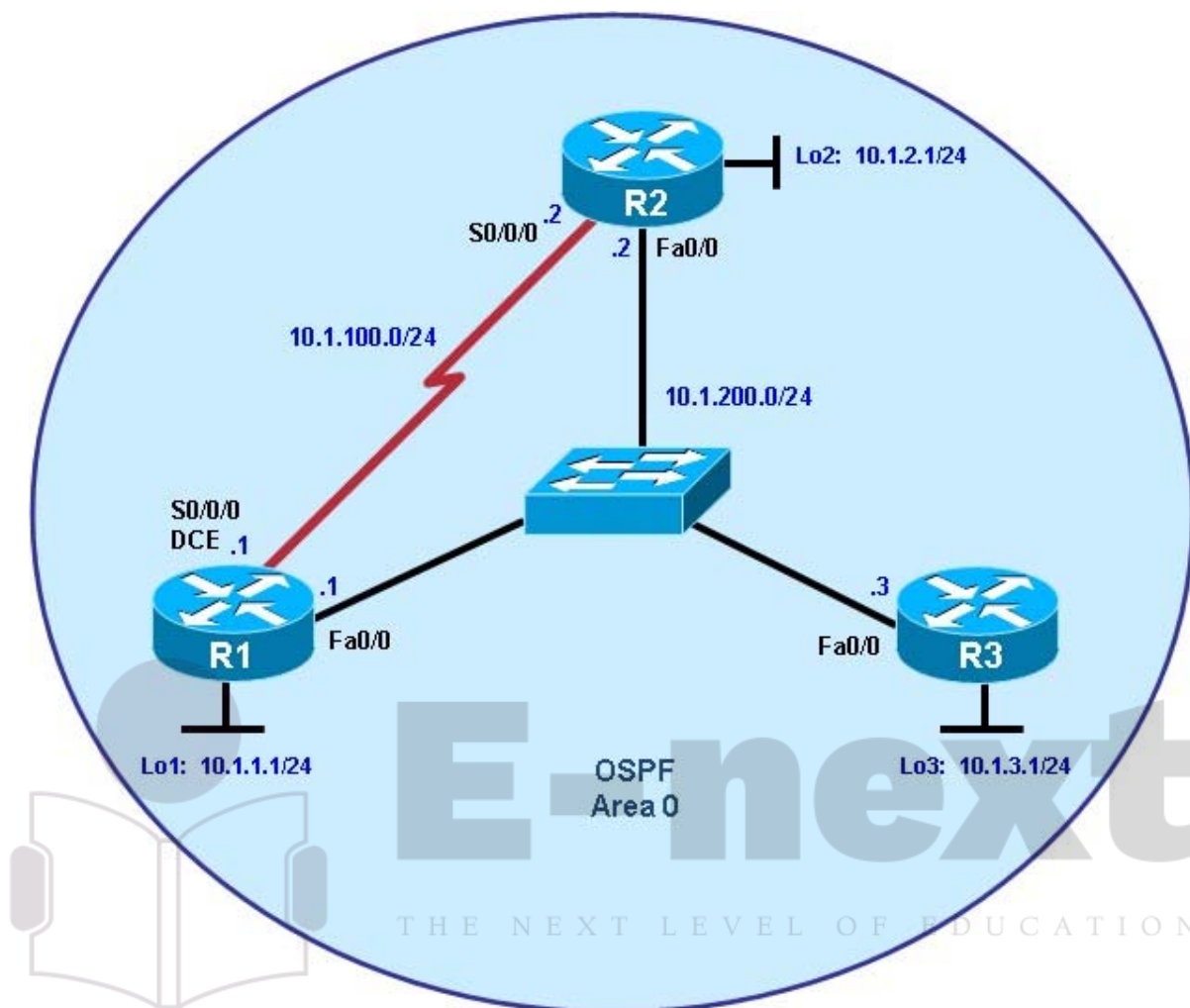# Chapter 1 Lab 1-1, Single-Area OSPF Link Costs and Interface Priorities

Topology

Objectives

- Configure single-area OSPF on a router.
- Advertise loopback interfaces into OSPF.
- Verify OSPF adjacencies.
- Verify OSPF routing information exchange.
- Modify OSPF link costs.
- Change interface priorities.
- Utilize debugging commands for troubleshooting OSPF.

Background

You are responsible for configuring the new network to connect your company's engineering, marketing, and accounting departments, represented by the loopback interfaces on each of the three routers. The physical devices have just been installed and connected by Fast Ethernet and serial cables. Configure OSPF to allow full connectivity between all departments.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. The switch is a Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin. You can use other routers (such as a 2801 or 2811), switches (such as a 2950), and Cisco IOS Software versions if they have comparable capabilities and features.

Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- 1 switch (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- Serial and Ethernet cables

Step 1: Configure addressing and loopbacks.

a. Using the addressing scheme in the diagram, apply IP addresses to the Fast Ethernet interfaces on R1, R2, and R3. Create Loopback1 on R1, Loopback2 on R2, and Loopback3 on R3, and address them according to the diagram.

Note: Depending on the router models you have, you might need to add clock rates to the DCE end of each connection (newer equipment adds this automatically). Verify connectivity across each serial link.

```
R1# configure terminal
R1(config)# interface Loopback1
R1(config-if)# description Engineering Department R1(config-if)#
ip address 10.1.1.1 255.255.255.0
R1(config-if)# exit
R1(config)# interface FastEthernet0/0
R1(config-if)# ip address 10.1.200.1 255.255.255.0
R1(config-if)# no shutdown

R2# configure terminal
R2(config)# interface Loopback2
R2(config-if)# description Marketing Department
R2(config-if)# ip address 10.1.2.1 255.255.255.0
R2(config-if)# exit
R2(config)# interface FastEthernet0/0
R2(config-if)# ip address 10.1.200.2 255.255.255.0 R2(config-
if)# no shutdown

R3# configure terminal
R3(config)# interface Loopback3
R3(config-if)# description Accounting Department
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# exit
R3(config)# interface FastEthernet0/0
R3(config-if)# ip address 10.1.200.3 255.255.255.0
R3(config-if)# no shutdown
```
Leave the switch in its default (blank) configuration. By default, all switch ports are in VLAN1 and are not administratively down.

b. Configure the serial interfaces on R1 and R2 with the IP addresses shown in the diagram. Add the **clockrate** command where needed.

```
R1(config)# interface Serial 0/0/0
R1(config-if)# ip address 10.1.100.1 255.255.255.0
R1(config-if)# clockrate 64000 R1(config-
if)# bandwidth 64 R1(config-if)# no
shutdown
```

```
R2(config)# interface Serial 0/0/0
R2(config-if)# ip address 10.1.100.2 255.255.255.0
R2(config-if)# bandwidth 64
R2(config-if)# no shutdown
```

Note: The **bandwidth** command on the serial interfaces is used to match the actual bandwidth of the link. By default, OSPF calculates the cost of links based on the default interface bandwidth which may be either 128 or 1544 Kb/s, depending on the WIC type. In this case the **bandwidth 64** command is used because the real bandwidth of the serial interfaces is set to 64 Kbps. Refer to Step 5 for information on modifying OSPF link costs.

c. Verify that the appropriate interfaces are up and that you can ping across each link.

Step 2: Add physical interfaces to OSPF.

a. Enter the OSPF configuration prompt using the **router ospf** *process_number* command. The process number is a locally significant number that does not affect how OSPF works. For this lab, use process number 1 on all the routers.

b. Add interfaces with the **network** *address wildcard_mask* **area** *area* command. The address is an IP address. The mask is an inverse mask, similar to the kind used in an access list. The area is the OSPF area to put the interface. For this lab, use area 0, the backbone area, for all interfaces.

This command can be confusing at first. What it means is that any interface with an IP address that matches the address and wildcard mask combination in the network statement is added to the OSPF process in that area. The wildcard mask used in the **network** command has no influence on the actual IP subnet mask that is advertised with a network on an interface. The **network** command selects interfaces to be included into OSPF, but OSPF advertises the real subnet mask of the network attached to that interface (with the only exception being loopback interfaces).

For example, the command **network 10.1.200.1 0.0.0.0 area 0** adds the interface with the IP address of 10.1.200.1 and its network to the OSPF process into area 0. The wildcard mask of 0.0.0.0 means that all 32 bits of the IP address have to be an exact match. A 0 bit in the wildcard mask means that portion of the interface IP must match the address. A 1 bit means that the bit in the interface IP does not have to match that portion of the IP address.

The command **network 10.1.100.0 0.0.0.255 area 0** means that any interface whose IP address matches 10.1.100.0 for the first 3 octets will match the command and add it to area 0. The last octet is all 1s, because in the wildcard mask it is 255. This means that an interface with an IP of 10.1.100.1, 10.1.100.2, or 10.1.100.250 would match this address and wildcard combination and get added to OSPF.

Instead of using wildcard masks in the **network** command, it is possible to use subnet masks. The router converts the subnet masks to the wildcard format automatically. An easy way to calculate a wildcard mask from the subnet mask is to subtract the octet value for each octet from 255. For example, a subnet mask of 255.255.255.252 (/30) becomes 0.0.0.3 to capture all interfaces on that subnet:

```
   255.255.255.255
 – 255.255.255.252
 =  0.  0.  0.  3
```

Note: Another option for adding individual directly connected networks into the OSPF process is to use the **ip ospf** *process-id* **area** *area-id* interface command that is available with Cisco IOS version 12.3(11)T and later.

c. Enter the commands on R1. Exit to privileged EXEC mode and type **debug ip ospf adj**. The **debug** command lets you watch OSPF neighbors come up and see neighbor relationships.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.100.0 0.0.0.255 area 0
```

```
R1(config-router)# network 10.1.200.0 0.0.0.255 area 0
R1(config-router)# end
R1#


R1# debug ip ospf adj
OSPF adjacency events debugging is on
```

d. Add network statements to the other two routers.

```
R2(config)# router ospf 1
R2(config-router)# network 10.1.100.0 0.0.0.255 area 0
R2(config-router)# network 10.1.200.0 0.0.0.255 area 0


R3(config)# router ospf 1
R3(config-router)# network 10.1.200.0 0.0.0.255 area 0
```

e. Observe the debug output on R1. When you are finished, turn off debugging on R1 with the **undebug all** command.

f. What is the advantage of adding networks with a wildcard mask instead of using classful network addresses?

_____

_____

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Using wildcard masks to add network addresses provides more control in determining which interfaces participate in the OSPF process.

In OSPF, interfaces can be assigned to different areas. Many times, a router is routing inside of a major network, but different interfaces belong to different areas. You need the level of control given by wildcard masks to assign different interfaces to their appropriate areas and not restrict an entire major network to be in one area. There might be networks connected to a router that the administrator does not want to advertise but which are in the same major network as the OSPF-enabled interface. Without using wildcard masks, it would be practically impossible to implement this.

Step 3: Use OSPF show commands.

a. The **show ip protocols** command displays basic high-level routing protocol information. The output lists each OSPF process, the router ID, and which networks OSPF is routing for in each area. This information can be useful in debugging routing operations.

```
R1# show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.1.100.0 0.0.0.255 area 0
    10.1.200.1 0.0.0.0 area 0
 Reference bandwidth unit is 100 mbps
```

```
   Routing Information Sources:
      Gateway         Distance      Last Update
   Distance: (default is 110)
```

b. The **show ip ospf** command displays the OSPF process ID and router ID.

```
R1# show ip ospf
Routing Process "ospf 1" with ID 10.1.1.1
 Start time: 00:17:44.612, Time elapsed: 00:10:51.408
 Supports only single TOS(TOS0) routes
Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 Router is not originating router-LSAs with maximum metric
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 1. 1 normal 0 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm last executed 00:03:21.132 ago
        SPF algorithm executed 5 times
        Area ranges are
        Number of LSA 4. Checksum Sum 0x021A30
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
```

Notice the router ID listed in the output. The R1 ID is 10.1.1.1, even though you have not added this loopback into the OSPF process. The router chooses the router ID using the highest IP on a loopback interface when OSPF is configured. If an additional loopback interface with a higher IP address is added after OSPF is turned on, it does not become the router ID unless the router is reloaded, the OSPF configuration is removed and reentered, or the OSPF-level command **router-id** is used to modify the RID manually and the **clear ip ospf process** command is subsequently entered. If no loopback interfaces are present on the router, the router selects the highest available IP address among interfaces that are activated using the **no shutdown** command. If no IP addresses are assigned to interfaces, the OSPF process does not start.

c. The **show ip ospf neighbor** command displays important neighbor status, including the adjacency state, address, router ID, and connected interface.

```
R1# show ip ospf neighbor


Neighbor ID   Pri   State           Dead Time   Address         Interface
```

```
10.1.2.1          1    FULL/BDR        00:00:36    10.1.200.2    FastEthernet0/0
10.1.3.1          1    FULL/DR         00:00:35    10.1.200.3    FastEthernet0/0
10.1.2.1          0    FULL/  -        00:00:36    10.1.100.2    Serial0/0/0
```

If you need more detail than the standard one-line summaries of neighbors, use the **show ip ospf neighbor detail** command. However, generally, the regular command gives you all that you need.

d. The **show ip ospf interface** *interface_type number* command shows interface timers and network types.

```
R1# show ip ospf interface FastEthernet 0/0

FastEthernet0/0 is up, line protocol is up
  Internet Address 10.1.200.1/24, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type BROADCAST, Cost: 1
Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 10.1.3.1, Interface address 10.1.200.3
  Backup Designated router (ID) 10.1.2.1, Interface address 10.1.200.2
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40     Hello due in 00:00:09
  Supports Link-local Signaling (LLS)
Cisco NSF helper support enabled    IETF
NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 2, Adjacent neighbor count is 2
     Adjacent with neighbor 10.1.3.1 (Designated Router)
     Adjacent with neighbor 10.1.2.1
Suppress hello for 0 neighbor(s)
```

e. A variation of the previous command is the **show ip ospf interface brief** command, which displays each interface that is participating in the OSPF process on the router, the area it is in, its IP address, cost, state, and number of neighbors.

```
R1# show ip ospf interface brief
Interface    PID    Area      IP Address/Mask    Cost   State   Nbrs F/C
Fa0/0        1      0         10.1.200.1/24      1      DROTH   2/2
Se0/0/0      1      0         10.1.100.1/24      1      P2P     1/1
```

f. The **show ip ospf database** command displays the various LSAs in the OSPF database, organized by area and type.

```
R1# show ip ospf database

OSPF Router with ID (10.1.1.1) (Process ID 1)

             Router Link States (Area 0)

Link ID          ADV Router        Age         Seq#         Checksum Link count
10.1.1.1         10.1.1.1          1782        0x80000002 0x001AC7 3
10.1.2.1         10.1.2.1          1783        0x80000001 0x001DC2 3
10.1.3.1         10.1.3.1          1720        0x80000002 0x00F077 1


             Net Link States (Area 0)

Link ID          ADV Router        Age         Seq#         Checksum
10.1.200.1       10.1.1.1          1719        0x80000002 0x00EC3C
```

```
                    OSPF Router with ID (10.1.1.1) (Process ID 1)
```

Step 4: Add loopback interfaces to OSPF.

a. All three routers have loopback interfaces, but they are not yet advertised in the routing process. You can verify this with the **show ip route** command on the three routers.

```
R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.1.0 is directly connected, Loopback1
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0


R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
D       - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
         N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
         E1 - OSPF external type 1, E2 - OSPF external type 2
         i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
         ia - IS-IS inter area, * - candidate default, U - per-user static route
         o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.2.0 is directly connected, Loopback2
C       10.1.100.0 is directly connected, Serial0/0/0
C       10.1.200.0 is directly connected, FastEthernet0/0


R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
D       - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
         N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
         E1 - OSPF external type 1, E2 - OSPF external type 2
         i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
         ia - IS-IS inter area, * - candidate default, U - per-user static route
         o - ODR, P - periodic downloaded static route


Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.3.0 is directly connected, Loopback3
O       10.1.100.0 [110/65] via 10.1.200.2, 00:06:39, FastEthernet0/0
                   [110/65] via 10.1.200.1, 00:06:39, FastEthernet0/0 C
10.1.200.0 is directly connected, FastEthernet0/0
```

b. For each router, the only loopback address displayed is the locally connected one. Add the loopbacks into the routing process for each router using the same **network** command previously used to add the physical interfaces.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.1.0 0.0.0.255 area 0

R2(config)# router ospf 1
R2(config-router)# network 10.1.2.0 0.0.0.255 area 0

R3(config)# router ospf 1
R3(config-router)# network 10.1.3.0 0.0.0.255 area 0
```

c. Verify that these networks have been added to the routing table using the **show ip route** command.

```
R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O       10.1.2.1/32 [110/2] via 10.1.200.2, 00:00:03, FastEthernet0/0
O       10.1.3.1/32 [110/2] via 10.1.200.3, 00:00:03, FastEthernet0/0
C       10.1.1.0/24 is directly connected, Loopback1
C       10.1.100.0/24 is directly connected, Serial0/0/0
C       10.1.200.0/24 is directly connected, FastEthernet0/0
```

Now you can see the loopbacks of the other routers, but their subnet mask is incorrect, because the default network type on loopback interfaces advertises them as /32 (host) routes. As you can see in the output of the **show ip ospf interface Lo1** command, the default OSPF network type for a loopback interface is LOOPBACK, causing the OSPF to advertise host routes instead of actual network masks.

```
R1# show ip ospf interface Lo1
Loopback1 is up, line protocol is up
  Internet Address 10.1.1.1/24, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type LOOPBACK, Cost: 1
  Loopback interface is treated as a stub Host
```

Note: The OSPF network type of LOOPBACK is a Cisco-proprietary extension that is not configurable but that is present on loopback interfaces by default. In some applications such as MPLS, the possible discrepancy between the real loopback interface mask and the advertised address/mask can lead to reachability or functionality issues, and care must be taken to either use /32 mask on loopbacks, or whenever a different mask is used, the OSPF network type must be changed to point-to-point.

d. To change this default behavior use the **ip ospf network point-to-point** command in interface configuration mode for each loopback. After the routes propagate, you see the correct subnet masks associated with those loopback interfaces.

```
R1(config)# interface loopback1
R1(config-if)# ip ospf network point-to-point
```

```
R2(config)# interface loopback2
R2(config-if)# ip ospf network point-to-point


R3(config)# interface loopback3
R3(config-if)# ip ospf network point-to-point


R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2          E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/24 is subnetted, 5 subnets
O        10.1.3.0 [110/2] via 10.1.200.3, 00:00:01, FastEthernet0/0
O        10.1.2.0 [110/2] via 10.1.200.2, 00:00:01, FastEthernet0/0
C        10.1.1.0 is directly connected, Loopback1
C        10.1.100.0 is directly connected, Serial0/0/0
C        10.1.200.0 is directly connected, FastEthernet0/0
```

e. Use the following Tcl script to verify connectivity to all addresses in the topology.

```
R1# tclsh
 foreach address
{
10.1.1.1
10.1.2.1
10.1.3.1
10.1.100.1
10.1.100.2
10.1.200.1
10.1.200.2
10.1.200.3
} { ping
$address }
```

Step 5: Modify OSPF link costs.

When you use the **show ip route** command on R1, you see that the most direct route to the R2 loopback is through its Ethernet connection. Next to this route is a pair in the form [administrative distance / metric]. The default administrative distance of OSPF on Cisco routers is 110. The metric depends on the link type. OSPF always chooses the route with the lowest metric, which is a sum of all link costs.

You can modify a single link cost by using the interface command **ip ospf cost** *cost*. Use this command on both ends of the link. In the following commands, the link cost of the Fast Ethernet connection between the three routers is changed to a cost of 50. Notice the change in the metrics in the routing table.

```
R1(config)# interface FastEthernet 0/0 R1(config-if)#
ip ospf cost 50


R2(config)# interface FastEthernet 0/0
R2(config-if)# ip ospf cost 50


R3(config)# interface FastEthernet 0/0
```

```
R3(config-if)# ip ospf cost 50


R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2          E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/24 is subnetted, 5 subnets
O      10.1.3.0 [110/51] via 10.1.200.3, 00:01:40, FastEthernet0/0 O
10.1.2.0 [110/51] via 10.1.200.2, 00:01:40, FastEthernet0/0
C      10.1.1.0 is directly connected, Loopback1
C      10.1.100.0 is directly connected, Serial0/0/0
C      10.1.200.0 is directly connected, FastEthernet0/0
```

For reference, here are some default link costs (taken from Cisco.com):

- 64-kb/s serial link: 1562
- T1 (1.544-Mb/s serial link): 64
- E1 (2.048-Mb/s serial link): 48
- Ethernet: 10
- Fast Ethernet: 1
- FDDI: 1
- X25: 5208
- ATM: 1

OSPF uses a reference bandwidth of 100 Mb/s for cost calculation. The formula to calculate the cost is the reference bandwidth divided by the interface bandwidth. For example, in the case of Ethernet, is the cost is 100 Mb/s / 10 Mb/s = 10.

The above link costs do not include Gigabit Ethernet, which is significantly faster than Fast Ethernet, but would still have a cost of 1 using the default reference bandwidth of 100 Mb/s.

The cost calculation can be adjusted to account for network links that are faster than 100 Mb/s by using the **auto-cost reference-bandwidth** command to change the reference bandwidth. For example, to change the reference bandwidth to 1000 Mb/s (Gigabit Ethernet), use the following commands:

```
R1(config)# router ospf 1
R1(config-router)# auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
   Please ensure reference bandwidth is consistent across all routers.
```

Note: If the **ip ospf cost** *cost* command is used on the interface, as is the case here, it overrides this formulated cost.

Note: The above example is for reference only and should not be entered on R1.

Step 6: Modify interface priorities to control the DR and BDR election.

If you use the **show ip ospf neighbor detail** command on any of the routers, you see that for the Ethernet network, R3 is the DR (designated router) and R2 is the BDR (backup designated router). These designations are determined by the interface priority for all routers in that network, which you see in the **show** output.

The default priority is 1. If all the priorities are the same (which happens by default), the DR election is then based on router IDs. The highest router ID router becomes the DR, and the second highest becomes the BDR. All other routers become DROTHERs.

Note: If your routers do not have this exact behavior, it might be because of the order in which the routers came up. Sometimes a router does not leave the DR position unless its interface goes down and another router takes over. Your routers might not behave exactly like the example.

Use the **ip ospf priority** *number* interface command to change the OSPF priorities on R1 and R2 to make R1 the DR and R2 the BDR. After changing the priority on both interfaces, look at the output of the **show ip ospf neighbor detail** command. You can also see the change with the **show ip ospf neighbor** command, but it requires more interpretation because it comes up with states per neighbor, rather than stating the DR and BDR on a neighbor adjacency network.

```
R1(config)# interface FastEthernet 0/0 R1(config-if)#
ip ospf priority 10

R2(config)# interface FastEthernet 0/0 R2(config-if)#
ip ospf priority 5

R1# show ip ospf neighbor detail
 Neighbor 10.1.2.1, interface address 10.1.200.2
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 5, State is FULL, 12 state changes
    DR is 10.1.200.1 BDR is 10.1.200.2
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:37
    Neighbor is up for 00:01:32
    Index 3/3, retransmission queue length 0, number of retransmission 0
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 0, maximum is 0
    Last retransmission scan time is 0 msec, maximum is 0 msec
  Neighbor 10.1.3.1, interface address 10.1.200.3
    In the area 0 via interface FastEthernet0/0
    Neighbor priority is 1, State is FULL, 12 state changes
    DR is 10.1.200.1 BDR is 10.1.200.2
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:30
    Neighbor is up for 00:01:12
    Index 1/1, retransmission queue length 0, number of retransmission 3
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 1, maximum is 1
    Last retransmission scan time is 0 msec, maximum is 0 msec
  Neighbor 10.1.2.1, interface address 10.1.100.2
    In the area 0 via interface Serial0/0/0
    Neighbor priority is 0, State is FULL, 12 state changes
    DR is 0.0.0.0 BDR is 0.0.0.0
    Options is 0x52
    LLS Options is 0x1 (LR)
    Dead timer due in 00:00:35
    Neighbor is up for 00:01:44
    Index 2/2, retransmission queue length 0, number of retransmission 2
    First 0x0(0)/0x0(0) Next 0x0(0)/0x0(0)
    Last retransmission scan length is 2, maximum is 2
    Last retransmission scan time is 0 msec, maximum is 0 msec
```

Note: To make a router take over as DR, use the **clear ip ospf process** command on all the routers after changing the priorities. Another method of demonstrating the election process and priorities is to shutdown and reactivate all ports on the switch simultaneously. The switch can be configured with **spanning-tree portfast default** and all ports can be shutdown and reactivated using the following commands. `interface range fa0/1 - 24  shutdown  no shutdown`

What is the purpose of a DR in OSPF?

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_____ The most important function of the DR is to represent the multi-access segment by generating the Type-2 LSA on behalf of that segment. Without the Type-2 LSA originated by the DR, on a multi-access segment with n routers, each router would be required to generate its own Type-1 LSA containing n-1 entries (also called links), one entry for each neighbor, to indicate a full reachability. The link-state database on each router would then contain n(n-1) links collected from Type-1 LSAs originated by the n routers on this segment.

With the Type-2 LSA representing the multi-access segment itself, each of the n routers attached to the segment inserts only one entry in their Type-1 LSAs, describing a connection to the multi-access segment represented by the Type-2 LSA. The DR will, in addition to its own Type-1 LSA, generate a Type-2 LSA containing n entries, in turn indicating a connection from the multi-access segment to each of its attached routers. Essentially, the multi-access segment will be described as each router having a link to the segment and the segment in turn having a link to each router. The link-state database on each router will now contain only *n+1* links which is, for large n, significantly lower than the former count *n(n-1)*.

What is the purpose of a BDR in OSPF?

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A BDR is a backup designated router. Its purpose is to take over as the DR if the current DR goes down. When the BDR becomes the DR, a new BDR election is held for the next BDR.

Challenge: Topology Change

OSPF, like many link-state routing protocols, is reasonably fast when it comes to convergence. To test this, have R3 send a large number of pings to the R1 loopback. By default, the pings take the path from R3 to R1 over Fast Ethernet because it has the lowest total path cost.

a. Check the path from R3 to R1 by performing a traceroute on R3 to the loopback of R1.

```
R3# traceroute 10.1.1.1

Type escape sequence to abort.
Tracing the route to 10.1.1.1

  1 10.1.200.1 0 msec 0 msec *
```

Note: Read the next substep carefully before trying out the commands on routers.

b. Initiate a ping from R3 to the R1 loopback with a high repeat number using the command **ping** *ip* **repeat** *number* command. While this ping is going on, shut down the R1 Fa0/0 interface.

```
R3# ping 10.1.1.1 repeat 10000

R1(config)# interface FastEthernet 0/0
R1(config-if)# shutdown
```

Did you notice that some packets were dropped but then the pings started returning again?

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Yes. Some pings were dropped because of the time it took for the OSPF adjacency to time out and for the network topology to reconverge.

How do you think OSPF convergence compares to other routing protocols, such as RIP? What about EIGRP?

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OSPF should perform better than RIP in this situation because it has a shorter dead time compared to the RIP hold-down time. If you are using the default settings, OSPF might not perform as well as EIGRP which has a shorter dead time than OSPF. However, the hello and dead intervals for both protocols can be adjusted to provide a fair comparison.

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations (Instructor version)

Router R1

```
hostname R1 ! interface Loopback1
description Engineering Department
ip address 10.1.1.1 255.255.255.0 !
interface FastEthernet0/0  ip
address 10.1.200.1 255.255.255.0  ip
ospf cost 50  ip ospf priority 10
no shutdown !
interface Serial0/0/0  ip address
10.1.100.1 255.255.255.0  clock rate
64000  bandwidth 64  no shutdown !
router ospf 1  network 10.1.1.0
0.0.0.255 area 0  network 10.1.100.0
0.0.0.255 area 0  network 10.1.200.0
0.0.0.255 area 0 ! end
```

Router R2

```
hostname R2 ! interface Loopback2
description Marketing Department
ip address 10.1.2.1 255.255.255.0
ip ospf network point-to-point !
interface FastEthernet0/0  ip
address 10.1.200.2 255.255.255.0  ip
ospf cost 50  ip ospf priority 5  no
shutdown !
interface Serial0/0/0  ip address
10.1.100.2 255.255.255.0  bandwidth
64  no shutdown !
router ospf 1  network 10.1.2.0
0.0.0.255 area 0  network 10.1.100.0
0.0.0.255 area 0  network 10.1.200.0
0.0.0.255 area 0 ! end
```

Router R3

```
hostname R3 ! interface Loopback3
description Accounting Department
ip address 10.1.3.1 255.255.255.0
ip ospf network point-to-point !
interface FastEthernet0/0  ip
address 10.1.200.3 255.255.255.0  ip
ospf cost 50  no shutdown !
router ospf 1  network 10.1.3.0
0.0.0.255 area 0  network 10.1.200.0
0.0.0.255 area 0 ! end
```

1-2, Multi-Area OSPF with Stub Areas and Authentication

Topology
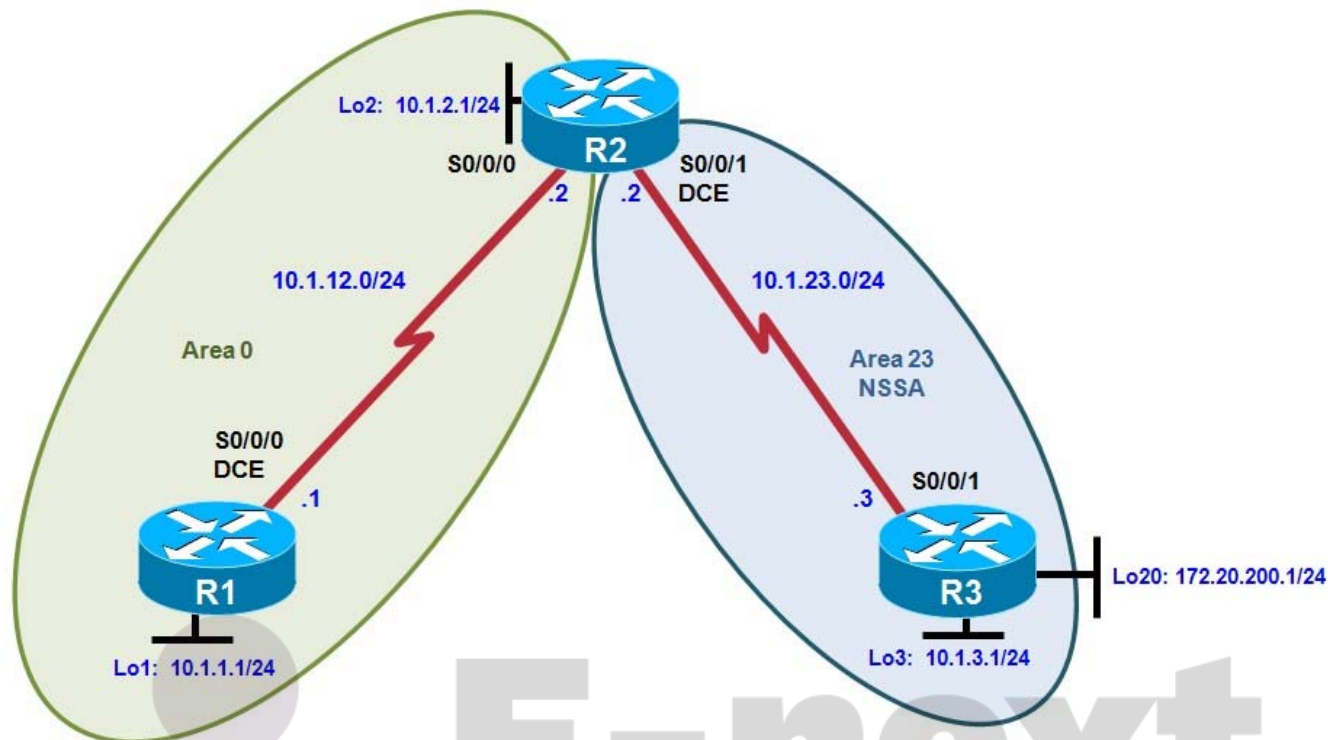
Objectives

- Configure multiple-area OSPF on a router.
- Verify multiple-area behavior.
- Configure OSPF stub, totally stubby, and not-so-stubby areas.
- Configure OSPF authentication.

Background

You are responsible for configuring the new network to connect your company's engineering, marketing, and accounting departments, represented by loopback interfaces on each of the three routers. The physical devices have just been installed and connected by serial cables. Configure multiple-area OSPF to allow full connectivity between all departments.

R3 also has a loopback representing a connection to another autonomous system that is not part of OSPF. **Note:** This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Configure addressing and loopbacks.

a. Using the addressing scheme in the diagram, apply IP addresses to the serial interfaces on R1, R2, and R3. Create loopbacks on R1, R2, and R3, and address them according to the diagram.

Note: Depending on the router models you have, you might need to add clock rates to the DCE end of each connection (newer equipment adds this automatically). Verify connectivity across each serial link.

```
R1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# interface loopback 1
R1(config-if)# description Engineering Department
R1(config-if)# ip address 10.1.1.1 255.255.255.0 R1(config-
if)# interface serial 0/0/0
R1(config-if)# ip address 10.1.12.1 255.255.255.0
R1(config-if)# clockrate 64000
R1(config-if)# no shutdown


R2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# interface loopback 2
R2(config-if)# description Marketing Department
R2(config-if)# ip address 10.1.2.1 255.255.255.0 R2(config-
if)# interface serial 0/0/0
R2(config-if)# ip address 10.1.12.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip address 10.1.23.2 255.255.255.0
R2(config-if)# clockrate 64000
R2(config-if)# no shutdown


R3# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)# interface loopback 3
R3(config-if)# description Accounting Department
R3(config-if)# ip address 10.1.3.1 255.255.255.0 R3(config-
if)# interface loopback 20
R3(config-if)# description Connection to another AS
R3(config-if)# ip address 172.20.200.1 255.255.255.0
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip address 10.1.23.3 255.255.255.0
R3(config-if)# no shutdown Step
```

2: Add interfaces into OSPF.

a. Create OSPF process 1 on routers R1 and R2. Configure the subnet of the serial link between R1 and R2 to be in OSPF area 0 using the **network** command. Add loopback 1 on R1 and loopback 2 on R2 into OSPF area 0. Change the network type on the loopback interfaces so that they are advertised with the correct subnet.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.12.0 0.0.0.255 area 0
R1(config-router)# network 10.1.1.0 0.0.0.255 area 0
R1(config-router)# exit
R1(config)# interface loopback 1
R1(config-if)# ip ospf network point-to-point


R2(config)# router ospf 1
```

```
R2(config-router)# network 10.1.12.0 0.0.0.255 area 0
R2(config-router)# network 10.1.2.0 0.0.0.255 area 0
R2(config-router)# exit
R2(config)# interface loopback 2
R2(config-if)# ip ospf network point-to-point
```

Note: Another option for adding individual directly connected networks into the OSPF process is to use the **ip ospf** *process-id* **area** *area-id* interface command that is available with Cisco IOS version 12.3(11)T and later.

b. Verify that both routers have OSPF neighbors using the **show ip ospf neighbors** command. R1# **show ip ospf neighbor**

```
Neighbor ID     Pri   State           Dead Time   Address       Interface
10.1.2.1          0   FULL/  -        00:00:38    10.1.12.2     Serial0/0/0
```

```
R2# show ip ospf neighbor
```

```
Neighbor ID     Pri   State           Dead Time   Address       Interface
10.1.1.1          0   FULL/  -        00:00:35    10.1.12.1     Serial0/0/0
```

c. Verify that the routers can see each other's loopback with the **show ip route** command.

```
R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.2.0 [110/65] via 10.1.12.2, 00:00:10, Serial0/0/0
C       10.1.1.0 is directly connected, Loopback1

R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
D      - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
         N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
         E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 4 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:00:30, Serial0/0/0 C
10.1.23.0 is directly connected, Serial0/0/1
```

d. Add the subnet between R2 and R3 into OSPF area 23 using the **network** command. Add loopback 3 on R3 into area 23.

```
R2(config)# router ospf 1
R2(config-router)# network 10.1.23.0 0.0.0.255 area 23

R3(config)# router ospf 1
R3(config-router)# network 10.1.23.0 0.0.0.255 area 23
R3(config-router)# network 10.1.3.0 0.0.0.255 area 23
R3(config-router)# exit
R3(config)# interface loopback 3
R3(config-if)# ip ospf network point-to-point
```

e. Verify that this neighbor relationship comes up using the **show ip ospf neighbors** command. R2# **show ip ospf neighbor**

```
Neighbor ID     Pri   State          Dead Time   Address      Interface
10.1.1.1          0   FULL/  -       00:00:36    10.1.12.1    Serial0/0/0
10.1.3.1          0   FULL/  -       00:00:36    10.1.23.3    Serial0/0/1
```

f. If you look at the output of the **show ip route** command on R1, you see a route to the R3 loopback. Notice that it is identified as an inter-area route.

