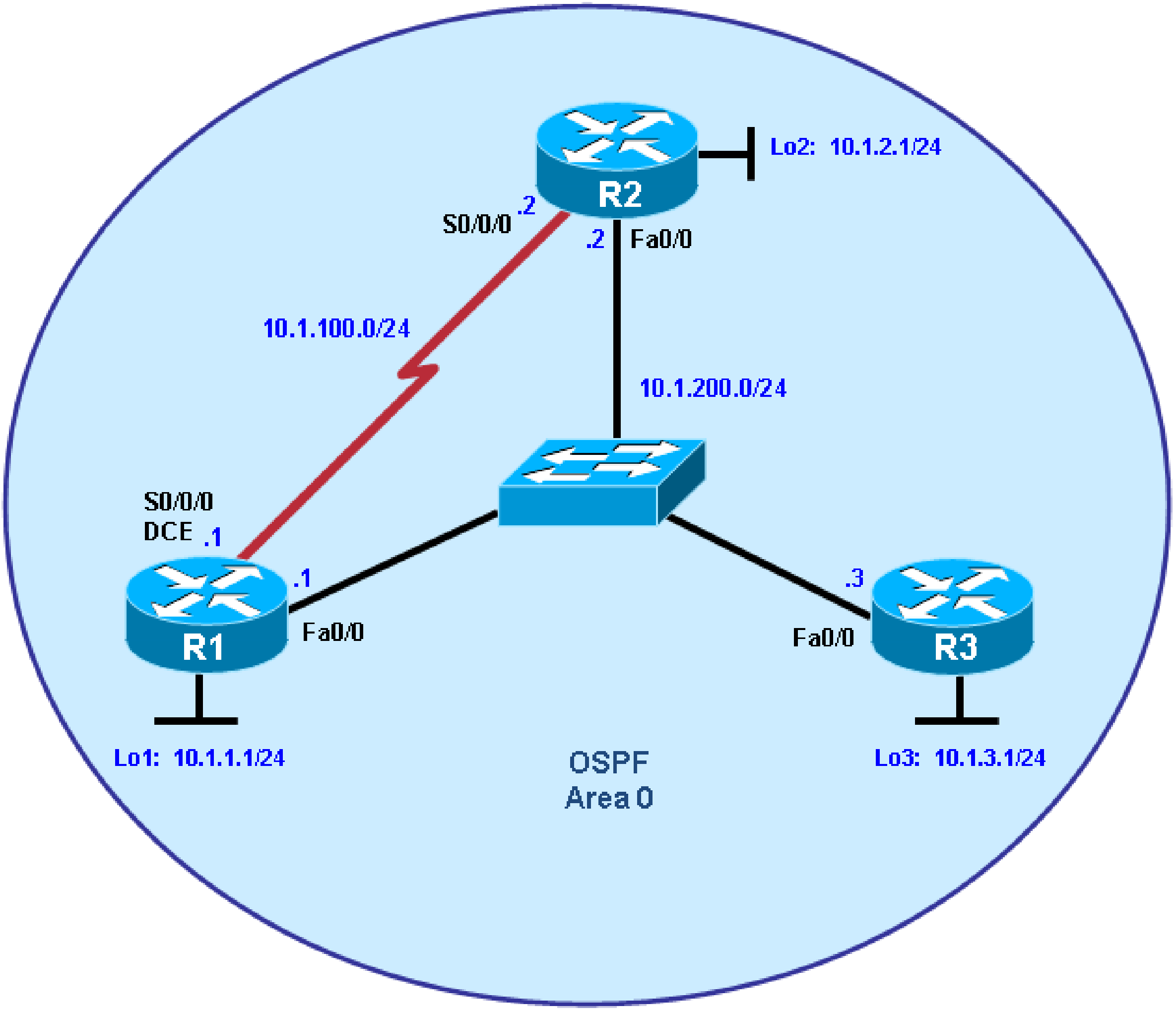
Chapter 3 Lab 3-1, Single-Area OSPF Link Costs and Interface Priorities **Instructor Version**

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?

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

<table>
<tr><th colspan="5">Router Interface Summary</th></tr>
<tr><td>Router Model</td><td>Ethernet Interface #1</td><td>Ethernet Interface #2</td><td>Serial Interface #1</td><td>Serial Interface #2</td></tr>
<tr><td>1700</td><td>Fast Ethernet 0 (FA0)</td><td>Fast Ethernet 1 (FA1)</td><td>Serial 0 (S0)</td><td>Serial 1 (S1)</td></tr>
<tr><td>1800</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0/0 (S0/0/0)</td><td>Serial 0/0/1 (S0/0/1)</td></tr>
<tr><td>2600</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0 (S0/0)</td><td>Serial 0/1 (S0/1)</td></tr>
<tr><td>2800</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0/0 (S0/0/0)</td><td>Serial 0/0/1 (S0/0/1)</td></tr>
<tr><td colspan="5"><b>Note:</b> 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.</td></tr>
</table>

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

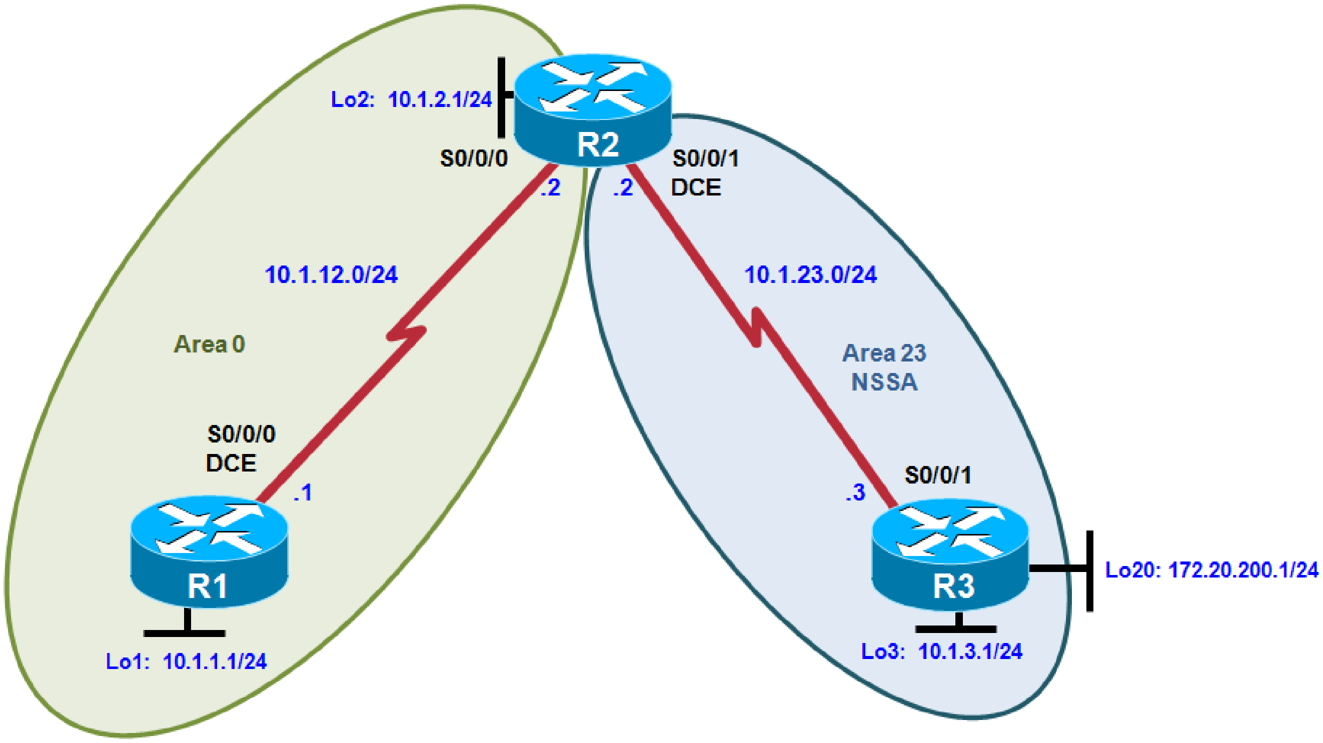
```
hostname R2
!
interface Loopback2
 description Marketing Department
 ip address 10.1.2.1 255.255.255.0
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 10.1.200.2 255.255.255.0
 ip ospf cost 50
 ip ospf priority 5
 no shutdown
!
interface Serial0/0/0
 ip address 10.1.100.2 255.255.255.0
 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
```

Chapter 3 Lab 3-2, Multi-Area OSPF with Stub Areas and Authentication **Instructor Version**

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
        Number of interfaces in this area is 1
        It is a stub area
          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?

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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-information-originate** 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 (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 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

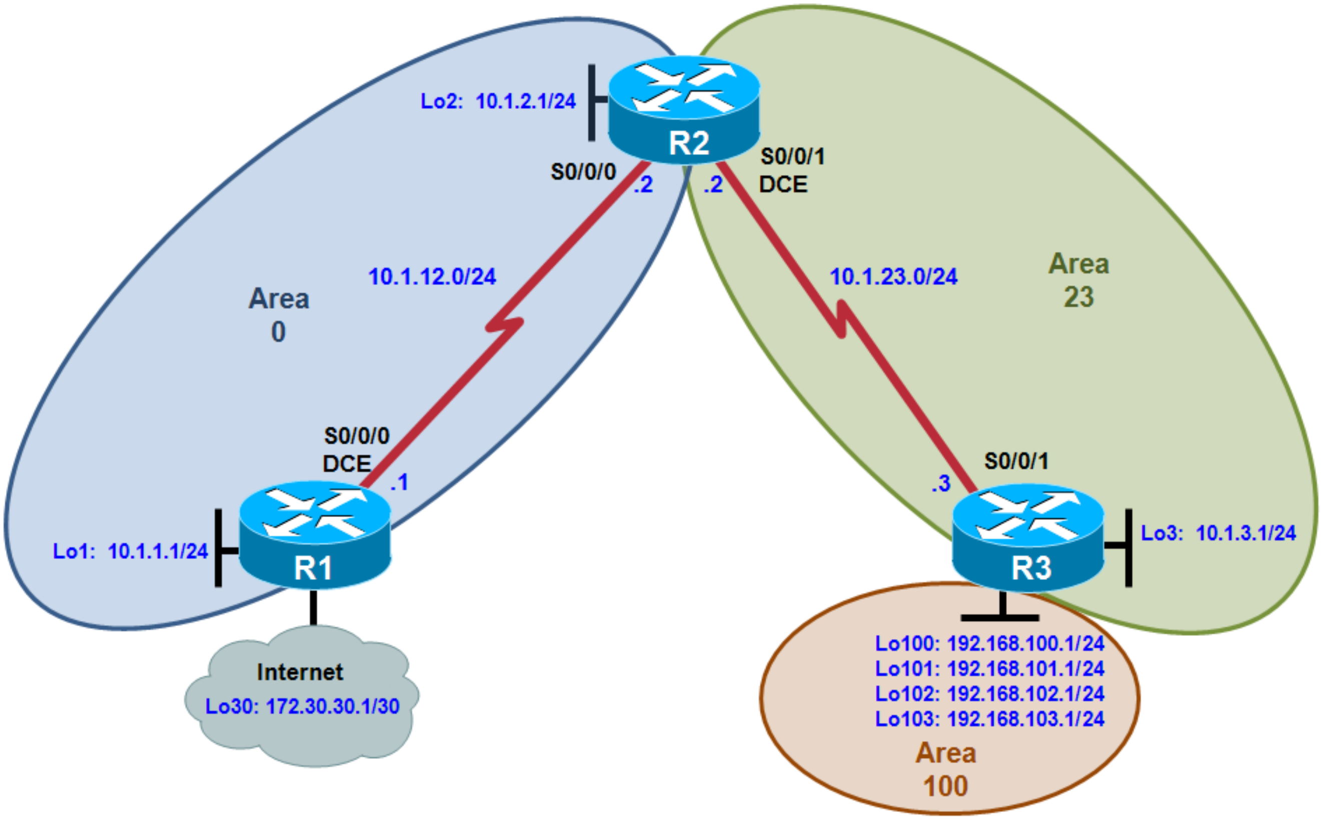
```
hostname R3
!
```

```
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
```

Chapter 3 Lab 3-3, OSPF Virtual Links and Area Summarization

Instructor Version

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?

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

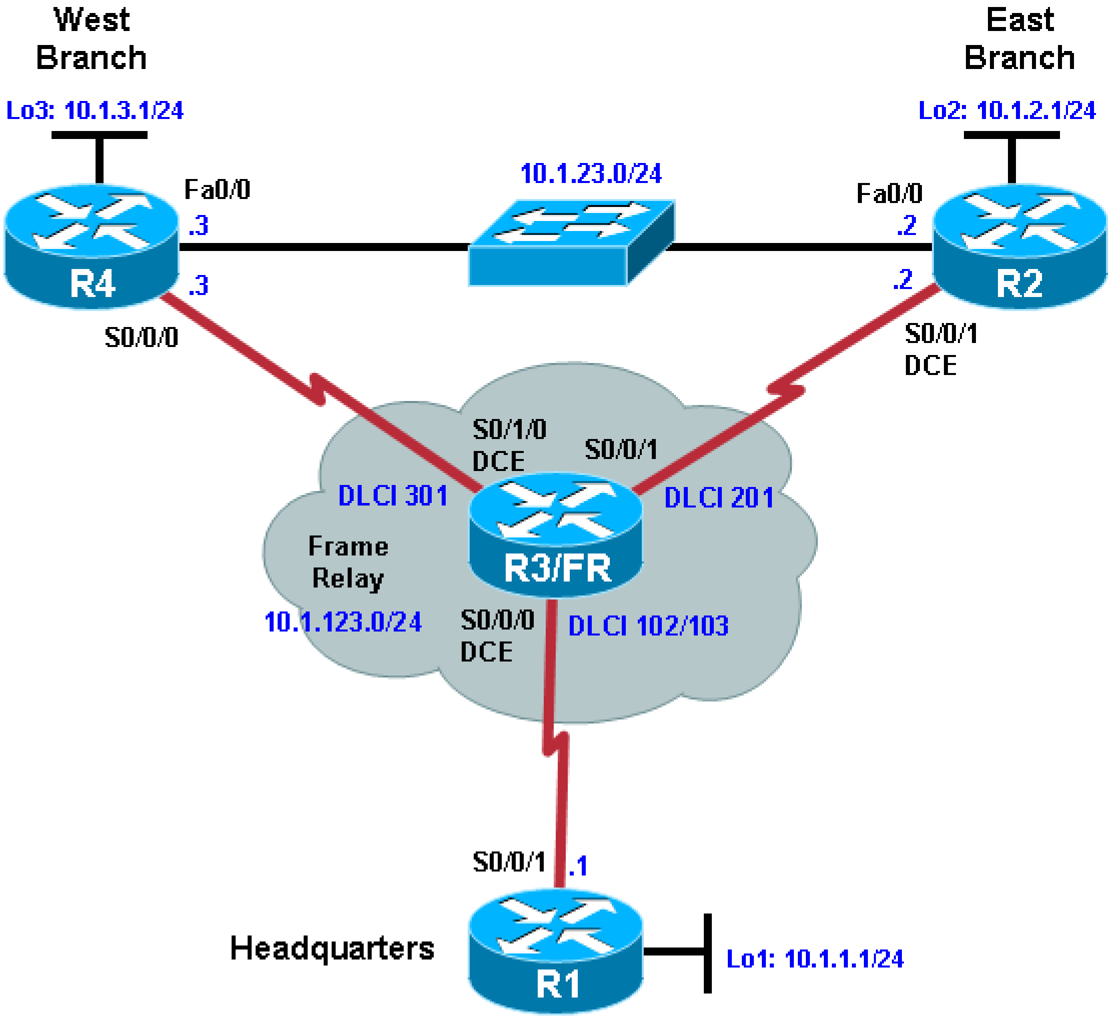
```
hostname R2
!
interface Loopback2
 description Marketing Department
 ip address 10.1.2.1 255.255.255.0
 ip ospf network point-to-point
!
interface Serial0/0/0
 ip address 10.1.12.2 255.255.255.0
 no shutdown
!
interface Serial0/0/1
 ip address 10.1.23.2 255.255.255.0
 clock rate 64000
 no shutdown
!
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
```

Chapter 3 Lab 3-4, OSPF over Frame Relay **Instructor Version**

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-to-multipoint 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

WEST(config)# interface fastEthernet 0/0
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)

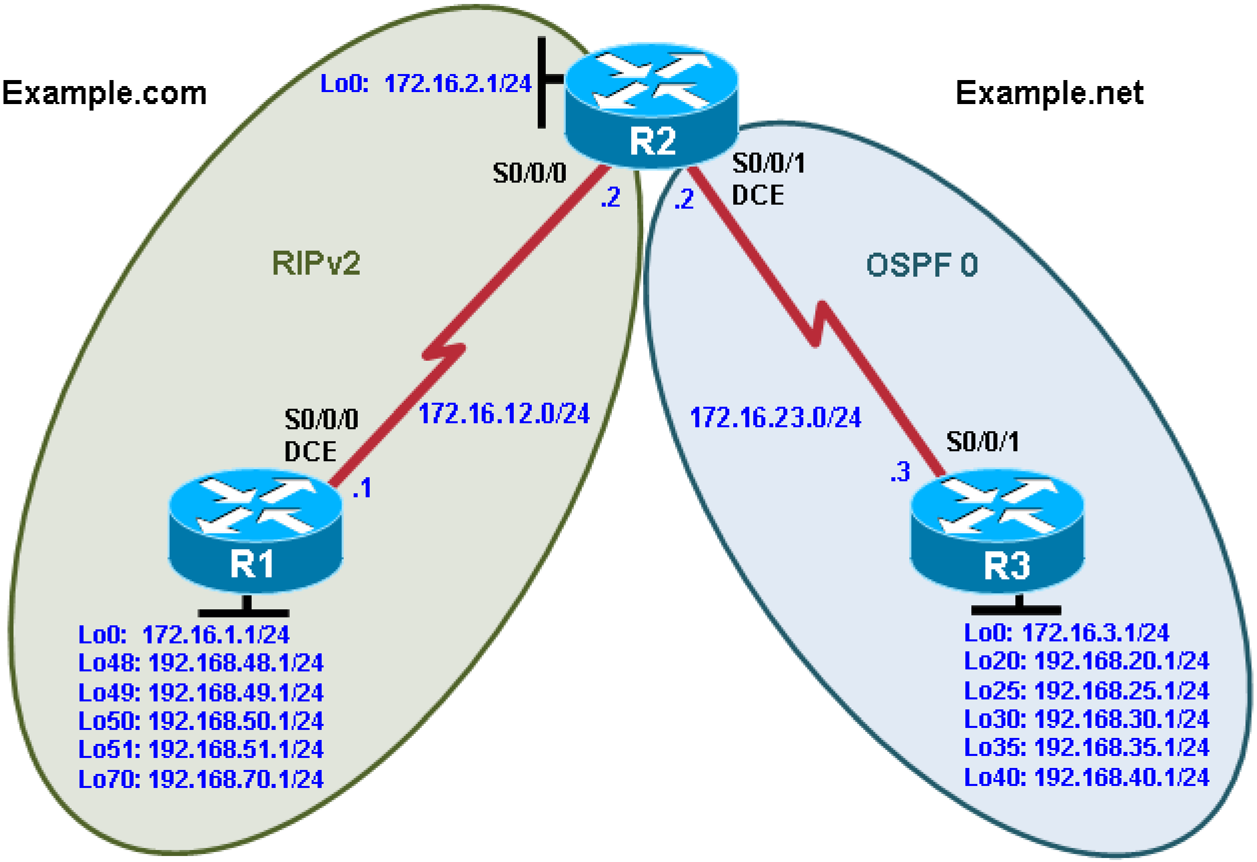
```
hostname WEST
!
interface Loopback3
 ip address 10.1.3.1 255.255.255.0
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 10.1.23.3 255.255.255.0
 ip ospf dead-interval minimal hello-multiplier 5
 no shutdown
!
interface Serial0/0/0
 ip address 10.1.123.3 255.255.255.0
 encapsulation 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
```

Chapter 4 Lab 4-1, Redistribution Between RIP and OSPF **Instructor Version**

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 {
172.16.1.1
192.168.48.1
192.168.49.1
192.168.50.1
192.168.51.1
192.168.70.1
172.16.12.1
172.16.2.1
172.16.12.2
172.16.23.2
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?

____

____

____

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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 **passive-interface** 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.

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?

____

____

____

____

____

____

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?

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?

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 **passive-interface 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?

____

____

____

____

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?

____

____

____

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?

