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CHAPTER

ADVANCED ROUTER CONFIGURATION II

Chapter Outline

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Objectives

- Be able to configure a basic setup for OSPF, ISIS, and EIGRP routing protocols
- Be able to configure load balancing and redundancy
- Be able to configure route redistribution
- Understand the relative amount of traffic generated by each protocol
- Describe the purpose of the “Hello” packet

Key Terms

OSPF	L1/L2 routers	H
IETF	ABR	address
Link State Advertisements	Connectionless Network Service (CLNS)	interface
link state protocol	integrated IS-IS	hold
Hello packets	NET	SRTT
areas	area ID	RTO
backbone	system ID	Q Cnt
Variable Length Subnet Masks (VLSM)	Network Service Access Point Selector (NSEL)	Seq Num
route flapping	IS-IS	show ip eigrp topology
router ospf process id	cnls routing	bandwidth
network number	router isis	delay
wild card bits	ip router isis	routing redistribution
Area 0	show ip route isis (sh ip route isis)	redistribute protocol
Neighbor ID	show cnls is-neighbors	redistribute connected
Designated Router (DR)	show cnls interface	redistribute static
Backup Designated Router (BDR)	EIGRP	redistribute ospf
state of FULL	hybrid routing protocol	<i>process_id</i> metric 0-16
dead time	show ip eigrp neighbors	redistribute eigrp
interface cost	uptime	<i>AS_number</i> metric 0-16
L1 routers	Q Cnt	redistribute isis IS-IS
L2 routers		<i>Level</i> metric 0-16
		redistribute connected subnets

continues

KEY TERMS continued

E2

redistribute eigrp *AS_id*
[**metric** *0-16777214*]

redistribute rip

redistribute isis *IS-IS Level*

EX

redistribute rip metric

bandwidth delay reliability
load MTU

default-metric *bandwidth*
delay reliability load MTU

“Hello” packets

network mask

Hello Interval

Router Dead Interval

RID

OSPF/IGP

IGP

INTRODUCTION

This chapter examines advanced routing protocols. Configuring the link state protocols Open Shortest Path First (OSPF) and Intermediate System-to-Intermediate System (IS-IS) are examined in Sections 3-1 and 3-2. In link state protocols, updates are only sent when there is a change in the network. There are many similarities between IS-IS and OSPF; however, there is a difference in the way in which the areas are defined for each protocol. Another big difference is that the IS-IS backbone area can be segmented, unlike the backbone area in OSPF.

The steps for configuring the Enhanced Interior Gateway Routing Protocol (EIGRP) are examined in Section 3-3. EIGRP is a Cisco proprietary protocol and is often called a hybrid routing protocol that incorporates the best of the distance vector and link-state algorithms.

Section 3-4 takes a look at advanced route redistribution. This section explores different routing redistribution techniques used to redistribute routes into dynamic routing protocols, such as Routing Information Protocol (RIP), OSPF, IS-IS, and EIGRP. This chapter concludes with a look at the OSPF “Hello” packets that are used by routers to initiate and maintain communication with neighbor routers. The parameters of the “Hello” packet are examined using a network protocol analyzer.

Each routing protocol section in this chapter contains a networking challenge that is included with the Net-Challenge Software. These challenges enable you to configure each routing protocol on a virtual router.

3-1 CONFIGURING LINK STATE PROTOCOLS—OSPF

Open Shortest Path First (**OSPF**) is a dynamic routing protocol, classified specifically as a link state protocol. It was developed by the Interior Gateway Protocol (IGP) working group for the Internet Engineering Task Force (**IETF**) specifically for use in TCP/IP networks. OSPF is an open, not proprietary, protocol and is supported by many vendors. The main advantages of OSPF are rapid convergence and the consumption of very little bandwidth. When a network is completely *converged*, all the routers in the network agree on the best routes. After the initial flooding of routes in the form of **link state advertisements (LSA)**, OSPF sends route updates only when there is a change in the network. Every time LSAs are sent, each router must recalculate the routing table.

This is a distinct advantage over RIP. Recall that RIP exchanges the entire routing table at fixed time intervals and RIP updates every 30 seconds. Also, in RIP, the routing table update is propagated through the network at regular timer intervals; therefore, the convergence to final routes is slow. In OSPF, an LSA is sent only when a loss of a route has been detected or when a network comes back online. The loss is immediately reported to neighbor routers, and new routes are calculated much faster than with RIP.

OSPF

Open Shortest Path First routing protocol.

IETF

Internet Engineering Task Force.

Link State Advertisement (LSA)

The exchange of updated link state information when routes change.

Link State Protocol

Establishes a relationship with a neighboring router and uses route advertisements to build routing tables.

Hello Packets

Used in the OSPF protocol to verify that the links are still communicating.

Areas

The partition of a large OSPF network into smaller OSPF networks.

Backbone

The primary path for data traffic to and from destinations and sources in the campus network.

Variable Length Subnet Masks (VLSM)

Enables the use of subnet masks to better fit the needs of the network, thereby minimizing the waste of IP addresses when interconnecting subnets.

Link State Protocols

Link state protocols establish a relationship with a neighboring router. The routers exchange LSAs to update neighbors regarding route status. The LSAs are sent only if there is a change or loss in the network routes and the link state protocols converge to route selection quickly. This is a distinct advantage over distance vector protocols that exchange updated routing tables at fixed time intervals and are slow to converge. In fact, link state routing protocols are replacing distance vector protocols in most modern networks. Link state protocols are also called *shortest-path first protocols*, based on the algorithm developed by E. W. Dijkstra. Link state protocols use “Hello” packets to verify that communication is still established with neighbor routers. The key issues of link state protocols are summarized as follows:

- Finds neighbors/adjacencies
- Uses route advertisements to build routing table
- Sends “Hello” packets
- Sends updates when routing changes

OSPF sends small “**Hello**” packets at regular time intervals to adjacent routers to verify that the link between two routers is active and the routers are communicating. If a router fails to respond to a Hello it is assumed that the link or possibly the router is down. The OSPF Hello packet captured with a network protocol analyzer is discussed in Section 3-5.

OSPF uses the concept of **areas** to partition a large network into smaller networks. The advantage of this is that the routers have to calculate routes only for their area. If a route goes down in a given area, only the routers in that area have to calculate new routes. Any number between 0 and 4,294,967,295 ($2^{32} - 1$) can be used; however, area 0 is reserved for the root area, which is the **backbone** for the network. The backbone is the primary path for data traffic to and from destinations and sources in the campus network. All areas must connect to area 0, and area 0 cannot be split. The area numbers can also be expressed in IP notation—for example, area 0 could be 0.0.0.0—or you can specify an area as 192.168.25.0 or in subnet notation. Hence, the need for the large upper-area number ($2^{32} - 1$) = 255.255.255.255 when converted to a decimal number.

OSPF allows the use of **variable length subnet masks (VLSM)**, which enable different size subnets in the network to better meet the needs of the network and more efficiently use the network’s limited IP address space. For example, point-to-point inter-router links don’t need a large block of addresses assigned to them. Figure 3-1 illustrates an example of an inter-router link.

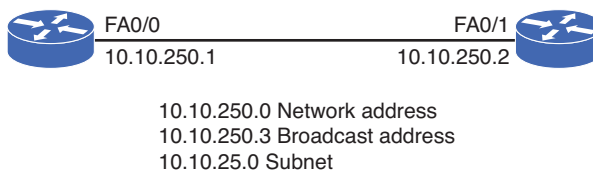


FIGURE 3-1 An inter-router link subnetted to provide for two host IP addresses, a network address, and a broadcast address

A subnet of size 4 is sufficient for the inter-router link that includes the IP addresses for the router interfaces, the network address, and the broadcast address. A subnet mask of 255.255.255.252 meets this requirement of a subnet size 4 and is permissible in OSPF. This subnet mask provides for the addressing of the two host addresses (the router interfaces on each end), and the network and broadcast addresses, which provides the total subnet size of 4. This is an important advantage of OSPF because using variable length subnet masks minimizes the waste of IP addresses when interconnecting subnets. Table 3-1 summarizes the advantages and disadvantages of OSPF.

TABLE 3-1 Summary of Advantages and Disadvantages of OSPF

Advantages	Disadvantages
Not proprietary—available for use by all vendors.	Can be complicated to implement.
Link state changes are immediately reported, which enables rapid convergence.	Is process intensive due to routing table calculations.
Consumes little network bandwidth.	Intermittent routes that are going up and down will create excessive LSA updates—this is called route flapping .
Uses VLSM	
Uses areas to partition the network into smaller networks, minimizing the number of route calculations.	

Route Flapping
Intermittent routes going up and down creating excessive LSA updates.

Configuring Routes with OSPF

This section describes a procedure for configuring OSPF on a router. The first example is for configuring the three routers in the campus LAN shown in Figure 3-2.

The routers will be configured to run OSPF on each of the router’s three Ethernet interfaces. The example begins with configuring Router A. Router A must first be placed in the router’s configuration mode [Router(config)#], as shown:

```
RouterA#conf t
Enter configuration commands, one per line. End with CNTL/Z.
RouterA(config)#
```

The next step is to enter the information about the IP address for each of the Ethernet interfaces. The IP addresses for Router A are as follows:

```
FastEthernet0/0: 10.10.20.250
FastEthernet0/1: 10.10.200.1
FastEthernet0/2: 10.10.100.1
```

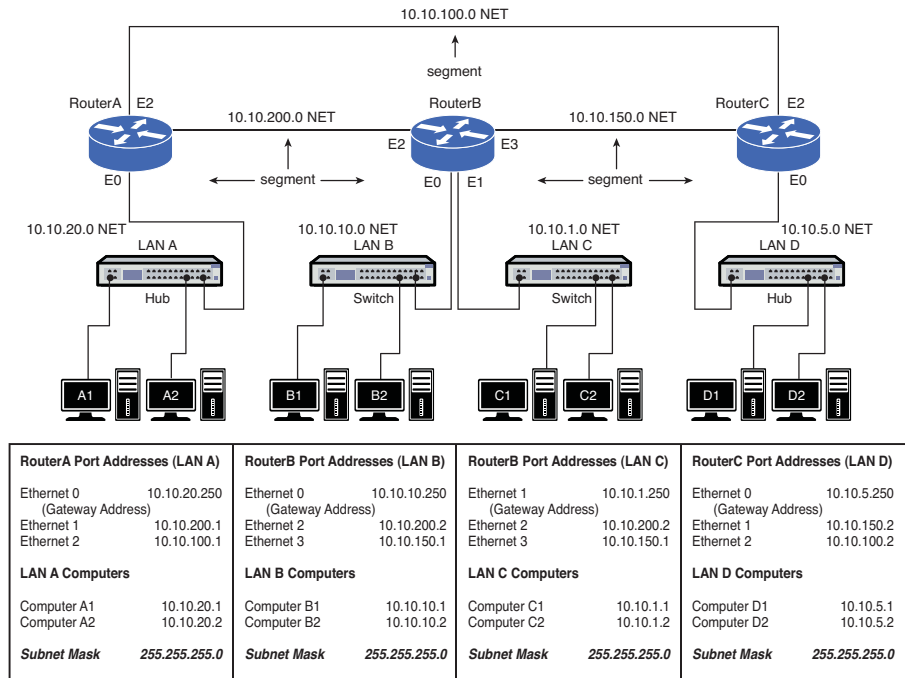


FIGURE 3-2 The three-router campus LAN

A subnet mask of 255.255.255.0 is assigned to each of the FastEthernet interfaces. After the FastEthernet interfaces are configured, verify the configuration settings using the **sh ip int brief** command, as shown. Make sure that the status for the FastEthernet interfaces are *up*. This indicates that the interfaces are turned on and an Ethernet networking device is connected. The protocol will show *down* until the Ethernet cable is connected and the connecting interface is enabled. In this case, the connecting interfaces to FA0/1 and FA0/2 are not enabled and, therefore, show a status of *down*.

```
RouterA#sh ip int brief
Interface          IP-Address      OK?    Method    Status    Protocol
FastEthernet0/0    10.10.20.250   YES    manual    up        up
FastEthernet0/1    10.10.200.1    YES    manual    up        down
FastEthernet0/2    10.10.100.1    YES    manual    up        down
```

router ospf [process id]

The command used to enable OSPF routing.

Next, the command **router ospf process id** is used to enable OSPF routing. In this case, the command **router ospf 100** is entered. The 100 is the *process id number*. This number must be the same on each router for OSPF to exchange routes. The process ID number is selected by the network administrator and is not used for routing outside the network. It is customary to use the same process ID throughout the network for ease of management, but it is not required. Entering the **router ospf 100** command places the router in the RouterA(config-router)# prompt:

```
RouterA(config)#router ospf 100
RouterA(config-router)#
```

The next step is to define the network running OSPF by entering the **network** command followed by the IP address of the interface, the OSPF wild card bits, and then an area number. The following text shows each step and lists the results of entering a question mark as the command is entered. When entering the command **network ?**, the router prompts you to enter the IP address of the interface:

```
RouterA(config-router)#network ?  
A.B.C.D Network number
```

A.B.C.D is the IP address or **network number** for the Ethernet interface. Next, entering network 10.10.20.250 ? prompts you to enter the OSPF wild card bits in the form of A.B.C.D. The **wild card bits**, also called the *inverse mask bits*, are used to match the network IP address (A.B.C.D format) to interface IPs. If there is a match, the subnet on the interface is advertised out OSPF, and OSPF packets are sent out the interface. A 0 wild card bit is used to indicate a “must” match. A 255 is a “don’t care,” hence the name *inverse mask*.

The last entry when defining an OSPF route is for the area. Remember, areas are used to partition a large network into smaller networks. **Area 0** is the root area and is the backbone for the network. All other areas must connect to area 0. Area 0 cannot be split. Other area numbers are specified by the network administrator.

Assume that the router command **network 10.10.20.250 0.0.0.0 area 0** is entered. The wild card bits indicate that any interface with an address of 10.10.20.250 must run OSPF on the interface and will be assigned to area 0 (the network backbone). Assume that the router command **network 10.10.20.250 0.255.255.255 area 0** is entered. The wild card bits indicate that any interface with an IP address of 10.x.x.x must run OSPF on the interface and will be assigned to area 0:

```
RouterA(config-router)#network 10.10.20.250 ?  
A.B.C.D OSPF wild card bits  
RouterA(config-router)#network 10.10.20.250 0.0.0.0 ?  
area Set the OSPF area ID  
RouterA(config-router)#network 10.10.20.250 0.0.0.0 area 0
```

The following command sequence details the three OSPF network entries needed to configure OSPF routing for Router A:

```
RouterA(config-router)#network 10.10.20.250 0.0.0.0 area 0  
RouterA(config-router)#network 10.10.200.1 0.0.0.0 area 0  
RouterA(config-router)#network 10.10.100.1 0.0.0.0 area 0
```

Note that the Router A interface to LAN A (10.10.20.250 NET) is listed when configuring OSPF. This is used in OSPF to advertise the LAN to the other routers. Also note that the network has been assigned to area 0 (the backbone). The command **sh ip int brief** is used to check the status of the interfaces. The output **Protocol down** indicates that the cable to the interface is either unplugged or the interface is shut down:

```
RouterA#show int brief  
Interface      IP-Address      OK?  Method  Status  Protocol  
FastEthernet0/0  10.10.20.250    YES  NVRAM   up      up  
FastEthernet0/1  10.10.200.1     YES  manual  up      down  
FastEthernet0/2  10.10.100.1     YES  manual  up      down
```

Network Number

Another name for the IP subnet.

