Alan Palayil

EC 407

ECE 407

Introduction to Computer Networks Laboratory

Practice 7 – Dynamic Routing: RIPv2 and OSPFv2

Objectives

The goal of this experiment is to:

1. Familiarize students with configuring RIPv2, a distance vector routing algorithm.
2. Familiarize students with configuring OSPFv2, a link state routing algorithm.

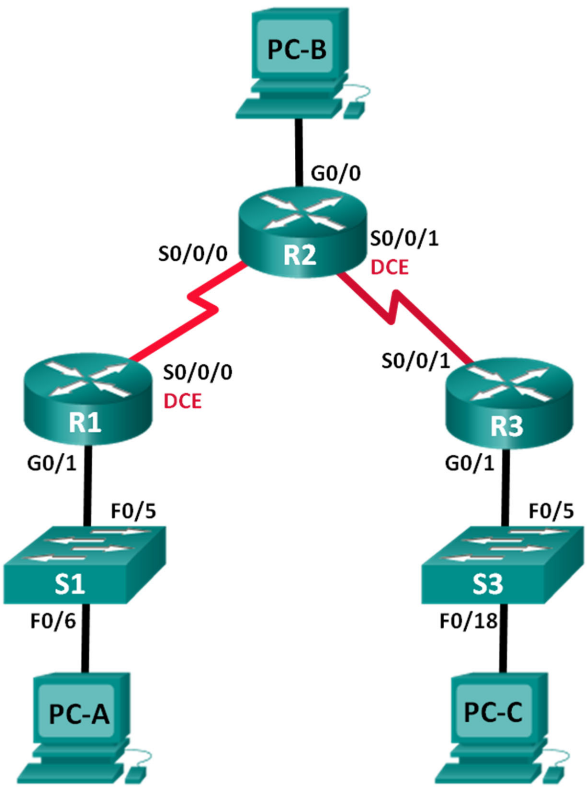
Background

RIP version 2 (RIPv2) is used for routing of IPv4 addresses in small networks. RIPv2 is a classless, distance-vector routing protocol, as defined by RFC 1723. Because RIPv2 is a classless routing protocol, subnet masks are included in the routing updates. By default, RIPv2 automatically summarizes networks at major network boundaries. When automatic summarization has been disabled, RIPv2 no longer summarizes networks to their classful address at boundary routers. In distance vector routing algortihms, **each router sends its distance vector (i.e., routing table) to its directly connected neighbors only.** When a router sees a cost change in one of its direclty attached links, or receives a distance vector from one of its neighbors, it will update its distanc vector (routing table) based on the bellman ford algorithm, and then will propagate its new routing table to its directly connected neighbors. A distance-vector algorithm is therefore iterative (information is exchanged iteratively until the algorithm converges), asynchronous (routers exchange information at asynchronized times), and distributed (each router runs the algorithm based on the information it has received thus far).

Open Shortest Path First (OSPF) is a link-state routing protocol for IP networks. OSPFv2 is defined for IPv4 networks, and OSPFv3 is defined for IPv6 networks. OSPF detects changes in the topology, such as link failures, and converges on a new loop-free routing structure very quickly. It computes each route using Dijkstra's algorithm, a shortest path first algorithm. To make OSPF more efficient and scalable, OSPF supports hierarchical routing using the concept of areas. An OSPF area is a group of routers that share the same link-state information in their link-state databases (LSDBs). When a large OSPF area is divided into smaller areas, it is called multi-area OSPF. Multi-area OSPF is useful in larger network deployments to reduce processing and memory overhead. **In a link-state routing algorithm, each router will broadcast information about its directly attached links only, to all other routers.** The result of this broadcast is that routers have an identical and complete view of the network. Each router will then run the Dijkstra's algorithm to determine the least-cost path to every other router.

Exercise 1: Configuring Basic RIPv2 (3.2.1.9)

Topology



Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	G0/1	172.30.10.1	255.255.255.0	N/A
	S0/0/0 (DCE)	10.1.1.1	255.255.255.252	N/A
R2	G0/0	209.165.201.1	255.255.255.0	N/A
	S0/0/0	10.1.1.2	255.255.255.252	N/A
	S0/0/1 (DCE)	10.2.2.2	255.255.255.252	N/A
R3	G0/1	172.30.30.1	255.255.255.0	N/A
	S0/0/1	10.2.2.1	255.255.255.252	N/A
PC-A	NIC	172.30.10.3	255.255.255.0	172.30.10.1
PC-B	NIC	209.165.201.2	255.255.255.0	209.165.201.1
PC-C	NIC	172.30.30.3	255.255.255.0	172.30.30.1

A. Build the Network and Configure Basic Device Settings in Cisco Packet Tracer

Step 1: Cable the network as shown in the topology.

Step 2: Configure basic settings for each router and switch.

a. Disable DNS lookup.
b. Configure device names as shown in the topology.
c. Configure password encryption.
d. Assign **class** as the privileged EXEC password.
e. Assign **cisco** as the console and vty passwords.
f. Configure a MOTD banner to warn users that unauthorized access is prohibited.
g. Configure **logging synchronous** for the console line.
h. Configure the IP addresses listed in the Addressing Table for all interfaces.
i. Configure a description for each interface with an IP address.
j. Configure the clock rate, if applicable, to the DCE serial interface.
k. Copy the running-configuration to the startup-configuration.

Step 3: Configure PC IP Addressing.

Refer to the Addressing Table for IP address information of the PCs.

Step 4: Test connectivity.

At this point, the PCs are unable to ping each other.

a. Each workstation should be able to ping the attached router. Verify and troubleshoot if necessary.

l. The routers should be able to ping one another. Verify and troubleshoot if necessary.

B. Configure and Verify RIPv2 Routing

In this part, you will configure RIPv2 routing on all routers in the network and then verify that the routing tables are updated correctly. After RIPv2 has been verified, you will disable automatic summarization, configure a default route, and verify end-to-end connectivity.

a. Configure RIPv2 routing.

i. Configure RIPv2 on R1as the routing protocol and advertise the appropriate connected networks.

R1# **config t**

R1(config)# **router rip**

R1(config-router)# **version 2**

R1(config-router)# **passive-interface g0/1**

R1(config-router)# **network 172.30.0.0**

R1(config-router)# **network 10.0.0.0**

The **passive-interface** command stops routing updates out the specified interface. This process prevents unnecessary routing traffic on the LAN. However, the network that the specified interface belongs to is still advertised in routing updates that are sent out across other interfaces.

ii. Configure RIPv2 on R3 and use the **network** statement to add the appropriate connected networks and prevent routing updates on the LAN interface.

iii. Configure RIPv2 on R2 and use the network statements to add the appropriate connected networks. Do not advertise the 209.165.201.0 network.

Note: It is not necessary to make the G0/0 interface passive on R2 because the network associated with this interface is not being advertised.

b. Examine the current state of the network.

i. The status of the two serial links can quickly be verified using the **show ip interface brief** command on R2.

R2# **show ip interface brief**

```
Interface                  IP-Address      OK? Method Status                Protocol
Embedded-Service-Engine0/0 unassigned      YES unset  administratively down down
GigabitEthernet0/0         209.165.201.1   YES manual up                    up
GigabitEthernet0/1         unassigned      YES unset  administratively down down
Serial0/0/0                10.1.1.2        YES manual up                    up
Serial0/0/1                10.2.2.2        YES manual up                    up
```

ii. Check connectivity between PCs.

From PC-A, is it possible to ping PC-B? _________ Why?

No it is not, R2 is not on the route to PC-B.

From PC-A, is it possible to ping PC-C? _________ Why?