____

____

____

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

<table>
<tr><th colspan="5">Router Interface Summary</th></tr>
<tr><td>Router Model</td><td>Ethernet Interface #1</td><td>Ethernet Interface #2</td><td>Serial Interface #1</td><td>Serial Interface #2</td></tr>
<tr><td>1700</td><td>Fast Ethernet 0 (FA0)</td><td>Fast Ethernet 1 (FA1)</td><td>Serial 0 (S0)</td><td>Serial 1 (S1)</td></tr>
<tr><td>1800</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0/0 (S0/0/0)</td><td>Serial 0/0/1 (S0/0/1)</td></tr>
<tr><td>2600</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0 (S0/0)</td><td>Serial 0/1 (S0/1)</td></tr>
<tr><td>2800</td><td>Fast Ethernet 0/0 (FA0/0)</td><td>Fast Ethernet 0/1 (FA0/1)</td><td>Serial 0/0/0 (S0/0/0)</td><td>Serial 0/0/1 (S0/0/1)</td></tr>
<tr><td colspan="5"><b>Note:</b> 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.</td></tr>
</table>

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
```

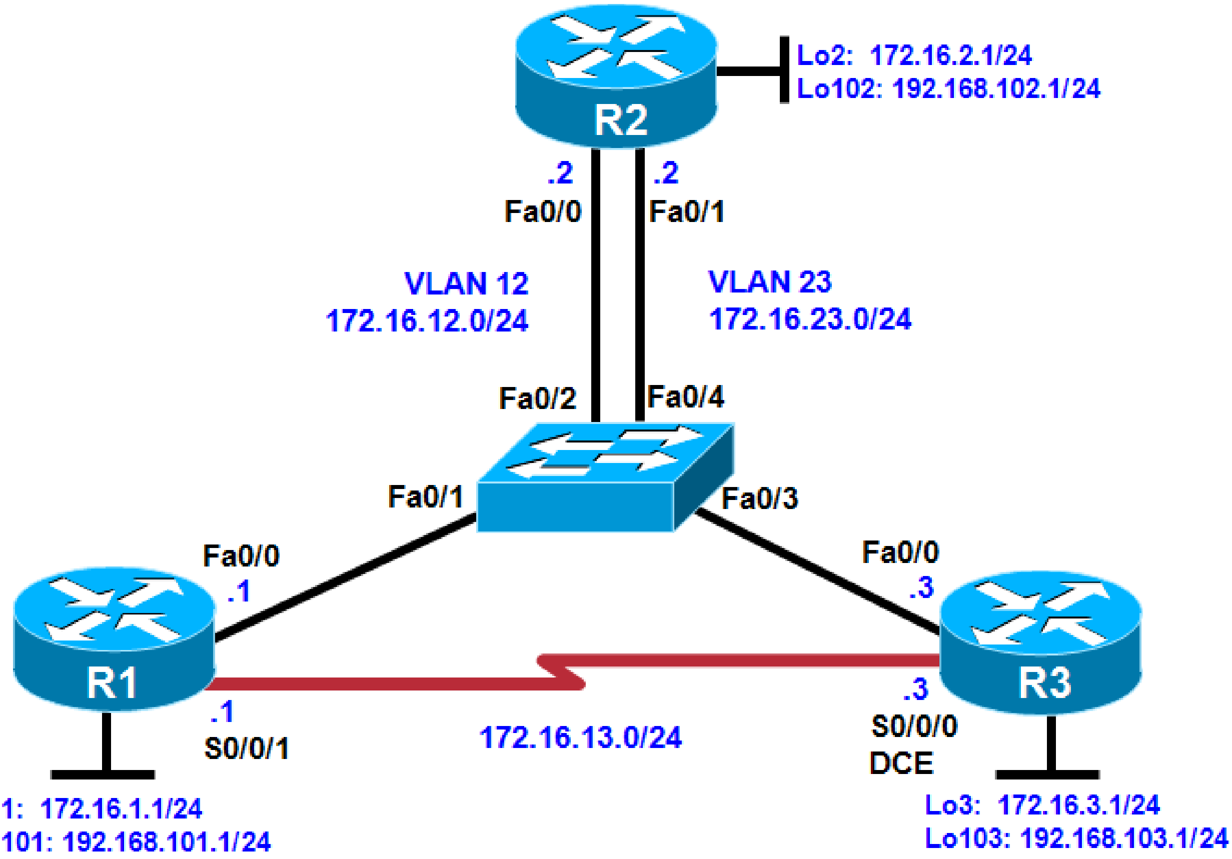
Router R3

```
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
```

Chapter 4 Lab 4-3, Manipulating Administrative Distances **Instructor Version**

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?

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____

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?

____

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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?

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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)
    Address         Wild mask       Distance  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?

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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?

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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.				

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

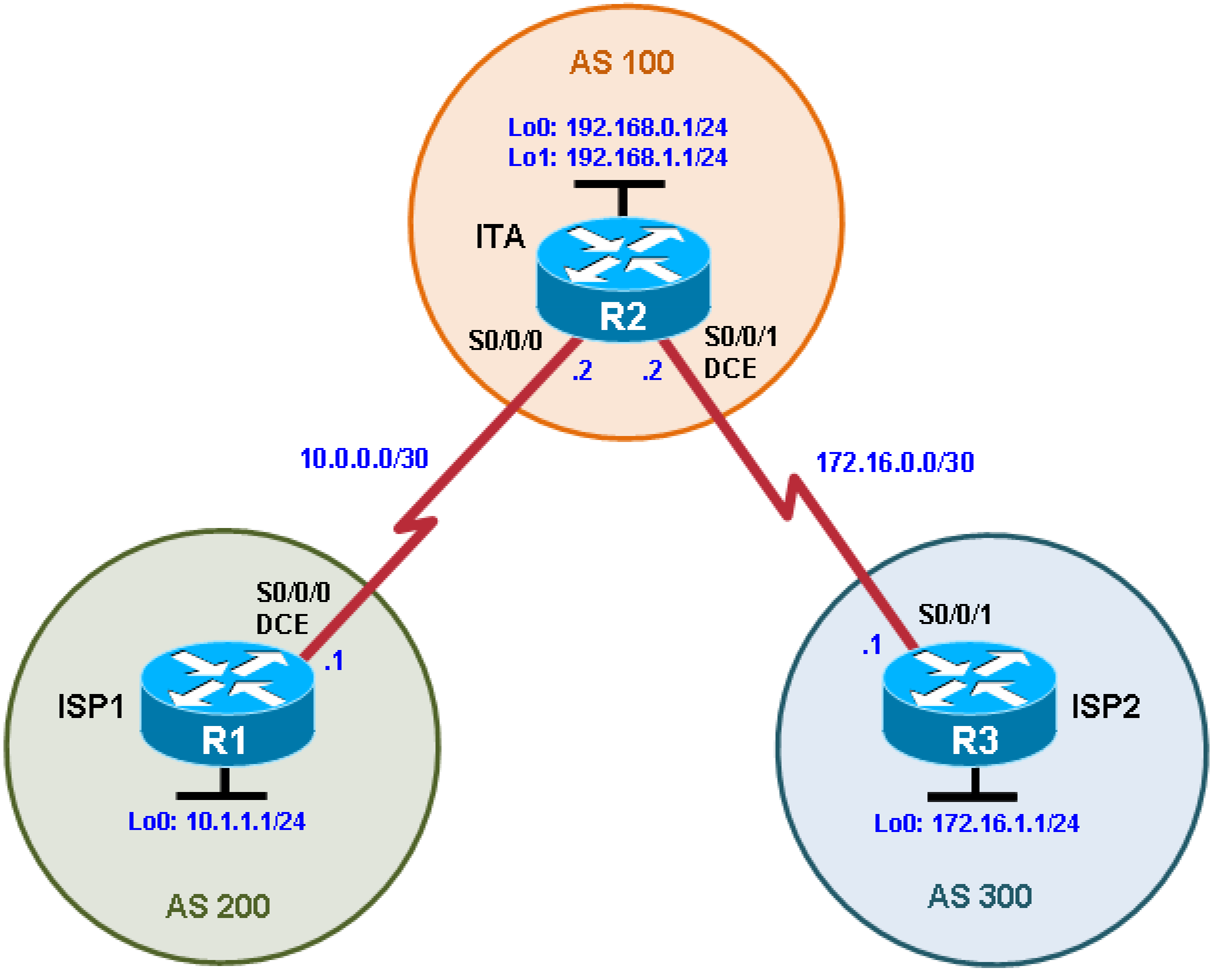
```
hostname R2
!
interface Loopback2
 ip address 172.16.2.1 255.255.255.0
 ip ospf network point-to-point
!
interface Loopback102
 ip address 192.168.102.1 255.255.255.0
 ip ospf network point-to-point
!
interface FastEthernet0/0
 ip address 172.16.12.2 255.255.255.0
 no shutdown
!
interface FastEthernet0/1
 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
```

Chapter 6 Lab 6-1, 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?

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____

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)

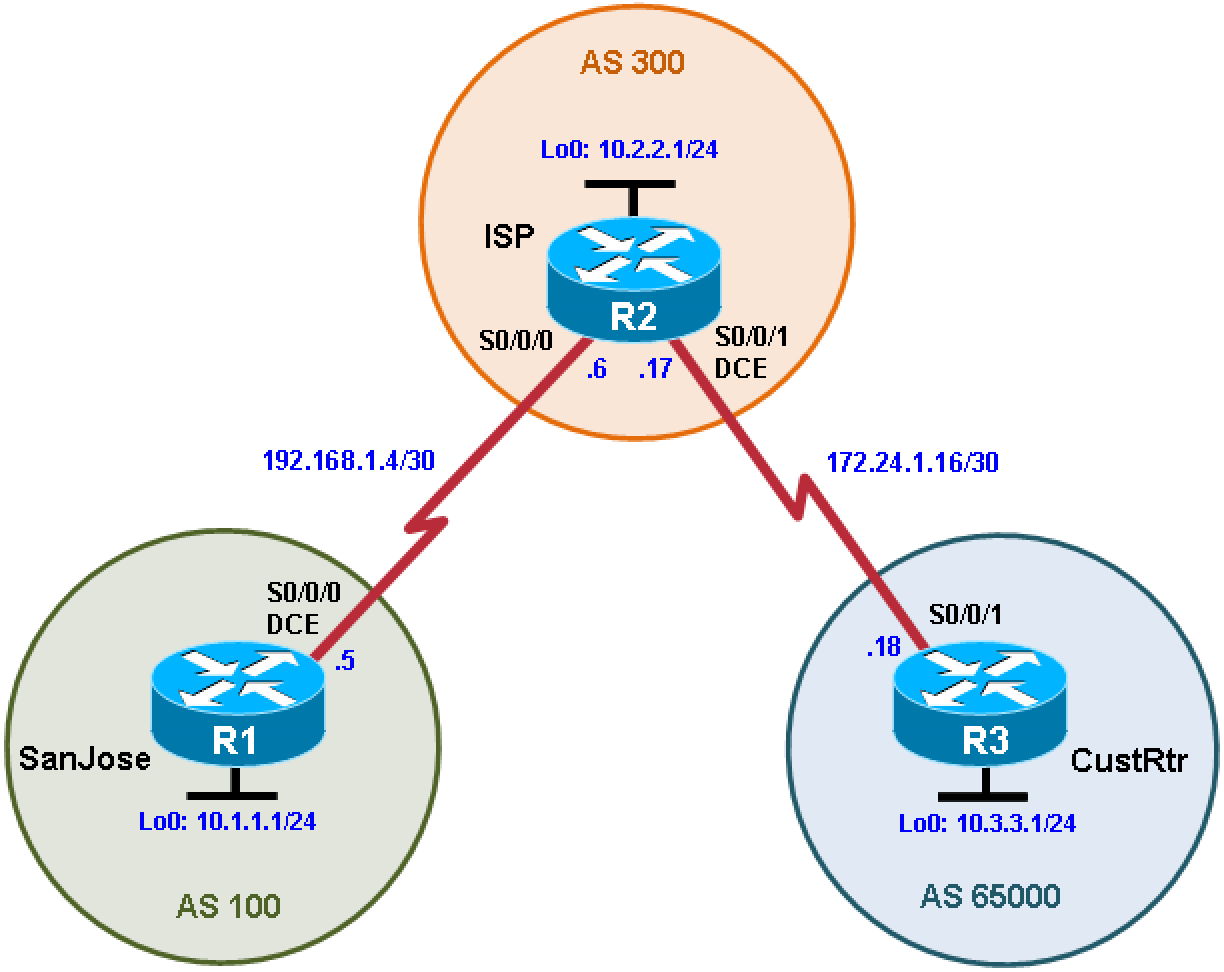
```
hostname ITA
!
interface Loopback0
 description Core router network link 1
 ip address 192.168.0.1 255.255.255.0
!
interface Loopback1
 description Core router network link 2
 ip address 192.168.1.1 255.255.255.0
!
interface Serial0/0/0
 description ITA -> ISP1
 ip address 10.0.0.2 255.255.255.252
 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
```

Chapter 6 Lab 6-2, 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?

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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?

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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
```

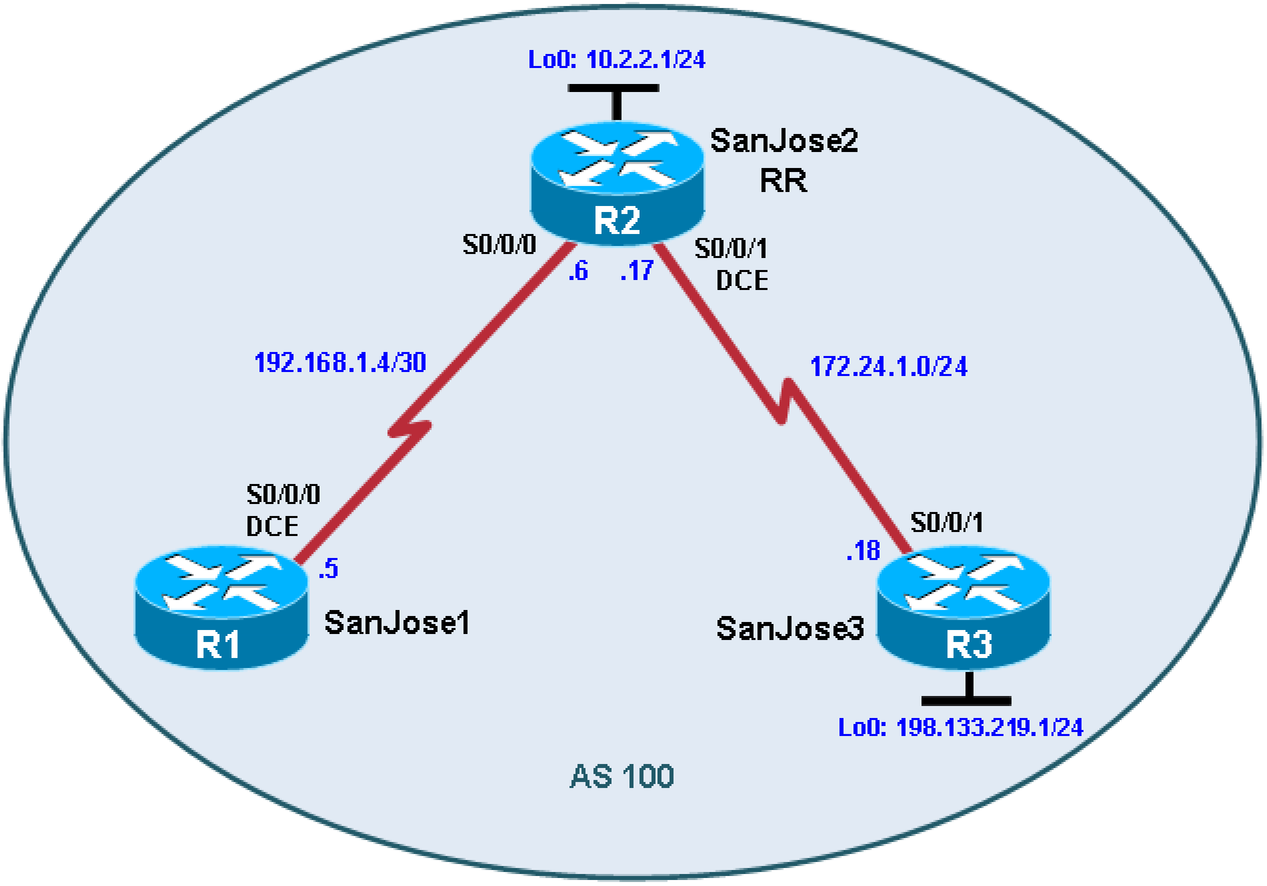
Router CustRtr

```
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
```

Chapter 6 Lab 6-4, 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 client-learned 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?

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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?

____

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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)

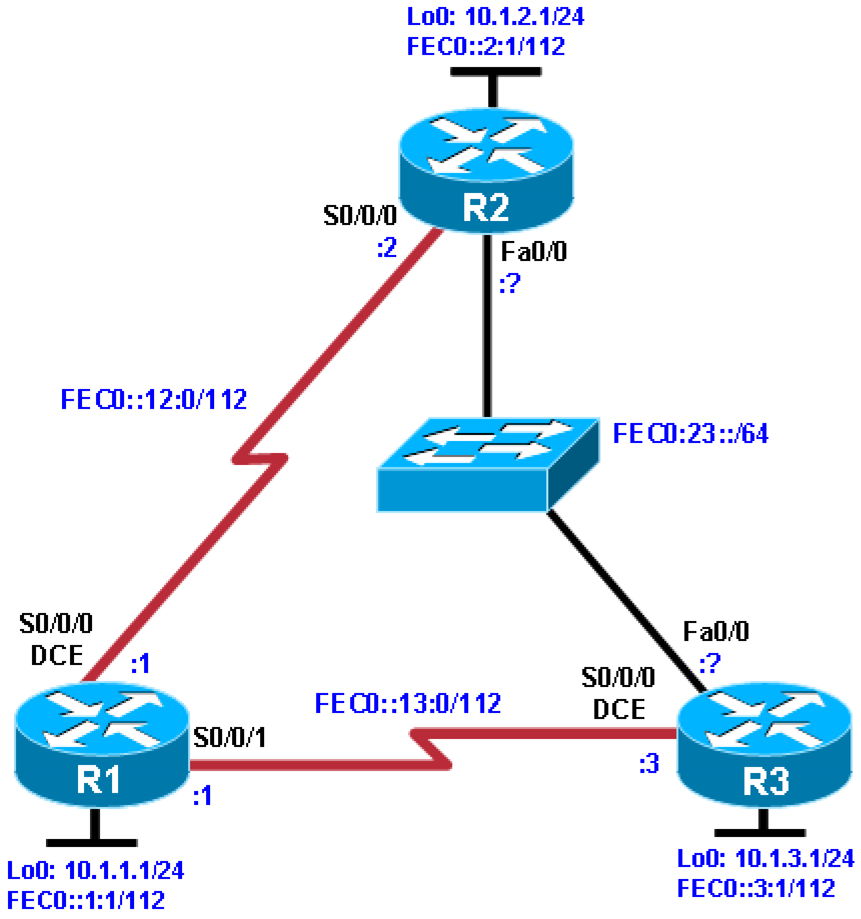
```
hostname SanJose2
!
interface Loopback0
 ip address 10.2.2.1 255.255.255.0
!
interface Serial0/0/0
 ip address 192.168.1.6 255.255.255.252
 no shutdown
!
interface Serial0/0/1
 ip address 172.24.1.17 255.255.255.0
 clock rate 128000
 no shutdown
!
router rip
 version 2
 network 172.24.0.0
 network 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
```

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]
    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

ipv6 router ospf 1
area 500 range FEC0:500::/64
```

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
!
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

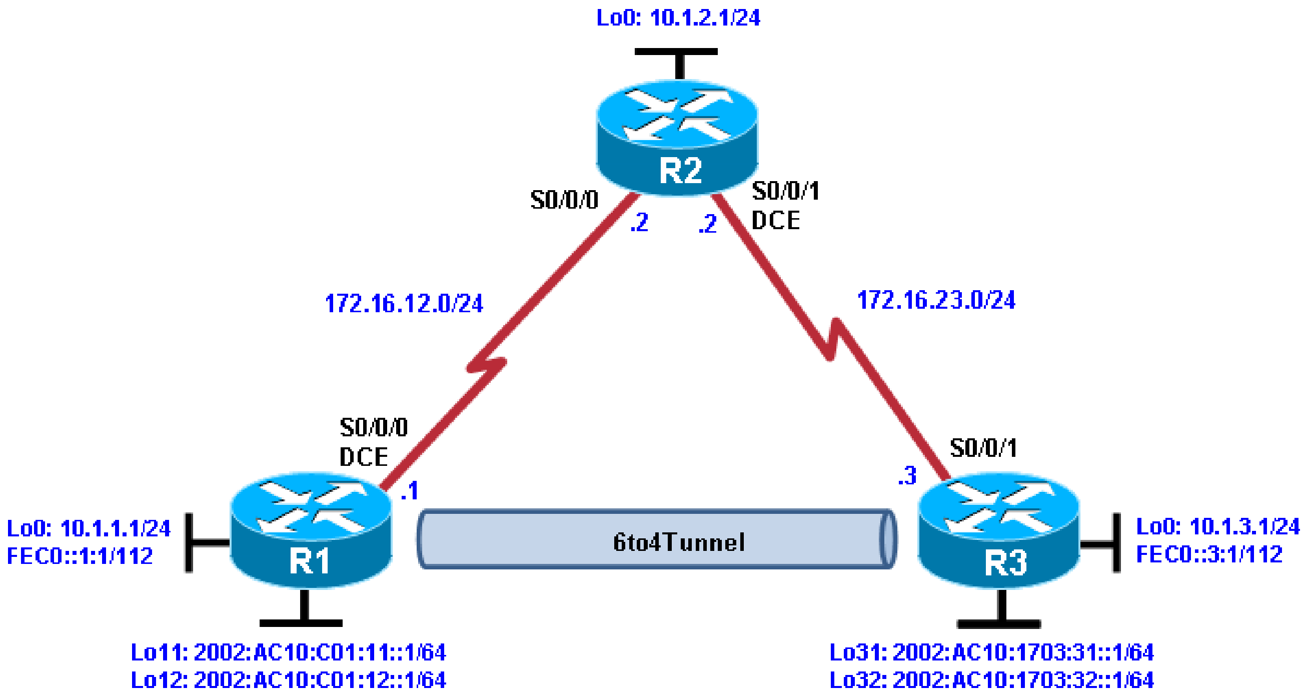
```
hostname R2
!
ipv6 unicast-routing
ipv6 cef
!
interface Loopback0
 ip address 10.1.2.1 255.255.255.0
 ipv6 address FEC0::2:1/112
 ipv6 ospf 1 area 0
!
interface FastEthernet0/0
 ipv6 address FEC0:23::/64 eui-64
 ipv6 ospf 1 area 0
 no shutdown
!
interface Serial0/0/0
 ipv6 address FEC0::12:2/112
 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   2002:AC10:1703:32::1/128 [0/0]
     via Loopback32, receive
S   FEC0::1:0/112 [1/0]
     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.				