Wild Card Bits

Used to match network IP addresses to interface IPs.

Area 0

In OSPF, this is the root area and is the backbone for the network.

This problem with the **Protocol down** is fixed by reestablishing the physical connection between the routers.

The next step is to configure RouterB. First, configure the four FastEthernet interfaces on RouterB. Next, the OSPF routing protocol for RouterB is set. In this example, one command-line instruction is used to configure RouterB to run OSPF on all four of its interfaces. This is done with a subnet mask or wild card in OSPF. First, enter RouterB's configuration mode using the **conf t** command. The command **router ospf 100** is entered. Note that the same process ID number of 100 is being used. The next step is to enter **network 10.0.0.0 0.255.255.255 area 0**. This command tells the router that any address that starts with a "10" belongs to area 0 on RouterB:

```
RouterB#conf t
Enter configuration commands, one per line. End with CNTL/Z.
RouterB(config)#router ospf 100
RouterB(config-router)#network 10.0.0.0 0.255.255.255 area 0
```

Verify that the interfaces are properly configured using the **sh ip int brief** command, as shown:

```
RouterB#sh ip int brief
```

Interface	IP-Address	OK?	Method	Status	Protocol
FastEthernet0/0	10.10.10.250	YES	manual	up	up
FastEthernet0/1	10.10.1.250	YES	manual	up	up
FastEthernet0/2	10.10.200.2	YES	manual	up	up
FastEthernet0/3	10.10.150.1	YES	manual	up	down

The FastEthernet0/3 interface shows the protocol is **down** because the connecting interface is shut down on RouterC.

The next step is to configure RouterC. The OSPF routing protocol for RouterC is set using the command **router OSPF 100** followed by **network 10.0.0.0 0.255.255.255 area 0**, as shown:

```
RouterC(config)#router ospf 100
RouterC(config-router)#network 10.0.0.0 0.255.255.255 area 0
```

The interfaces on RouterC are checked using the **sh ip int brief** command, as shown:

```
RouterC#sh ip int brief
```

Interface	IP-Address	OK?	Method	Status	Protocol
FastEthernet0/0	10.10.5.250	YES	manual	up	up
FastEthernet0/1	10.10.150.2	YES	manual	up	up
FastEthernet0/2	10.10.100.2	YES	manual	up	up

Notice that the **Protocol** column shows **up** for all interfaces. This is because all interfaces are connected and the interfaces are enabled.

The following is a partial listing of the running-configuration file on Router A that shows the router OSPF network configuration. Similar information will appear on Routers B and C:

```
.
.
router ospf 100
 network 10.10.200.1 0.0.0.0 area 0
 network 10.10.20.250 0.0.0.0 area 0
 network 10.10.100.1 0.0.0.0 area 0
.
.
```

The routing table for Router A can be checked using the command **sh ip route**, as shown. The routing table indicates there are seven subnets in the campus network shown in Figure 3-2. The **O**s indicate the subnets running OSPF, and **C** indicates the subnets directly connected to the router:

```
RouterA#sh ip route
Codes: C connected, S static, I IGRP, 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, E EGP
i IS-IS, L1 IS-IS level-1, L2 IS-IS level-2, * candidate default
U per-user static route, o ODR T traffic engineered route
Gateway of last resort is not set
10.0.0.0/24 is subnetted, 7 subnets
O 10.10.5.0 [110/74] via 10.10.100.2, 00:03:28, FastEthernet0/2
O 10.10.10.0 [110/74] via 10.10.200.2, 00:03:28, FastEthernet0/1
O 10.10.1.0 [110/74] via 10.10.200.2, 00:03:28, FastEthernet0/1
C 10.10.20.0 is directly connected, FastEthernet0/0
C 10.10.100.0 is directly connected, FastEthernet0/2
O 10.10.150.0 [110/128] via 10.10.200.2, 00:03:28, FastEthernet0/1
                               [110/128] via 10.10.100.2, 00:03:28,
FastEthernet0/2
C 10.10.200.0 is directly connected, FastEthernet0/1
```

To display only the OSPF routes, you can use the **sh ip route ospf** command. The following are the results for this command from Router A:

```
RouterA#sh ip route ospf
10.0.0.0/24 is subnetted, 6 subnets
O 10.10.5.0 [110/74] via 10.10.100.2, 00:10:03, FastEthernet0/2
O 10.10.10.0 [110/74] via 10.10.200.2, 00:10:03, FastEthernet0/1
O 10.10.150.0 [110/128] via 10.10.200.2, 00:10:03, FastEthernet0/1
                               [110/128] via 10.10.100.2, 00:10:03,
FastEthernet0/2
```

Another command used for displaying protocol information for the router is **sh ip protocol**. The following are the results for entering this command for Router A:

```
RouterA#sh ip protocol
Routing Protocol is "ospf 100" Sending updates every 0 seconds
Invalid after 0 seconds, hold down 0, flushed after 0
Outgoing update filter list for all interfaces is Incoming update
filter list for all interfaces is Redistributing: ospf 100
Routing for Networks:
10.10.20.250/32
10.10.100.1/32
10.10.200.1/32
Routing Information Sources:
Gateway Distance Last Update
10.10.100.1 110 00:06:01
10.10.200.2 110 00:06:01
Distance: (default is 110)
```

To verify the adjacent OSPF neighbors of the router and observe the neighbor state, you can use the **sh ip ospf neighbor** command. This command displays the directly connected neighbors, since the hello packets are exchanged among them. The following are the results for this command from Router A:

```
RouterA#sh ip ospf neighbor
Neighbor ID      Pri   State           Dead Time   Address
Interface
10.10.150.2      1    FULL/BDR        00:00:39   10.10.100.2
FastEthernet0/2
10.10.200.2      1    FULL/DR         00:00:31   10.10.200.2
FastEthernet0/1
```

Neighbor ID

The highest IP address defined by the loopback address of the neighbor router ID.

Designated Router (DR)

The router with the highest priority.

Backup Designated Router (BDR)

The router or routers with lower priority.

State of FULL

Indicates that the routers are fully adjacent to each other.

Dead Time

The Hello time interval an OSPF router will wait before terminating adjacency with a neighbor.

The **show ip ospf neighbor** command shows there are two adjacent neighbors: 10.10.150.2 and 10.10.200.2. The **Neighbor ID** is the highest IP address defined by the loopback address of the neighbor router ID. In this case, 10.10.150.2 is the highest IP address for Router C, and 10.10.200.2 is the highest IP address of Router B. Refer to Figure 3-2 for the IP assignments for each router. The **Pri** column stands for Priority, which indicates the priority of the neighbor routers. The router with the highest priority becomes the **Designated Router (DR)**, and the router or routers with lower priority will become a **Backup Designated Router (BDR)**. In this case, the priority is the same, so the router with the highest router ID becomes the DR, which is Router B, and Router C becomes the BDR. This process is called a **DR Election**. It happens during the exchange of Hello packets. The main purpose of the DR router is to maintain the OSPF topology table of the network. This way, there is only one source that can send the OSPF routing updates to the routers within the area, thus minimizing the network traffic. Every router also sends its update to the DR and BDR via the multicast address. If the DR should fail, the BDR will assume the role of the designated router. The **state of FULL** is a good and desired state, which indicates that the routers are fully adjacent to each other. The **dead time** is the Hello time interval an OSPF router will wait before terminating

adjacency with a neighbor. The address is the IP address of its directly connected neighbor and the interface indicates the interface on which the neighbor is connected.

Load Balancing and Redundancy with OSPF

As long as there is an equal cost path, traffic load balancing on a per-packet basis can be configured with OSPF. For example, if there is an additional link of the same type interface and speed between Router A and Router B (refer to Figure 3-2), OSPF will automatically load balance the network traffic to the network 10.10.10.0 NET between the two links because they both have the same OSPF cost. To find out the OSPF cost of an interface, use the **sh ip ospf interface** command. The following example shows the OSPF interface information on FastEthernet0/2, including its interface cost of 1.

```
RouterA#sh ip ospf interface
FastEthernet0/2 is up, line protocol is up
  Internet Address 10.10.100.1/24, Area 0
  Process ID 100, Router ID 10.10.200.1, Network Type BROADCAST, Cost:
1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.10.200.1, Interface address 10.10.100.1
  Backup Designated router (ID) 10.10.150.2, Interface address
10.10.100.2
      :
      :
```

With the Shortest Path First protocol, OSPF uses the Dijkstra algorithm to calculate the shortest path. The algorithm takes into consideration the topology path and the associated cost and calculates the cumulative cost to reach a destination.

With destinations with multiple paths, OSPF will calculate the best shortest path and install the route into the routing table. For the example network (refer to Figure 3-2), Router A has two paths to reach the 10.10.10.0 network on Router B. One route is via FastEthernet0/1 to Router B and another route is via FastEthernet0/2 to Router C and then to Router B. The output of **show ip route** shows that the Router A has selected the path via its FastEthernet0/1 as the best path and this is confirmed when issuing the command **sh ip route 10.10.10.0**.

```
RouterA#sh ip route 10.10.10.0
Routing entry for 10.10.10.0/24
  Known via "ospf 100", distance 110, metric 2, type intra area
  Last update from 10.10.200.2 on FastEthernet0/1, 00:44:13 ago
  Routing Descriptor Blocks:
  * 10.10.200.2, from 10.10.200.2, 00:44:13 ago, via FastEthernet0/1
    Route metric is 2, traffic share count is 1
```

When the path via the interface FastEthernet0/1 becomes unavailable, the OSPF database gets updated, and another available route via RouterC is automatically selected, as shown here:

```
*Mar 1 01:31:40.399: %LINEPROTO-5-UPDOWN: Line protocol on Interface
FastEthernet0/1, changed state to down
*Mar 1 01:31:41.411: %OSPF-5-ADJCHG: Process 100, Nbr 10.10.200.2 on
FastEthernet0/1 from FULL to DOWN, Neighbor Down: Interface down or
detached
RouterA#sh ip route 10.10.10.0
Routing entry for 10.10.10.0/24
  Known via "ospf 100", distance 110, metric 3, type intra area
  Last update from 10.10.100.2 on FastEthernet1/0, 00:00:16 ago
  Routing Descriptor Blocks:
  * 10.10.100.2, from 10.10.200.2, 00:00:16 ago, via FastEthernet1/0
    Route metric is 3, traffic share count is 1
```

Interface Cost

One of the factors used in calculating the best path.

Because OSPF uses the **interface cost** as one of the factors in calculating the best path, one of the easiest ways to influence the OSPF path selection is by manipulating the interface cost. In our example, there are two equal routes to the network 10.10.150.0 Net, as shown.

```
RouterA#sh ip route 10.10.150.0
Routing entry for 10.10.150.0/24
  Known via "ospf 100", distance 110, metric 2, type intra area
  Last update from 10.10.200.2 on FastEthernet0/1, 00:00:05 ago
  Routing Descriptor Blocks:
  * 10.10.100.2, from 10.10.200.2, 00:00:05 ago, via FastEthernet0/2
    Route metric is 2, traffic share count is 1
  10.10.200.2, from 10.10.200.2, 00:00:05 ago, via FastEthernet0/1
    Route metric is 2, traffic share count is 1
```

If the preferred route to reach the 10.10.150.0 network is via Router B, then the OSPF cost of the interface connected to Router C can be increased. The default OSPF cost of the interface is 1. To change the cost of this interface, issue the **ip ospf cost** command at the interface, as shown:

```
RouterA(config)#int fastEthernet 0/2
RouterA(config-if)#ip ospf cost 5
RouterA#sh ip route 10.10.150.0
Routing entry for 10.10.150.0/24
  Known via "ospf 100", distance 110, metric 2, type intra area
  Last update from 10.10.200.2 on FastEthernet0/1, 00:00:07 ago
  Routing Descriptor Blocks:
  * 10.10.200.2, from 10.10.200.2, 00:00:07 ago, via FastEthernet0/1
    Route metric is 2, traffic share count is 1
```

By increasing the OSPF cost of interface0/2, the route to the network 10.10.150.0 is being preferred via the interface FastEthernet0/1 off Router B. However, changing the OSPF cost could have side effects if you are not careful. In our case, because the interface to Router C now has a higher OSPF cost, what will happen to the LAN

D or 10.10.5.0 network? The following output shows the current routing table after the OSPF cost has changed:

```
RouterA#sh ip route ospf
      10.0.0.0/24 is subnetted, 7 subnets
O       10.10.1.0 [110/2] via 10.10.200.2, 00:09:08, FastEthernet0/1
O       10.10.5.0 [110/3] via 10.10.200.2, 00:09:08, FastEthernet0/1
O       10.10.10.0 [110/2] via 10.10.200.2, 00:09:08, FastEthernet0/1
O       10.10.150.0 [110/2] via 10.10.200.2, 00:09:08, FastEthernet0/1
```

As you can see, the route to LAN D is now preferred through Router B. This means one extra router hop that it must take from Router A to reach LAN D. By increasing the interface cost, it affects everything along its path. This is definitely not the desirable side effect that you want. The network engineer must understand the network topology before adjusting the OSPF cost, Administrative Distance (AD), or any routing protocol metrics. This has to be carefully done and thoroughly verified; otherwise, it can result in a routing abnormality such as this.

Networking Challenge—OSPF

Use the Net-Challenge Simulator Software included with the text's companion CD-ROM to demonstrate that you can configure OSPF for Router A in the campus LAN (the campus LAN is shown in Figure 3-2 and is displayed by clicking the View Topology button when the software is started). Place the Net-Challenge CD-ROM in your computer's drive. Open the Net-Challenge folder and click **NetChallenge V3-2.exe**. When the software is running, click the **Select Router Challenge** button to open a **Select Router Challenge** drop-down menu. Select **Chapter 3—OSPF**. This opens a checkbox that can be used to verify that you have completed all the tasks:

1. Enter the privileged EXEC mode on the router.
2. Enter the router's terminal configuration mode: **Router(config)**.
3. Set the hostname to *Router A*.
4. Configure the FastEthernet0/0 interface with the following:
IP address: 10.10.20.250
Subnet mask: 255.255.255.0
5. Enable the FA0/0 interface.
6. Configure the FastEthernet0/1 interface with the following:
IP address: 10.10.200.1
Subnet mask: 255.255.255.0
7. Enable the FA0/1 interface.
8. Configure the FastEthernet0/2 interface with the following:
IP address: 10.10.100.1
Subnet mask: 255.255.255.0

9. Enable the FA0/2 interface.
10. Enable OSPF with a network number of 100.
11. Use a single command-line instruction to configure Router A to run OSPF on all three of the FastEthernet interfaces (use area 100).
12. Use the **sh ip int brief** command to check the interface status.
13. Use the **sh ip protocol** command to see whether OSPF is running on Router A.
14. Use the **sh ip route** command to verify that the three FastEthernet ports are connected to Router A.
15. Use the **sh run** command to view the running-configuration file on Router A. Verify that OSPF is enabled and the proper network address is specified.
16. The preferred route to reach the 10.10.150.0 network is via Router B. Issue the command to increase the OSPF cost of the interface connected to Router C to 5 using the **ip ospf cost** command.