```
R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O IA    10.1.3.0 [110/129] via 10.1.12.2, 00:00:28, Serial0/0/0
O       10.1.2.0 [110/65] via 10.1.12.2, 00:01:38, Serial0/0/0 C
10.1.1.0 is directly connected, Loopback1
O IA    10.1.23.0 [110/128] via 10.1.12.2, 00:01:38, Serial0/0/0
```

g. Issue the **show ip route** command on R2. Notice that R2 has no inter-area routes because R2 is in both areas. It is an ABR, or area border router.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2          E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
```

```
O        10.1.3.0 [110/65] via 10.1.23.3, 00:00:50, Serial0/0/1
C        10.1.2.0 is directly connected, Loopback2
O        10.1.1.0 [110/65] via 10.1.12.1, 00:02:00, Serial0/0/0 C
10.1.23.0 is directly connected, Serial0/0/1
```

h. Using a Tcl script, verify connectivity to all interfaces from any router, with the exception of loopback 20 on R3 (172.20.200.1), which has not yet been configured as part of OSPF.

i. Use the following Tcl script to verify that you can ping all addresses in the topology.

```
R1# tclsh
R1(tcl)#
foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.12.1
10.1.12.2
10.1.23.2
10.1.23.3
172.20.200.1 }
{ ping $address
}
```

Step 3: Configure a stub area.

a. Under the OSPF process on R2 and R3, make area 23 the stub area using the **area** *area* **stub** command. The adjacency between the two routers might go down during the transition period, but it should come back up afterwards.

```
R2(config)# router ospf 1
R2(config-router)# area 23 stub

R3(config)# router ospf 1
R3(config-router)# area 23 stub
```

b. Confirm that it comes up by using the **show ip ospf neighbors** command.

```
R2# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.1.1          0   FULL/  -        00:00:36    10.1.12.1       Serial0/0/0
10.1.3.1          0   FULL/  -        00:00:36    10.1.23.3       Serial0/0/1


R3# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
10.1.2.1          0   FULL/  -        00:00:31    10.1.23.2       Serial0/0/1
```

c. Using the **show ip route** command, you can see that R3 now has a default route pointing toward R2. A stub area does not receive any external routes. It receives a default route and OSPF inter-area routes.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
```

```
        o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.23.2 to network 0.0.0.0


     172.20.0.0/24 is subnetted, 1 subnets
C       172.20.200.0 is directly connected, Loopback20
     10.0.0.0/24 is subnetted, 5 subnets
O IA    10.1.12.0 [110/128] via 10.1.23.2, 00:00:56, Serial0/0/1 C
10.1.3.0 is directly connected, Loopback3
O IA    10.1.2.0 [110/65] via 10.1.23.2, 00:00:56, Serial0/0/1
O IA    10.1.1.0 [110/129] via 10.1.23.2, 00:00:56, Serial0/0/1 C
10.1.23.0 is directly connected, Serial0/0/1
O*IA 0.0.0.0/0 [110/65] via 10.1.23.2, 00:00:56, Serial0/0/1
```

d. Look at the output of the **show ip ospf** command to see what type each area is.

```
R2# show ip ospf
 Routing Process "ospf 1" with ID 10.1.2.1
 Supports only single TOS(TOS0) routes
Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 It is an area border router
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 0. Checksum Sum 0x000000
Number of opaque AS LSA 0. Checksum Sum 0x000000
Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 2. 1 normal 1 stub 0 nssa
 Number of areas transit capable is 0
 External flood list length 0
    Area BACKBONE(0)
        Number of interfaces in this area is 2
        Area has no authentication
        SPF algorithm last executed 00:02:11.680 ago
        SPF algorithm executed 5 times
        Area ranges are
        Number of LSA 4. Checksum Sum 0x01A85A
        Number of opaque link LSA 0. Checksum Sum 0x000000
        Number of DCbitless LSA 0
        Number of indication LSA 0
        Number of DoNotAge LSA 0
        Flood list length 0
    Area 23
        It is a stub area                          Number of interfaces in this
                                                   area is 1
                                                   generates stub default route
with cost 1
        Area has no authentication
```

```
         SPF algorithm last executed 00:01:38.276 ago
         SPF algorithm executed 8 times
         Area ranges are
         Number of LSA 6. Checksum Sum 0x027269
         Number of opaque link LSA 0. Checksum Sum 0x000000
         Number of DCbitless LSA 0
         Number of indication LSA 0
         Number of DoNotAge LSA 0
Flood list length 0
```

What are the advantages of having a router receive a default route rather than a more specific route?

_____

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Router memory and processing are conserved because the router has fewer routes to contend with.

Why do all routers in a stub area need to know that the area is a stub?

_____

_____

_____

Routers need to know that an area is a stub for consistency so that no routers generate type 5 LSAs or other OSPF features (such as virtual links) in an area in which they cannot exist.

Step 4: Configure a totally stubby area.

A modified version of a stubby area is a totally stubby area. A totally stubby area ABR only allows in a single, default route from the backbone. To configure a totally stubby area, you only need to change a command at the ABR, R2 in this scenario. Under the router OSPF process, you will enter the **area 23 stub no-summary** command to replace the existing stub command for area 23. The **no-summary** option tells the router that this area will not receive summary (inter-area) routes.

a. To see how this works, issue the **show ip route** command on R3. Notice the inter-area routes, in addition to the default route generated by R2.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.23.2 to network 0.0.0.0

     172.20.0.0/24 is subnetted, 1 subnets
C       172.20.200.0 is directly connected, Loopback20
     10.0.0.0/24 is subnetted, 5 subnets
O IA    10.1.12.0 [110/128] via 10.1.23.2, 00:00:56, Serial0/0/1 C
10.1.3.0 is directly connected, Loopback3
O IA    10.1.2.0 [110/65] via 10.1.23.2, 00:00:56, Serial0/0/1
O IA    10.1.1.0 [110/129] via 10.1.23.2, 00:00:56, Serial0/0/1 C
10.1.23.0 is directly connected, Serial0/0/1
O*IA 0.0.0.0/0 [110/65] via 10.1.23.2, 00:00:56, Serial0/0/1
```

b. Look at the output of the **show ip ospf database** command on R2 to see which LSAs are in its OSPF database.

```
R2# show ip ospf database

            OSPF Router with ID (10.1.2.1) (Process ID 1)

                Router Link States (Area 0)

Link ID          ADV Router       Age        Seq#         Checksum Link count
10.1.1.1         10.1.1.1         435        0x80000004 0x0056D6 3
10.1.2.1         10.1.2.1         358        0x80000003 0x0057D2 3


                Summary Net Link States (Area 0)

Link ID          ADV Router       Age        Seq#         Checksum
10.1.3.0         10.1.2.1         174        0x80000001 0x00EFEF
10.1.23.0        10.1.2.1         354        0x80000001 0x0009C3


                Router Link States (Area 23)

Link ID          ADV Router       Age        Seq#         Checksum Link count
10.1.2.1         10.1.2.1         188        0x80000004 0x00298C 2 10.1.3.1
10.1.3.1         188          0x80000004 0x00B762 3


                Summary Net Link States (Area 23)

Link ID          ADV Router       Age        Seq#         Checksum
0.0.0.0          10.1.2.1         207        0x80000001 0x003BF4
10.1.1.0         10.1.2.1         209        0x80000002 0x0022C0
10.1.2.0         10.1.2.1         209        0x80000002 0x00948D
10.1.12.0        10.1.2.1         209        0x80000002 0x009E3A
```

c. Enter the **stub no-summary** command on R2 (the ABR) under the OSPF process.

```
R2(config)# router ospf 1
R2(config-router)# area 23 stub no-summary
```

d. Go back to R3 and issue the **show ip route** command again. Notice that it shows only one incoming route from OSPF.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is 10.1.23.2 to network 0.0.0.0


     172.20.0.0/24 is subnetted, 1 subnets
C       172.20.200.0 is directly connected, Loopback20
     10.0.0.0/24 is subnetted, 2 subnets
C       10.1.3.0 is directly connected, Loopback3
C       10.1.23.0 is directly connected, Serial0/0/1
O*IA 0.0.0.0/0 [110/65] via 10.1.23.2, 00:00:10, Serial0/0/1
```

e. Look at the **show ip ospf database** output to see which routes are in area 23.

```
R3# show ip ospf database

             OSPF Router with ID (10.1.3.1) (Process ID 1)

             Router Link States (Area 23)

Link ID           ADV Router        Age          Seq#         Checksum Link count
10.1.2.1          10.1.2.1          275          0x80000004 0x00298C 2 10.1.3.1
10.1.3.1          276          0x80000004 0x00B762 3


             Summary Net Link States (Area 23)

Link ID           ADV Router        Age          Seq#         Checksum
0.0.0.0           10.1.2.1          68           0x80000002 0x0039F5
```

What are the advantages of making an area totally stubby instead of a regular stub area? What are the disadvantages?

_____

_____

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By making an area totally stubby, routers in the area only see intra-area routes and a default route. This can save a lot of router memory and processor time. However, as with any type of route aggregation, the loss of routing detail makes it possible for a non-optimal route to be chosen.

Why did only the ABR need to know that the area was totally stubby rather than all routers in the area?

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The ABR is the gateway to the rest of the area and therefore is the boundary that all inter-area LSAs need to pass through. Because of this, it only needs to filter out the type 3 LSAs and let the default route through.

Step 5: Configure a not-so-stubby area.

Not-so-stubby areas (NSSAs) are similar to regular stub areas, except that they allow routes to be redistributed from an ASBR into that area with a special LSA type, which gets converted to a normal external route at the ABR.

a. Change area 23 into an NSSA. NSSAs are not compatible with stub areas, so the first thing to do is issue the **no area 23 stub** command on routers R2 and R3. Next, issue the **area** *area* **nssa** command on routers R2 and R3 to change area 23 to an NSSA. To generate an external route into the NSSA, use the **redistribute connected subnets** command on R3. This adds the previously unreachable loopback 20 into OSPF. Be sure to include the **subnets** keyword; otherwise, only classful networks are redistributed.

```
R2(config)# router ospf 1
R2(config-router)# no area 23 stub
R2(config-router)# area 23 nssa

R3(config)# router ospf 1
R3(config-router)# no area 23 stub
```

```
R3(config-router)# area 23 nssa
R3(config-router)# redistribute connected subnets
```

b. In the output of the **show ip ospf** command on R2, notice that area 23 is an NSSA and that R2 is performing the LSA type 7 to type 5 translation. If there are multiple ABRs to an NSSA, the ABR with the highest router ID performs the translation.

```
R2# show ip ospf
 Routing Process "ospf 1" with ID 10.1.2.1
 Supports only single TOS(TOS0) routes
Supports opaque LSA
 Supports Link-local Signaling (LLS)
 Supports area transit capability
 It is an area border and autonomous system boundary router
 Redistributing External Routes from,
 Initial SPF schedule delay 5000 msecs
 Minimum hold time between two consecutive SPFs 10000 msecs
 Maximum wait time between two consecutive SPFs 10000 msecs
 Incremental-SPF disabled
 Minimum LSA interval 5 secs
 Minimum LSA arrival 1000 msecs
 LSA group pacing timer 240 secs
 Interface flood pacing timer 33 msecs
 Retransmission pacing timer 66 msecs
 Number of external LSA 1. Checksum Sum 0x00CA2F
 Number of opaque AS LSA 0. Checksum Sum 0x000000
 Number of DCbitless external and opaque AS LSA 0
 Number of DoNotAge external and opaque AS LSA 0
 Number of areas in this router is 2. 1 normal 0 stub 1 nssa
 Number of areas transit capable is 0
 External flood list length 0
     Area BACKBONE(0)
         Number of interfaces in this area is 2
         Area has no authentication
         SPF algorithm last executed 00:03:11.636 ago
         SPF algorithm executed 9 times
         Area ranges are
         Number of LSA 4. Checksum Sum 0x01AC53
         Number of opaque link LSA 0. Checksum Sum 0x000000
         Number of DCbitless LSA 0
         Number of indication LSA 0
         Number of DoNotAge LSA 0
         Flood list length 0
     Area 23
         Number of interfaces in this area is 1
             It is a NSSA
                 area                          Perform type-7/type-5 LSA
                                               translation
                                               Area has no authentication
         SPF algorithm last executed 00:00:16.408 ago
         SPF algorithm executed 16 times
         Area ranges are
         Number of LSA 6. Checksum Sum 0x025498
         Number of opaque link LSA 0. Checksum Sum 0x000000
         Number of DCbitless LSA 0
         Number of indication LSA 0
         Number of DoNotAge LSA 0
 Flood list length 0
```

c. Look at the **show ip route** output on R2. Notice that the external route comes in as type N2 from R3. This is because it is a special NSSA external route.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.20.0.0/24 is subnetted, 1 subnets
O N2    172.20.200.0 [110/20] via 10.1.23.3, 00:00:41, Serial0/0/1
     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:00:47, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:03:42, Serial0/0/0 C
10.1.23.0 is directly connected, Serial0/0/1
```

d. Look at the **show ip route** output on R1. Notice that the route is now a regular E2 external route, because R2 has performed the type 7 to type 5 translation.

```
R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.20.0.0/24 is subnetted, 1 subnets
O E2    172.20.200.0 [110/20] via 10.1.12.2, 00:01:22, Serial0/0/0
     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O IA    10.1.3.0 [110/129] via 10.1.12.2, 00:02:06, Serial0/0/0
O       10.1.2.0 [110/65] via 10.1.12.2, 00:04:22, Serial0/0/0 C
10.1.1.0 is directly connected, Loopback1
O IA    10.1.23.0 [110/128] via 10.1.12.2, 00:04:22, Serial0/0/0
```

e. Look at the **show ip route** output on R3. Notice that it no longer has a default route in it, but inter-area routes are coming in.

Note: An NSSA does not have the default route injected by the ABR (R2) automatically. It is possible to make the ABR inject the default route into the NSSA using the **area 23 nssa default-informationoriginate** command on R2.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2          E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
```

```
              ia - IS-IS inter area, * - candidate default, U - per-user static route
              o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


      172.20.0.0/24 is subnetted, 1 subnets
C        172.20.200.0 is directly connected, Loopback20
      10.0.0.0/24 is subnetted, 5 subnets
O IA     10.1.12.0 [110/128] via 10.1.23.2, 00:02:11, Serial0/0/1 C
10.1.3.0 is directly connected, Loopback3
O IA     10.1.2.0 [110/65] via 10.1.23.2, 00:02:11, Serial0/0/1
O IA     10.1.1.0 [110/129] via 10.1.23.2, 00:02:11, Serial0/0/1 C
10.1.23.0 is directly connected, Serial0/0/1
```

f.   Yet another type of area is a totally-stubby NSSA that combines the property of an NSSA area (injecting external routing information into OSPF) with a totally stubby behavior (accepting only default route from the backbone). Issue the **area 23 nssa no-summary** command on R2, similar to converting a stub area into a totally stubby area.

```
R2(config)# router ospf 1
R2(config-router)# area 23 nssa no-summary
```

g.   Check the routing table on R3. Notice that the inter-area routes have been replaced by a single default route.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is 10.1.23.2 to network 0.0.0.0


      172.20.0.0/24 is subnetted, 1 subnets
C        172.20.200.0 is directly connected, Loopback20
      10.0.0.0/24 is subnetted, 2 subnets
C        10.1.3.0 is directly connected, Loopback3
C        10.1.23.0 is directly connected, Serial0/0/1
O*IA 0.0.0.0/0 [110/65] via 10.1.23.2, 00:00:20, Serial0/0/1
```

h.   On R2, look at the **show ip ospf database** output to see the various LSA types.

```
R2# show ip ospf database


            OSPF Router with ID (10.1.2.1) (Process ID 1)


            Router Link States (Area 0)


Link ID         ADV Router      Age         Seq#        Checksum Link count
10.1.1.1        10.1.1.1        944         0x80000004 0x0056D6 3
10.1.2.1        10.1.2.1        383         0x80000004 0x005BCB 3


            Summary Net Link States (Area 0)


Link ID         ADV Router      Age         Seq#        Checksum
```

```
10.1.3.0          10.1.2.1      242        0x80000001 0x00EFEF
10.1.23.0         10.1.2.1      862        0x80000001 0x0009C3

                  Router Link States (Area 23)

Link ID           ADV Router    Age        Seq#       Checksum Link count
10.1.2.1          10.1.2.1      257        0x80000007 0x00B0F7 2
10.1.3.1          10.1.3.1      209        0x80000007 0x003FCD 3

                  Summary Net Link States (Area 23)

Link ID           ADV Router    Age        Seq#       Checksum
0.0.0.0           10.1.2.1      34         0x80000001 0x00C265

                  Type-7 AS External Link States (Area 23)

Link ID           ADV Router    Age        Seq#       Checksum Tag
10.1.3.0          10.1.3.1      200        0x80000001 0x0076FC 0

                  Type-5 AS External Link States

Link ID           ADV Router    Age        Seq#       Checksum Tag
10.1.3.0          10.1.2.1      199        0x80000001 0x00CA2F 0
```

Where would it be useful to make an area into an NSSA?

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An NSSA is useful if you want to allow an area to inject external routes into an OSPF domain while still retaining some of the stub characteristics of the area such as not accepting external routes that are originated in other areas.

Step 6: Configure OSPF interface authentication.

For security purposes, you can configure OSPF interfaces to use authentication.

a. Configure the link between R2 and R3 for plaintext authentication. To set up plaintext authentication on an interface, type **ip ospf authentication** at the interface command prompt. Then set the password to **cisco** with the **ip ospf authentication-key** *key-string* command.

```
R2(config)# interface serial 0/0/1
R2(config-if)# ip ospf authentication
R2(config-if)# ip ospf authentication-key cisco


R3(config)# interface serial 0/0/1
R3(config-if)# ip ospf authentication
R3(config-if)# ip ospf authentication-key cisco
```
Note: While configuring the authentication, the adjacency might go down if the dead timer expires on one of the routers. The relationship should be reestablished once authentication is configured on both sides.

b. Verify the authentication using the **show ip ospf interface** *interface* command. R2# **show ip ospf interface serial 0/0/1**

```
Serial0/0/1 is up, line protocol is up
  Internet Address 10.1.23.2/24, Area 23
  Process ID 1, Router ID 10.1.2.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
oob-resync timeout 40      Hello due in 00:00:09
  Supports Link-local Signaling (LLS)
  Index 1/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 4
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.3.1
  Suppress hello for 0 neighbor(s)
  Simple password authentication enabled
```

c. MD5 authentication encrypts the password for stronger security. Configure the link between R1 and R2 for MD5 authentication using the **ip ospf authentication message-digest** interface command. Then set the password to **cisco** with the **ip ospf message-digest-key** *key_number* **md5** *key-string* command. Make sure that the key number is the same on both routers. In this case, use 1 for simplicity.

```
R1(config)# interface serial 0/0/0
R1(config-if)# ip ospf authentication message-digest
R1(config-if)# ip ospf message-digest-key 1 md5 cisco

R2(config)# interface serial 0/0/0
R2(config-if)# ip ospf authentication message-digest
R2(config-if)# ip ospf message-digest-key 1 md5 cisco
```

Note: The MD5 key number works differently than key chains. The router uses the most recently added key for authenticating sent packets. The key number does not have a direct influence on this behavior, that is, if the interface was configured with the MD5 key number 10 and later the key with number 5 was added, the router would use the key number 5 to digitally sign outbound sent packets. If a router having several MD5 keys on an interface detects that at least one of its neighbors has not yet started using the most recently added key, it engages in a simple key migration procedure: it sends each OSPF packet multiple times, with each instance of the packet authenticated by a particular MD5 key configured on the interface, one instance for each key. This ensures a smooth, gradual migration.

d. Verify the configuration using the **show ip ospf interface** *interface* command. R1#

show ip ospf interface serial 0/0/0

```
Serial0/0/0 is up, line protocol is up
  Internet Address 10.1.12.1/24, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
oob-resync timeout 40      Hello due in 00:00:08
  Supports Link-local Signaling (LLS)
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 0, Adjacent neighbor count is 0
  Suppress hello for 0 neighbor(s)
  Message digest authentication enabled
                                        Youngest key id is 1
```

Why is configuring authentication for OSPF, or any routing protocol, a good idea?

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Configuring routing protocol authentication is beneficial because without it, you could have a rogue router on a subnet advertising false routes.

e. Use the following Tcl script to verify connectivity to all addresses in the topology.

```
R1# tclsh
R1(tcl)#
foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.12.1
10.1.12.2
10.1.23.2
10.1.23.3
172.20.200.1
} {
ping $address }
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations

Router R1

```
hostname R1
! interface Loopback1  description
Engineering Department  ip address
10.1.1.1 255.255.255.0  ip ospf network
point-to-point ! interface Serial0/0/0
ip address 10.1.12.1 255.255.255.0  ip
ospf authentication message-digest  ip
ospf message-digest-key 1 md5 cisco
clock rate 64000  no shutdown
!
router ospf 1  network 10.1.1.0
0.0.0.255 area 0  network 10.1.12.0
0.0.0.255 area 0
! end
```

Router R2

```
hostname R2
! interface Loopback2  description
Marketing Department  ip address
10.1.2.1 255.255.255.0  ip ospf network
point-to-point ! interface Serial0/0/0
ip address 10.1.12.2 255.255.255.0  ip
ospf authentication message-digest  ip
ospf message-digest-key 1 md5 cisco  no
shutdown
! interface Serial0/0/1  ip address
10.1.23.2 255.255.255.0  ip ospf
authentication  ip ospf
authentication-key cisco  clock
rate 64000  no shutdown
!
router ospf 1  area 23 nssa no-
summary  network 10.1.2.0 0.0.0.255
area 0  network 10.1.12.0 0.0.0.255
area 0  network 10.1.23.0 0.0.0.255
area 23
! end
```

Router R3

```
hostname R3 !
interface Loopback3  description
Accounting Department  ip address
10.1.3.1 255.255.255.0  ip ospf
network point-to-point ! interface
Loopback20  description Connection to
another AS  ip address 172.20.200.1
255.255.255.0
! interface Serial0/0/1  ip address
10.1.23.3 255.255.255.0  ip ospf
authentication  ip ospf
authentication-key cisco  no
shutdown
!
```

```
router ospf 1  area 23 nssa
redistribute connected subnets
network 10.1.3.0 0.0.0.255 area 23
network 10.1.23.0 0.0.0.255 area 23
! end
```

1-3, OSPF Virtual Links and Area Summarization

Topology
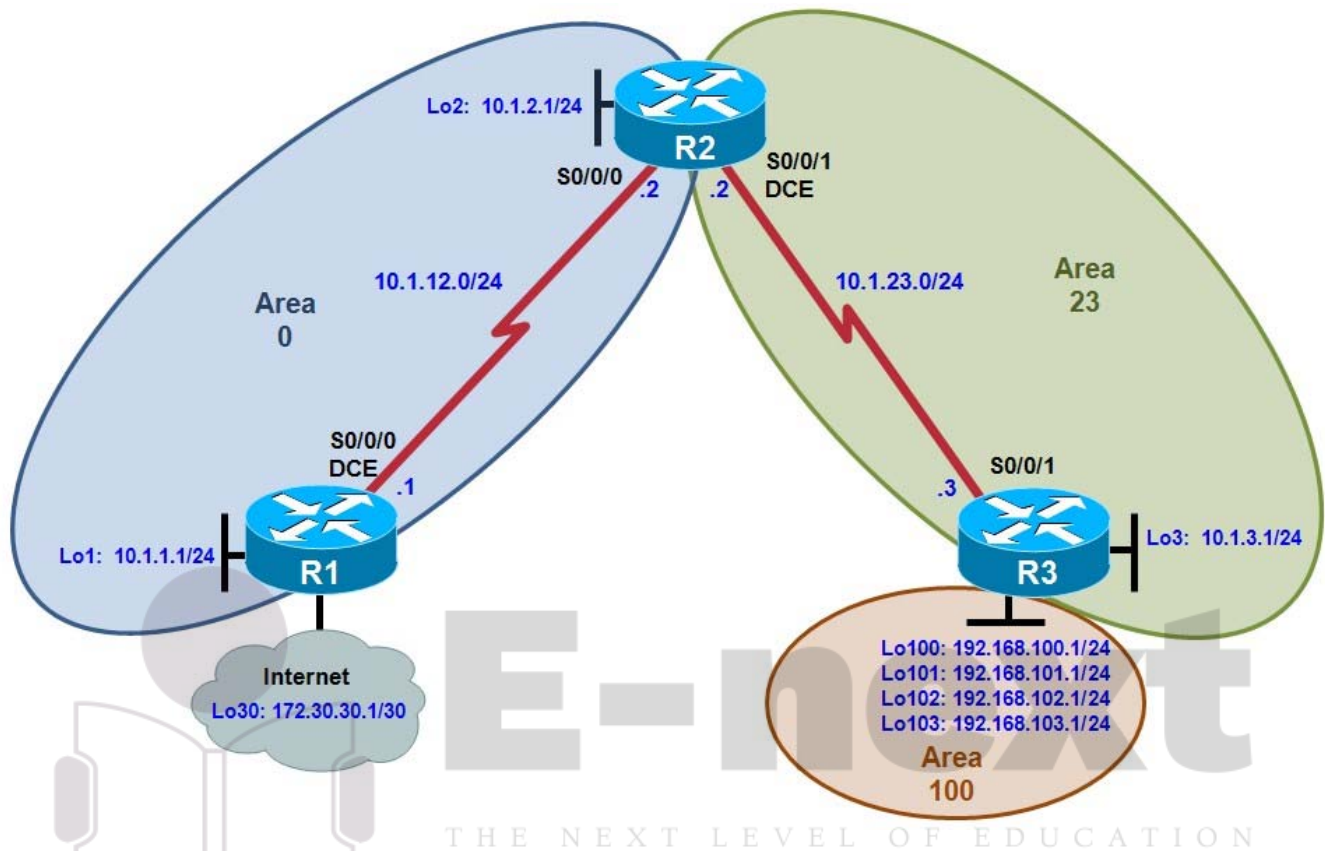
Objectives

- Configure multi-area OSPF on a router.
- Verify multi-area behavior.
- Create an OSPF virtual link.
- Summarize an area.
- Generate a default route into OSPF.

Background

You are responsible for configuring the new network to connect your company's engineering, marketing, and accounting departments, represented by loopback interfaces on each of the three routers. The physical devices have just been installed and connected by serial cables. Configure multiple-area OSPF to allow full connectivity between all departments.

In addition, R1 has a loopback interface representing a connection to the Internet. This connection will not be added into OSPF. R3 will have four additional loopback interfaces representing connections to branch offices.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Configure addressing and loopbacks.

Using the addressing scheme in the diagram, apply IP addresses to the serial interfaces on R1, R2, and R3. Create loopbacks on R1, R2, and R3, and address them according to the diagram.

```
R1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z. R1(config)#
interface loopback 1
R1(config-if)# description Engineering Department R1(config-
if)# ip address 10.1.1.1 255.255.255.0
R1(config-if)# interface loopback 30
R1(config-if)# ip address 172.30.30.1 255.255.255.252
R1(config-if)# interface serial 0/0/0
R1(config-if)# ip address 10.1.12.1 255.255.255.0
R1(config-if)# clockrate 64000 R1(config-if)#
no shutdown


R2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R2(config)# interface loopback 2
R2(config-if)# description Marketing Department
R2(config-if)# ip address 10.1.2.1 255.255.255.0 R2(config-
if)# interface serial 0/0/0
R2(config-if)# ip address 10.1.12.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# interface serial 0/0/1
R2(config-if)# ip address 10.1.23.2 255.255.255.0
R2(config-if)# clockrate 64000 R2(config-if)# no
shutdown


R3# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)# interface loopback 3
R3(config-if)# description Accounting Department
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# interface loopback 100
R3(config-if)# ip address 192.168.100.1 255.255.255.0
R3(config-if)# interface loopback 101
R3(config-if)# ip address 192.168.101.1 255.255.255.0
R3(config-if)# interface loopback 102
R3(config-if)# ip address 192.168.102.1 255.255.255.0
R3(config-if)# interface loopback 103
R3(config-if)# ip address 192.168.103.1 255.255.255.0
R3(config-if)# interface serial 0/0/1
R3(config-if)# ip address 10.1.23.3 255.255.255.0
R3(config-if)# no shutdown
```

Step 2: Add interfaces into OSPF.

a. Create OSPF process 1 on all three routers. Using the **network** command, configure the subnet of the serial link between R1 and R2 to be in OSPF area 0. Add loopback 1 on R1 and loopback 2 on R2 into OSPF area 0.

Note: The default behavior of OSPF for loopback interfaces is to advertise a 32-bit host route. To ensure that the full /24 network is advertised, use the **ip ospf network point-to-point** command. Change the network type on the loopback interfaces so that they are advertised with the correct subnet.

```
R1(config)# router ospf 1
R1(config-router)# network 10.1.12.0 0.0.0.255 area 0
R1(config-router)# network 10.1.1.0 0.0.0.255 area 0
R1(config-router)# exit
R1(config)# interface loopback 1
R1(config-if)# ip ospf network point-to-point

R2(config)# router ospf 1
R2(config-router)# network 10.1.12.0 0.0.0.255 area 0
R2(config-router)# network 10.1.2.0 0.0.0.255 area 0
R2(config-router)# exit
R2(config)# interface loopback 2
R2(config-if)# ip ospf network point-to-point
```

b. Verify that you can see OSPF neighbors in the **show ip ospf neighbors** output on both routers. Verify that the routers can see each other's loopback with the **show ip route** command.

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address        Interface
10.1.2.1          0   FULL/  -        00:00:38    10.1.12.2      Serial0/0/0

R1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2       E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.2.0 [110/65] via 10.1.12.2, 00:00:10, Serial0/0/0
C       10.1.1.0 is directly connected, Loopback1
172.30.0.0/30 is subnetted, 1 subnets
C       172.30.30.0 is directly connected, Loopback30

R2# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address        Interface
172.30.30.1       0   FULL/  -        00:00:35    10.1.12.1      Serial0/0/0

R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
```

```
            o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

      10.0.0.0/24 is subnetted, 4 subnets
C        10.1.12.0 is directly connected, Serial0/0/0
C        10.1.2.0 is directly connected, Loopback2
O        10.1.1.0 [110/65] via 10.1.12.1, 00:00:30, Serial0/0/0 C
10.1.23.0 is directly connected, Serial0/0/1
```

c. Add the subnet between R2 and R3 into OSPF area 23 using the **network** command. Add loopback 3 on R3 into area 23.

```
R2(config)# router ospf 1
R2(config-router)# network 10.1.23.0 0.0.0.255 area 23


R3(config)# router ospf 1
R3(config-router)# network 10.1.23.0 0.0.0.255 area 23
R3(config-router)# network 10.1.3.0 0.0.0.255 area 23
R3(config-router)# exit
R3(config)# interface loopback 3
R3(config-if)# ip ospf network point-to-point
```

d. Verify that this neighbor relationship comes up with the **show ip ospf neighbors** command. R2# **show ip ospf neighbor**

```
Neighbor ID      Pri    State          Dead Time    Address           Interface
172.30.30.1       0     FULL/   -       00:00:36     10.1.12.1          Serial0/0/0
192.168.103.1     0     FULL/   -       00:00:36     10.1.23.3          Serial0/0/1
```

e. Using a Tcl script, verify connectivity to all interfaces from any router, with the exception of loopback 30 on R1, and R3 loopbacks 100 through 103.

```
R1# tclsh
R1(tcl)#
foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.12.1
10.1.12.2
10.1.23.2
10.1.23.3
172.30.30.1
192.168.100.1
192.168.101.1
192.168.102.1
192.168.103.1
```

Step 3: Create a virtual link.

a. Add loopbacks 100 through 103 on R3 to the OSPF process in area 100 using the **network** command. Change the network type to advertise the correct subnet mask.

```
R3(config)# router ospf 1
R3(config-router)# network 192.168.100.0 0.0.3.255 area 100
R3(config-router)# exit
```

```
R3(config)# interface loopback 100
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 101
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 102
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 103
R3(config-if)# ip ospf network point-to-point
```

b. Look at the output of the **show ip route** command on R2. Notice that the routes to those networks do not appear. The reason for this behavior is that area 100 on R3 is not connected to the backbone. It is only connected to area 23. If an area is not connected to the backbone, its routes are not advertised outside of its area.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:01:00, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:03:10, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
```

What would happen if routes could pass between areas without going through the backbone?

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Routing loops might occur because any route could get advertised to different areas. By passing through the backbone, type 3 LSAs are generated by their respective areas and not sent back in.

You can get around this situation by creating a virtual link. A virtual link is an OSPF feature that creates a logical extension of the backbone area across a regular area, without actually adding any physical interfaces into area 0.

Note: Prior to creating a virtual link you need to identify the OSPF router ID for the routers involved (R2 and R3), using a command such as **show ip ospf**, **show ip protocols** or **show ip ospf interface**. The output for the **show ip ospf** command on R1 and R3 is shown below.

```
R2# show ip ospf
 Routing Process "ospf 1" with ID 10.1.2.1
<output omitted>


R3# show ip ospf
 Routing Process "ospf 1" with ID 192.168.103.1
<output omitted>
```

c. Create a virtual link using the **area** *transit_area* **virtual-link** *router-id* OSPF configuration command on both R2 and R3.

```
R2(config)# router ospf 1
R2(config-router)# area 23 virtual-link 192.168.103.1

R3(config)# router ospf 1
R3(config-router)# area 23 virtual-link 10.1.2.1
```

Note: To ensure that the router ID of the virtual link endpoints remains constant, you can statically configure the OSPF router ID of the virtual link endpoints using the **router-id** command.

d. After you see the adjacency over the virtual interface come up, issue the **show ip route** command on R2 and see the routes from area 100. You can verify the virtual link with the **show ip ospf neighbor** and **show ip ospf interface** commands.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2         E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:01:35, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:01:35, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
O IA 192.168.102.0/24 [110/65] via 10.1.23.3, 00:00:05, Serial0/0/1
O IA 192.168.103.0/24 [110/65] via 10.1.23.3, 00:00:05, Serial0/0/1
O IA 192.168.100.0/24 [110/65] via 10.1.23.3, 00:00:57, Serial0/0/1
O IA 192.168.101.0/24 [110/65] via 10.1.23.3, 00:00:16, Serial0/0/1

R2# show ip ospf neighbor
Neighbor ID     Pri   State          Dead Time   Address         Interface
192.168.103.1     0   FULL/  -          -        10.1.23.3       OSPF_VL0
172.30.30.1       0   FULL/  -       00:00:30    10.1.12.1       Serial0/0/0
192.168.103.1     0   FULL/  -       00:00:30    10.1.23.3       Serial0/0/1

R2# show ip ospf interface
OSPF_VL0 is up, line protocol is up
  Internet Address 10.1.23.2/24, Area 0
  Process ID 1, Router ID 10.1.2.1, Network Type VIRTUAL_LINK, Cost: 64
  Configured as demand circuit.
  Run as demand circuit.
  DoNotAge LSA allowed.
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
Hello due in 00:00:03
  Supports Link-local Signaling (LLS)
  Index 3/4, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
```

```
   Neighbor Count is 1, Adjacent neighbor count is 1
      Adjacent with neighbor 192.168.103.1  (Hello suppressed)
   Suppress hello for 1 neighbor(s) <output
omitted>
```

When are virtual links useful?

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Virtual links are useful when there needs to be a temporary extension of the backbone, either because the backbone became discontiguous or a new area got added onto an existing area.

Why are virtual links a poor long-term solution?

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Virtual links are a poor long-term solution because they add processing overhead and basically extend the backbone area onto routers where it might not belong. They can also add a lot of complexity to troubleshooting.

Step 4: Summarize an area.

Loopbacks 100 through 103 can be summarized into one supernet of 192.168.100.0 /22. You can configure area 100 to be represented by this single summary route.

a. Configure R3 (the ABR) to summarize this area using the **area** *area* **range** *network mask* command.

```
R3(config)# router ospf 1
R3(config-router)# area 100 range 192.168.100.0 255.255.252.0
```

b. You can see the summary route on R2 with the **show ip route** and **show ip ospf database** commands.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2         E1
- OSPF external type 1, E2 - OSPF external type 2
        i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
        ia - IS-IS inter area, * - candidate default, U - per-user static route
        o - ODR, P - periodic downloaded static route


Gateway of last resort is not set

      10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:07:25, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
O       10.1.1.0 [110/65] via 10.1.12.1, 00:07:25, Serial0/0/0
C       10.1.23.0 is directly connected, Serial0/0/1
O IA 192.168.100.0/22 [110/65] via 10.1.23.3, 00:00:01, Serial0/0/1


R2# show ip ospf database

                OSPF Router with ID (10.1.2.1) (Process ID 1)

                        Router Link States (Area 0)
```

```
Link ID          ADV Router       Age          Seq#         Checksum Link count
10.1.2.1         10.1.2.1         341          0x80000003 0x0028DD 4
172.30.30.1      172.30.30.1      1665         0x80000002 0x000E67 3
192.168.103.1    192.168.103.1    1    (DNA) 0x80000003 0x00A374 1


                 Summary Net Link States (Area 0)


Link ID          ADV Router       Age          Seq#         Checksum
10.1.3.0         10.1.2.1         1268         0x80000001 0x00EFEF
10.1.3.0         192.168.103.1    6    (DNA) 0x80000001 0x00FD5E
10.1.23.0        10.1.2.1         1311         0x80000001 0x0009C3
10.1.23.0        192.168.103.1    6    (DNA) 0x80000001 0x00996F
192.168.100.0    192.168.103.1    1    (DNA) 0x80000002 0x009A04


                 Router Link States (Area 23)


Link ID          ADV Router       Age          Seq#         Checksum Link count
10.1.2.1         10.1.2.1         341          0x80000003 0x00DD8B 2
192.168.103.1    192.168.103.1    342          0x80000003 0x002E57 3


                 Summary Net Link States (Area 23)


Link ID          ADV Router       Age          Seq#         Checksum
10.1.1.0         10.1.2.1         1321         0x80000001 0x0006DB
10.1.2.0         10.1.2.1         1321         0x80000001 0x0078A8
10.1.12.0        10.1.2.1         1321         0x80000001 0x008255
192.168.100.0    192.168.103.1    157          0x80000002 0x009A04
```

c. Notice on R3 that OSPF has generated a summary route pointing toward Null0.