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
```

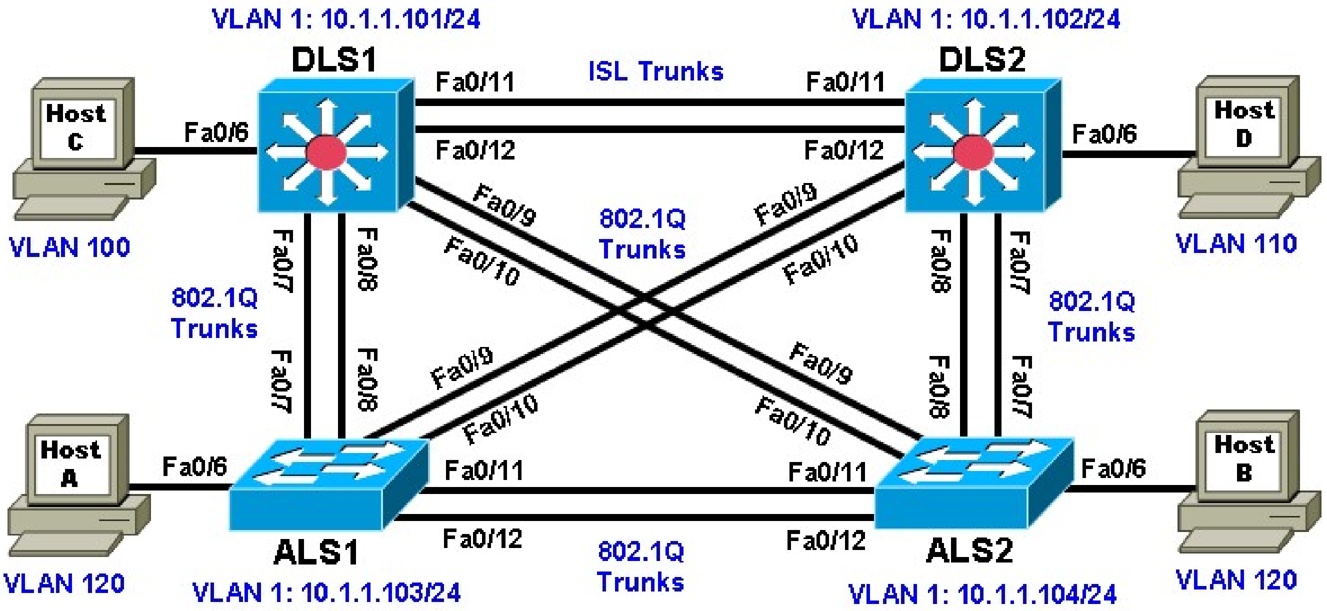
```
!
router eigrp 1
 network 10.0.0.0
 network 172.16.0.0
 no auto-summary
end
```

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
```

Practical 6, Static VLANS, VLAN Trunking, and VTP Domains and Modes

Topology



Objectives

- Set up a VTP domain.
- Create and maintain VLANs.
- Configure ISL and 802.1Q trunking.

Background

VLANs logically segment a network by function, team, or application, regardless of the physical location of the users. End stations in a particular IP subnet are often associated with a specific VLAN. VLAN membership on a switch that is assigned manually for each interface is known as static VLAN membership.

Trunking, or connecting switches, and the VLAN Trunking Protocol (VTP) are technologies that support VLANs. VTP manages the addition, deletion, and renaming of VLANs on the entire network from a single central switch.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.12246.SE.bin, and Catalyst 3560-24PS with the Cisco IOS image c3560-advipservicesk9-mz.122-46.SE.bin. You can use other switches (such as a 2950 or 3550) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-M image or comparable)
- 4 PCs (optional)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

Power up the switches and use the standard process for establishing a HyperTerminal console connection from a workstation to each switch in your pod. If you are connecting remotely to the switches, follow the instructions that have been supplied by your instructor.

Remove all VLAN information and configurations that may have been previously entered into the switches. Refer to Lab 1-1, “Clearing a Switch,” and Lab 1-2, “Clearing a Switch Connected to a Larger Network.”

Step 2: Configure basic switch parameters.

Assign each switch a hostname and configure an IP address on the management VLAN according to the diagram. By default, VLAN 1 is used as the management VLAN.

Enter basic configuration commands on each switch according to the diagram.

DLS1 example:

```
Switch# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
Switch(config)# hostname DLS1
DLS1(config)# interface vlan 1
DLS1(config-if)# ip address 10.1.1.101 255.255.255.0 DLS1(config-
if)# no shutdown
```

(Optional) On each switch, create an enable secret password and configure the vty lines to allow remote access from other network devices. DLS1 example:

```
DLS1(config)# enable secret cisco
DLS1(config)# line vty 0 15
DLS1(config-line)# password cisco
DLS1(config-line)# login
```

Step 3: Display the switch default VLAN information.

Use the **show vlan** command in privileged mode on any switch. The following output is for a 2960 switch.

```
ALS1# show vlan


VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                                Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                                Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                                Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                                Gi0/1, Gi0/2
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2 ---- ----- ---------- ----- ------ ------ -------- ---- -------- -----
- ------ 1    enet  100001     1500  -      -      -        -    -        0
0    1002 fddi  101002     1500  -      -      -        -    -        0
0    1003 tr    101003     1500  -      -      -        -    -        0
0    1004 fdnet 101004     1500  -      -      -        ieee -        0
```

```
0    1005 trnet 101005     1500  -      -      -        ibm  -        0
0
Remote SPAN VLANs
------------------------------------------------------------------------------


Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

The following output is for a 3560 switch.

```
DLS1# show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                                Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                                Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                                Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                                Gi0/1, Gi0/2
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2 -
--- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------ 1
enet  100001     1500  -      -      -        -    -        0      0    1002
fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    -        0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0
Remote SPAN VLANs
------------------------------------------------------------------------------


Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

Note the default VLAN numbers, names, and associated types, and that all switch ports are automatically assigned to VLAN 1.

You can use the **show vlan** command to determine the mode of a port. Ports configured for a particular VLAN are shown in that VLAN. Ports configured for trunk mode are not associated with a specific VLAN, and so are not included in the output.

Step 4: Examine VTP information.

A VTP domain, also called a VLAN management domain, consists of trunked switches that are under the administrative responsibility of a switch or switches in server VTP mode. A switch can be in only one VTP domain with the same VTP domain name. The default VTP mode for the 2960 and 3560 switches is server mode. VLAN information is not propagated until a domain name is specified and trunks are set up between the devices.

The following table describes the three VTP modes.

VTP Mode	Description
VTP server	You can create, modify, and delete VLANs and specify other configuration parameters, such as VTP version and VTP pruning, for the entire VTP domain. VTP servers advertise their VLAN configuration to other switches in the same VTP domain and synchronize their VLAN configuration with other switches based on advertisements received over trunk links. VTP server is the default mode.
VTP client	VTP clients behave the same way as VTP servers, but you cannot create, change, or delete VLANs on a VTP client.
VTP transparent	VTP transparent switches do not participate in VTP. A VTP transparent switch does not advertise its VLAN configuration nor synchronize its VLAN configuration based on received advertisements. Transparent switches do forward VTP advertisements that they receive out their trunk ports in VTP Version 2.

Use the **show vtp status** command on any switch. The output should be similar to the following sample for DLS1.

```
DLS1# show vtp status
VTP Version                     : running VTP1 (VTP2 capable)
Configuration Revision          : 0
Maximum VLANs supported locally : 1005
Number of existing VLANs        : 5
VTP Operating Mode              :
Server
VTP Domain Name                 :
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x57 0xCD 0x40 0x65 0x63 0x59 0x47 0xBD
Configuration last modified by 0.0.0.0 at 0-0-00 00:00:00
Local updater ID is 10.1.1.101 on interface Vl1 (lowest numbered VLAN interface
found)
```

Because no VLAN configurations were made, all settings are the defaults. Notice that the VTP mode is server mode. The number of existing VLANs is the five built-in VLANs. The 3560 switch supports 1,005 maximum VLANs locally. The 2960 switch supports 255 VLANs. The configuration revision is 0, and the default VTP version is 1. All switches in the VTP domain must run the same VTP version.

The importance of the configuration revision number is that the switch with the highest revision number in VTP server mode propagates VLAN information over trunked ports. Every time VLAN information is modified and saved in the VLAN database or vlan.dat file, the revision number is increased by one when the user exits from VLAN configuration mode.

Multiple switches in the VTP domain can be in VTP server mode. These switches can be used to manage all other switches in the VTP domain. This is suitable for small-scale networks where the VLAN information is small and easily stored in all switches. In a large network, the administrator must determine which switches make the best VTP servers. The network administrator should select switches to function as VTP servers. The other switches in the VTP domain can be configured as clients. The number of VTP servers should be consistent based on the amount of redundancy desired in the network.

Step 5: Configure VTP on the switches.

Change the VTP domain name on DLS1 to SWLAB using the **vtp domain** command. If the VTP version defaults to 1, set it manually to version 2 using the **vtp version** command.

```
DLS1(config)# vtp domain SWLAB
Changing VTP domain name from NULL to SWLAB

DLS1(config)# vtp version 2
```

Note: The newest VTP version, VTPv3, is not supported by the IOS used on the switches in this lab. However, it is supported in IOS versions 12.2(52)SE and newer on all platforms eligible for this IOS (2960, 3560, 3750, etc.). VTPv3 has improvements in three major areas.

Better administrative control over which device is allowed to update other devices' view of the VLAN topology. The chance of unintended and disruptive changes is significantly reduced, and availability is increased.

Functionality for the VLAN environment has been significantly expanded. In addition to supporting the earlier ISL VLAN range from 1 to 1001, the new version supports the whole IEEE 802.1Q VLAN range up to 4095. In addition to supporting the concept of normal VLANs, VTP version 3 can transfer information regarding Private VLAN (PVLAN) structures.

The third area of major improvement is support for databases other than VLAN (for example, MST).

Set up the switches so that the distribution layer switches are in VTP server mode, and the access layer switches are in VTP client mode. Set the version number to 2 on the DL switches.

```
DLS1(config)# vtp mode server Device
mode already VTP SERVER.
```

Because the default mode is server, you receive a message on DLS1 stating that the device mode is already VTP server.

```
ALS1(config)# vtp mode client Setting
device to VTP CLIENT mode.
```

Note: You cannot modify the version in VTP client mode

Use the **show vtp status** command on either of the AL switches. The output should be similar to the following sample for ALS1.

```
ALS1# show vtp status
VTP Version                     : running VTP1 (VTP2 capable)
Configuration Revision          : 0
Maximum VLANs supported locally : 255
Number of existing VLANs        : 5
VTP Operating Mode              : Client
VTP Domain Name                 :
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x57 0xCD 0x40 0x65 0x63 0x59 0x47 0xBD
Configuration last modified by 0.0.0.0 at 0-0-00 00:00:00
```

Notice that you do not see the VTP domain name that you set up on DLS1. Because no trunks are set up between the switches, they have not started to distribute any VLAN information. There is no IP address (0.0.0.0) or time listed for the last configuration modification.

Step 6: Configure trunking.

The **show interfaces switchport** command lists the configured mode of each port in detail. The following partial sample output is for a 2960 switch on Fa0/7.

```
ALS1# show interfaces fastEthernet 0/7 switchport
Name: Fa0/7
Switchport: Enabled
Administrative Mode: dynamic auto
Operational Mode: static access
Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: native
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
Administrative private-vlan host-association: none
Administrative private-vlan mapping: none
Administrative private-vlan trunk native VLAN: none
Administrative private-vlan trunk Native VLAN tagging: enabled
Administrative private-vlan trunk encapsulation: dot1q Administrative
private-vlan trunk normal VLANs: none
Administrative private-vlan trunk private VLANs: none
Operational private-vlan: none Trunking VLANs
Enabled: ALL
Pruning VLANs Enabled: 2-1001 Capture
Mode Disabled
Capture VLANs Allowed: ALL

Protected: false
Unknown unicast blocked: disabled
Unknown multicast blocked: disabled
Appliance trust: none
```

Ports on the 2960 and 3560 switches are set to dynamic auto by default. This means that they are willing to negotiate a trunk with the neighbor; however, if both sides are set to dynamic auto, the link will remain in access mode. This can be done by configuring one end of the trunk using the **switchport mode trunk** command. On the 3560 switches, you also need to configure the trunk encapsulation with the **switchport trunk encapsulation** command. The 3560 switch can use either Inter-Switch Link (ISL) or 802.1Q encapsulation, whereas the 2960 switch only supports 802.1Q.

Refer to the lab diagram for which ports to set up as trunks and the type of encapsulation to use.

Configure only the interfaces on DLS1 and ALS1 with the **switchport mode trunk** command, and leave DLS2 and ALS2 as the default port types for Fast Ethernet interfaces 0/9–0/12. Fast Ethernet 0/7 and 0/8 of DLS2 also need to be configured with the **switchport mode trunk** command for the trunks connecting DLS2 and ALS2.

The 2960 and 3560 switches have a **range** command that you can use to designate multiple individual ports or a continuous range of ports for an operation. Use the **interface range** command to configure all trunk ports at once for trunking. The following is a sample configuration for the 802.1Q and ISL trunk ports on DLS1.

```
DLS1(config)# interface range fastEthernet 0/7 - 10
```

```
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk

DLS1(config)# interface range fastEthernet 0/11 - 12
DLS1(config-if-range)# switchport trunk encapsulation isl
DLS1(config-if-range)# switchport mode trunk
```

The following is a sample configuration for the trunk ports on ALS1.

```
ALS1(config)# interface range fastEthernet 0/7 – 12

ALS1(config-if)# switchport mode trunk
```

The following is a sample configuration for the trunk ports on DLS2.

```
DLS2(config)# interface range fastEthernet 0/7 - 8
DLS2(config-if-range)# switchport trunk encapsulation dot1q
DLS2(config-if-range)# switchport mode trunk
```

Note: This lab uses dynamic trunking protocol (DTP) to negotiate trunking, which can lead to security issues. In general, when configuring trunks, it is a good practice to deactivate DTP using the **switchport nonegotiate** command and configure all trunks statically.

Step 7: Verify trunk configuration.

Use the show interfaces fastEthernet 0/7 switchport command on ALS2.

```
ALS2# show interfaces fastEthernet 0/7 switchport
Name: Fa0/7
Switchport: Enabled
Administrative Mode: dynamic auto
                                  Operational Mode: trunk
                                  Administrative Trunking Encapsulation: dot1q
Operational Trunking Encapsulation: dot1q
Negotiation of Trunking: On
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
Administrative private-vlan host-association: none
Administrative private-vlan mapping: none
Administrative private-vlan trunk native VLAN: none
Administrative private-vlan trunk Native VLAN tagging: enabled
Administrative private-vlan trunk encapsulation: dot1q Administrative
private-vlan trunk normal VLANs: none
Administrative private-vlan trunk private VLANs: none
Operational private-vlan: none Trunking
VLANs Enabled: ALL
Pruning VLANs Enabled: 2-1001 Capture
Mode Disabled
Capture VLANs Allowed: ALL

Protected: false
Unknown unicast blocked: disabled
Unknown multicast blocked: disabled
Appliance trust: none
```

Notice that administrative mode on Fa0/7 is still the default dynamic auto. Fa0/7 on ALS2 is operating as a trunk, because port Fa0/7 of DLS2 was configured using the switchport mode trunk command. Once this command was issued, trunking was negotiated between the two switch ports. Use the **show interfaces trunk** command on DLS1.

```
DLS1# show interfaces trunk

Port        Mode         Encapsulation  Status        Native vlan
Fa0/7       on           802.1q         trunking      1
Fa0/8       on           802.1q         trunking      1
Fa0/9       on           802.1q         trunking      1
Fa0/10      on           802.1q         trunking      1
Fa0/11      on           isl            trunking      1
Fa0/12      on           isl            trunking      1
Port      Vlans allowed on trunk
                                Fa0/7       1-4094
Fa0/8       1-4094
Fa0/9       1-4094
Fa0/10      1-4094
Fa0/11      1-4094
Fa0/12      1-4094

Port        Vlans allowed and active in management domain
Fa0/7       1
Fa0/8       1
Fa0/9       1
Fa0/10      1
Fa0/11      1

Port        Vlans allowed and active in management domain
Fa0/12      1

Port        Vlans in spanning tree forwarding state and not pruned
Fa0/7       1
Fa0/8       1
Fa0/9       1
Fa0/10      1
Fa0/11      1
Fa0/12      none
```

Note: By default, all VLANs are allowed on all trunks. You can explicitly control which VLANs are allowed on a trunk by using the **switchport trunk allowed vlan** *vlan-id* command on the interface at each end of the trunk. In addition, you can specify a native VLAN other than the default VLAN 1, using the **switchport trunk native vlan** *vlan-id* command. These two measures can help reduce the possibility of VLAN attacks. Use the **show interfaces trunk** command on DLS2.

```
DLS2# show interfaces trunk

Port        Mode         Encapsulation  Status        Native vlan
Fa0/7       on           802.1q         trunking      1
Fa0/8       on           802.1q         trunking      1
Fa0/9       auto         n-802.1q       trunking      1
Fa0/10      auto         n-802.1q       trunking      1
Fa0/11      auto         n-isl          trunking      1
Fa0/12      auto         n-isl          trunking      1
```

```
Port      Vlans allowed on trunk
Fa0/7       1-4094
Fa0/8       1-4094
Fa0/9       1-4094
Fa0/10      1-4094
Fa0/11      1-4094
Fa0/12      1-4094

Port        Vlans allowed and active in management domain
Fa0/7       1
Fa0/8       1
Fa0/9       1
Fa0/10      1
Fa0/11      1

Port        Vlans allowed and active in management domain
Fa0/12      1

Port        Vlans in spanning tree forwarding state and not pruned
Fa0/7       1
Fa0/8       1
Fa0/9       1
Fa0/10      1
Fa0/11      1
Fa0/12      1
```

Notice the highlighted portion of the above output from DLS2 where it indicates that these ports became trunks by negotiation. For example, port Fa0/9 mode is Auto and encapsulation is n-802.1q. The “n” indicates the 802.1q encapsulation was negotiated. The connected ports of the respective switches were configured using the **switchport mode trunk** command.

Step 8: Configure access ports.

A port on the 2960 switch can operate in one of three modes, and a port on the 3560 switch can operate in one of five modes. Use the **switchport mode ?** command for interface Fast Ethernet 0/6 in interface configuration mode to view the modes. The following command output is for a 2960 switch.

```
ALS1(config)# interface fastEthernet 0/6
ALS1#(config-if)# switchport mode ?   access   Set
trunking mode to ACCESS unconditionally
  dynamic  Set trunking mode to dynamically negotiate access or trunk mode
trunk    Set trunking mode to TRUNK unconditionally
```

The following command output is for a 3560 switch.

```
DLS1(config)# interface fastEthernet 0/6
DLS1(config-if)# switchport mode ?   access        Set
trunking mode to ACCESS unconditionally   dot1q-tunnel
set trunking mode to TUNNEL unconditionally
  dynamic       Set trunking mode to dynamically negotiate access or trunk
mode
  private-vlan  Set the mode to private-vlan host or promiscuous
trunk         Set trunking mode to TRUNK unconditionally
```

The Fast Ethernet ports connected to the hosts on the network can be set up as static access because they are not to be used as trunk ports. Use the **switchport mode access** command to set the access mode on the

Fast Ethernet 0/6 port on all four switches in the pod. The following is a sample configuration for the access port on ALS1.

```
ALS1(config)# interface fastEthernet 0/6 ALS1(config-if)#
switchport mode access
```

Use the **show interfaces** command for Fast Ethernet 0/6 to verify the configuration. The following command is for a 3560 switch.

```
DLS1# show interfaces fastEthernet 0/6 switchport
Name: Fa0/6
Switchport: Enabled
Administrative Mode: static access
Operational Mode: down
Administrative Trunking Encapsulation: negotiate
Negotiation of Trunking: Off
Access Mode VLAN: 1 (default)
Trunking Native Mode VLAN: 1 (default)
Administrative Native VLAN tagging: enabled
Voice VLAN: none
Administrative private-vlan host-association: none
Administrative private-vlan mapping: none
Administrative private-vlan trunk native VLAN: none
Administrative private-vlan trunk Native VLAN tagging: enabled
Administrative private-vlan trunk encapsulation: dot1q Administrative
private-vlan trunk normal VLANs: none
Administrative private-vlan trunk private VLANs: none
Operational private-vlan: none Trunking VLANs
Enabled: ALL
Pruning VLANs Enabled: 2-1001 Capture
Mode Disabled
Capture VLANs Allowed: ALL

Protected: false
Unknown unicast blocked: disabled
Unknown multicast blocked: disabled Appliance
trust: none
```

Note that administrative mode has now changed to static access and that trunking negotiation is off. The Fast Ethernet 0/6 ports on all four switches are now statically set to connect to a host device.

Step 9: Verify VTP configuration.

Before configuring the VLANs, verify the VTP configuration within the domain by using the **show vtp status** command on ALS1 and ALS2. The following sample output is from ALS1.

```
ALS1# show vtp status
VTP Version                     : running VTP2
Configuration Revision          : 1
Maximum VLANs supported locally : 255
Number of existing VLANs        : 5
VTP Operating Mode              : Client
VTP Domain Name                 : SWLAB
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Enabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0xD1 0xC0 0x36 0xF9 0xC4 0x3E 0x73 0xA0
Configuration last modified by 10.1.1.101 at 3-1-93 00:12:43
```

The following sample output is from ALS2.

```
ALS2# show vtp status
VTP Version                     : running VTP2
Configuration Revision          : 1
Maximum VLANs supported locally : 255
Number of existing VLANs        : 5
VTP Operating Mode              : Client
VTP Domain Name                 : SWLAB
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Enabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0xD1 0xC0 0x36 0xF9 0xC4 0x3E 0x73 0xA0
Configuration last modified by 10.1.1.101 at 3-1-93 00:12:43
```

At this point, all switches in the lab are in VTP domain SWLAB and have five existing VLANs. All are running VTP version 2. DLS1 and DLS2 are configured as VTP servers, and ALS1 and ALS2 are configured as clients.

Note: You can limit the VLAN traffic passed between switches using VTP pruning. Pruning increases available bandwidth by restricting flooded traffic to those trunk links that the traffic must use to access the destination devices. You can enable VTP pruning on a switch in VTP server mode using the **vtp pruning** command. For example, if a VLAN is not defined on access switch ALS1 but is defined on distribution switches DLS1 and DLS2, the VLAN will be pruned from the trunk links between ALS1 and the distribution switches but not from the link between the two distribution switches.

Step 10: Configure VLANs by assigning port membership.

VLANs can be configured on a switch in different ways, depending on the type of switch used and the Cisco IOS version.