No as R1 and R3 have no routes to the remote network. R2 has 2 equal cost balancing routes connected to the 172.30.0.0/16 which is not supposed to happen.

From PC-C, is it possible to ping PC-B? _________ Why?

No it is not, R2 is not on the route to PC-B.

From PC-C, is it possible to ping PC-A? _________ Why?

No as once again R1 and R3 have no routes to the remote network. R2 has 2 equal cost balancing routes connected to the 172.30.0.0/16 which is not supposed to happen.

iii. Verify that RIPv2 is running on the routers.

You can use the **debug ip rip**, **show ip protocols**, and **show run** commands to confirm that RIPv2 is running. The **show ip protocols** command output for R1 is shown below.

```
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 7 seconds
Invalid after 180 seconds, hold down 180, flushed after 240
Redistributing: rip
Default version control: send version 2, receive 2
  Interface        Send  Recv  Triggered RIP  Key-chain
  Serial0/0/0       2     2
Automatic network summarization is in effect
Maximum path: 4
Routing for Networks:
  10.0.0.0
  172.30.0.0
Passive Interface(s):
```

```
  GigabitEthernet0/1
Routing Information Sources:
  Gateway         Distance      Last Update
  10.1.1.2            120
Distance: (default is 120)
```

When issuing the **debug ip rip** command on R2, what information is provided that confirms RIPv2 is running?

RIP: Sending v2 updates to 224.0.0.9 via Serial 0/0/0 (10.1.1.2)

When you are finished observing the debugging outputs, issue the **undebug all** command at the privileged EXEC prompt.

When issuing the **show run** command on R3, what information is provided that confirms RIPv2 is running?

router rip

version 2

iv. Examine the automatic summarization of routes.

The LANs connected to R1 and R3 are composed of discontiguous networks. R2 displays two equal-cost paths to the 172.30.0.0/16 network in the routing table. R2 displays only the major classful network address of 172.30.0.0 and does not display any of the subnets for this network.

```
R2# show ip route
<Output omitted>
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.1.1.0/30 is directly connected, Serial0/0/0
L       10.1.1.2/32 is directly connected, Serial0/0/0
C       10.2.2.0/30 is directly connected, Serial0/0/1
L       10.2.2.2/32 is directly connected, Serial0/0/1
R    172.30.0.0/16 [120/1] via 10.2.2.1, 00:00:23, Serial0/0/1
                   [120/1] via 10.1.1.1, 00:00:09, Serial0/0/0
     209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C       209.165.201.0/24 is directly connected, GigabitEthernet0/0
L       209.165.201.1/32 is directly connected, GigabitEthernet0/0
```

R1 displays only its own subnet for the 172.30.10.0/24 network. R1 does not have a route for the 172.30.30.0/24 subnet on R3.

```
R1# show ip route
<Output omitted>
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.1.1.0/30 is directly connected, Serial0/0/0
L       10.1.1.1/32 is directly connected, Serial0/0/0
```

R 10.2.2.0/30 [120/1] via 10.1.1.2, 00:00:21, Serial0/0/0

172.30.0.0/16 is variably subnetted, 2 subnets, 2 masks

C 172.30.10.0/24 is directly connected, GigabitEthernet0/1

L 172.30.10.1/32 is directly connected, GigabitEthernet0/1

R3 only displays its own subnet for the 172.30.30.0/24 network. R3 does not have a route for the 172.30.10.0/24 subnets on R1.

R3# **show ip route**

<Output omitted>

10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks

C 10.2.2.0/30 is directly connected, Serial0/0/1

L 10.2.2.1/32 is directly connected, Serial0/0/1

R 10.1.1.0/30 [120/1] via 10.2.2.2, 00:00:23, Serial0/0/1

172.30.0.0/16 is variably subnetted, 2 subnets, 2 masks

C 172.30.30.0/24 is directly connected, GigabitEthernet0/1

L 172.30.30.1/32 is directly connected, GigabitEthernet0/1

Use the **debug ip rip** command on R2 to determine the routes received in the RIP updates from R3 and list them here.

172.30.0.0/16

R3 is not sending any of the 172.30.0.0 subnets, only the summarized route of 172.30.0.0/16, including the subnet mask. Therefore, the routing tables on R1 and R2 do not display the 172.30.0.0 subnets on R3.

c. **Disable automatic summarization.**

i. The **no auto-summary** command is used to turn off automatic summarization in RIPv2. Disable auto summarization on all routers. The routers will no longer summarize routes at major classful network boundaries. R1 is shown here as an example.

R1(config)# **router rip**

R1(config-router)# **no auto-summary**

ii. Issue the **clear ip route *** command to clear the routing table.

R1(config-router)# **end**

R1# **clear ip route ***

iii. Examine the routing tables. Remember that it will take some time to converge the routing tables after clearing them.

The LAN subnets connected to R1 and R3 should now be included in all three routing tables.

R2# **show ip route**

<Output omitted>

Gateway of last resort is not set

```
     10.0.0.0/8 is variably subnetted, 4 subnets, 2 masks
C       10.1.1.0/30 is directly connected, Serial0/0/0
L       10.1.1.2/32 is directly connected, Serial0/0/0
C       10.2.2.0/30 is directly connected, Serial0/0/1
L       10.2.2.2/32 is directly connected, Serial0/0/1
     172.30.0.0/16 is variably subnetted, 3 subnets, 2 masks
R       172.30.0.0/16 [120/1] via 10.2.2.1, 00:01:01, Serial0/0/1
                      [120/1] via 10.1.1.1, 00:01:15, Serial0/0/0
R       172.30.10.0/24 [120/1] via 10.1.1.1, 00:00:21, Serial0/0/0
R       172.30.30.0/24 [120/1] via 10.2.2.1, 00:00:04, Serial0/0/1
     209.165.201.0/24 is variably subnetted, 2 subnets, 2 masks
C       209.165.201.0/24 is directly connected, GigabitEthernet0/0
L       209.165.201.1/32 is directly connected, GigabitEthernet0/0
```

R1# **show ip route**

```
<Output omitted>
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.1.1.0/30 is directly connected, Serial0/0/0
L       10.1.1.1/32 is directly connected, Serial0/0/0
R       10.2.2.0/30 [120/1] via 10.1.1.2, 00:00:12, Serial0/0/0
     172.30.0.0/16 is variably subnetted, 3 subnets, 2 masks
C       172.30.10.0/24 is directly connected, GigabitEthernet0/1
L       172.30.10.1/32 is directly connected, GigabitEthernet0/1
R       172.30.30.0/24 [120/2] via 10.1.1.2, 00:00:12, Serial0/0/0
```

R3# **show ip route**

```
<Output omitted>
     10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C       10.2.2.0/30 is directly connected, Serial0/0/1
L       10.2.2.1/32 is directly connected, Serial0/0/1
R       10.1.1.0/30 [120/1] via 10.2.2.2, 00:00:23, Serial0/0/1
     172.30.0.0/16 is variably subnetted, 2 subnets, 2 masks
C       172.30.30.0/24 is directly connected, GigabitEthernet0/1
L       172.30.30.1/32 is directly connected, GigabitEthernet0/1
R       172.30.10.0 [120/2] via 10.2.2.2, 00:00:16, Serial0/0/1
```

iv. Use the **debug ip rip** command on R2 to examine the RIP updates.

R2# debug ip rip

After 60 seconds, issue the **no debug ip rip** command.

What routes are in the RIP updates that are received from R3?

172.30.30.0/24

Are the subnet masks included in the routing updates? Yes

d. Configure and redistribute a default route for Internet access.

i. From R2, create a static route to network 0.0.0.0 0.0.0.0, using the **ip route** command. This forwards any traffic with an unknown destination address to PC-B at 209.165.201.2, simulating the Internet by setting a Gateway of Last Resort on router R2.

