)# **ip igmp join-group** *ip-address*	Causes an interface to join the specified multicast group
Router(config)# **ip pim rp-address** *ip-address*	Statically configures a rendezvous point

Lab 13

Configuring IPv6 Addressing

This *Routing Video Mentor* lab introduces IP version 6 (IPv6). IPv6 brings several enhancements to IPv4, including a vastly expanded number of available addresses. This lab begins with a discussion of such benefits. Also, this lab discusses the three types of IPv6 addresses: unicast, multicast, and anycast. The address structure of an IPv6 address is examined, and shortcuts are provided that allow you to abbreviate many IPv6 addresses. Finally, the configuration component of this lab focuses on enabling routers for IPv6 and assigning IPv6 addresses to router interfaces.

The objectives of this lab are as follows:

- Introduce IPv6
- Illustrate IPv6 addressing
- Show IPv6 syntax
- Globally enable IPv6 on a router
- Configure IPv6 addressing on router interfaces
- Verify IPv6 configuration

Scenario

This lab contains two main configuration steps, as follows:

Step 1 Globally enable the routers for IPv6 support.

Step 2 Assign IPv6 addresses to router interfaces.

Initial Configurations

The initial lab configuration has IPv4 addresses already assigned to the router interfaces. However, no routing protocol is configured. Examples 13-1, 13-2, 13-3, and 13-4 illustrate the initial configuration.

Example 13-1 Initial Configuration for R1

```
hostname R1
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
```

continues

Example 13-1 Initial Configuration for R1 continued

```
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 frame-relay interface-dlci 182
```

Example 13-2 Initial Configuration for R2

```
hostname R2
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
```

Example 13-3 Initial Configuration for BB1

```
hostname BB1
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 frame-relay interface-dlci 811
```

Example 13-4 Initial Configuration for BB2

```
hostname BB2
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
```

continues

Example 13-4 Initial Configuration for BB2 continued

```
 ip address 10.1.1.2 255.255.255.252
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 frame-relay interface-dlci 821
```

Global IPv6 Configuration

Cisco IOS needs to be configured to allow the routing of IPv6 traffic. In this lab, two global configuration mode commands are issued to enable this routing. First, IPv6 unicast routing is enabled, and then Cisco Express Forwarding (CEF) is enabled for IPv6. Example 13-5 illustrates this global IPv6 configuration on router R1. This lab applies an identical global configuration to the remaining routers in the topology.

Example 13-5 Global IPv6 Configuration for R1

```
ipv6 unicast-routing
ipv6 cef
```

Interface IPv6 Configuration

Next, this lab assigns IPv6 addresses to the router interfaces. Examples 13-6, 13-7, 13-8, and 13-9 illustrate this configuration.

Example 13-6 Assigning IPv6 Addresses to Interfaces on R1

```
interface FastEthernet0/0
 ipv6 address B:B:B:B::1/64
!
interface Serial0/0.1 point-to-point
 ipv6 address C:C:C:C::1/64
!
interface Serial0/0.2 point-to-point
 ipv6 address D:D:D:D::1/64
```

Example 13-7 Assigning IPv6 Addresses to Interfaces on R2

```
interface FastEthernet0/0
 ipv6 address B:B:B:B::2/64
!
interface FastEthernet0/1
 ipv6 address A:A:A:A::2/64
```

Example 13-8 Assigning IPv6 Addresses to Interfaces on BB1

```
interface Serial0/0.1 point-to-point
 ipv6 address E:E:E:E::1/64
!
interface Serial0/0.2 point-to-point
 ipv6 address C:C:C:C::2/64
```