An older way to configure VLANs is to use the VLAN database. This method is being deprecated and is no longer recommended. However, the VLAN database is still accessible for those who choose to use it. For example, the following command is for a 3560 switch.

```
DLS1# vlan database
% Warning: It is recommended to configure VLAN from config mode,
as VLAN database mode is being deprecated. Please consult user
documentation for configuring VTP/VLAN in config mode.
```

A more current method to create a VLAN is to assign a port to a VLAN that does not yet exist. If the switch is in VTP Server or Transparent mode, it automatically creates the VLAN to the port that it has been assigned to.

VLAN 1 is the management VLAN by default. By default, all ports are set to dynamic mode and their access VLAN is set to 1. There is no need to create a VLAN 1, assign ports to it, or to set the mode of each port.

According to the lab diagram, VLANs 100, 110, and 120 must be created, and port 6 must be assigned to each VLAN. You will create VLANs 100 and 110 on the distribution switches using the port assignment method. You will create VLAN 120 for the access switches using global configuration commands and then assign ports to those VLANs.

Use the **switchport access vlan** command to assign port 6 on DLS1 and DLS2, according to the diagram. Port Fast Ethernet 0/6 of DLS1 will be assigned to VLAN 100, and Fast Ethernet 0/6 on DLS2 will be assigned to VLAN 110. The following command is for the 3560 switches.

```
DLS1(config)# interface FastEthernet 0/6
DLS1(config-if-range)# switchport access vlan 100 %
Access VLAN does not exist. Creating vlan 100
```

VLAN 100 was created at the same time port 6 was assigned to it. Configure DLS2 in the manner similar to DLS1, but this time use VLAN 110.

```
DLS2(config)# interface FastEthernet 0/6
DLS2(config-if-range)# switchport access vlan 110
% Access VLAN does not exist. Creating vlan 110
```

Issue the **show vlan** command on DLS1 to verify that VLANs 100 and 110 have been created. The output should be similar to the following output.

```
DLS1# show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -----------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
Fa0/5, Fa0/13, Fa0/14
                                                Fa0/15, Fa0/16, Fa0/17,
Fa0/18
                                                Fa0/19, Fa0/20, Fa0/21,
Fa0/22
                                                Fa0/23, Fa0/24, Gi0/1, Gi0/2
100  VLAN0100                         active    Fa0/6
110  VLAN0110                         active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ -----
1     enet  100001      1500  -      -      -         -    -         0       0
100   enet  100100      1500  -      -      -         -    -         0       0
110  enet  100110     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ -----
1003 tr     101003      1500  -      -      -         -    -         0       0
1004 fdnet 101004       1500  -      -      -       ieee -          0       0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0
Remote SPAN VLANs
------------------------------------------------------------------------------



Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

Because VLAN 100 and 110 were not named, the switch automatically assigns default names, which are VLAN0100 and VLAN0110.

Note that on DLS1, port Fa0/6 is active in VLAN 100. A **show vlan** command issued on DLS2 should show port Fa0/6 active in VLAN 110.

Step 11: Configure VLANs in configuration mode.

Another way of creating VLANs is to create them in configuration mode without assigning port membership.

You can create a VLAN in global configuration mode using the **vlan** command. Because ALS1 and ALS2 are configured for VTP client mode and it is not possible to create a VLAN when a switch is in client mode, you must create the VLAN on the switch that is acting as a server for the network. The VLAN then propagates to the other switches that are in client mode. Issue the **vlan** command in global configuration mode on DLS1.

```
DLS1(config)# vlan 120
```

Ports still need to be assigned to VLAN 120. Port assignment to a VLAN is an interface configuration operation. Use the **switchport access vlan** command on Fast Ethernet 0/6 of ALS1 and ALS2 to configure ports for VLAN 120.

```
ALS1(config)# interface fastEthernet 0/6
ALS1(config-if)# switchport access vlan 120

ALS2(config)# interface fastEthernet 0/6
ALS2(config-if)# switchport access vlan 120
```

Use the **show vlan** command to verify the creation of VLAN 120, with port Fa0/6 assigned to it. The output should be similar to the following.

```
ALS1# show vlan

VLAN Name                             Status    Ports
---- ------------------------------ --------- -----------------------------
1    default                        active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                              Fa0/5, Fa0/13, Fa0/14, Fa0/15
                                              Fa0/16, Fa0/17, Fa0/18, Fa0/19
                                              Fa0/20, Fa0/21, Fa0/22, Fa0/23
                                              Fa0/24, Gi0/1, Gi0/2
100  VLAN0100                         active
110  VLAN0110                         active
120  VLAN0120                         active    Fa0/6
1002 fddi-default                     act/unsup  1003
token-ring-default               act/unsup  1004
fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ -----
1    enet  100001     1500  -      -      -        -    -        0      0
100  enet  100100     1500  -      -      -        -    -        0      0
110  enet  100110     1500  -      -      -        -    -        0      0
120  enet  100120     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ -----
1003 tr    101003     1500  -      -      -        -    srb      0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0
Remote SPAN VLANs
------------------------------------------------------------------------------


Primary Secondary Type              Ports
```

```
------- --------- ----------------- ------------------------------------------
```

Step 12: Change the VLAN names.

The VLANs have not been named yet. Naming VLANs can help network administrators identify the functionality of those VLANs. To add names, use the **name** command in VLAN configuration mode. The following is a sample configuration for naming the three VLANs created in the domain.

```
DLS1(config)# vlan 100
DLS1(config-vlan)# name Server-Farm-1
DLS1(config-vlan)# exit
DLS1(config)# vlan 110
DLS1(config-vlan)# name Server-Farm-2
DLS1(config-vlan)# exit
DLS1(config)# vlan 120
DLS1(config-vlan)#  name  Net-Eng  DLS1(config-vlan)#  exit  Use the
```

show vlan command on DLS1 to verify that the new names have been added.

```
DLS1# show vlan

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/7, Fa0/8, Fa0/9
                                                Fa0/10, Fa0/11, Fa0/12, Fa0/13
                                                Fa0/14, Fa0/15, Fa0/16, Fa0/17
                                                Fa0/18, Fa0/19, Fa0/20, Fa0/21
                                                Fa0/22, Fa0/23, Fa0/24, Gi0/1
                                                Gi0/2
100  Server-Farm-1                    active    Fa0/6
110  Server-Farm-2                    active
120  Net-Eng                          active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
1    enet  100001     1500  -      -      -        -    -        0      0    100
enet  100100     1500  -      -      -        -    -        0      0
110  enet  100110     1500  -      -      -        -    -        0      0
VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1 Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ ------
120   enet   100120     1500  -      -      -        -    -        0      0
1002 fddi  101002     1500  -      -      -        -    -        0      0
1003 tr    101003     1500  -      -      -        -    -        0      0
1004 fdnet 101004     1500  -      -      -        ieee -        0      0
1005 trnet 101005     1500  -      -      -        ibm  -        0      0
Remote SPAN VLANs
------------------------------------------------------------------------------


Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

Step 13: Change the VLAN status to deactivate ports.

The default status of VLAN 1 and user-created VLANs is "active". A VLAN can be made locally inactive in the VLAN configuration mode by entering the command **shutdown** for the particular VLAN (does not apply to an SVI). This will cause all ports on a switch in a particular VLAN to stop transmitting data. Shutting down the VLAN on a switch does not influence its state on other switches in a VTP domain.

Shutdown the Net-Eng VLAN 120 on ALS1, wait a few moments, exit vlan configuration mode and then issue the **show vlan brief** command. The status should change to “act/lshut”.

```
ALS1(config)# vlan 120
ALS1(config-vlan)# shutdown

ALS1# show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/7, Fa0/8, Fa0/9
                                                Fa0/10, Fa0/11, Fa0/12, Fa0/13
                                                Fa0/14, Fa0/15, Fa0/16, Fa0/17
                                                Fa0/18, Fa0/19, Fa0/20, Fa0/21
                                                Fa0/22, Fa0/23, Fa0/24, Gi0/1
                                                Gi0/2
100  Server-Farm-1                    active    Fa0/6
110  Server-Farm-2                    active
120  Net-Eng                          act/lshut
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

Reactivate all ports in ALS1 Net-Eng VLAN 120 using the **no shutdown** command in VLAN configuration mode..

```
ALS1(config)# vlan 120
ALS1(config-vlan)# no shutdown
```

You can also put a VLAN into “suspend” status. The "suspend" state is configured in the VLAN configuration mode using the command state suspend. Suspending a VLAN causes all ports in that VLAN throughout the VTP domain to stop transferring data.

Suspend Net-Eng VLAN 120 on ALS1, wait a few moments, exit VLAN configuration mode and then issue the **show vlan brief** command. The status should change to “suspended”.

```
ALS1(config)# vlan 120
ALS1(config-vlan)# state suspend

ALS1# show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
Fa0/5, Fa0/7, Fa0/8, Fa0/9
                                                Fa0/10, Fa0/11, Fa0/12, Fa0/13
                                                Fa0/14, Fa0/15, Fa0/16, Fa0/17
                                                Fa0/18, Fa0/19, Fa0/20, Fa0/21
                                                Fa0/22, Fa0/23, Fa0/24, Gi0/1
                                                Gi0/2
100  Server-Farm-1                    active    Fa0/6
110  Server-Farm-2                    active
120  Net-Eng                          suspended
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

Reactivate VLAN 120 using the **state active** command in VLAN configuration mode..

```
ALS1(config)# vlan 120
ALS1(config-vlan)# state active
```

Note: The suspend state is advertised by VTP while the lshut state is not. The **state suspend** command can be issued on any switch in the VTP domain. It does not have to be issued on the VTP server.

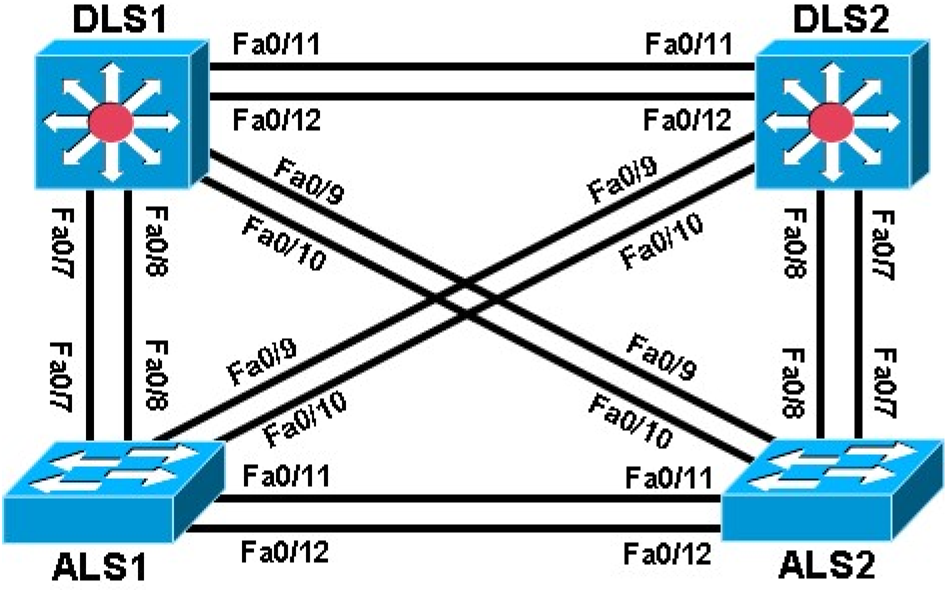
Both options can be used to temporarily take a particular VLAN out of operation which can be useful in certain scenarios - especially for guests, infrequently used conference rooms and similar deployments.

Step 14: Prepare for the next lab.

Prepare for the next lab by removing all the VLAN information and configurations. The VLAN database and startup configuration need to be deleted.

Practical 6b, Configuring EtherChannel

Topology



Objective

- Configure EtherChannel.

Background

Four switches have just been installed. The distribution layer switches are Catalyst 3560 switches, and the access layer switches are Catalyst 2960 switches. There are redundant uplinks between the access layer and distribution layer. Usually, only one of these links could be used; otherwise, a bridging loop might occur. However, using only one link utilizes only half of the available bandwidth. EtherChannel allows up to eight redundant links to be bundled together into one logical link. In this lab, you configure Port Aggregation Protocol (PAgP), a Cisco EtherChannel protocol, and Link Aggregation Control Protocol (LACP), an IEEE 802.3ad open standard version of EtherChannel.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.12246.SE.bin, and Catalyst 3560-24PS with the Cisco IOS image c3560-advipservicesk9-mz.122-46.SE.bin. You can use other switches (such as a 2950 or 3550) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560- ADVIPSERVICESK9-M image or comparable)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

Delete vlan.dat, erase the startup configuration, and reload all your switches. Refer to Lab 1-1, “Clearing a Switch,” and Lab 1-2, “Clearing a Switch Connected to a Larger Network.”

Step 2: Configure basic switch parameters.

a. Assign each switch a hostname according to the topology diagram.

b. Configure ports Fa0/7 through Fa0/12 as trunks. On the 3560 switches, you must first set the trunk encapsulation to 802.1Q. On the 2960s, only dot1q is supported, therefore the **switchport trunk encapsulation** command is unavailable, but the mode still needs to be changed to trunk.

Note: If the ports are configured with dynamic auto mode and you do not set the mode of the ports to trunk, the links do not form trunks and remain access ports. The default mode on a 3560 or 2960 switch is dynamic auto. The default mode on a 3550 or 2950 switch is dynamic desirable. DLS1 example:

```
DLS1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
DLS1(config)# interface range fastEthernet 0/7 - 12
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
```

Step 3: Configure an EtherChannel with Cisco PAgP.

Note: When configuring EtherChannels, it is a recommended best practice to shutdown the physical ports being grouped on both devices before configuring them into channel groups. Otherwise, the EtherChannel Misconfig Guard may place these ports into err-disabled state. The ports and port channel can be re-enabled after the EtherChannel is configured.

a. The first EtherChannel created for this lab aggregates ports Fa0/11 and Fa0/12 between ALS1 and ALS2. Make sure that you have a trunk link active for those two links with the **show interfaces trunk** command.

```
ALS1# show interfaces trunk

Port        Mode         Encapsulation  Status        Native vlan
Fa0/7       on           802.1q         trunking      1
Fa0/8       on           802.1q         trunking      1
Fa0/9       on           802.1q         trunking      1
Fa0/10      on           802.1q         trunking      1
Fa0/11      on           802.1q         trunking      1
Fa0/12      on           802.1q         trunking      1

<output omitted>
```

b. On both switches, add ports Fa0/11 and Fa0/12 to port channel 1 with the **channel-group 1 mode desirable** command. The **mode desirable** option indicates that you want the switch to actively negotiate to form a PAgP link.

```
ALS1(config)# interface range fastEthernet 0/11 - 12
ALS1(config-if-range)# channel-group 1 mode desirable
Creating a port-channel interface Port-channel 1
```

c. Configure the logical interface to become a trunk by first entering the **interface port-channel** *number* command and then the **switchport mode trunk** command. Add this configuration to both switches.

```
ALS1(config)# interface port-channel 1
ALS1(config-if)# switchport mode trunk
```

d. Verify that EtherChannel is working by issuing the **show etherchannel summary** command on both switches. This command displays the type of EtherChannel, the ports utilized, and port states.

```
ALS1# show etherchannel summary
Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling         w - waiting to be
aggregated         d - default port

Number of channel-groups in use: 1
Number of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+---------------------------------------- 1
Po1(SU)         PAgP      Fa0/11(P)   Fa0/12(P)

ALS2# show etherchannel summary
Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling         w - waiting to be
aggregated         d - default port


Number of channel-groups in use: 1 Number
of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+-----------+---------------------------------------- 1
Po1(SU)         PAgP      Fa0/11(P)   Fa0/12(P)
```

e. If the EtherChannel does not come up, you might want to try "flapping" the physical interfaces on both ends of the EtherChannel. This involves using the **shut** command on those interfaces, followed by a **no shut** command a few seconds later.

   The **show interfaces trunk** and **show spanning-tree** commands also show the port channel as one logical link.

```
ALS1# show interfaces trunk

Port        Mode         Encapsulation  Status        Native vlan
Fa0/7       on           802.1q         trunking      1
Fa0/8       on           802.1q         trunking      1
Fa0/9       on           802.1q         trunking      1 Fa0/10
on           802.1q         trunking      1
Po1         on           802.1q         trunking      1

<output omitted>

ALS1# show spanning-tree
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     0017.5a53.a380
             Cost        19
             Port        9 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     001d.4635.0c80
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface           Role Sts Cost      Prio.Nbr Type
------------------- ---- --- --------- -------- ----------------------------
Fa0/7               Altn BLK 19        128.7    P2p
Fa0/8               Altn BLK 19        128.8    P2p
Fa0/9               Root FWD 19        128.9    P2p
Fa0/10              Altn BLK 19        128.10   P2p
Po1                 Desg FWD 12        128.56   P2p
```

Step 4: Configure an 802.3ad LACP EtherChannel.

a. In 2000, the IEEE passed 802.3ad, which is an open standard version of EtherChannel. Using the previous commands, configure the link between DLS1 and ALS1 on ports Fa0/7 and Fa0/8 as an LACP EtherChannel. You must use a different port channel number on ALS1 than 1, because you already used that in the previous step. To configure a port channel as LACP, use the interface-level command **channel-group** *number* **mode active**. Active mode indicates that the switch actively tries to negotiate that link as LACP, as opposed to PAgP.

```
ALS1(config)# interface range fastEthernet 0/7 - 8
ALS1(config-if-range)# channel-group 2 mode active
Creating a port-channel interface Port-channel 2

ALS1(config-if-range)# interface port-channel 2

ALS1(config-if)# switchport mode trunk
```

b. Apply a similar configuration on DLS1. Verify the configuration with the **show etherchannel summary** command.

```
ALS1# show etherchannel summary
Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling        w - waiting to be
aggregated         d - default port


Number of channel-groups in use: 2 Number
of aggregators:           2
Group  Port-channel  Protocol    Ports
------+-------------+----------+-----------------------------------------
   1  Po1(SU)         PAgP      Fa0/11(P)   Fa0/12(P)
   2  Po2(SU)         LACP      Fa0/7(P)    Fa0/8(P)
```

Step 5: Configure a Layer 3 EtherChannel.

In the previous steps, you configured EtherChannels as Layer 2 trunk connections between switches. You can also configure EtherChannels as Layer 3 (routed) connections on switches that support routed ports. Because DLS1 and DLS2 are both multilayer switches, they can support routed ports.

a. Use the **no switchport** command on Fa0/11 and Fa0/12 to make them Layer 3 ports, and then add them to the channel group with the **channel-group** *number* **mode desirable** command. On the logical interface, issue the **no switchport** command to make it a Layer 3 port. Add the IP address 10.0.0.1 for DLS1 and 10.0.0.2 for DLS2. Configure both with a /24 subnet mask.

```
DLS1(config)# interface range fastEthernet 0/11 - 12
   DLS1(config-if-range)# no switchport
   DLS1(config-if-range)# channel-group 3 mode desirable
   Creating a port-channel interface Port-channel 3 DLS1(config-if-range)#
   interface port-channel 3
   DLS1(config-if)# no switchport
   DLS1(config-if)# ip address 10.0.0.1 255.255.255.0
```

b. Verify that you have Layer 3 connectivity by attempting to ping the other side of the link.

```
DLS1# ping 10.0.0.2


Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.0.0.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/1 ms
```

c. If you look at the output of the **show etherchannel summary** command, you see that it lists the port channel as a routed port, not a switched port. The RU in parentheses next to the name means routed and up, as opposed to switched and up (SU).

```
DLS1# show etherchannel summary
Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling         w - waiting to be
aggregated         d - default port



Number of channel-groups in use: 2 Number
of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+-----------+----------------------------------------
2      Po2(SU)         LACP      Fa0/7(P)    Fa0/8(P)
3      Po3(RU)         PAgP      Fa0/11(P)   Fa0/12(P)
```

Step 6: Configure load balancing.

The switches can use different methods to load-balance traffic going through a port channel. The available methods as well as the default method used varies by hardware platform. By default, Cisco Catalyst 3560 and Catalyst 2960 switches load-balance using the source MAC address.

a. You can view the current load-balancing configuration with the **show etherchannel load-balance** command.

```
DLS1# show etherchannel load-balance
EtherChannel Load-Balancing Operational State (src-mac):
```

```
Non-IP: Source MAC address
IPv4: Source MAC address
  IPv6: Source IP address
```

Other methods of load balancing are based on the destination MAC address, both source and destination MAC addresses, source IP address, destination IP address, and both source and destination IP addresses. Some older platforms, such as the Cisco Catalyst 2950 and Catalyst 3550 switches, may not support all of these methods.

b. For this scenario, configure ALS1 to load-balance by both source and destination MAC addresses using the global configuration command **port-channel load-balance** *method*, where the method is **src-dstmac**.

```
ALS1(config)# port-channel load-balance src-dst-mac
```

c. Verify the configuration with the **show etherchannel load-balance** command.