R2(config)# **ip route 0.0.0.0 0.0.0.0 209.165.201.2**

ii. R2 will advertise a route to the other routers if the **default-information originate** command is added to its RIP configuration.

R2(config)# **router rip**

R2(config-router)# **default-information originate**

e. Verify the routing configuration.

i. View the routing table on R1.

```
R1# show ip route
<Output omitted>
Gateway of last resort is 10.1.1.2 to network 0.0.0.0

R*    0.0.0.0/0 [120/1] via 10.1.1.2, 00:00:13, Serial0/0/0
      10.0.0.0/8 is variably subnetted, 3 subnets, 2 masks
C        10.1.1.0/30 is directly connected, Serial0/0/0
L        10.1.1.1/32 is directly connected, Serial0/0/0
R        10.2.2.0/30 [120/1] via 10.1.1.2, 00:00:13, Serial0/0/0
      172.30.0.0/16 is variably subnetted, 3 subnets, 2 masks
C        172.30.10.0/24 is directly connected, GigabitEthernet0/1
L        172.30.10.1/32 is directly connected, GigabitEthernet0/1
R        172.30.30.0/24 [120/2] via 10.1.1.2, 00:00:13, Serial0/0/0
```

How can you tell from the routing table that the subnetted network shared by R1 and R3 has a pathway for Internet traffic?

The Gateway of Last Resort occurs and there is just a default route which appears being received by the RIP.

ii. View the routing table on R2.

How is the pathway for Internet traffic provided in its routing table?

Commented [1]: here

The R2 contains a default route to 0.0.0.0 via 209.165.201.2 connected to G0/0

f. Verify connectivity.

i. Simulate sending traffic to the Internet by pinging from PC-A and PC-C to 209.165.201.2.

Were the pings successful? Yes

ii. Verify that hosts within the subnetted network can reach each other by pinging between PC-A and PC-C.

Were the pings successful? Yes

Reflection

1. Why would you turn off automatic summarization for RIPv2?

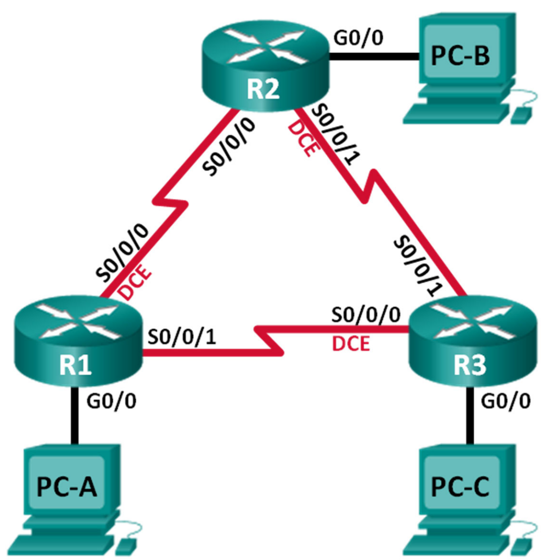
   This is in order for the routers to not summarize routes at classful boundaries of the network

2. How did R1 and R3 learn the pathway to the Internet?

   They are learned from the RIP routing updates received from the router which contained the default route.

Exercise 2: Configuring Basic Single-Area OSPFv2 (8.2.4.5)

Topology



Addressing Table

Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	G0/0	192.168.1.1	255.255.255.0	N/A
	S0/0/0 (DCE)	192.168.12.1	255.255.255.252	N/A
	S0/0/1	192.168.13.1	255.255.255.252	N/A
R2	G0/0	192.168.2.1	255.255.255.0	N/A
	S0/0/0	192.168.12.2	255.255.255.252	N/A
	S0/0/1 (DCE)	192.168.23.1	255.255.255.252	N/A
R3	G0/0	192.168.3.1	255.255.255.0	N/A
	S0/0/0 (DCE)	192.168.13.2	255.255.255.252	N/A
	S0/0/1	192.168.23.2	255.255.255.252	N/A
PC-A	NIC	192.168.1.3	255.255.255.0	192.168.1.1
PC-B	NIC	192.168.2.3	255.255.255.0	192.168.2.1
PC-C	NIC	192.168.3.3	255.255.255.0	192.168.3.1

A. Build the Network and Configure Basic Device Settings in Cisco Packet Tracer

Step 1: Cable the network as shown in the topology.

Step 2: Configure basic settings for each router.

a. Disable DNS lookup.
b. Configure device name as shown in the topology.
c. Assign **class** as the privileged EXEC password.
d. Assign **cisco** as the console and vty passwords.
e. Configure a message of the day (MOTD) banner to warn users that unauthorized access is prohibited.
f. Configure **logging synchronous** for the console line.
g. Configure the IP address listed in the Addressing Table for all interfaces.
h. Set the clock rate for all DCE serial interfaces at **128000**.
i. Copy the running configuration to the startup configuration.

Step 3: Configure PC hosts.

Step 4: Test connectivity.

The routers should be able to ping one another, and each PC should be able to ping its default gateway. The PCs are unable to ping other PCs until OSPF routing is configured. Verify and troubleshoot if necessary.

B. Configure and Verify OSPF Routing

Now, you will configure OSPFv2 routing on all routers in the network and then verify that routing tables are updated correctly.

a. Configure OSPF on R1.

i. Use the **router ospf** command in global configuration mode to enable OSPF on R1.

R1(config)# **router ospf 1**

Note: The OSPF process id is kept locally and has no meaning to other routers on the network.

ii. Configure the **network** statements for the networks on R1. Use an area ID of 0.

R1(config-router)# **network 192.168.1.0 0.0.0.255 area 0**

R1(config-router)# **network 192.168.12.0 0.0.0.3 area 0**

R1(config-router)# **network 192.168.13.0 0.0.0.3 area 0**

b. Configure OSPF on R2 and R3.

Use the **router ospf** command and add the **network** statements for the networks on R2 and R3. Neighbor adjacency messages display on R1 when OSPF routing is configured on R2 and R3.

```
R1#
00:22:29: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.23.1 on Serial0/0/0 from LOADING to FULL, Loading Done
R1#
00:23:14: %OSPF-5-ADJCHG: Process 1, Nbr 192.168.23.2 on Serial0/0/1 from LOADING to FULL, Loading Done
R1#
```

c. Verify OSPF neighbors and routing information.

i. Issue the **show ip ospf neighbor** command to verify that each router lists the other routers in the network as neighbors.

R1# **show ip ospf neighbor**

Neighbor ID	Pri	State	Dead Time	Address	Interface
192.168.23.2	0	FULL/ -	00:00:33	192.168.13.2	Serial0/0/1
192.168.23.1	0	FULL/ -	00:00:30	192.168.12.2	Serial0/0/0

ii. Issue the **show ip route** command to verify that all networks display in the routing table on all routers.

```
R1# show ip route
Codes: L - local, 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, 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

     192.168.1.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.1.0/24 is directly connected, GigabitEthernet0/0
L       192.168.1.1/32 is directly connected, GigabitEthernet0/0
O    192.168.2.0/24 [110/65] via 192.168.12.2, 00:32:33, Serial0/0/0
O    192.168.3.0/24 [110/65] via 192.168.13.2, 00:31:48, Serial0/0/1
     192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.12.0/30 is directly connected, Serial0/0/0
L       192.168.12.1/32 is directly connected, Serial0/0/0
     192.168.13.0/24 is variably subnetted, 2 subnets, 2 masks
C       192.168.13.0/30 is directly connected, Serial0/0/1
L       192.168.13.1/32 is directly connected, Serial0/0/1
     192.168.23.0/30 is subnetted, 1 subnets
O       192.168.23.0/30 [110/128] via 192.168.12.2, 00:31:38, Serial0/0/0
                        [110/128] via 192.168.13.2, 00:31:38, Serial0/0/1
```

What command would you use to only see the OSPF routes in the routing table?