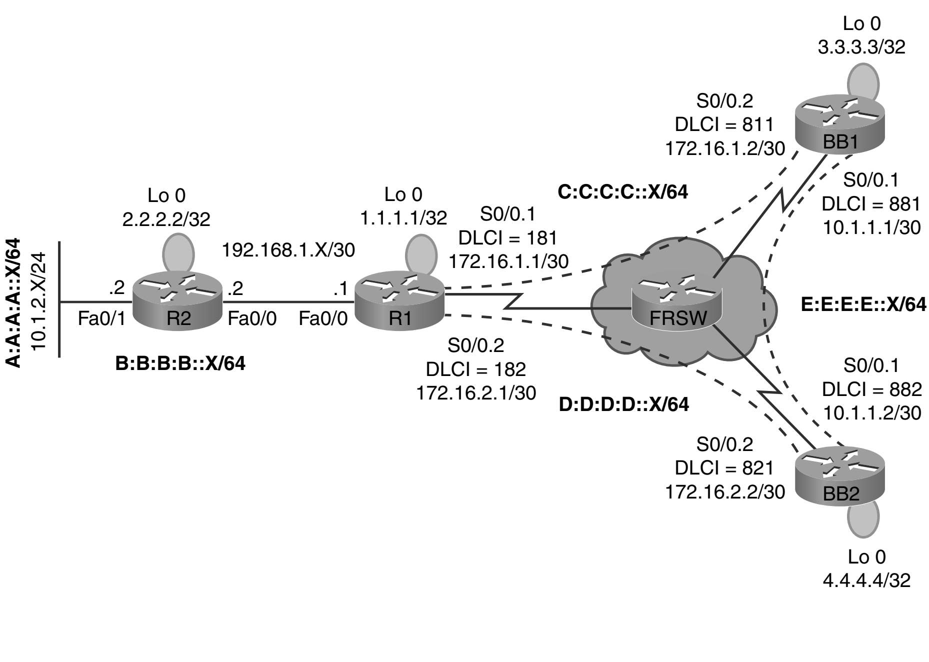
Example 13-9 Assigning IPv6 Addresses to Interfaces on BB2

```
interface Serial0/0.1 point-to-point
 ipv6 address E:E:E:E::2/64
!
interface Serial0/0.2 point-to-point
 ipv6 address D:D:D:D::2/64
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 13-1.

Figure 13-1 Lab 13 Topology



This lab also illustrates the use of various IPv6-related commands. The syntax for these commands is presented in Table 13-1.

Table 13-1 IOS Command Reference for Lab 13

Command	Description
Router(config)# **ipv6 cef**	Configures Cisco Express Forwarding for IPv6
Router(config)# **ipv6 unicast-routing**	Globally instructs a router to forward IPv6 traffic
Router(config-if)# **ipv6 address** *ipv6-address/prefix-length* [**eui-64**]	Assigns an IPv6 address to an interface (NOTE: The **eui-64** option allows a router to complete the low-order 64 bits of an address, based on an interface's MAC address)

Lab 14

Configuring IPv6 OSPF Routing

This *Routing Video Mentor* lab builds on the previous lab's configuration (Lab 13, "*Configuring IPv6 Addressing*"). Specifically, Lab 13 assigned IPv6 addresses to router interfaces. This lab uses OSPFv3 to route between those previously configured IPv6 networks.

The objectives of this lab are as follows:

- Identify options for routing between IPv6 networks
- Introduce OSPFv3
- Review syntax for OSPFv3 routing
- Configure routers to route IPv6 networks using OSPFv3
- Verify OSPFv3 routing of IPv6 traffic

Scenario

This lab contains two main configuration steps, as follows:

Step 1 Define the OSPFv3 router ID.

Step 2 Configure interfaces to participate in OSPFv3.

Initial Configurations

The initial lab configuration has IPv4 and IPv6 addresses already assigned to the interfaces interconnecting the routers in the topology. However, no routing protocol is configured. Examples 14-1, 14-2, 14-3, and 14-4 illustrate the initial configuration.

Example 14-1 Initial Configuration for R1

```
hostname R1
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
 ipv6 address B:B:B:B::1/64
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 ipv6 address C:C:C:C::1/64
```

continues

Example 14-1 Initial Configuration for R1 *continued*

```
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 ipv6 address D:D:D:D::1/64
 frame-relay interface-dlci 182
```

Example 14-2 Initial Configuration for R2

```
hostname R2
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 ipv6 address B:B:B:B::2/64
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 ipv6 address A:A:A:A::2/64
```

Example 14-3 Initial Configuration for BB1

```
hostname BB1
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 ipv6 address E:E:E:E::1/64
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 ipv6 address C:C:C:C::2/64
 frame-relay interface-dlci 811
```

Example 14-4 Initial Configuration for BB2

```
hostname BB2
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 ipv6 address E:E:E:E::2/64
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 ipv6 address D:D:D:D::2/64
 frame-relay interface-dlci 821
```

OSPFv3 Router ID Configuration

This lab enables an OSPFv3 routing process on each router. Note that OSPFv3 supports multiple OSPF instances. However, this lab uses a single instance. After starting the OSPFv3 routing process, an OSPF router ID can be configured in router configuration mode. The router ID is an IPv4 address, rather than an IPv6 address. In this lab, the IPv4 address of each router's loopback interface is used for that router's OSPF router ID. Examples 14-5, 14-6, 14-7, and 14-8 illustrate this OSPF router ID configuration.

Example 14-5 OSPFv3 Router ID Configuration on R1