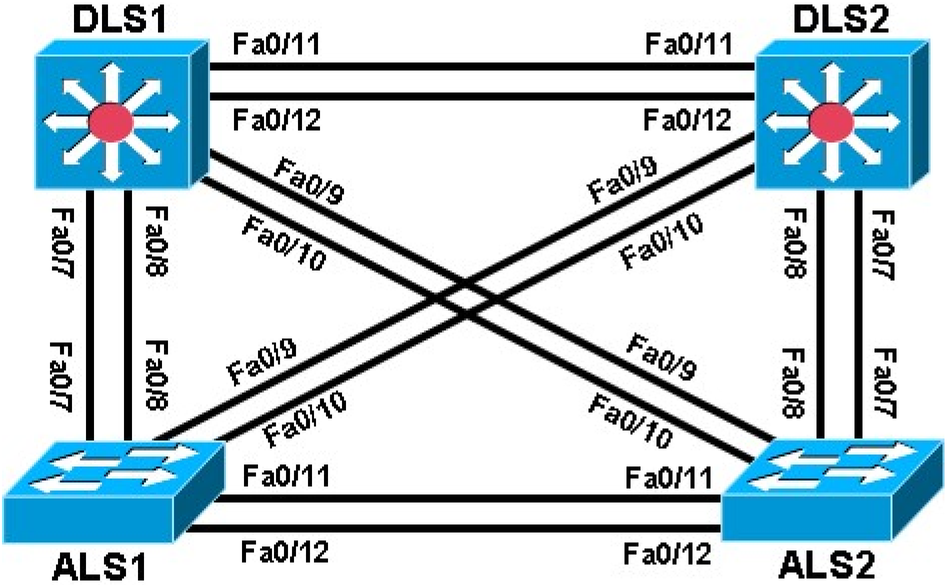
```
ALS1# show etherchannel load-balance
EtherChannel Load-Balancing Operational State (src-dst-mac):
Non-IP: Source XOR Destination MAC address
IPv4: Source XOR Destination MAC address
  IPv6: Source XOR Destination IP address
```

Challenge

The topology still has redundant links that you can aggregate. Experiment with the other port channel modes using the question mark on the interface-level command **channel-group** *number* **mode ?**. Look at the descriptions and implement some port channels in different ways. If The port mode is set to desirable, auto, active or passive (when PAgP or LACP are used), the command **channel-protocol** can be used. It cannot be used with **channel-group** *number* **mode on** command. The “on” mode statically sets the EtherChannel protocol without negotiation.

Practical 7a, Spanning Tree Protocol (STP) Default Behavior

Topology



Objective

- Observe the default behavior of STP.

Background

Four switches have just been installed. The distribution layer switches are Catalyst 3560s, and the access layer switches are Catalyst 2960s. There are redundant uplinks between the access layer and distribution layer. Because of the possibility of bridging loops, spanning tree logically removes any redundant links. In this lab, you will observe what spanning tree does and why.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin and Catalyst 3560-24PS switches with the Cisco IOS image c3560-advipservicesk9-mz.12246.SE.bin. Other switches (such as a 2950 or 3550), and Cisco IOS Software versions can be used if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-M image or comparable)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

Refer to Lab 1-1 Clearing a Switch and Lab 1-2 Clearing a Switch Connected to a Larger Network to prepare all four switches for this lab. Cable the equipment as shown. If you are accessing your equipment remotely, ask your instructor for instructions on how to do this.

Step 2: Configure basic switch parameters.

a. Configure the four switches as shown in the diagram with a hostname. ALS1 example:

```
Switch> enable
Switch# configure terminal
Switch(config)# hostname ALS1
```

b. Optionally, configure an enable secret password and console security. Configure the

console line with **logging synchronous** and no timeout. ALS1 example:

```
ALS1(config)# enable secret class
ALS1(config)# line console 0
ALS1(config-line)# logging synchronous
ALS1(config-line)# exec-timeout 0 0 ALS1(config-
line)# password cisco
ALS1(config-line)# login
```

Note: After the cables are connected spanning tree is initiated and the switch detects the redundant links.

By default, spanning tree runs on every port. When a new link becomes active, the port goes through the IEEE 802.1D spanning tree listening and learning states before transitioning to forwarding state. During this period, the switch discovers if it is connected to another switch or an end-user device.

One of the switches is elected as the root bridge for the tree. Then an agreement is established as to which links to keep active and which links to logically remove from the spanning tree (disable) if multiple links exist.

What type of frame does STP use to communicate with other switches?

____

The results in this lab will vary. Spanning tree operation is based on the MAC addresses of the switches. c. Observe the LEDs on the switch to check the status of the link. For access ports a bright green light indicates an active link. An amber light indicates an inactive link.

Step 3: Display default spanning tree information for all switches.

a. Verify IEEE 802.1D STP with the **show spanning-tree** command on DLS1.

Note: Your output may differ, based on the root bridge selected in your topology. The sample output below may also differ from those in your lab, because they were generated with a different set of switches.

```
DLS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8b3.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ------------------------------
```

```
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

b. Verify STP with the **show spanning-tree** command on DLS2. DLS2#

show spanning-tree

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ------------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p
```

c. Verify STP with the **show spanning-tree** command on ALS1. ALS1#

show spanning-tree

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.0635.5780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ------------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
```

```
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p
Fa0/11              Altn BLK 19        128.11   P2p
Fa0/12              Altn BLK 19        128.12   P2p
```

d. Verify STP with the **show spanning-tree** command on ALS2. ALS2#

```
show spanning-tree
```

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        9 (FastEthernet0/7)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ------------------------------
Fa0/7            Root FWD 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Notice that between each pair of switches, at least one of the two ports is blocking. Blocking can occur on the access layer switch or the distribution layer switch. If all ports have their default setting, the higher interface number of the two ports will block.

A port is placed in the blocking state because the switch detects two links between the same switches. A bridging loop would result if one of the switches did not logically disable a redundant link. e. Display the spanning tree information for DLS2 again.

```
DLS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
```

```
---------------- ---- --- --------- -------- ------------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p
```

After reviewing the spanning tree output, answer the following questions.

Which switch is the root of the spanning tree?

____

How can the root switch be identified?

____

Why was that switch selected as the root?

____

What caused one port to be in blocking state over another?

____

____

What caused one link to be blocked over another?

____

____

f. Another useful STP command is **show spanning-tree root**. This command displays a summary listing of the VLANs defined, the Root (bridge) ID for each one, the Root Cost and the Root Port that the switch uses to reach the root bridge. In this lab the only active VLAN is default VLAN 1. Issue the **show spanning-tree root** command on ALS1. The output shows the priority and MAC address of DLS2 as the Root ID for VLAN 1. The Root Cost is 19 and ALS1 uses port Fa0/9 to reach DLS2.

```
ALS1# show spanning-tree root

                                        Root    Hello Max Fwd
Vlan                   Root ID          Cost    Time  Age Dly  Root Port
---------------- -------------------- --------- ----- --- ---  ------------
VLAN0001         32769 0017.5a53.a380        19    2   20  15  Fa0/9
```

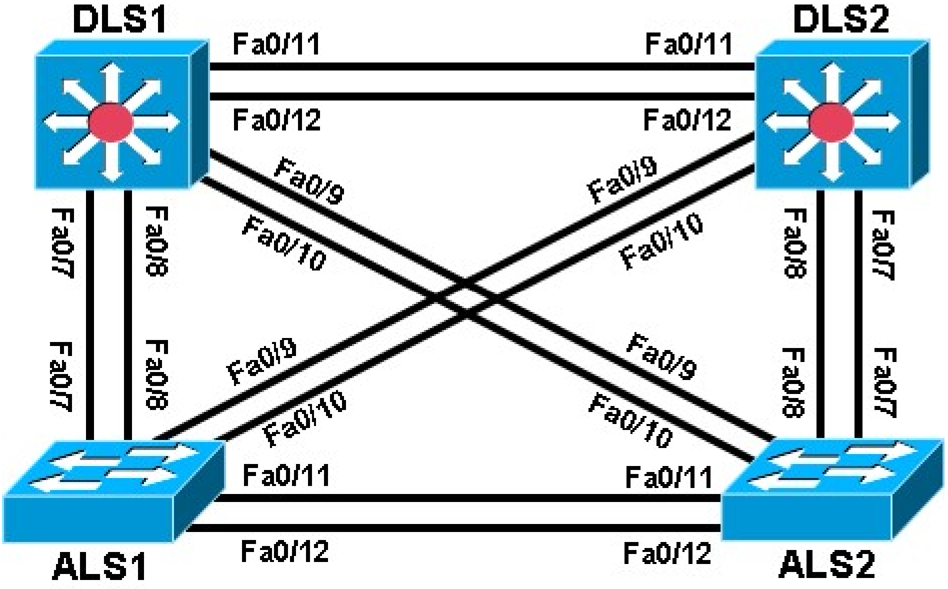
g. Issue the **show spanning-tree root** command on DLS2. The output shows the priority and MAC address of DLS2 as the Root ID for VLAN 1. The Root Cost is 0 and there is no Root Port listed because DLS2 is the root bridge.

```
DSL2# show spanning-tree root

                                        Root    Hello Max Fwd
Vlan                   Root ID          Cost    Time  Age Dly  Root Port
---------------- -------------------- --------- ----- --- ---  -----------

- VLAN0001         32769 0017.5a53.a380         0    2   20  15 Step 4:
```

Diagram the STP topology for VLAN 1.

Diagram the spanning tree topology for VLAN 1. With Cisco Catalyst switches, there is a different spanning tree state for each VLAN. Identify the root bridge, root forwarding ports, designated forwarding ports, and alternate blocking ports.

On the lab diagram provided below, indicate which switch is the root and the STP port role and state for the switch ports. Place the letter R (Root FWD), D (Desg FWD) or A (Altn BLK) next to each port identified in the topology.



In this lab, the default operation of IEEE 802.1D spanning tree was observed. Since no bridge priorities were specified, the switch with the lowest MAC address was elected as the root. The link providing the lowest root path cost was chosen as the active link. If costs were equal, the tie was broken first by the lowest sender BID of the BPDU, then by the lowest sending port priority and last by the lowest sending port number.

In the next lab, the default STP behavior will be modified so that spanning tree works according to specifications.

Challenge

Try to guess how your topology would look if you completely removed the root switch. Remember that the switch with the lowest MAC address becomes the root.

a. Shut down all the ports on your current root switch.

```
Switch# conf t
Switch(config)# interface range fastEthernet 0/1-24
Switch(config-if-range)# shutdown
```

Note: If you are on a 48 port switch, use interface range Fa0/1 – 48. If there are Gigabit Ethernet ports on the switch, they are not used with this lab, so it is not necessary to shut them down.

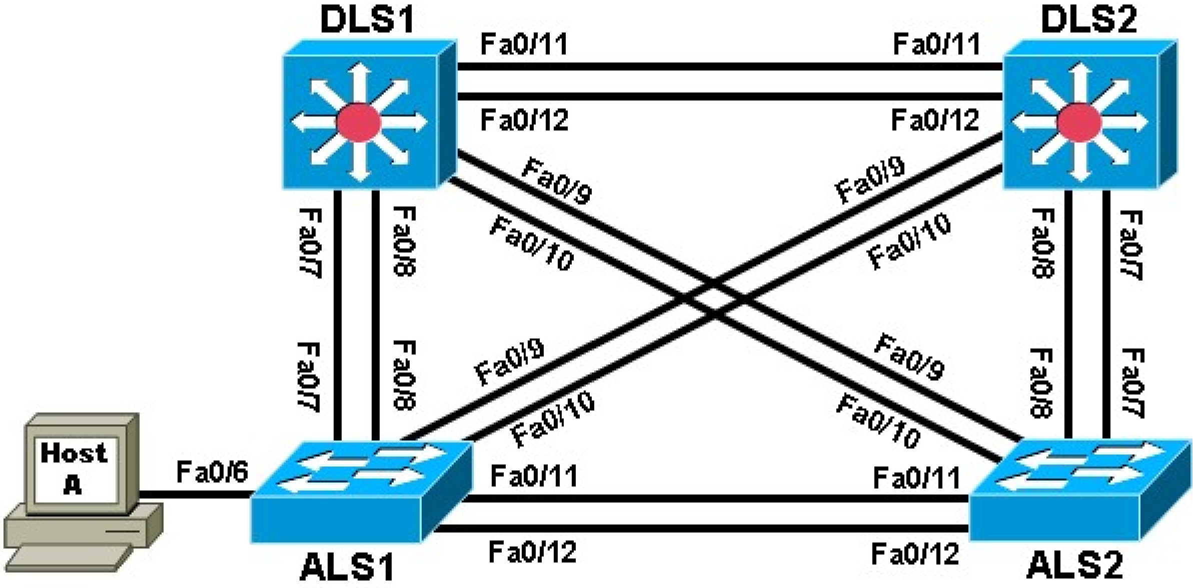
b. Issue the **show spanning-tree** command on the other switches. Did the topology converge the way you thought it would?

____

____

Practical 7b, Modifying Default Spanning Tree Behavior

Topology



Objective

- Observe what happens when the default spanning tree behavior is modified.

Background

Four switches have just been installed. The distribution layer switches are Catalyst 3560s, and the access layer switches are Catalyst 2960s. There are redundant uplinks between the access layer and distribution layer. Because of the possibility of bridging loops, spanning tree logically removes any redundant links. In this lab, you will see what happens when the default spanning tree behavior is modified.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin and Catalyst 3560-24PS switches with the Cisco IOS image c3560-advipservicesk9-mz.12246.SE.bin. Other switches (such as a 2950 or 3550) and Cisco IOS Software versions can be used if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-M image or comparable)
- 1 PC (optional) attached to switch ALS1.
- Ethernet and console cables

Note: Configuring PortFast in Step 5 requires a PC attached to one of the access switches.

Step 1: Prepare the switches for the lab.

a. Delete vlan.dat, erase the startup configuration, and reload all switches.

b. Give each switch a hostname according to the topology diagram.

c. Configure ports Fa0/7 through Fa0/12 on all switches to be trunks. On the 3560s, first set the trunk encapsulation to dot1q. On the 2960s, only dot1q is supported, therefore the **switchport trunk encapsulation** command is unavailable, but the mode still needs to be changed to trunk. If you do not set the mode of the ports to trunk, they will negotiate the operational mode according to their default DTP settings.

Note: The default mode on a 3560 or 2960 is dynamic auto; the default mode on a 3550 or 2950 is dynamic desirable. DLS1 example:

```
DLS1(config)# interface range fastEthernet 0/7 - 12
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
```

Step 2: Display default spanning tree information for all switches.

a. Use the **show spanning-tree** command to check how the non-configured switches created a spanning tree. Verify which switch became the root bridge. In the topology used in this lab, DLS2 is the root bridge.

```
DLS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

```
DLS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
```

```
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p


ALS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.0635.5780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p


ALS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
Cost        19
             Port        9 (FastEthernet0/7)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
```

```
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Root FWD 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

b. If you receive the following message “No spanning tree instance exists”, issue the **no shutdown** command on all interfaces.

```
Switch# show spanning-tree

No spanning tree instance exists.

Switch# conf t
Switch(config)# interface range fastEthernet 0/1-24
Switch(config-if-range)# no shutdown
Switch(config-if-range)# end
Switch# show spanning-tree
```

Now that the switch is communicating with the other switches in the topology, you should receive spanning tree output.

c. Issue the **show interfaces trunk** command on DLS1 to verify the trunking mode, encapsulation and status for the trunk links.

```
DSL1# show interfaces trunk

Port         Mode             Encapsulation  Status        Native vlan Fa0/7
on                802.1q         trunking                                  8
Fa0/8        on               802.1q         trunking                      8
Fa0/9        on               802.1q         trunking                      8
Fa0/10       on               802.1q         trunking                      8
Fa0/11       on               802.1q         trunking                      2
Fa0/12       on               802.1q         trunking                      2



Port         Vlans allowed on trunk
Fa0/7        1-4094
Fa0/8        1-4094
Fa0/9        1-4094
Fa0/10       1-4094
Fa0/11       1-4094
Fa0/12       1-4094
<output omitted>
```

Are BPDUs propagated without trunk links?

Step 3: Configure specific switches to be primary and secondary root.

In this step you configure other switches to be the primary root and secondary root. Because DLS2 is the root switch in this topology, this lab changes DLS1 to be the primary root and ALS1 to be the secondary. Do the same in your topology, regardless of which switch is the initial root. On one of the switches that you are not changing, you can use the **debug spanning-tree events** command to monitor topology changes. To change the spanning tree root status, use the global configuration commands **spanning-tree vlan** *vlan_number* **root primary** and **spanning-tree vlan** *vlan_number* **root secondary**. On a switch that you are not going to be modifying, issue the **debug** command and then watch the output. a. Issue the **debug** command on DLS2.

```
DLS2# debug spanning-tree events
Spanning Tree event debugging is on
```

b. Change DLS1 to be the primary root switch.

```
DLS1(config)# spanning-tree vlan 1 root primary
```

c. Change ALS1 to the secondary root.

```
ALS1(config)# spanning-tree vlan 1 root secondary
```

You can see the topology changes on the switch that you enabled debugging on (your output may vary depending on your initial topology):

```
DLS2#
00:10:43: STP: VLAN0001 heard root 24577-000a.b8a9.d780 on Fa0/11
00:10:43:     supersedes 32769-000a.b8a9.d680
00:10:43: STP: VLAN0001 new root is 24577, 000a.b8a9.d780 on port Fa0/11, cost
19
00:10:43: STP: VLAN0001 sent Topology Change Notice on Fa0/11
00:10:43: STP: VLAN0001 Fa0/12 -> blocking
00:10:53: STP: VLAN0001 sent Topology Change Notice on Fa0/11
00:10:53: STP: VLAN0001 Fa0/9 -> blocking
00:10:53: STP: VLAN0001 Fa0/10 -> blocking
```

Notice the timestamps on the debugs to see the difference between changes caused by the commands done in both steps.

d. Display the running config on the new root switches, DLS1 and ALS1.

```
DLS1# show run | include span spanning-tree mode pvst
spanning-tree  extend  system-id  spanning-tree  vlan  1
priority 24576
```

```
ALS1# show run | include span
spanning-tree mode pvst spanning-
tree extend system-id spanning-tree
vlan 1 priority 28672
```

Notice the spanning tree commands in the running configuration. You see a different command than the one you entered. This is because **spanning-tree vlan** *vlan_number* **root** is a command that sets the priority number on that VLAN automatically rather than typing in a specific priority number. The priority number of a VLAN can be between 0 and 61440 in increments of 4096. To manually set the specific priority number, use the **spanning-tree vlan** *vlan_number* **priority** *priority_number* command.

The command **spanning-tree vlan** *vlan_number* **root primary** sets the priority to 24576 instead of the default (32768). The command **spanning-tree vlan** *vlan_number* **root secondary** sets the priority to 28672. Given this information, would a lower or higher priority number result in a switch becoming the root bridge?

____

____

e. You can also view the priority modification with the **show spanning-tree** command: `DLS1#` **`show spanning-tree`**

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    24577  (priority 24576 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p
```

Step 4: Change the root port using the spanning-tree port-priority command.

With spanning tree, you can also modify port priorities to determine which ports are forwarding and which are blocking. To choose which port becomes the root on a non-root switch when faced with equal-cost redundant root paths via the same neighbor, the switch looks at the port priorities first. If the sender port priorities are the same, the switch picks the port that receives BPDUs with the lowest sender port number. On the link between DLS1 and DLS2, the default forwarding port is Fa0/11 because it is lower, and the default blocking port is Fa0/12 because it is higher. The two ports have equal costs because they have the same speed.

a. You can verify this using the **show spanning-tree** command on the non-root switch, which is DLS2. `DLS2#` **`show spanning-tree`**

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300
```

```
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

b. For comparison, issue the **show spanning-tree** command on DLS1. Notice that all ports are forwarding because it is the root switch.

```
DLS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    24577  (priority 24576 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p
```

Port priorities range from 0 to 240, in increments of 16. The default priority is 128, and a lower priority is preferred. To change port priorities, change them on the switch closer to the root.

c. To make DLS2 Fa0/12 the root port, and Fa0/11 block, change the port priority on DLS1 with the interface-level command **spanning-tree port-priority** *priority*.

```
DLS1(config)# int fastEthernet 0/12
DLS1(config-if)# spanning-tree port-priority 112
```

d. Issue the **show spanning-tree** command to verify which port is blocking on DLS2. `DLS2#` **show** **spanning-tree**

```
VLAN0001
  Spanning tree enabled protocol ieee
  Root ID    Priority    24577
             Address     000a.b8a9.d780
             Cost        19
             Port        14 (FastEthernet0/12)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Root FWD 19        128.14   P2p
```

On DLS2, although the root port has changed, the port priorities have not. On DLS1, you can see the port priorities have changed, although all ports are still forwarding (because it is the root switch).

```
DLS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    24577  (priority 24576 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        112.14   P2p
```

Using the above output, how does DLS2 know which port to change to the root port, without changing the port priorities on DLS2?

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Step 5: Configure PortFast on an access port.

a. (Optional) If you have a host attached to ASL1 Fa0/6 you can perform this step. If not, read through the following information to see how a port goes through the spanning tree states with and without PortFast enabled.

Another feature of spanning tree is PortFast. PortFast allows you to bypass the normal states of IEEE 802.1D spanning tree and move a port to the forwarding state as soon as it is turned on. This is useful when connecting hosts to a switch, because they can start communicating on the VLAN instantly rather than waiting for spanning tree. There is no danger of creating a spanning tree loop because you are not connecting another switch. A client that runs DHCP as soon as it starts up benefits, because the DHCP requests could be ignored if the port was not in the spanning tree forwarding state. PortFast must be used carefully to avoid inadvertently creating spanning tree loops.

b. Ensure that the port to which the host is attached (Fa0/6) on ALS1 is shut down initially.

```
ALS1(config)# interface fastEthernet 0/6
ALS1(config-if)# shutdown
```

c. Enable spanning tree debugging on ALS1.

```
ALS1# debug spanning-tree events
Spanning Tree event debugging is on
```

d. Set port Fa0/6 switchport mode to access, enable the port and observe the debug output. Notice what happens when the port is brought up. Your output may vary.

```
ALS1(config)# interface fastEthernet 0/6
ALS1(config-if)# switchport mode access
ALS1(config-if)# no shut
ALS1(config-if)# end
ALS1#

22:32:23: set portid: VLAN0001 Fa0/6: new port id 800D
22:32:23: STP: VLAN0001 Fa0/6 -> listening
22:32:25: %LINK-3-UPDOWN: Interface FastEthernet0/6, changed state to up
22:32:26: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/6,
changed state to up
22:32:38: STP: VLAN0001 Fa0/6 -> learning
                                                           22:32:53: STP: VLAN0001 Fa0/6 ->
                                                           forwarding
22:32:53: STP: VLAN0001 sent Topology Change Notice on Fa0/7
```

e. Shut down the port for the next part.

```
ALS1(config)# interface fastEthernet 0/6
ALS1(config-if)# shutdown
```

f. Activate PortFast on the port with the interface-level command **spanning-tree portfast**. The switch warns you about the possibility of creating switching loops.

```
ALS1(config)# interface fastEthernet 0/6
ALS1(config-if)# spanning-tree portfast
%Warning: portfast should only be enabled on ports connected to a single
host. Connecting hubs, concentrators, switches, bridges, etc... to this
interface  when portfast is enabled, can cause temporary bridging loops.  Use
with CAUTION
```

```
%Portfast has been configured on FastEthernet0/6 but will only
have effect when the interface is in a non-trunking mode.
```

g. Now, bring up the port by issuing the **no shutdown** command on the interface. `ALS1(config-if)#` **`no shutdown`**

```
22:43:23: set portid: VLAN0001 Fa0/6: new port id 800D
22:43:23: STP: VLAN0001 Fa0/6 ->jump to forwarding from blocking
22:43:25: %LINK-3-UPDOWN: Interface FastEthernet0/6, changed state to up
22:43:26: %LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/6,
changed state to up
```

h. Be sure to turn off debugging before continuing:

```
ALS1(config-if)# end
ALS1#
22:55:23: %SYS-5-CONFIG_I: Configured from console by console
ALS1# undebug all
All possible debugging has been turned off
```

Why could enabling portfast on redundant switch access links be a bad idea?