L1 Routers

Analogous to OSPF nonbackbone routers.

L2 Routers

Analogous to OSPF backbone routers.

L1/L2 Routers

Analogous to OSPF area border routers.

ABR

Area border routers.

Connectionless Network Service (CLNS)

IS-IS is designed to work on the same network layer just like IP; therefore, it does not require an IP protocol for it to function.

Integrated IS-IS

Term indicating IS-IS was adapted to work with IP.

NET

Network Entity Title.

Area ID

Analogous to OSPF area number, and it is used by L2 routers.

3-2 CONFIGURING LINK STATE PROTOCOLS—IS-IS

There are many similarities between IS-IS and OSPF. Both protocols use the link state protocol with the Dijkstra algorithm. Both are classless protocols, which enable the support of VLSM. Both protocols use Hello packets to form and maintain adjacencies and both use the area concept. However, there is a difference in the way in which the areas are defined for each protocol. In IS-IS, there are two hierarchical topology areas: level 1 (Intra-area) and level 2 (Inter-area). A router can either be a level 1 (L1) router, a level 2 (L2) router, or both (L1/L2) routers. **L1 routers** are analogous to OSPF nonbackbone routers, **L2 routers** are analogous to OSPF backbone routers, and **L1/L2 routers** are analogous to OSPF area border routers (**ABR**). Unlike OSPF ABRs, L1/L2 routers do not advertise routes from L2 routers to L1 routers. The packets from different areas can only be routed through the L1/L2 routers. Essentially, L1/L2 routers are default gateways to L1 routers. Another big difference is that the IS-IS backbone area can be segmented. Unlike the backbone area in OSPF, all routers in area 0 must be connected; the IS-IS L2 routers do not need to be connected directly together.

IS-IS was originally designed as part of the Open System Interconnection (OSI) network layer service called **Connectionless Network Service (CLNS)**. This means that IS-IS is designed to work on the same network layer just like IP; therefore, it does not require IP protocol for it to function. Later, it was adapted to work with IP. Hence, it is sometimes referred to as **integrated IS-IS**. In IS-IS, every router uses the Network Entity Title (**NET**) to define its process. The NET address is unique to each router; it is comprised of the following components in hexadecimal format:

- The **area ID** in IS-IS is analogous to OSPF area number, and it is used by L2 routers.

- The **system ID** is analogous to the OSPF router ID, and it is used by L1 routers.
- The **Network Service Access Point Selector (NSEL)** identifies the network service type.

The NET address can look intimidating because of its long hexadecimal format, but it is not as bad as it seems. The way to work with a NET address is to start from right and work left. For example, given a NET address of 49.0001.0014.a909.5201.00, the last 1 byte from the right is NSEL, which is always set to 00 on a router. The next six bytes from the right are separated into three groups of 2 bytes and define the system ID. In this example, the system ID is 0014.a909.5201. The system ID is always unique and is typically represented as the MAC address of the router. The remaining numbers to the left of the System ID define the Area ID, which is 49.0001. The area ID has a variable length, but its first number must be at least 1 byte long.

System ID

Analogous to the OSPF router ID, and it is used by L1 routers.

Network Service Access Point Selector (NSEL)

Identifies the network service type.

IS-IS

Interior Gateway Routing Protocol.

Configuring Routes with IS-IS

This section demonstrates how to configure the routers to use the **IS-IS** routing protocol for the three-router campus network shown in Figure 3-3. For this exercise, RouterB has been turned off. This is reflected in the output of the command **show ip int brief**. Notice that the Router A interface FastEthernet0/1, which connects RouterB, is showing Status **down** and Protocol **down**.

```
RouterA#show ip int brief
```

```
Interface      IP-Address      OK?  Method  Status  Protocol
FastEthernet0/0 10.10.20.250   YES  NVRAM   up      up
FastEthernet0/1 10.10.200.1    YES  manual  down    down
FastEthernet0/2 10.10.100.1    YES  manual  up      up
```

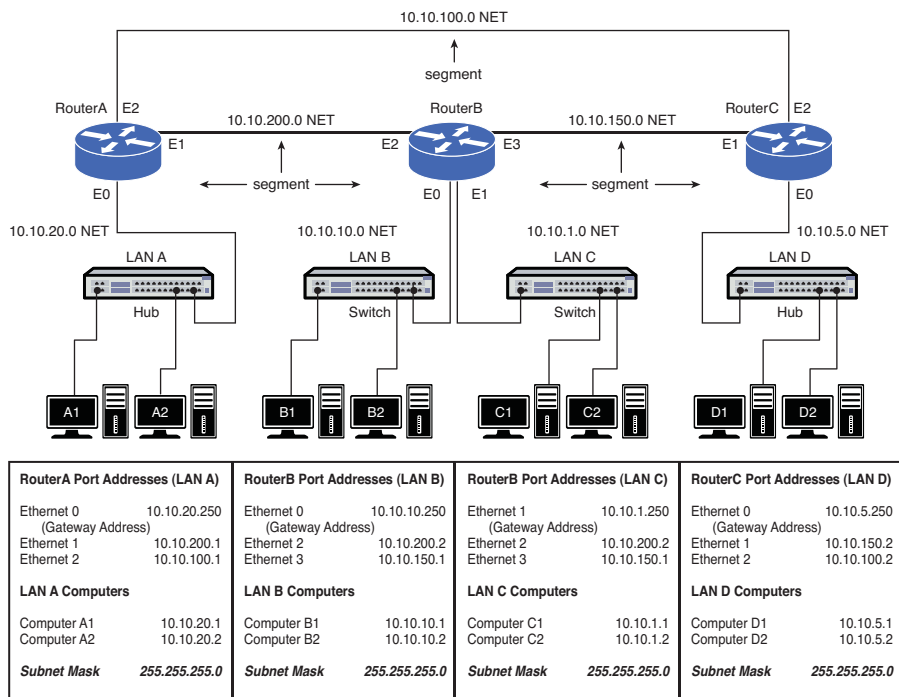


FIGURE 3-3 Routers A, B, and C in the three-router campus network

cnls routing

The global command for IS-IS.

router isis

Starts the IS-IS routing protocol.

ip router isis

Specifies the network that will be using IS-IS for routing.

The first step in configuring Router A to use IS-IS is to enable the protocol globally. As mentioned earlier, IS-IS is a part of CNLS as its network layer routing protocol. When configuring most routing protocols, the global command of **ip routing** must be issued. With IS-IS, the global command of **cnls routing** must be issued. Then, at the *RouterA(config)#* prompt, enter the command **router isis** to start using the IS-IS routing protocol. Next, the NET address will need to be entered to specify the area the router belongs to as well as defining the System ID and the NSEL of 00. Unlike other routing protocols, to specify the network that will be using IS-IS for routing, this will need to be configured at each individual interface with the command **ip router isis**. These steps are as follows:

```
RouterA(config)#cnls routing
RouterA(config)#router isis
RouterA(config-router)# net 49.0001.c202.00e8.0000.00
RouterA(config-router)#interface fastethernet0/0
RouterA(config-router)#ip router isis
RouterA(config-router)#interface fastethernet0/2
RouterA(config-router)#ip router isis
```

On Router A, the interface FastEthernet 0/0 and the interface Fastethernet 0/2 are configured to use IS-IS. The same set of commands is issued on Router B and Router C to route with IS-IS. You can verify that IS-IS is running on Router A by entering the command **sh ip protocol**, as shown at the enable prompt (**RouterA#**):

```
RouterA# sh ip protocol
Routing Protocol is "isis"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Redistributing: isis
  Address Summarization:
    None
  Maximum path: 4
  Routing for Networks:
    FastEthernet0/0
    FastEthernet0/1
    FastEthernet0/2
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.10.100.2      115          00:02:44
    10.10.150.1     115          00:02:44
  Distance: (default is 115)
```

The text shows that the routing protocol is “isis.” The networks it is routing are on the interface FastEthernet0/0, FastEthernet0/1, and FastEthernet0/2. It also shows that it is receiving routing information from the source 10.10.100.2, which is the Router C interface FastEthernet0/2 and 10.10.150.1, which is the Router B interface FastEthernet0/3. The routing information was updated 2 minutes 44 seconds ago.

Next, the command **show ip route (sh ip route)** can be used to examine the contents of Router A’s routing table to see if any IS-IS routes have been received:

```

RouterA# sh 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, 7 subnets
i L1  10.10.1.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1  10.10.5.0 [115/20] via 10.10.100.2, FastEthernet0/2
i L1  10.10.10.0 [115/20] via 10.10.200.2, FastEthernet0/1
C     10.10.20.0 is directly connected, FastEthernet0/0
C     10.10.100.0 is directly connected, FastEthernet0/2
i L1  10.10.150.0 [115/20] via 10.10.100.2, FastEthernet0/2
           [115/20] via 10.10.200.2, FastEthernet0/1
C     10.10.200.0 is directly connected, FastEthernet0/1

```

The command **sh ip route** indicates that the network 10.10.5.0 has been received via the IP 10.10.100.2, which is directly connected to the interface FastEthernet0/2. The routes for network 10.10.1.0 and 10.10.10.0 are learned via the IP 10.10.200.2 on interface FastEthernet0/1. The network 10.10.150.0 is learned via both FastEthernet0/1 and FastEthernet0/2. As a matter of fact, the routing table looks similar to the one of OSPF. The “i” before the route indicates IS-IS routes, and “L1” stands for IS-IS level 1. The command **show ip route isis** can be used to view the routing table just for IS-IS, as shown:

```

RouterA#sh ip route isis
10.0.0.0/24 is subnetted, 7 subnets
i L1  10.10.1.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1  10.10.5.0 [115/20] via 10.10.100.2, FastEthernet0/2
i L1  10.10.10.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1  10.10.150.0 [115/20] via 10.10.100.2, FastEthernet0/2
           [115/20] via 10.10.200.2, FastEthernet0/1

```

Similar to an OSPF router, IS-IS establishes its adjacencies with its neighbors and the neighbor information can be found with the command **show clns is-neighbors**.

```
RouterA#sh clns is-neighbors
```

System Id Format	Interface	State	Type	Priority	Circuit Id
RouterB Phase V	Fa0/1	Up	L1L2	64/64	RouterA.02
RouterC Phase V	Fa1/0	Up	L1L2	64/64	RouterA.03

show ip route isis (sh ip route isis)

Displays only the IS-IS routes.

show clns is-neighbors

Command used in IS-IS to find adjacencies with neighbors.

IS-IS is identified by its NET address not the IP address. Therefore, the network administrator will need to remember the NET address. This can be a challenge, especially in a big network but IS-IS does provide dynamic hostname exchange. This allows the ASCII router name to be exchanged among the routers; therefore, it can be used to associate with the system instead of the NET address. An example of the IS-IS dynamic hostname exchange is next shown resulting from the **sh clns is-neighbor** command. Notice that the router names are displayed in the System ID and Circuit ID fields.

One confusing issue regarding IS-IS is when to use the command **isis** or **clns**. The **clns** commands are used when dealing with the protocol at the Layer 2 level. The **isis** commands are used when dealing with IP information. For example, the similar neighbor information can be displayed with command **show isis neighbor**. The differences are the IP address and IS-IS level type information are displayed using **show isis neighbor**.

```
RouterA#sh isis neighbors
System Id  Type  Interface IP Address  State  Holdtime  Circuit Id
RouterB    L1   Fa0/1    10.10.200.2  UP     28        RouterA.02
RouterB    L2   Fa0/1    10.10.200.2  UP     20        RouterA.02
RouterC    L1   Fa1/0    10.10.100.2  UP     20        RouterA.03
RouterC    L2   Fa1/0    10.10.100.2  UP     22        RouterA.03
```

The final step is to view the running-configuration in each router using the **sh run** command. The running-configuration for Router A is provided. Notice the entries for **router isis** and **net 49.0001.c202.00e8.000.00**, and **ip router isis** in the running-configuration file.

```
RouterA#sh run
Building configuration...
Current configuration:
!
version 12.0
service timestamps debug uptime service timestamps log uptime no
service password-encryption
!
hostname RouterA
!
enable secret 5 $1$6M4r$dleo7h1WP0AYu0K/cm6M91
enable password Salsa
!
ip subnet-zero
!
interface FastEthernet0/0
 ip address 10.10.20.250 255.255.255.0
 ip router isis
 no ip directed-broadcast
!
interface FastEthernet0/1
 ip address 10.10.200.1 255.255.255.0
 no ip directed-broadcast
```

```

!
interface FastEthernet0/2
 ip address 10.10.100.1 255.255.255.0
 ip router isis
 no ip directed-broadcast
!
router isis
 net 49.0001.c202.00e8.0000.00
!
ip classless
!
line con 0
transport input none line aux 0
line vty 0 4 password chile login
!
end

```

Remember to use the **copy run start** command to save the changes made to NVRAM.

Load Balancing and Redundancy with IS-IS

Because IS-IS is another SPF protocol, its load balancing and redundancy capabilities are almost identical to those used by OSPF. IS-IS can load balance the network traffic over equal cost paths. On the unequal cost paths, only the best path is installed into the routing table and that path becomes the primary route where the network traffic will flow. When the primary link fails, the routes will converge to the secondary link until the primary link is back in operation. All of these examples have been shown within the OSPF section.

These same concepts explored in the OSPF section, as well as the cautions, still apply to IS-IS. The only big differences between the two protocols usually are the command syntax used in configuring some of the functions. In OSPF, an OSPF cost is the value assigned to the interface, and its default value is 1. In IS-IS, it is a metric that is assigned to the interface and its default metric value is 10. The IS-IS metric can be adjusted at the interface level with the following command sequence:

```

RouterA(config)#int fastEthernet 0/2
RouterA(config-if)#isis metric 30

```

By increasing the IS-IS metric on the FastEthernet0/2 on Router A, the same results happen as when increasing the OSPF cost on this very same interface. That is all routes destined to any networks on Router C now prefer the interface FastEthernet0/1 via Router B as their primary route or best path. The result of adjusting the IS-IS metric is shown via command **show ip route isis**:

```

RouterA#sh ip route isis
10.0.0.0/24 is subnetted, 7 subnets
i L1   10.10.1.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1   10.10.5.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1   10.10.10.0 [115/20] via 10.10.200.2, FastEthernet0/1
i L1   10.10.150.0 [115/20] via 10.10.200.2, FastEthernet0/1

```

show clns interface

The command used to verify the IS-IS interface metric.