```
ipv6 router ospf 1
 router-id 1.1.1.1
```

Example 14-6 OSPFv3 Router ID Configuration on R2

```
ipv6 router ospf 1
 router-id 2.2.2.2
```

Example 14-7 OSPFv3 Router ID Configuration on BB1

```
ipv6 router ospf 1
 router-id 3.3.3.3
```

Example 14-8 OSPFv3 Router ID Configuration on BB2

```
ipv6 router ospf 1
 router-id 4.4.4.4
```

Configuring the Networks to be Advertised via OSPFv3

Interestingly, unlike OSPFv2, networks are added to an OSPFv3 routing process through the **ipv6 ospf** *process-id* **area** *area-id* command in interface configuration mode, as opposed to OSPFv2s approach of using the **network** *network-address* **area** *area-id* in router configuration mode. Note that this lab divides the topology into two OSPF areas. Examples 14-9, 14-10, 14-11, and 14-12 illustrate this interface configuration on the routers in the topology.

Example 14-9 Configuring Networks to be Advertised via OSPFv3 on R1

```
interface FastEthernet0/0
 ipv6 ospf 1 area 1
!
interface Serial0/0.1
 ipv6 ospf 1 area 0
!
interface Serial0/0.2
 ipv6 ospf 1 area 0
```

Example 14-10 Configuring Networks to be Advertised via OSPFv3 on R2

```
interface FastEthernet0/0
 ipv6 ospf 1 area 1
!
interface FastEthernet0/1
 ipv6 ospf 1 area 1
```

Example 14-11 Configuring Networks to be Advertised via OSPFv3 on BB1

```
interface Serial0/0.1
 ipv6 ospf 1 area 0
!
interface Serial0/0.2
 ipv6 ospf 1 area 0
```

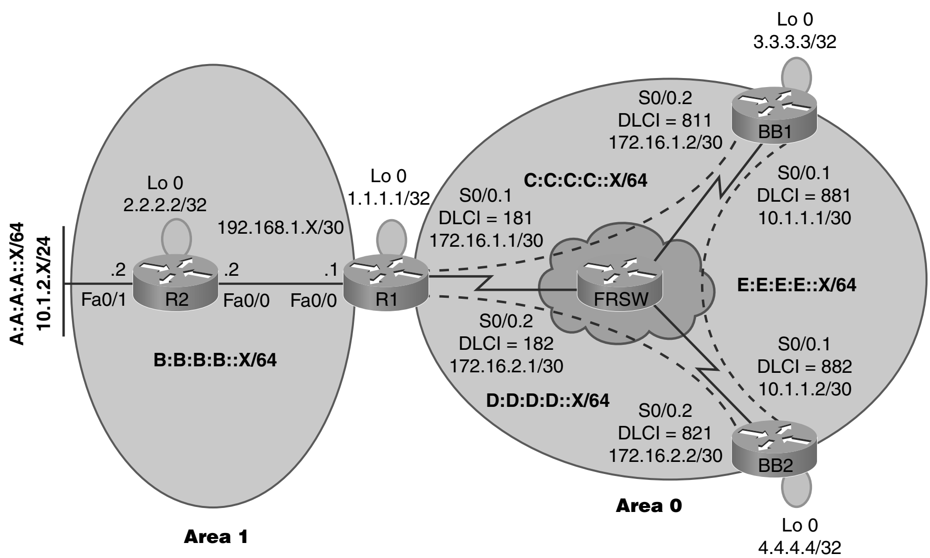
Example 14-12 Configuring Networks to be Advertised via OSPFv3 on BB2

```
interface Serial0/0.1
 ipv6 ospf 1 area 0
!
interface Serial0/0.2
 ipv6 ospf 1 area 0
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 14-1.

Figure 14-1 Lab 14 Topology



This lab also illustrates the use of various OSPFv3-related commands. The syntax for these commands is presented in Table 14-1.

Table 14-1 IOS Command Reference for Lab 14

Command	Description
Router(config-if)# **ipv6 ospf** *process-id* **area** *area-id*	Allows the IPv6 address configured on an interface to participate in an OSPFv3 routing process
Router(config)# **ipv6 router ospf** *process-id*	Globally enables an OSPFv3 routing process on a router
Router(config-rtr)# **router-id** *ipv4-address*	Specifies the IPv4 address to be used by OSPFv3 as a router's router ID

Lab 15

Tunneling IPv6 via IPv4

This *Routing Video Mentor* lab builds on the previous lab's configuration (Lab 14, "Configuring IPv6 OSPF Routing"). Specifically, Lab 14 added OSPFv3 routing configurations to each of the routers in the topology, permitting full reachability between all IPv6 networks. This lab simulates a real-world scenario where a network might not yet be end-to-end IPv6 (for example, during a transition from IPv4 to IPv6).