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Note: The **spanning-tree portfast trunk** interface-level command can be useful if a trunk is being connected to a router or a server. If RSTP is used, both trunk and access links can be moved to a forwarding state rapidly. The **spanning-tree portfast trunk** command is to be used only on trunks connected to non-switching devices.

Step 6: Change root port using the spanning-tree cost command.

Another way of changing which port becomes the root is to modify the port costs using the interface command **spanning-tree cost** *cost*. The default cost is 4 for a gigabit Ethernet port, 19 for a Fast Ethernet port, and 100 for a 10baseT Ethernet port. Lower cost is preferred.

Note: Each port has a default cost value based on a guideline established as part of IEEE 802.1d. In the original specification, the cost of a port cost is calculated as 1,000 Mbps (1 gigabit per second) divided by the bandwidth at which the port is functioning. A 10 Mbps connection have a cost of (1,000/10) or 100. As the speed of networks has increased beyond gigabit, the standard cost has been modified somewhat. The new cost values are:

Bandwidth	STP Cost
4 Mbps	250
10 Mbps	100
16 Mbps	62
45 Mbps	39
100 Mbps	19

155 Mbps	14
622 Mbps	6
1 Gbps	4
10 Gbps	2

a. For this scenario, change the cost of port Fa0/10 on ALS2. First, look at the current port costs using the **show spanning-tree** command.

Note: The cost shown here is for the port. The root bridge path cost is the sum of link port costs between a switch and the root bridge. The cost of traversing this path is the sum of the costs of the segments on the path. This determines how far away the root bridge is.

```
ALS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Note that Fa0/9 is currently the root port.

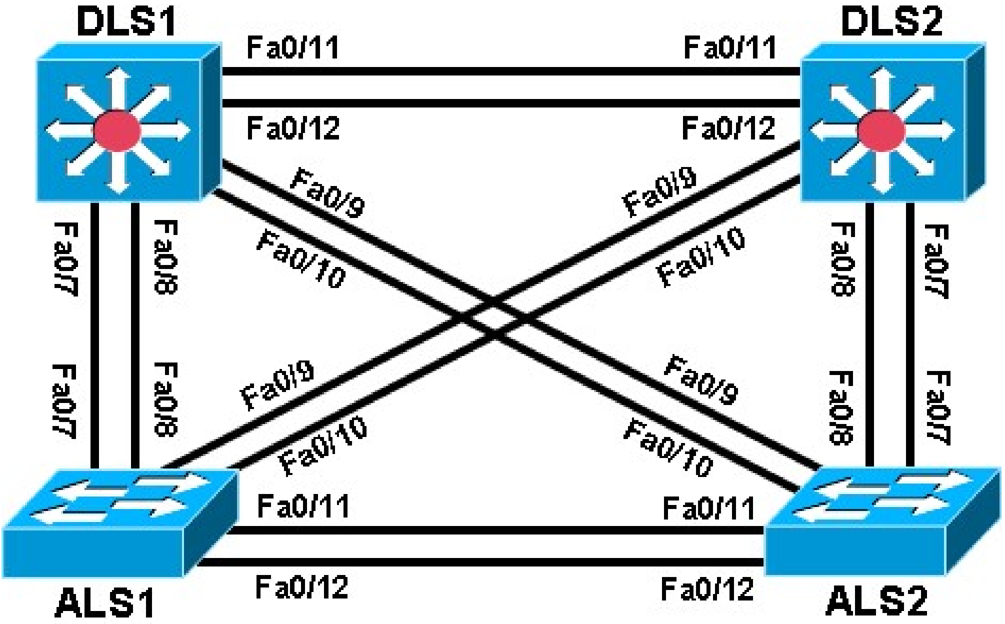
b. Change the port cost for Fa0/10 on ALS2 to 10 and then issue the **show spanning-tree** command.

```
ALS2(config)# interface fastEthernet 0/10
ALS2(config-if-range)# spanning-tree cost 10
```

```
ALS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    24577
             Address     000a.b8a9.d780
             Cost        10
             Port        12 (FastEthernet0/10)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn FWD 19        128.11   P2p
Fa0/10           Root FWD 10        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Practical 8a, Per-VLAN Spanning Tree Behavior

Topology



Objectives

- Observe the behavior of a separate spanning tree instance per VLAN.
- Change spanning tree mode to rapid spanning tree.

Background

Four switches have just been installed. The distribution layer switches are Catalyst 3560s, and the access layer switches are Catalyst 2960s. There are redundant uplinks between the access layer and distribution layer. Because of the possibility of bridging loops, spanning tree logically removes any redundant links. In this lab, you will see what happens when spanning tree is configured differently for different VLANs.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.12246.SE.bin and Catalyst 3560-24PS with the Cisco IOS image c3560-advipservicesk9-mz.122-46.SE.bin. Other switches (such as a 2950 or 3550), and Cisco IOS Software versions can be used if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-M image or comparable)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

a. Delete the vlan.dat file, erase the startup configuration, and reload the switches.

b. Give each switch a hostname according to the topology diagram.

c. Configure ports Fa0/7 through Fa0/12 on all switches to be trunks. On the 3560s, first set the trunk encapsulation to dot1q. On the 2960s, only dot1q is supported, therefore the **switchport trunk encapsulation** command is unavailable, but the mode still needs to be changed to trunk. If you do not set the mode of the ports to trunk, they will negotiate the operational mode according to their default DTP settings.

Note: The default mode on a 3560 or 2960 is dynamic auto; the default mode on a 3550 or 2950 is dynamic desirable.

DLS1 example:

```
DLS1(config)# interface range fastEthernet 0/7 - 12
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
```

Step 2: Configure VTP.

a. Configure all switches with VTP mode transparent and VTP domain CISCO. Add VLAN 10 and 20 to all of them. Use the **show vlan brief** command to view the VLAN configurations. DLS1 example:

```
DLS1(config)# vtp mode transparent
Setting device to VTP TRANSPARENT mode.

DLS1(config)# vtp domain CISCO
Changing VTP domain name from NULL to CISCO

DLS1(config)# vlan 10,20
DLS1(config-vlan)# end


DLS1# show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, Fa0/9, Fa0/10
                                                Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                                Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                                Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                                Gi0/1, Gi0/2
10   VLAN0010                         active
20   VLAN0020                         active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

b. Issue the **show spanning-tree** command on any of the four switches. Notice that instead of just one VLAN there are three non-reserved VLANs. VLANs 1002-1005 are reserved for internal switch usage. All other VLANs shown are non-reserved.

Note: By default Cisco switches use PVST+, a Cisco-proprietary IEEE 802.1Q-compatible per-VLAN spanning tree protocol.

```
DLS1# show spanning-tree
```

```
VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p



VLAN0010
  Spanning tree enabled protocol ieee
Root ID    Priority    32778
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32778  (priority 32768 sys-id-ext 10)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p



VLAN0020
Spanning tree
enabled protocol
ieee   Root ID
Priority    32788
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Step 3: Assign a root switch for each VLAN.

Notice that all the ports have identical spanning tree behavior for each VLAN. This is because all VLANs are running spanning tree with the default behavior. However, you can modify the default spanning tree behavior on a per-VLAN basis. The default priority is 32768. Configuring a switch with a lower priority value for a given VLAN makes it the root bridge for that VLAN. For this lab, we assign DLS1 as the root bridge for VLAN 10, and DLS2 for VLAN 20.

a. To change the priority for a given VLAN, use the **spanning-tree vlan** *number* **priority** *number* command. Configure DLS1 with priority 4096 for VLAN 10. Configure DLS2 similarly for VLAN 20.

```
DLS1(config)# spanning-tree vlan 10 priority 4096
DLS2(config)# spanning-tree vlan 20 priority 4096
```

b. If you look at the output of **show spanning-tree** on the four switches, you see that the port states and root switches vary on a per VLAN basis.

```
DLS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0010
```

```
  Spanning tree enabled protocol ieee
Root ID    Priority    4106
             Address     000a.b8a9.d780
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    4106   (priority 4096 sys-id-ext 10)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p



VLAN0020
  Spanning tree enabled protocol ieee
Root ID    Priority    4116
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


DLS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p



VLAN0010
  Spanning tree enabled protocol ieee
Root ID    Priority    4106
             Address     000a.b8a9.d780
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32778  (priority 32768 sys-id-ext 10)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p



VLAN0020
  Spanning tree enabled protocol ieee
Root ID    Priority    4116
             Address     000a.b8a9.d680
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    4116   (priority 4096 sys-id-ext 20)
             Address     000a.b8a9.d680
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
```

```
Fa0/12           Desg FWD 19        128.14   P2p


ALS1# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.0635.5780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p



VLAN0010
  Spanning tree enabled protocol ieee
Root ID    Priority    4106
             Address     000a.b8a9.d780
Cost        19
             Port        9 (FastEthernet0/7)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32778  (priority 32768 sys-id-ext 10)
             Address     0019.0635.5780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Root FWD 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p



VLAN0020
  Spanning tree enabled protocol ieee
Root ID    Priority    4116
             Address     000a.b8a9.d680
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     0019.0635.5780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p


ALS2# show spanning-tree

VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
Cost        19
             Port        9 (FastEthernet0/7)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Root FWD 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p



VLAN0010
  Spanning tree enabled protocol ieee
Root ID    Priority    4106
             Address     000a.b8a9.d780
             Cost        19
             Port        11 (FastEthernet0/9)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32778  (priority 32768 sys-id-ext 10)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ---------------------------- Fa0/7
Altn BLK 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Root FWD 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0020
  Spanning tree enabled protocol ieee
Root ID    Priority    4116
             Address     000a.b8a9.d680
             Cost        19
             Port        9 (FastEthernet0/7)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     0019.068d.6980
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 15

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Root FWD 19        128.9    P2p
Fa0/8            Altn BLK 19        128.10   P2p
Fa0/9            Altn BLK 19        128.11   P2p
Fa0/10           Altn BLK 19        128.12   P2p
Fa0/11           Altn BLK 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Step 4: Configure RSTP.

Other spanning tree modes besides PVST+ are available. One of these is RSTP (rapid spanning tree protocol), which greatly reduces the time for a port to transition to forwarding state while still preventing bridging loops. Cisco-proprietary per-VLAN rapid spanning tree (PVRST+) combines the functionality of RSTP and PVST.

Note: You can use the **clear spanning-tree detected-protocols** command after configuring different spanning tree modes. This can avoid a mutual deadlock between two switches when they consider themselves as 802.1D legacy bridges when in fact they were configured for RSTP.

a. To change the spanning tree mode to PVRST+, use the global configuration command **spanning-tree mode rapid-pvst**. Configure this on all four switches. During the transition period, rapid spanning tree falls back to 802.1D spanning tree on the links that have 802.1D spanning tree configured on one side.

```
DLS1(config)# spanning-tree mode rapid-pvst
```

b. After configuring all four switches with this command, use the **show spanning-tree** command to verify the configuration:

```
DLS1# show spanning-tree
```

```
VLAN0001
  Spanning tree enabled protocol rstp
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0010
  Spanning tree enabled protocol rstp
Root ID    Priority    4106
             Address     000a.b8a9.d780
             This bridge is the root
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    4106   (priority 4096 sys-id-ext 10)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Desg FWD 19        128.13   P2p
Fa0/12           Desg FWD 19        128.14   P2p


VLAN0020
  Spanning tree enabled protocol rstp
Root ID    Priority    4116
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- --------------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Challenge

a. On each switch, add VLANs 50, 60, 70, 80, 90, and 100. Configure ALS1 to be the root bridge for VLANs 50, 60, and 70, and ALS2 to be the root bridge for VLANs 80, 90, and 100. Configure the root bridges with a single line on each switch.

HINT: Use the question mark when you type the global configuration command **spanning-tree vlan ?**. Notice that you can modify spanning tree attributes in ranges.

____

____

____

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____ b.

Change the spanning tree cost of VLAN 20 on Fa0/11 and Fa0/12 between DLS1 and DLS2 to 15.

HINT: Use the question mark on the interface level command **spanning-tree vlan *number* ?**.

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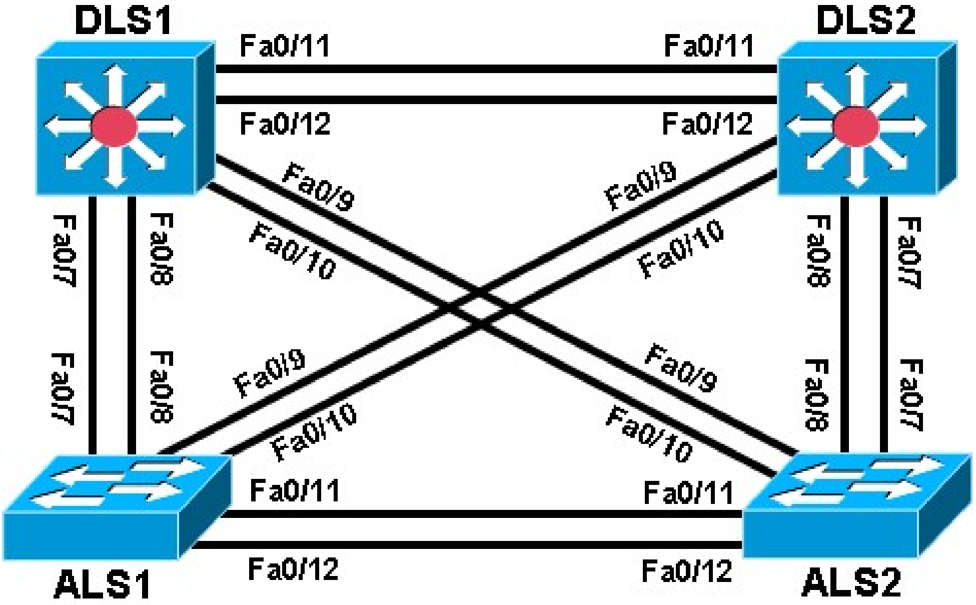
Practical 7b, Multiple Spanning Tree

Topology



Objective

- Observe the behavior of multiple spanning tree (MST).

Background

Four switches have just been installed. The distribution layer switches are Catalyst 3560s, and the access layer switches are Catalyst 2960s. There are redundant uplinks between the access layer and distribution layer. Because of the possibility of bridging loops, spanning tree logically removes any redundant links. In this lab, we will group VLANs using MST so that we can have fewer spanning tree instances running at once to minimize switch CPU load.

Note: This lab uses Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin and Catalyst 3560-24PS switches with the Cisco IOS image c3560-advipservicesk9-mz.122-46.SE.bin. Other switches (such as a 2950 or 3550), and Cisco IOS Software versions can be used if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Note: VTP version 3, is not supported by the IOS used on the switches in this lab. However, it is supported in IOS versions 12.2(52)SE and newer on all platforms eligible for this IOS (2960, 3560, 3750, etc.). VTPv3 has improvements in three major areas.

- Better administrative control over which device is allowed to update other devices' view of the VLAN topology. The chance of unintended and disruptive changes is significantly reduced, and availability is increased.
- Functionality for the VLAN environment has been significantly expanded. In addition to supporting the earlier ISL VLAN range from 1 to 1001, the new version supports the whole IEEE 802.1Q VLAN range up to 4095. In addition to supporting the concept of normal VLANs, VTP version 3 can transfer information regarding Private VLAN (PVLAN) structures.

- The third area of major improvement is support for databases other than VLAN. For example, VTPv3 supports MST mapping propagation instances, can synchronize MST configuration and be very helpful in maintaining the coherent MST configuration on all switches.

Required Resources

- 2 switch (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 2 switches (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-M image or comparable)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

a. Delete vlan.dat file, erase the startup config, and reload the switches.

b. Give each switch a hostname according to the topology diagram.

c. Configure ports Fa0/7 through Fa0/12 on all switches to be trunks. On the 3560s, first set the trunk encapsulation to dot1q. On the 2960s, only dot1q is supported, therefore the **switchport trunk encapsulation** command is unavailable, but the mode still needs to be changed to trunk. If you do not set the mode of the ports to trunk, they will negotiate the operational mode according to their default DTP settings.

Note: The default mode on a 3560 or 2960 is dynamic auto; the default mode on a 3550 or 2950 is dynamic desirable. DLS1 example:

```
DLS1(config)# interface range fastEthernet 0/7 - 12
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
```

Step 2: Configure VTP and VLANs.

a. Configure all switches with VTP mode transparent and VTP domain CISCO. Add VLANs

10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 to all of them. DLS1 example:

```
DLS1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
DLS1(config)# vtp mode transparent
Setting device to VTP TRANSPARENT mode.
DLS1(config) #vtp domain CISCO
Changing VTP domain name from NULL to CISCO
DLS1(config)# vlan 10,20,30,40,50,60,70,80,90,100
DLS1(config-vlan)# end
```

b. Issue the **show vlan brief** command to view the VLAN configurations. `DLS1#` **`show`**

```
vlan brief

00:11:56: %SYS-5-CONFIG_I: Configured from console by console

VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                                Fa0/13, Fa0/14, Fa0/15, Fa0/16
                                                Fa0/17, Fa0/18, Fa0/19, Fa0/20
                                                Fa0/21, Fa0/22, Fa0/23, Fa0/24
                                                Gi0/1, Gi0/2
10   VLAN0010                         active
20   VLAN0020                         active
30   VLAN0030                         active
40   VLAN0040                         active
50   VLAN0050                         active
60   VLAN0060                         active
70   VLAN0070                         active
80   VLAN0080                         active
90   VLAN0090                         active
100  VLAN0100                         active
1002 fddi-default                     act/unsup
1003 token-ring-default               act/unsup
1004 fddinet-default                  act/unsup
1005 trnet-default                    act/unsup
```

Step 3: Display spanning tree information.

Issue the **show spanning-tree** command on one of the switches. How many spanning tree instances are running?

____

____

```
DLS1# show spanning-tree


VLAN0001
  Spanning tree enabled protocol ieee
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0010
  Spanning tree enabled protocol ieee
Root ID    Priority    32778
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32778  (priority 32768 sys-id-ext 10)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0020
  Spanning tree enabled protocol ieee
Root ID    Priority    32788
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec

  Bridge ID  Priority    32788  (priority 32768 sys-id-ext 20)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
             Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p

<output omitted>

VLAN0090
  Spanning tree enabled protocol ieee
Root ID    Priority    32858
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32858  (priority 32768 sys-id-ext 90)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300
```

```
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p


VLAN0100
  Spanning tree enabled protocol ieee
Root ID    Priority    32868
             Address     000a.b8a9.d680
             Cost        19
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32868  (priority 32768 sys-id-ext 100)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Aging Time 300

Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 19        128.9    P2p
Fa0/8            Desg FWD 19        128.10   P2p
Fa0/9            Desg FWD 19        128.11   P2p
Fa0/10           Desg FWD 19        128.12   P2p
Fa0/11           Root FWD 19        128.13   P2p
Fa0/12           Altn BLK 19        128.14   P2p
```

Spanning tree is running a separate spanning tree instance for each VLAN created, plus VLAN 1. This method assumes that each VLAN could be running on a differently shaped topology. However, in many networks, multiple VLANs follow the same physical topology, so multiple spanning-tree calculations for the same topologies can get redundant. MST lets you configure different spanning tree instances. Each instance can hold a group of VLANs and manages its own spanning tree calculation.

MST is convenient in that it is backward compatible with PVST and RPVST+. Two switches only run MST with each other if they are in the same MST region. An MST region is defined by switches having identical region names, revision numbers, and VLAN-to-instance assignments. If they differ by any single attribute, they are considered different MST regions and fall back to RPVST+.

Step 4: Configure MST globally.

a. To configure MST, first use the global configuration command **spanning-tree mode mst** on all four switches. The command is shown for DLS1 only.

```
DLS1(config)# spanning-tree mode mst
```

By default, all VLANs are assigned to instance 0, but can be moved around to different instances when MST is configured.

b. Issue the **show spanning-tree** command and observe that there is only one spanning tree (instance 0) coming up. Also notice that the mode is listed as MSTP.

```
DLS1# show spanning-tree
MST00

Spanning tree enabled protocol mstp
Root ID    Priority    32768
             Address     000a.b8a9.d680
             Cost        0
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32768  (priority 32768 sys-id-ext 0)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 200000    128.9    P2p
Fa0/8            Desg BLK 200000    128.10   P2p
Fa0/9            Desg FWD 200000    128.11   P2p
Fa0/10           Desg FWD 200000    128.12   P2p
Fa0/11           Root FWD 200000    128.13   P2p
Fa0/12           Altn BLK 200000    128.14   P2p
```

c. If you use the **show spanning-tree mst configuration** command, you can see a switch's current MST configuration. Because you have not configured any MST region settings, the switch shows the default settings.

```
DLS1# show spanning-tree mst configuration
Name      []
Revision  0
Instance  Vlans mapped
--------  ---------------------------------------------------------------
0         1-4094
-------------------------------------------------------------------------
```

Step 5: Configure the MST region and instances.

Now that MST has been enabled, we can configure the MST region settings to group VLANs. We use the region name CISCO and a revision number of 1. We put VLANs 20 through 50 into instance 1, and 80 and 100 into instance 2. The rest of the VLANs remain in instance 0, the default.

a. To begin modifying the MST configuration, type the global configuration command **spanning-tree mst configuration**. Configuring MST is different from other switch configurations, because changes are not applied until you are finished (similar to the deprecated VLAN database mode), and you can abort changes if you wish.