____

d. Verify OSPF protocol settings.

The **show ip protocols** command is a quick way to verify vital OSPF configuration information. This information includes the OSPF process ID, the router ID, networks the router is advertising, the neighbors the router is receiving updates from, and the default administrative distance, which is 110 for OSPF.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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 192.168.13.1
Number of areas in this router is 1. 1 normal 0 stub 0 nssa
Maximum path: 4
Routing for Networks:
  192.168.1.0 0.0.0.255 area 0
  192.168.12.0 0.0.0.3 area 0
  192.168.13.0 0.0.0.3 area 0
Routing Information Sources:
  Gateway         Distance      Last Update
  192.168.23.2         110      00:19:16
  192.168.23.1         110      00:20:03
Distance: (default is 110)
```

e. Verify OSPF process information.

Use the **show ip ospf** command to examine the OSPF process ID and router ID. This command displays the OSPF area information, as well as the last time the SPF algorithm was calculated.

R1# **show ip ospf**

```
Routing Process "ospf 1" with ID 192.168.13.1
Start time: 00:20:23.260, Time elapsed: 00:25:08.296
Supports only single TOS(TOS0) routes
Supports opaque LSA
Supports Link-local Signaling (LLS)
Supports area transit capability
Supports NSSA (compatible with RFC 3101)
Event-log enabled, Maximum number of events: 1000, Mode: cyclic
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
IETF NSF helper support enabled
Cisco NSF helper support enabled
Reference bandwidth unit is 100 mbps
  Area BACKBONE(0)
    Number of interfaces in this area is 3
    Area has no authentication
    SPF algorithm last executed 00:22:53.756 ago
    SPF algorithm executed 7 times
    Area ranges are
    Number of LSA 3. Checksum Sum 0x019A61
    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
```

f. Verify OSPF interface settings.

i. Issue the **show ip ospf interface brief** command to display a summary of OSPF-enabled interfaces.

```
R1# show ip ospf interface brief
Interface    PID   Area         IP Address/Mask    Cost  State Nbrs F/C
Se0/0/1      1     0            192.168.13.1/30    64    P2P   1/1
Se0/0/0      1     0            192.168.12.1/30    64    P2P   1/1
Gi0/0        1     0            192.168.1.1/24     1     DR    0/0
```

ii. For a more detailed list of every OSPF-enabled interface, issue the **show ip ospf interface** command.

```
R1# show ip ospf interface
Serial0/0/1 is up, line protocol is up
  Internet Address 192.168.13.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 192.168.13.1, Network Type POINT_TO_POINT, Cost: 64
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           64        no          no            Base
  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 00:00:01
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  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 192.168.23.2
  Suppress hello for 0 neighbor(s)
Serial0/0/0 is up, line protocol is up
  Internet Address 192.168.12.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 192.168.13.1, Network Type POINT_TO_POINT, Cost: 64
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           64        no          no            Base
  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)
  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 1, Adjacent neighbor count is 1
    Adjacent with neighbor 192.168.23.1
  Suppress hello for 0 neighbor(s)
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0, Attached via Network Statement
  Process ID 1, Router ID 192.168.13.1, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.13.1, Interface address 192.168.1.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:01
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  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)
```

g. Verify end-to-end connectivity.

Each PC should be able to ping the other PCs in the topology. Verify and troubleshoot if necessary.

C. Change Router ID Assignments

The OSPF router ID is used to uniquely identify the router in the OSPF routing domain. Cisco routers derive the router ID in one of three ways and with the following precedence:

1. IP address configured with the OSPF **router-id** command, if present
2. Highest IP address of any of the router's loopback addresses, if present
3. Highest active IP address on any of the router's physical interfaces

Because no router IDs or loopback interfaces have been configured on the three routers, the router ID for each router is determined by the highest IP address of any active interface.

a. Change router IDs using loopback addresses.

i. Assign an IP address to loopback 0 on R1.

R1(config)# **interface lo0**

R1(config-if)# **ip address 1.1.1.1 255.255.255.255**

R1(config-if)# **end**

ii. Assign IP addresses to Loopback 0 on R2 and R3. Use IP address 2.2.2.2/32 for R2 and 3.3.3.3/32 for R3.

iii. Save the running configuration to the startup configuration on all three routers.

iv. You must reload the routers in order to reset the router ID to the loopback address. Issue the **reload** command on all three routers. Press Enter to confirm the reload.

v. After the router completes the reload process, issue the **show ip protocols** command to view the new router ID.

R1# **show ip protocols**

```
*** IP Routing is NSF aware ***

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 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.1.0 0.0.0.255 area 0
```

```
    192.168.12.0 0.0.0.3 area 0
    192.168.13.0 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:01:00
    2.2.2.2              110      00:01:14
  Distance: (default is 110)
```

vi. Issue the **show ip ospf neighbor** command to display the router ID changes for the neighboring routers.

R1# **show ip ospf neighbor**

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
3.3.3.3           0   FULL/  -        00:00:35    192.168.13.2    Serial0/0/1
2.2.2.2           0   FULL/  -        00:00:32    192.168.12.2    Serial0/0/0
R1#
```

b. Change the router ID on R1 using the router-id command.

The preferred method for setting the router ID is with the **router-id** command.

i. Issue the **router-id 11.11.11.11** command on R1 to reassign the router ID. Notice the informational message that appears when issuing the **router-id** command.

R1(config)# **router ospf 1**

R1(config-router)# **router-id 11.11.11.11**

Reload or use "clear ip ospf process" command, for this to take effect

R1(config)# **end**

ii. You will receive an informational message telling you that you must either reload the router or use the **clear ip ospf process** command for the change to take effect. Issue the **clear ip ospf process** command on all three routers. Type **yes** to reply to the reset verification message, and press ENTER.

iii. Set the router ID for R2 to **22.22.22.22** and the router ID for R3 to **33.33.33.33**. Then use **clear ip ospf process** command to reset ospf routing process.

iv. Issue the **show ip protocols** command to verify that the router ID changed on R1.

R1# **show ip protocols**

```
*** IP Routing is NSF aware ***

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 11.11.11.11
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
```

```
Routing for Networks:
  192.168.1.0 0.0.0.255 area 0
  192.168.12.0 0.0.0.3 area 0
  192.168.13.0 0.0.0.3 area 0
Passive Interface(s):
  GigabitEthernet0/1
Routing Information Sources:
  Gateway         Distance      Last Update
  33.33.33.33          110      00:00:19
  22.22.22.22          110      00:00:31
  3.3.3.3              110      00:00:41
  2.2.2.2              110      00:00:41
Distance: (default is 110)
```

v. Issue the **show ip ospf neighbor** command on R1 to verify that new router ID for R2 and R3 is listed.

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
33.33.33.33       0   FULL/  -        00:00:36    192.168.13.2    Serial0/0/1
22.22.22.22       0   FULL/  -        00:00:32    192.168.12.2    Serial0/0/0
```

D. Configure OSPF Passive Interfaces

The **passive-interface** command prevents routing updates from being sent through the specified router interface. This is commonly done to reduce traffic on the LANs as they do not need to receive dynamic routing protocol communication. In Part 4, you will use the **passive-interface** command to configure a single interface as passive. You will also configure OSPF so that all interfaces on the router are passive by default, and then enable OSPF routing advertisements on selected interfaces.

a. Configure a passive interface.

i. Issue the **show ip ospf interface g0/0** command on R1. Notice the timer indicating when the next Hello packet is expected. Hello packets are sent every 10 seconds and are used between OSPF routers to verify that their neighbors are up.