Specifically, this lab removes IPv6 configurations from the link interconnecting routers R1 and R2. Then an IPv4 tunnel is constructed to join together the discontiguous IPv6 portions of the network. The tunnel then acts as a conduit allowing IPv6 traffic to pass through an IPv4 portion of the network.

The objectives of this lab are as follows:

- Identify options for IPv6 networks to coexist with IPv4 networks
- Discuss the operation of an IPv6-over-IPv4 tunnel
- Review the syntax for IPv6-over-IPv4 tunneling
- Remove the existing IPv6 configuration from a portion of the topology
- Create an IPv6-over-IPv4 tunnel to span the IPv4 portion of the topology
- Verify IPv6 traffic is routed over the IPv6-over-IPv4 tunnel

Scenario

This lab contains three main configuration steps, as follows:

Step 1 Remove IPv6 configurations from the link interconnecting routers R1 and R2.

Step 2 Create a tunnel to span the IPv4 portion of the network.

Step 3 Configure the tunnel to transmit IPv6 network traffic.

Initial Configurations

The initial lab configuration has IPv4 and IPv6 addresses already assigned to the interfaces interconnecting the routers in the topology. Also, OSPFv3 is acting as a routing protocol for IPv6. Examples 15-1, 15-2, 15-3, and 15-4 illustrate the initial configuration.

Example 15-1 Initial Configuration for R1

```
hostname R1
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 1.1.1.1 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.1 255.255.255.252
```

continues

Example 15-1 Initial Configuration for R1 continued

```
 duplex auto
 speed auto
 ipv6 address B:B:B:B::1/64
 ipv6 ospf 1 area 1
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 128
 ip address 172.16.1.1 255.255.255.252
 ipv6 address C:C:C:C::1/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 181
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.1 255.255.255.252
 ipv6 address D:D:D:D::1/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 182
!
ipv6 router ospf 1
 router-id 1.1.1.1
```

Example 15-2 Initial Configuration for R2

```
hostname R2
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 2.2.2.2 255.255.255.255
!
interface FastEthernet0/0
 ip address 192.168.1.2 255.255.255.252
 duplex auto
 speed auto
 ipv6 address B:B:B:B::2/64
 ipv6 ospf 1 area 1
!
interface FastEthernet0/1
 ip address 10.1.2.2 255.255.255.0
 duplex auto
 speed auto
 ipv6 address A:A:A:A::2/64
 ipv6 ospf 1 area 1
!
ipv6 router ospf 1
 router-id 2.2.2.2
```

Example 15-3 Initial Configuration for BB1

```
hostname BB1
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 3.3.3.3 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.1 255.255.255.252
 ipv6 address E:E:E:E::1/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 881
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.1.2 255.255.255.252
 ipv6 address C:C:C:C::2/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 811
!
ipv6 router ospf 1
 router-id 3.3.3.3
```

Example 15-4 Initial Configuration for BB2

```
hostname BB2
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 4.4.4.4 255.255.255.255
!
interface Serial0/0
 no ip address
 encapsulation frame-relay
!
interface Serial0/0.1 point-to-point
 bandwidth 256
 ip address 10.1.1.2 255.255.255.252
 ipv6 address E:E:E:E::2/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 882
!
interface Serial0/0.2 point-to-point
 bandwidth 128
 ip address 172.16.2.2 255.255.255.252
 ipv6 address D:D:D:D::2/64
 ipv6 ospf 1 area 0
 frame-relay interface-dlci 821
!
ipv6 router ospf 1
 router-id 4.4.4.4
```

Removing IPv6 Configuration from R1-to-R2 Link

To simulate a real-world environment, where an enterprise might be undergoing a transition from IPv4 to IPv6, this lab begins by removing the IPv6 configuration from the link interconnecting routers R1 and R2. However, the interfaces at each end of the link still have IPv4 addressing, which will be used later in this lab to construct a tunnel between R1 and R2. Examples 15-5 and 15-6 illustrate the process of removing the IPv6 configuration on this link (that is, the FastEthernet 0/0 interfaces on routers R1 and R2).