To verify the IS-IS interface metric, issue the **show clns interface** command. The output displays the interface FastEthernet0/2, which now has the level1-metric and level2-metric of 30:

```
RouterA#sh clns interface
:
FastEthernet0/2 is up, line protocol is up
  Checksums enabled, MTU 1497, Encapsulation SAP
  ERPDUs enabled, min. interval 10 msec.
  RDPDUs enabled, min. interval 100 msec., Addr Mask enabled
  Congestion Experienced bit set at 4 packets
  CLNS fast switching enabled
  CLNS SSE switching disabled
  DEC compatibility mode OFF for this interface
  Next ESH/ISH in 19 seconds
Routing Protocol: IS-IS
  Circuit Type: level-1-2
  Interface number 0x2, local circuit ID 0x3
  Level-1 Metric: 30, Priority: 64, Circuit ID: RouterA.03
  Level-1 IPv6 Metric: 10
  Number of active level-1 adjacencies: 1
  Level-2 Metric: 30, Priority: 64, Circuit ID: RouterA.03
  Level-2 IPv6 Metric: 10
  Number of active level-2 adjacencies: 1
```

Networking Challenge: IS-IS

Use the Net-Challenge Simulator Software included with the text's companion CD-ROM to demonstrate that you can configure IS-IS for Router A in the campus LAN. (The campus LAN is shown in Figure 3-3 and is displayed on the computer screen after the software is started.) Place the Net-Challenge CD-ROM in your computer's drive. Open the **Net-Challenge** folder, and click **NetChallenge V3-2.exe**.

When the software is running, click the **Select Router Challenge** button to open a **Select Router Challenge** drop-down menu. Select **Chapter 3—IS-IS**. This opens a checkbox that can be used to verify that you have completed all the tasks. A check next to a task indicates that the task has been successfully completed:

1. Click the Router A button.
2. Enter the privileged EXEC mode on the router.
3. Enter the router configuration mode, **Router(config)**.
4. Set the hostname to **RouterA**.
5. Configure the FastEthernet0/0 interface with the following:
IP address: 10.10.20.2
Subnet mask: 255.255.255.0
6. Enable the FA0/0 interface.

7. Configure the FastEthernet0/1 interface with the following:
IP address: 10.10.200.1
Subnet mask: 255.255.255.0
8. Enable the FA0/1 interface.
9. Configure the FastEthernet0/2 interface with the following:
IP address: 10.10.100.1
Subnet mask: 255.255.255.0
10. Enable the FA0/2 interface.
11. Enable CNLS routing.
12. Enable IS-IS on Router A.
13. Use the **net** command to specify the NET address to be used by IS-IS.
14. Enable IS-IS on FA0/0 and FA0/2.
15. Use the **sh ip int brief** command to check the interface status.
16. Use the **sh ip protocol** to see whether IS-IS is running.
17. Use the **sh ip route** command to verify that the four FastEthernet ports are connected to the router.
18. Use the **sh run** command to view the running-configuration file. Verify that IGRP is enabled and the proper network address is specified.
19. Copy the running-configuration to the startup-configuration.
20. Display the contents of the startup configuration.

3-3 CONFIGURING HYBRID ROUTING PROTOCOLS—EIGRP

This section introduces techniques for configuring a router's interface to run **EIGRP**, the Enhanced Interior Gateway Routing Protocol. EIGRP is an enhanced version of the Interior Gateway Routing Protocol (IGRP). EIGRP is a Cisco proprietary protocol and is often called a **hybrid routing protocol** that incorporates the best of the distance vector and link-state algorithms.

EIGRP allows the use of variable length subnet masks, which is beneficial when you're trying to conserve the use of IP addresses. EIGRP also uses Hello packets to verify that a link from one router to another is still active. This is similar to the OSPF Hello packet described in Section 3-5. The routing table updates are exchanged when there is a change in the network. In other words, the routers don't exchange unnecessary information unless a route changes. This helps conserve the limited bandwidth of the network data link. When route information is exchanged, EIGRP quickly converges to the new route selection.

EIGRP

Enhanced Interior Gateway Routing Protocol.

Hybrid Routing Protocol

Protocol that incorporates the best of the distance vector and link-state algorithms.

The four components of EIGRP are as follows:

- **Neighbor Discovery Recovery:** Used to learn about other routers on directly attached networks. This is also used to discover whether neighbor routers are unreachable. This discovery is accomplished by periodically sending Hello packets. The Hello packets are used to verify that a neighbor router is functioning.
- **Reliable Transport Protocol:** Used to guarantee delivery of EIGRP packets to neighbor routers. Both unicast and multicast packet transmission are supported.
- **DUAL Finite State Machine:** Used to track all routes advertised by its neighbors and is used for route computation to obtain loop-free routing.
- **Protocol Dependent Modules:** Responsible for handling network layer, protocol-specific requirements. For example, the IP-EIGRP module is responsible for extracting information from the EIGRP packets and passing this information to DUAL. DUAL uses this information to make routing decisions, and IP-EIGRP then redistributes the learned routes.

Configuring Routes with EIGRP

This section describes a procedure for configuring EIGRP on a router. The first example is for configuring Router A in the campus LAN shown in Figure 3-4.

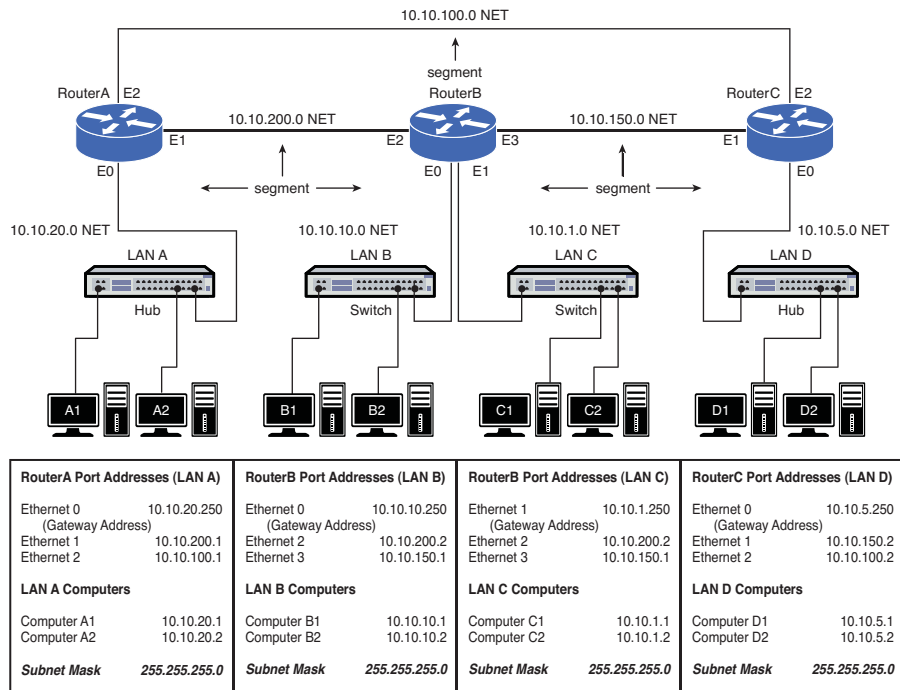


FIGURE 3-4 The three-router campus LAN

The first step is to configure the interfaces on each of the three routers. Table 3-2 lists the IP addresses and the subnet masks for the router interfaces.

TABLE 3-2 Router Interface IP Addresses and Subnet Masks

Interface	IP Address	Subnet Mask
Router A		
FA0/0	10.10.20.250	255.255.255.0
FA0/1	10.10.200.1	255.255.255.0
FA0/2	10.10.100.1	255.255.255.0
Router B		
FA0/0	10.10.10.250	255.255.255.0
FA0/1	10.10.1.250	255.255.255.0
FA0/2	10.10.200.2	255.255.255.0
FA0/3	10.10.150.1	255.255.255.0
RouterC		
FA0/0	10.10.5.250	255.255.255.0
FA0/1	10.10.150.2	255.255.255.0
FA0/2	10.10.100.2	255.255.255.0

After configuring the router interfaces, the EIGRP routing protocol for Router A will be configured. Use the **conf t** command to enter the router's configuration mode. Next, enter the command **router eigrp [AS-number]**. Any AS number can be used. The router uses the AS numbers to determine which routers share routing tables. Only routers with the same AS number will share routing updates. The command **router eigrp 150** is entered as shown. The prompt changes to (config-router) and the next command entered sets the network to run EIGRP. In this example, the command **network 10.0.0.0** is entered. This instructs the router to run EIGRP on any of the router's interfaces that have an IP address that begins with 10. A different network command will be used on Router B to show how the command can be used to specify a limited IP address range.

```
RouterA(config)#router eigrp 150
RouterA(config-router)#network 10.0.0.0
```

Now, the 10.x.x.x interfaces on Router A are configured to run EIGRP. The command **sh ip protocol** is entered to verify that the EIGRP routing protocol is enabled on Router A:

```
RouterA# sh ip protocol
Routing Protocol is "eigrp 150"
Outgoing update filter list for all interfaces is Incoming update
filter list for all interfaces is Default networks flagged in outgoing
updates Default networks accepted from incoming updates EIGRP metric
weight K1 1, K2 0, K3 1, K4 0, K5 0
```

```

EIGRP maximum hopcount 100
EIGRP maximum metric variance 1
Redistributing: eigrp 150
Automatic network summarization is in effect
Routing for Networks:
10.0.0.0
Routing Information Sources:
Gateway Distance Last Update
10.10.200.2 90 00:00:09
Distance: internal 90 external 170

```

The top line states that the routing protocol is “eigrp 150” and indicates that it has been 9 seconds since the last update to the routing table. In EIGRP, updates to the routing table are made when there are changes in the network.

Another useful command is **sh ip route**. The following are the results of entering the command. In this case, the router does not show any EIGRP routes to the subnets in the network, because EIGRP has not been configured on Router B or Router C:

```

RouterA#sh ip route
Codes: C connected, S static, I IGRP, 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, E EGP
i IS-IS, L1 IS-IS level-1, L2 IS-IS level-2, * candidate default
U per-user static route, o ODR T traffic engineered route
Gateway of last resort is not set
10.0.0.0/24 is subnetted, 3 subnets
C 10.10.20.0 is directly connected, FastEthernet0/0
C 10.10.200.0 is directly connected, FastEthernet0/1
C 10.10.100.0 is directly connected, FastEthernet0/2

```

The command **sh ip int brief** is entered and the status and protocols for the Ethernet interfaces are **up**. These will show **up** as long as there is a network connection to the interfaces:

```

RouterA#sh ip int brief
Interface          IP-Address      OK?    Method   Status   Protocol
FastEthernet0/0    10.10.20.250    YES    NVRAM    up       up
FastEthernet0/1    10.10.200.1     YES    manual   up       up
FastEthernet0/2    10.10.100.1     YES    manual   up       up

```

The **sh run** command is used to view the contents of the router’s running-configuration file. The following shows the part of the configuration file that shows the entries for EIGRP. Notice that these entries are the same as the commands entered earlier when configuring EIGRP:

```

!
router eigrp 150
 network 10.0.0.0
!

```

The next step is to configure Router B. The configuration mode (config)# for Router B is entered and the command **router eigrp 150** is entered. Remember, 150 is the AS number, which is the same number used when configuring Router A. The next command is used to set the network that is running EIGRP. In this case, the command **network 10.10.0.0** is entered. This means that interfaces on Router B with a 10.10.x.x address will run the EIGRP protocol. In this case, all interfaces on Router B have a 10.10.x.x address and will run EIGRP:

```
RouterB#conf t
Enter configuration commands, one per line. End with CNTL/Z.
RouterB(config)#router eigrp 150
RouterB(config-router)#network 10.10.0.0
```

The command **sh ip protocol** is used to verify that EIGRP is running on Router B. The text shows that eigrp 150 is running on Router B, and it has been 27 seconds since the last update to the routing table:

```
RouterB#sh ip protocol
Routing Protocol is "eigrp 150"
Outgoing update filter list for all interfaces is Incoming update
filter list for all interfaces is Default networks flagged in outgoing
updates Default networks accepted from incoming updates EIGRP metric
weight K1 1, K2 0, K3 1, K4 0, K5 0
EIGRP maximum hopcount 100
EIGRP maximum metric variance 1
Redistributing: eigrp 150
Automatic network summarization is in effect
Routing for Networks:
10.0.0.0
Routing Information Sources:
Gateway Distance Last Update
10.10.200.1 90 00:00:27
Distance: internal 90 external 170
```

The **sh ip route** command for Router B shows that six routes are on Router B, and there are EIGRP routes to the 10.10.20.0 and 10.10.100.0 subnets. The code for the EIGRP routes is D. Remember, the C code is for the subnets directly connected to the router:

```
RouterB#sh ip route
Codes: C connected, S static, I IGRP, 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, E EGP
i IS-IS, L1 IS-IS level-1, L2 IS-IS level-2, * candidate default
U per-user static route, o ODR T traffic engineered route
Gateway of last resort is not set
10.0.0.0/24 is subnetted, 6 subnets
C 10.10.10.0 is directly connected, FastEthernet0/0
C 10.10.1.0 is directly connected, FastEthernet0/1
D 10.10.20.0 [90/2195456] via 10.10.200.1, 00:00:09, FastEthernet0/2
D 10.10.100.0 [90/2681856] via 10.10.200.1, 00:00:09, FastEthernet0/2
```

```
C 10.10.150.0 is directly connected, FastEthernet0/3
C 10.10.200.0 is directly connected, FastEthernet0/2
```

A check of the IP routes on Router A also shows that Router A and Router B are exchanging routes with each other. Router A now shows six subnets. Once again, the D indicates the EIGRP routes, and the C indicates the directly connected subnets:

```
RouterA#sh ip route
Codes: C connected, S static, I IGRP, 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, E EGP
i IS-IS, L1 IS-IS level-1, L2 IS-IS level-2, * candidate default
U per-user static route, o ODR T traffic engineered route
Gateway of last resort is not set
10.0.0.0/24 is subnetted, 6 subnets
D 10.10.10.0 [90/2195456] via 10.10.200.2, 00:00:50, FastEthernet0/1
D 10.10.1.0 [90/2195456] via 10.10.200.2, 00:00:50, FastEthernet0/1
C 10.10.20.0 is directly connected, FastEthernet0/0
C 10.10.100.0 is directly connected, FastEthernet0/2
D 10.10.150.0 [90/2681856] via 10.10.200.2, 00:00:50, FastEthernet0/1
C 10.10.200.0 is directly connected, FastEthernet0/1
```

The last step is to configure EIGRP for Router C using the **router eigrp 150** command. The command **network 10.10.0.0** is used to instruct the router to assign EIGRP to all interfaces that are part of the 10.10.0.0 network. In this case, all interfaces on Router C have a 10.10.x.x address and therefore will run EIGRP:

```
RouterC(config)#router eigrp 150
RouterC(config-router)#network 10.10.0.0
```

The **sh ip route** command is used to display the IP routes for Router C. Router C shows seven subnets. In fact, there are seven subnets in the campus LAN shown in Figure 3-4. This completes the setup for running EIGRP on the campus LAN:

```
RouterC#sh ip route
Codes: C connected, S static, I IGRP, R RIP, M mobile, B BGP D EIGRP,
EX EIGRP external, O OSPF, IA OSPF inter area
E1 OSPF external type 1, E2 OSPF external type 2, E EGP
i IS-IS, L1 IS-IS level-1, L2 IS-IS level-2, * candidate default
Gateway of last resort is not set
10.0.0.0 255.255.255.0 is subnetted, 7 subnets
C 10.10.5.0 is directly connected, FastEthernet0/0
D 10.10.10.0 [90/2195456] via 10.10.150.1, 00:00:01, FastEthernet0/1
D 10.10.1.0 [90/2195456] via 10.10.150.1, 00:00:01, FastEthernet0/1
D 10.10.20.0 [90/2195456] via 10.10.100.1, 00:00:01, FastEthernet0/2
C 10.10.100.0 is directly connected, FastEthernet0/2
C 10.10.150.0 is directly connected, FastEthernet0/1
D 10.10.200.0 [90/2681856] via 10.10.150.1, 00:00:01, FastEthernet0/1
[90/2681856] via 10.10.100.1, 00:00:01,
FastEthernet0/2
```

Just like other dynamic routing protocols, one useful command for troubleshooting routing problems is to look at the router's neighbors, because that is how routes are exchanged. The command **show ip eigrp neighbors** will display the EIGRP adjacency neighbor.

```
RouterA#sh ip eigrp neighbors
IP-EIGRP neighbors for process 150
H  Address          Interface  Hold  Uptime    SRTT  RTO  Q    Seq
   (sec)           (ms)
1  10.10.200.2      Fa0/1     10    00:31:06  152   912  0    30
0  10.10.100.2     Fa0/2     11    00:31:51  86    516  0    37
```

The output result of the **show ip eigrp neighbors** command is simpler comparing to other routing protocol **neighbor** commands. There is no state that one has to decipher. If the neighbor adjacency is established it will be displayed. The important fields that one should pay attention to when troubleshooting EIGRP routing are **Uptime** and **Q Cnt**. The uptime indicates the time the neighbor has last established its adjacency. If the number is much lower than the others, there could be a neighbor or connection issue. The Q Cnt is the number of EIGRP packets being queued to its neighbor. The expected number is 0. If the number is consistently higher, this could mean that there is a link issue or link congestion.