```
R1# show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0, Attached via Network Statement
  Process ID 1, Router ID 11.11.11.11, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 11.11.11.11, Interface address 192.168.1.1
```

```
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:02
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  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)
```

ii. Issue the **passive-interface** command to change the G0/0 interface on R1 to passive.

R1(config)# **router ospf 1**

R1(config-router)# **passive-interface g0/0**

iii. Re-issue the **show ip ospf interface g0/0** command to verify that G0/0 is now passive.

R1# **show ip ospf interface g0/0**

```
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0, Attached via Network Statement
  Process ID 1, Router ID 11.11.11.11, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 11.11.11.11, Interface address 192.168.1.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    No Hellos (Passive interface)
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  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)
```

iv. Issue the **show ip route** command on R2 and R3 to verify that a route to the 192.168.1.0/24 network is still available.

R2# **show ip route**

```
Codes: L - local, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

      2.0.0.0/32 is subnetted, 1 subnets
C        2.2.2.2 is directly connected, Loopback0
O     192.168.1.0/24 [110/65] via 192.168.12.1, 00:58:32, Serial0/0/0
      192.168.2.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.2.0/24 is directly connected, GigabitEthernet0/0
L        192.168.2.1/32 is directly connected, GigabitEthernet0/0
O     192.168.3.0/24 [110/65] via 192.168.23.2, 00:58:19, Serial0/0/1
      192.168.12.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.12.0/30 is directly connected, Serial0/0/0
L        192.168.12.2/32 is directly connected, Serial0/0/0
      192.168.13.0/30 is subnetted, 1 subnets
O        192.168.13.0 [110/128] via 192.168.23.2, 00:58:19, Serial0/0/1
                      [110/128] via 192.168.12.1, 00:58:32, Serial0/0/0
      192.168.23.0/24 is variably subnetted, 2 subnets, 2 masks
C        192.168.23.0/30 is directly connected, Serial0/0/1
L        192.168.23.1/32 is directly connected, Serial0/0/1
```

b. Set passive interface as the default on a router.

i. Issue the **show ip ospf neighbor** command on R1 to verify that R2 is listed as an OSPF neighbor.

R1# **show ip ospf neighbor**

```
Neighbor ID     Pri   State        Dead Time   Address         Interface
33.33.33.33       0   FULL/  -     00:00:31    192.168.13.2    Serial0/0/1
22.22.22.22       0   FULL/  -     00:00:32    192.168.12.2    Serial0/0/0
```

ii. Issue the **passive-interface default** command on R2 to set the default for all OSPF interfaces as passive.

R2(config)# **router ospf 1**

R2(config-router)# **passive-interface default**

R2(config-router)#

*Apr 3 00:03:00.979: %OSPF-5-ADJCHG: Process 1, Nbr 11.11.11.11 on Serial0/0/0 from FULL to DOWN, Neighbor Down: Interface down or detached

*Apr 3 00:03:00.979: %OSPF-5-ADJCHG: Process 1, Nbr 33.33.33.33 on Serial0/0/1 from FULL to DOWN, Neighbor Down: Interface down or detached

iii. Re-issue the **show ip ospf neighbor** command on R1. After the dead timer expires, R2 will no longer be listed as an OSPF neighbor.

R1# **show ip ospf neighbor**

```
Neighbor ID     Pri   State        Dead Time   Address         Interface
33.33.33.33       0   FULL/  -     00:00:34    192.168.13.2    Serial0/0/1
```

iv. Issue the **show ip ospf interface S0/0/0** command on R2 to view the OSPF status of interface S0/0/0.

R2# **show ip ospf interface s0/0/0**

```
Serial0/0/0 is up, line protocol is up
  Internet Address 192.168.12.2/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 22.22.22.22, Network Type POINT_TO_POINT, Cost: 64
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           64        no          no            Base
  Transmit Delay is 1 sec, State POINT_TO_POINT
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    No Hellos (Passive interface)
  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 0, maximum is 0
  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)
```

v. If all interfaces on R2 are passive, then no routing information is being advertised. In this case, R1 and R3 should no longer have a route to the 192.168.2.0/24 network. You can verify this by using the **show ip route** command.

vi. On R2, issue the **no passive-interface** command so the router will send and receive OSPF routing updates. After entering this command, you will see an informational message that a neighbor adjacency has been established with R1.

R2(config)# **router ospf 1**

R2(config-router)# **no passive-interface s0/0/0**

R2(config-router)#

*Apr 3 00:18:03.463: %OSPF-5-ADJCHG: Process 1, Nbr 11.11.11.11 on Serial0/0/0 from LOADING to FULL, Loading Done

vii. Re-issue the **show ip route** and **show ip ospf neighbor** commands on R1 and R3, and look for a route to the 192.168.2.0/24 network.

What interface is R3 using to route to the 192.168.2.0/24 network? S0/0/0

What is the accumulated cost metric for the 192.168.2.0/24 network on R3? 129

Does R2 show up as an OSPF neighbor on R1? Yes

Does R2 show up as an OSPF neighbor on R3? No

What does this information tell you?

All of the traffic to 192.168.2.0/24 from R3 comes through R1. The 129 result comes from the concept that when going to 192.168.2.0/24 from R3 it goes through two T1 serial links (64 each) along with a single R2 G 0/0 LAN (1 each).

viii. Change interface S0/0/1 on R2 to allow it to advertise OSPF routes. Record the commands used below.

R2(config)# **router ospf 1**

R2(config-router)# **no passive-interface s0/0/1**

ix. Re-issue the **show ip route** command on R3.

What interface is R3 using to route to the 192.168.2.0/24 network? S0/0/1

What is the accumulated cost metric for the 192.168.2.0/24 network on R3 now and how is this calculated?

65 through one T1 and a single R2 G 0/0 LAN

Is R2 listed as an OSPF neighbor to R3? Yes

E. Change OSPF Metrics

Lastly, you will change OSPF metrics using the **auto-cost reference-bandwidth** command, the **bandwidth** command, and the **ip ospf cost** command.

Note: All DCE interfaces should have been configured with a clocking rate of 128000 in A.

a. Change the reference bandwidth on the routers.

The default reference-bandwidth for OSPF is 100Mb/s (Fast Ethernet speed). However, most modern infrastructure devices have links that are faster than 100Mb/s. Because the OSPF cost metric must be an integer, all links with transmission speeds of 100Mb/s or higher have a cost of 1. This results in Fast Ethernet, Gigabit Ethernet, and 10G Ethernet interfaces all having the same cost. Therefore, the reference-bandwidth must be changed to a higher value to accommodate networks with links faster that 100Mb/s.

i. Issue the **show interface** command on R1 to view the default bandwidth setting for the G0/0 interface.

```
R1# show interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is CN Gigabit Ethernet, address is c471.fe45.7520 (bia c471.fe45.7520)
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 100 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full Duplex, 100Mbps, media type is RJ45
  output flow-control is unsupported, input flow-control is unsupported
  ARP type: ARPA, ARP Timeout 04:00:00
  Last input never, output 00:17:31, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0
  Queueing strategy: fifo
  Output queue: 0/40 (size/max)
  5 minute input rate 0 bits/sec, 0 packets/sec
  5 minute output rate 0 bits/sec, 0 packets/sec
     0 packets input, 0 bytes, 0 no buffer
     Received 0 broadcasts (0 IP multicasts)
     0 runts, 0 giants, 0 throttles
     0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignored
     0 watchdog, 0 multicast, 0 pause input
     279 packets output, 89865 bytes, 0 underruns
     0 output errors, 0 collisions, 1 interface resets
     0 unknown protocol drops
     0 babbles, 0 late collision, 0 deferred
     1 lost carrier, 0 no carrier, 0 pause output
     0 output buffer failures, 0 output buffers swapped out
```

Note: The bandwidth setting on G0/0 may differ from what is shown above if the PC host interface can only support Fast Ethernet speed. If the PC host interface is not capable of supporting gigabit speed, then the bandwidth will most likely be displayed as 100000 Kbit/sec.

ii. Issue the **show ip route ospf** command on R1 to determine the route to the 192.168.3.0/24 network.