```
R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/24 is subnetted, 5 subnets
O       10.1.12.0 [110/128] via 10.1.23.2, 00:01:18, Serial0/0/1 C
10.1.3.0 is directly connected, Loopback3
O       10.1.2.0 [110/65] via 10.1.23.2, 00:01:18, Serial0/0/1
O       10.1.1.0 [110/129] via 10.1.23.2, 00:01:18, Serial0/0/1
C       10.1.23.0 is directly connected, Serial0/0/1
C    192.168.102.0/24 is directly connected, Loopback102
C    192.168.103.0/24 is directly connected, Loopback103
C    192.168.100.0/24 is directly connected, Loopback100
C    192.168.101.0/24 is directly connected, Loopback101
O    192.168.100.0/22 is a summary, 00:01:19, Null0
```

This behavior is known as sending unknown traffic to the "bit bucket." This means that if the router advertising the summary route receives a packet destined for something covered by that summary but not in the routing table, it drops it.

What is the reasoning behind this behavior?

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The reason that summaries generate local routes to Null0 is that when a router creates a summary address, it should have routes to all the existent more-specific routes. If the router lacks a more-specific route for a prefix within the summary, it is assumed that the route does not exist, and packets destined for that prefix should be dropped. If the route did not exist, bandwidth could be wasted if this router has a less specific route (such as a default route) and forwards the packet to the route until it is dropped further down the line.

The discard route also solves another problem. Depending on the contents of the routing table, a routing loop can be formed between two routers, one receiving a summary route from the second one, while the second one uses the first one as its default gateway. If a packet for a nonexistent component of the summary route was received and there was no discard route installed in the second router, the packet would loop between the routers until its TTL was decremented to 0.

Step 5: Generate a default route into OSPF.

You can simulate loopback 30 on R1 to be a connection to the Internet. You do not need to advertise this specific network to the rest of the network. Instead, you can just have a default route for all unknown traffic to go to R1.

a. To have R1 generate a default route, use the OSPF configuration command **default-information originate always**. The **always** keyword is necessary for generating a default route in this scenario. Without this keyword, a default route is generated only into OSPF if one exists in the routing table.

```
R1(config)# router ospf 1
R1(config-router)# default-information originate always
```

b. Verify that the default route appears on R2 and R3 with the **show ip route** command.

```
R2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is 10.1.12.1 to network 0.0.0.0

     10.0.0.0/24 is subnetted, 5 subnets
C       10.1.12.0 is directly connected, Serial0/0/0
O       10.1.3.0 [110/65] via 10.1.23.3, 00:10:36, Serial0/0/1
C       10.1.2.0 is directly connected, Loopback2
```

```
O        10.1.1.0 [110/65] via 10.1.12.1, 00:00:19, Serial0/0/0 C
10.1.23.0 is directly connected, Serial0/0/1
O*E2 0.0.0.0/0 [110/1] via 10.1.12.1, 00:00:09, Serial0/0/0
O IA 192.168.100.0/22 [110/65] via 10.1.23.3, 00:00:19, Serial0/0/1


R3# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is 10.1.23.2 to network 0.0.0.0


     10.0.0.0/24 is subnetted, 5 subnets
O        10.1.12.0 [110/128] via 10.1.23.2, 00:00:35, Serial0/0/1 C
10.1.3.0 is directly connected, Loopback3
O        10.1.2.0 [110/65] via 10.1.23.2, 00:00:35, Serial0/0/1
O        10.1.1.0 [110/129] via 10.1.23.2, 00:00:35, Serial0/0/1 C
10.1.23.0 is directly connected, Serial0/0/1
C     192.168.102.0/24 is directly connected, Loopback102
C     192.168.103.0/24 is directly connected, Loopback103
C     192.168.100.0/24 is directly connected, Loopback100
C     192.168.101.0/24 is directly connected, Loopback101
O*E2 0.0.0.0/0 [110/1] via 10.1.23.2, 00:00:26, Serial0/0/1 O
192.168.100.0/22 is a summary, 00:03:28, Null0
```

c. You should be able to ping the interface connecting to the Internet from R2 or R3, despite never being advertised into OSPF.

```
R3# ping 172.30.30.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.30.30.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/30/32 ms
```

d. Use the following Tcl script to verify connectivity to all addresses in the topology.

```
R1# tclsh
R1(tcl)#
foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.12.1
10.1.12.2
10.1.23.2
10.1.23.3
172.30.30.1
192.168.100.1
192.168.101.1
192.168.102.1
192.168.103.1
} { ping
$address }
```

Challenge: Configure OSPF Authentication

Configure OSPF MD5 authentication on the link between R2 and R3, using key ID 1 and the password cisco. Record the commands used below.

_____

_____

_____

Enter the following configuration commands on R2 and R3: `interface serial0/0/1`

```
ip ospf authentication message-digest
ip ospf message-digest-key 1 md5 cisco
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations (Instructor version)

Router R1

```
hostname R1 ! interface Loopback1
description Engineering Department  ip
address 10.1.1.1 255.255.255.0  ip ospf
network point-to-point ! interface
Loopback30  ip address 172.30.30.1
255.255.255.252 ! interface Serial0/0/0
ip address 10.1.12.1 255.255.255.0
clock rate 64000  no shutdown !
router ospf 1  network 10.1.1.0
0.0.0.255 area 0  network 10.1.12.0
0.0.0.255 area 0  default-information
originate always ! end
```

Router R2

```
hostname R2 ! interface Loopback2
description Marketing Department
ip address 10.1.2.1 255.255.255.0
ip ospf network point-to-point !
interface Serial0/0/0  ip address
10.1.12.2 255.255.255.0  no
shutdown ! interface Serial0/0/1
ip address 10.1.23.2 255.255.255.0
clock rate 64000  no shutdown !
router ospf 1  area 23 virtual-link
192.168.103.1
 network 10.1.2.0 0.0.0.255 area 0
network 10.1.12.0 0.0.0.255 area 0
network 10.1.23.0 0.0.0.255 area 23
! end
```

Router R3

```
hostname R3 ! interface Loopback3
description Accounting Department  ip
address 10.1.3.1 255.255.255.0  ip ospf
network point-to-point ! interface
Loopback100  ip address 192.168.100.1
255.255.255.0  ip ospf network point-
to-point ! interface Loopback101  ip
address 192.168.101.1 255.255.255.0  ip
ospf network point-to-point !
interface Loopback102  ip address
192.168.102.1 255.255.255.0  ip ospf
network point-to-point ! interface
Loopback103  ip address 192.168.103.1
255.255.255.0  ip ospf network point-to-
point ! interface Serial0/0/1  ip address
10.1.23.3 255.255.255.0  no shutdown !
router ospf 1  area 23 virtual-link
10.1.2.1
 area 100 range 192.168.100.0 255.255.252.0
network 10.1.3.0 0.0.0.255 area 23  network
10.1.23.0 0.0.0.255 area 23  network
192.168.100.0 0.0.3.255 area 100 ! end
```

1-4, OSPF over Frame Relay

Topology
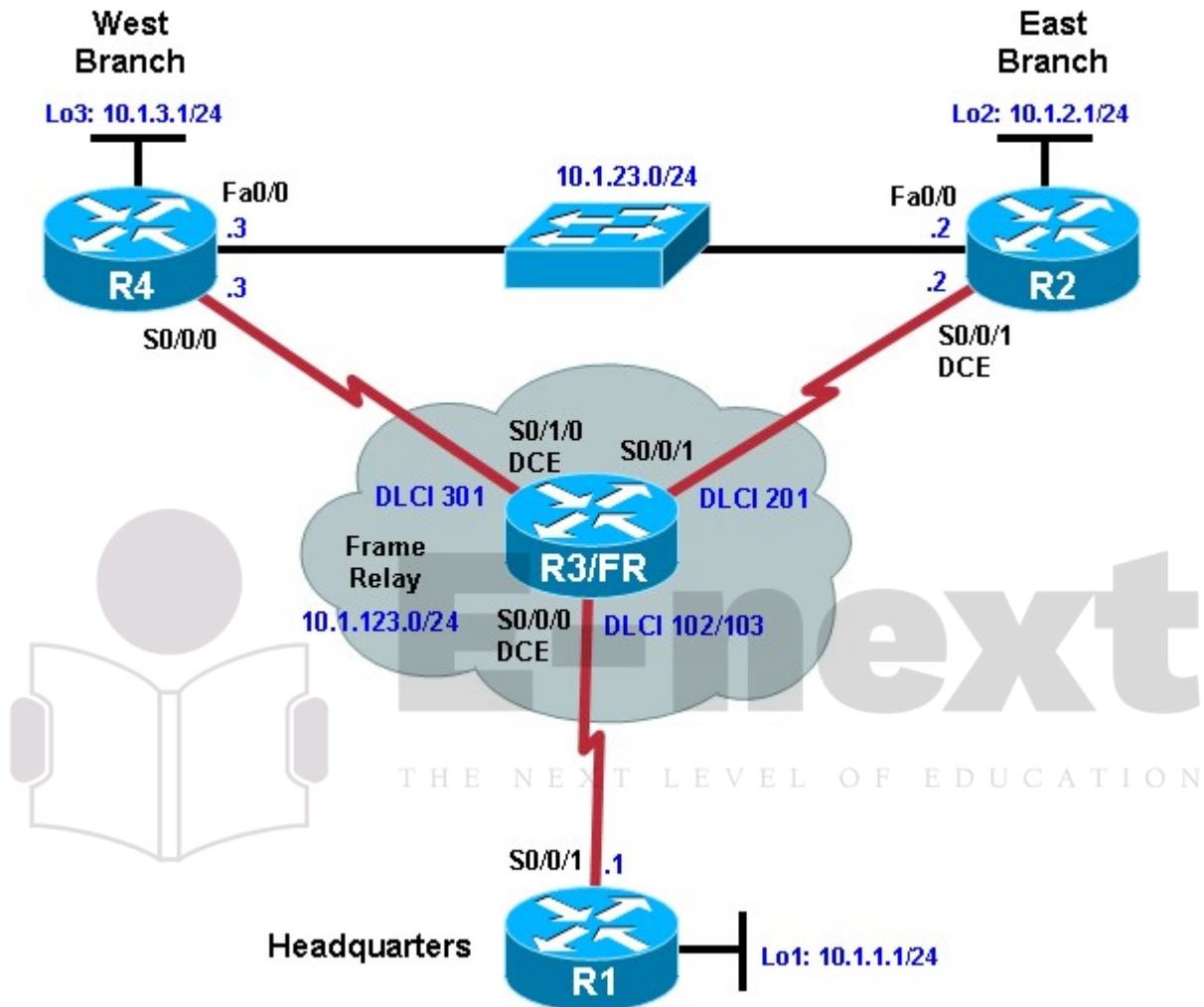
Objectives

- Configure OSPF over Frame Relay.
- Use non-broadcast and point-to-multipoint OSPF network types.
- Modify default OSPF timers.

Background

You are responsible for configuring the new network to connect your company's East branch and West branch through the company headquarters represented by loopback interfaces on each of the three routers. The physical devices have just been installed and connected over Frame Relay hub-and-spoke topology. Configure OSPF to allow full connectivity between all departments.

To simulate the Frame Relay WAN connections, use a router with three serial ports to act as a Frame Relay switch. The configuration of the router as a Frame Relay switch is described in Step 2. The Fast Ethernet connection between router EAST and router WEST represents a backup link from a service provider.

In real-world Frame Relay deployments, a modem or CSU/DSU normally provides the clocking functions (DCE) for each serial link. However, in this lab, R2 interface Serial0/0/1 is configured as the DCE for compatibility with other labs. If you are uncertain which side of the connection is the DCE, use the **show controllers serial** *interface-number* command:

```
FRS# show controllers serial0/0/0
Interface Serial0/0/0
Hardware is GT96K
DCE V.35, clock rate 64000
```

Note: In this lab, router R3 acts as the Frame Relay switch and requires two serial interface cards. If you are using an Adtran as a Frame Relay switch, see Appendix A for the Adtran configuration. When using the Adtran as the Frame Relay switch, the clock (DCE) is provided for each serial link.

Instructor note: You can also use Lab 3.4b from CCNP version 5 in the instructor lab manual, if available.
Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. The switch is a Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 4 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- 1 switch (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- Serial and Ethernet cables

Step 1: Configure Frame Relay and addressing on the HQ, EAST, and WEST routers.

a. Configure the router physical interfaces with IP addresses. On the interfaces connected to the Frame Relay switch, configure Frame Relay encapsulation with Inverse ARP disabled. Inverse ARP is disabled in this lab so that you have exclusive control over the IP/DLCI mappings. Use **frame relay map** statements to configure local Frame Relay maps so that you can ping the router's interface. Also set up the loopback interfaces. **Router R1 (Hostname HQ)**

```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.

Router(config)# hostname HQ
HQ(config)# interface loopback 1
HQ(config-if)# ip address 10.1.1.1 255.255.255.0 HQ(config-
if)# interface serial 0/0/1
HQ(config-if)# ip address 10.1.123.1 255.255.255.0
HQ(config-if)# encapsulation frame-relay ietf HQ(config-if)#
no frame-relay inverse-arp
HQ(config-if)# frame-relay map ip 10.1.123.1 102
HQ(config-if)# frame-relay map ip 10.1.123.2 102
HQ(config-if)# frame-relay map ip 10.1.123.3 103
HQ(config-if)#   no   shutdown
```

Router R2 (Hostname EAST)

```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
```

```
Router(config)# hostname EAST
EAST(config)# interface loopback 2
EAST(config-if)# ip address 10.1.2.1 255.255.255.0
EAST(config-if)# interface serial 0/0/1
EAST(config-if)# ip address 10.1.123.2 255.255.255.0
EAST(config-if)# clock rate 64000
EAST(config-if)# encapsulation frame-relay ietf EAST(config-
if)# no frame-relay inverse-arp
EAST(config-if)# frame-relay map ip 10.1.123.1 201
EAST(config-if)# frame-relay map ip 10.1.123.2 201
EAST(config-if)# frame-relay map ip 10.1.123.3 201
EAST(config-if)# no shutdown
EAST(config-if)# interface FastEthernet 0/0
EAST(config-if)# ip address 10.1.23.2 255.255.255.0
EAST(config-if)#  no  shutdown
```

Router R4 (Hostname WEST)

```
Router# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.


Router(config)# hostname WEST
WEST(config)# interface loopback 3
WEST(config-if)# ip address 10.1.3.1 255.255.255.0
WEST(config-if)# interface serial 0/0/0
WEST(config-if)# ip address 10.1.123.3 255.255.255.0
WEST(config-if)# encapsulation frame-relay ietf WEST(config-
if)# no frame-relay inverse-arp
WEST(config-if)# frame-relay map ip 10.1.123.1 301
WEST(config-if)# frame-relay map ip 10.1.123.2 301
WEST(config-if)# frame-relay map ip 10.1.123.3 301
WEST(config-if)# no shutdown
WEST(config-if)# interface FastEthernet 0/0
WEST(config-if)# ip address 10.1.23.3 255.255.255.0
WEST(config-if)# no shutdown
```

b. Verify that you have local subnet connectivity with **ping**.

Step 2: Configure the Frame Relay switch.

Use a fourth Cisco router with three serial interfaces as a Frame Relay switch, and cable the routers according to the diagram. Configure the Frame Relay switch to have the DLCIs indicated in the diagram between HQ and EAST and HQ and WEST.

```
Router  R3  (FRS) hostname
FRS   !   frame-relay
switching   interface
Serial0/0/0   no   ip
address
 encapsulation frame-relay ietf
no ip route-cache
 clock rate 64000  frame-
relay intf-type dce
 frame-relay route 102 interface Serial0/0/1 201
frame-relay route 103 interface Serial0/1/0 301
no shutdown
```

```
!  interface
Serial0/0/1  no ip
address
 encapsulation frame-relay ietf  frame-
relay intf-type dce
 frame-relay route 201 interface Serial0/0/0 102
no shutdown
! interface
Serial0/1/0  no ip
address
 encapsulation frame-relay ietf
no ip route-cache  frame-relay
intf-type dce  clock rate 64000
 frame-relay route 301 interface Serial0/0/0 103
no shutdown
```

Step 3: Configure OSPF network type NBMA.

Frame Relay is inherently a non-broadcast multi-access (NBMA) network. In this step, you configure OSPF for hub-and-spoke over Frame Relay using the NBMA OSPF network type, which is the default for Frame Relay physical interfaces and multipoint-type subinterfaces. HQ is the hub; EAST and WEST are the spokes.
a. Create OSPF process 1. Add the Frame Relay interfaces on each router into area 0 with the **network** command. Add the loopback interfaces on each router into area 0, and then change the network type to allow the correct subnet mask to be advertised.

```
HQ(config)# router ospf 1
HQ(config-router)# network 10.1.123.0 0.0.0.255 area 0
HQ(config-router)# network 10.1.1.0 0.0.0.255 area 0
HQ(config-router)# exit
HQ(config)# interface loopback 1
HQ(config-if)# ip ospf network point-to-point

EAST(config)# router ospf 1
EAST(config-router)# network 10.1.123.0 0.0.0.255 area 0
EAST(config-router)# network 10.1.2.0 0.0.0.255 area 0
EAST(config-router)# exit
EAST(config)# interface loopback 2
EAST(config-if)# ip ospf network point-to-point

WEST(config)# router ospf 1
WEST(config-router)# network 10.1.123.0 0.0.0.255 area 0
WEST(config-router)# network 10.1.3.0 0.0.0.255 area 0
WEST(config-router)# exit
WEST(config)# interface loopback 3
WEST(config-if)# ip ospf network point-to-point
```

b. On EAST and WEST, change the Frame Relay interfaces to have OSPF priority 0. This priority ensures that HQ becomes the DR.

```
EAST(config)# interface serial 0/0/1
EAST(config-if)# ip ospf priority 0

WEST(config)# interface serial 0/0/0 WEST(config-if)#
ip ospf priority 0
```

c. No OSPF Frame Relay adjacencies will be established yet because the default network type is nonbroadcast. You can change this by adding **neighbor** statements. Configure **neighbor** statements on

HQ pointing toward EAST and WEST. Only the router starting the exchange needs the statements (HQ in this case). However, it is considered best practice to also specify HQ as a neighbor on the EAST and WEST routers. Because the hello timers are longer on serial nonbroadcast links, the neighbor adjacencies might take longer to come up.

```
HQ(config)# router ospf 1
HQ(config-router)# neighbor 10.1.123.2
HQ(config-router)# neighbor 10.1.123.3

EAST(config)# router ospf 1
EAST(config-router)# neighbor 10.1.123.1

WEST(config)# router ospf 1
WEST(config-router)# neighbor 10.1.123.1
```

Note: Neighbor commands shown for the EAST and WEST routers will not appear in the running config. This is because the local router's OSPF priority has been set to 0 on the interface which would be used to communicate with the designated neighbor.

d. You can verify adjacency states with the **show ip ospf neighbor** command.

```
HQ# show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address       Interface
10.1.2.1          0   FULL/DROTHER   00:01:57    10.1.123.2    Serial0/0/1
10.1.3.1          0   FULL/DROTHER   00:01:57    10.1.123.3    Serial0/0/1
```

Step 4: Change the network type to point-to-multipoint.

Point-to-multipoint is an OSPF network type that lends itself well to a hub-and-spoke topology. Point-tomultipoint does not elect DRs or BDRs, so it does not need interface priorities. Instead, it treats the network as a collection of point-to-point networks and advertises host routes for any neighbors that it has.

a. To configure point-to-multipoint links, remove the previously configured **neighbor** statements and interface priorities..

```
HQ(config)# router ospf 1
HQ(config-router)# no neighbor 10.1.123.2
HQ(config-router)# no neighbor 10.1.123.3

EAST(config)# interface serial 0/0/1
EAST(config-if)# no ip ospf priority 0
EAST(config-if)# exit
EAST(config)# router ospf 1
EAST(config-router)# no neighbor 10.1.123.1

WEST(config)# interface serial 0/0/0
WEST(config-if)# no ip ospf priority 0
WEST(config-if)# exit
WEST(config)# router ospf 1
WEST(config-router)# no neighbor 10.1.123.1
```

b. Use the interface command **ip ospf network point-to-multipoint** and reapply the Frame Relay maps using the **broadcast** option. Reset the OSPF process using the **clear ip ospf process** command. Verify that the adjacencies are active with the **show ip ospf neighbor** command.

```
HQ(config)# interface serial 0/0/1
HQ(config-if)# ip ospf network point-to-multipoint
HQ(config-if)# frame-relay map ip 10.1.123.2 102 broadcast
HQ(config-if)# frame-relay map ip 10.1.123.3 103 broadcast


EAST(config)# interface serial 0/0/1
EAST(config-if)# ip ospf network point-to-multipoint
EAST(config-if)# frame-relay map ip 10.1.123.1 201 broadcast
EAST(config-if)# frame-relay map ip 10.1.123.3 201 broadcast


WEST(config)# interface serial 0/0/0
WEST(config-if)# ip ospf network point-to-multipoint
WEST(config-if)# frame-relay map ip 10.1.123.1 301 broadcast
WEST(config-if)# frame-relay map ip 10.1.123.2 301 broadcast


HQ# show ip ospf neighbor


Neighbor ID     Pri   State          Dead Time   Address       Interface
10.1.3.1          0   FULL/  -       00:01:34    10.1.123.3    Serial0/0/1
10.1.2.1          0   FULL/  -       00:01:45    10.1.123.2    Serial0/0/1
```

c. Observe the routing table on one of the spoke routers. Notice how the routing table has host routes in it. This is part of point-to-multipoint behavior.

```
EAST# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     10.0.0.0/8 is variably subnetted, 7 subnets, 2 masks
O       10.1.3.0/24 [110/129] via 10.1.123.1, 00:01:07, Serial0/0/1 C
10.1.2.0/24 is directly connected, Loopback2
O       10.1.1.0/24 [110/65] via 10.1.123.1, 00:01:07, Serial0/0/1
C       10.1.23.0/24 is directly connected, FastEthernet0/0
C       10.1.123.0/24 is directly connected, Serial0/0/1
O       10.1.123.1/32 [110/64] via 10.1.123.1, 00:01:07, Serial0/0/1
O       10.1.123.3/32 [110/128] via 10.1.123.1, 00:01:07, Serial0/0/1
```

d. Look at the output of the **show ip ospf interface** *interface* command on your routers. Notice that the interface type is point-to-multipoint.

```
EAST# show ip ospf interface serial 0/0/1
Serial0/0/1 is up, line protocol is up
  Internet Address 10.1.123.2/24, Area 0
  Process ID 1, Router ID 10.1.2.1, Network Type POINT_TO_MULTIPOINT, Cost:
64
  Transmit Delay is 1 sec, State POINT_TO_MULTIPOINT,
  Timer intervals configured, Hello 30, Dead 120, Wait 120, Retransmit 5
oob-resync timeout 120
    Hello due in 00:00:16
```

```
Supports Link-local Signaling (LLS)
Index 1/1, flood queue length 0
Next 0x0(0)/0x0(0)
Last flood scan length is 1, maximum is 1
Last flood scan time is 0 msec, maximum is 0 msec
Neighbor Count is 1, Adjacent neighbor count is 1
  Adjacent with neighbor 10.1.1.1
Suppress hello for 0 neighbor(s)
```

Step 5: Change OSPF timers.

a. Add the Ethernet link connecting EAST and WEST to the OSPF process using the **network** command.

```
EAST(config)# router ospf 1
EAST(config-router)# network 10.1.23.0 0.0.0.255 area 0

WEST(config)# router ospf 1
WEST(config-router)# network 10.1.23.0 0.0.0.255 area 0
```

b. Look at the interface OSPF properties with the **show ip ospf interface** *interface* command. EAST#

show ip ospf interface FastEthernet 0/0

```
FastEthernet0/0 is up, line protocol is up
Internet Address 10.1.23.2/24, Area 0
Process ID 1, Router ID 10.1.2.1, Network Type BROADCAST, Cost: 1
Transmit Delay is 1 sec, State BDR, Priority 1
Designated Router (ID) 10.1.3.1, Interface address 10.1.23.3
Backup Designated router (ID) 10.1.2.1, Interface address 10.1.23.2
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
  oob-resync timeout 40    Hello due in 00:00:00
Supports Link-local Signaling (LLS)
Index 3/3, flood queue length 0
Next 0x0(0)/0x0(0)
Last flood scan length is 1, maximum is 1
Last flood scan time is 0 msec, maximum is 0 msec
Neighbor Count is 1, Adjacent neighbor count is 1
  Adjacent with neighbor 10.1.3.1  (Designated Router)
Suppress hello for 0 neighbor(s)
```

Because it is a Fast Ethernet link, the default network type is broadcast and the default network timers are those associated with a broadcast network. You might want to change the default timers to allow for better network convergence. Neighbors that go down are detected more quickly with lower dead timers. The disadvantage of lower dead timers is higher router CPU utilization and more bandwidth being consumed by hello packets.

c. Use the **ip ospf hello-interval** *seconds* command to change the default hello timer interval to 5 seconds on both sides. Change the dead timer to 15 seconds with the **ip ospf dead-interval** *seconds* command.

```
EAST(config)# interface FastEthernet 0/0
EAST(config-if)# ip ospf hello-interval 5 EAST(config-if)#
ip ospf dead-interval 15

WEST(config)# interface FastEthernet 0/0
WEST(config-if)# ip ospf hello-interval 5
WEST(config-if)# ip ospf dead-interval 15
```

d. Verify the changes with the **show ip ospf interface** *interface* command.

```
EAST# show ip ospf int Fa0/0
  FastEthernet0/0 is up, line protocol is up
  Internet Address 10.1.23.2/24, Area 0
  Process ID 1, Router ID 10.1.2.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 10.1.3.1, Interface address 10.1.23.3
  Backup Designated router (ID) 10.1.2.1, Interface address 10.1.23.2
  Timer intervals configured, Hello 5, Dead 15, Wait 15, Retransmit 5
    oob-resync timeout 40      Hello due in 00:00:01
  Supports Link-local Signaling (LLS)
  Index 3/3, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.3.1  (Designated Router)
Suppress hello for 0 neighbor(s)
```

What are some disadvantages to changing the timers if they are not tuned correctly?

_____

_____

_____

_____

_____

_____

_____

If timers are not tuned correctly, there are many negative side effects. Hello packets can saturate a slower link or overload a slower router. Route instability and route flapping can occur from bad timers having an adjacency come up and down. If timers are tuned to take too long, reconvergence of a network after topology changes can be slower.

e. Use the following Tcl script to verify connectivity to all addresses in the topology.

```
HQ# tclsh
HQ(tcl)#
foreach address {
10.1.1.1
10.1.2.1
10.1.3.1
10.1.123.1
10.1.123.2
10.1.123.3
10.1.23.2
10.1.23.3 } {
ping $address }
```

Challenge: Minimal Hello Intervals

Configure the Fast Ethernet link between EAST and WEST to lower the convergence time using the **ip ospf dead-interval minimal hello-multiplier** *multiplie*r command. This command sets the dead interval to 1 second. Hellos will be sent at the rate of *multiplier* per second.

Note: The use of this command overrides hello and dead intervals configured on EAST and WEST Fa0/0 in Step 5.

a. Configure the routers to send five hellos a second.

_____

_____

```
EAST(config)#                                                      interface
                                                                   fastEthernet
           0/0
EAST(config-if)# ip ospf dead-interval minimal hello-multiplier 5
 interface fastEthernet 0/0
WEST(config)#

WEST(config-if)# ip ospf dead-interval minimal hello-multiplier 5
```

Note: Although you could use this command on the serial links, it would create additional OSPF overhead on these relatively slow (64 Kb/s) links and could result in flapping adjacencies if a link begins to experience congestion. Using this command with high-speed serial links would be less of an issue.

b. Look at the dead time column of the **show ip ospf neighbor** command. Is it a different format than before for that connection?

_____

Now the dead timer is displayed in milliseconds, not seconds.

```
EAST# show ip ospf neighbor
Neighbor ID     Pri   State        Dead Time   Address         Interface
10.1.1.1          0   FULL/  -     00:01:52    10.1.123.1      Serial0/0/1

10.1.3.1          1   FULL/DR      928 msec    10.1.23.3       FastEthernet0/0
```

c. Display the OSPF information for Fa0/0 on EAST or WEST using the **show ip ospf interface fastEthernet 0/0** command. What are the Hello and Dead intervals now?

_____

The Hello interval is 200 msec (1/5 of a second) and the Dead interval is 1 second.

```
EAST# show ip ospf interface fastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
  Internet Address 10.1.23.2/24, Area 0
  Process ID 1, Router ID 10.1.2.1, Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 10.1.3.1, Interface address 10.1.23.3
  Backup Designated router (ID) 10.1.2.1, Interface address 10.1.23.2
Timer intervals configured, Hello 200 msec, Dead 1, Wait 1, Retransmit 5
    oob-resync timeout 40      Hello due in 147 msec
  Supports Link-local Signaling (LLS)
Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 4 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.3.1  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Appendix A: Adtran Frame Relay Switch Configuration

If an Adtran Atlas 550 is used for the Frame Relay switch, connect the serial cable from each router interface in the topology diagram to the Adtran interface indicated in the table below. The Adtran is preconfigured to simulate a Frame Relay service that provides the following PVCs.

Frame Relay Switching Configuration

Connected Router	Router Interface	Adtran Interface	Ingress DLCI	Egress DLCI	Egress Router
HQ	S0/0/1 DTE	port 1/1	102	201	EAST
HQ	S0/0/1 DTE	port 1/1	103	301	WEST
EAST	S0/0/1 DTE	port 1/2	201	102	HQ
WEST	S0/0/0 DTE	port 2/1	301	103	HQ

The Adtran Frame Relay switch interfaces all provide the DCE clock. Be sure to use the appropriate cable between each router and the Adtran. All the router interfaces are DTE, and the cable to the Adtran interface should be serial to V.35 DCE. Use the **show controllers** command to verify which cable type is connected to a given router interface.

```
HQ# show controllers s0/0/1
Interface Serial0/0/1
Hardware is GT96K
DTE V.35 TX and RX clocks detected.

<output omitted>
```

Device Configurations (Instructor version)

Router HQ (R1)

```
hostname HQ
! interface Loopback1  ip address 10.1.1.1
255.255.255.0  ip ospf network point-to-
```

```
point ! interface Serial0/0/1  ip address
10.1.123.1 255.255.255.0  encapsulation
frame-relay ietf  ip ospf network point-to-
multipoint  frame-relay map ip 10.1.123.1
102  frame-relay map ip 10.1.123.2 102
broadcast  frame-relay map ip 10.1.123.3
103 broadcast  no frame-relay inverse-arp
no shutdown
! router ospf
1
 network 10.1.1.0 0.0.0.255 area 0
network 10.1.123.0 0.0.0.255 area 0
! end
```

Router EAST (R2)

```
hostname EAST
! interface Loopback2  ip address 10.1.2.1
255.255.255.0  ip ospf network point-to-point  !
interface FastEthernet0/0  ip address 10.1.23.2
255.255.255.0  ip ospf dead-interval minimal
hello-multiplier 5  no shutdown
!
interface Serial0/0/1  ip address 10.1.123.2
255.255.255.0  encapsulation frame-relay
ietf  clock rate 64000  ip ospf network
point-to-multipoint  frame-relay map ip
10.1.123.1 201 broadcast  frame-relay map
ip 10.1.123.2 201  frame-relay map ip
10.1.123.3 201 broadcast  no frame-relay
inverse-arp  no shutdown
!
router ospf 1
 network 10.1.2.0 0.0.0.255 area 0
network 10.1.23.0 0.0.0.255 area 0
network 10.1.123.0 0.0.0.255 area 0
! end
```

Router WEST (R4)

```
hostname WEST
! interface Loopback3  ip address 10.1.3.1
255.255.255.0  ip ospf network point-to-point !
interface FastEthernet0/0  ip address 10.1.23.3
255.255.255.0  ip ospf dead-interval minimal
hello-multiplier 5  no shutdown
! interface Serial0/0/0  ip address
10.1.123.3 255.255.255.0  encapsulation
frame-relay ietf  ip ospf network point-to-
multipoint  frame-relay map ip 10.1.123.1
301 broadcast  frame-relay map ip
10.1.123.2 301 broadcast  frame-relay map
ip 10.1.123.3 301  no frame-relay inverse-
arp  no shutdown
! router ospf
1
```

```
 network 10.1.3.0 0.0.0.255 area 0
network 10.1.23.0 0.0.0.255 area 0
network 10.1.123.0 0.0.0.255 area 0
! end
```

Router FRS (R3)

```
hostname FRS !
frame-relay switching
!
interface Serial0/0/0  no ip
address  encapsulation frame-
relay ietf  no ip route-cache
clock rate 64000  frame-relay
intf-type dce
 frame-relay route 102 interface Serial0/0/1 201
frame-relay route 103 interface Serial0/1/0 301
no shutdown
!
interface Serial0/0/1  no ip
address  encapsulation frame-
relay ietf  frame-relay intf-
type dce
 frame-relay route 201 interface Serial0/0/0 102
no shutdown
! interface
Serial0/1/0  no ip
address
encapsulation frame-
relay ietf  no ip
route-cache  frame-
relay intf-type dce
clock rate 64000
 frame-relay route 301 interface Serial0/0/0 103
no shutdown
!
end
```

2-1, Redistribution Between RIP and OSPF
Topology
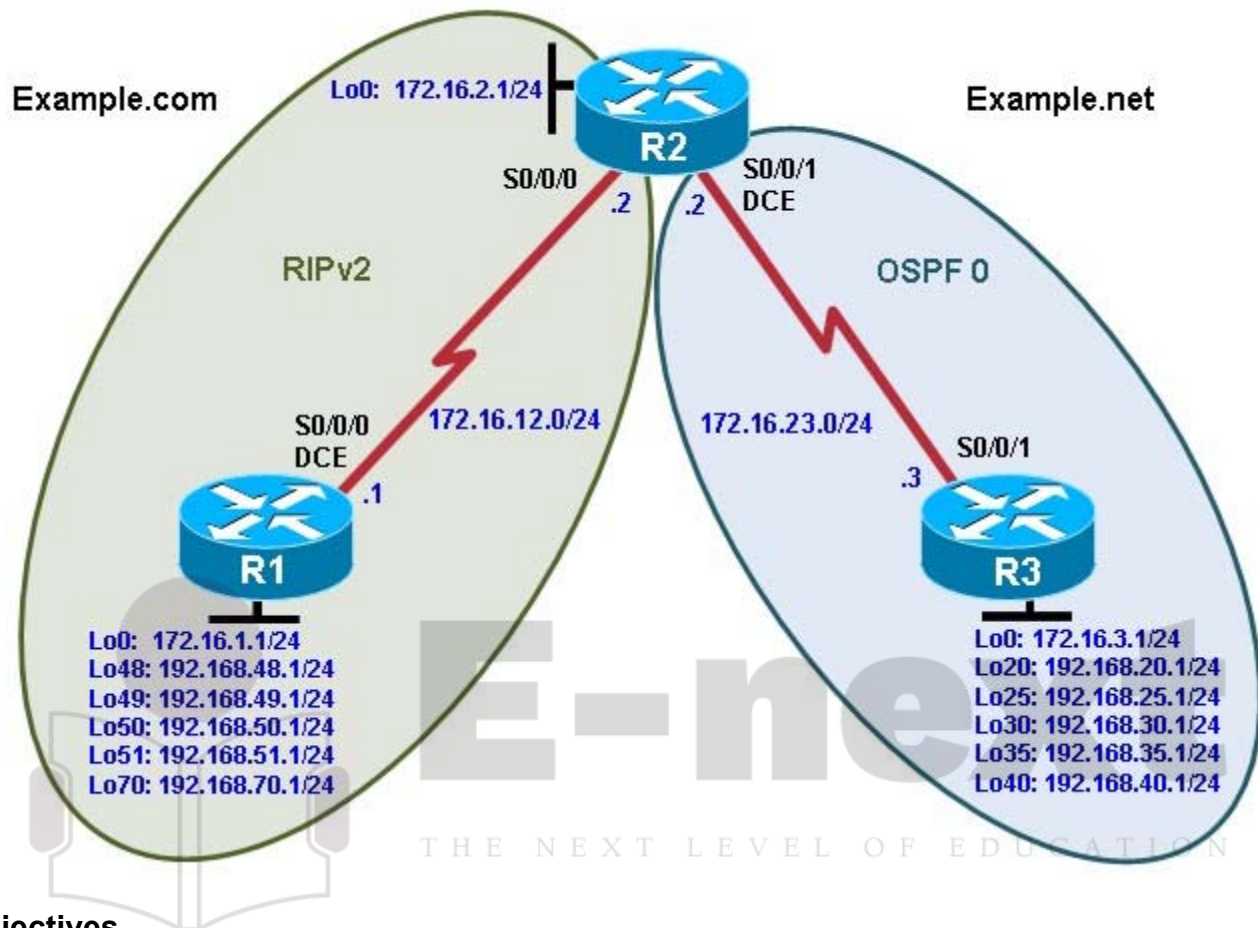
Objectives

- Review configuration and verification of RIP and OSPF.
- Configure passive interfaces in both RIP and OSPF.
- Filter routing updates using distribute lists.
- Redistribute static routes into RIP.
- Redistribute RIP routes into OSPF.
- Redistribute OSPF routes into RIP.
- Originate a default route into OSPF.
- Set a default seed metric.
- Modify OSPF external network types.
- Configure summary addresses.

Background

Two online booksellers, Example.com and Example.net, have merged and now need a short-term solution to inter-domain routing. Since these companies provide client services to Internet users, it is essential to have minimal downtime during the transition.

Example.com is a small firm running RIP, while Example.net has a somewhat larger network running OSPF. The diagram identifies R2 as the router that will bridge the two networks. Because it is imperative that the two booksellers continuously deliver Internet services, you should bridge these two routing domains without interfering with each router's path through its own routing domain to the Internet.

The CIO determines that it is preferable to keep the two protocol domains shown in the diagram during the transition period, because the network engineers on each side need to understand the other's network before deploying a long-term solution. Redistribution will be a short-term solution.

In this scenario, R1 and R2 are running RIPv2, but the 172.16.23.0/24 network between R2 and R3 is running OSPF. You need to configure R2 to enable these two routing protocols to interact to allow full connectivity between all networks.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Configure loopbacks and assign addresses.

a. Configure all loopback interfaces on the three routers in the diagram. Configure the serial interfaces with the IP addresses, bring them up, and set a DCE clock rate where appropriate.