Note: You must apply identical configurations on each switch for MST to work properly. The commands are shown for DLS1 only.

```
DLS1(config)# spanning-tree mst configuration
DLS1(config-mst)#
```

b. When you are in MST configuration mode, you can view the current configuration using the **show current** command. You do not need to leave configuration mode to execute this command. Notice that the output is identical to **show spanning-tree mst configuration**.

```
DLS1(config-mst)# show current
Current MST configuration
```

```
Name      []
Revision  0
Instance  Vlans mapped
--------  ----------------------------------------------------------------
0         1-4094
--------------------------------------------------------------------------
```

Change the region name by typing **name** *name*. Change the revision number by typing **revision** *number*.

```
DLS1(config-mst)# name CISCO
DLS1(config-mst)# revision 1
```

Note: The MST revision number is not like the configuration revision number used with VTP. It does not increment when changes are made. Along with the region name, the revision number identifies the MST domain and must be the same on all systems in the MST region.

c. The last configuration change you have to make is putting VLANs into instances. Use the command **instance** *number* **vlan** *vlan_range*. The instance number can be between 0 and 15. Remember that 0 is the default instance number.

```
DLS1(config-mst)# instance 1 vlan 20-50
DLS1(config-mst)# instance 2 vlan 80,100
```

d. You can verify the changes you are about to make with the **show pending** command. Remember that the changes that you just entered are not committed until you type **exit, end** or **Ctrl+C**. If you do not like the changes you made, you can leave the prompt without committing them by typing **abort**. In the output below, notice the difference between **show current** and **show pending**.

```
DLS1(config-mst)# show current
Current MST configuration
Name      []
Revision  0
Instance  Vlans mapped
--------  ----------------------------------------------------------------
0         1-4094
--------------------------------------------------------------------------

DLS1(config-mst)# show pending
Pending MST configuration
Name      [CISCO]
Revision  1
Instance  Vlans mapped
--------  ----------------------------------------------------------------
0         1-19,51-79,81-99,101-4094
1         20-50
2         80,100
--------------------------------------------------------------------------

DLS1(config-mst)# exit
```

e. If you enter the **show spanning-tree mst configuration** command, you can see that the current configuration reflects the changes you just committed. Remember to perform the same configuration on all four switches.

```
DLS1# show span mst configuration
```

```
Name      [CISCO]
Revision  1
Instance  Vlans mapped
--------  ---------------------------------------------------------
0         1-19,51-79,81-99,101-4094
1         20-50
2         80,100
-------------------------------------------------------------------
```

Why do the switches wait until you are finished making changes to MST to commit them, rather than changing MST as you enter commands (like most switch commands)?

____

____

____

f. Verify that separate instances of spanning tree are running.

```
DLS1# show spanning-tree

MST0
  Spanning tree enabled protocol mstp
Root ID    Priority    32768
             Address     000a.b8a9.d680
             Cost        0
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32768  (priority 32768 sys-id-ext 0)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 200000    128.9    P2p
Fa0/8            Desg FWD 200000    128.10   P2p
Fa0/9            Desg FWD 200000    128.11   P2p
Fa0/10           Desg FWD 200000    128.12   P2p
Fa0/11           Root FWD 200000    128.13   P2p
Fa0/12           Altn BLK 200000    128.14   P2p


MST1
  Spanning tree enabled protocol mstp
Root ID    Priority    32769
             Address     000a.b8a9.d680
             Cost        200000
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32769  (priority 32768 sys-id-ext 1)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 200000    128.9    P2p
Fa0/8            Desg FWD 200000    128.10   P2p
Fa0/9            Desg FWD 200000    128.11   P2p
Fa0/10           Desg FWD 200000    128.12   P2p
```

```
Fa0/11           Root FWD 200000    128.13   P2p
Fa0/12           Altn BLK 200000    128.14   P2p


MST2
  Spanning tree enabled protocol mstp
Root ID    Priority    32770
             Address     000a.b8a9.d680
             Cost        200000
             Port        13 (FastEthernet0/11)
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
  Bridge ID  Priority    32770  (priority 32768 sys-id-ext 2)
             Address     000a.b8a9.d780
             Hello Time   2 sec  Max Age 20 sec  Forward Delay 15 sec
Interface        Role Sts Cost      Prio.Nbr Type
---------------- ---- --- --------- -------- ----------------------------
Fa0/7            Desg FWD 200000    128.9    P2p
Fa0/8            Desg FWD 200000    128.10   P2p
Fa0/9            Desg FWD 200000    128.11   P2p
Fa0/10           Desg FWD 200000    128.12   P2p
Fa0/11           Root FWD 200000    128.13   P2p
Fa0/12           Altn BLK 200000    128.14   P2p
```

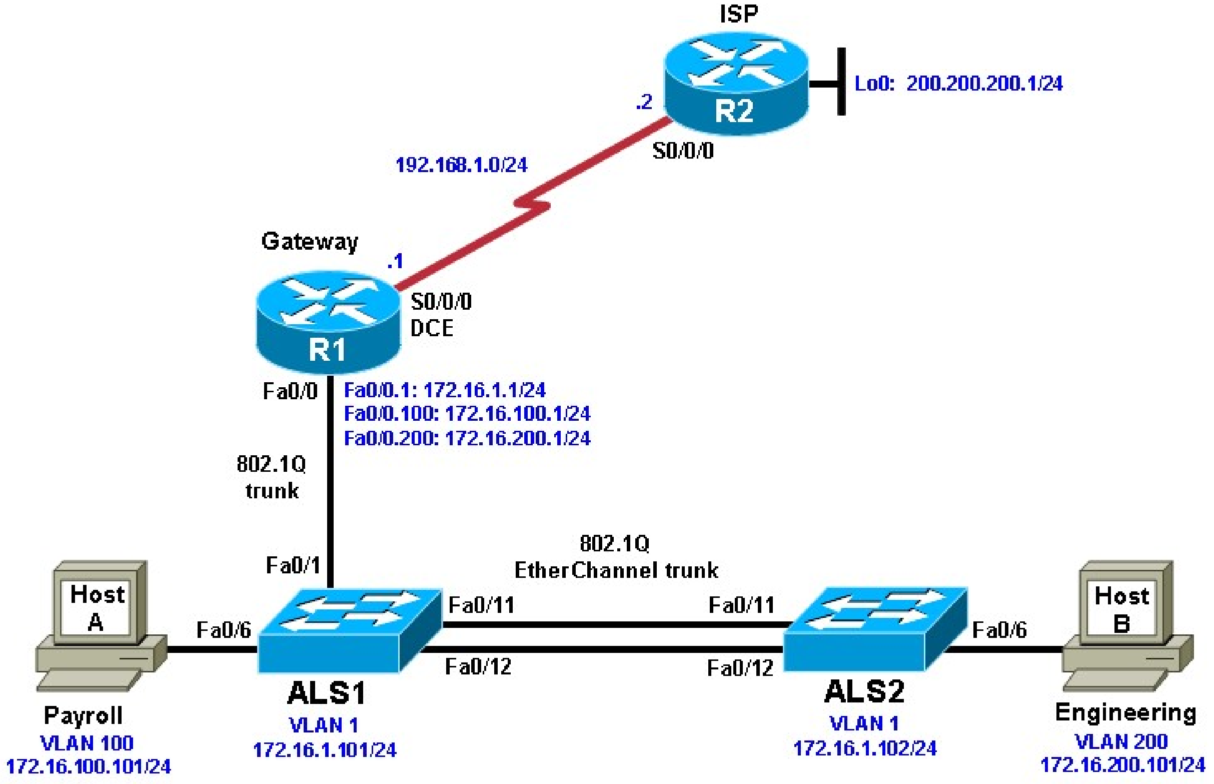
Challenge

You can modify per-instance MST spanning tree attributes the same way you can modify per-VLAN attributes. Make DLS1 the root of instance 1 and DLS2 the root of instance 2.

HINT: Use a question mark on the global configuration command **spanning-tree mst ?**.

Practical 9a, Inter-VLAN Routing with an External Router

Topology



Objective

- Configure inter-VLAN routing using an external router, also known as a router on a stick.

Background

Inter-VLAN routing using an external router can be a cost-effective solution when it is necessary to segment a network into multiple broadcast domains. In this lab, you split an existing network into two separate VLANs on the access layer switches, and use an external router to route between the VLANs. An 802.1Q trunk connects the switch and the Fast Ethernet interface of the router for routing and management. Static routes are used between the gateway router and the ISP router. The switches are connected via an 802.1Q EtherChannel link.

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 switches are Cisco WS-C2960-24TT-L with the Cisco IOS image c2960-lanbasek9-mz.122-46.SE.bin. You can use other routers (such as 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

- 2 routers (Cisco 1841 with Cisco IOS Release 12.4(24)T1 Advanced IP Services or comparable)
- 2 switches (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 switches and routers for the lab.

a. Cable the network as shown in the topology diagram. On each switch, erase the startup configuration, delete the vlan.dat file, and reload the switches. Refer to Lab 1-1, “Clearing a Switch” and Lab 1-2, “Clearing a Switch Connected to a Larger Network” to prepare the switches for this lab.

b. Erase the startup configuration and reload the routers.

Step 2: Configure the hosts.

Configure PC hosts A and B with the IP address, subnet mask (/24), and default gateway shown in the topology.

Step 3: Configure the routers.

a. Configure the ISP router for communication with your gateway router. The static route used for the internal networks provides a path for the local network from the ISP. In addition, configure a loopback interface on the ISP router to simulate an external network.

```
Router(config)# hostname ISP
ISP(config)# interface Loopback0
ISP(config-if)# ip address 200.200.200.1 255.255.255.0
ISP(config-if)# interface Serial0/0/0
ISP(config-if)# ip address 192.168.1.2 255.255.255.0 ISP(config-
if)# no shutdown
ISP(config-if)# exit
ISP(config)# ip route 172.16.0.0 255.255.0.0 192.168.1.1
```

b. Configure the Gateway router to communicate with the ISP router. Notice the use of a static default route. The default route tells the router to send any traffic with an unknown destination network to the ISP router.

```
Router(config)# hostname Gateway
Gateway(config)# interface Serial0/0/0
Gateway(config-if)# ip address 192.168.1.1 255.255.255.0
Gateway(config-if)# clockrate 64000
Gateway(config-if)# no shutdown
Gateway(config-if)# exit
Gateway(config)# ip route 0.0.0.0 0.0.0.0 192.168.1.2
```

c. Verify connectivity from the Gateway router using the **ping** command.

Was this ping successful?

____

Step 4: Configure the switches.

a. Configure the switch hostnames and IP addresses on the management VLAN according to the diagram. By default, VLAN 1 is used as the management VLAN. Create a default gateway on both access layer switches using the **ip default-gateway** *ip_address* command. The following is a sample configuration for switch ALS1.

```
Switch(config)# hostname ALS1
ALS1(config)# interface vlan 1
ALS1(config-if)# ip address 172.16.1.101 255.255.255.0
ALS1(config-if)# no shutdown
ALS1(config-if)# exit
ALS1(config)# ip default-gateway 172.16.1.1
```

The following is a sample configuration for switch ALS2.

```
Switch(config)# hostname ALS2
ALS2(config)# interface vlan 1
ALS2(config-if)# ip address 172.16.1.102 255.255.255.0
ALS2(config-if)# no shutdown
ALS2(config-if)# exit
ALS2(config)# ip default-gateway 172.16.1.1
```

b. (Optional) Set an enable secret password and configure the vty lines for Telnet access to the switch.

```
ALS1(config)# enable secret cisco
ALS1(config)# line vty 0 15
ALS1(config-line)# password cisco
ALS1(config-line)# login
ALS1(config-line)# end

ALS2(config)# enable secret cisco
ALS2(config)# line vty 0 15
ALS2(config-line)# password cisco
ALS2(config-line)# login ALS2(config-line)#
end
```

c. By default, how many lines are available for Telnet on the access switches?

Step 5: Confirm the VLANs.

a. Verify that the only existing VLANs are the built-in VLANs. Issue the **show vlan** command from privileged mode on both access layer switches. ALS1# **show vlan**

```
VLAN Name                             Status    Ports
---- -------------------------------- --------- -------------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                Fa0/9, Fa0/10, Fa0/11, Fa0/12
                                                Fa0/13, Fa0/14, Fa0/15,
Fa0/16
                                                Fa0/17, Fa0/18, Fa0/19,
Fa0/20
                                                Fa0/21, Fa0/22, Fa0/23,
Fa0/24
                                                Gi0/1, Gi0/2
1002  fddi-default                     act/unsup  1003 token-
ring-default               act/unsup  1004 fddinet-default
act/unsup  1005 trnet-default                   act/unsup

VLAN Type  SAID       MTU   Parent RingNo BridgeNo Stp  BrdgMode Trans1
Trans2
---- ----- ---------- ----- ------ ------ -------- ---- -------- ------ -----
1     enet  100001      1500  -       -       -         -    -         0       0
1002 fddi  101002     1500  -       -      -        -    -        0      0
1003  tr    101003     1500  -       -      -        -    -
0      0    1004 fdnet 101004     1500  -       -      -
ieee -        0      0    1005 trnet 101005     1500  -      -
-        ibm  -        0      0
Remote SPAN VLANs
```

```
----------------------------------------------------------------------------


Primary Secondary Type              Ports
------- --------- ----------------- ------------------------------------------
```

Which VLAN is the default management VLAN for Ethernet? What types of traffic are carried on this VLAN?

____

____

____

____

Step 6: Configure trunk links and EtherChannel on switches.

a. Use the Fast Ethernet 0/11 and 0/12 ports of ALS1 and ALS2 to create an EtherChannel trunk between the switches.

```
ALS1# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
ALS1(config)# interface range fastEthernet 0/11 - 12
ALS1(config-if-range)# switchport mode trunk
ALS1(config-if-range)# channel-group 1 mode desirable
ALS1(config-if-range)# end

ALS2# configure terminal
Enter configuration commands, one per line.  End with CNTL/Z.
ALS2(config)# interface range fastEthernet 0/11 - 12
ALS2(config-if-range)# switchport mode trunk
ALS2(config-if-range)# channel-group 1 mode desirable  ALS2(config-if-range)#
end
```

b. Verify the EtherChannel configuration using the **show etherchannel** command. ALS1#

```
show etherchannel 1 summary

Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling         w - waiting to be
aggregated         d - default port



Number of channel-groups in use: 1 Number
of aggregators:           1

Group  Port-channel  Protocol    Ports
------+-------------+----------+-----------------------------------------
1      Po1(SU)         PAgP      Fa0/11(P)   Fa0/12(P)
```

Step 7: Configure VTP.

a. Set up the VTP domain for the access layer switches in global configuration mode. The default VTP mode is server for both switches. Configure ALS2 as a VTP client, and leave ALS1 as a server. Configure the VTP domain name and version on VTP server ALS1.

```
ALS2(config)# vtp mode client
Setting device to VTP CLIENT mode.

ALS1(config)# vtp domain SWLAB
Changing VTP domain name from NULL to SWLAB
%SW_VLAN-6-VTP_DOMAIN_NAME_CHG: VTP domain name changed to SWLAB.

ALS1(config)# vtp version 2
```

b. Use the **show vtp status** command to verify the ALS1 VTP configuration and that client ALS2 has learned the new VTP domain information from ALS1.

```
ALS1# show vtp status
VTP Version                     : running VTP2
Configuration Revision          : 1
Maximum VLANs supported locally : 255 Number
of existing VLANs        : 5
VTP Operating Mode              : Server VTP
Domain Name                 : SWLAB
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Enabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x6A 0x1A 0x90 0xA3 0x10 0xCE 0x86 0xFA
Configuration last modified by 172.16.1.101 at 2-28-10 00:36:24 Local
updater ID is 172.16.1.101 on interface Vl1 (lowest numbered VLAN
interface found)

ALS2# show vtp status
VTP Version                     : running VTP2
Configuration Revision          : 1
Maximum VLANs supported locally : 255 Number
of existing VLANs        : 5
VTP Operating Mode              : Client
VTP Domain Name                 : SWLAB
VTP Pruning Mode                : Disabled
VTP V2 Mode                     : Enabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0x6A 0x1A 0x90 0xA3 0x10 0xCE 0x86 0xFA
Configuration last modified by 172.16.1.101 at 2-28-10 00:36:24
```

Step 8: Configure VLANs and switch access ports.

a. Configure the VLAN 100 named Payroll and VLAN 200 named Engineering on VTP server ALS1.

```
ALS1(config)# vlan 100
ALS1(config-vlan)# name Payroll ALS1(config-vlan)#
vlan 200
ALS1(config-vlan)# name Engineering
```

b. Use the **show vlan brief** command on ALS2 to verify that ALS2 has learned the new VLANs from ALS1.

```
ALS2# show vlan brief


VLAN Name                             Status    Ports
---- -------------------------------- --------- -----------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
Fa0/5, Fa0/6, Fa0/7, Fa0/8
                                                Fa0/9, Fa0/10, Fa0/13, Fa0/14
                                                Fa0/15, Fa0/16, Fa0/17,
Fa0/18
                                                Fa0/19, Fa0/20, Fa0/21,
Fa0/22
                                                Fa0/23, Fa0/24, Gi0/1, Gi0/2
100  Payroll                          active
200  Engineering                      active
1002 fddi-default                     act/unsup
1003 trcrf-default                    act/unsup 1004 fddinet-
     default                  act/unsup 1005 trbrf-default
     act/unsup
```

c. Configure the switch access ports for the hosts according to the diagram. Statically set the switch port mode to access, and use Spanning Tree PortFast on the interfaces. Assign the host attached to ALS1 Fast Ethernet 0/6 to VLAN 100, and the host attached to ALS2 Fast Ethernet 0/6 to VLAN 200.

```
ALS1(config)# interface fastEthernet 0/6 ALS1(config-if)#
switchport mode access
ALS1(config-if)# switchport access vlan 100
ALS1(config-if)# spanning-tree portfast
%Warning: portfast should only be enabled on ports connected to a single
host. Connecting hubs, concentrators, switches, bridges, etc... to this
interface when portfast is enabled, can cause temporary bridging loops.
Use with CAUTION

%Portfast has been configured on FastEthernet0/6 but will only
have effect when the interface is in a non-trunking mode.

ALS2(config)# interface fastEthernet 0/6 ALS2(config-if)#
switchport mode access
ALS2(config-if)# switchport access vlan 200
ALS2(config-if)# spanning-tree portfast
%Warning: portfast should only be enabled on ports connected to a single
host. Connecting hubs, concentrators, switches, bridges, etc... to this
interface when portfast is enabled, can cause temporary bridging loops.
Use with CAUTION

%Portfast has been configured on FastEthernet0/6 but will only
have effect when the interface is in a non-trunking mode.
```

d. Use the **show vlan brief** command to verify that Fa0/6 is in VLAN 100 on ALS1 and in VLAN 200 on ALS2.

```
ALS1# show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -----------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/7, Fa0/8, Fa0/9
                                                Fa0/10, Fa0/13, Fa0/14,
Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18,
Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22,
Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
100  Payroll                          active    Fa0/6
200  Engineering                      active
1002 fddi-default                     act/unsup
```

```
1003 trcrf-default                    act/unsup 1004 fddinet-
     default                  act/unsup 1005 trbrf-default
     act/unsup

ALS2# show vlan brief

VLAN Name                             Status    Ports
---- -------------------------------- --------- -----------------------------
1    default                          active    Fa0/1, Fa0/2, Fa0/3, Fa0/4
                                                Fa0/5, Fa0/7, Fa0/8, Fa0/9
                                                Fa0/10, Fa0/13, Fa0/14,
Fa0/15
                                                Fa0/16, Fa0/17, Fa0/18,
Fa0/19
                                                Fa0/20, Fa0/21, Fa0/22,
Fa0/23
                                                Fa0/24, Gi0/1, Gi0/2
100  Payroll                          active
200  Engineering                      active    Fa0/6
1002 fddi-default                     act/unsup
1003 trcrf-default                    act/unsup 1004 fddinet-
     default                  act/unsup
1005 trbrf-default                    act/unsup
```

Step 9: Configure ALS1 trunking to the Gateway router.

Configure switch ALS1 interface Fast Ethernet 0/1 for trunking with the Gateway router Fast Ethernet interface, according to the topology diagram.

```
ALS1(config)# interface fastEthernet 0/1
ALS1(config-if)# switchport mode trunk
ALS1(config-if)# end
```

Note: Optionally, you can apply the **spanning-tree portfast trunk** command to interface Fa0/1 of switch ALS1. This allows the link to the router to rapidly transition to the forwarding state despite being a trunk.

Step 10: Configure the Gateway router Fast Ethernet interface for VLAN trunking.