The output of the **show ip eigrp neighbors** command consists of the following fields:

- **H:** The order in which the adjacency is established with the specific neighbor.
- **Address:** The IP address of the neighbor router interface.
- **Interface:** The router interface connected to the neighbor.
- **Hold:** Amount of time EIGRP will wait to hear from its neighbor before declaring it down.
- **Uptime:** The uptime of the adjacent neighbor.
- **SRTT:** Smooth Round Trip Time for sending and receiving EIGRP packet from its neighbor.
- **RTO:** Retransmission Timeout to resend EIGRP packet as calculated by SRTT.
- **Q Cnt:** Queue count is the number of EIGRP packets in the queue waiting to be sent.
- **Seq Num:** Sequence number of the last update sent by its neighbor.

Load Balancing and Redundancy

EIGRP is a popular routing protocol to use on Cisco routers, not because it is Cisco proprietary, but because it is easy to configure and manage. Like other dynamic protocols, EIGRP is capable of load balancing over equal cost paths. By design, EIGRP can use bandwidth, delay, reliability, load, and MTU as values to calculate its composite metric to determine the best path to a destination.

By default, only bandwidth and delay are used by Cisco to calculate the composite metric. Bandwidth is the minimum bandwidth of the entire path. Delay is the total

show ip eigrp neighbors

The command used to display the EIGRP adjacency neighbor.

Uptime

Indicates the time the neighbor has last established its adjacency.

Q Cnt

The number of EIGRP packets being queued to its neighbor.

show ip eigrp topology

Command used to view the composite metric of the current EIGRP topology, the command.

delay of the entire path. To view the composite metric of the current EIGRP topology, issue the **show ip eigrp topology** command. The highlighted numbers are the EIGRP composite metric of each path:

```
RouterA#sh ip eigrp topology
IP-EIGRP Topology Table for AS(150)/ID(10.10.200.1)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 10.10.1.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.5.0/24, 1 successors, FD is 30720
   via 10.10.100.2 (30720/28160), FastEthernet0/2
P 10.10.10.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.20.0/24, 1 successors, FD is 28160
   via Connected, FastEthernet0/0
P 10.10.100.0/24, 1 successors, FD is 28160
   via Connected, FastEthernet1/0
P 10.10.150.0/24, 2 successors, FD is 30720
   via 10.10.100.2 (30720/28160), FastEthernet0/2
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.200.0/24, 1 successors, FD is 28160
   via Connected, FastEthernet0/1
```

bandwidth

Command used to adjust the bandwidth value.

It is typically not recommended to manually adjust the EIGRP composite metric. Cisco's recommendation is to leave the EIGRP as it is; however, if this must be done, then the two less destructive ways for setting an EIGRP preferred path is by adjusting the bandwidth value or by adjusting the delay value. To adjust the bandwidth value, this can be done via the **bandwidth** command at the router interface:

```
RouterA(config)#int fastEthernet 0/2
RouterA(config-if)#bandwidth 1000
```

The **bandwidth** command is in kilobits, so **bandwidth 1000** would mean 1,000 Kbits or 1 Mbits as its value. The interface FastEthernet0/2 on Router A is connecting Router C. By reducing the bandwidth value, the composite metric of any route via the interface FastEthernet0/2 has changed as reflected in the recent **show ip eigrp topology** command. The composite metric that used to be 30,720 is now 2,565,120:

```
RouterA#sh ip eigrp topology
IP-EIGRP Topology Table for AS(150)/ID(10.10.200.1)

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

P 10.10.1.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.5.0/24, 1 successors, FD is 33280
```

```

        via 10.10.200.2 (33280/30720), FastEthernet0/1
        via 10.10.100.2 (2565120/28160), FastEthernet0/2
P 10.10.10.0/24, 1 successors, FD is 30720
    via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.20.0/24, 1 successors, FD is 28160
    via Connected, FastEthernet0/0
P 10.10.100.0/24, 1 successors, FD is 2562560
    via Connected, FastEthernet1/0
    via 10.10.200.2 (33280/30720), FastEthernet0/1
P 10.10.150.0/24, 1 successors, FD is 30720
    via 10.10.200.2 (30720/28160), FastEthernet0/1
    via 10.10.100.2 (2565120/28160), FastEthernet0/2
P 10.10.200.0/24, 1 successors, FD is 28160
    via Connected, FastEthernet0/1

```

The **show ip route eigrp** also confirms that the path via FastEthernet0/1 to Router B is now the preferred path for all network routes:

```

RouterA#sh ip route eigrp
  10.0.0.0/24 is subnetted, 7 subnets
D       10.10.1.0 [90/30720] via 10.10.200.2, 00:11:42,
FastEthernet0/1
D       10.10.5.0 [90/33280] via 10.10.200.2, 00:11:42,
FastEthernet0/1
D       10.10.10.0 [90/30720] via 10.10.200.2, 00:11:42,
FastEthernet0/1
D       10.10.150.0 [90/30720] via 10.10.200.2, 00:11:42,
FastEthernet0/1

```

Changing the bandwidth value could have more impact beyond EIGRP routing; other protocols, like QoS, depend on the bandwidth value to make their decisions. Between the **bandwidth** value and the **delay** value, the **delay** value command is the one with the least impact. Therefore, to manipulate the EIGRP composite metric, adjusting the delay value is preferred over adjusting the bandwidth value. To adjust the bandwidth value, this can be done by adjusting the **delay** command at the router interface:

```

RouterA(config)#int fastEthernet 0/2
RouterA(config-if)#delay 100

```

The delay value is measured in tens of microseconds. The command **delay 100** changes the default delay value from 100 microseconds to 1,000 microseconds. This, in turn, increases the composite metric of the interface FastEthernet0/2 on Router A connecting to Router C. The composite metric of any route via the interface FastEthernet0/2 has changed as reflected in the recent **show ip eigrp topology** command. The path composite metric that used to be 30,720 is now 53,760. Again, the path via FastEthernet0/1 to Router B is now a more preferred path for all network routes.

```

RouterA#sh ip eigrp topology
IP-EIGRP Topology Table for AS(150)/ID(10.10.200.1)

```

delay

This command sets the delay on the interface. The delay value is measured in tens of microseconds.

Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
r - reply Status, s - sia Status

```
P 10.10.1.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.5.0/24, 1 successors, FD is 33280
   via 10.10.200.2 (33280/30720), FastEthernet0/1
   via 10.10.100.2 (53760/28160), FastEthernet0/2
P 10.10.10.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
P 10.10.20.0/24, 1 successors, FD is 28160
   via Connected, FastEthernet0/0
P 10.10.100.0/24, 1 successors, FD is 51200
   via Connected, FastEthernet1/0
   via 10.10.200.2 (33280/30720), FastEthernet0/1
P 10.10.150.0/24, 1 successors, FD is 30720
   via 10.10.200.2 (30720/28160), FastEthernet0/1
   via 10.10.100.2 (53760/28160), FastEthernet0/2
P 10.10.200.0/24, 1 successors, FD is 28160
   via Connected, FastEthernet0/1
```

Networking Challenge: EIGRP

Use the Net-Challenge Simulator Software included with the text's companion CD-ROM to demonstrate that you can configure EIGRP for Router A in the campus LAN (the campus LAN is shown in Figure 3-2 and is displayed by clicking the View Topology button when the software is started). Place the Net-Challenge CD-ROM in your computer's drive. Open the Net-Challenge folder and click **Net Challenge V3-2.exe**. When the software is running, click the **Select Router Challenge** button to open a **Select Router Challenge** drop-down menu. Select **Chapter 3—EIGRP**. This opens a checkbox that can be used to verify that you have completed all the tasks:

1. Enter the privileged EXEC mode on the router.
2. Enter the router configuration mode: **Router(config)**.
3. Set the hostname to **RouterA**.
4. Configure the FastEthernet0/0 interface with the following:
IP address: 10.10.20.250
Subnet mask: 255.255.255.0
5. Enable the FA0/0 interface.
6. Configure the FastEthernet0/1 interface with the following:
IP address: 10.10.200.1
Subnet mask: 255.255.255.0
7. Enable the FA0/1 interface.

8. Configure the FastEthernet0/2 interface with the following:
IP address: 10.10.100.1
Subnet mask: 255.255.255.0
9. Enable the FA0/2 interface.
10. Enable EIGRP with an AS number of 200.
11. Enter the **network** command that enables EIGRP on the router.
12. Use the **sh ip int brief** command to check the interface status.
13. Use the **sh ip protocol** command to see whether EIGRP is running on Router A.
14. Use the **sh ip route** command to verify that the three FastEthernet ports are connected to Router A.
15. Use the **sh run** command to view the running-configuration file on Router A.
Verify that EIGRP is enabled and the proper network address is specified.
16. Use the **ping** command to verify connection to the following interfaces:

10.10.5.250
10.10.150.1
10.10.200.2
10.10.100.2

3-4 ADVANCED ROUTING REDISTRIBUTION

Routing redistribution is another important practice that a network engineer may have to address when working in a big network environment. **Routing redistribution** is the technique of injecting routes from one routing protocol into another routing protocol. In general, routes are only exchanged automatically with other routers that are running the same routing protocol (for example, OSPF-OSPF or EIGRP-EIGRP). Each routing protocol speaks its own language and does not automatically communicate with other routing protocols. Additionally, each routing protocol has its own metric or cost associated with it. For example, static routes use administrative distance, OSPF uses cost, IS-IS uses metric, and EIGRP uses a composite metric. Therefore, routes from different routing protocols cannot be exchanged automatically. As will be demonstrated, this process of exchanging routes has to be configured manually.

There are several reasons why routing redistribution is necessary:

- **One common reason is to redistribute static routes:** These routes are not learned, but are configured manually. They must be redistributed into a dynamic routing protocol so that they can be advertised.
- **Another reason is when two or more dynamic routing protocols are used on the network:** This scenario happens often when connecting one network to another either for peering purposes or for when companies merge their network

Routing Redistribution

The technique of injecting routes from one routing protocol into another routing protocol.

infrastructures due to a business acquisition. It is much easier to accept the new routing protocol from another network and distribute the new routes into the existing routing protocol rather than converting both routers to single routing protocol. This saves time and money.

- **Another reason is that certain routing protocols may not be supported by certain network devices:** A prime example of this is the EIGRP, which is a Cisco proprietary protocol and is not supported by other network vendors. If a non-Cisco router connects to a Cisco router that is running EIGRP, then the Cisco router will need to redistribute routes learned from the other routing protocol into EIGRP.

This section explores different routing redistribution techniques to redistribute routes into dynamic routing protocols, such as RIP, OSPF, IS-IS, and EIGRP. Static routing is not a dynamic routing protocol and is not applicable in this case, because static routes must be configured manually. The configuration for this section is based on the network diagram of Figure 3-5. Router A and Router B make up an existing network and both routers are connected and are running the same routing protocol. Router C brings in a new network with a different routing protocol that will need to be redistributed into the existing network. Router B is where the redistribution happens since this is the router that is directly connected to Router C.

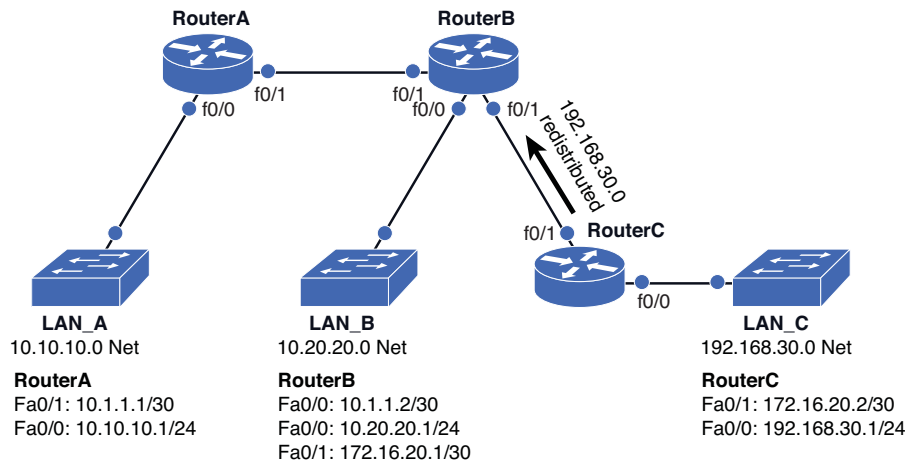


FIGURE 3-5 Route redistribution from LAN C network to LAN A and LAN B

Route Redistribution into RIP

This section examines route redistribution into RIP. First, let's explore the basic RIPv2 configuration required for Router A and Router B. Both routers will have the same routing configuration as shown and will be running a 10.0.0.0 classful network:

```
!
router rip
  version 2
  network 10.0.0.0
!
```

The output from the **show ip route** command displays the expected network routes are being learned via RIPv2. The following is the result from Router A when the command **sh ip route rip** is issued. This result shows that Router A has a RIP route to the 10.20.20.0/24 network via the 10.1.1.2 interface on Router B:

```
RouterA#sh ip route rip
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
R       10.20.20.0/24 [120/1] via 10.1.1.2, 00:00:02, FastEthernet0/1
```

However, Router B has an interface that is connected to Router C that is not part of the network advertised via RIP. This interconnected interface on Router B is FastEthernet0/1 and has an IP address of 172.16.20.1. This interface is not expected to participate in RIP advertisement since Router C is running a different routing protocol. This is why this route it is not included as a network statement in the RIP configuration. Nonetheless, Router A should still learn about this interconnected network, so Router A can reach it over the network.