```
R1(config)# interface Loopback0
R1(config-if)# ip address 172.16.1.1 255.255.255.0
R1(config-if)# interface Loopback48
R1(config-if)# ip address 192.168.48.1 255.255.255.0
R1(config-if)# interface Loopback49
R1(config-if)# ip address 192.168.49.1 255.255.255.0
R1(config-if)# interface Loopback50
R1(config-if)# ip address 192.168.50.1 255.255.255.0
R1(config-if)# interface Loopback51
R1(config-if)# ip address 192.168.51.1 255.255.255.0
R1(config-if)# interface Loopback70
R1(config-if)# ip address 192.168.70.1 255.255.255.0
R1(config-if)# interface Serial0/0/0
R1(config-if)# ip address 172.16.12.1 255.255.255.0
R1(config-if)# clock rate 64000 R1(config-
if)# bandwidth 64 R1(config-if)# no
shutdown

R2(config)# interface Loopback0
R2(config-if)# ip address 172.16.2.1 255.255.255.0
R2(config-if)# interface Serial0/0/0
R2(config-if)# ip address 172.16.12.2 255.255.255.0
R2(config-if)# bandwidth 64
R2(config-if)# no shutdown
R2(config-if)# interface Serial0/0/1
R2(config-if)# ip address 172.16.23.2 255.255.255.0
R2(config-if)# clock rate 64000 R2(config-
if)# bandwidth 64 R2(config-if)# no
shutdown

R3(config)# interface Loopback0
R3(config-if)# ip address 172.16.3.1 255.255.255.0 R3(config-
if)# interface Loopback20
```

```
R3(config-if)# ip address 192.168.20.1 255.255.255.0
R3(config-if)# interface Loopback25
R3(config-if)# ip address 192.168.25.1 255.255.255.0
R3(config-if)# interface Loopback30
R3(config-if)# ip address 192.168.30.1 255.255.255.0
R3(config-if)# interface Loopback35
R3(config-if)# ip address 192.168.35.1 255.255.255.0
R3(config-if)# interface Loopback40
R3(config-if)# ip address 192.168.40.1 255.255.255.0
R3(config-if)# interface Serial0/0/1
R3(config-if)# ip address 172.16.23.3 255.255.255.0
R3(config-if)# bandwidth 64 R3(config-if)# no
shutdown
```

b. (Optional) On each router, create an enable secret password. Configure the console line for synchronous logging and no timeout. Configure the vty lines to allow Telnet to and remote configuration of network devices. R1 example:

```
R1(config)# enable secret cisco

R1(config)# line con 0
R1(config-line)# logging synchronous
R1(config-line)# exec-timeout 0 0

R1(config)# line vty 0 4
R1(config-line)# password cisco R1(config-line)#
login
```

c. Verify that you can ping across the serial links when you are finished. Use the following Tcl script to check full and partial connectivity throughout this lab.

```
R1# tclsh

foreach address { 172.16.1 ........................Error! Bookmark not defined.
192.168.48 ...............................................................4
192.168.49 ...............................................................4
192.168.50 ...............................................................4
192.168.51 ...............................................................4
192.168.70 ...............................................................4
172.16.12 ...............................................................15
172.16.2 ................................................................15
172.16.12 ...............................................................6
172.16.23 ................................................................7


172.16.3.1
192.168.20.1
192.168.25.1
192.168.30.1
192.168.35.1
192.168.40.1
172.16.23.3
} { ping $address }
```

At this point, the only pings that you should receive back are those of the connected networks of the router from which you are pinging.

Step 2: Configure RIPv2.

Configuring RIPv2 on a router is fairly simple:

- Type the global configuration command **router rip** to enter RIP configuration mode.
- Enable RIPv2 with the **version 2** command.
- Enter the **no auto-summary** command to disable automatic summarization at classful network boundaries.
- Add the networks you want using the **network** *network* command.

Unlike EIGRP and OSPF, the RIP **network** command only requires the classful network address to be entered and does not support a wildcard mask. This behavior is inherited from the classful RIPv1 protocol configuration and is kept for backward compatibility with older Cisco IOS versions that would not otherwise be able to process **network** commands with wildcard masks. Classful protocols do not support subnets; therefore, subnet or wildcard masks are unnecessary.

Based on the topology diagram, which major networks need to be advertised into RIP for R1?

_____

_____

_____

_____

_____

_____

172.16.0.0/16

192.168.48.0/24

192.168.49.0/24

192.168.50.0/24

192.168.51.0/24

192.168.70.0/24

Which major networks need to be advertised into RIP for R2?

_____

_____

Only 172.16.0.0/16

a. Apply the following commands to R1 and R2.

```
R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# no auto-summary
R1(config-router)# network 172.16.0.0
R1(config-router)# network 192.168.48.0
R1(config-router)# network 192.168.49.0 R1(config-router)#
network 192.168.50.0 R1(config-router)# network
192.168.51.0
R1(config-router)# network 192.168.70.0

R2(config)# router rip
R2(config-router)# version 2
R2(config-router)# no auto-summary
R2(config-router)# network 172.16.0.0
```

b. Verify that the RIP routes were learned from the other routers using the **show ip route rip** command on each router.

```
R1# show ip route rip
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.23.0 [120/1] via 172.16.12.2, 00:00:03, Serial0/0/0
R       172.16.2.0 [120/1] via 172.16.12.2, 00:00:03, Serial0/0/0


R2# show ip route rip
     172.16.0.0/24 is subnetted, 4 subnets
R        172.16.1.0 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.51.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.50.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.49.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.70.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.48.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
```

c. You can also verify which routes are coming in from RIP advertisements with the **show ip rip database** command.

```
R1# show ip rip database
172.16.0.0/16    auto-summary
172.16.1.0/24    directly connected, Loopback0
172.16.2.0/24
                                          [1] via 172.16.12.2, 00:00:06,
                                          Serial0/0/0
172.16.12.0/24    directly connected, Serial0/0/0
172.16.23.0/24
                                          [1] via
                                          172.16.12.2,
00:00:06, Serial0/0/0 192.168.48.0/24    auto-summary
192.168.48.0/24    directly connected, Loopback48
192.168.49.0/24    auto-summary
192.168.49.0/24    directly connected, Loopback49
192.168.50.0/24    auto-summary
192.168.50.0/24    directly connected, Loopback50
192.168.51.0/24    auto-summary
192.168.51.0/24    directly connected, Loopback51
192.168.70.0/24    auto-summary
192.168.70.0/24    directly connected, Loopback70


R2# show ip rip database
172.16.0.0/16    auto-summary
172.16.1.0/24
                                          [1] via 172.16.12.1, 00:00:10,
                                          Serial0/0/0
172.16.2.0/24    directly connected, Loopback0
172.16.12.0/24    directly connected, Serial0/0/0
172.16.23.0/24    directly connected, Serial0/0/1 192.168.48.0/24
auto-summary
192.168.48.0/24
                                          [1] via
                                          172.16.12.1,
00:00:10, Serial0/0/0 192.168.49.0/24    auto-summary
192.168.49.0/24
                                          [1] via
                                          172.16.12.1,
00:00:10, Serial0/0/0 192.168.50.0/24    auto-summary
```

```
192.168.50.0/24
                                                [1] via
                                                172.16.12.1,
00:00:10, Serial0/0/0 192.168.51.0/24    auto-summary
192.168.51.0/24
                                                [1] via
                                                172.16.12.1,
00:00:10, Serial0/0/0 192.168.70.0/24    auto-summary
192.168.70.0/24

        [1] via 172.16.12.1, 00:00:10, Serial0/0/0
```

Step 3: Configure passive interfaces in RIP.

a. On R1, use the **show ip route rip** command to view the RIP routes in the routing table. Notice that the network for the serial interface of R2 that connects to R3 is present, even though you do not have a RIP neighbor on that interface. This is because the entire class B network 172.16.0.0 /16 was added to RIP on R2.

```
R1# show ip route rip
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.23.0 [120/1] via 172.16.12.2, 00:00:03, Serial0/0/0
R       172.16.2.0 [120/1] via 172.16.12.2, 00:00:03, Serial0/0/0
```

b. Issue the **show ip protocols** command to verify that RIPv2 updates are being sent out both serial interfaces.

```
R2# show ip protocols
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 13 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface              Send  Recv  Triggered RIP  Key-chain
    Serial0/0/0            2     2
                                                            Serial0/0/1
                                                            2     2
    Loopback0             2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
                   172.16.0.0
                   Routing Information Sources:
    Gateway          Distance      Last Update
    172.16.12.1        120         00:00:26
  Distance: (default is 120)
```

For security reasons and to reduce unnecessary traffic, RIP updates should not be propagated into the OSPF domain. You can disable sending updates with the **passive-interface** interface_type interface_number router configuration command

c. On R2, configure the serial interface connecting to R3 as passive. Notice that the interface is no longer listed in the output of the **show ip protocols** command.

```
R2(config)# router rip
R2(config-router)# passive-interface serial 0/0/1


R2# show ip protocols
```

```
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 23 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface            Send  Recv  Triggered RIP  Key-chain
    Serial0/0/0          2     2
    Loopback0            2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
  Passive Interface(s):
    Serial0/0/1
  Routing Information Sources:
    Gateway          Distance      Last Update
    172.16.12.1         120        00:00:17
Distance: (default is 120)
```

d. On R1, issue the **show ip route rip** command. Notice that the 172.16.23.0 network is still in the routing table and being sourced from RIP.

```
R1# show ip route rip
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.23.0 [120/1] via 172.16.12.2, 00:00:19, Serial0/0/0
R       172.16.2.0 [120/1] via 172.16.12.2, 00:00:19, Serial0/0/0
```

Making an interface in RIP passive only disables updates from being sent through RIP. It does not affect routes being received through it.

What are some reasons to prevent RIP from sending updates out a particular interface?

_____

_____

_____

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RIPv2 does not use an adjacency system. Therefore, RIPv2 floods all of its routing updates out of its interfaces rather than developing adjacencies with short hello packets like EIGRP and OSPF. Because RIPv2 could flood packets out interfaces where there are no RIPv2 receivers, it is a best practice to prevent RIP packets from being sent out these interfaces.

Putting a RIPv2 interface in passive mode saves the router from sending multicast RIP packets out an interface that has no neighbors.

Does RIPv2 send advertisements out loopback interfaces?

_____

_____

_____

_____

By default, loopback interfaces act like normal interfaces in RIPv2 when sending and receiving packets. However, a router will never have RIPv2 neighbors out its loopback interface, so loopback interfaces can always be configured as passive interfaces, thereby saving CPU resources.

e. If you are unsure, monitor the output of the **debug ip rip** command to verify your answer. On R1 and R2, configure all loopbacks from which RIPv2 is sending advertisements in passive state with the **passiveinterface** command.

```
R1(config)# router rip
R1(config-router)# passive-interface loopback 0
R1(config-router)# passive-interface loopback 48
R1(config-router)# passive-interface loopback 49
R1(config-router)# passive-interface loopback 50
R1(config-router)# passive-interface loopback 51
R1(config-router)# passive-interface loopback 70

R2(config)# router rip
R2(config-router)# passive-interface loopback 0
```

When running RIPv2, implement passive interfaces as a common practice to save CPU processor cycles and bandwidth on interfaces that do not have multicast RIPv2 neighbors.

Note: An alternative to making each loopback interface on R1 passive is to make all interfaces passive with the **passive-interface default** command in router configuration mode. Then make any interfaces that need to send updates, such as S0/0/0, nonpassive.

```
R1(config)# router rip
R1(config-router)# passive-interface default
R1(config-router)# no passive-interface Serial0/0/0
```

Step 4: Summarize a supernet with RIP.

a. On R2, issue the **show ip route rip** command. Notice that you can see all prefixes from R1 in the R2 routing table.

```
R2# show ip route rip
     172.16.0.0/24 is subnetted, 4 subnets
R       172.16.1.0 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.51.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.50.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.49.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.70.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
R     192.168.48.0/24 [120/1] via 172.16.12.1, 00:00:29, Serial0/0/0
```

In preparing for redistribution, you want to redistribute the minimum number of destination prefixes into each of the routing protocols. Which RIP routes should you summarize because they are contiguous and which mask should you use?

_____

_____

Summarize 192.168.48.0/24 through 192.168.51.0/24. Use a 22-bit mask to create the supernet.

Under normal circumstances, you could simply summarize the four consecutive class-C networks with the **ip summary address rip** command on the R1 serial 0/0/0 interface. However, the RIP implementation in the Cisco IOS Software does not allow summarizing to a mask length that is less than the classful

network prefix (in this case, 24 bits). This limitation does not affect other routing protocols. If you do try, you receive the following error message:

```
R1(config)# interface serial 0/0/0
R1(config-if)# ip summary-address rip 192.168.48.0 255.255.252.0
Summary mask must be greater or equal to major net
```

Recall from the EIGRP labs that summary routes display in the summarizing device's routing table as having the next hop being the Null0 interface. You can create an entry manually using the **ip route** command and redistribute it into RIP, thereby emulating the approach of EIGRP to a certain extent.

b. To get around the **ip summary-address rip** message error, create a static route on R1 to summarize the networks of loopbacks 48 through 51. Then redistribute the route on R1.

```
R1(config)# ip route 192.168.48.0 255.255.252.0 null0
R1(config)# router rip
R1(config-router)# redistribute static
```

This solution might seem unusual, but for RIPv2, it resembles many effects of summarization as performed in other routing protocols like EIGRP or OSPF. Again, this is not a limitation of RIPv2, but rather a Cisco IOS implementation issue.

c. On R1 and R2, verify that the RIP supernet has been added to the routing table with the **show ip route** command.

```
R1# show ip route
<output omitted>

Gateway of last resort is not set

      172.16.0.0/24 is subnetted, 4 subnets
R       172.16.23.0 [120/1] via 172.16.12.2, 00:00:27, Serial0/0/0
C       172.16.12.0 is directly connected, Serial0/0/0
C       172.16.1.0 is directly connected, Loopback0
R       172.16.2.0 [120/1] via 172.16.12.2, 00:00:27, Serial0/0/0
C    192.168.51.0/24 is directly connected, Loopback51
C    192.168.50.0/24 is directly connected, Loopback50
C    192.168.49.0/24 is directly connected, Loopback49
C    192.168.70.0/24 is directly connected, Loopback70
C    192.168.48.0/24 is directly connected, Loopback48
S    192.168.48.0/22 is directly connected, Null0

R2# show ip route
<output omitted>

Gateway of last resort is not set

      172.16.0.0/24 is subnetted, 4 subnets
C       172.16.23.0 is directly connected, Serial0/0/1
C       172.16.12.0 is directly connected, Serial0/0/0
R       172.16.1.0 [120/1] via 172.16.12.1, 00:00:05, Serial0/0/0 C
172.16.2.0 is directly connected, Loopback0
R    192.168.51.0/24 [120/1] via 172.16.12.1, 00:00:05, Serial0/0/0
R    192.168.50.0/24 [120/1] via 172.16.12.1, 00:00:05, Serial0/0/0
R    192.168.49.0/24 [120/1] via 172.16.12.1, 00:00:05, Serial0/0/0
R    192.168.70.0/24 [120/1] via 172.16.12.1, 00:00:07, Serial0/0/0
R    192.168.48.0/24 [120/1] via 172.16.12.1, 00:00:07, Serial0/0/0
R    192.168.48.0/22 [120/1] via 172.16.12.1, 00:00:07, Serial0/0/0
```

Will this route to Null0 affect routing to prefixes with longer addresses on R1? Explain.

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The routing table first matches based on longest IP prefix. If any of the summarized networks are routable on R1, as in this situation, R1 uses the connected route with the longer mask to reach those networks. If one of those interfaces were to be shut down, R1 would send traffic for that network to its Null0 virtual interface.

Step 5: Suppress routes using prefix lists.

Sometimes you might not want to advertise certain networks out a particular interface, or you might want to filter updates as they come in. This is possible with distance-vector routing protocols, such as RIP or EIGRP. However, link-state protocols are less flexible, because every router in an area is required to have a synchronized database as a condition for full adjacency.

Distribute lists can be used with either access lists or prefix lists to filter routes by network address. With prefix lists, they can also be configured to filter routes by subnet masks.

In this scenario, you want to filter updates from R1 to R2, allowing only the networks of Loopback 0 and Loopback 70 and the summary route to be advertised. You want to suppress the more specific prefixes so that routing tables are kept small, and CPU processor cycles on the routers are not wasted.

The 22-bit summary and the 24-bit major network address both have the same address, so access lists will not accomplish the filtering correctly. Therefore, it is necessary to use prefix lists. To create a prefix list or add a prefix list entry, use the **ip prefix-list** command in global configuration mode. `ip prefix-list {list-name | list-number} {deny network/length | permit network/length} [ge ge-length] [le le-length]`

The **ge** keyword represents the "greater than or equal to" operator. The **le** keyword represents the "less than or equal to" operator. If both the **ge** and **le** keywords are omitted, the prefix list is processed using an exact match.

a. On R1, use a prefix list as a distribution filter to prevent the more specific routes to loopbacks 48 through 51 from being advertised. Allow all other destination networks, including the summary route.

```
R1(config)# ip prefix-list RIP-OUT permit 192.168.48.0/22
R1(config)# ip prefix-list RIP-OUT deny 192.168.48.0/22 le 24
R1(config)# ip prefix-list RIP-OUT permit 0.0.0.0/0 le 32
```

Line 1 of the prefix list permits the summary route and nothing else, because no other route can match that network address with a mask of exactly 22 bits.

Line 2 denies all prefixes with a network address in the 192.168.48.0/22 block of addresses that have subnet masks from 22 bits to 24 bits. This removes exactly four network addresses matching the 22, 23, and 24 bits in length of the subnet mask. Line 2 would deny the 192.168.48.0/22 summary route you created if Line 1 did not explicitly permit the summary route.

Line 3 allows all IPv4 prefixes that are not explicitly denied in previous statements of the prefix list.

b. From the RIP configuration prompt on R1, apply this access list with the **distribute-list** command.

```
R1(config)# router rip
```

```
R1(config-router)# distribute-list prefix RIP-OUT out serial0/0/0
```

c. On R2, verify that the filtering has taken place using the **show ip route rip** and **show ip rip database** commands.

```
R2# show ip route rip
      172.16.0.0/24 is subnetted, 4 subnets
R        172.16.1.0 [120/1] via 172.16.12.1, 00:00:12, Serial0/0/0
R     192.168.70.0/24 [120/1] via 172.16.12.1, 00:00:12, Serial0/0/0
R     192.168.48.0/22 [120/1] via 172.16.12.1, 00:00:12, Serial0/0/0
```

Note: You might need to issue the **clear ip route *** command on R2 to see the removal of the more specific R1 prefixes. Also, if the network 192.168.48.0/22 does not appear on R2, this is incorrect behavior and might be corrected in recent versions of Cisco IOS Software. A workaround is to remove the **network 192.168.48.0** command from RIP and issue the **clear ip route *** command on R1.

```
R2# show ip rip database
172.16.0.0/16     auto-summary
172.16.1.0/24
    [1] via 172.16.12.1, 00:00:11, Serial0/0/0
172.16.2.0/24     directly connected, Loopback0
172.16.12.0/24    directly connected, Serial0/0/0
172.16.23.0/24    directly connected, Serial0/0/1
192.168.48.0/22
    [1] via 172.16.12.1, 00:00:11, Serial0/0/0
192.168.70.0/24    auto-summary
192.168.70.0/24
    [1] via 172.16.12.1, 00:00:11, Serial0/0/0
```

Why would you want to filter updates being sent out or coming in?

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The intention is to summarize addresses at R1, achieving benefits such as smaller routing tables and the prevention of route flapping disturbing network stability. By redistributing the static route into RIPv2, only the summary route was added, but the more specific routes were not filtered. To achieve these benefits, filter the outgoing routes to R2 by allowing all routes except the 24-bit routes.

Step 6: Configure OSPF.

a. Configure single-area OSPF between R2 and R3. On R2, include just the serial link connecting to R3. On R3, include the serial link and all loopback interfaces.

```
R2(config)# router ospf 1
R2(config-router)# network 172.16.23.0 0.0.0.255 area 0

R3(config)# router ospf 1
R3(config-router)# network 172.16.0.0 0.0.255.255 area 0
R3(config-router)# network 192.168.0.0 0.0.255.255 area 0
15:01:37.047: %OSPF-5-ADJCHG: Process 1, Nbr 172.16.2.1 on Serial0/0/1 from
LOADING to FULL, Loading Done
```

b. On R3, change the network type for the loopback interfaces to point-to-point so that they are advertised with the correct subnet mask (/24 instead of /32).

```
R3(config)# interface Loopback0
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface Loopback20
R3(config-if)# ip ospf network point-to-point R3(config-if)#
interface Loopback25
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface Loopback30
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface Loopback35
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface Loopback40
R3(config-if)# ip ospf network point-to-point
```

c. Verify the OSPF adjacencies on R2 and R3 with the **show ip ospf neighbors** command. Also make sure that you have routes from OSPF populating the routing tables with the **show ip route ospf** command. R2# **show ip ospf neighbor**

```
Neighbor ID     Pri   State          Dead Time   Address         Interface
192.168.40.1      0   FULL/  -       00:00:37    172.16.23.3     Serial0/0/1


R3# show ip ospf neighbor

Neighbor ID     Pri   State          Dead Time   Address         Interface
172.16.2.1        0   FULL/  -       00:00:39    172.16.23.2     Serial0/0/1

R2# show ip route ospf
O     192.168.30.0/24 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1
O     192.168.25.0/24 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1
O     192.168.40.0/24 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1
      172.16.0.0/24 is subnetted, 5 subnets
O        172.16.3.0 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1
O     192.168.20.0/24 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1
O     192.168.35.0/24 [110/1563] via 172.16.23.3, 00:01:23, Serial0/0/1


R3# show ip route ospf

R3#
```

Note that output of the **show ip route ospf** command on R3 is blank.

The **network 192.168.0.0 0.0.255.255 area 0** command allows OSPF to involve interfaces that have IP addresses in that range.

A common misconception is that OSPF advertises the entire range of the network given in the router's **network** statement; it does not. However, it does advertise any connected subnets in that range of addresses to adjacent routers. You can verify this by viewing the output of the **show ip route** command on R2. Do you see a 192.168.0.0/16 supernet?

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No, because the **network** command selects interfaces by IP address. It does not set the exact prefix to be advertised.

R2 is the only router with all routes in the topology (except for those that were filtered out), because it is involved with both routing protocols.

Step 7: Configure passive interfaces in OSPF.

Passive interfaces save CPU cycles, router memory, and link bandwidth by preventing broadcast and multicast routing updates on interfaces that have no neighbors. In link-state protocols, adjacencies must be formed before routers exchange routing information. The **passive-interface** command in OSPF configuration mode prevents an interface from sending or processing OSPF packets on that interface. OSPF included the R3 loopback interfaces in its **network** statements shown in Step 6.

a. On R3, configure Loopback0 as a passive interface in OSPF. At the OSPF router configuration prompt, use the **passive-interface** *interface_type interface_number* command. `R3(config-router)# passive-interface loopback 0`

How is this different from the RIP version of this command?

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Passive interfaces in RIPv2 prevent *outgoing* routing information via multicast.

Because OSPF must create an adjacency before sending routing updates, the OSPF version of the **passive-interface** command prevents sending or processing OSPF packets and, therefore, prevents adjacencies.

b. Cisco IOS Software provides a quick way of selecting interfaces for passive mode. Use the **passiveinterface default** command to make all interfaces passive. Then use the **no passive-interface** *interface interface_number* command to bring the Serial0/0/1 interface out of passive mode.

```
R3(config)# router ospf 1
R3(config-router)# passive-interface default
R3(config-router)#
*Oct 15 01:49:44.174: %OSPF-5-ADJCHG: Process 1, Nbr 172.16.2.1 on
Serial0/0/1 from FULL to DOWN, Neighbor Down: Interface down or detached
R3(config-router)# no passive-interface serial 0/0/1
R3(config-router)#
*Oct 15 01:49:55.438: %OSPF-5-ADJCHG: Process 1, Nbr 172.16.2.1 on Serial0/0/1
from LOADING to FULL, Loading Done
```

c. You can verify the application of this command by issuing the **show ip protocols** command. R3#

```
show ip protocols

Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
```

```
   Incoming update filter list for all interfaces is not set
   Router ID 192.168.40.1
   Number of areas in this router is 1. 1 normal 0 stub 0 nssa
   Maximum path: 4
   Routing for Networks:
     172.16.0.0 0.0.255.255 area 0
     192.168.0.0 0.0.255.255 area 0
Reference bandwidth unit is 100 mbps
   Passive Interface(s):
     FastEthernet0/0
     FastEthernet0/1
Serial0/0/0
     Serial0/1/0
     Serial0/1/1
Loopback0
     Loopback20
     Loopback25
     Loopback30
     Loopback35
     Loopback40
  Routing Information Sources:
    Gateway          Distance        Last Update
    172.16.2.1          110          00:03:04
Distance: (default is 110)
```

Step 8: Allow one-way redistribution.

a. On R2, configure OSPF to redistribute into RIP under the RIP configuration prompt
    with the **redistribute ospf** *process* **metric** *metric* command, where *process* is the
    OSPF process number, and *metric* is the default metric with which you want to
    originate the routes into RIP. If you do not specify a default metric in RIP, it gives
    routes an infinite metric and they are not advertised.

```
R2(config)# router rip
R2(config-router)# redistribute ospf 1 metric 4
```

b. Verify the redistribution with the **show ip protocols** command. R2# **show ip**

    protocols

```
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 24 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip, ospf 1
  Default version control: send version 2, receive version 2
    Interface            Send  Recv  Triggered RIP  Key-chain
    Serial0/0/0           2     2
  Automatic network summarization is not in effect
Maximum path: 4
  Routing for Networks:
    172.16.0.0
  Passive Interface(s):
    Serial0/0/1
    Loopback0
  Routing Information Sources:
    Gateway          Distance        Last Update
    172.16.12.1         120          00:00:19
```

```
      Distance: (default is 120)

   <output omitted>
```

c. On R1, look at the routing table with the **show ip route rip** command. It has all the routes in the topology.

```
R1# show ip route rip
R        192.168.30.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0 R
192.168.25.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0 R
192.168.40.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0
      172.16.0.0/24 is subnetted, 5 subnets
R        172.16.23.0 [120/1] via 172.16.12.2, 00:00:11, Serial0/0/0
R        172.16.2.0 [120/1] via 172.16.12.2, 00:00:11, Serial0/0/0
R        172.16.3.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0
R        192.168.20.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0
R        192.168.35.0 [120/4] via 172.16.12.2, 00:00:11, Serial0/0/0
```

d. On R1, ping a loopback on R3. Notice that it shows that R1 has a route to R3, but R3 does not have a route back to R1.

```
R1# ping 192.168.30.1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.30.1, timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
```

e. On R1, verify that R3 does not have a route back with the **traceroute** command.

```
R1# traceroute 192.168.30.1

Type escape sequence to abort.
Tracing the route to 192.168.30.1

1  172.16.12.2 12 msec 12 msec 16 msec
2  *   *   *
3  *   *   *
4  *   *   *
<output omitted>
```

To address this problem, you can originate a default route into OSPF that points toward R2 so that the pings are routed back toward R2. R2 uses its information from RIPv2 to send pings back to R1.

f. From the OSPF configuration prompt, issue the **default-information originate always** command to force R2 to advertise a default route in OSPF.

```
R2(config)# router ospf 1
R2(config-router)# default-information originate always
```

g. Verify that this route is present in the R3 routing table.

```
R3# show ip route ospf
O*E2 0.0.0.0/0 [110/1] via 172.16.23.2, 00:05:13, Serial0/0/1
```

You should now have full connectivity between all networks in the diagram.

h. Use the Tcl script from Step 1 to verify full connectivity.

Step 9: Redistribute between two routing protocols.

You can substitute this default route with actual, more specific routes.

a. On R2, under the OSPF router configuration prompt, remove the default route advertisement with the **no default-information originate always** command. Next, use the **redistribute rip** command. You do not need to specify a default metric in OSPF. Notice the warning.

```
R2(config)# router ospf 1
R2(config-router)# no default-information originate always
R2(config-router)# redistribute rip
% Only classful networks will be redistributed
```

b. If you display the routing table on R3, the external OSPF routes that were added are the 192.168.70.0/24 and 192.168.48.0/22 networks.

```
R3# show ip route ospf
O E2 192.168.70.0/24 [110/20] via 172.16.23.2, 00:00:51, Serial0/0/1
O E2 192.168.48.0/22 [110/20] via 172.16.23.2, 00:00:51, Serial0/0/1
```

This is because, by default, OSPF only accepts classful networks and supernets when redistributing into it. The only classful network coming into R2 from RIP is the class C network 192.168.70.0, and the only supernet is the 192.168.48.0/22.

c. You can modify this behavior by adding the **subnets** keyword to the **redistribute** command.

```
R2(config)# router ospf 1
R2(config-router)# redistribute rip subnets
```

d. On R3, verify the configuration with the **show ip route ospf** command.

```
R3# show ip route ospf
     172.16.0.0/24 is subnetted, 5 subnets
O E2    172.16.12.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2    172.16.1.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2    172.16.2.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2 192.168.70.0/24 [110/20] via 172.16.23.2, 00:04:19, Serial0/0/1
O E2 192.168.48.0/22 [110/20] via 172.16.23.2, 00:04:19, Serial0/0/1
```

You should again have full connectivity between all networks in the diagram.

e. Run the Tcl script on each router to verify full connectivity.

Step 10: Set a default seed metric.

Under any routing protocol, you can specify a default seed metric to be used for redistribution instead of, or in addition to, setting metrics on a per-protocol basis. A seed metric is a protocol-independent feature of the Cisco IOS Software that is usually configured when redistributing into distance-vector protocols. Notice that the metric listed in the R3 routing table is 20.

```
R3# show ip route ospf
     172.16.0.0/24 is subnetted, 5 subnets
O E2    172.16.12.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2    172.16.1.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2    172.16.2.0 [110/20] via 172.16.23.2, 00:00:01, Serial0/0/1
O E2 192.168.70.0/24 [110/20] via 172.16.23.2, 00:04:19, Serial0/0/1
O E2 192.168.48.0/22 [110/20] via 172.16.23.2, 00:04:19, Serial0/0/1
```

You can override the global creation of a default seed metric on a per-protocol basis by using the *metric* argument in a redistribution command. You can also use the **metric** command under other routing protocols. a. On R2, in OSPF configuration mode, issue the **default-metric** *metric* command to configure a default metric for redistributed routes. The default metric for all OSPF redistributed routes is 20, except for BGP, which is 1. Setting the metric for RIP to a higher number makes it less preferable to routes redistributed from other routing protocols.

```
R2(config)# router ospf 1
R2(config-router)# default-metric 10000
```

b. Verify the new metric in the R3 routing table. It might take some time for the new metric to propagate.

```
R3# show ip route ospf
     172.16.0.0/24 is subnetted, 5 subnets
O E2    172.16.12.0 [110/10000] via 172.16.23.2, 00:02:56, Serial0/0/1
O E2    172.16.1.0 [110/10000] via 172.16.23.2, 00:02:56, Serial0/0/1
O E2    172.16.2.0 [110/10000] via 172.16.23.2, 00:02:56, Serial0/0/1
O E2 192.168.70.0/24 [110/10000] via 172.16.23.2, 00:02:56, Serial0/0/1
O E2 192.168.48.0/22 [110/10000] via 172.16.23.2, 00:02:56, Serial0/0/1
```

Step 11: Change the OSPF external network type.

Look at the R3 routing table. Notice that the external (redistributed) routes have O E2 as their type. In the output, O means OSPF, and E2 means external, type 2. OSPF has two external metric types, and E2 is the default. External type 1 metrics increase like a usual route, whereas external type 2 metrics do not increase as they get advertised through the OSPF domain. Also notice that the metric is exactly the same as the seed metric in the previous step.

Where would an external type 1 metric be useful?

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If there are multiple paths through an OSPF domain to an external destination network, use E1 routes so that OSPF will evaluate the shortest cost path. Especially use this option if multiple ASBRs are advertising the same destination network to prevent suboptimal routing.

Where would an external type 2 metric be useful?

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If there is only one ASBR advertising an external route, use E2 routes. In this scenario, use the E1 type even though only one ASBR is advertising the external routes.

a. You can change the external type using the **metric-type** argument with the **redistribute** command. Change the type to E1 for RIP redistributed routes.

```
R2(config)# router ospf 1
R2(config-router)# redistribute rip subnets metric-type 1
```

b. Display the R3 routing table again.