The native VLAN cannot be configured on a subinterface for Cisco IOS releases earlier than 12.1(3)T. The native VLAN IP address must be configured on the physical interface. Other VLAN traffic is configured on subinterfaces. Cisco IOS release 12.1(3)T and later support native VLAN configuration on a subinterface with the **encapsulation dot1q native** command. If a subinterface is configured using the **encapsulation dot1q native** command, the configuration on the physical interface is ignored. This technique is used in the lab configuration.

a. Create a subinterface for each VLAN. Enable each subinterface with the proper trunking protocol, and configure it for a particular VLAN with the **encapsulation** command. Assign an IP address to each subinterface, which hosts on the VLAN can use as their default gateway. The following is a sample configuration for the Fast Ethernet 0/0 interface.

```
Gateway(config)# interface fastEthernet 0/0 Gateway(config-if)#
no shut
```

The following is a sample configuration for the VLAN 1 subinterface.

```
Gateway(config)# interface fastEthernet 0/0.1
Gateway(config-subif)# description Management VLAN 1
Gateway(config-subif)# encapsulation dot1q 1 native
Gateway(config-subif)# ip address 172.16.1.1 255.255.255.0
```

Note: For enhanced switch security, it is considered best practice to use independent unused VLANs for native and management VLANs. The following is a sample configuration for the VLAN 100 subinterface.

```
Gateway(config-subif)# interface fastEthernet 0/0.100
Gateway(config-subif)# description Payroll VLAN 100
Gateway(config-subif)# encapsulation dot1q 100
Gateway(config-subif)# ip address 172.16.100.1 255.255.255.0
```

The following is a sample configuration for the VLAN 200 subinterface.

```
Gateway(config-subif)# interface fastEthernet 0/0.200
Gateway(config-subif)# description Engineering VLAN 200
Gateway(config-subif)# encapsulation dot1q 200
Gateway(config-subif)# ip address 172.16.200.1 255.255.255.0 Gateway(config-
subif)# end
```

b. Use the **show ip interface brief** command to verify the interface configuration and status.

```
Gateway# show ip interface brief
Interface            IP-Address      OK? Method Status
Protocol
FastEthernet0/0      unassigned      YES unset  up                    up
FastEthernet0/1.1    172.16.1.1      YES manual up                    up
FastEthernet0/1.100  172.16.100.1    YES manual up                    up
FastEthernet0/1.200  172.16.200.1    YES manual up                    up
FastEthernet0/1      unassigned      YES unset  administratively down down
Serial0/0/0          192.168.1.1     YES manual up                    up
Serial0/0/1          unassigned      YES unset  administratively down down
```

c. Use the **show interfaces description** command to verify the interface status and description assigned.

```
Gateway# show interfaces description

Interface                      Status         Protocol Description
Fa0/0                          up             up
Fa0/0.1                        up             up       Management VLAN 1
Fa0/0.100                      up             up       Payroll VLAN 100
Fa0/0.200                      up             up       Engineering VLAN 200
Fa0/1                          admin down     down
Se0/0/0                        up             up
Se0/0/1                        admin down     down
```

d. Use the **show vlans** command on the Gateway router. `Gateway#` **`show vlans`**

```

Virtual LAN ID:  1 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface:   FastEthernet0/1.1

 This is configured as native Vlan for the following interface(s) :
FastEthernet0/1

   Protocols Configured:   Address:             Received:        Transmitted:
           IP              172.16.1.1                 198                  54
        Other                                           0                  29
   277 packets, 91551 bytes input
   83 packets, 15446 bytes output
```

```
Virtual LAN ID:  100 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface:   FastEthernet0/1.100

   Protocols Configured:   Address:             Received:        Transmitted:
           IP              172.16.100.1                 1                  25
   0 packets, 0 bytes input
   25 packets, 2350 bytes output

Virtual LAN ID:  200 (IEEE 802.1Q Encapsulation)

   vLAN Trunk Interface:   FastEthernet0/1.200

   Protocols Configured:   Address:             Received:        Transmitted:
           IP              172.16.200.1                 1                  25
   0 packets, 0 bytes input
   25 packets, 2350 bytes output
```

e. Use the **show cdp neighbor detail** command on the Gateway router to verify that ALS1 is a neighbor. Telnet to the IP address given in the CDP information.

```
Gateway# show cdp neighbor detail
-------------------------
Device ID: ISP
Entry address(es):
  IP address: 192.168.1.2
Platform: Cisco 1841,  Capabilities: Router Switch IGMP
Interface: Serial0/0/0,  Port ID (outgoing port): Serial0/0/0
Holdtime : 174 sec

Version :
Cisco IOS Software, 1841 Software (C1841-ADVIPSERVICESK9-M), Version
12.4(24)T1,
 RELEASE SOFTWARE (fc3)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2009 by Cisco Systems, Inc.
Compiled Fri 19-Jun-09 13:56 by prod_rel_team

advertisement version: 2 VTP
Management Domain: ''

-------------------------
Device ID: ALS1
Entry address(es):
  IP address: 172.16.1.101
Platform: cisco WS-C2960-24TT-L,  Capabilities: Switch IGMP
Interface: FastEthernet0/0.1,  Port ID (outgoing port): FastEthernet0/1
Holdtime : 118 sec

Version :
Cisco IOS Software, C2960 Software (C2960-LANBASEK9-M), Version 12.2(46)SE,
RELE
ASE SOFTWARE (fc2)
Copyright (c) 1986-2008 by Cisco Systems, Inc.
Compiled Thu 21-Aug-08 15:59 by nachen
```

```
advertisement version: 2
Protocol Hello:  OUI=0x00000C, Protocol ID=0x0112; payload len=27,
value=0000000
0FFFFFFFF010221FF00000000000000001D46350C80FF0000
VTP Management Domain: 'SWLAB'
Native VLAN: 1 Duplex:
full
```

Was the Telnet successful?

____

Step 11: Verify inter-VLAN routing on the Gateway router and the host devices.

a. Ping to the 200.200.200.1 ISP loopback interface from either host. Was this ping successful?

____

____

b. Ping from Host A to Host B. Was this ping successful?

____

____

c. Telnet to the ALS2 VLAN 1 management IP address from the Engineering host. Was this Telnet successful?

____

____

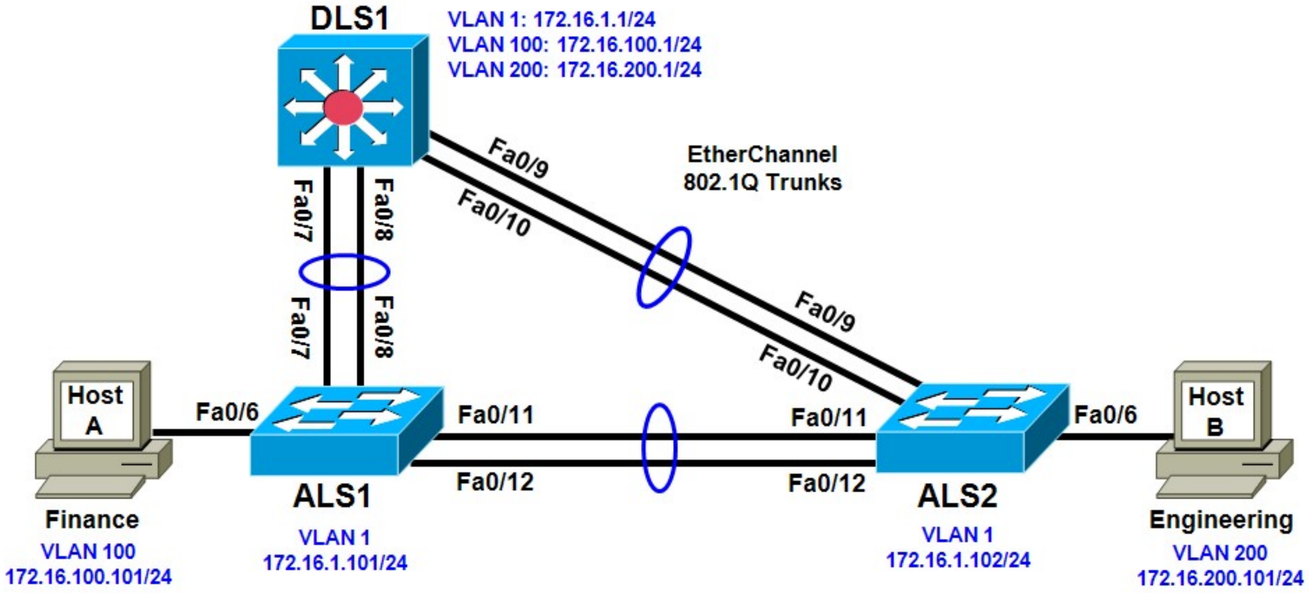
If any of the tests failed, make the necessary corrections to the configurations for the router and switches.

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.				

Practical 9b, Inter-VLAN Routing with an Internal Route Processor and Monitoring CEF Functions

Topology



Objective

- Route between VLANs using a 3560 switch with an internal route processor using Cisco Express Forwarding (CEF).

Background

The current network equipment includes a 3560 distribution layer switch and two 2960 access layer switches. The network is segmented into three functional subnets using VLANs for better network management. The VLANs include Finance, Engineering, and a subnet for equipment management, which is the default management VLAN, VLAN 1. After VTP and trunking have been configured for the switches, switched virtual interfaces (SVI) are configured on the distribution layer switch to route between these VLANs, providing full connectivity to the internal network.

Note: This lab uses Cisco WS-C2960-24TT-L switches with the Cisco IOS image c2960-lanbasek9-mz.12246.SE.bin and Catalyst 3560-24PS with the Cisco IOS image c3560-advipservicesk9-mz.122-46.SE.bin. You can use other switches (such as 2950 or 3550) and Cisco IOS Software versions if they have comparable capabilities and features. Depending on the switch model and Cisco IOS Software version, the commands available and output produced might vary from what is shown in this lab.

Required Resources

- 2 switches (Cisco 2960 with the Cisco IOS Release 12.2(46)SE C2960-LANBASEK9-M image or comparable)
- 1 switch (Cisco 3560 with the Cisco IOS Release 12.2(46)SE C3560-ADVIPSERVICESK9-mz image or comparable)
- Ethernet and console cables

Step 1: Prepare the switches for the lab.

Erase the startup configuration, delete the vlan.dat file, and reload the switches.

Step 2: Configure basic switch parameters.

a. Configure the hostname, password, and optionally, Telnet access on each switch.

```
Switch(config)# hostname ALS1
ALS1(config)# enable secret cisco
ALS1(config)# line vty 0 15
ALS1(config-line)# password cisco
ALS1(config-line)# login

Switch(config)# hostname ALS2
ALS2(config)# enable secret cisco
ALS2(config)# line vty 0 15
ALS2(config-line)# password cisco
ALS2(config-line)# login

Switch(config)# hostname DLS1
DLS1(config)# enable secret cisco
DLS1(config)# line vty 0 15
DLS1(config-line)#password cisco DLS1(config-line)#
login
```

b. Configure management IP addresses on VLAN 1 for all three switches according to the diagram.

```
ALS1(config)# interface vlan 1
ALS1(config-if)# ip address 172.16.1.101 255.255.255.0
ALS1(config-if)# no shutdown

ALS2(config)# interface vlan 1
ALS2(config-if)# ip address 172.16.1.102 255.255.255.0
ALS2(config-if)# no shutdown

DLS1(config)# interface vlan 1
DLS1(config-if)# ip address 172.16.1.1 255.255.255.0 DLS1(config-
if)# no shutdown
```

c. Configure default gateways on the access layer switches. The distribution layer switch will not use a default gateway, because it acts as a Layer 3 device. The access layer switches act as Layer 2 devices and need a default gateway to send management VLAN traffic off of the local subnet.

```
ALS1(config)# ip default-gateway 172.16.1.1

ALS2(config)# ip default-gateway 172.16.1.1
```

Step 3: Configure trunks and EtherChannels between switches.

To distribute VLAN and VTP information between the switches, trunks are needed between the three switches. Configure these trunks according to the diagram. EtherChannel is used for these trunks.

EtherChannel allows you to utilize both Fast Ethernet interfaces that are available between each device, thereby doubling the bandwidth.

a. Configure the trunks and EtherChannel from DLS1 to ALS1. The **switchport trunk encapsulation** [**isl** | **dot1q**] command is used because this switch also supports ISL encapsulation.

```
DLS1(config)# interface range fastEthernet 0/7 - 8
```

```
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
DLS1(config-if-range)# channel-group 1 mode desirable

Creating a port-channel interface Port-channel 1
```

b. Configure the trunks and EtherChannel from DLS1 to ALS2.

```
DLS1(config)# interface range fastEthernet 0/9 - 10
DLS1(config-if-range)# switchport trunk encapsulation dot1q
DLS1(config-if-range)# switchport mode trunk
DLS1(config-if-range)# channel-group 2 mode desirable

Creating a port-channel interface Port-channel 2
```

c. Configure the trunks and EtherChannel between ALS1 and DLS1, and for the trunks and EtherChannel between ALS1 and ALS2.

```
ALS1(config)# interface range fastEthernet 0/11 - 12
ALS1(config-if-range)# switchport mode trunk
ALS1(config-if-range)# channel-group 1 mode desirable

Creating a port-channel interface Port-channel 1

ALS1(config-if-range)# exit
ALS1(config)# interface range fastEthernet 0/7 - 8
ALS1(config-if-range)# switchport mode trunk
ALS1(config-if-range)# channel-group 2 mode desirable

Creating a port-channel interface Port-channel 2
```

d. Configure the trunks and EtherChannel between ALS2 and DLS1, and for the trunks and EtherChannel between ALS2 and ALS1.

```
ALS2(config)# interface range fastEthernet 0/11 - 12
ALS2(config-if-range)# switchport mode trunk
ALS2(config-if-range)# channel-group 1 mode desirable

Creating a port-channel interface Port-channel 1

ALS2(config-if-range)# exit
ALS2(config)# interface range fastEthernet 0/9 - 10
ALS2(config-if-range)# switchport mode trunk
ALS2(config-if-range)# channel-group 2 mode desirable

Creating a port-channel interface Port-channel 2
```

e. Verify trunking between DLS1, ALS1, and ALS2 using the **show interface trunk** command on all switches.

```
DLS1# show interface trunk

Port        Mode         Encapsulation  Status        Native vlan
Po1         on           802.1q         trunking      1
Po2         on           802.1q         trunking      1

Port      Vlans allowed on trunk
```

```
Po1         1-4094
Po2         1-4094

Port        Vlans allowed and active in management domain
Po1         1
Po2         1

Port        Vlans in spanning tree forwarding state and not pruned
Po1         1
Po2         1
```

f. Use the **show etherchannel summary** command on each switch to verify the EtherChannels. The following is sample output from ALS1. Notice the two EtherChannels on the access layer switches.

```
ALS1# show etherchannel summary
Flags:  D - down        P - in port-channel
I - stand-alone s - suspended         H -
Hot-standby (LACP only)         R - Layer3
S - Layer2
        U - in use      f - failed to allocate aggregator
u - unsuitable for bundling         w - waiting to be
aggregated         d - default port



Number of channel-groups in use: 2 Number
of aggregators:           2

Group  Port-channel  Protocol    Ports
------+-------------+----------+-----------------------------------------
   1  Po1(SU)         PAgP      Fa0/11(P)   Fa0/12(P)
   2  Po2(SU)         PAgP      Fa0/7(P)    Fa0/8(P)
```

On ALS1, which ports are used for channel group 2?

Step 4: Configure VTP on ALS1 and ALS2.

a. Change the VTP mode of ALS1 and ALS2 to client.

```
ALS1(config)# vtp mode client
Setting device to VTP CLIENT mode.



ALS2(config)# vtp mode client
Setting device to VTP CLIENT mode.
```

b. Verify the VTP changes with the **show vtp status** command. The output on ALS2 is similar to that of ALS1.

```
ALS2# show vtp status
VTP Version                      : running VTP1 (VTP2 capable)
Configuration Revision           : 0
Maximum VLANs supported locally : 255
Number of existing VLANs         : 5
VTP Operating Mode               : Client
VTP Domain Name                  :
VTP Pruning Mode                 : Disabled
VTP V2 Mode                     : Disabled
VTP Traps Generation            : Disabled
MD5 digest                      : 0xC8 0xAB 0x3C 0x3B 0xAB 0xDD 0x34 0xCF
Configuration last modified by 0.0.0.0 at 3-1-93 15:47:34
```

How many VLANs can be supported locally on the 2960 switch?

____

Step 5: Configure VTP on DLS1.

a. Create the VTP domain on DLS1 and create VLANs 100 and 200 for the domain.

```
DLS1(config)# vtp domain SWPOD
DLS1(config)# vtp version 2

DLS1(config)# vlan 100
DLS1(config-vlan)# name Finance DLS1(config-vlan)#
vlan 200
DLS1(config-vlan)# name Engineering
```

b. Verify VTP information throughout the domain using the **show vlan** and **show vtp status** commands.

How many existing VLANs are in the VTP domain?

____

Step 6: Configure ports.

Configure the host ports for the appropriate VLANs according to the diagram.

```
ALS1(config)# interface fastEthernet 0/6 ALS1(config-if)#
switchport mode access
ALS1(config-if)# switchport access vlan 100

ALS2(config)# interface fastEthernet 0/6 ALS2(config-if)#
switchport mode access
ALS2(config-if)# switchport access vlan 200
```

Ping from the host on VLAN 100 to the host on VLAN 200. Was the ping successful? Why do you think this is the case?

____

____

____

Ping from a host to the VLAN 1 management IP address of DLS1. Was the ping successful? Why do you think this is the case?

____

____

____

Step 7: Configure VLAN interfaces and enable routing.

a. On DLS1, create the Layer 3 VLAN interfaces to route between VLANs using the **interface vlan** *vlan-id* command. These are known as SVIs. You do not need to set up VLAN 1, because this was done in Step 2.

```
DLS1(config)# interface vlan 100
DLS1(config-if)# ip add 172.16.100.1 255.255.255.0
DLS1(config-if)# no shut
DLS1(config-if)# interface vlan 200
DLS1(config-if)# ip address 172.16.200.1 255.255.255.0
DLS1(config-if)# no shutdown
```

b. The **ip routing** command is also needed to allow the switch to act as a Layer 3 device to route between these VLANs. Because the VLANs are all considered directly connected, a routing protocol is not needed at this time.

```
DLS1(config)# ip routing
```

c. Verify the configuration using the **show ip route** command on DLS1.

```
DLS1# 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, E - EGP        i - IS-IS,
su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2        ia - IS-IS
inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.200.0 is directly connected, Vlan200
C       172.16.1.0 is directly connected, Vlan1
C       172.16.100.0 is directly connected, Vlan100
```

Step 8: Verify inter-VLAN routing by the internal route processor.

a. Ping from the Engineering host to the Finance host. Was the ping successful this time?

___

b. Telnet from one of the hosts to the VLAN 1 IP address of DLS1. Can this switch be remotely accessed from this host?

___

Step 9: Examine the CEF configuration.

CEF implements an advanced IP lookup and forwarding algorithm to deliver maximum Layer 3 switching performance. CEF is less CPU-intensive than route caching.

In dynamic networks, fast-switching cache entries are frequently invalidated because of routing changes. This can cause traffic to be process-switched using the routing table, instead of fast-switched using the route cache. CEF uses the Forwarding Information Base (FIB) lookup table to perform destination-based switching of IP packets.

CEF is enabled by default on the 3560 switch.

a. Use the **show ip cef** command to display the CEF FIB.

```
DLS1# show ip cef
Prefix              Next Hop             Interface 0.0.0.0/32
receive
172.16.1.0/24       attached             Vlan1
172.16.1.0/32       receive
```

```
172.16.1.1/32        receive
172.16.1.101/32      attached             Vlan1
172.16.1.102/32      attached             Vlan1
172.16.1.255/32      receive
172.16.100.0/24      attached             Vlan100
172.16.100.0/32      receive
172.16.100.1/32      receive
172.16.100.255/32    receive
172.16.200.0/24      attached             Vlan200
172.16.200.0/32      receive
172.16.200.1/32      receive
172.16.200.255/32    receive
224.0.0.0/4          drop
224.0.0.0/24         receive
255.255.255.255/32   receive
```

b. Use the **show ip interface** command to verify that CEF is enabled on an interface. The following output shows that CEF is enabled on VLAN 100.

```
DLS1# show ip interface vlan 100
Vlan100 is up, line protocol is up
  Internet address is 172.16.100.1/24
  Broadcast address is 255.255.255.255
  Address determined by setup command
  MTU is 1500 bytes
  Helper address is not set
  Directed broadcast forwarding is disabled
  Outgoing access list is not set
  Inbound  access list is not set
Proxy ARP is enabled
  Local Proxy ARP is disabled
Security level is default
  Split horizon is enabled
  ICMP redirects are always sent
  ICMP unreachables are always sent
  ICMP mask replies are never sent
IP fast switching is enabled
          IP CEF switching is
                      enabled  IP CEF switching turbo vector
                               IP multicast fast switching is disabled
                               IP multicast distributed fast switching is
disabled
  IP route-cache flags are Fast, CEF
  Router Discovery is disabled
  IP output packet accounting is disabled
  IP access violation accounting is disabled
  TCP/IP header compression is disabled
RTP/IP header compression is disabled
  Probe proxy name replies are disabled
Policy routing is disabled
  Network address translation is disabled
  WCCP Redirect outbound is disabled
  WCCP Redirect inbound is disabled
  WCCP Redirect exclude is disabled
BGP Policy Mapping is disabled
```

c. Use the **show ip cef summary** command to display the CEF table summary.

```
DLS1# show ip cef summary
IPv4 CEF is enabled for distributed and running
VRF Default:
 18 prefixes (18/0 fwd/non-fwd)
 Table id 0, 0 resets
 Database epoch: 1 (18 entries at this epoch)
```

d. The **show ip cef detail** command shows CEF operation in detail for the switch.

```
DLS1# show ip cef detail
IPv4 CEF is enabled for distributed and running
VRF Default:
 18 prefixes (18/0 fwd/non-fwd)
 Table id 0, 0 resets
 Database epoch: 1 (18 entries at this epoch)

0.0.0.0/32, epoch 1, flags receive
Special source: receive   receive
172.16.1.0/24, epoch 1, flags attached, connected
attached to Vlan1
172.16.1.0/32, epoch 1, flags receive
receive
172.16.1.1/32, epoch 1, flags receive
receive
172.16.1.101/32, epoch 1
  Adj source: IP adj out of Vlan1, addr 172.16.1.101
attached to Vlan1 172.16.1.102/32, epoch 1
  Adj source: IP adj out of Vlan1, addr 172.16.1.102
attached to Vlan1
172.16.1.255/32, epoch 1, flags receive
receive
172.16.100.0/24, epoch 1, flags attached, connected
attached to Vlan100
172.16.100.0/32, epoch 1, flags receive
receive
172.16.100.1/32, epoch 1, flags receive
receive
172.16.100.255/32, epoch 1, flags receive
receive
172.16.200.0/24, epoch 1, flags attached, connected
attached to Vlan200
172.16.200.0/32, epoch 1, flags receive
receive
172.16.200.1/32, epoch 1, flags receive
receive
172.16.200.255/32, epoch 1, flags receive
receive 224.0.0.0/4, epoch 1   Special
source: drop   drop
224.0.0.0/24, epoch 1, flags receive
Special source: receive   receive
255.255.255.255/32, epoch 1, flags receive
  Special source: receive
  Receive
```