In order to accomplish this, Router B can redistribute its connected network into RIP. The command to do this is **redistribute protocol**. The following is a list of the options of what can be used to redistribute the networks into RIP:

```
RouterB(config)#router rip
RouterB(config-router)#redistribute ?
  bgp          Border Gateway Protocol (BGP)
  connected    Connected
  eigrp        Enhanced Interior Gateway Routing Protocol (EIGRP)
  isis         I    SO IS-IS
  iso-igrp     IGRP for OSI networks
  metric       Metric for redistributed routes
  mobile       Mobile routes
  odr          On Demand stub Routes
  ospf         Open Shortest Path First (OSPF)
  rip          Routing Information Protocol (RIP)
  route-map    Route map reference
  static       Static routes
  <CR>
RouterB(config-router)#redistribute connected
```

Therefore, the command **redistribute connected** can be issued to redistribute the connected networks, which, in this case, is the interface between Router B and Router C.

Once the command is issued, you can verify the results on Router A. The **show ip route rip** command now shows that the network 172.16.20.0 is being advertised by RIP:

```
RouterA#sh ip route rip
      172.16.0.0/30 is subnetted, 1 subnets
R       172.16.20.0 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
R       10.20.20.0/24 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1
```

redistribute protocol

The command used to inject routes from one routing protocol into another routing protocol.

redistribute connected

The command issued to redistribute the connected networks.

redistribute static

The command issued to redistribute the static networks.

Now, assume there is a static route on Router B to the LAN C network of 192.168.30.0. This static route is only known by Router B; therefore, it will need to be redistributed into RIP, so that Router A can learn of it as well. Similar to the **redistribute connected** command, you can use the **redistribute static** command on Router B:

```
RouterB(config)#ip route 192.168.30.0 255.255.255.0 172.16.20.2
RouterB(config)#router rip
RouterB(config-router)#redistribute static
```

As a result, the redistributed static route to the 192.168.30.0 network entered in Router B, is now known to Router A and as shown, Router A now learns of the route to the LAN C network via RIP:

```
RouterA#sh ip route rip
R   192.168.30.0/24 [120/1] via 10.1.1.2, 00:00:12, FastEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
R       172.16.20.0 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
R       10.20.20.0/24 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1
```

The other dynamic protocols are distributed into RIP in similar fashion. If Router C runs OSPF as its routing protocol, then Router B will need to run the same in order for the routers to communicate. To do this, both routers will have to agree on the OSPF Process ID. In the following example, the OSPF Process ID will be 200. The OSPF configuration for Router C and Router B are shown.

Router C's OSPF configuration:

```
!
router ospf 200
  log-adjacency-changes
  network 192.168.30.0 0.255.255.255 area 0
  network 172.16.20.0 0.0.0.3 area 0
!
```

Router B's OSPF configuration:

```
!
router ospf 200
  log-adjacency-changes
  network 10.0.0.0 0.255.255.255 area 0
  network 172.16.20.0 0.0.0.3 area 0
!
```

Now, Router B can receive an OSPF route from Router C as shown as the result of issuing the command **show ip route**. Along with it, Router B receives a RIP route from Router A. It is important to verify the routes of the protocol one is trying to redistribute. Note: This important step is often neglected. Remember, the router cannot redistribute what it doesn't know and the route must be there for you to redistribute.

```

RouterB#sh 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

```

O    192.168.30.0/24 [110/2] via 172.16.20.2, 00:00:09,
FastEthernet0/1
     172.16.0.0/30 is subnetted, 1 subnets
C    172.16.20.0 is directly connected, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C    10.20.20.0/24 is directly connected, FastEthernet0/0
R    10.10.10.0/24 [120/1] via 10.1.1.1, 00:00:23, FastEthernet1/0
C    10.1.1.0/30 is directly connected, FastEthernet1/0

```

Router A does not know of the new OSPF route yet, so the route has to be redistributed. On Cisco routers, there is a caveat for redistributing dynamic routing protocols into RIP. That caveat is the metric must be assigned in order for the routes to be redistributed properly. This is not required for static and connected routes since RIP assigns the metric of 1 to each of these by default. Also, recall that the metric value for RIP is hop count and each hop count along the path has the value of 1. The maximum hop count value is 16. The command to redistribute OSPF routes into RIP is **redistribute ospf process_id metric 0-16**.

```

RouterB(config)#router rip
RouterB(config-router)#redistribute ospf 200 metric 1

```

Now, the RIP routing table on Router A shows the route 192.168.30.0 that is learned from the LAN C network:

```

RouterA#sh ip route rip
R    192.168.30.0/24 [120/1] via 10.1.1.2, 00:00:12, FastEthernet0/1
     172.16.0.0/30 is subnetted, 1 subnets
R    172.16.20.0 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
R    10.20.20.0/24 [120/1] via 10.1.1.2, 00:00:08, FastEthernet0/1

```

For EIGRP, the command to redistribute routes into RIP is almost the same as OSPF. The command is **redistribute eigrp AS_number metric 0-16**. For IS-IS, the command is **redistribute isis IS-IS_Level metric 0-16**. The configuration example is as follows:

```

RouterB(config)#router rip
RouterB(config-router)#redistribute eigrp 200 metric 1
RouterB(config-router)#redistribute isis level-1-2 metric 1

```

redistribute ospf process_id metric 0-16

The command to redistribute OSPF routes into RIP.

redistribute eigrp AS_number metric 0-16

Command to redistribute EIGRP routes into RIP.

redistribute isis IS-IS_Level metric 0-16

Command to redistribute IS-IS routes into RIP.

Route Redistribution into OSPF

Next, the steps for route redistribution for OSPF are examined for Router A and Router B in the network shown in Figure 3-5. Both routers have been configured to run OSPF using the following commands:

```
!  
router ospf 200  
  network 10.0.0.0 0.255.255.255 area 0  
!
```

Once the basic configuration for OSPF has been configured, the routers will have the OSPF neighbor adjacency established and the OSPF routes will be exchanged. The result of the **show ip ospf neighbor** and **show ip route ospf** on Router A are shown in the output examples that follow. The results confirm the neighbor adjacency and that the expected network routes are being learned via OSPF:

```
RouterA#sh ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address
Interface				
172.16.20.1	1	FULL/BDR	00:00:34	10.1.1.2
FastEthernet0/1				

```
RouterA#sh ip route ospf
```

```
10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks  
O          10.20.20.0/24 [110/2] via 10.1.1.2, 00:15:38, FastEthernet0/1
```

Router B's connected interface to Router C is not advertised as a network statement in the OSPF configuration. Therefore, its connected network will not be shown in Router A's routing table. This is the same behavior demonstrated for RIP. Just like RIP, connected networks can be redistributed in OSPF by using the **redistribute connected** command. This command is next issued on Router B:

```
RouterB(config)#router ospf 200  
RouterB(config-router)#redistribute connected  
% Only classful networks will be redistributed
```

However, what we get is the message stating that only classful networks can be redistributed. Because the connected network is 172.16.20.0/30, which is not a classful network, this will not work. Cisco provides a solution to this problem with a slightly different command:

```
RouterB(config-router)#redistribute connected subnets
```

This command allows the classless network to be distributed. Once the command is issued, we can then verify the result on Router A. The **show ip route** command now shows the network 172.16.20.0 is being advertised by OSPF. Not only that, the network route is flagged as an **E2** or an OSPF external type 2 route, which is different than other OSPF internal routes. By default, any routes that are being redistributed from another routing protocol into OSPF will appear as OSPF E2 routes that are the least preferred among the OSPF route types.

```
RouterA#sh ip route  
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP  
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
```

redistribute connected subnets

Allows the classless network to be distributed.

E2

An OSPF external type 2 route.

```

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
O E2 172.16.20.0 [110/20] via 10.1.1.2, 00:01:59, FastEthernet0/1
10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O 10.20.20.0/24 [110/2] via 10.1.1.2, 00:06:49, FastEthernet0/1
C 10.10.10.0/24 is directly connected, FastEthernet0/0
C 10.1.1.0/30 is directly connected, FastEthernet0/1

```

Now, configure a static route on Router B to the LAN C network of 192.168.30.0 and redistribute it into OSPF. This enables Router A to learn the route to 192.168.30.0. To redistribute static routes, issue the command **redistribute static** on Router B:

```

RouterB(config)#ip route 192.168.30.0 255.255.255.0 172.16.20.2
RouterB(config)#router ospf 200
RouterB(config-router)#redistribute static
% Only classful networks will be redistributed

```

The same warning message is shown saying that, “only classful networks will be redistributed.” This time, the network 192.168.30.0/24 is a classful network, so the network will be redistributed; otherwise, the command **redistribute static subnets** will need to be used to distribute classless networks similar to what was done for the connected network. As a result of the redistributed static route entered in Router B, Router A now learns of the route to LAN C network via OSPF and the network is shown as an OSPF external type 2 route:

```

RouterA#sh ip route ospf
O E2 192.168.30.0/24 [110/20] via 10.1.1.2, 00:03:37, FastEthernet0/1
172.16.0.0/30 is subnetted, 1 subnets
O E2 172.16.20.0 [110/20] via 10.1.1.2, 00:51:59, FastEthernet0/1
10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O 10.20.20.0/24 [110/2] via 10.1.1.2, 00:42:28, FastEthernet0/1

```

The other dynamic protocols are distributed into OSPF in similar fashion. For example, if Router C runs EIGRP as its routing protocol, then Router B will need to run EIGRP in order for Router B and Router C to communicate. Both routers have to agree on an EIGRP Autonomous system number. In this example, an EIGRP AS number of 200 is selected. The EIGRP routing configuration for Router C and Router B follow.

redistribute static subnets

Allows the static network to be distributed.

Router C's EIGRP configuration:

```
!  
router eigrp 200  
  network 192.168.30.0 0.  
  network 172.16.0.0  
no auto-summary  
!
```

Router B's EIGRP configuration:

```
!  
router eigrp 200  
  network 10.0.0.0  
  network 172.16.0.0  
no auto-summary  
!
```

Now, verify that Router B is able to receive an EIGRP route from Router C before proceeding with the route redistribution. This can be done using the **sh ip route** command. The routing table for Router B is shown. It shows a network route of 192.168.30.0/24 learned from Router C's interface 172.16.20.2 via EIGRP:

RouterB#**sh 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

```
D 192.168.30.0/24 [90/30720] via 172.16.20.2, 00:50:45,  
FastEthernet0/1  
  172.16.0.0/30 is subnetted, 1 subnets  
C    172.16.20.0 is directly connected, FastEthernet0/1  
  10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks  
C    10.20.20.0/24 is directly connected, FastEthernet0/0  
O    10.10.10.0/24 [110/2] via 10.1.1.1, 00:53:18, FastEthernet1/0  
C    10.1.1.0/30 is directly connected, FastEthernet1/0
```

The next step is to configure Router B to redistribute a learned EIGRP route into OSPF. Recall that the OSPF cost or metric is derived from the bandwidth of the interface. By default, Cisco routers will assign an OSPF cost/metric of 20 to any redistributed routes with exception for redistributed routes from BGP. If the metric does not need to be set, the command to distribute dynamic routing protocols is all the same for OSPF. The command to redistribute EIGRP routes into OSPF is

redistribute eigrp AS_id [metric 0-16777214]. This time, the keyword **subnets** will be used to avoid the warning message of only classful networks will be redistributed:

```
RouterB(config)#router ospf 200
RouterB(config-router)#redistribute eigrp 200 subnets
```

The command **show ip route ospf** on Router A would confirm the result that the network 192.168.30.0/24 is advertised as an OSPF external type 2 route:

```
RouterA#sh ip route ospf
O E2 192.168.30.0/24 [110/20] via 10.1.1.2, 00:03:37, FastEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
O E2   172.16.20.0 [110/20] via 10.1.1.2, 00:51:59, FastEthernet0/1
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
O     10.20.20.0/24 [110/2] via 10.1.1.2, 00:42:28, FastEthernet0/1
```

To redistribute RIP into OSPF, the command is **redistribute rip**. For IS-IS, the command is **redistribute isis IS-IS_Level**. The configuration example is as follows:

```
RouterB(config)#router ospf 200
RouterB(config-router)#redistribute rip
RouterB(config-router)#redistribute isis level-1-2
```

Route Redistribution into EIGRP

Next, the steps for route redistribution of routers into EIGRP is examined. First, EIGRP is configured for Router A and Router B. Both routers will have the same EIGRP routing configuration, as shown:

```
!
router eigrp 200
 network 10.0.0.0
 no auto-summary
!
```

The EIGRP neighbor adjacency can be verified with the command **show ip eigrp neighbor**, and the EIGRP route is verified with **show ip route eigrp** on Router A. The results confirm that the neighbor adjacency is established and the correct network routes are being exchanged via EIGRP:

```
RouterA#sh ip eigrp neighbors
IP-EIGRP neighbors for process 200
H Address      Interface Hold  Uptime    SRTT  RTO  Q      Seq
          (sec)          (ms)    Cnt      Num
0 10.1.1.2 Fa0/1      11    00:03:39  40    240  0      4

RouterA#show ip route eigrp
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
D     10.20.20.0/24 [90/30720] via 10.1.1.2, 00:03:48,
FastEthernet0/1
```

redistribute eigrp AS_id [metric 0-16777214]

The command to redistribute EIGRP routes into RIP.

redistribute rip

The command to redistribute RIP into OSPF.

redistribute isis IS-IS_Level

The command to redistribute EIGRP routes into IS-IS.

Router B's connected interface to Router C will need to be redistributed, because it is not included as a network statement in the EIGRP configuration. Router A's routing table does not show a connected network for 172.16.20.0/30. This is expected, because it has not yet been redistributed by Router B, as previously discussed in the RIP and OSPF example. The command **redistribute connected** is issued on Router B to redistribute the connected network:

```
RouterB(config)#router eigrp 200
RouterB(config-router)#redistribute connected
```

EX

External EIGRP type.

Once the command **redistribute connected** is issued, the command **sh ip route** can be issued on Router A to verify that the network 172.16.20.0 is being advertised via EIGRP. The network route is also flagged as an **EX** or an external EIGRP type. The external EIGRP route has an administrative distance (AD) value of 170, which is higher than the internal EIGRP route's AD value of 90:

```
RouterA#sh 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
D EX 172.16.20.0 [170/30720] via 10.1.1.2, 00:23:14,
FastEthernet0/1
10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
D 10.20.20.0/24 [90/30720] via 10.1.1.2, 00:37:20,
FastEthernet0/1
C 10.10.10.0/24 is directly connected, FastEthernet0/0
C 10.1.1.0/30 is directly connected, FastEthernet0/1
```

Next, a static route on Router B needs to be configured to the LAN C network of 192.168.30.0. Additionally, the static route must be redistributed into EIGRP. This enables Router A to learn the route as well. To redistribute static routes, the command **redistribute static** is issued on Router B.

```
RouterB(config)#ip route 192.168.30.0 255.255.255.0 172.16.20.2
RouterB(config)#router eigrp 200
RouterB(config-router)#redistribute static
```

As a result, Router A now learns of the route to LAN C network via EIGRP, and the network 192.168.30.0 is displayed as an EIGRP external route, just like the distributed connected route:

```

RouterA#sh ip route eigrp
D EX 192.168.30.0/24 [170/30720] via 10.1.1.2, 00:00:17,
FastEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
D EX    172.16.20.0 [170/30720] via 10.1.1.2, 00:33:53,
FastEthernet0/1
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
D      10.20.20.0/24 [90/30720] via 10.1.1.2, 00:47:59,
FastEthernet0/1

```

As we have learned, EIGRP uses a composite metric, which consists of bandwidth, delay, reliability, load, and MTU. To redistribute other dynamic routing protocols, the metric value has to be converted into EIGRP's metric values or new EIGRP metric values must be assigned. Routes will not be redistributed properly without these values. Cisco recommends that every redistributed dynamic routing protocol be assigned with EIGRP metrics. As it turns out, even though only the two EIGRP metric values of bandwidth and delay are used by default, Cisco enforces all the metric values be defined. The parameters defining the EIGRP metric assignments are as follows:

- Bandwidth metric is a value between 1–4294967295 in Kbps.
- Delay metric is a value between 0–4294967295 in ten microseconds.
- Reliability metric is a value between 1–255, where 255 is 100 percent reliable.
- Load metric is a value between 0–255, where 255 is a 100 percent load.
- MTU is a maximum transfer unit value between 1-65,535, where 1,500 is a norm.