```
R3# show ip route ospf
     172.16.0.0/24 is subnetted, 5 subnets
O E1    172.16.12.0 [110/11562] via 172.16.23.2, 00:03:05, Serial0/0/1
O E1    172.16.1.0 [110/11562] via 172.16.23.2, 00:03:05, Serial0/0/1
O E1    172.16.2.0 [110/11562] via 172.16.23.2, 00:03:05, Serial0/0/1
O E1 192.168.70.0/24 [110/11562] via 172.16.23.2, 00:03:05, Serial0/0/1
O E1 192.168.48.0/22 [110/11562] via 172.16.23.2, 00:03:05, Serial0/0/1
```

Which attributes of the routes changed?

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The external route type has been changed from E2 to E1. The metric, previously 10000, has been

incremented to represent the path through the OSPF network to the ASBR.

Note: Be sure to save your final configurations through Step 11 for use in Lab 4-2, "Redistribution Between EIGRP and OSPF.

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations (Instructor version)

Router R1

```
hostname R1 ! interface Loopback0
ip address 172.16.1.1 255.255.255.0
! interface Loopback48
 ip address 192.168.48.1 255.255.255.0
! interface Loopback49
 ip address 192.168.49.1 255.255.255.0
! interface Loopback50
 ip address 192.168.50.1 255.255.255.0
! interface Loopback51
 ip address 192.168.51.1 255.255.255.0
! interface Loopback70
 ip address 192.168.70.1 255.255.255.0
! interface Serial0/0/0  ip address
172.16.12.1 255.255.255.0  clock rate
64000  bandwidth 64  no shutdown !
router rip  version 2  redistribute
static  passive-interface Loopback0
passive-interface Loopback48  passive-
interface Loopback49  passive-
interface Loopback50  passive-
interface Loopback51  passive-
interface Loopback70  network
172.16.0.0  network 192.168.48.0
network 192.168.49.0  network
192.168.50.0  network 192.168.51.0
network 192.168.70.0
 distribute-list prefix RIP-OUT out Serial0/0/0
no auto-summary !
ip route 192.168.48.0 255.255.252.0 Null0 !
ip prefix-list RIP-OUT seq 5 permit 192.168.48.0/22 ip
prefix-list RIP-OUT seq 10 deny 192.168.48.0/22 le 24 ip
prefix-list RIP-OUT seq 15 permit 0.0.0.0/0 le 32 ! end
```

Router R2

```
hostname R2 ! interface Loopback0  ip
address 172.16.2.1 255.255.255.0 !
interface Serial0/0/0  ip address
172.16.12.2 255.255.255.0  bandwidth
64  no shutdown ! interface
Serial0/0/1  ip address 172.16.23.2
255.255.255.0  clock rate 64000
bandwidth 64  no shutdown !
router ospf 1
 redistribute rip metric-type 1 subnets
network 172.16.23.0 0.0.0.255 area 0
default-metric 10000 !
router rip  version 2

 redistribute ospf 1 metric 4
passive-interface Serial0/0/1
passive-interface Loopback0
network 172.16.0.0  no auto-
summary ! end
```

Router R3

```
hostname R3 !
interface Loopback0  ip address
172.16.3.1 255.255.255.0  ip ospf
network point-to-point
!
interface Loopback20  ip address
192.168.20.1 255.255.255.0  ip ospf
network point-to-point !
interface Loopback25  ip address
192.168.25.1 255.255.255.0  ip ospf
network point-to-point !
interface Loopback30  ip address
192.168.30.1 255.255.255.0   ip ospf
network point-to-point !
interface Loopback35  ip address
192.168.35.1 255.255.255.0  ip ospf
network point-to-point !
interface Loopback40  ip address
192.168.40.1 255.255.255.0  ip ospf
network point-to-point ! interface
Serial0/0/1  ip address 172.16.23.3
255.255.255.0  bandwidth 64  no
shutdown !
router ospf 1  passive-interface
default  no passive-interface
Serial0/0/1  network 172.16.0.0
0.0.255.255 area 0  network 192.168.0.0
0.0.255.255 area 0 ! end
```
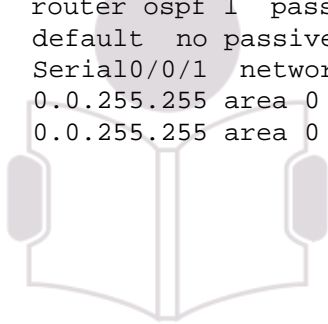
2-2, Manipulating Administrative Distances
Topology
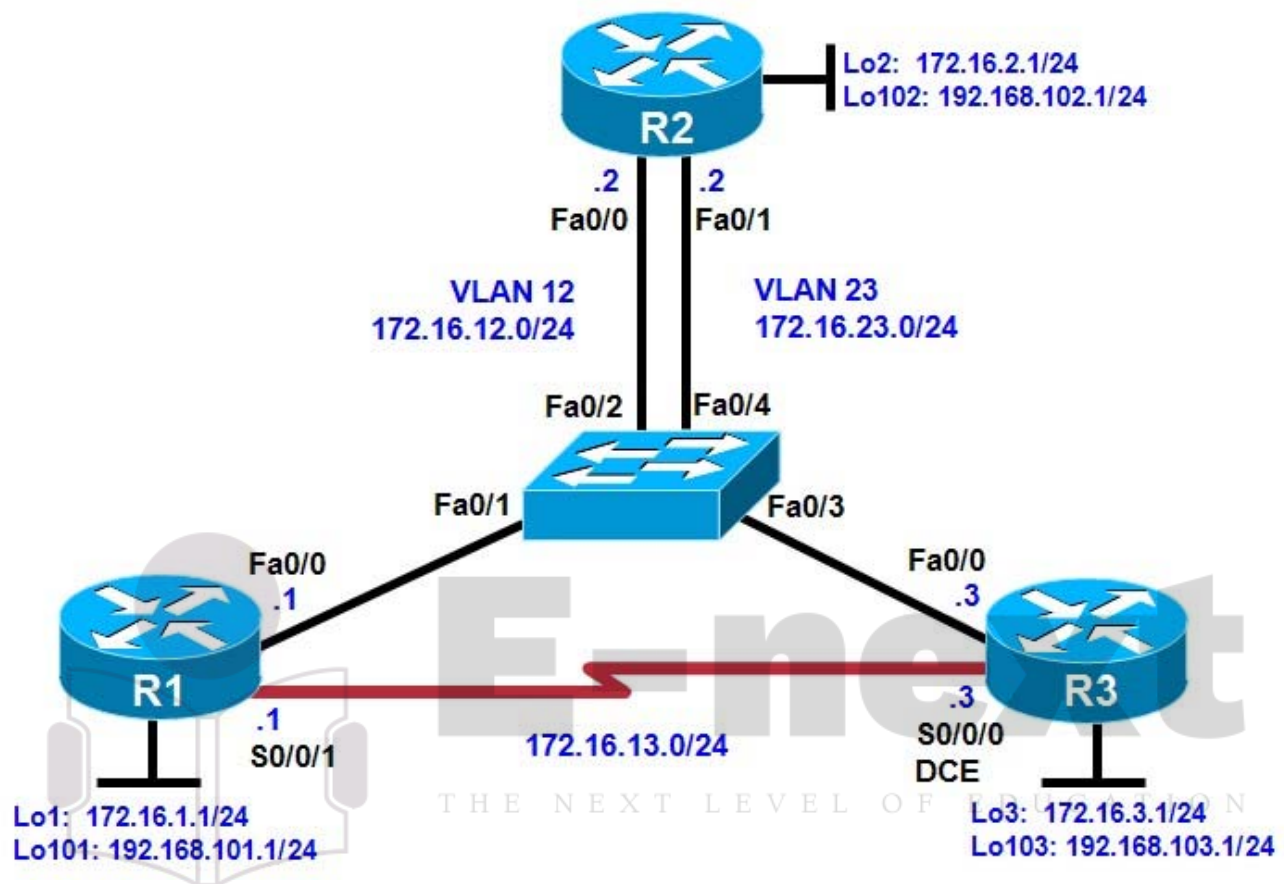
Objectives

- Configure RIP on a router.
- Configure OSPF on a router.
- Manipulate administrative distances.
- Compare routing protocol behavior.

Background

In this lab, you will compare the RIP and OSPF routing protocols based on how efficient they are at selecting routes, as well as what happens when you manipulate administrative distances in the routing table.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. The switch is a Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin. You can use other routers (such as a 2801 or 2811), switches (such as 2950), and Cisco IOS Software versions if they have comparable capabilities and features.

Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)

- 1 switch (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- Serial and Ethernet cables

Step 1: Review default administrative distances.

Fill in the following table with all the administrative distances you can recall from your reading.

Protocol	Administrative Distance
Connected	0
Static	1
EIGRP Summary Route	5
External BGP	20
EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
EGP	140
On-Demand Routing (ODR)	160
External EIGRP	170
Internal BGP	200
Unknown	255

Of the interior gateway protocols (IGPs) that you have studied, which one is considered the most trusted on a Cisco router and why?

_____

_____

Currently, EIGRP is considered the most trusted IGP on Cisco routers with an administrative distance of 90.

Step 2: Configure router loopbacks and addressing.

Configure all loopback interfaces on the three routers in the diagram. Configure the serial interface with the IP addresses, bring them up, and set a clock rate where appropriate.

```
R1# conf t
R1(config)# interface loopback 1
R1(config-if)# ip address 172.16.1.1 255.255.255.0
R1(config-if)# interface loopback 101
```

```
R1(config-if)# ip address 192.168.101.1 255.255.255.0
R1(config-if)# interface fastethernet 0/0
R1(config-if)# ip address 172.16.12.1 255.255.255.0
R1(config-if)# no shutdown
R1(config-if)# interface serial 0/0/1
R1(config-if)# bandwidth 64
R1(config-if)# ip address 172.16.13.1 255.255.255.0 R1(config-
if)# no shutdown


R2# conf t
R2(config)# interface loopback 2
R2(config-if)# ip address 172.16.2.1 255.255.255.0 R2(config-
if)# interface loopback 102
R2(config-if)# ip address 192.168.102.1 255.255.255.0
R2(config-if)# interface fastethernet 0/0
R2(config-if)# ip address 172.16.12.2 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# interface fastethernet 0/1
R2(config-if)# ip address 172.16.23.2 255.255.255.0 R2(config-
if)# no shutdown


R3# conf t
R3(config)# interface loopback 3
R3(config-if)# ip address 172.16.3.1 255.255.255.0
R3(config-if)# interface loopback 103
R3(config-if)# ip address 192.168.103.1 255.255.255.0
R3(config-if)# interface fastethernet 0/0
R3(config-if)# ip address 172.16.23.3 255.255.255.0
R3(config-if)# no shutdown
R3(config-if)# interface serial 0/0/0
R3(config-if)# bandwidth 64
R3(config-if)# ip address 172.16.13.3 255.255.255.0
R3(config-if)# clock rate 64000 R3(config-if)#
no shutdown
```

Step 3: Configure switch VLANs.

a. Configure the switch VLANs, and place the correct access ports in each VLAN.

Note: The switch ports used are not important as long as the ports connecting to R1 Fa0/0 and R2 Fa0/0 are in VLAN 12 and the ports connecting to R3 Fa0/0 and R2 Fa0/1 are in VLAN 23.

```
Switch(config)# vlan 12
Switch(config-vlan)# name R1-R2
Switch(config-vlan)# vlan 23
Switch(config-vlan)# name R2-R3
Switch(config-vlan)# exit

Switch(config)# interface fastEthernet 0/1 Switch(config-if)#
description To R1 Fa0/0 Switch(config-if)# switchport mode
access
Switch(config-if)# switchport access vlan 12

Switch(config-if)# interface fastEthernet 0/2 Switch(config-
if)# description To R2 Fa0/0 Switch(config-if)# switchport
mode access
Switch(config-if)# switchport access vlan 12
```

```
Switch(config-if)# interface fastEthernet 0/3 Switch(config-
if)# description To R3 Fa0/0 Switch(config-if)# switchport
mode access
Switch(config-if)# switchport access vlan 23

Switch(config-if)# interface fastEthernet 0/4 Switch(config-
if)# description To R2 Fa0/1 Switch(config-if)# switchport
mode access
Switch(config-if)# switchport access vlan 23
```

b. Verify that you can ping across the local subnets.

Step 4: Configure RIP.

a. Configure RIPv2 on all three routers for the major networks. Disable automatic summarization.

```
R1(config)# router rip
R1(config-router)# version 2
R1(config-router)# no auto-summary
R1(config-router)# network 172.16.0.0
R1(config-router)# network 192.168.101.0

R2(config)# router rip
R2(config-router)# version 2
R2(config-router)# no auto-summary
R2(config-router)# network 172.16.0.0
R2(config-router)# network 192.168.102.0

R3(config)# router rip
R3(config-router)# version 2
R3(config-router)# no auto-summary
R3(config-router)# network 172.16.0.0
R3(config-router)# network 192.168.103.0
```

b. Verify the configuration using the **show ip route rip** command on each router.

```
R1# show ip route rip
     172.16.0.0/24 is subnetted, 6 subnets
R        172.16.23.0 [120/1] via 172.16.13.3, 00:02:29, Serial0/0/1
                     [120/1] via 172.16.12.2, 00:02:15, FastEthernet0/0
R        172.16.2.0 [120/1] via 172.16.12.2, 00:02:15, FastEthernet0/0 R
172.16.3.0 [120/1] via 172.16.13.3, 00:02:29, Serial0/0/1
R     192.168.102.0/24 [120/1] via 172.16.12.2, 00:02:15, FastEthernet0/0 R
192.168.103.0/24 [120/1] via 172.16.13.3, 00:02:29, Serial0/0/1

R2# show ip route rip
     172.16.0.0/24 is subnetted, 6 subnets
R        172.16.13.0 [120/1] via 172.16.23.3, 00:02:18, FastEthernet0/1
                     [120/1] via 172.16.12.1, 00:02:20, FastEthernet0/0
R        172.16.1.0 [120/1] via 172.16.12.1, 00:02:20, FastEthernet0/0 R
172.16.3.0 [120/1] via 172.16.23.3, 00:02:18, FastEthernet0/1
R     192.168.103.0/24 [120/1] via 172.16.23.3, 00:02:18, FastEthernet0/1
R     192.168.101.0/24 [120/1] via 172.16.12.1, 00:02:20, FastEthernet0/0

R3# show ip route rip
     172.16.0.0/24 is subnetted, 6 subnets
R        172.16.12.0 [120/1] via 172.16.23.2, 00:02:32, FastEthernet0/0
```

```
                      [120/1] via 172.16.13.1, 00:02:47, Serial0/0/0 R
172.16.1.0 [120/1] via 172.16.13.1, 00:02:47, Serial0/0/0
R        172.16.2.0 [120/1] via 172.16.23.2, 00:02:32, FastEthernet0/0
R     192.168.102.0/24 [120/1] via 172.16.23.2, 00:02:32, FastEthernet0/0 R
192.168.101.0/24 [120/1] via 172.16.13.1, 00:02:47, Serial0/0/0
```

Notice that on R1, RIP chooses the serial interface as the best next hop for the R3 loopback interface.

c. Verify that each router is receiving RIP routes from other routers using the **show ip protocols** command.

```
R1# show ip protocols
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 26 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface           Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0      2     2
    Serial0/0/1          2     2
    Loopback1            2     2
    Loopback101          2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.101.0
  Routing Information Sources:
    Gateway          Distance      Last Update
172.16.12.2          120        00:00:21
    172.16.13.3          120        00:00:03
  Distance: (default is 120)

R2# show ip protocols
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 23 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface           Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0      2     2
    FastEthernet0/1      2     2
    Loopback2            2     2
    Loopback102          2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.102.0
  Routing Information Sources:
    Gateway          Distance      Last Update
172.16.23.3          120        00:00:02
    172.16.12.1          120        00:00:24
  Distance: (default is 120)
```

```
R3# show ip protocols
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 22 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface             Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0       2     2
    Serial0/0/0           2     2
    Loopback3             2     2
    Loopback103           2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.103.0
  Routing Information Sources:
    Gateway          Distance      Last Update
172.16.23.2          120        00:00:06
    172.16.13.1          120
00:00:17   Distance: (default is 120)
```

Step 5:

Configure OSPF.

a. Configure OSPF on all routers. Include the entire major network in area 0 on all three routers. Remember to change the network type on the loopback interfaces.

```
R1(config)# interface loopback 1
R1(config-if)# ip ospf network point-to-point
R1(config-if)# interface loopback 101
R1(config-if)# ip ospf network point-to-point
R1(config-if)# router ospf 1
R1(config-router)# network 172.16.0.0 0.0.255.255 area 0
R1(config-router)# network 192.168.101.0 0.0.0.255 area 0

R2(config)# interface loopback 2
R2(config-if)# ip ospf network point-to-point
R2(config-if)# interface loopback 102
R2(config-if)# ip ospf network point-to-point
R2(config-if)# router ospf 1
R2(config-router)# network 172.16.0.0 0.0.255.255 area 0
R2(config-router)# network 192.168.102.0 0.0.0.255 area 0

R3(config)# interface loopback 3
R3(config-if)# ip ospf network point-to-point
R3(config-if)# interface loopback 103
R3(config-if)# ip ospf network point-to-point
R3(config-if)# router ospf 1
R3(config-router)# network 172.16.0.0 0.0.255.255 area 0
R3(config-router)# network 192.168.103.0 0.0.0.255 area 0
```

b. Verify the configuration using the **show ip ospf neighbors** and **show ip route** commands on each router.

```
R1# show ip ospf neighbor


Neighbor ID    Pri   State     Dead Time    Address        Interface
```

```
192.168.103.1    0   FULL/  -  00:00:39    172.16.13.3   Serial0/0/1
192.168.102.1    1   FULL/DR   00:00:39    172.16.12.2   FastEthernet0/0
```

R1# **show ip route**
```
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
O       172.16.23.0 [110/2] via 172.16.12.2, 00:00:48, FastEthernet0/0
C       172.16.12.0 is directly connected, FastEthernet0/0
C       172.16.13.0 is directly connected, Serial0/0/1
C       172.16.1.0 is directly connected, Loopback1
O       172.16.2.0 [110/2] via 172.16.12.2, 00:00:48, FastEthernet0/0
O       172.16.3.0 [110/3] via 172.16.12.2, 00:00:48, FastEthernet0/0
O    192.168.102.0/24 [110/2] via 172.16.12.2, 00:00:48, FastEthernet0/0
O    192.168.103.0/24 [110/3] via 172.16.12.2, 00:00:49, FastEthernet0/0 C
192.168.101.0/24 is directly connected, Loopback101
```

R2# **show ip ospf neighbor**
```

Neighbor ID      Pri   State     Dead Time   Address        Interface
192.168.103.1    1   FULL/DR   00:00:31    172.16.23.3  FastEthernet0/1
192.168.101.1    1   FULL/BDR  00:00:34    172.16.12.1  FastEthernet0/0
```

R2# **show ip route**
```
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.23.0 is directly connected, FastEthernet0/1
C       172.16.12.0 is directly connected, FastEthernet0/0
O       172.16.13.0 [110/1563] via 172.16.23.3, 00:01:19, FastEthernet0/1
                    [110/1563] via 172.16.12.1, 00:01:19, FastEthernet0/0
O       172.16.1.0 [110/2] via 172.16.12.1, 00:01:19, FastEthernet0/0
C       172.16.2.0 is directly connected, Loopback2
O       172.16.3.0 [110/2] via 172.16.23.3, 00:01:19, FastEthernet0/1 C
192.168.102.0/24 is directly connected, Loopback102
O    192.168.103.0/24 [110/2] via 172.16.23.3, 00:01:20, FastEthernet0/1
O    192.168.101.0/24 [110/2] via 172.16.12.1, 00:01:20, FastEthernet0/0
```

R3# **show ip ospf neighbor**
```

Neighbor ID      Pri   State     Dead Time   Address        Interface
192.168.101.1    0   FULL/  -  00:00:36    172.16.13.1  Serial0/0/0
192.168.102.1    1   FULL/BDR  00:00:33    172.16.23.2  FastEthernet0/0
```

R3# **show ip route**
```
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.23.0 is directly connected, FastEthernet0/0
O       172.16.12.0 [110/2] via 172.16.23.2, 00:02:10, FastEthernet0/0 C
172.16.13.0 is directly connected, Serial0/0/0
O       172.16.1.0 [110/3] via 172.16.23.2, 00:02:10, FastEthernet0/0
O       172.16.2.0 [110/2] via 172.16.23.2, 00:02:10, FastEthernet0/0
C       172.16.3.0 is directly connected, Loopback3
O    192.168.102.0/24 [110/2] via 172.16.23.2, 00:02:10, FastEthernet0/0
C    192.168.103.0/24 is directly connected, Loopback103
O    192.168.101.0/24 [110/3] via 172.16.23.2, 00:02:11, FastEthernet0/0
```

Notice that all the OSPF routes have replaced the RIP routes in the routing table. This is because OSPF has an administrative distance of 110, and RIP has an administrative distance of 120.

What is the best next hop on R1 for 172.16.3.1 with only RIP running?

_____

_____

On R1, the best next hop to 172.16.3.1 is the R3 serial 0/0/0 interface with an IP address of 172.16.13.3.

What is the best next hop on R1 for 172.16.3.1 with OSPF running?

_____

_____

_____

On R1, the best next hop to 172.16.3.1 is the R2 Fast Ethernet 0/0 interface with an IP address of 172.16.12.2.

On R1, the best next hop for the R3 loopback is now through the VLAN between R1 and R2. This is because the sum of the costs for the two Ethernet links is still less than that of the single low-bandwidth (64 kb/s) serial link. This is one of the reasons why RIP's metric of a hop count is not very effective.

Which metric does R1 use to make routing decisions about whether to cross the serial link to R3 to reach R3's 172.16.3.1?

_____

_____

_____

The metric R1 receives for the loopback 3 network on R3 via the serial link is 1562, which is not preferred by R1.

Use the following information for your answer.

```
R1# show ip ospf database router adv-router 192.168.103.1

            OSPF Router with ID (192.168.101.1) (Process ID 1)

              Router Link States (Area 0)

  LS age: 433
  Options: (No TOS-capability, DC)
LS Type: Router Links
  Link State ID: 192.168.103.1
  Advertising Router: 192.168.103.1
  LS Seq Number: 80000003
  Checksum: 0xE87F
Length: 84
  Number of Links: 5

    Link connected to: a Stub Network
     (Link ID) Network/subnet number: 192.168.103.0
     (Link Data) Network Mask: 255.255.255.0
      Number of TOS metrics: 0
       TOS 0 Metrics: 1

    Link connected to: a Stub Network
```

```
         (Link ID) Network/subnet number: 172.16.3.0
(Link Data) Network Mask: 255.255.255.0        Number
of TOS metrics: 0
         TOS 0 Metrics: 1

     Link connected to: another Router (point-to-point)
       (Link ID) Neighboring Router ID: 192.168.101.1
       (Link Data) Router Interface address: 172.16.13.3
       Number of TOS metrics: 0
         TOS 0 Metrics: 1562

     Link connected to: a Stub Network
       (Link ID) Network/subnet number: 172.16.13.0
       (Link Data) Network Mask: 255.255.255.0
       Number of TOS metrics: 0
         TOS 0 Metrics: 1562

     Link connected to: a Transit Network
       (Link ID) Designated Router address: 172.16.23.3
       (Link Data) Router Interface address: 172.16.23.3
       Number of TOS metrics: 0
TOS 0 Metrics: 1
```

Step 6: Modify the routing protocol distance.

The **distance** command is a protocol-independent way to manipulate routing protocol distances. This command is different from the routing protocol-specific commands such as **distance ospf** and **distance eigrp**. This command lets you globally change a routing protocol's distances, change only routes from a certain neighbor or those matching an access list, or a combination of any two of these three options.

Try applying the **distance** *distance* command, which changes the distance of every route. The previous output of the **show ip route** command shows that OSPF marks routes it injects into the routing table with a default administrative distance of 110. RIP injects routes into the routing table with a default administrative distance of 120.

What would happen if the administrative distance on each router for RIP were set to 100?

_____

_____

All RIP routes would be preferred in the routing tables over OSPF routes.

a. On all three routers, change the distance of RIP to 100.

```
R1(config)# router rip
R1(config-router)# distance 100

R2(config)# router rip
R2(config-router)# distance 100

R3(config)# router rip
R3(config-router)# distance 100
```

b. Examine the output of the **show ip route** command. Notice that *all* the routes have become RIP routes because RIP now has a lower distance than OSPF.

```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
```

```
R          172.16.23.0 [100/1] via 172.16.13.3, 00:00:17, Serial0/0/1
                       [100/1] via 172.16.12.2, 00:00:09, FastEthernet0/0
C          172.16.12.0 is directly connected, FastEthernet0/0
C          172.16.13.0 is directly connected, Serial0/0/1
C          172.16.1.0 is directly connected, Loopback1
R          172.16.2.0 [100/1] via 172.16.12.2, 00:00:09, FastEthernet0/0 R
172.16.3.0 [100/1] via 172.16.13.3, 00:00:17, Serial0/0/1
R      192.168.102.0/24 [100/1] via 172.16.12.2, 00:00:10, FastEthernet0/0
R      192.168.103.0/24 [100/1] via 172.16.13.3, 00:00:18, Serial0/0/1
C      192.168.101.0/24 is directly connected, Loopback101


R2# show ip route
<output omitted>
      172.16.0.0/24 is subnetted, 6 subnets
C          172.16.23.0 is directly connected, FastEthernet0/1
C          172.16.12.0 is directly connected, FastEthernet0/0
R          172.16.13.0 [100/1] via 172.16.23.3, 00:00:07, FastEthernet0/1
                       [100/1] via 172.16.12.1, 00:00:07, FastEthernet0/0
R          172.16.1.0 [100/1] via 172.16.12.1, 00:00:07, FastEthernet0/0
C          172.16.2.0 is directly connected, Loopback2
R          172.16.3.0 [100/1] via 172.16.23.3, 00:00:07, FastEthernet0/1 C
192.168.102.0/24 is directly connected, Loopback102
R      192.168.103.0/24 [100/1] via 172.16.23.3, 00:00:08, FastEthernet0/1
R      192.168.101.0/24 [100/1] via 172.16.12.1, 00:00:08, FastEthernet0/0


R3# show ip route
<output omitted>
      172.16.0.0/24 is subnetted, 6 subnets
C          172.16.23.0 is directly connected, FastEthernet0/0
R          172.16.12.0 [100/1] via 172.16.23.2, 00:00:07, FastEthernet0/0
                       [100/1] via 172.16.13.1, 00:00:02, Serial0/0/0 C
172.16.13.0 is directly connected, Serial0/0/0
R          172.16.1.0 [100/1] via 172.16.13.1, 00:00:02, Serial0/0/0
R          172.16.2.0 [100/1] via 172.16.23.2, 00:00:07, FastEthernet0/0
C          172.16.3.0 is directly connected, Loopback3
R      192.168.102.0/24 [100/1] via 172.16.23.2, 00:00:08, FastEthernet0/0 C
192.168.103.0/24 is directly connected, Loopback103
R      192.168.101.0/24 [100/1] via 172.16.13.1, 00:00:03, Serial0/0/0
```

c. You can display the new default distance for RIP using the **show ip protocols** command. R1#

```
show ip protocols

Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 11 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface            Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0       2     2
    Serial0/0/1          2     2
    Loopback1            2     2
    Loopback101          2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
```

```
        172.16.0.0
        192.168.101.0
     Routing Information Sources:
        Gateway          Distance      Last Update
        172.16.13.3         100        00:00:14
        172.16.12.2         100        00:00:22
     Distance: (default is 100)
<output omitted>
```

Step 7: Modify distance based on route source.

You can also modify administrative distance based on route source using the **distance** *distance address wildcard* command, where *address* and *wildcard* represent the peer advertising the route. For OSPF, the address is the router ID.

a. On all three routers, change the OSPF administrative distance to 85 for any routes being advertised from routers with IDs in the range of 192.168.100.0/21.

```
R1(config)# router ospf 1
R1(config-router)# distance 85 192.168.100.0 0.0.3.255


R2(config)# router ospf 1
R2(config-router)# distance 85 192.168.100.0 0.0.3.255


R3(config)# router ospf 1
R3(config-router)# distance 85 192.168.100.0 0.0.3.255
```

b. Verify the change with the **show ip protocols** and **show ip route** commands.

```
R1# show ip route
<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 6 subnets
O       172.16.23.0 [85/2] via 172.16.12.2, 00:00:31, FastEthernet0/0
C       172.16.12.0 is directly connected, FastEthernet0/0
C       172.16.13.0 is directly connected, Serial0/0/1
C       172.16.1.0 is directly connected, Loopback1
O       172.16.2.0 [85/2] via 172.16.12.2, 00:00:31, FastEthernet0/0
O       172.16.3.0 [85/3] via 172.16.12.2, 00:00:31, FastEthernet0/0
O   192.168.102.0/24 [85/2] via 172.16.12.2, 00:00:31, FastEthernet0/0 O
192.168.103.0/24 [85/3] via 172.16.12.2, 00:00:32, FastEthernet0/0 C
192.168.101.0/24 is directly connected, Loopback101


R2# show ip route
<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.23.0 is directly connected, FastEthernet0/1
C       172.16.12.0 is directly connected, FastEthernet0/0
O       172.16.13.0 [85/1563] via 172.16.23.3, 00:00:53, FastEthernet0/1
                    [85/1563] via 172.16.12.1, 00:00:53, FastEthernet0/0
O       172.16.1.0 [85/2] via 172.16.12.1, 00:00:53, FastEthernet0/0
C       172.16.2.0 is directly connected, Loopback2
```

```
O         172.16.3.0 [85/2] via 172.16.23.3, 00:00:53, FastEthernet0/1 C
192.168.102.0/24 is directly connected, Loopback102
O     192.168.103.0/24 [85/2] via 172.16.23.3, 00:00:54, FastEthernet0/1
O     192.168.101.0/24 [85/2] via 172.16.12.1, 00:00:54, FastEthernet0/0


        R3# show ip route
        <output omitted>

        Gateway of last resort is not set

            172.16.0.0/24 is subnetted, 6 subnets
C          172.16.23.0 is directly connected, FastEthernet0/0
O          172.16.12.0 [85/2] via 172.16.23.2, 00:01:15, FastEthernet0/0 C
172.16.13.0 is directly connected, Serial0/0/0
O          172.16.1.0 [85/3] via 172.16.23.2, 00:01:15, FastEthernet0/0
O          172.16.2.0 [85/2] via 172.16.23.2, 00:01:15, FastEthernet0/0
C          172.16.3.0 is directly connected, Loopback3
O     192.168.102.0/24 [85/2] via 172.16.23.2, 00:01:15, FastEthernet0/0
C     192.168.103.0/24 is directly connected, Loopback103
O     192.168.101.0/24 [85/3] via 172.16.23.2, 00:01:16, FastEthernet0/0

        R1# show ip protocols
        Routing Protocol is "ospf 1"
          Outgoing update filter list for all interfaces is not set
          Incoming update filter list for all interfaces is not set
          Router ID 192.168.101.1
          Number of areas in this router is 1. 1 normal 0 stub 0 nssa
          Maximum path: 4
          Routing for Networks:
            172.16.0.0 0.0.255.255 area 0
            192.168.101.0 0.0.0.255 area 0
        Reference bandwidth unit is 100 mbps
          Routing Information Sources:
            Gateway          Distance        Last Update
        192.168.103.1          85          00:05:47
            192.168.102.1          85          00:05:47
          Distance: (default is 110)
            Address          Wild mask          Distance  List
            192.168.100.0          0.0.3.255          85
```

Each of the routers should have an entry similar to the one highlighted above.

Step 8: Modify distance based on an access list.

You can also modify administrative distance based on which routes match an access list using the **distance** *distance address wildcard acl* command. The way you list routes in an access list which will be used to modify distance is similar to how you list them when the access list is used to filter routes. For this lab, create an access list containing all the subnets of 172.16.0.0/16. Then associate the access list with the **distance** command, setting the address and wildcard to be any IP address (i.e., any route source). a. On all three routers, change the distances of the affected routes to 65.

```
R1(config)# access-list 1 permit 172.16.0.0 0.0.255.255
R1(config)# router rip
R1(config-router)# distance 65 0.0.0.0 255.255.255.255 1

R2(config)# access-list 1 permit 172.16.0.0 0.0.255.255
```

```
R2(config)# router rip
R2(config-router)# distance 65 0.0.0.0 255.255.255.255 1

R3(config)# access-list 1 permit 172.16.0.0 0.0.255.255
R3(config)# router rip
R3(config-router)# distance 65 0.0.0.0 255.255.255.255 1
```

b. Verify the change with the **show ip protocols** and **show ip route** commands. R1#

```
show ip protocols
<output omitted>

Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 22 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface           Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0     2     2
    Serial0/0/1         2     2
    Loopback1           2     2
    Loopback101         2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.101.0
  Routing Information Sources:
    Gateway         Distance      Last Update
172.16.12.2           64        00:00:11
    172.16.13.3         64        00:00:12
Distance: (default is 100)
    Address            Wild mask         Distance
                                         List 0.0.0.0
                                         255.255.255.255       65   1

R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
R       172.16.23.0 [65/1] via 172.16.13.3, 00:00:20, Serial0/0/1
                    [65/1] via 172.16.12.2, 00:00:19, FastEthernet0/0
C       172.16.12.0 is directly connected, FastEthernet0/0
C       172.16.13.0 is directly connected, Serial0/0/1
C       172.16.1.0 is directly connected, Loopback1
R       172.16.2.0 [65/1] via 172.16.12.2, 00:00:19, FastEthernet0/0 R
172.16.3.0 [65/1] via 172.16.13.3, 00:00:20, Serial0/0/1
O    192.168.102.0/24 [85/2] via 172.16.12.2, 00:09:09, FastEthernet0/0
O    192.168.103.0/24 [85/3] via 172.16.12.2, 00:09:09, FastEthernet0/0
C    192.168.101.0/24 is directly connected, Loopback101

R2# show ip protocols
<output omitted>
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
```

```
    Sending updates every 30 seconds, next due in 27 seconds
    Invalid after 180 seconds, hold down 180, flushed after 240
    Redistributing: rip
    Default version control: send version 2, receive version 2
      Interface              Send  Recv  Triggered RIP  Key-chain
      FastEthernet0/0         2     2
      FastEthernet0/1         2     2
      Loopback2               2     2
      Loopback102             2     2
Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.102.0
  Routing Information Sources:
    Gateway          Distance       Last Update
172.16.23.3              65        00:00:06
    172.16.12.1           65        00:00:22
Distance: (default is 100)
          Address          Wild mask        Distance
                                          List 0.0.0.0
                                          255.255.255.255        65    1

R2# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.23.0 is directly connected, FastEthernet0/1
C       172.16.12.0 is directly connected, FastEthernet0/0
R       172.16.13.0 [65/1] via 172.16.23.3, 00:00:10, FastEthernet0/1
                    [65/1] via 172.16.12.1, 00:00:00, FastEthernet0/0
R       172.16.1.0 [65/1] via 172.16.12.1, 00:00:00, FastEthernet0/0
C       172.16.2.0 is directly connected, Loopback2
R       172.16.3.0 [65/1] via 172.16.23.3, 00:00:10, FastEthernet0/1 C
192.168.102.0/24 is directly connected, Loopback102
O    192.168.103.0/24 [85/2] via 172.16.23.3, 00:09:35, FastEthernet0/1
O    192.168.101.0/24 [85/2] via 172.16.12.1, 00:09:35, FastEthernet0/0

R3# show ip protocols
<output omitted>
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 15 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface              Send  Recv  Triggered RIP  Key-chain
    FastEthernet0/0         2     2
    Serial0/0/0            2     2
    Loopback3              2     2
    Loopback103            2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    172.16.0.0
    192.168.103.0
  Routing Information Sources:
```

```
      Gateway          Distance      Last Update
172.16.23.2             65        00:00:24
    172.16.13.1           65         00:00:16
Distance: (default is 100)
```

```
                                            List 0.0.0.0
                                                 255.255.255.255      65   1
```

```
R3# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 6 subnets
C       172.16.23.0 is directly connected, FastEthernet0/1
R       172.16.12.0 [65/1] via 172.16.23.2, 00:00:00, FastEthernet0/1
                    [65/1] via 172.16.13.1, 00:00:19, Serial0/0/0 C
172.16.13.0 is directly connected, Serial0/0/0
R       172.16.1.0 [65/1] via 172.16.13.1, 00:00:19, Serial0/0/0
R       172.16.2.0 [65/1] via 172.16.23.2, 00:00:00, FastEthernet0/1
C       172.16.3.0 is directly connected, Loopback3
O   192.168.102.0/24 [85/2] via 172.16.23.2, 00:09:43, FastEthernet0/1
C   192.168.103.0/24 is directly connected, Loopback103
O   192.168.101.0/24 [85/3] via 172.16.23.2, 00:09:43, FastEthernet0/1
```

c. Verify full connectivity with the following Tcl script.