```
R1# show ip route ospf
Codes: L - local, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.2.0/24 [110/65] via 192.168.12.2, 00:01:08, Serial0/0/0
O     192.168.3.0/24 [110/65] via 192.168.13.2, 00:00:57, Serial0/0/1
      192.168.23.0/30 is subnetted, 1 subnets
O        192.168.23.0 [110/128] via 192.168.13.2, 00:00:57, Serial0/0/1
                      [110/128] via 192.168.12.2, 00:01:08, Serial0/0/0
```

Note: The accumulated cost to the 192.168.3.0/24 network from R1 is 65.

iii. Issue the **show ip ospf interface** command on R3 to determine the routing cost for G0/0.

R3# **show ip ospf interface g0/0**

```
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.3.1/24, Area 0, Attached via Network Statement
  Process ID 1, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 1
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           1         no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.23.2, Interface address 192.168.3.1
  No backup designated router on this network
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:05
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  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)
```

iv. Issue the **show ip ospf interface s0/0/1** command on R1 to view the routing cost for S0/0/1.

R1# **show ip ospf interface s0/0/1**

```
Serial0/0/1 is up, line protocol is up
  Internet Address 192.168.13.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type POINT_TO_POINT, Cost: 64
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           64        no          no            Base
  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 00:00:04
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  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 192.168.23.2
  Suppress hello for 0 neighbor(s)
```

The sum of the costs of these two interfaces is the accumulated cost for the route to the 192.168.3.0/24 network on R3 (1 + 64 = 65), as can be seen in the output from the **show ip route** command.

v. Issue the **auto-cost reference-bandwidth 10000** command on R1 to change the default reference bandwidth setting. With this setting, 10Gb/s interfaces will have a cost of 1, 1 Gb/s interfaces will have a cost of 10, and 100Mb/s interfaces will have a cost of 100.

R1(config)# **router ospf 1**

R1(config-router)# **auto-cost reference-bandwidth 10000**

```
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
```

vi. Issue the **auto-cost reference-bandwidth 10000** command on routers R2 and R3.

vii. Re-issue the **show ip ospf interface** command to view the new cost of G0/0 on R3, and S0/0/1 on R1.

R3# **show ip ospf interface g0/0**

```
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 192.168.3.1/24, Area 0, Attached via Network Statement
  Process ID 1, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 10
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           10        no          no            Base
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 192.168.23.2, Interface address 192.168.3.1
  No backup designated router on this network
```

```
  Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:02
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 1/1, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 0, maximum is 0
  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)
```

Note: If the device connected to the G0/0 interface does not support Gigabit Ethernet speed, the cost will be different than the output display. For example, the cost will be 100 for Fast Ethernet speed (100Mb/s).

R1# **show ip ospf interface s0/0/1**

```
Serial0/0/1 is up, line protocol is up
  Internet Address 192.168.13.1/30, Area 0, Attached via Network Statement
  Process ID 1, Router ID 1.1.1.1, Network Type POINT_TO_POINT, Cost: 6476
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           6476      no          no            Base
  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 00:00:05
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  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 192.168.23.2
  Suppress hello for 0 neighbor(s)
```

viii. Re-issue the **show ip route ospf** command to view the new accumulated cost for the 192.168.3.0/24 route (10 + 6476 = 6486).

Note: If the device connected to the G0/0 interface does not support Gigabit Ethernet speed, the total cost will be different than the output display. For example, the accumulated cost will be 6576 if G0/0 is operating at Fast Ethernet speed (100Mb/s).

R1# **show ip route ospf**

```
Codes: L - local, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.2.0/24 [110/6486] via 192.168.12.2, 00:05:40, Serial0/0/0
O     192.168.3.0/24 [110/6486] via 192.168.13.2, 00:01:08, Serial0/0/1
      192.168.23.0/30 is subnetted, 1 subnets
O        192.168.23.0 [110/12952] via 192.168.13.2, 00:05:17, Serial0/0/1
                      [110/12952] via 192.168.12.2, 00:05:17, Serial0/0/
```

Note: Changing the default reference-bandwidth on the routers from 100 to 10,000 in effect changed the accumulated costs of all routes by a factor of 100, but the cost of each interface link and route is now more accurately reflected.

ix. To reset the reference-bandwidth back to its default value, issue the **auto-cost reference-bandwidth 100** command on all three routers.

R1(config)# **router ospf 1**

R1(config-router)# **auto-cost reference-bandwidth 100**

```
% OSPF: Reference bandwidth is changed.
        Please ensure reference bandwidth is consistent across all routers.
```

Why would you want to change the OSPF default reference-bandwidth?

It is because modern day tech can withstand link speeds >100 Mb/s so the faster the better.

b. Change the bandwidth for an interface.

On most serial links, the bandwidth metric will default to 1544 Kbits (that of a T1). If this is not the actual speed of the serial link, the bandwidth setting will need to be changed to match the actual speed to allow the route cost to be calculated correctly in OSPF. Use the **bandwidth** command to adjust the bandwidth setting on an interface.

Note: A common misconception is to assume that the **bandwidth** command will change the physical bandwidth, or speed, of the link. The command modifies the bandwidth metric used by OSPF to calculate routing costs, and does not modify the actual bandwidth (speed) of the link.

i. Issue the **show interface s0/0/0** command on R1 to view the current bandwidth setting on S0/0/0. Even though the clock rate, link speed on this interface was set to 128Kb/s, the bandwidth is still showing 1544Kb/s.

```
R1# show interface s0/0/0
Serial0/0/0 is up, line protocol is up
  Hardware is WIC MBRD Serial
  Internet address is 192.168.12.1/30
  MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
     reliability 255/255, txload 1/255, rxload 1/255
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
<Output omitted>
```

ii. Issue the **show ip route ospf** command on R1 to view the accumulated cost for the route to network 192.168.23.0/24 using S0/0/0. Note that there are two equal-cost (128) routes to the 192.168.23.0/24 network, one via S0/0/0 and one via S0/0/1.

```
R1# show ip route ospf
Codes: L - local, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.2.0/24 [110/65] via 192.168.12.2, 00:00:26, Serial0/0/0
O     192.168.3.0/24 [110/65] via 192.168.13.2, 00:00:26, Serial0/0/1
      192.168.23.0/30 is subnetted, 1 subnets
O        192.168.23.0 [110/128] via 192.168.13.2, 00:00:26, Serial0/0/1
                      [110/128] via 192.168.12.2, 00:00:26, Serial0/0/0
```

iii. Issue the **bandwidth 128** command to set the bandwidth on S0/0/0 to 128Kb/s.

```
R1(config)# interface s0/0/0
R1(config-if)# bandwidth 128
```

iv. Re-issue the **show ip route ospf** command. The routing table no longer displays the route to the 192.168.23.0/24 network over the S0/0/0 interface. This is because the best route, the one with the lowest cost, is now via S0/0/1.