The following example demonstrates how to redistribute RIPv2 routes into EIGRP. Router C and Router B are both configured to run RIPv2. The RIPv2 routing configurations for Router C and Router B follow:

Router C's RIPv2 configuration:

```

!
router rip
  version 2
  network 172.16.0.0
  network 192.168.30.0
!

```

Router B's RIPv2 configuration:

```

!
router rip
  version 2
  network 10.0.0.0
  network 172.16.0.0
!

```

Now, you must verify that Router B is able to receive a RIP route from Router C before proceeding with the route redistribution. The routing table of Router B is

shown in the output that follows that shows a network route of 192.168.30.0/24, learned from Router C's 172.16.20.2 interface via RIP.

```
RouterB#sh 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

R    192.168.30.0/24 [120/1] via 172.16.20.2, 00:00:20,
FastEthernet0/1
     172.16.0.0/30 is subnetted, 1 subnets
C    172.16.20.0 is directly connected, FastEthernet0/1
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C    10.20.20.0/24 is directly connected, FastEthernet0/0
D    10.10.10.0/24 [90/30720] via 10.1.1.1, 00:48:39,
FastEthernet1/0
C    10.1.1.0/30 is directly connected, FastEthernet1/0
```

redistribute rip metric bandwidth delay reliability load MTU

The command to redistribute RIP routes into EIGRP.

The next step is to configure Router B to redistribute a learned RIP route into EIGRP. As previously discussed, all the EIGRP metric values will need to be assigned to the redistributed routing protocol. The command to redistribute RIP routes into EIGRP is **redistribute rip metric bandwidth delay reliability load MTU**, as demonstrated here:

```
RouterB(config)#router eigrp 200
RouterB(config-router)#redistribute rip metric 100000 10 255 1 1500
```

default-metric bandwidth delay reliability load MTU

The command for setting the default metric.

Instead of entering the long metric command every time, a default metric can be defined. For every redistribute statement, it will use the default metric. If the **redistribute** statement has metric values assigned, it overrides the default metric. The command for setting the default metric is **default-metric bandwidth delay reliability load MTU**. The following is an example of how a default metric is configured:

```
RouterB(config)#router eigrp 200
RouterB(config-router)#default-metric 100000 10 255 1 1500
RouterB(config-router)#redistribute rip
```

This command sets the default metric to the following:

```
Bandwidth: 100000 kbps
Delay: 1000 microseconds
Reliability: 100 percent reliable
Load: minimal
MTU: norm
```

The command **show ip route eigrp** on Router A confirms the result that the network 192.168.30.0/24 is advertised as an external EIGRP route:

```
RouterA#sh ip route eigrp
D EX 192.168.30.0/24 [170/30720] via 10.1.1.2, 00:00:02,
FastEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
D EX    172.16.20.0 [170/30720] via 10.1.1.2, 01:18:33,
FastEthernet0/1
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
D      10.20.20.0/24 [90/30720] via 10.1.1.2, 01:32:39,
FastEthernet0/1
```

Once the default metric is defined in EIGRP, the command **redistribute ospf** can be used to redistribute OSPF into EIGRP. For IS-IS, the command is **redistribute isis IS-IS_Level**. The configuration example is as follows:

```
RouterB(config)#router eigrp 200
RouterB(config-router)#redistribute rip
RouterB(config-router)#redistribute isis level-1-2
```

Route Redistribution into IS-IS

Surprisingly, the configuration for route redistribution into IS-IS is simple to apply. First, let's configure Router A and Router B with IS-IS routing and then enable the interfaces that will participate in IS-IS routing. The running configuration files for Router A and Router B are next shown for IS-IS.

Router A's configuration

```
interface FastEthernet0/0
 ip address 10.10.10.1 255.255.255.0
 ip router isis
!
interface FastEthernet0/1
 ip address 10.1.1.1 255.255.255.252
 ip router isis
!
router isis
 net 49.0001.c202.00e8.0001.00
!
```

Router B's configuration:

```
interface FastEthernet0/0
 ip address 10.20.20.1 255.255.255.0
 ip router isis
!
interface FastEthernet1/0
 ip address 10.1.1.2 255.255.255.252
 ip router isis
!
```

```

router isis
 net 49.0001.c202.00e8.0002.00
!
```

The IS-IS routing is verified with **show ip route isis** on Router A. The result confirms the correct network routes are being exchanged via IS-IS:

```

RouterA#sh ip route isis
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
i L1   10.20.20.0/24 [115/20] via 10.1.1.2, FastEthernet0/1
```

One caveat to know about redistributing routes into IS-IS is that if no metric is assigned, all distributed routes will be automatically assigned a metric value of 0. In IS-IS, the default metric value for each interface is 10. Therefore, redistributed routes could end up with lower metric values than IS-IS learned routes. If there happens to be multiple routes to the same network, one is learned via internal IS-IS routes and another one is learned via redistributed routes. IS-IS would prefer the redistributed routes. It is recommended that at least a metric value of 10 be assigned to redistributed routes. To advertise a connected network of 172.16.20.0/30, the command **redistribute connected** is issued on Router B with a metric of 10:

```

RouterB(config)#router isis
RouterB(config-router)#redistribute connected metric 10
```

Once the command is issued, you can then verify the results on Router A. The **show ip route** command now shows the network 172.16.20.0 is being advertised via IS-IS and the network route is also flagged as an L2 or an IS-IS level-2 type:

```

RouterA#sh 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
i L2   172.16.20.0 [115/20] via 10.1.1.2, FastEthernet0/1
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
i L1   10.20.20.0/24 [115/20] via 10.1.1.2, FastEthernet0/1
C      10.10.10.0/24 is directly connected, FastEthernet0/0
C      10.1.1.0/30 is directly connected, FastEthernet0/1
```

Now, configure a static route on Router B to the LAN C network of 192.168.30.0 and redistribute it into IS-IS. This enables Router A to learn the route as well. To redistribute static routes into IS-IS, the command **redistribute static** is issued on Router B.

```
RouterB(config)#ip route 192.168.30.0 255.255.255.0 172.16.20.2
RouterB(config)#router isis
RouterB(config-router)#redistribute static metric 10
```

As a result, Router A now learns of the route to LAN C network via IS-IS and the network is displayed as an IS-IS level-2 route just like the distributed connected route:

```
RouterA#sh ip route isis
i L2 192.168.30.0/24 [115/20] via 10.1.1.2, FastEthernet0/1
    172.16.0.0/30 is subnetted, 1 subnets
i L2   172.16.20.0 [115/20] via 10.1.1.2, FastEthernet0/1
    10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
i L1   10.20.20.0/24 [115/20] via 10.1.1.2, FastEthernet0/1
```

To redistribute dynamic routing protocols into IS-IS, the **redistribute** command is configured in the same fashion. The following configurations show how to redistribute RIP, OSPF, and EIGRP into IS-IS respectively:

```
RouterB(config)#router isis
RouterB(config-router)#redistribute rip metric 10
RouterB(config-router)#redistribute ospf 200 metric 10
RouterB(config-router)#redistribute eigrp 200 metric 10
```

As long as those dynamic routing protocols are configured on Router B and Router C correctly and their routes are exchanged, the result of **show ip route isis** on Router A should yield the same result as the one from the static route.

3-5 ANALYZING OSPF “HELLO” PACKETS

Hello packets are periodically sent in OSPF networks to initiate and maintain communications with neighbor routers. The Hello packets contain parameters including specifications for the following:

- **Network Mask:** The mask contains 32 bits in four octets (8-bit groups). The masking is a logical AND operation, and the bits that are set high allow the address data to pass. For example, a network mask of 255.255.255.0 has the first 24 bits set high in the first three octets. The hexadecimal equivalent (base 16) for this network mask is 0xfffff00.
- **Hello Interval:** The time between Hello packets.
- **Router Dead Interval:** The length of time a router neighbor is quiet (no Hello packets) before assuming the neighbor is dead.

OSPF uses a Class D multicast IP address to send out the Hello packets to the neighbors. OSPF networks have been assigned the multicast IP address of 224.0.0.5 for sending Hello packets. Multicast IP addresses for use with multicast protocols are in the range of 224.0.0.0 to 239.255.255.255. This is called the *Class D IP address range*. The IP address range above Class D is called Class E, and addresses

Hello Packets

Periodically sent in link state protocols to initiate and maintain communications with neighbor routers.

Network Mask

A 32-bit value used to divide sections of IP addresses.

Hello Interval

The time between Hello packets.

Router Dead Interval

The length of time a router neighbor is quiet (no Hello packets) before assuming the neighbor is dead.

range from 240.0.0.0 to 254.255.255.255. Class E is called the *IP address experimental range*.

RID
Router ID.

The test network shown in Figure 3-6 was set up so that the transmission of OSPF Hello packets could be viewed. The Wireshark protocol analyzer was installed on computer D1 in LAN D (192.168.1.0 NET). LAN D has been configured to be an OSPF advertised route; therefore, computers in LAN D will receive the OSPF multicasts used to capture the data packets. OSPF broadcasts the LAN address as part of the routed addresses. The multicast is sent to all neighbor OSPF router connections. Figure 3-7 shows the captured data packets for the network. The highlighted line, beginning with the ID of “000001” in the first column, is the first detected occurrence of a data packet on the network. The elapsed time is 5.278.530.840 seconds (column 2). The size of the packet is 82 bytes (column 3). The destination (specified in column 4) is an OSPFIGP_Router multicast. The source IP address is 192.168.1.250, which is the IP address for the router interface. The packet summary (column 6) indicates this is an OSPF Hello from **RID** (router ID) 192.168.200.11.

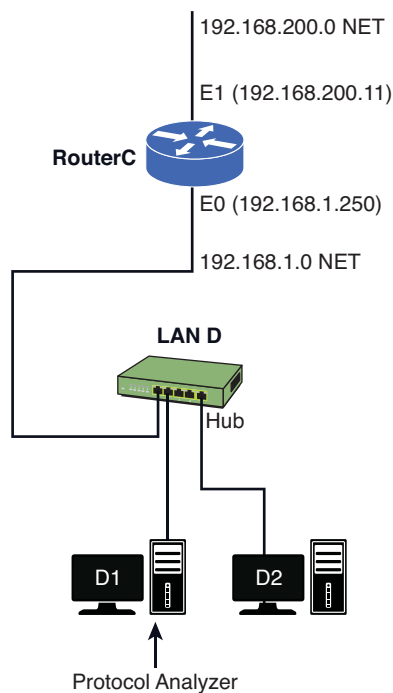


FIGURE 3-6 The test network for capturing the OSPF Hello packets

One of the complex things about OSPF is the assignment of the router ID (RID). The router ID is an IP address chosen from all interfaces on the router. Cisco IOS first examines the loopback address for the router’s ID IP address. If a loopback address is not being used, the highest IP address for a router interface is selected as the router ID. In this case, the highest loopback IP address is 192.168.200.11, the IP address for the E1 Ethernet interface. The middle panel in Figure 3-7 shows

that the destination address is 224.0.0.5 and defines this as OSPFIGP_Router. **OSPF** stands for Open Shortest Path First Interior Gateway Protocol, which is a concatenated form of OSPF and IGP. The OSPF protocol is classified as an Interior Gateway Protocol (IGP). **IGP** represents entities under the same autonomous domain (administrative and security policies). Remember, when you specify the OSPF protocol, a process ID number is entered; for example, **router ospf 100**.

OSPF
 Open Shortest Path
 First Interior Gateway
 Protocol.

IGP
 Interior Gateway
 Protocol.

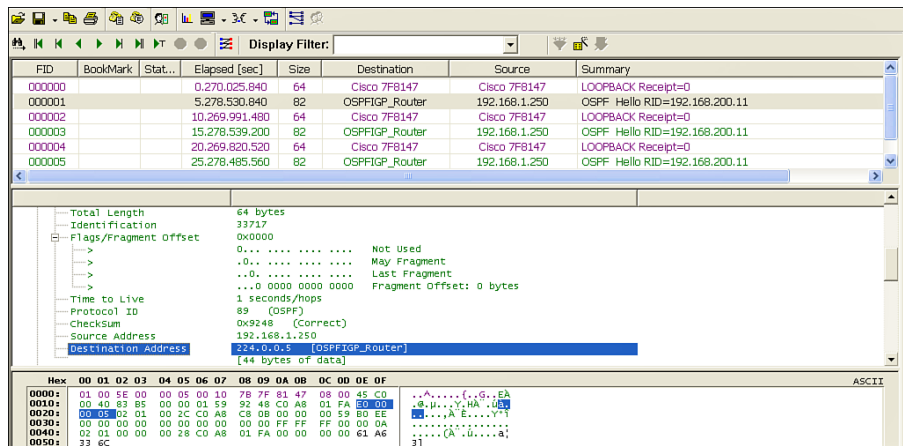


FIGURE 3-7 The captured OSPF multicasts

The bottom panel in Figure 3-7 is the actual data packet displayed in hexadecimal (base 16) code. The highlighted hex code is

E 0 0 0 0 0 5

This is the hexadecimal value for 224.0.0.5, the destination IP address of the multicast.

Hexadecimal Value: E 0 0 0 0 0 0 5
 Decimal Equivalent: 224 0 0 5

Note

The decimal equivalent of E0 is 14, and $(14 \times 16 + 0) = 224$.

A detailed view of the OSPF packet information is provided in Figure 3-8. This information is available in the Open Shortest Path First (OSPF) window, as shown in Figure 3-8.

Open Shortest Path First (OSPF)	
Version	2
Type	1 (Hello)
Length	44 bytes
Router ID	192.168.200.11
Area ID	0.0.0.89
Checksum	0xB0EE
AuthType	0 (Null Authentication)
Authentication	0000000000000000
Network Mask	255.255.255.0
Hello Interval	10 seconds
Optional Capabilities	0x02
>	0... .. Not Used (MBZ)
>	.0... .. Opaque-LSAs NOT Forwarded
>	..0... .. Demand Circuit Bit
>	...0... .. External Attributes Bit
>0... .. No NSSA Capability
>0... .. No Multicast Capability
>01... .. External Routing Capability
>00... .. No Type of Service Routing Capability
Router Priority	1
Router Dead Interval	40 seconds
Designated Router	192.168.1.250
Backup Designated Router	0.0.0.0

FIGURE 3-8 A detailed view of the OSPF packet information

In addition to the version number, the router ID is listed (192.168.200.11), and the Hello interval is specified to be 10 seconds. Looking again at Figure 3-7, the OSPF Hello packets are approximately 10 seconds apart. The router dead interval is 40 seconds.