```
R1# tclsh
 foreach address
{
172.16.1.1
172.16.2.1
172.16.3.1
172.16.12.1
172.16.12.2
172.16.13.1
172.16.13.3
172.16.23.2
172.16.23.3
192.168.101.1
192.168.102.1
192.168.103.1
} { ping $address }
```

Challenge

Attempt this exercise based on what you know about OSPF, Dijkstra's algorithm, and the **distance** command. Using only the **distance** command, write out the commands necessary to confuse the routers in this topology so that packets destined for 172.16.3.1 would continually bounce between R1 to R2?

_____

_____

_____ A permanent routing loop between R1 and R2 can be created by leaving the administrative distances at their default values on R1 and, on R2, by setting the administrative distance of RIP-discovered routes from R1 to a value lower than 110 to favor them more than OSPF-discovered routes.

Because it is possible to intentionally break routing in this way, what degree of caution should be exercised when manipulating administrative distances in a production network?

_____

_____

_____

Extreme caution should be used when manipulating administrative distances.

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

THE NEXT LEVEL OF EDUCATION

Device Configurations (Instructor version)

Router R1

```
hostname R1 ! interface Loopback1  ip
address 172.16.1.1 255.255.255.0  ip
ospf network point-to-point ! interface
Loopback101  ip address 192.168.101.1
255.255.255.0  ip ospf network point-
to-point ! interface FastEthernet0/0
ip address 172.16.12.1 255.255.255.0
no shutdown ! interface Serial0/0/1
bandwidth 64
 ip address 172.16.13.1 255.255.255.0
no shutdown ! router ospf 1
 network 172.16.0.0 0.0.255.255 area 0
network 192.168.101.0 0.0.0.255 area 0
distance 85 192.168.100.0 0.0.3.255 !
router rip  version 2
 network 172.16.0.0
network 192.168.101.0
distance 100
 distance 65 0.0.0.0 255.255.255.255 1
no auto-summary !
access-list 1 permit 172.16.0.0 0.0.255.255
! end
```

Router R2

```
hostname R2 !
interface Loopback2  ip address
172.16.2.1 255.255.255.0  ip ospf
network point-to-point !
interface Loopback102  ip address
192.168.102.1 255.255.255.0  ip ospf
network point-to-point !
interface FastEthernet0/0  ip address
172.16.12.2 255.255.255.0  no
shutdown ! interface FastEthernet0/1
ip address 172.16.23.2 255.255.255.0
no shutdown ! router ospf 1
 network 172.16.0.0 0.0.255.255 area 0
network 192.168.102.0 0.0.0.255 area 0
distance 85 192.168.100.0 0.0.3.255 !
router rip  version 2
 network 172.16.0.0
network 192.168.102.0
distance 100
 distance 65 0.0.0.0 255.255.255.255 1
no auto-summary !
access-list 1 permit 172.16.0.0 0.0.255.255
! end
```

Router R3

```
hostname R3 ! interface Loopback3  ip
address 172.16.3.1 255.255.255.0  ip
ospf network point-to-point ! interface
Loopback103  ip address 192.168.103.1
```

```
255.255.255.0  ip ospf network point-
to-point ! interface FastEthernet0/0
ip address 172.16.23.3 255.255.255.0
no shutdown ! interface Serial0/0/0
bandwidth 64
 ip address 172.16.13.3 255.255.255.0
clock rate 64000  no shutdown !
router ospf 1
 network 172.16.0.0 0.0.255.255 area 0
network 192.168.103.0 0.0.0.255 area 0
distance 85 192.168.100.0 0.0.3.255 !
router rip  version 2
 network 172.16.0.0
network 192.168.103.0
distance 100
 distance 65 0.0.0.0 255.255.255.255 1
no auto-summary !
access-list 1 permit 172.16.0.0 0.0.255.255
! end
```

4-1 Configuring BGP with Default Routing Instructor Version

Topology
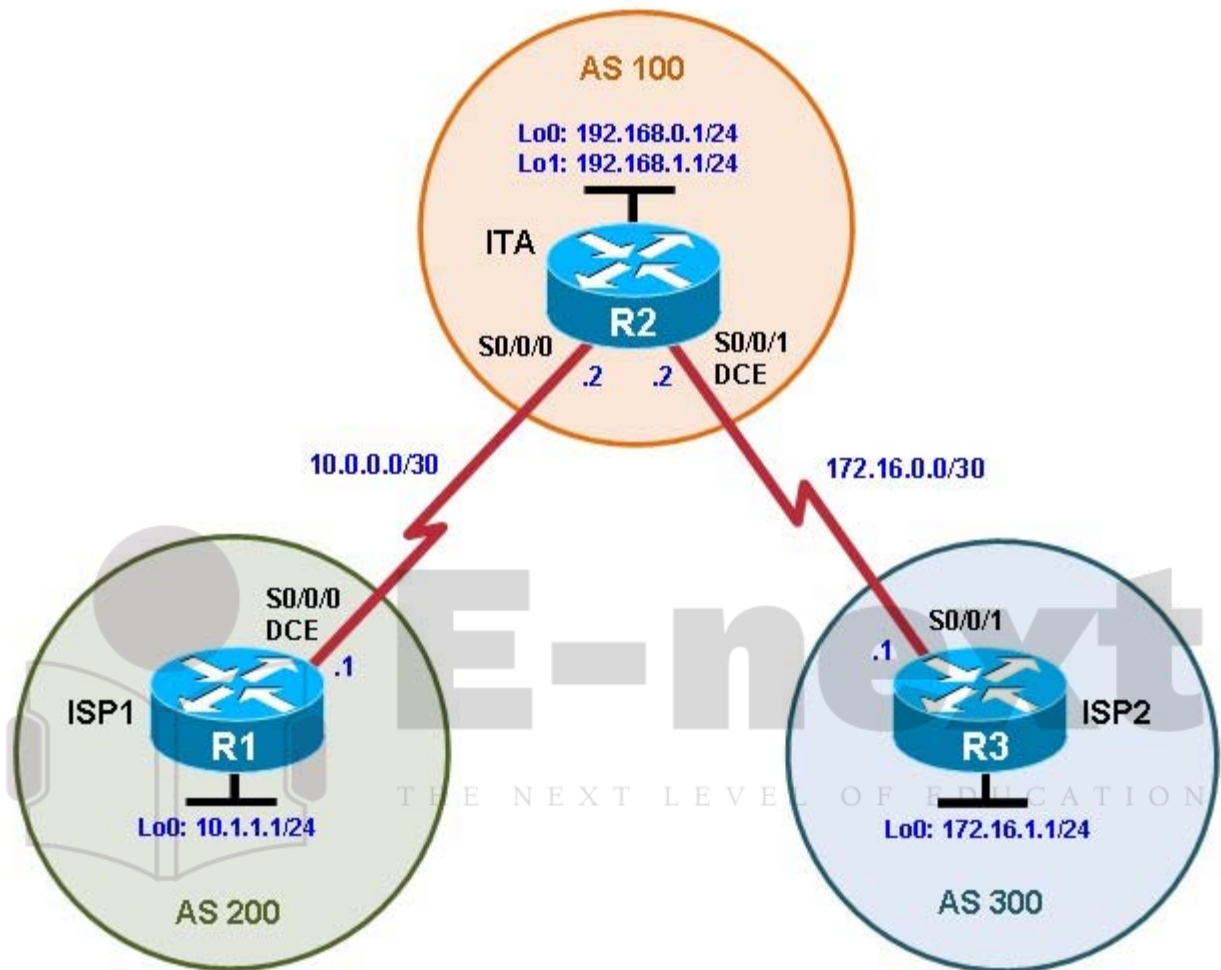
Objectives

- Configure BGP to exchange routing information with two ISPs.

Background

The International Travel Agency (ITA) relies extensively on the Internet for sales. For this reason, the ITA has decided to create a multihomed ISP connectivity solution and contracted with two ISPs for Internet connectivity with fault tolerance. Because the ITA is connecting to two different service providers, you must configure BGP, which runs between the ITA boundary router and the two ISP routers.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Prepare the routers for the lab.

Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear previous configurations.

Step 2: Configure the hostname and interface addresses.

a. Assign the routers hostnames. Using the addressing scheme in the diagram, create the loopback interfaces and apply IP addresses to these and the serial interfaces on ISP1 (R1), ISP2 (R3), and ITA (R2). The ISP loopbacks simulate real networks that can be reached through the ISP. The two loopbacks for the ITA router simulate the connections between the ITA boundary router and their core routers. Set a clock rate on the DCE serial interfaces.

You can copy and paste the following configurations into your routers to begin.

Router R1 (hostname ISP1) `hostname ISP1 ! interface Lo0`
```
 description ISP1 Internet Network
ip address 10.1.1.1 255.255.255.0 !
interface Serial0/0/0  description
ISP1 -> ITA  ip address 10.0.0.1
255.255.255.252  clock rate 128000
no shutdown ! end
```

Router R2 (hostname ITA)
```
hostname ITA !
interface Lo0
 description Core router network link 1
ip address 192.168.0.1 255.255.255.0 !
interface Lo1
 description Core router network link 2
ip address 192.168.1.1 255.255.255.0 !
interface Serial0/0/0  description
ITA -> ISP1  ip address 10.0.0.2
255.255.255.252  no shutdown

interface Serial0/0/1
description ITA -> ISP2
 ip address 172.16.0.2 255.255.255.252
clock rate 128000  no shutdown ! end
```

Router R3 (hostname ISP2)
```
hostname    ISP2     !
interface Lo0
 description ISP2 Internet Network
ip address 172.16.1.1 255.255.255.0 !
interface Serial0/0/1
description ISP2 -> ITA
 ip address 172.16.0.1 255.255.255.252
no shutdown ! end
```

b. Use **ping** to test the connectivity between the directly connected routers. Note that router ISP1 cannot reach router ISP2.

Step 3: Configure BGP on the ISP routers.

On the ISP1 and ISP2 routers, configure BGP to peer with the ITA boundary router and advertise the ISP loopback networks.

```
ISP1(config)# router bgp 200
ISP1(config-router)# neighbor 10.0.0.2 remote-as 100
ISP1(config-router)# network 10.1.1.0 mask 255.255.255.0

ISP2(config)# router bgp 300
ISP2(config-router)# neighbor 172.16.0.2 remote-as 100
ISP2(config-router)# network 172.16.1.0 mask 255.255.255.0
```

Step 4: Configure BGP on the ITA boundary router.

a. Configure the ITA router to run BGP with both Internet providers.

```
ITA(config)# router bgp 100
ITA(config-router)# neighbor 10.0.0.1 remote-as 200
ITA(config-router)# neighbor 172.16.0.1 remote-as 300
ITA(config-router)# network 192.168.0.0
ITA(config-router)# network 192.168.1.0
```

You should see BGP neighbor peering messages on the console similar to the following.

```
*Mar  4 14:07:38.667: %BGP-5-ADJCHANGE: neighbor 10.0.0.2 Up
```

b. To verify the configuration, check the ITA routing table with the **show ip route** command.

```
ITA# show ip route
<output omitted>

Gateway of last resort is not set
172.16.0.0/16 is variably
subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/1
B       172.16.1.0/24 [20/0] via 172.16.0.1, 00:00:32
        10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B       10.1.1.0/24 [20/0] via 10.0.0.1, 00:00:31
C       10.0.0.0/30 is directly connected, Serial0/0/0 C
        192.168.0.0/24 is directly connected, Loopback0
C   192.168.1.0/24 is directly connected, Loopback1
```

ITA has routes to the loopback networks at each ISP router.

c. Run the following Tcl script on all routers to verify connectivity If these pings are not successful, troubleshoot.

Note: The WAN subnets connecting ITA (R2) to the ISPs (R1 and R3) are not advertised in BGP, so the ISPs will not be able to ping each other's serial interface address.

```
ITA# tclsh
 foreach address
{
10.0.0.1
10.0.0.2
10.1.1.1
172.16.0.1
172.16.0.2
172.16.1.1
192.168.0.1
192.168.1.1 } {
ping $address }
```

Step 5: Verify BGP on the routers.

a. To verify the BGP operation on ITA, issue the **show ip bgp** command.

```
ITA# show ip bgp
BGP table version is 5, local router ID is 192.168.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i - internal
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          Metric LocPrf Weight Path
*> 10.1.1.0/24      10.0.0.1               0            0 200 i
*> 172.16.1.0/24    172.16.0.1             0            0 300 i *>
192.168.0.0       0.0.0.0                0        32768 i
*> 192.168.1.0      0.0.0.0                0        32768 i
```

What is the local router ID?

_____

The local router ID is 192.168.1.1.

Which table version is displayed?

_____

The table version displayed is 5.

An asterisk (*) next to a route indicates that it is valid. An angle bracket (>) indicates that the route has been selected as the best route.

b. To verify the operation of ISP1, issue the **show ip bgp** command.

```
ISP1# show ip bgp
BGP table version is 5, local router ID is 10.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          Metric LocPrf Weight Path
*> 10.1.1.0/24      0.0.0.0                0        32768 i
*> 172.16.1.0/24    10.0.0.2                            0 100 300 i *>
192.168.0.0       10.0.0.2               0          0 100 i
*> 192.168.1.0      10.0.0.2               0          0 100 i
```

From ISP1, what is the path to network 172.16.1.0/24?

_____

The path is through AS 100 (ITA) and AS 300 (ISP2).

c. On the ISP1 router, issue the **shutdown** command on Loopback0. Then on ITA, issue the **show ip bgp** command again.

```
ITA# show ip bgp
BGP table version is 6, local router ID is 192.168.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal,
r RIB-failure, S Stale
Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          Metric LocPrf Weight Path
```

```
*> 172.16.1.0/24    172.16.0.1                    0             0 300 i *>
192.168.0.0         0.0.0.0                       0         32768 i
*> 192.168.1.0      0.0.0.0                       0         32768 i
```

Which table version is displayed? Why?

_____

_____

The table version displayed is an increment of the last one, which is 6 in the example. The **shutdown** command causes a routing table update, so the version should be one higher than the last

What happened to the route for network 10.1.1.0/24?

_____

It is no longer in the BGP table because interface Lo0 on ISP1 is down.

d. Bring ISP1 router Loopback0 back up by issuing the **no shutdown** command.

e. On ITA, issue the **show ip bgp neighbors** command. The following is a partial sample output of the command showing neighbor 172.16.0.1.

```
BGP neighbor is 172.16.0.1,  remote AS 300, external link
  BGP version 4, remote router ID 172.16.1.1
  BGP state = Established, up for 00:16:00
  Last read 00:00:54, last write 00:00:43, hold time is 180, keepalive
interval is 60 seconds
  Neighbor capabilities:
    Route refresh: advertised and received(new)
    New ASN Capability: advertised and received
    Address family IPv4 Unicast: advertised and received
  Message statistics:
    InQ depth is 0
    OutQ depth is 0

                    Sent        Rcvd
    Opens:           1           1
    Notifications:   0           0
    Updates:         5           1
    Keepalives:      15          17
    Route Refresh:   0           0
    Total:           21          19
  Default minimum time between advertisement runs is 30 seconds
<output omitted>
```

Based on the output of this command, what is the BGP state between this router and ISP2?

_____

_____ The

BGP state is established.

How long has this connection been up?

_____

The connection has been up for 00:16:00.

Step 6: Configure route filters.

a. Check the ISP2 routing table using the **show ip route** command. ISP2 should have a route that belongs to ISP1, network 10.1.1.0.

```
ISP2# show ip route
<output omitted>


    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C      172.16.0.0/30 is directly connected, Serial0/0/1
C      172.16.1.0/24 is directly connected, Loopback0
    10.0.0.0/24 is subnetted, 1 subnets
B      10.1.1.0 [20/0] via 172.16.0.2, 00:05:22
B   192.168.0.0/24 [20/0] via 172.16.0.2, 00:17:45
B   192.168.1.0/24 [20/0] via 172.16.0.2, 00:17:45
```

If ITA advertises a route belonging to ISP1, ISP2 installs that route in its table. ISP2 might then attempt to route transit traffic through the ITA. Configure the ITA router so that it advertises only ITA networks 192.168.0.0 and 192.168.1.0 to both providers.

b. On the ITA router, configure the following access list.

```
ITA(config)# access-list 1 permit 192.168.0.0 0.0.1.255
```

c. Apply this access list as a route filter using the **distribute-list** keyword with the BGP **neighbor** statement.

```
ITA(config)# router bgp 100
ITA(config-router)# neighbor 10.0.0.1 distribute-list 1 out
ITA(config-router)# neighbor 172.16.0.1 distribute-list 1 out
```

d. Check the routing table for ISP2 again. The route to 10.1.1.0, ISP1, should still be in the table.

e. Return to ITA and issue the **clear ip bgp *** command. Wait until the routers reach the established state, which might take several seconds, and then recheck the ISP2 routing table. The route to ISP1, network 10.1.1.0, should no longer be in the routing table for ISP2, and the route to ISP2, network 172.16.1.0, should not be in the routing table for ISP1.

```
ITA# clear ip bgp *
ITA#
*Mar  4 14:45:28.091: %BGP-5-ADJCHANGE: neighbor 10.0.0.1 Down User reset
*Mar  4 14:45:28.091: %BGP-5-ADJCHANGE: neighbor 172.16.0.1 Down User reset
*Mar  4 14:45:31.151: %BGP-5-ADJCHANGE: neighbor 172.16.0.1 Up
*Mar  4 14:45:47.095: %BGP-5-ADJCHANGE: neighbor 10.0.0.1 Up
```

Note: The **clear ip bgp *** command is disruptive because it completely resets all BGP adjacencies. This is acceptable in a lab environment but could be problematic in a production network. Instead, if only a change of inbound/outbound routing policies is to be performed, it is sufficient to issue the **clear ip bgp * in** or **clear ip bgp * out** commands**.** These commands perform only a new BGP database synchronization without the disruptive effects of a complete BGP adjacency reset. All current Cisco IOS versions support the route refresh capability that replaces the inbound soft reconfiguration feature that previously had to be configured on a per-neighbor basis.

```
ISP2# show ip route
<output omitted>


    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C      172.16.0.0/30 is directly connected, Serial0/0/1
C      172.16.1.0/24 is directly connected, Loopback0 B
192.168.0.0/24 [20/0] via 172.16.0.2, 00:02:13
B      192.168.1.0/24 [20/0] via 172.16.0.2, 00:02:13


ISP1# show ip route
<output omitted>


    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
```

```
C        10.1.1.0/24 is directly connected, Loopback0
C        10.0.0.0/30 is directly connected, Serial0/0/0
B     192.168.0.0/24 [20/0] via 10.0.0.2, 00:05:06
B        192.168.1.0/24 [20/0] via 10.0.0.2, 00:05:06
```

Step 7: Configure primary and backup routes using floating static routes.

With bidirectional communication established with each ISP via BGP, configure the primary and backup routes. This can be done with floating static routes or BGP. a. Issue the **show ip route** command on the ITA router.

```
ITA# show ip route
<output omitted>

Gateway of last resort is not set

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.0.0/30 is directly connected, Serial0/0/1
B        172.16.1.0/24 [20/0] via 172.16.0.1, 00:06:58
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B        10.1.1.0/24 [20/0] via 10.0.0.1, 00:06:58
C        10.0.0.0/30 is directly connected, Serial0/0/0 C
         192.168.0.0/24 is directly connected, Loopback0
C     192.168.1.0/24 is directly connected, Loopback1
```

Notice that there is no gateway of last resort defined. This is a problem because ITA is the border router for the corporate network.

b. Configure static routes to reflect the policy that ISP1 is the primary provider and that ISP2 acts as the backup by specifying a lower distance metric for the route to ISP1 (210) as compared to the backup route to ISP2 (distance metric 220).

```
ITA(config)# ip route 0.0.0.0 0.0.0.0 10.0.0.1 210
ITA(config)# ip route 0.0.0.0 0.0.0.0 172.16.0.1 220
```

c. Verify that a default route is defined using the **show ip route** command.

```
ITA# show ip route
<output omitted>

Gateway of last resort is 10.0.0.1 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.0.0/30 is directly connected, Serial0/0/1
B        172.16.1.0/24 [20/0] via 172.16.0.1, 00:11:41
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B        10.1.1.0/24 [20/0] via 10.0.0.1, 00:11:41
C        10.0.0.0/30 is directly connected, Serial0/0/0 C
         192.168.0.0/24 is directly connected, Loopback0
C     192.168.1.0/24 is directly connected, Loopback1 S*
0.0.0.0/0 [210/0] via 10.0.0.1
```

d. Test this default route by creating an unadvertised loopback on the router for ISP1.

```
ISP1# config t
ISP1(config)# interface loopback 100
ISP1(config-if)# ip address 192.168.100.1 255.255.255.0
```

e. Issue the **show ip route** command to ensure that the newly added 192.168.100.0 /24 network does not appear in the routing table.

```
ITA# show ip route
<output omitted>

Gateway of last resort is 10.0.0.1 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/1
B       172.16.1.0/24 [20/0] via 172.16.0.1, 00:16:24
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks B
10.1.1.0/24 [20/0] via 10.0.0.1, 00:01:47
C       10.0.0.0/30 is directly connected, Serial0/0/0 C
192.168.0.0/24 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, Loopback1 S*
0.0.0.0/0 [210/0] via 10.0.0.1
```

f. In extended ping mode, ping the ISP1 loopback 1 interface 192.168.100.1 with the source originating from the ITA loopback 1 interface 192.168.1.1.

```
ITA# ping
Protocol [ip]:
Target IP address: 192.168.100.1
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 192.168.1.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 192.168.100.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 32/32/36 ms
```

Note: You can bypass extended ping prompted mode and ping while specifying a source address using one of these abbreviated commands:

```
ITA# ping 192.168.100.1 source 192.168.1.1
```

or

```
ITA# ping 192.168.100.1 source Lo1
```

Note: Testing the default route by creating an unadvertised network on ISP1 and pinging it works only because the default route also points toward ISP1. If the preferred default route pointed toward ISP2, the ping to that unadvertised network on ISP1 would not succeed. If the link to ISP1 failed, the default route to ISP2 would become active, but the pings would be successful only if ISP1 and ISP2 have another working interconnection and appropriate BGP peering between them, which is currently not the case.

Step 8: Configure primary and backup routes using a default network and a static route.

Another method for configuring primary and backup routes is to use the **ip default-network** command instead of a 0.0.0.0/0 route.

a. Remove the floating static routes configured in Step 7.

```
ITA(config)# no ip route 0.0.0.0 0.0.0.0 10.0.0.1 210
ITA(config)# no ip route 0.0.0.0 0.0.0.0 172.16.0.1 220
```

b. The network that was added in Step 7, 192.168.100.0/24, should now be advertised on the ISP1 router. You might need to wait a few moments for BGP to advertise the new network.

```
ISP1(config)# router bgp 200
ISP1(config-router)# network 192.168.100.0 ISP1(config-router)#
end
```

c. Make sure that the classful network 192.168.100.0 /24 appears in the ITA routing table.

```
ITA# show ip route
<output omitted>

Gateway of last resort is not set

      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.0.0/30 is directly connected, Serial0/0/1
B        172.16.1.0/24 [20/0] via 172.16.0.1, 00:30:10
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks B
10.1.1.0/24 [20/0] via 10.0.0.1, 00:02:33
C        10.0.0.0/30 is directly connected, Serial0/0/0 C
192.168.0.0/24 is directly connected, Loopback0
C     192.168.1.0/24 is directly connected, Loopback1
B     192.168.100.0/24 [20/0] via 10.0.0.1, 00:02:33
```

d. On the ITA router, configure the **ip default-network** statement to reestablish a gateway of last resort.

```
ITA(config)# ip default-network 192.168.100.0
```

Note: The behavior of this command is oriented toward legacy classful protocols and should be used only with classful networks.

e. Wait a few moments and then reexamine the routing table on ITA.

```
ITA# show ip route
<output omitted>

Gateway of last resort is 10.0.0.1 to network 192.168.100.0
      172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C        172.16.0.0/30 is directly connected, Serial0/0/1
B        172.16.1.0/24 [20/0] via 172.16.0.1, 00:32:55
      10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B        10.1.1.0/24 [20/0] via 10.0.0.1, 00:05:19
C        10.0.0.0/30 is directly connected, Serial0/0/0 C
         192.168.0.0/24 is directly connected, Loopback0
C     192.168.1.0/24 is directly connected, Loopback1 B*
192.168.100.0/24 [20/0] via 10.0.0.1, 00:05:19
```

This establishes ISP1 as the only default route.

f. Make ISP2 the backup ISP by adding a backup route on ITA to ISP2 serial 0/0/1 interface 172.16.0.1.

```
ITA(config)# ip route 0.0.0.0 0.0.0.0 172.16.0.1 220
```

EBGP learned routes have an administrative distance of 20 and are preferred over any routes with an administrative distance greater than 20, such as the default route defined above with an administrative

distance of 220. The default route acts as a backup if the 192.168.100.0 /24 network is unavailable because of a fault or misconfiguration, or during the short period after a **clear ip bgp 10.0.0.1** command is issued.

g. Verify that this newly added route establishes a consistent default route while the BGP conversation between ITA and ISP1 reestablishes. Notice that the routing table includes two candidate default routes (*), only one of which is used because of different administrative distances.

```
ITA# show ip route
<output omitted>

Gateway of last resort is 10.0.0.1 to network 192.168.100.0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/1
B       172.16.1.0/24 [20/0] via 172.16.0.1, 00:35:42
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks  B
10.1.1.0/24 [20/0] via 10.0.0.1, 00:08:05
C       10.0.0.0/30 is directly connected, Serial0/0/0  C
192.168.0.0/24 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, Loopback1
B*   192.168.100.0/24 [20/0] via 10.0.0.1, 00:08:05
                                           S*   0.0.0.0/0 [220/0] via
                                           172.16.0.1


ITA# clear ip bgp 10.0.0.1
ITA# show ip route
<output omitted>

Gateway of last resort is 172.16.0.1 to network 0.0.0.0

     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/1
B       172.16.1.0/24 [20/0] via 172.16.0.1, 00:36:46
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B       10.1.1.0/24 [20/0] via 10.0.0.1, 00:00:00
C       10.0.0.0/30 is directly connected, Serial0/0/0  C
        192.168.0.0/24 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, Loopback1
B    192.168.100.0/24 [20/0] via 10.0.0.1, 00:00:00
S*   0.0.0.0/0 [220/0] via 172.16.0.1


ITA# show ip route
<output omitted>

Gateway of last resort is 10.0.0.1 to network 192.168.100.0
     172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.16.0.0/30 is directly connected, Serial0/0/1
B       172.16.1.0/24 [20/0] via 172.16.0.1, 00:38:05
     10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
B       10.1.1.0/24 [20/0] via 10.0.0.1, 00:01:19
C       10.0.0.0/30 is directly connected, Serial0/0/0  C
        192.168.0.0/24 is directly connected, Loopback0
C    192.168.1.0/24 is directly connected, Loopback1
B*   192.168.100.0/24 [20/0] via 10.0.0.1, 00:01:19
                                           S*   0.0.0.0/0 [220/0] via
                                           172.16.0.1
```

As expected, while the BGP conversation was down between ITA and ISP1, the route to ISP2 was added as the gateway of last resort. However, when BGP reestablished the conversation between ITA and ISP1, the default route of 192.168.100.0 was again set as the gateway of last resort on ITA.

h. Run the following Tcl script on router ITA to verify connectivity.

```
ITA# tclsh
 foreach address
{
10.0.0.1
10.0.0.2
10.1.1.1
172.16.0.1
172.16.0.2
172.16.1.1
192.168.0.1
192.168.1.1
192.168.100.1
} { ping
$address }
```

Should ISP1 and ISP2 be able to ping all networks in the topology?

_____

_____

_____

_____

_____

No. Router ITA has been configured with route filters and does not advertise the ISP1 networks to ISP2 and vice versa. The ITA router advertises only ITA networks 192.168.0.0 and 192.168.1.0 to both providers. Pings from ISP1 to any of the ISP2 172.16.x.x networks will fail. Pings from ISP2 to any of the ISP1 10.x.x.x networks will fail.

Note: Another option for setting up default routing is to inject a default route via BGP. The following example configures the ISP1 router to inject a default route to itself that can be used by the ITA router:

```
ISP1(config)# router bgp 200
ISP1(config-router)# neighbor 10.0.0.2 default-originate
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations (Instructor version)

Router ISP1 (R1)

```
hostname ISP1 ! interface Loopback0
description ISP1 Internet network  ip
address  10.1.1.1 255.255.255.0 !
interface Loopback100  ip address
192.168.100.1 255.255.255.0 ! interface
Serial0/0/0  description ISP1 -> ITA
ip address 10.0.0.1 255.255.255.252
clock rate 128000  no shutdown ! router
bgp 200  no synchronization  network
10.1.1.0 mask 255.255.255.0  network
192.168.100.0  neighbor 10.0.0.2
remote-as 100  no auto-summary ! end
```

Router ITA (R2)

```
hostname ITA ! interface Loopback0
description Core router network link 1
ip address 192.168.0.1 255.255.255.0
!
interface Loopback1  description Core
router network link 2  ip address
192.168.1.1 255.255.255.0 !
interface Serial0/0/0  description
ITA -> ISP1  ip address 10.0.0.2
255.255.255.252  no shutdown !
interface Serial0/0/1  description ITA
-> ISP2  ip address 172.16.0.2
255.255.255.252  clock rate 128000  no
shutdown
!        router bgp 100  no
synchronization  network 192.168.0.0
network 192.168.1.0  neighbor 10.0.0.1
remote-as 200  neighbor 10.0.0.1
distribute-list 1 out  neighbor
172.16.0.1 remote-as 300  neighbor
172.16.0.1 distribute-list 1 out  no
auto-summary ! ip default-network
192.168.100.0 ip route 0.0.0.0 0.0.0.0
172.16.0.1 220 !
access-list 1 permit 192.168.0.0 0.0.1.255
! end
```

Router ISP2 (R3)

```
hostname ISP2 ! interface Loopback0
description ISP2 Internet Network
ip address 172.16.1.1 255.255.255.0
!
interface Serial0/0/1  description
ISP2 -> ITA  ip address 172.16.0.1
255.255.255.252  no shutdown ! router
bgp 300  no synchronization  network
```

```
172.16.1.0 mask 255.255.255.0
neighbor 172.16.0.2 remote-as 100  no
auto-summary ! end
```

4-2, Using the AS_PATH Attribute **Instructor Version**

Topology
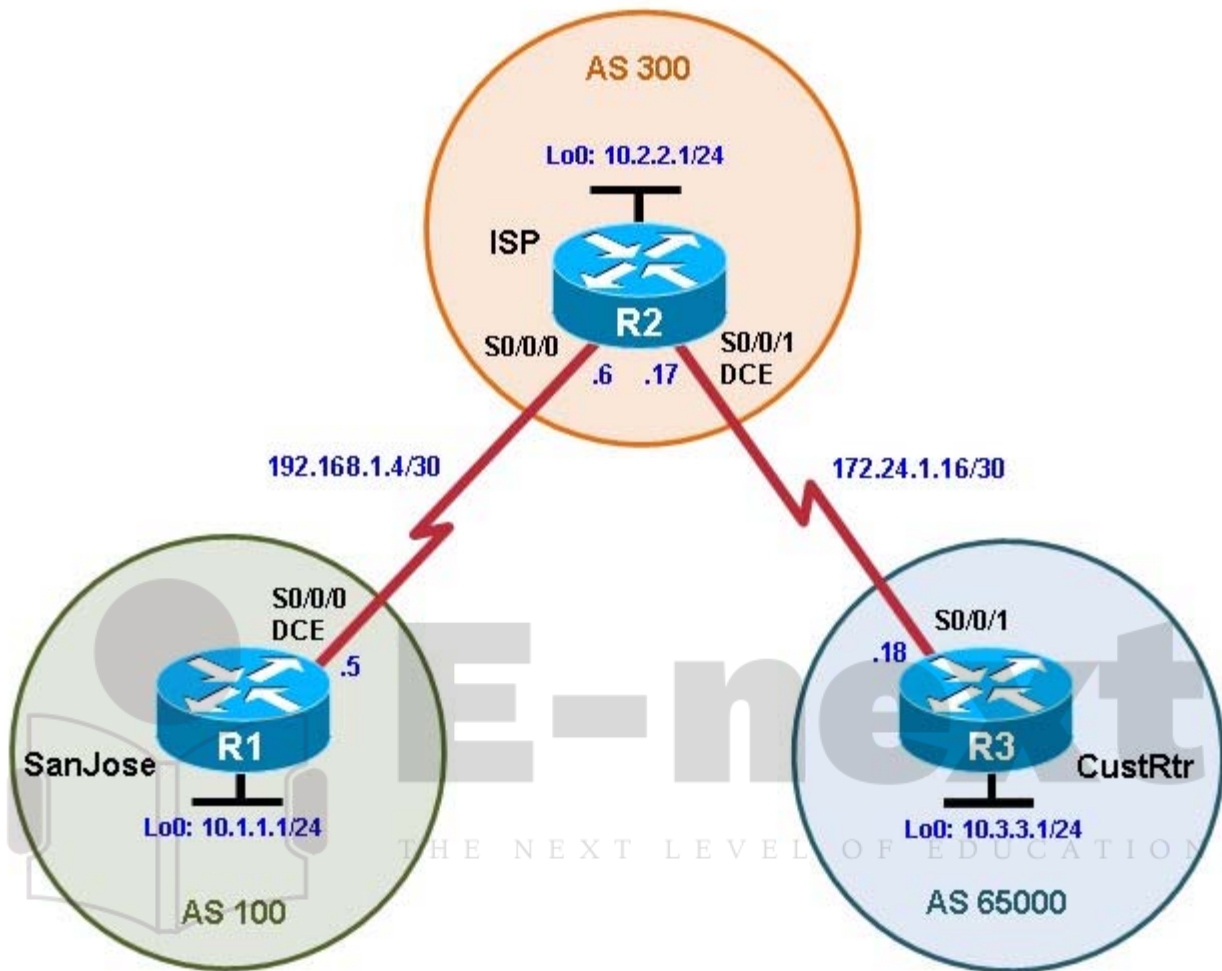
Objectives

- Use BGP commands to prevent private AS numbers from being advertised to the outside world.
- Use the AS_PATH attribute to filter BGP routes based on their source AS numbers.

Background

The International Travel Agency's ISP has been assigned an AS number of 300. This provider uses BGP to exchange routing information with several customer networks. Each customer network is assigned an AS number from the private range, such as AS 65000. Configure the ISP router to remove the private AS numbers from the AS Path information of CustRtr. In addition, the ISP would like to prevent its customer networks from receiving route information from International Travel Agency's AS 100. Use the AS_PATH attribute to implement this policy.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as 2801 or 2811) and Cisco IOS Software versions, if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- • 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- • Serial and console cables

Step 1: Prepare the routers for the lab.

Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear previous configurations.

Step 2: Configure the hostname and interface addresses.

a. You can copy and paste the following configurations into your routers to begin.

Router R1 (hostname SanJose) `hostname SanJose`

```
! interface
Loopback0
 ip address 10.1.1.1 255.255.255.0
! interface
Serial0/0/0
 ip address 192.168.1.5 255.255.255.252
clock rate 128000  no shutdown
```

Router R2 (hostname ISP) `hostname`

```
ISP
! interface
Loopback0
 ip address 10.2.2.1 255.255.255.0
! interface
Serial0/0/0
 ip address 192.168.1.6 255.255.255.252
no shutdown
!
interface Serial0/0/1
 ip address 172.24.1.17 255.255.255.252
clock rate 128000  no shutdown
```

Router R3 (hostname CustRtr)

```
hostname CustRtr
! interface
Loopback0
 ip address 10.3.3.1 255.255.255.0
! interface
Serial0/0/1
 ip address 172.24.1.18 255.255.255.252
no shutdown
```

b. Use **ping** to test the connectivity between the directly connected routers.

Note: SanJose will not be able to reach either ISP's loopback (10.2.2.1) or CustRtr's loopback (10.3.3.1), nor will it be able to reach either end of the link joining ISP to CustRtr (172.24.1.17 and 172.24.1.18).

Step 3: Configure BGP.

a. Configure BGP for normal operation. Enter the appropriate BGP commands on each router so that they identify their BGP neighbors and advertise their loopback networks.

```
SanJose(config)# router bgp 100
```

```
SanJose(config-router)# neighbor 192.168.1.6 remote-as 300
SanJose(config-router)# network 10.1.1.0 mask 255.255.255.0

ISP(config)# router bgp 300
ISP(config-router)# neighbor 192.168.1.5 remote-as 100
ISP(config-router)# neighbor 172.24.1.18 remote-as 65000
ISP(config-router)# network 10.2.2.0 mask 255.255.255.0

CustRtr(config)# router bgp 65000
CustRtr(config-router)# neighbor 172.24.1.17 remote-as 300
CustRtr(config-router)# network 10.3.3.0 mask 255.255.255.0
```

b. Verify that these routers have established the appropriate neighbor relationships by issuing the **show ip bgp neighbors** command on each router.

```
ISP# show ip bgp neighbors
BGP neighbor is 172.24.1.18,  remote AS 65000, external link
  BGP version 4, remote router ID 10.3.3.1
BGP state = Established, up for 00:02:05
<output omitted>

BGP neighbor is 192.168.1.5,  remote AS 100, external link
  BGP version 4, remote router ID 10.1.1.1
  BGP state = Established, up for 00:04:19
<output omitted>
```

Step 4: Remove the private AS.

a. Display the SanJose routing table using the **show ip route** command. SanJose should have a route to both 10.2.2.0 and 10.3.3.0. Troubleshoot if necessary.

```
SanJose# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-
2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     10.0.0.0/24 is subnetted, 3 subnets
B      10.3.3.0 [20/0] via 192.168.1.6, 00:01:11 B
       10.2.2.0 [20/0] via 192.168.1.6, 00:02:16
C      10.1.1.0 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 1 subnets
C      192.168.1.4 is directly connected, Serial0/0/0
```

b. Ping the 10.3.3.1 address from SanJose.

Why does this fail?

_____

_____

This fails because SanJose sources the ping with its closest connected interface s0/0/0 with IP address

192.168.1.5. CustRtr does not have a route back to that interface, so the ping replies cannot return to SanJose.

c. Ping again, this time as an extended ping, sourcing from the Loopback0 interface address.

```
SanJose# ping
Protocol [ip]:
Target IP address: 10.3.3.1
Repeat count [5]:
Datagram size [100]:
Timeout in seconds [2]:
Extended commands [n]: y
Source address or interface: 10.1.1.1
Type of service [0]:
Set DF bit in IP header? [no]:
Validate reply data? [no]:
Data pattern [0xABCD]:
Loose, Strict, Record, Timestamp, Verbose[none]:
Sweep range of sizes [n]:
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/64/68 ms
```

Note: You can bypass extended ping mode and specify a source address using one of these commands:

```
SanJose# ping 10.3.3.1 source 10.1.1.1
```

or

```
SanJose# ping 10.3.3.1 source Lo0
```

d. Check the BGP table from SanJose by using the **show ip bgp** command. Note the AS path for the 10.3.3.0 network. The AS 65000 should be listed in the path to 10.3.3.0.

```
SanJose# show ip bgp

BGP table version is 5, local router ID is 10.1.1.1
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal   Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop          Metric LocPrf Weight Path
*> 10.1.1.0         0.0.0.0                0         32768 i
*> 10.2.2.0         192.168.1.6            0             0 300 i   *>
10.3.3.0           192.168.1.6                          0 300 65000 i
```

Why is this a problem?

_____

_____

AS 65000 is a private AS, which should not be publicly advertised on the Internet. Otherwise, clients of two interconnected ISPs having the same private AS number would see their own AS in the route advertisements of each other. As a result, each client would incorrectly conclude that the advertisement came from itself and it would ignore it.

e. Configure ISP to strip the private AS numbers from BGP routes exchanged with SanJose using the following commands.

```
ISP(config)# router bgp 300
ISP(config-router)# neighbor 192.168.1.5 remove-private-as
```

f. After issuing these commands, use the **clear ip bgp *** command on ISP to reestablish the BGP
    relationship between the three routers. Wait several seconds and then return to SanJose to check its
    routing table.