```
R1# show ip route ospf
Codes: L - local, 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, H - NHRP, l - LISP
+ - replicated route, % - next hop override

Gateway of last resort is not set

O    192.168.2.0/24 [110/129] via 192.168.12.2, 00:01:47, Serial0/0/0
O    192.168.3.0/24 [110/65] via 192.168.13.2, 00:04:51, Serial0/0/1
     192.168.23.0/30 is subnetted, 1 subnets
O       192.168.23.0 [110/128] via 192.168.13.2, 00:04:51, Serial0/0/1
```

v. Issue the **show ip ospf interface brief** command. The cost for S0/0/0 has changed from 64 to 781 which is an accurate cost representation of the link speed.

R1# **show ip ospf interface brief**

Interface	PID	Area	IP Address/Mask	Cost	State	Nbrs F/C
Se0/0/1	1	0	192.168.13.1/30	64	P2P	1/1
Se0/0/0	1	0	192.168.12.1/30	781	P2P	1/1
Gi0/0	1	0	192.168.1.1/24	1	DR	0/0

vi. Change the bandwidth for interface S0/0/1 to the same setting as S0/0/0 on R1.

vii. Re-issue the **show ip route ospf** command to view the accumulated cost of both routes to the 192.168.23.0/24 network. Note that there are again two equal-cost (845) routes to the 192.168.23.0/24 network, one via S0/0/0 and one via S0/0/1.

R1# **show ip route ospf**

```
Codes: L - local, 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, H - NHRP, l - LISP
    + - replicated route, % - next hop override

Gateway of last resort is not set

O    192.168.2.0/24 [110/782] via 192.168.12.2, 00:00:09, Serial0/0/0
O    192.168.3.0/24 [110/782] via 192.168.13.2, 00:00:09, Serial0/0/1
     192.168.23.0/30 is subnetted, 1 subnets
O       192.168.23.0 [110/845] via 192.168.13.2, 00:00:09, Serial0/0/1
                     [110/845] via 192.168.12.2, 00:00:09, Serial0/0/0
```

Explain how the costs to the 192.168.3.0/24 and 192.168.23.0/30 networks from R1 were calculated.

Cost of 192.168.3.0/24 = R1 S0/0/1 + R3 G0/0 = 781+1 = 782.

Cost of 192.168.23.0/30 = R1 S0/0/1+R3 S0/0/1 = 781 + 64 =845.

viii. Issue the **show ip route ospf** command on R3. The accumulated cost of the 192.168.1.0/24 is still showing as 65. Unlike the **clock rate** command, the **bandwidth** command needs to be applied on each side of a serial link.

```
R3# show ip route ospf
Codes: L - local, 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, H - NHRP, l - LISP
       + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.1.0/24 [110/65] via 192.168.13.1, 00:30:58, Serial0/0/0
O     192.168.2.0/24 [110/65] via 192.168.23.1, 00:30:58, Serial0/0/1
      192.168.12.0/30 is subnetted, 1 subnets
O        192.168.12.0 [110/128] via 192.168.23.1, 00:30:58, Serial0/0/1
                      [110/128] via 192.168.13.1, 00:30:58, Serial0/0/0
```

ix. Issue the **bandwidth 128** command on all remaining serial interfaces in the topology.

What is the new accumulated cost to the 192.168.23.0/24 network on R1? Why?

1,562 as each serial link has a value of 781 and we pass through two of them.

c. Change the route cost.

OSPF uses the bandwidth setting to calculate the cost for a link by default. However, you can override this calculation by manually setting the cost of a link using the **ip ospf cost** command. Like the **bandwidth** command, the **ip ospf cost** command only affects the side of the link where it was applied.

i. Issue the **show ip route ospf** on R1.

```
R1# show ip route ospf
Codes: L - local, 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, H - NHRP, l - LISP
        + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.2.0/24 [110/782] via 192.168.12.2, 00:00:26, Serial0/0/0
O     192.168.3.0/24 [110/782] via 192.168.13.2, 00:02:50, Serial0/0/1
      192.168.23.0/30 is subnetted, 1 subnets
O        192.168.23.0 [110/1562] via 192.168.13.2, 00:02:40, Serial0/0/1
                      [110/1562] via 192.168.12.2, 00:02:40, Serial0/0/0
```

ii. Apply the **ip ospf cost 1565** command to the S0/0/1 interface on R1. A cost of 1565 is higher than the accumulated cost of the route through R2 which is 1562.

R1(config)# **interface s0/0/1**

R1(config-if)# **ip ospf cost 1565**

iii. Re-issue the **show ip route ospf** command on R1 to display the effect this change has made on the routing table. All OSPF routes for R1 are now being routed through R2.

R1# **show ip route ospf**

```
Codes: L - local, 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, H - NHRP, l - LISP
        + - replicated route, % - next hop override