Example 15-5 Removing the IPv6 Configuration on R1's Fast Ethernet 0/0 Interface

```
interface fa 0/0
 no ipv6 ospf 1 area 1
 no ipv6 address
```

Example 15-6 Removing the IPv6 Configuration on R2's Fast Ethernet 0/0 Interface

```
interface fa 0/0
 no ipv6 ospf 1 area 1
 no ipv6 address
```

Creating a Tunnel between Routers R1 and R2

With the IPv6 configuration now removed from the FastEthernet 0/0 interfaces on routers R1 and R2, this lab creates a tunnel to span the link interconnecting these routers. Keep in mind, that even though the tunnel in this lab only interconnects two routers, such a tunnel could span multiple routers, as long as the routers at each end of the tunnel have IPv4 reachability with one another. Examples 15-7 and 15-8 illustrate the creation of this tunnel.

Example 15-7 Creating a Tunnel Interface on R1

```
interface tunnel 1
 tunnel source 192.168.1.1
 tunnel destination 192.168.1.2
```

Example 15-8 Creating a Tunnel Interface on R2

```
interface tunnel 1
 tunnel source 192.168.1.2
 tunnel destination 192.168.1.1
```

Adding an IPv6 Configuration to the Tunnel Interfaces

After a tunnel has been created to span the IPv4 portion of the network, the tunnel interfaces in the routers at each end of the link are next configured to transmit IPv6 packets. Examples 15-9 and 15-10 show this IPv6 configuration for the tunnel interfaces.

Example 15-9 Configuring IPv6 Parameters on R1's Tunnel Interface

```
interface tunnel 1
 ipv6 address b:b:b:b::1/64
 ipv6 ospf 1 area 1
 tunnel mode ipv6ip
```

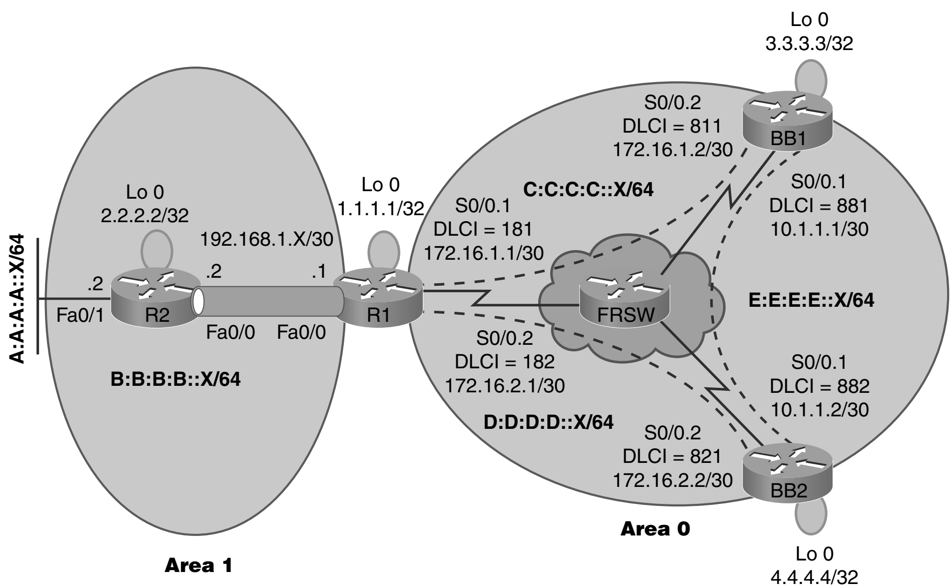
Example 15-10 Configuring IPv6 Parameters on R2's Tunnel Interface

```
interface tunnel 1
 ipv6 address b:b:b:b::2/64
 ipv6 ospf 1 area 1
 tunnel mode ipv6ip
```

Video Presentation Reference

This lab presents a diagram of the topology to better illustrate the concepts addressed. As a reference, this diagram is shown in Figure 15-1.

Figure 15-1 Lab 15 Topology



This lab also illustrates the use of various IPv6-over-IPv4 tunnel-related commands. The syntax for these commands is presented in Table 15-1.

Table 15-1 IOS Command Reference for Lab 15

Command	Description
Router(config)# **interface tunnel** *interface-id*	Creates a virtual IPv4 tunnel interface over which encapsulated IPv6 packets can flow
Router(config-if)# **tunnel source** *ipv4-address*	Identifies the IPv4 address of the local end of a tunnel
Router(config-if)# **tunnel destination** *ipv4-address*	Identifies the IPv4 address of the remote end of a tunnel
Router(config-if)# **tunnel mode ipv6ip**	Configures the interface to act as a manual IPv6 tunnel
Router(config-if)# **ipv6 address** *ipv6-address***/***prefix-length*	Specifies the IPv6 address assigned to a tunnel interface
Router(config-if)# **ipv6 ospf** *process-id* **area** *area-id*	Allows the IPv6 address configured on a tunnel interface to participate in an OSPFv3 routing process