    Note: The **clear ip bgp * soft** command can also be used to force each router to resend its BGP table.

    Does SanJose still have a route to 10.3.3.0?

    _____

    _ Yes, learned via BGP from ISP 192.168.1.6. SanJose should be able to ping 10.3.3.1 using its

    loopback 0 interface as the source of the ping.

    ```
    SanJose# ping 10.3.3.1 source lo0

    Type escape sequence to abort.
    Sending 5, 100-byte ICMP Echos to 10.3.3.1, timeout is 2 seconds: Packet
    sent with a source address of 10.1.1.1
    !!!!!
    Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
    ```

g. Now check the BGP table on SanJose. The AS_ PATH to the 10.3.3.0 network should be AS 300. It no
    longer has the private AS in the path.

    ```
    SanJose# show ip bgp

    BGP table version is 8, local router ID is 10.1.1.1
    Status codes: s suppressed, d damped, h history, * valid, > best, i -
    internal   Origin codes: i - IGP, e - EGP, ? - incomplete


       Network          Next Hop          Metric LocPrf Weight Path
    *> 10.1.1.0         0.0.0.0                0          32768 i
    *> 10.2.2.0         192.168.1.6            0              0 300 i
    *> 10.3.3.0         192.168.1.6                           0 300 i
    ```

Step 5: Use the AS_PATH attribute to filter routes.

As a final configuration, use the AS_PATH attribute to filter routes based on their origin. In a complex
environment, you can use this attribute to enforce routing policy. In this case, the provider router, ISP, must
be configured so that it does not propagate routes that originate from AS 100 to the customer router CustRtr.

AS-path access lists are read like regular access lists. The statements are read sequentially, and there is an
implicit deny at the end. Rather than matching an address in each statement like a conventional access list,
AS path access lists match on something called a regular expression. Regular expressions are a way of
matching text patterns and have many uses. In this case, you will be using them in the AS path access list to
match text patterns in AS paths.

a. Configure a special kind of access list to match BGP routes with an AS_PATH attribute that both begins
    and ends with the number 100. Enter the following commands on ISP.

    ```
    ISP(config)# ip as-path access-list 1 deny ^100$ ISP(config)#
    ip as-path access-list 1 permit .*
    ```

    The first command uses the **^** character to indicate that the AS path must begin with the given number
    100. The **$** character indicates that the AS_PATH attribute must also end with 100. Essentially, this

statement matches only paths that are sourced from AS 100. Other paths, which might include AS 100 along the way, will not match this list.

In the second statement, the **.** (period) is a wildcard, and the ***** (asterisk) stands for a repetition of the wildcard. Together, **.*** matches any value of the AS_PATH attribute, which in effect permits any update that has not been denied by the previous **access-list** statement.

For more details on configuring regular expressions on Cisco routers, see:

http://www.cisco.com/en/US/docs/ios/12_2/termserv/configuration/guide/tcfaapre_ps1835_TSD_Products_Configuration_Guide_Chapter.html

b. Apply the configured access list using the **neighbor** command with the **filter-list** option.

```
ISP(config)# router bgp 300
ISP(config-router)# neighbor 172.24.1.18 filter-list 1 out
```

The **out** keyword specifies that the list is applied to routing information sent to this neighbor.

c. Use the **clear ip bgp *** command to reset the routing information. Wait several seconds and then check the routing table for ISP. The route to 10.1.1.0 should be in the routing table.

Note: To force the local router to resend its BGP table, a less disruptive option is to use the **clear ip bgp * out** or **clear ip bgp * soft** command (the second command performs both outgoing and incoming route resync).

```
ISP# show ip route
<output omitted>


     172.24.0.0/30 is subnetted, 1 subnets
C       172.24.1.16 is directly connected, Serial0/0/1
     10.0.0.0/24 is subnetted, 3 subnets
B       10.3.3.0 [20/0] via 172.24.1.18, 00:07:34
C       10.2.2.0 is directly connected, Loopback0
B       10.1.1.0 [20/0] via 192.168.1.5, 00:10:53
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0/0
```

d. Check the routing table for CustRtr. It should not have a route to 10.1.1.0 in its routing table.

```
CustRtr# show ip route
<output omitted>


     172.24.0.0/30 is subnetted, 1 subnets
C       172.24.1.16 is directly connected, Serial0/0/1
     10.0.0.0/24 is subnetted, 2 subnets
C       10.3.3.0 is directly connected, Loopback0
B       10.2.2.0 [20/0] via 172.24.1.17, 00:11:57
```

e. Return to ISP and verify that the filter is working as intended. Issue the **show ip bgp regexp ^100$** command.

```
ISP# show ip bgp regexp ^100$
BGP table version is 4, local router ID is 10.2.2.1
Status codes: s suppressed, d damped, h history, * valid, > best, i -
internal   Origin codes: i - IGP, e - EGP, ? - incomplete

   Network          Next Hop           Metric LocPrf Weight Path
*> 10.1.1.0         192.168.1.5             0          0 100 i
```

The output of this command shows all matches for the regular expressions that were used in the access list. The path to 10.1.1.0 matches the access list and is filtered from updates to CustRtr.

f. Run the following Tcl script on all routers to verify whether there is connectivity. All pings from ISP should be successful. SanJose should not be able to ping the CustRtr loopback 10.3.3.1 or the WAN link 172.24.1.16/30. CustRtr should not be able to ping the SanJose loopback 10.1.1.1 or the WAN link 192.168.1.4/30.

```
ISP# tclsh
 foreach address
{
10.1.1.1
10.2.2.1
10.3.3.1
192.168.1.5
192.168.1.6
172.24.1.17
172.24.1.18
} {
ping $address }
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

Device Configurations (Instructor version)

Router SanJose

```
hostname SanJose
! interface Loopback0  ip address
10.1.1.1 255.255.255.0
! ! interface Serial0/0/0  ip address
192.168.1.5 255.255.255.252  clock rate
128000  no shutdown
! router bgp 100  no synchronization
network 10.1.1.0 mask 255.255.255.0
neighbor 192.168.1.6 remote-as 300
no auto-summary
! end
```

Router ISP

```
hostname ISP
! interface Loopback0  ip address
10.2.2.1 255.255.255.0
! interface Serial0/0/0  ip address
192.168.1.6 255.255.255.252  no
shutdown
! interface Serial0/0/1  ip address
172.24.1.17 255.255.255.252  clock rate
128000  no shutdown
! router bgp 300  no synchronization
network 10.2.2.0 mask 255.255.255.0
neighbor 172.24.1.18 remote-as 65000
neighbor 172.24.1.18 filter-list 1 out
neighbor 192.168.1.5 remote-as 100
neighbor 192.168.1.5 remove-private-as
no auto-summary !
ip as-path access-list 1 deny ^100$
ip as-path access-list 1 permit .*
! end
```

Router CustRtr `hostname`

```
CustRtr
! interface Loopback0  ip address
10.3.3.1 255.255.255.0
!
interface Serial0/0/1  ip address
172.24.1.18 255.255.255.252  no
shutdown
! router bgp 65000  no
synchronization  network 10.3.3.0
mask 255.255.255.0  neighbor
172.24.1.17 remote-as 300  no auto-
summary
!
end
```

4-3, BGP Route Reflectors and Route Filters Instructor Version

Topology
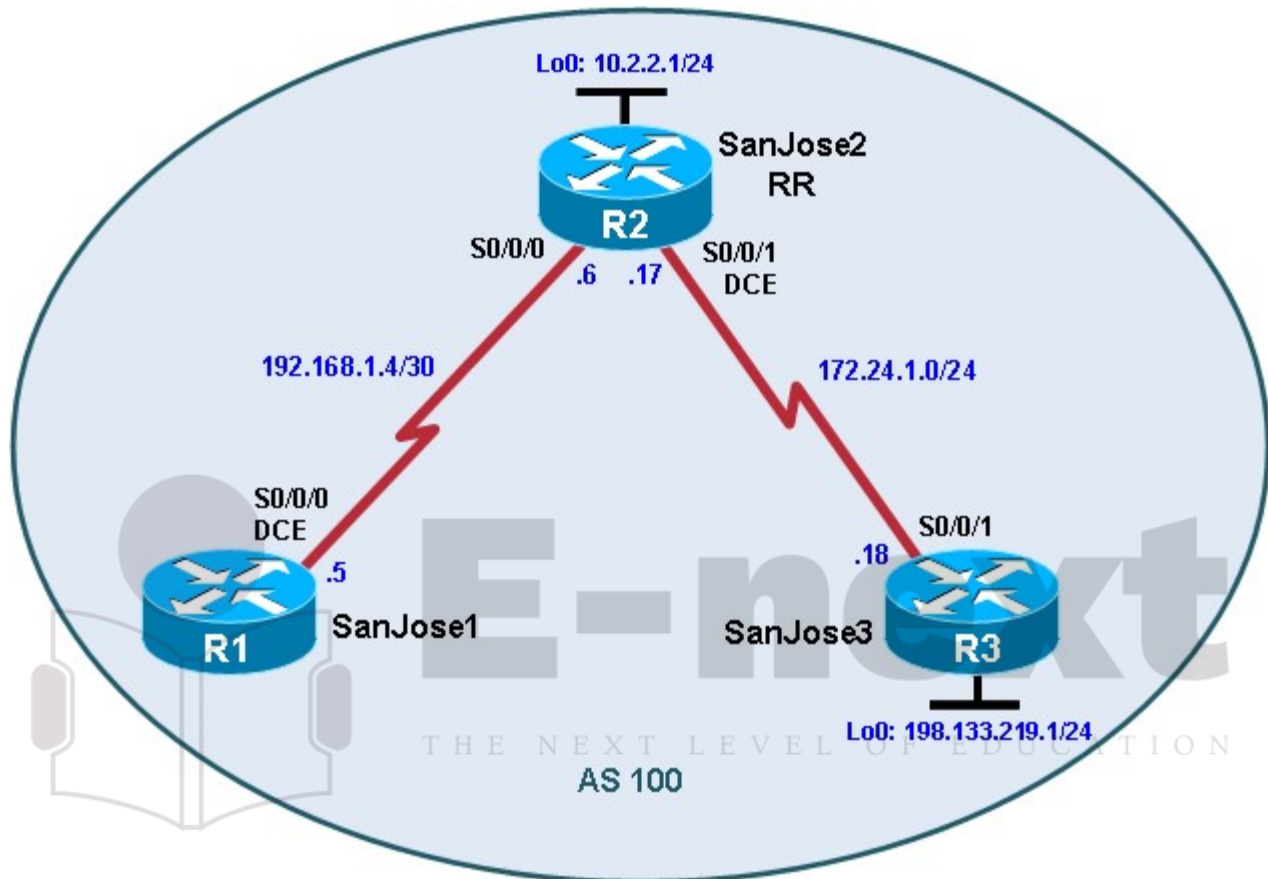
Objectives

- Configure IBGP routers to use a route reflector and a simple route filter.

Background

The International Travel Agency maintains a full-mesh IBGP network that has quickly scaled beyond 100 routers. The company wants to implement route reflectors to work around the full-mesh IBGP requirement. Configure a small cluster and observe how BGP operates in this configuration. Use IP prefix filters to control the updates between IBGP peers.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- Serial and console cables

Step 1: Prepare the routers for the lab.

Cable the network as shown in the topology diagram. Erase the startup configuration and reload each router to clear previous configurations. Do not configure Loopback 0 on SanJose3 at this time.

Step 2: Configure the hostname and interface addresses.

You can copy and paste the following configurations into your routers to begin.

Router R1 (hostname SanJose1)

```
hostname SanJose1

!
interface Serial0/0/0
 ip address 192.168.1.5 255.255.255.252
clock rate 128000  no shutdown
```

Router R2 (hostname SanJose2)

```
hostname SanJose2

! interface
Loopback0
 ip address 10.2.2.1 255.255.255.0
! interface
Serial0/0/0
 ip address 192.168.1.6 255.255.255.252
no shutdown
! interface
Serial0/0/1
 ip address 172.24.1.17 255.255.255.0
clock rate 128000  no shutdown
```

Router R3 (hostname SanJose3)

```
hostname SanJose3

!
interface Serial0/0/1
 ip address 172.24.1.18 255.255.255.0
no shutdown
```

Note: Do not configure R3 (SanJose3) with loopback 0 at this time. That will be done in a later step.

Step 3: Configure RIPv2.

a. Build and configure the network according to the diagram. Use RIPv2 as the IGP. Do not configure the 198.133.219.0 network under the RIP process.

```
SanJose1(config)# router rip
SanJose1(config-router)# version 2
SanJose1(config-router)# no auto-summary
SanJose1(config-router)# network 192.168.1.0

SanJose2(config)# router rip
SanJose2(config-router)# version 2
SanJose2(config-router)# no auto-summary
SanJose2(config-router)# network 172.24.0.0
SanJose2(config-router)# network 192.168.1.0
```

```
SanJose2(config-router)# network 10.0.0.0

SanJose3(config)# router rip
SanJose3(config-router)# version 2
SanJose3(config-router)# no auto-summary
SanJose3(config-router)# network 172.24.0.0
```

b. Issue the **show ip route** command on the routers to verify that each router has a complete routing table.

```
SanJose1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2        E1
- OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.24.0.0/24 is subnetted, 1 subnets
R       172.24.1.0 [120/1] via 192.168.1.6, 00:00:21, Serial0/0/0
     10.0.0.0/24 is subnetted, 1 subnets
R       10.2.2.0 [120/1] via 192.168.1.6, 00:00:21, Serial0/0/0
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0/0
```

c. Run the following Tcl script on all routers to verify connectivity.

```
SanJose1# tclsh
 foreach address
{
10.2.2.1
192.168.1.5
192.168.1.6
172.24.1.17
172.24.1.18

} { ping
$address }
```

Step 4: Configure IBGP peers and route reflectors.

In this lab, you will configure a route reflector. By default, a router that receives an EBGP route advertises it to its EBGP and IBGP peers. However, if it receives it through IBGP, it does not advertise it to its IBGP peers, as a loop prevention mechanism. To maintain loop prevention, a route reflector adds two optional, nontransitive BGP attributes to each reflected route, the ORIGINATOR_ID and CLUSTER_LIST. It uses these attributes in a similar way to AS_PATH list to prevent routing loops from occurring. See http://tools.ietf.org/html/rfc4456 for more information.

However, because of this behavior, the only way for all IBGP routers to receive a route after it is originated into the AS is to have a full mesh of IBGP peers. This can get complex with a large number of peers. A route reflector allows a topology to get around the IBGP limitation of having to have a full mesh. To do this, a route reflector specifies some of its neighbors as route reflector clients. When a route reflector receives an update

from a route reflector client, it can pass it on to its other clients. The route reflector would also pass that clientlearned route on to its other non-client peers (both IBGP and EBGP peers). Similarly, a route learned from a non-client peer (again, from either an IBGP or EBGP peer) would be passed on to its client peers. This greatly simplifies configuration because only the route reflector needs to know all the other peers. The clients do not even know that they are clients. To them, it is just a normal IBGP peering relationship. You can even set up multiple route reflectors in a more advanced configuration for redundancy.

a. Configure the IBGP peers for BGP. Later, you will configure SanJose2 as the route reflector. However, first configure it to peer with both of the other routers.

```
SanJose2(config)# router bgp 100
SanJose2(config-router)# neighbor 192.168.1.5 remote-as 100
SanJose2(config-router)# neighbor 172.24.1.18 remote-as 100
```

After SanJose2 is configured, configure the other two routers as route reflector clients. Remember that to set up clients simply, configure peering between the client and the server. IBGP does not need to be configured in a full mesh.

b. Issue the following commands on SanJose1:

```
SanJose1(config)# router bgp 100
SanJose1(config-router)# neighbor 192.168.1.6 remote-as 100
```

c. Issue the following commands on SanJose3:

```
SanJose3(config)# router bgp 100
SanJose3(config-router)# neighbor 172.24.1.17 remote-as 100
```

d. Use the **show ip bgp neighbors** command to verify that SanJose2 has established a peering relationship with both SanJose1 and SanJose3. Troubleshoot as necessary.

```
SanJose2# show ip bgp neighbors
BGP neighbor is 172.24.1.18,  remote AS 100, internal link
  BGP version 4, remote router ID 172.24.1.18
  BGP state = Established, up for 00:02:10

<output omitted>

BGP neighbor is 192.168.1.5,  remote AS 100, internal link
  BGP version 4, remote router ID 192.168.1.5
BGP state = Established, up for 00:04:15
```

SanJose1 and SanJose3 should not have established a connection. Why?

_____

_____

No neighbor statements were created for that adjacency. Therefore, the routers will not attempt to bring up that adjacency.

SanJose1 and SanJose3 were not configured with the appropriate BGP **neighbor** command. As route reflector clients, SanJose1 and SanJose3 do not need to reach an established state.

Step 5: Inject a network into BGP.

a. To observe the full effect of using a route reflector, configure SanJose3 to inject external routing information into BGP.

```
SanJose3(config)# interface loopback 0
SanJose3(config-if)# ip address 198.133.219.1 255.255.255.0
```

```
SanJose3(config-if)# router bgp 100
SanJose3(config-router)# network 198.133.219.0
```

This configuration forces SanJose3 to inject the external route 198.133.219.0 into BGP. Use the **show ip route** command to check if SanJose2 has picked up this route through BGP. SanJose2 should have a route to 198.133.219.0.

```
SanJose2# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     172.24.0.0/24 is subnetted, 1 subnets
C       172.24.1.0 is directly connected, Serial0/0/1
10.0.0.0/24 is subnetted, 1 subnets
C       10.2.2.0 is directly connected, Loopback0
B       198.133.219.0/24 [200/0] via 172.24.1.18, 00:01:48
C       10.2.2.0 is directly connected, Loopback0
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0/0
```

What is the next hop for this route? Explain.

_____

_____

The next hop is 172.24.1.18 because that is the source IP address used on SanJose3 to establish BGP adjacency with SanJose2.

b. Verify that you can ping 198.133.219.1 from SanJose2. If not, troubleshoot.

c. Check the routing table of SanJose1. There should not be a route to 198.133.219.0. Why?

_____

_____

The default behavior of IBGP is to not advertise routes received through IBGP to other IBGP peers.

d. Remember that SanJose1 is not configured to peer with SanJose3. To eliminate the need for a full IBGP mesh, SanJose2 must be configured as a route reflector. Issue the following commands on SanJose2:

```
SanJose2(config)# router bgp 100
SanJose2(config-router)# neighbor 192.168.1.5 route-reflector-client
SanJose2(config-router)# neighbor 172.24.1.18 route-reflector-client
*Mar  9 19:02:27.831: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Down RR client
conf ig change
*Mar  9 19:02:27.931: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Down RR client
conf ig change
*Mar  9 19:02:32.387: %BGP-5-ADJCHANGE: neighbor 172.24.1.18 Up
*Mar  9 19:02:37.507: %BGP-5-ADJCHANGE: neighbor 192.168.1.5 Up
```

e. Verify that an IBGP cluster was successfully created by issuing the **show ip protocols** command on SanJose2. The output of this command should indicate that SanJose2 is a route reflector.

```
SanJose2# show ip protocols
Routing Protocol is "rip"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Sending updates every 30 seconds, next due in 26 seconds
  Invalid after 180 seconds, hold down 180, flushed after 240
  Redistributing: rip
  Default version control: send version 2, receive version 2
    Interface              Send  Recv  Triggered RIP  Key-chain
    Serial0/0/0             2     2
Serial0/0/1              2     2
    Loopback0              2     2
  Automatic network summarization is not in effect
  Maximum path: 4
  Routing for Networks:
    10.0.0.0
    172.24.0.0
    192.168.1.0
  Routing Information Sources:
    Gateway         Distance      Last Update
  Distance: (default is 120)


Routing Protocol is "bgp 100"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Route Reflector for address family IPv4 Unicast, 2 clients
  Route Reflector for address family IPv6 Unicast, 2 clients
Route Reflector for address family IPv4 MDT, 2 clients
  Route Reflector for address family VPNv4 Unicast, 2 clients
  Route Reflector for address family VPNv6 Unicast, 2 clients
  Route Reflector for address family IPv4 Multicast, 2 clients
  Route Reflector for address family IPv6 Multicast, 2 clients
  Route Reflector for address family NSAP Unicast, 2 clients
  IGP synchronization is disabled
  Automatic route summarization is disabled
  Neighbor(s):
    Address          FiltIn FiltOut DistIn DistOut Weight RouteMap
    172.24.1.18
    192.168.1.5
  Maximum path: 1
  Routing Information Sources:
    Gateway         Distance      Last Update
172.24.1.18          200       00:01:43  Distance:
external 20 internal 200 local 200
```

How many clients does SanJose2 have?

_____

SanJose2 has two clients.

f. Issue the **show ip protocols** command on SanJose1. The output of this command does not include information about route reflectors. Remember that SanJose1 is a client and not a route reflector server, so it is unaware of route reflection.

g. Finally, verify that route reflection is working by checking the routing table on SanJose1. SanJose1 will have a route to network 198.133.219.0.

```
SanJose1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route


Gateway of last resort is not set


     172.24.0.0/24 is subnetted, 1 subnets
R       172.24.1.0 [120/1] via 192.168.1.6, 00:00:08, Serial0/0/0
     10.0.0.0/24 is subnetted, 1 subnets
R       10.2.2.0 [120/1] via 192.168.1.6, 00:00:08, Serial0/0/0
B       198.133.219.0/24 [200/0] via 172.24.1.18, 00:01:25
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0/0
```

Is 172.24.1.18 the IP address of the next hop of this route on the SanJose1 table? Explain.

_____

_____

Yes, because the default behavior of IBGP is to not change the next-hop address.

Notice that SanJose1 is not directly connected to the IP network for the next hop. Why? **Hint:** From which router did SanJose1 learn the route?

_____

_____

The default behavior of IBGP is to not change the next-hop address. The actual next hop is R2 S0/0/0 192.168.1.6.

h. Ping 198.133.219.1 from SanJose1. This ping should be successful.

Notice that SanJose1 pings to R3 198.133.219.1 are successful even though the next-hop address is not on a directly-connected network. For example, the next-hop address could be 192.168.1.6 on R2 if it were not for the behavior of IBGP.

Step 6: Inject a summary address into BGP.

a. For the purpose of this lab, configure SanJose3 to inject a summary address into BGP.

```
SanJose3(config)# router bgp 100
SanJose3(config-router)# aggregate-address 198.0.0.0 255.0.0.0
```

BGP should now send the supernet route 198.0.0.0.0/8 to SanJose2 with the attribute ATOMIC_AGGREGATE set.

Note: By default, BGP on Cisco routers advertises both aggregate routes and the individual component routes. If only the aggregate route is to be advertised, use the **aggregate-address** *network mask* **summary-only** command.

b. On SanJose2, issue the following command:

```
SanJose2# show ip bgp 198.0.0.0
BGP routing table entry for 198.0.0.0/8, version 8
Paths: (1 available, best #1, table Default-IP-Routing-Table)
Flag: 0x820
  Advertised to update-groups:
1
  Local, (aggregated by 100 172.24.1.18), (Received from a RR-client)
    172.24.1.18 from 172.24.1.18 (172.24.1.18)
    Origin IGP, metric 0, localpref 100, valid, internal, atomic-aggregate,
best
```

According to the output of this command, which address aggregated this route?

_____

The address that aggregated the route is 172.24.1.18.

What indicates that route reflection is involved in this process?

_____

The output states that it was received from a route reflector client.

Is there an indication that the ATOMIC_AGGREGATE attribute has been set?

_____

Yes. In the list of attributes at the end of the output, the tag atomic-aggregate appears.

c. SanJose2 should, in turn, reflect this route to SanJose1. Check both the routing table and BGP table on SanJose1 to be sure. Both the route to 198.133.219.0 and the supernet route 198.0.0.0 should be installed in the SanJose1 routing table and the BGP table.

```
SanJose1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static
route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.24.0.0/24 is subnetted, 1 subnets
R       172.24.1.0 [120/1] via 192.168.1.6, 00:00:20, Serial0/0/0
     10.0.0.0/24 is subnetted, 1 subnets
R       10.2.2.0 [120/1] via 192.168.1.6, 00:00:20, Serial0/0/0
B     198.133.219.0/24 [200/0] via 172.24.1.18, 00:08:34
192.168.1.0/30 is subnetted, 1 subnets
C     192.168.1.4 is directly connected, Serial0/0/0 B
198.0.0.0/8 [200/0] via 172.24.1.18, 00:04:19
```

The International Travel Agency has decided to filter specific routes to the 198.0.0.0/8 address space. Configure a route filter to prevent SanJose2 from sending the 198.133.219.0/24 route to its other clients, in this case to SanJose1.

d.   Issue the following commands on SanJose2:

```
SanJose2(config)# ip prefix-list SUPERNETONLY permit 198.0.0.0/8
SanJose2(config)# router bgp 100
SanJose2(config-router)# neighbor 192.168.1.5 prefix-list SUPERNETONLY out
```

e.   Return to SanJose1, issue the **clear ip bgp * soft** command, and verify that the prefix list has done its job by issuing a **show ip bgp** command. Troubleshoot as necessary.

Unlike before, where routes to 198.133.219.0 and 198.0.0.0 were present, now only one route to 198.0.0.0 in the routing and BGP tables should be seen. Troubleshoot as necessary.

```
SanJose1# show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.24.0.0/24 is subnetted, 1 subnets
R       172.24.1.0 [120/1] via 192.168.1.6, 00:00:20, Serial0/0/0
     10.0.0.0/24 is subnetted, 1 subnets
R       10.2.2.0 [120/1] via 192.168.1.6, 00:00:20, Serial0/0/0
     192.168.1.0/30 is subnetted, 1 subnets
C       192.168.1.4 is directly connected, Serial0/0/0 B
198.0.0.0/8 [200/0] via 172.24.1.18, 00:04:19
```

f.   Run the following Tcl script on all routers to verify full connectivity. All pings should be successful.

```
SanJose1# tclsh
 foreach address
{ 10.2.2.1
198.133.219.1 192.168.1.5
192.168.1.6
172.24.1.17
172.24.1.18

} { ping
$address }
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2

1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)

Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than try to list all the combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. An example of this is an ISDN BRI interface. The string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.

Device Configurations (Instructor version)

Router SanJose1 (R1)

```
hostname SanJose1
! interface
Serial0/0/0
 ip address 192.168.1.5 255.255.255.252
clock rate 128000  no shutdown
!         router
rip  version 2
network 192.168.1.0
no auto-summary
!
router bgp 100  no synchronization
neighbor 192.168.1.6 remote-as 100
no auto-summary
! end
```

Router SanJose2 (R2)

```
hostname SanJose2
! interface Loopback0   ip address
10.2.2.1 255.255.255.0
! interface
Serial0/0/0
 ip address 192.168.1.6 255.255.255.252
no shutdown
! interface Serial0/0/1  ip address
172.24.1.17 255.255.255.0  clock rate
128000  no shutdown
!
router rip  version
2  network
172.24.0.0  network
192.168.1.0  network
10.0.0.0  no auto-
summary
!
router bgp 100  no synchronization  neighbor
172.24.1.18 remote-as 100   neighbor 172.24.1.18 route-
reflector-client   neighbor 192.168.1.5 remote-as 100
neighbor 192.168.1.5 route-reflector-client   neighbor
192.168.1.5 prefix-list SUPERNETONLY out   no auto-
summary ! ip prefix-list SUPERNETONLY seq 5 permit
198.0.0.0/8 ip prefix-list SUPERNETONLY seq 10 permit
172.24.1.0/24 ip prefix-list SUPERNETONLY seq 15
permit 10.2.2.0/24 ! end
```

Router SanJose3 (R3)

```
hostname SanJose3
! interface
Loopback0
```

```
 ip address 198.133.219.1 255.255.255.0
! interface Serial0/0/1  ip address
172.24.1.18 255.255.255.0  no
shutdown
!
router rip  version 2  network
172.24.0.0  no auto-summary ! router
bgp 100  no synchronization  network
198.133.219.0   aggregate-address
198.0.0.0 255.0.0.0  neighbor
172.24.1.17 remote-as 100  no auto-
summary end
```

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Chapter 8 Lab 8-1, Configuring OSPF for IPv6 Instructor Version

Topology
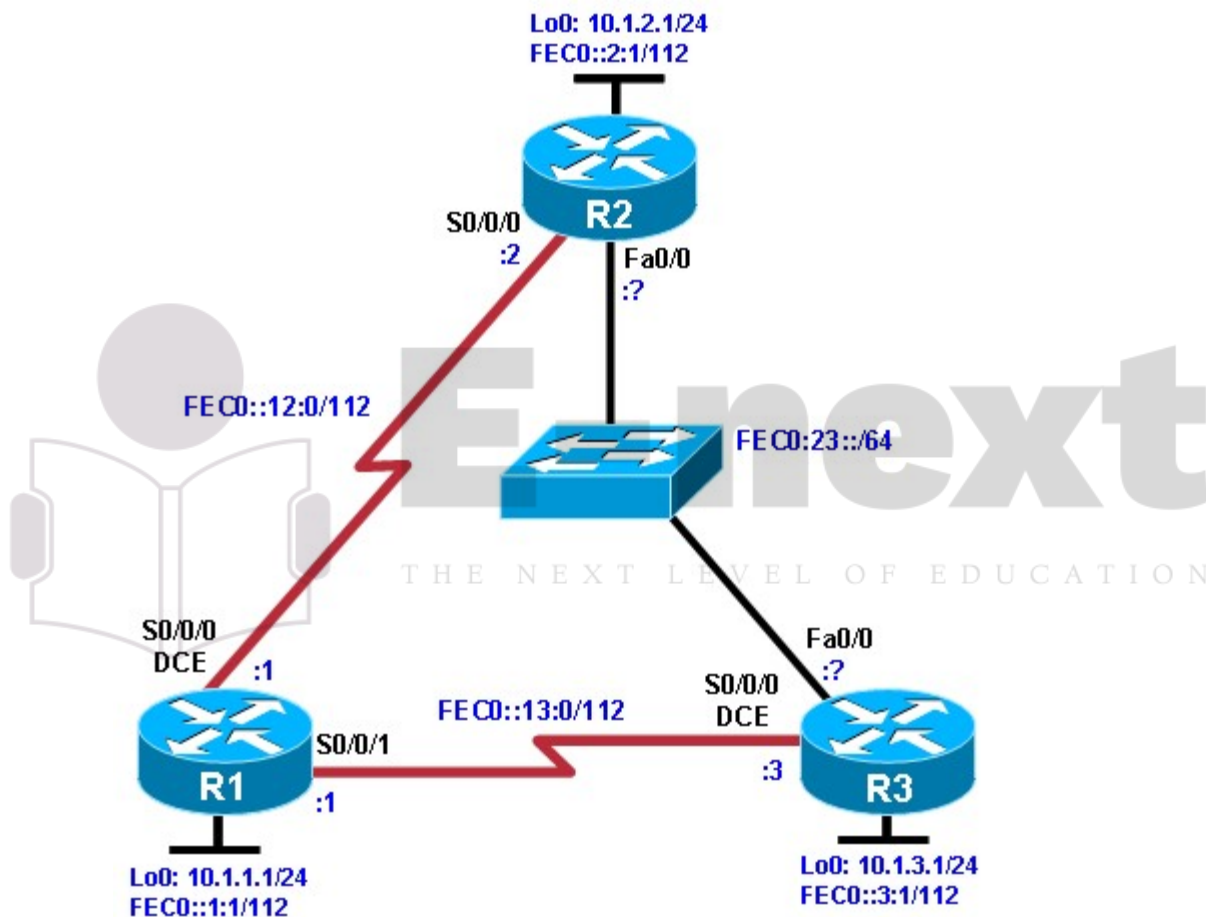
Objectives

- Configure a static IPv6 address on an interface.
- Change the default link-local address on an interface.
- Configure an EUI-64 IPv6 address on an interface.
- Enable IPv6 routing and CEF.
- Configure and verify single-area OSPFv3 operation.

Background

In this lab, you configure static IPv6 addresses and EUI-64 IPv6 addresses on interfaces. You then configure OSPFv3 to route between the IPv6 networks.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services

Image c1841-advipservicesk9-mz.124-24.T1.bin. The switch is a Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin. You can use other routers (such as a 2801 or 2811), switches (such as 2950), and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router or switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- 1 switch (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- Serial and Ethernet cables

Step 1: Prepare the routers for the lab.

Cable the network as shown in the topology diagram. Erase the startup configuration, and reload each router to clear the previous configurations.

Step 2: Configuring the hostname and loopback interfaces.

Configure the loopback interface on each router with both the IPv4 address and IPv6 address shown in the diagram. The IPv4 address is configured using the **ip address** *address mask* command. The IPv6 address configuration is similar, using the **ipv6 address** *address/mask* command. With IPv6 addresses, you can enter the mask length in bits with a decimal /mask, rather than entering the whole mask out in hexadecimal.

IPv6 addresses consist of eight groups of 16 bits (four hexadecimal characters) separated by colons. You can also enter the IPv6 address in an abbreviated form. For example, you can abbreviate any continuous group of zeros with two colons ":". However, you can only use this abbreviation once per address. Also, leading zeros in each group can be omitted. For example, FEC0:0:0:0:0:0:12:1 /112 can be shortened to FEC0::12:1 /112.

```
Router(config)# hostname R1
R1(config)# interface loopback0
R1(config-if)# ip address 10.1.1.1 255.255.255.0 R1(config-
if)# ipv6 address FEC0::1:1/112

Router(config)# hostname R2
R2(config)# interface loopback0
R2(config-if)# ip address 10.1.2.1 255.255.255.0 R2(config-
if)# ipv6 address FEC0::2:1/112

Router(config)# hostname R3
R3(config)# interface loopback0
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# ipv6 address FEC0::3:1/112
```

If you accidentally enter the wrong IPv6 address on an interface, make sure you remove it with the **no** version of the command that you entered. Unlike IPv4 addresses, where the **ip address** command overwrites the existing address, multiple IPv6 addresses can exist on an interface. Issuing the **ipv6 address** command multiple times adds more addresses rather than replacing them.

Notice that both an IPv4 and an IPv6 address are on the same interface, and they do not conflict with each other. This is because they are different Layer 3 protocols, and they run independently.

Step 3: Configure static IPv6 addresses.

a. Configure the two serial links with IPv6 addresses. Use the **ipv6 address** *address/mask* command to configure the interfaces with the addresses shown in the diagram. Set the clock rates where appropriate, and bring up the interfaces.

```
R1(config)# interface serial0/0/0
R1(config-if)# ipv6 address FEC0::12:1/112
R1(config-if)# clockrate 64000 R1(config-
if)# bandwidth 64 R1(config-if)# no
shutdown

R1(config-if)# interface serial0/0/1
R1(config-if)# ipv6 address FEC0::13:1/112
R1(config-if)# bandwidth 64 R1(config-if)#
no shutdown

R2(config)# interface serial0/0/0
R2(config-if)# ipv6 address FEC0::12:2/112
R2(config-if)# bandwidth 64 R2(config-if)#
no shutdown

R3(config)# interface serial0/0/0
R3(config-if)# ipv6 address FEC0::13:3/112
R3(config-if)# clockrate 64000 R3(config-
if)# bandwidth 64 R3(config-if)# no
shutdown
```

b. Use **ping** to verify local subnet connectivity.

```
R1# ping FEC0::12:2

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::12:2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms

R1# ping FEC0::13:3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::13:3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms

R2# ping FEC0::12:1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::12:1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms

R3# ping FEC0::13:1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::13:1, timeout is 2 seconds:
!!!!!
```

```
     Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
```
Step 4: Change the link-local address on an interface.

a. Use the **show ipv6 interface** command to look at IPv6-related properties of the router interfaces. You can also specify a type/number of an interface to see the output of that interface only.

```
R1# show ipv6 interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::219:6FF:FE23:4380
  No Virtual link-local address(es):
  Global unicast address(es):
    FEC0::12:1, subnet is FEC0::12:0/112
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF12:1
    FF02::1:FF23:4380
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds


R2# show ipv6 interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::218:B9FF:FE92:28D8
  Global unicast address(es):
    FEC0::12:2, subnet is FEC0::12:0/112
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF12:2
    FF02::1:FF92:28D8
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
```

Notice that in addition to the address that you already configured, there is a link-local address starting with FE80 (your actual address will vary). You can change the addresses on the link between R1 and R2 by putting the link-local address FE80::1 on R1 and FE80::2 on R2. Link-local addresses do not have a subnet mask because they are not routed, hence the term "link-local."

b. To change the link-local address, use the **ipv6 address** *address* **link-local** command.

```
R1(config)# interface serial0/0/0
R1(config-if)# ipv6 address FE80::1 link-local


R2(config)# interface serial0/0/0
R2(config-if)# ipv6 address FE80::2 link-local
```

c. Verify that you can ping the link-local address on the other side. When pinging link-local addresses, you must specify an outgoing interface because the addresses are not routed and not in the routing table.