Gateway of last resort is not set

O     192.168.2.0/24 [110/782] via 192.168.12.2, 00:02:06, Serial0/0/0
O     192.168.3.0/24 [110/1563] via 192.168.12.2, 00:05:31, Serial0/0/0
      192.168.23.0/30 is subnetted, 1 subnets
O        192.168.23.0 [110/1562] via 192.168.12.2, 01:14:02, Serial0/0/0
```

Note: Manipulating link costs using the **ip ospf cost** command is the easiest and preferred method for changing OSPF route costs. In addition to changing the cost based on bandwidth, a network administrator may have other reasons for changing the cost of a route, such as preference for a particular service provider or the actual monetary cost of a link or route.

Explain why the route to the 192.168.3.0/24 network on R1 is now going through R2?

> It is because we will travel through the past with the lowest cost. So here we pass through R1 S0/0/0, then R2 S0/0/1, then R3 G0/0, or 781 + 781 + 1 = 1,563 as compared to a R1 S0/0/1 and R3 G0/0 = 1565 + 1 = 1,566.

Reflection

1. Why is it important to control the router ID assignment when using the OSPF protocol?

   It is important as it has control over the designated router and backup designated router for a large network. This way if the interface goes down there is a safe backup which we choose. It should be set to the IP address of a loopback interface to ensure it will not go down.

2. Why is the DR/BDR election process not a concern in this lab?

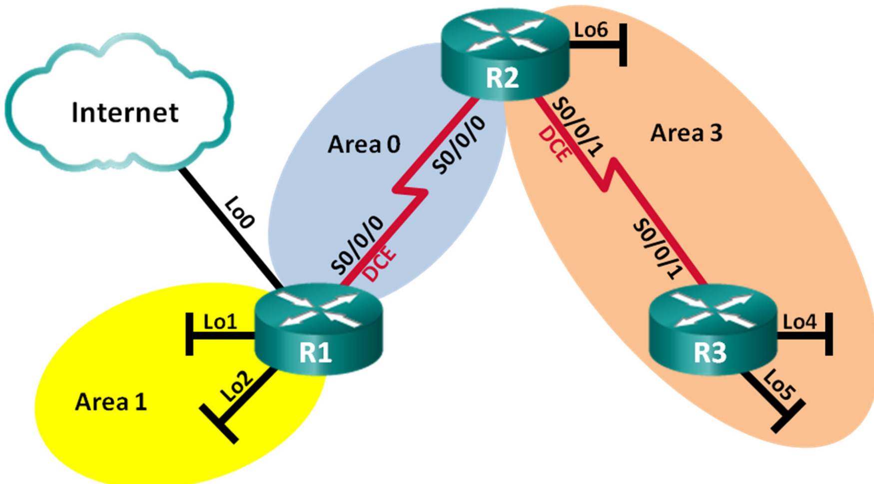
   It only is a concern with a multiaccess network (i.e., Frame Relay, Ethernet, etc.). The serial links go from point to pink so there is no DR/BDR.

3. Why would you want to set an OSPF interface to passive?

   Having a passive LAN interface will get rid of OSPF routing information that isn't necessary which helps to free up bandwidth.

Exercise 3: Configuring Multi-area OSPFv2 (9.2.2.8)

Topology



Addressing Table

Device	Interface	IP Address	Subnet Mask
R1	Lo0	209.165.200.225	255.255.255.252
	Lo1	192.168.1.1	255.255.255.0
	Lo2	192.168.2.1	255.255.255.0
	S0/0/0 (DCE)	192.168.12.1	255.255.255.252
R2	Lo6	192.168.6.1	255.255.255.0
	S0/0/0	192.168.12.2	255.255.255.252
	S0/0/1 (DCE)	192.168.23.1	255.255.255.252
R3	Lo4	192.168.4.1	255.255.255.0
	Lo5	192.168.5.1	255.255.255.0
	S0/0/1	192.168.23.2	255.255.255.252

A. Build the Network and Configure Basic Device Settings in Cisco Packet Tracer

a. Cable the network as shown in the topology.

b. Configure basic settings for each router.

i. Disable DNS lookup.
ii. Configure device name, as shown in the topology.
iii. Assign **class** as the privileged EXEC password.
iv. Assign **cisco** as the console and vty passwords.
v. Configure **logging synchronous** for the console line.
vi. Configure an MOTD banner to warn users that unauthorized access is prohibited.
vii. Configure the IP addresses listed in the Addressing Table for all interfaces. DCE interfaces should be configured with a clock rate of 128000. Bandwidth should be set to 128 Kb/s on all serial interfaces.
viii. Copy the running configuration to the startup configuration.

c. Verify Layer 3 connectivity.

Use the **show ip interface brief** command to verify that the IP addressing is correct and that the interfaces are active. Verify that each router can ping their neighbor's serial interface.

B. Configure a Multi-area OSPFv2 Network

Here, you will configure a multi-area OSPFv2 network with a process ID of 1. All LAN loopback interfaces should be passive.

a. Identify the OSPF router types in the topology.

Identify the Backbone router(s): R1, R2

Identify the Autonomous System Boundary Router(s) (ASBR): R1

Identify the Area Border Router(s) (ABR): R1,R2

Identify the Internal router(s): R3

b. Configure OSPF on R1.

i. Configure a router ID of 1.1.1.1 with OSPF process ID of 1.
ii. Add the networks for R1 to OSPF.

R1(config-router)# **network 192.168.1.0 0.0.0.255 area 1**
R1(config-router)# **network 192.168.2.0 0.0.0.255 area 1**
R1(config-router)# **network 192.168.12.0 0.0.0.3 area 0**

iii. Set LAN loopback interfaces, Lo1 and Lo2, as passive.

iv. Create a default route to the Internet using exit interface Lo0.

Note: You may see the "%Default route without gateway, if not a point-to-point interface, may impact performance" message. This is normal behavior if using a Loopback interface to simulate a default route.

v. Configure OSPF to propagate the routes throughout the OSPF areas.

c. Configure OSPF on R2.

i. Configure a router ID of 2.2.2.2 with OSPF process ID of 1.

ii. Add the networks for R2 to OSPF. Add the networks to the correct area. Write the commands used in the space below.

R2(config-router)# network 192.168.12.0 0.0.0.3 area 0

R2(config-router)# network 192.168.23.0 0.0.0.3 area 3

R2(config-router)# network 192.168.6.0 0.0.0.255 area 3

iii. Set all LAN loopback interfaces as passive.

d. Configure OSPF on R3.

i. Configure a router ID of 3.3.3.3 with OSPF process ID of 1.

ii. Add the networks for R3 to OSPF. Write the commands used in the space below.

R3(config-router)# network 192.168.23.0 0.0.0.3 area 3

R3(config-router)# network 192.168.4.0 0.0.0.255 area 3

R3(config-router)# network 192.168.5.0 0.0.0.255 area 3

iii. Set all LAN loopback interfaces as passive.

e. Verify that OSPF settings are correct and adjacencies have been established between routers.

i. Issue the **show ip protocols** command to verify OSPF settings on each router. Use this command to identify the OSPF router types and to determine the networks assigned to each area.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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 1.1.1.1
```

```
  It is an area border and autonomous system boundary router
 Redistributing External Routes from,
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.1.0 0.0.0.255 area 1
    192.168.2.0 0.0.0.255 area 1
    192.168.12.0 0.0.0.3 area 0
  Passive Interface(s):
    Loopback1
    Loopback2
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:01:45
  Distance: (default is 110)
```

R2# **show ip protocols**

```
*** IP Routing is NSF aware ***

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 2.2.2.2
  It is an area border router
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    192.168.6.0 0.0.0.255 area 3
    192.168.12.0 0.0.0.3 area 0
    192.168.23.0 0.0.0.3 area 3
  Passive Interface(s):
    Loopback6
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:01:20
    1.1.1.1              110      00:10:12
  Distance: (default is 110)
```

R3# **show ip protocols**

```
*** IP Routing is NSF aware ***

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 3.3.3.3

Number of areas in this router is 1. 1 normal 0 stub 0 nssa

Maximum path: 4

Routing for Networks:

192.168.4.0 0.0.0.255 area 3

192.168.5.0 0.0.0.255 area 3

192.168.23.0 0.0.0.3 area 3

Passive Interface(s):

Loopback4

Loopback5

Routing Information Sources:

Gateway	Distance	Last Update
1.1.1.1	110	00:07:46
2.2.2.2	110	00:07:46

Distance: (default is 110)

What is the OSPF router type for each router?

R1: ABR, ASBR

R2: ABR

R3: No special type

ii. Issue the **show ip ospf neighbor** command to verify that OSPF adjacencies have been established between routers.

R1# **show ip ospf neighbor**

Neighbor ID	Pri	State	Dead Time	Address	Interface
2.2.2.2	0	FULL/ -	00:00:34	192.168.12.2	Serial0/0/0

R2# **show ip ospf neighbor**

Neighbor ID	Pri	State	Dead Time	Address	Interface
1.1.1.1	0	FULL/ -	00:00:36	192.168.12.1	Serial0/0/0
3.3.3.3	0	FULL/ -	00:00:36	192.168.23.2	Serial0/0/1

R3# **show ip ospf neighbor**

Neighbor ID	Pri	State	Dead Time	Address	Interface
2.2.2.2	0	FULL/ -	00:00:38	192.168.23.1	Serial0/0/1

iii. Issue the **show ip ospf interface brief** command to display a summary of interface route costs.

R1# **show ip ospf interface brief**

Interface PID Area IP Address/Mask Cost State Nbrs F/C

```
Se0/0/0    1    0    192.168.12.1/30    781    P2P   1/1
Lo1        1    1    192.168.1.1/24     1      LOOP  0/0
Lo2        1    1    192.168.2.1/24     1      LOOP  0/0
```

R2# **show ip ospf interface brief**

```
Interface  PID  Area    IP Address/Mask    Cost  State Nbrs F/C
Se0/0/0    1    0       192.168.12.2/30    781   P2P   1/1
Lo6        1    3       192.168.6.1/24     1     LOOP  0/0
Se0/0/1    1    3       192.168.23.1/30    781   P2P   1/1
```

R3# **show ip ospf interface brief**

```
Interface  PID  Area    IP Address/Mask    Cost  State Nbrs F/C
Lo4        1    3       192.168.4.1/24     1     LOOP  0/0
Lo5        1    3       192.168.5.1/24     1     LOOP  0/0
Se0/0/1    1    3       192.168.23.2/30    781   P2P   1/1
```

Reflection

What are three advantages for designing a network with multi-area OSPF?

- Lowers link-state update overhead
- Small routing tables
- Lower frequency on SPF calculations