This section has demonstrated how to use the Surveyor Demo Protocol Analyzer to capture OSPF “Hello” packets. Figures 3-7 and 3-8 and the accompanying text explained how to extract information from the captured packets.

SUMMARY

This chapter presented examples of configuring routing protocols. The network challenge exercises provided the opportunity for the student to test her or his configuration skill prior to actually configuring a real router. The student should be able to configure and verify operation of the following protocols:

- Static
- RIP/RIPv2
- OSPF
- ISIS
- EIGRP

Additionally, this chapter examined the steps for route redistribution. The last section examined the OSPF Hello packets.

QUESTIONS AND PROBLEMS

Section 3-1

1. OSPF is (select all that apply)
 - a. Open Shortest Path First routing protocol
 - b. An open protocol
 - c. Developed specifically for TCP/IP networks
 - d. Developed specifically for IPX networks
 - e. A distance vector protocol
 - f. A dynamic routing protocol
 - g. A link state protocol
 - h. A high consumer of bandwidth
2. In OSPF, route updates are sent in the form of
 - a. Link state advertisements
 - b. Exchanging routing tables every 30 seconds
 - c. Exchanging routing tables every 90 seconds
 - d. IETF packets
3. The OSPF routing protocol uses these to verify that a link between two routers is active and the routers are communicating
 - a. LSAs
 - b. Hello packets
 - c. ARP messages
 - d. Ping

4. Areas in the OSPF protocol are
 - a. Not used
 - b. Used to partition a large network into small networks
 - c. Used to combine small networks into one large network
 - d. An inefficient use of bandwidth
5. Variable length subnet masks
 - a. Minimize wasted IP address space when interconnecting subnets
 - b. Are not recommended in modern computer networks
 - c. Reduce the number of bits required in a subnet mask from 32 to 24
 - d. Are the same as classful addressing
6. Which is *not* an advantage of OSPF?
 - a. Very easy to implement
 - b. Uses VLSM
 - c. Link state changes are immediately reported
 - d. Not a proprietary protocol
7. Define router flapping.
8. The command structure for enabling OSPF routing on a router is
 - a. **router ospf**
 - b. **router ospf** [*area*]
 - c. **routing protocol ospf**
 - d. **router ospf** [*number*]
9. Another name for wild card bits is
 - a. OSPF pass-through bits
 - b. Area 0 selection bits
 - c. Inverse mask bits
 - d. Route selection bits
10. Area 0 is
 - a. Used to hide data packets
 - b. Root or backbone for the network
 - c. Inverse mask bits
 - d. Route selection bits

11. Which of the following is *not* a correct statement for configuring a route to run over OSPF? Assume that the OSPF protocol has been enabled.
 - a. network 10.10.20.1 1.1.1.1 area 0
 - b. network 10.10.20.1 1.0.0.0 area 0
 - c. network 10.0.0.0 1.0.0.0
 - d. network 10.10.100.1 0.0.0.0 area 0
12. The command **show ip route ospf** is best characterized by which of the following?
 - a. Is not valid in OSPF
 - b. Displays only the IP routes
 - c. Displays only the OSPF routes
 - d. Enables OSPF routing
13. The **sh ip route** command is entered on Router B in the campus LAN shown in Figure 3-2. The LAN has been fully configured to run the OSPF protocol.
 - a. How many OSPF subnets are running on the network?
 - b. Identify the connected C and OSPF O subnets.
14. The **sh ip route** command is entered on Router C in the campus LAN shown in Figure 3-2. The LAN has been fully configured to run the OSPF protocol.
 - a. How many OSPF subnets are running on the network?
 - b. Identify the connected C and OSPF O subnets.

Section 3-2

15. What are the two topology areas in IS-IS?
16. L1/L2 routers are analogous to what in OSPF?
17. IS-IS was designed as part of the Open System Interconnection (OSI) network layer service called Connectionless Network Service (CLNS). What is a Connectionless Network Service (CLNS)?
18. What command is used to enter the global configuration command in IS-IS?
19. What command is used to instruct the router to start IPv6 using the IS-IS routing protocol?

20. To specify the network that will be using IS-IS for routing, which of the following needs to be configured?
- The command **cls routing** will need to be configured at each individual interface.
 - The command **ip router isis** will need to be configured at each individual interface.
 - The command **ip router isis** will need to be configured globally for the router.
 - The command **router isis** will need to be configured globally for the router.
 - None of these answers are correct.
21. What is the command in IS-IS that is used to display adjacencies with its neighbors and the neighbor information?
22. What is the NET address in IS-IS? Also define the area ID, system ID, and NSEL.
23. Identify the NSEL, system ID, and area ID for the IS-IS NET address of 45.0001.0015.b2501.4808.00.
24. Why is the system ID in IS-IS always unique?
25. The command **show ip protocol** is issued on a router as displayed. What is required for routing to take place on the FastEthernet interfaces 0/0 and 0/2?

```
RouterA# sh ip protocol
Routing Protocol is "isis"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Redistributing: isis
  Address Summarization:
    None
  Maximum path: 4
  Routing for Networks:
    FastEthernet0/0
    FastEthernet0/2
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.12.5     115          00:02:44
    192.168.12.65    115          00:02:44
  Distance: (default is 115)
```

26. The command **sh ip route** is issued on a router. What does this information tell you about the 10.20.10.0 network? What does i L1 indicate?

```
Gateway of last resort is not set

    10.0.0.0/24 is subnetted, 7 subnets
i L1   10.20.15.0 [115/20] via 10.20.100.2, FastEthernet0/2
i L1   10.20.10.0 [115/20] via 10.20.200.2, FastEthernet0/1
C      10.20.20.0 is directly connected, FastEthernet0/0
C      10.20.100.0 is directly connected, FastEthernet0/2
```

```
i L1    10.20.150.0 [115/20] via 10.20.100.2, FastEthernet0/2
        [115/20] via 10.20.200.2, FastEthernet0/1
C      10.20.200.0 is directly connected, FastEthernet0/1
```

27. IS-IS can load balance which of the following?
- The network traffic over equal cost paths
 - On the unequal cost paths
 - On the unequal cost paths, only the best path is installed into the routing table
 - All of the above
28. In IS-IS, what is the IS-IS cost value assigned to the interface and its default value?
29. The following sequence of commands is entered on a router running IS-IS for the 3 router campus network shown in Figure 3-3:

```
RouterA(config)#int fastEthernet 0/1
RouterA(config-if)#isis metric 20
```

Section 3-3

30. *EIGRP* stands for
- Enhanced Interior Routing Protocol
 - Enhanced Interior Gateway Routing Protocol
 - Enhanced Internet Gateway Routing Protocol
 - None of these answers are correct
31. The command for enabling EIGRP on a router is
- router igrp** [as number]
 - router eigrp**
 - router eigrp** [as number]
 - router eigrp enable**
32. The command **network 10.10.0.0** is entered on a router after EIGRP has been enabled. Define what this means.
33. What router command can be used to verify EIGRP is running on the router?
- show run**
 - show ip int brief**
 - show history**
 - show ip protocol**

34. What router command will show how many subnets are configured?
- show run**
 - show ip int brief**
 - show list**
 - show ip route**
35. What router command will show whether the router is exchanging routes?
- show run**
 - show ip int brief**
 - show list**
 - show ip route**
36. The **sh ip route** command is entered on RouterA in the campus LAN shown in Figure 3-4. The LAN has been fully configured to run the EIGRP protocol.
- How many EIGRP subnets are running on the network?
 - Identify the connected C and EIGRP D subnets.
37. The **sh ip route** command is entered on Router B in the campus LAN shown in Figure 3-4. The LAN has been fully configured to run the EIGRP protocol.
- How many EIGRP subnets are running on the network?
 - Identify the connected C and EIGRP D subnets.
38. EIGRP can use which of the following to determine the best path to a destination?
- Bandwidth
 - Delay, reliability
 - Load
 - All of these answers are correct
 - None of these answers are correct
39. By default, only bandwidth and delay are used by Cisco to calculate the composite metric. Define bandwidth and delay.
40. What is the command to view the composite metric of the current EIGRP topology?
41. What does the command **bandwidth 1000** do?
42. What does the command **delay 1000** do on a router?

Section 3-4

43. Define routing redistribution.
44. List three reasons why routing distribution is necessary.
45. What is the command issued to redistribute the connected networks on a router?

46. Identify the prompt and the command to redistribute a connected network in RIP.
47. Identify the router prompt and the command to redistribute a static route.
48. Identify the router prompt and the command to redistribute an OSPF route into RIP. Use a process ID of 100 and a metric of 2.
49. Identify the router prompt and the command to redistribute an EIGRP route into RIP. Use an AS number of 100 and a metric of 5.
50. Identify the router prompt and the command to redistribute an IS-IS route into RIP. Use a metric of 10.
51. What is the router prompt and the command that is used to distribute classless networks, such as static routes?
52. The following information is displayed when redistributing a static route. What does this mean?

```
RouterB(config-router)#redistribute static
% Only classful networks will be redistributed
```

53. What is the command to redistribute EIGRP routes into RIP? Assume an AS ID of 100 and a hop count metric of 5. Also, include the command that prevents the warning about classful subnets.
54. What is the router prompt and the command to redistribute RIP into OSPF?
55. What is the router prompt and the command to redistribute IS-IS into OSPF?
56. The following command is entered on a router:

```
Router(config-router)#redistribute rip metric 100000 10 255 1 1500
```

What does this command do and what are the values indicating?

57. What does the following command do?


```
RouterB(config-router)#default-metric 100000 10 255 1 1500
```
58. What is the router prompt and the command to redistribute RIP into IS-IS? Use a metric of 5.
59. What is the router prompt and the command to redistribute OSPF into IS-IS? Use a process id of 150 and a metric of 10.
60. What is the router prompt and the command to redistribute EIGRP into IS-IS? Use an AS of 150 and a metric of 10.

Section 3-5

61. The hello interval is
 - a. The time between Hello packets
 - b. The timing of the Hello header
 - c. The timing of the router dead interval
 - d. None of these answers are correct

62. OSPF multicasts are sent out as what class of address?
- a. Class A
 - b. Class B
 - c. Class C
 - d. Class D
 - e. Class E
63. OSPF Hello packets are sent out every
- a. 30 seconds
 - b. 90 seconds
 - c. 10 seconds
 - d. None of these answers are correct
64. The Router ID (RID) in OSPF Hello packets is chosen from
- a. Loopback addresses
 - b. OSPF 16P_Router
 - c. Highest IP address on an interface
 - d. a and c
 - e. b and c

Critical Thinking

65. You are configuring a router connection to a remote network. What protocol would you select if there is only one network route to the remote network? Explain why you selected the protocol.
66. You are configuring the routing protocols for a small network. What routing protocol would you select and why?
67. Router A and Router B are connected and both are running OSPF protocol. The following is a sample configuration from Router A:

```
interface FastEthernet0/0
  ip address 10.10.3.1 255.255.255.252
  duplex auto
  speed auto
!
interface FastEthernet0/1
  ip address 10.100.1.1 255.255.255.0
  duplex auto
  speed auto
!
ip route 172.16.0.0 255.255.0.0 Null 0
!
router ospf 200
network 10.0.0.0 0.255.255.255 area 0
```

```

        redistribute static subnets
    !
The following is a sample configuration from RouterB:
interface FastEthernet0/0
    ip address 10.10.3.2 255.255.255.252
    duplex auto
    speed auto
!
interface FastEthernet0/1
    ip address 172.16.10.1 255.255.255.0
    duplex auto
    speed auto
!
router ospf 200
network 10.0.0.0 0.255.255.255 area 0
        redistribute connected subnets
    !

```

What routes are redistributed from Router A's and Router B's perspectives? What would be an effect of using the **redistribute connected** instead of **redistribute connected subnets** on Router B?

68. From the **show ip route** output and the configuration of Router A, reconstruct the rough network diagram from the point of view of Router A. Label the interfaces and draw the connections to other router(s). Specify the network learned from the connected router(s).

```

#####Configuration File#####
!
version 12.3
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname RouterA
!!
interface FastEthernet0/0
    ip address 192.168.3.1 255.255.255.252
    duplex auto
    speed auto
!
interface Serial0/0
    ip address 192.168.1.1 255.255.255.252
    clock rate 2000000
!
interface FastEthernet0/1
    ip address 10.100.1.1 255.255.255.0
    duplex auto
    speed auto
!
router eigrp 200
    network 10.0.0.0
    network 192.168.0.0 0.0.255.255
    no auto-summary

```

```

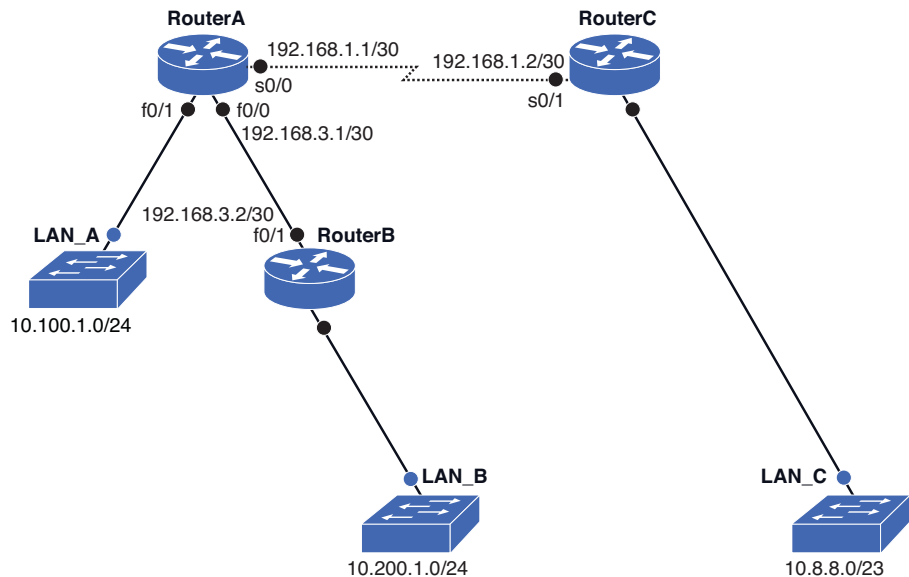
!
#####IP Route#####

RouterA#sh 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

    10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
D       10.8.8.0/23 [90/2172416] via 192.168.1.2, 00:05:30,
Serial0/0
C       10.100.1.0/24 is directly connected, FastEthernet0/1
D       10.200.1.0/24 [90/30720] via 192.168.3.2, 00:14:04,
FastEthernet0/0
    192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.0 is directly connected, Serial0/0
    192.168.3.0/30 is subnetted, 1 subnets
C       192.168.3.0 is directly connected, FastEthernet0/0
RouterA#

```



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