Note: When prompted for the output interface with this command, you must use the full interface name without spaces (for example, use serial0/0/0, not s0/0/0).

```
R1# ping FE80::2
Output Interface: Serial0/0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::2, timeout is 2 seconds: Packet
sent with a source address of FE80::1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms

R2# ping FE80::1
Output Interface: Serial0/0/0
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FE80::1, timeout is 2 seconds: Packet
sent with a source address of FE80::2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
```

d. Verify the link-local addresses with the **show ipv6 interface** command.

```
R1# show ipv6 interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::1
  No Virtual link-local address(es):
  Global unicast address(es):
    FEC0::12:1, subnet is FEC0::12:0/112
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:1
    FF02::1:FF12:1
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds

R2# show ipv6 interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::2
  Global unicast address(es):
    FEC0::12:2, subnet is FEC0::12:0/112
  Joined group address(es):
    FF02::1
    FF02::2
    FF02::1:FF00:2
    FF02::1:FF12:2
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds
```

Note: Manually modifying a link-local address is seldom needed. It is demonstrated here for the purpose of this lab.

Step 5: Configure EUI-64 addresses.

EUI-64 IPv6 addresses are addresses where the first 64 bits are the network portion of the address and are specified. The second 64 bits are the host portion of the address and are automatically generated by the device. RFC 4921 splits the 48-bit MAC address into two 24-bit segments: the Organizational Unique Identifier (OUI) and the NIC-specific component. The seventh bit of the OUI (bit 7 from the left) is inverted (changed from zero to one or vice versa). The 16-bit hex value 0xFFFE is then inserted between the modified OUI and the NIC-specific component to create the modified EUI-64 address. This can be seen in the highlighted EUI-64 address in Step 5b.

a. Configure IPv6 EUI-64 addresses on an interface using the **ipv6 address** *address/mask* **eui-64** command. Configure the R2 and R3 Fast Ethernet interfaces with the subnet shown in the diagram, and enable the interfaces.

```
R2(config)# interface fastEthernet 0/0
R2(config-if)# ipv6 address FEC0:23::/64 eui-64 R2(config-if)#
no shutdown

R3(config)# interface fastEthernet 0/0
R3(config-if)# ipv6 address FEC0:23::/64 eui-64 R3(config-if)#
no shutdown
```

b. Get the IPv6 addresses of the interfaces with the **show ipv6 interface** or **show ipv6 interface brief** command, and then ping the other side of the link.

```
R2# show ipv6 interface fastEthernet 0/0
FastEthernet0/0 is up, line protocol is up
  IPv6 is enabled, link-local address is FE80::218:B9FF:FE92:28D8
  No Virtual link-local address(es):
  Global unicast address(es):
    FEC0:23::218:B9FF:FE92:28D8, subnet is FEC0:23::/64 [EUI]
  Joined group address(es):
    FF02::1
    FF02::1:FF92:28D8
  MTU is 1500 bytes
  ICMP error messages limited to one every 100 milliseconds
  ICMP redirects are enabled
  ICMP unreachables are sent
  ND DAD is enabled, number of DAD attempts: 1
  ND reachable time is 30000 milliseconds (using 17162)

R2# show ipv6 interface brief
FastEthernet0/0            [up/up]
FE80::218:B9FF:FE92:28D8
    FEC0:23::218:B9FF:FE92:28D8
FastEthernet0/1           [administratively down/down]
Serial0/0/0               [up/up]
    FE80::2
    FEC0::12:2
Serial0/0/1               [administratively down/down]
Serial0/1/0               [administratively down/down]
Serial0/1/1               [administratively down/down]
Loopback0                 [up/up]
```

https://E-next.in

```
      FE80::218:B9FF:FE92:28D8
      FEC0::2:1


R3# show ipv6 interface brief
FastEthernet0/0          [up/up]
FE80::218:B9FF:FECD:BEF0
      FEC0:23::218:B9FF:FECD:BEF0
FastEthernet0/1          [administratively down/down]
Serial0/0/0              [up/up]
      FE80::218:B9FF:FECD:BEF0
      FEC0::13:3
Serial0/0/1              [administratively down/down]
Serial0/1/0              [administratively down/down]
Serial0/1/1              [administratively down/down]
Loopback0                [up/up]
      FE80::218:B9FF:FECD:BEF0
      FEC0::3:1


R2# ping FEC0:23::218:B9FF:FECD:BEF0


Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0:23::218:B9FF:FECD:BEF0, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/0/4 ms


R3# ping FEC0:23::218:B9FF:FE92:28D8


Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0:23::218:B9FF:FE92:28D8, timeout is 2
seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 0/0/0 ms
```

Note: Your addresses will be different from the addresses displayed in the example because EUI-64 addresses include the MAC address of the interface, which is unique per interface.

At this point, you should have local subnet connectivity.

Note: Although not configured in this lab, the **ipv6 general-prefix** command can simplify the configuration of IPv6 addresses, including the EUI-64. You can use this command to assign a name to an often-used IPv6 prefix and then use the name to configure interfaces.

Step 6: Enable IPv6 routing and CEF.

The Cisco IOS version used with the routers in this lab has IPv6 routing and IPv6 CEF disabled by default. To enable IPv6 routing, use the **ipv6 unicast-routing** command in global configuration mode. To enable IPv6 CEF, use the **ipv6 cef** command. Enter these commands on all three routers.

```
R1(config)# ipv6 unicast-routing
R1(config)# ipv6 cef

R2(config)# ipv6 unicast-routing
R2(config)# ipv6 cef
```

```
R3(config)# ipv6 unicast-routing
R3(config)# ipv6 cef Step
```

7: Configure OSPFv3.

Unlike IPv4 OSPF, where networks are added to the OSPF process using **network** statements under the routing protocol configuration prompt, IPv6 OSPF uses the interface-level command **ipv6 ospf** *process* **area** *area-id* to add an interface to an area.

a. Add all interfaces shown in the diagram into OSPF process 1, area 0. After you add the interfaces to the OSPF process, the OSPF process starts automatically. If the adjacencies do not come up after a reasonable period of time, troubleshoot using the **debug ipv6 ospf adjacency** and **debug ipv6 packet** commands. Make sure that the packets are being sent to their destination and that adjacencies are forming correctly.

```
R1(config)# interface loopback0
R1(config-if)# ipv6 ospf 1 area 0
R1(config-if)# interface serial0/0/0
R1(config-if)# ipv6 ospf 1 area 0
R1(config-if)# interface serial0/0/1
R1(config-if)# ipv6 ospf 1 area 0


R2(config)# interface loopback0
R2(config-if)# ipv6 ospf 1 area 0
R2(config-if)# interface serial0/0/0
R2(config-if)# ipv6 ospf 1 area 0
R2(config-if)# interface fastEthernet 0/0 R2(config-if)#
ipv6 ospf 1 area 0

R3(config)# interface loopback0
R3(config-if)# ipv6 ospf 1 area 0
R3(config-if)# interface serial0/0/0
R3(config-if)# ipv6 ospf 1 area 0
R3(config-if)# interface fastEthernet 0/0 R3(config-if)#
ipv6 ospf 1 area 0
```

b. Verify that you have OSPFv3 neighbors with the **show ipv6 ospf neighbor** command.

```
R1# show ipv6 ospf neighbor


Neighbor ID     Pri   State           Dead Time   Interface ID   Interface
10.1.3.1          1   FULL/   -       00:00:39    6              Serial0/0/1
10.1.2.1          1   FULL/   -       00:00:34    6              Serial0/0/0


R2# show ipv6 ospf neighbor


Neighbor ID     Pri   State           Dead Time   Interface ID   Interface
10.1.3.1          1   FULL/DR         00:00:39    4              FastEthernet0/0
10.1.1.1          1   FULL/   -       00:00:32    6              Serial0/0/0


R3# show ipv6 ospf neighbor


Neighbor ID     Pri   State           Dead Time   Interface ID   Interface
10.1.2.1          1   FULL/BDR        00:00:39    4              FastEthernet0/0
```

```
10.1.1.1         1  FULL/  -    00:00:39    7              Serial0/0/0
```

The router IDs for each router are created the same way that they are in OSPFv2 or BGP. Without any IPv4 addresses on the router, the OSPFv3 process will not start unless you manually set the router IDs. This is why the loopback interfaces have been configured with both IPv4 and IPv6 addresses.

c. View the routing table on all three routers with the **show ipv6 route** command.

```
R1# show ipv6 route
IPv6 Routing Table - 11 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
U - Per-user Static route
      I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
      O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
      ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
      D - EIGRP, EX - EIGRP external
L   FE80::/10 [0/0]
via ::, Null0 C
FEC0::1:0/112 [0/0]
via ::, Loopback0 L
FEC0::1:1/128 [0/0]
via ::, Loopback0 O
FEC0::2:1/128
[110/1562]     via
FE80::2, Serial0/0/0 O
FEC0::3:1/128
[110/1562]
    via FE80::218:B9FF:FECD:BEF0, Serial0/0/1
C   FEC0::12:0/112 [0/0]     via ::,
Serial0/0/0 L  FEC0::12:1/128 [0/0]     via
::, Serial0/0/0 C   FEC0::13:0/112 [0/0]
via ::, Serial0/0/1 L   FEC0::13:1/128 [0/0]
via ::, Serial0/0/1 O   FEC0:23::/64
[110/1563]     via FE80::2, Serial0/0/0
    via FE80::218:B9FF:FECD:BEF0, Serial0/0/1
L   FF00::/8 [0/0]     via ::, Null0

R2# show ipv6 route
IPv6 Routing Table - 11 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
U - Per-user Static route
      I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
      O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
      ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
L   FE80::/10 [0/0]
via ::, Null0
O   FEC0::1:1/128 [110/1562]
via FE80::1, Serial0/0/0 C
FEC0::2:0/112 [0/0]     via
::, Loopback0 L
FEC0::2:1/128 [0/0]     via
::, Loopback0 O
FEC0::3:1/128 [110/1]
     via FE80::218:B9FF:FECD:BEF0, FastEthernet0/0
C   FEC0::12:0/112 [0/0]     via ::, Serial0/0/0
```

```
L    FEC0::12:2/128 [0/0]      via ::, Serial0/0/0
O    FEC0::13:0/112 [110/1563]
      via FE80::218:B9FF:FECD:BEF0, FastEthernet0/0
C    FEC0:23::/64 [0/0]      via ::,
FastEthernet0/0
L    FEC0:23::218:B9FF:FE92:28D8/128 [0/0]
via ::, FastEthernet0/0 L   FF00::/8
[0/0]      via ::, Null0


R3# show ipv6 route
IPv6 Routing Table - 11 entries
Codes: C - Connected, L - Local, S - Static, R - RIP, B - BGP
U - Per-user Static route
       I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary
       O - OSPF intra, OI - OSPF inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
L    FE80::/10 [0/0]
via ::, Null0
O    FEC0::1:1/128 [110/1562]
      via FE80::219:6FF:FE23:4380, Serial0/0/0 O
FEC0::2:1/128 [110/1]
      via FE80::218:B9FF:FE92:28D8, FastEthernet0/0
C    FEC0::3:0/112 [0/0]
via ::, Loopback0 L
FEC0::3:1/128 [0/0]      via
::, Loopback0 O
FEC0::12:0/112 [110/1563]
      via FE80::218:B9FF:FE92:28D8, FastEthernet0/0
C    FEC0::13:0/112 [0/0]      via ::, Serial0/0/0
L    FEC0::13:3/128 [0/0]      via ::, Serial0/0/0
C    FEC0:23::/64 [0/0]      via ::,
FastEthernet0/0
L    FEC0:23::218:B9FF:FECD:BEF0/128 [0/0]
via ::, FastEthernet0/0 L   FF00::/8
[0/0]      via ::, Null0
```

d. You can also look at per-interface OSPF behavior with the **show ipv6 ospf interface** command.

```
R1# show ipv6 ospf interface
Serial0/0/1 is up, line protocol is up
  Link Local Address FE80::219:6FF:FE23:4380, Interface ID 7
  Area 0, Process ID 1, Instance ID 0, Router ID 10.1.1.1
  Network Type POINT_TO_POINT, Cost: 1562
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:06
  Index 1/3/3, flood queue length 0
  Next 0x0(0)/0x0(0)/0x0(0)
  Last flood scan length is 2, maximum is 2
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.3.1
Suppress hello for 0 neighbor(s)
Serial0/0/0 is up, line protocol is up
  Link Local Address FE80::1, Interface ID 6
  Area 0, Process ID 1, Instance ID 0, Router ID 10.1.1.1
```

```
     Network Type POINT_TO_POINT, Cost: 1562
     Transmit Delay is 1 sec, State POINT_TO_POINT,
     Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
       Hello due in 00:00:00
     Index 1/2/2, flood queue length 0
     Next 0x0(0)/0x0(0)/0x0(0)
     Last flood scan length is 1, maximum is 4
     Last flood scan time is 0 msec, maximum is 0 msec
     Neighbor Count is 1, Adjacent neighbor count is 1
       Adjacent with neighbor 10.1.2.1
   Suppress hello for 0 neighbor(s)
   Loopback0 is up, line protocol is up
     Link Local Address FE80::219:6FF:FE23:4380, Interface ID 20
     Area 0, Process ID 1, Instance ID 0, Router ID 10.1.1.1
     Network Type LOOPBACK, Cost: 1
     Loopback interface is treated as a stub Host


   R2# show ipv6 ospf interface
   FastEthernet0/0 is up, line protocol is up
     Link Local Address FE80::218:B9FF:FE92:28D8, Interface ID 4
     Area 0, Process ID 1, Instance ID 0, Router ID 10.1.2.1
     Network Type BROADCAST, Cost: 1
     Transmit Delay is 1 sec, State BDR, Priority 1
     Designated Router (ID) 10.1.3.1, local address FE80::218:B9FF:FECD:BEF0
     Backup Designated router (ID) 10.1.2.1, local address
   FE80::218:B9FF:FE92:28D8
     Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
       Hello due in 00:00:04
     Index 1/3/3, flood queue length 0
     Next 0x0(0)/0x0(0)/0x0(0)
     Last flood scan length is 2, maximum is 2
     Last flood scan time is 0 msec, maximum is 0 msec
     Neighbor Count is 1, Adjacent neighbor count is 1
       Adjacent with neighbor 10.1.3.1  (Designated Router)
     Suppress hello for 0 neighbor(s)
   Serial0/0/0 is up, line protocol is up
     Link Local Address FE80::2, Interface ID 6
     Area 0, Process ID 1, Instance ID 0, Router ID 10.1.2.1
     Network Type POINT_TO_POINT, Cost: 1562
     Transmit Delay is 1 sec, State POINT_TO_POINT,
     Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
       Hello due in 00:00:07
     Index 1/2/2, flood queue length 0
     Next 0x0(0)/0x0(0)/0x0(0)
     Last flood scan length is 1, maximum is 4
     Last flood scan time is 0 msec, maximum is 0 msec
     Neighbor Count is 1, Adjacent neighbor count is 1
       Adjacent with neighbor 10.1.1.1
   Suppress hello for 0 neighbor(s)
   Loopback0 is up, line protocol is up
     Link Local Address FE80::218:B9FF:FE92:28D8, Interface ID 17
     Area 0, Process ID 1, Instance ID 0, Router ID 10.1.2.1
     Network Type LOOPBACK, Cost: 1
     Loopback interface is treated as a stub Host
```

```
R3# show ipv6 ospf interface
FastEthernet0/0 is up, line protocol is up
  Link Local Address FE80::218:B9FF:FECD:BEF0, Interface ID 4
  Area 0, Process ID 1, Instance ID 0, Router ID 10.1.3.1
  Network Type BROADCAST, Cost: 1
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 10.1.3.1, local address FE80::218:B9FF:FECD:BEF0
  Backup Designated router (ID) 10.1.2.1, local address
FE80::218:B9FF:FE92:28D8
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:09
  Index 1/3/3, flood queue length 0
  Next 0x0(0)/0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 4
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.2.1  (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
Serial0/0/0 is up, line protocol is up
  Link Local Address FE80::218:B9FF:FECD:BEF0, Interface ID 6
  Area 0, Process ID 1, Instance ID 0, Router ID 10.1.3.1
  Network Type POINT_TO_POINT, Cost: 1562
  Transmit Delay is 1 sec, State POINT_TO_POINT,
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    Hello due in 00:00:07
  Index 1/2/2, flood queue length 0
  Next 0x0(0)/0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 4
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 10.1.1.1
  Suppress hello for 0 neighbor(s)
Loopback0 is up, line protocol is up
  Link Local Address FE80::218:B9FF:FECD:BEF0, Interface ID 17
  Area 0, Process ID 1, Instance ID 0, Router ID 10.1.3.1
  Network Type LOOPBACK, Cost: 1
  Loopback interface is treated as a stub Host
```

e. Run the following Tcl script on all routers to verify full connectivity. If these pings are not successful, troubleshoot. Modify the script to include the correct EUI addresses on the FEC0:23:: /64 subnet. The addresses for the router interfaces used in this lab are shown below. `tclsh`

```
foreach address {
FEC0::1:1
FEC0::2:1
FEC0::3:1
FEC0::12:1
FEC0::12:2
FEC0::13:1
FEC0::13:3
FEC0:23::
FEC0:23:: }
{
ping $address }
```

```
R1#tclsh
R1(tcl)#
R1(tcl)#foreach address {
+>(tcl)#FEC0::1:1
+>(tcl)#FEC0::2:1
+>(tcl)#FEC0::3:1
+>(tcl)#FEC0::12:1
+>(tcl)#FEC0::12:2
+>(tcl)#FEC0::13:1
+>(tcl)#FEC0::13:3
+>(tcl)#FEC0:23::218:B9FF:FE92:28D8
+>(tcl)#FEC0:23::218:B9FF:FECD:BEF0
+>(tcl)#} {
+>(tcl)#ping $address }
```

Challenge: Summarize OSPFv3 Areas

The commands available for OSPFv3 are similar to the commands available for OSPFv2. On R2, add in two loopback interfaces, with the addresses FEC0:500::100:1 /112 and FEC0:500::200:1 /112. Add both of these interfaces to the OSPF process in area 500. Summarize area 500 to FEC0:500:: /64. To enter the OSPF configuration prompt, use the **ipv6 router ospf** *process-id* command. Unlike the IPv4 (config-router) prompt, the IPv6 router prompt is (config-rtr). When in the IPv6 router prompt, use the **area range** command to summarize the address. Use the question mark (?) if you need help.

You would enter the following commands on R2:
```
interface    loopback100    ipv6
address  FEC0:500::100:1/112 ipv6
ospf  1  area  500      interface
loopback200    ipv6      address
FEC0:500::200:1/112 ipv6  ospf  1
area  500      area  500  range
FEC0:500::/64


ipv6 router ospf 1
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

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Device Configurations (Instructor version)

Router R1

```
hostname R1 ! ipv6 unicast-routing
ipv6 cef ! interface Loopback0  ip
address 10.1.1.1 255.255.255.0
ipv6 address FEC0::1:1/112  ipv6
ospf 1 area 0 ! interface
Serial0/0/0  ipv6 address FE80::1
link-local  ipv6 address
FEC0::12:1/112  ipv6 ospf 1 area 0
clock rate 64000  bandwidth 64  no
shutdown ! interface Serial0/0/1
ipv6 address FEC0::13:1/112  ipv6
ospf 1 area 0  bandwidth 64  no
shutdown ! end
```

Router R2

```
hostname R2 ! ipv6
unicast-routing ipv6
cef !
interface Loopback0  ip address
10.1.2.1 255.255.255.0  ipv6
address FEC0::2:1/112  ipv6 ospf 1
area 0 !
interface FastEthernet0/0  ipv6
address FEC0:23::/64 eui-64  ipv6
ospf 1 area 0  no shutdown !
interface Serial0/0/0
 ipv6 address FEC0::12:2/112
 ipv6 address FE80::2 link-local
  ipv6 ospf 1 area 0  bandwidth
64  no shutdown
!
end
```

Router R3

```
hostname R3 ! ipv6 unicast-routing
ipv6 cef ! interface Loopback0  ip
address 10.1.3.1 255.255.255.0
ipv6 address FEC0::3:1/112  ipv6
ospf 1 area 0 ! interface
FastEthernet0/0  ipv6 address
FEC0:23::/64 eui-64  ipv6 ospf 1
area 0  no shutdown ! interface
Serial0/0/0  ipv6 address
FEC0::13:3/112  ipv6 ospf 1 area 0
clock rate 64000  bandwidth 64  no
shutdown !
end
```

Chapter 8 Lab 8-3, Configuring 6to4 Tunnels Instructor Version

Topology
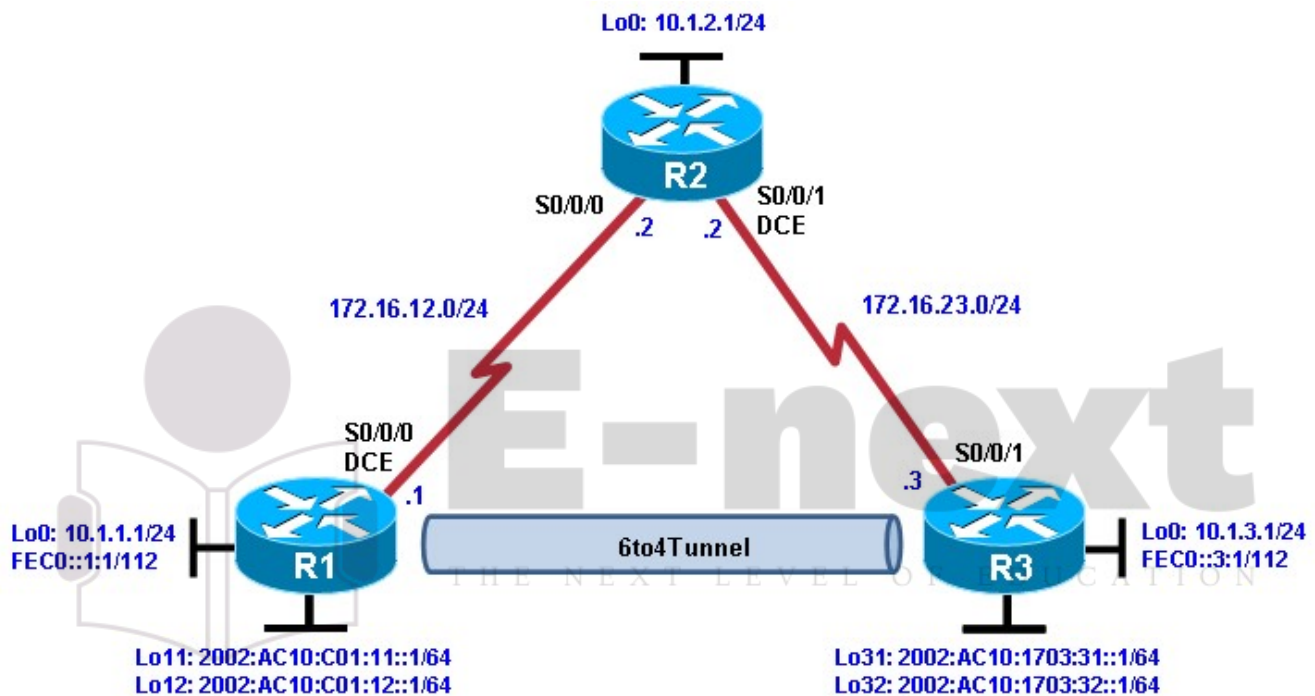
Objectives

- Configure EIGRP for IPv4.
- Create a 6to4 tunnel.
- Configure static IPv6 routes.

Background

In this lab, you configure EIGRP for full connectivity between all IPv4 subnets. You then create a 6to4 tunnel and create static routes over it.

Note: This lab uses Cisco 1841 routers with Cisco IOS Release 12.4(24)T1 and the Advanced IP Services image c1841-advipservicesk9-mz.124-24.T1.bin. You can use other routers (such as a 2801 or 2811) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the router model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 3 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)

• Serial and console cables

Step 1: Prepare the routers for the lab.

Clear previous configurations by erasing the startup configuration and reloading the routers. After the routers are reloaded, set up the appropriate hostnames.

Step 2: Configure loopbacks and physical interfaces.

a. Configure the loopback interfaces with IPv4 addresses and IPv6 addresses, where appropriate. Also configure the serial interfaces with the IPv4 addresses shown in the diagram. Set the clock rates on the appropriate interfaces and the bandwidth on all serial connections.

```
R1(config)# interface loopback0
R1(config-if)# ip address 10.1.1.1 255.255.255.0
R1(config-if)# ipv6 address FEC0::1:1/112
R1(config-if)# interface serial0/0/0
R1(config-if)# ip address 172.16.12.1 255.255.255.0
R1(config-if)# clockrate 64000 R1(config-if)#
bandwidth 64
R1(config-if)# no shutdown


R2(config)# interface loopback0
R2(config-if)# ip address 10.1.2.1 255.255.255.0 R2(config-
if)# interface serial0/0/0
R2(config-if)# ip address 172.16.12.2 255.255.255.0
R2(config-if)# bandwidth 64
R2(config-if)# no shutdown
R2(config-if)# interface serial0/0/1
R2(config-if)# ip address 172.16.23.2 255.255.255.0
R2(config-if)# clockrate 64000 R2(config-if)#
bandwidth 64
R2(config-if)# no shutdown


R3(config)# interface loopback0
R3(config-if)# ip address 10.1.3.1 255.255.255.0
R3(config-if)# ipv6 address FEC0::3:1/112
R3(config-if)# interface serial0/0/1
R3(config-if)# ip address 172.16.23.3 255.255.255.0
R3(config-if)# bandwidth 64 R3(config-if)#
no shutdown
```

b. Verify that you have local subnet connectivity with **ping**.

Step 3: Configure EIGRP.

Configure EIGRP for AS 1 for the major networks 172.16.0.0 and 10.0.0.0 on all three routers. You should have full IPv4 connectivity.

```
R1(config)# router eigrp 1
R1(config-router)# no auto-summary  R1(config-router)#
network 10.0.0.0
R1(config-router)# network 172.16.0.0


R2(config)# router eigrp 1
```

```
R2(config-router)# no auto-summary  R2(config-router)#
network 10.0.0.0
R2(config-router)# network 172.16.0.0

R3(config)# router eigrp 1
R3(config-router)# no auto-summary
R3(config-router)# network 10.0.0.0
R3(config-router)# network 172.16.0.0  Step
```

4: Configure a manual IPv6 6to4 tunnel.

A tunnel is a logical interface that acts as a logical connection between two endpoints. It is similar to a loopback interface in that there is no corresponding physical interface, but it is different in that there is more than one router involved. A 6to4 tunnel uses special IPv6 addresses in the 2002::/16 address space. The first 16 bits are the hexadecimal number 2002, and the next 32 bits are the original source IPv4 address in hexadecimal form. The remaining bits can be specified as shown in Step 4c. A 6to4 tunnel does not require a destination address because it is not a point-to-point link.

In this step, you configure additional 6to4 IPv6 loopback interfaces to represent LANs on R1 and R3, and then configure a 6to4 tunnel to provide IPv6 connectivity between the loopback interfaces. a. Add the following loopbacks to R1 and R3.

```
R1(config-if)# interface loopback11
R1(config-if)# ipv6 address 2002:AC10:0C01:11::1/64
R1(config-if)# interface loopback12
R1(config-if)# ipv6 address 2002:AC10:0C01:12::1/64

R3(config-if)# interface loopback31
R3(config-if)# ipv6 address 2002:AC10:1703:31::1/64
R3(config-if)# interface loopback32
R3(config-if)# ipv6 address 2002:AC10:1703:32::1/64
```

b. Configure a 6to4 tunnel using the **interface tunnel** *number* command to get to the tunnel interface configuration prompt. For simplicity, use interface number 0.

```
R1(config)# interface tunnel 0
```

c. Set the tunnel mode with the **tunnel mode ipv6ip 6to4** command. Then set up the IPv6 address with the **ipv6 address** *address*/*mask* command. The R1 address is 2002:AC10:0C01:1::1/64, because AC10:0C01 corresponds to 172.16.12.1, with 172 being AC, 16 being 10, 12 being C, and 1 being 1. The 1 after this address is just a more specific subnet, and the 1 at the end is the host address. The R3 address is 2002:AC10:1703:1::3/64. The two addresses are not in the same /64 subnet. After setting the IPv6 addresses, set the source interface for the tunnel with the **tunnel source** *type*/*number* command.

```
R1(config-if)# tunnel mode ipv6ip 6to4
R1(config-if)# ipv6 address 2002:AC10:0C01:1::1/64  R1(config-
if)# tunnel source serial0/0/0
```

d. Now that all the tunnel settings are set, enable IPv6 routing with the **ipv6 unicast-routing** command, and set up an IPv6 static route for the whole 2002::/16 network with the global command **ipv6 route** *address*/*mask interface*, with the interface being the tunnel you just created.

```
R1(config-if)# exit
R1(config)# ipv6 unicast-routing
R1(config)# ipv6 route 2002::/16 tunnel0
```

e. Enter the following commands on R3.

```
R3(config)# interface tunnel 0
R3(config-if)# tunnel mode ipv6ip 6to4
R3(config-if)# ipv6 address 2002:AC10:1703:1::3/64
R3(config-if)# tunnel source serial0/0/1
R3(config-if)# exit
R3(config)# ipv6 unicast-routing
R3(config)# ipv6 route 2002::/16 tunnel0
```

f. Verify that you can ping the other side of the tunnel from R1 to R3, and ping the newly created loopback interfaces from each router .

```
R1# ping 2002:AC10:1703:1::3

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:1703:1::3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/67/68 ms


R1# ping 2002:AC10:1703:31::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:1703:31::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/65/68 ms


R1# ping 2002:AC10:1703:32::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:1703:32::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/65/68 ms


R3# ping 2002:AC10:C01:1::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:C01:1::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/66/68 ms


R3# ping 2002:AC10:0C01:11::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:C01:11::1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/67/68 ms


R3# ping 2002:AC10:0C01:12::1

Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2002:AC10:C01:12::1, timeout is 2 seconds:
!!!!!
```

```
        Success rate is 100 percent (5/5), round-trip min/avg/max = 64/65/68 ms
```

Step 5: Configure static IPv6 routes.

Just like IPv4, IPv6 can have static routes entered into its routing table. You already created one for the 2002::/16 network in Step 4. Now you will configure a static route on R1 telling it how to get to the R3 loopback 0 address. On R3, you will configure a static route pointing to R1.

a. Static routes with a next-hop IPv6 address are created with the **ipv6 route** *address*/*mask next-hop* command. The next hop for both routers is the IPv6 address of the other end of the tunnel.

```
R1(config)# ipv6 route FEC0::3:0/112 2002:AC10:1703:1::3

R3(config)# ipv6 route FEC0::1:0/112 2002:AC10:C01:1::1
```

b. Verify the IPv6 static routes using the **show ipv6 route** command or by pinging the remote loopback address from each router.

```
R1# show ipv6 route
IPv6 Routing Table - Default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, M - MIPv6, R - RIP, I1 - ISIS L1
       I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
EX - EIGRP external
       O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
       ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
S   2002::/16 [1/0]

via Tunnel0, directly connected C
2002:AC10:C01:1::/64 [0/0]       via
Tunnel0, directly connected L
2002:AC10:C01:1::1/128 [0/0]      via
Tunnel0, receive C
2002:AC10:C01:11::/64 [0/0]       via
Loopback11, directly connected L
2002:AC10:C01:11::1/128 [0/0]     via
Loopback11, receive C
2002:AC10:C01:12::/64 [0/0]       via
Loopback12, directly connected L
2002:AC10:C01:12::1/128 [0/0]     via
Loopback12, receive C   FEC0::1:0/112
[0/0]
     via Loopback0, directly connected
L   FEC0::1:1/128 [0/0]      via
Loopback0, receive
S   FEC0::3:0/112 [1/0]

via 2002:AC10:1703:1::3 L
FF00::/8 [0/0]      via
Null0, receive

R3# show ipv6 route
IPv6 Routing Table - Default - 11 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route
       B - BGP, M - MIPv6, R - RIP, I1 - ISIS L1
```

```
        I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
EX - EIGRP external
        O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2
        ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
```

S   2002::/16 [1/0]

```
via Tunnel0, directly connected C
2002:AC10:1703:1::/64 [0/0]      via
Tunnel0, directly connected L
2002:AC10:1703:1::3/128 [0/0]     via
Tunnel0, receive C
2002:AC10:1703:31::/64 [0/0]     via
Loopback31, directly connected L
2002:AC10:1703:31::1/128 [0/0]    via
Loopback31, receive C
2002:AC10:1703:32::/64 [0/0]     via
Loopback32, directly connected L
```

S   FEC0::1:0/112 [1/0]

```
2002:AC10:1703:32::1/128 [0/0]     via
Loopback32, receive     via
2002:AC10:C01:1::1
C   FEC0::3:0/112 [0/0]
    via Loopback0, directly connected
L   FEC0::3:1/128 [0/0]     via
Loopback0, receive L   FF00::/8 [0/0]
via Null0, receive
```

c. From R1 and R3, ping the loopback 0 IPv6 address of the opposite router.

    R1# **ping FEC0::3:1**

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::3:1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/67/68 ms
```

    R3# **ping FEC0::1:1**

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to FEC0::1:1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 64/66/68 ms
```

d. Use the following Tcl script on R1 and R3 to verify network connectivity.

    R1# **tclsh**
    foreach address
    {
    10.1.1.1
    10.1.2.1
    10.1.3.1
    172.16.12.1
    172.16.12.2

```
172.16.23.2
172.16.23.3
FEC0::1:1
FEC0::3:1
2002:AC10:C01:1::1
2002:AC10:1703:1::3
2002:AC10:1703:31::1 2002:AC10:1703:32::1
2002:AC10:0C01:11::1 2002:AC10:0C01:12::1
} { ping
$address }
```

Were all pings successful?

_____

All pings should be successful for R1 and R3.

e. Run the Tcl script on R2. Were all IP addresses reachable? Explain.

_____

_____

_____

No. R2 cannot reach the R1 and R3 IPv6 loopback interface addresses or the IPv6 addresses for the
tunnel. R2 simply provides a physical path for the tunnel and has no knowledge of it or the R1 and R3
IPv6 loopback addresses.

```
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.2.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.1.3.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/28 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.12.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.12.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/56 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.23.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/58/64 ms
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.23.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
% Unrecognized host or address, or protocol not running.
```

```
% Unrecognized host or address, or protocol not running.
% Unrecognized host or address, or protocol not running. %
Unrecognized host or address, or protocol not running. %
Unrecognized host or address, or protocol not running.
% Unrecognized host or address, or protocol not running.
% Unrecognized host or address, or protocol not running.
% Unrecognized host or address, or protocol not running.
```

Router Interface Summary Table

Router Interface Summary				
Router Model	Ethernet Interface #1	Ethernet Interface #2	Serial Interface #1	Serial Interface #2
1700	Fast Ethernet 0 (FA0)	Fast Ethernet 1 (FA1)	Serial 0 (S0)	Serial 1 (S1)
1800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2600	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0 (S0/0)	Serial 0/1 (S0/1)
2800	Fast Ethernet 0/0 (FA0/0)	Fast Ethernet 0/1 (FA0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. Rather than list all combinations of configurations for each router class, this table includes identifiers for the possible combinations of Ethernet and serial interfaces in the device. The table does not include any other type of interface, even though a specific router might contain one. For example, for an ISDN BRI interface, the string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.				

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Device Configurations (Instructor version)

Router R1

```
hostname R1 !
ipv6 unicast-routing ! interface
Loopback0  ip address 10.1.1.1
255.255.255.0  ipv6 address
FEC0::1:1/112
! interface
Loopback11  no ip
address
 ipv6 address 2002:AC10:C01:11::1/64
! interface
Loopback12  no ip
address
 ipv6 address 2002:AC10:C01:12::1/64
! interface Tunnel0  ipv6 address
2002:AC10:C01:1::1/64  tunnel
source Serial0/0/0  tunnel mode
ipv6ip 6to4
! interface Serial0/0/0  ip address
172.16.12.1 255.255.255.0  clock rate
64000  bandwidth 64  no shutdown
! router eigrp 1
network 10.0.0.0
network 172.16.0.0
no auto-summary
!
ipv6 route 2002::/16 Tunnel0 ipv6 route
FEC0::3:0/112 2002:AC10:1703:1::3 end
```

Router R2

```
hostname R2
!
interface Loopback0  ip address
10.1.2.1 255.255.255.0
! interface Serial0/0/0  ip address
172.16.12.2 255.255.255.0  bandwidth
64  no shutdown
! interface Serial0/0/1  ip address
172.16.23.2 255.255.255.0  clock rate
64000  bandwidth 64  no shutdown
! router eigrp 1
network 10.0.0.0
network 172.16.0.0
no auto-summary end
```

Router R3

```
hostname R3 !
ipv6 unicast-routing ! interface
Loopback0  ip address 10.1.3.1
255.255.255.0  ipv6 address
FEC0::3:1/112
```

```
!
interface Loopback31
no ip address
 ipv6 address 2002:AC10:1703:31::1/64
! interface
Loopback32  no ip
address
 ipv6 address 2002:AC10:1703:32::1/64
! interface
Tunnel0  no ip
address
 ipv6 address 2002:AC10:1703:1::3/64
tunnel source Serial0/0/1  tunnel
mode ipv6ip 6to4
! interface Serial0/0/1  ip address
172.16.23.3 255.255.255.0  bandwidth
64  no shutdown
! router eigrp 1
network 10.0.0.0
network 172.16.0.0
no auto-summary
! ipv6 route 2002::/16 Tunnel0 ipv6 route
FEC0::1:0/112 2002:AC10:C01:1::1 end
```

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