20-1 OSPF Configuration - Answer Key

In this lab you will configure the OSPF routing protocol. IP addresses have already been configured on the router interfaces.

OSPF Basic Configuration

1) Enable a loopback interface on routers R1 to R5. Use the IP address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.3/32 on R3.

On routers R1 to R5:

```
R1(config)#interface loopback0
R1(config-if)#ip address 192.168.0.1 255.255.255.255
```

2) Enable single area OSPF on routers R1 to R5. Ensure all networks except 172.16.0.0/24 and 203.0.113.0/24 are advertised.

On routers R1 to R5:

```
R1(config)#router ospf 1
R1(config-router)#network 10.0.0.0 0.255.255.255 area 0
R1(config-router)#network 192.168.0.0 0.0.0.255 area 0
```

You can use different network statements, as long as they cover the range of IP addresses configured on the router interfaces.

3) What do you expect the OSPF Router ID to be on R1? Verify this.

The loopback address is used for the Router ID, 192.168.0.1

```
R1#sh 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 192.168.0.1
  Number of areas in this router is 1. 1 normal 0 stub 0
nssa
  Maximum path: 4
  Routing for Networks:
    10.0.0.0 0.255.255.255 area 0
    192.168.0.0 0.0.0.255 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.0.1          110      00:00:25
    192.168.0.2          110      00:00:25
    192.168.0.3          110      00:00:25
    192.168.0.4          110      00:00:25
    192.168.0.5          110      00:00:25
  Distance: (default is 110)
```

4) Verify routers R1 to R5 have formed adjacencies with each other.

```
R1#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.5       1   FULL/BDR        00:00:31    10.0.3.2        FastEthernet1/1
192.168.0.2       1   FULL/DR         00:00:39    10.0.0.2        FastEthernet0/0
```

5) Verify all 10.x.x.x networks and loopbacks are in the routing tables on R1 to R5.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2] via 10.0.0.2, 00:03:13, FastEthernet0/0
O 10.1.1.0/24 [110/3] via 10.0.0.2, 00:02:51, FastEthernet0/0
              [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 10.1.2.0/24 [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 10.1.3.0/24 [110/2] via 10.0.3.2, 00:02:51, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/2] via 10.0.0.2, 00:03:25, FastEthernet0/0
O 192.168.0.3/32 [110/3] via 10.0.0.2, 00:03:13, FastEthernet0/0
O 192.168.0.4/32 [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 192.168.0.5/32 [110/2] via 10.0.3.2, 00:03:25, FastEthernet1/1
```

6) Set the reference bandwidth so that a 100 Gbps interface will have a cost of 1.

Remember to do this on all routers R1 to R5.

```
R1(config)#router ospf 1
R1(config-router)#auto-cost reference-bandwidth 100000
```

7) What will the OSPF cost be on the FastEthernet links? Verify this.

OSPF Cost = Reference bandwidth / Interface bandwidth.
100000 / 100 = 1000

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

FastEthernet0/0 is up, line protocol is up
Internet address is 10.0.0.1/24, Area 0
Process ID 1, Router ID 192.168.0.1, Network Type BROADCAST, Cost: 1000
```

8) What effect does this have on the cost to the 10.1.2.0/24 network from R1?

The cost changes from 3 to 3000.
Before reference bandwidth change:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2] via 10.0.0.2, 00:03:13, FastEthernet0/0
O 10.1.1.0/24 [110/3] via 10.0.0.2, 00:02:51, FastEthernet0/0
              [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 10.1.2.0/24 [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 10.1.3.0/24 [110/2] via 10.0.3.2, 00:02:51, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/2] via 10.0.0.2, 00:03:25, FastEthernet0/0
O 192.168.0.3/32 [110/3] via 10.0.0.2, 00:03:13, FastEthernet0/0
O 192.168.0.4/32 [110/3] via 10.0.3.2, 00:02:51, FastEthernet1/1
O 192.168.0.5/32 [110/2] via 10.0.3.2, 00:03:25, FastEthernet1/1
```

After reference bandwidth change:

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:01:04, FastEthernet0/0
              [110/3000] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 10.1.2.0/24 [110/3000] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 10.1.3.0/24 [110/2000] via 10.0.3.2, 00:01:04, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 192.168.0.4/32 [110/2012] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 192.168.0.5/32 [110/1012] via 10.0.3.2, 00:01:04, FastEthernet1/1
```

OSPF Cost

9) There are two possible paths which R1 could use to reach the 10.1.2.0/24 network – either through R2 or R5. Which route is in the routing table?

   The path via R5 at 10.0.3.2.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:01:04, FastEthernet0/0
              [110/3000] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 10.1.2.0/24 [110/3000] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 10.1.3.0/24 [110/2000] via 10.0.3.2, 00:01:04, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:01:04, FastEthernet0/0
O 192.168.0.4/32 [110/2012] via 10.0.3.2, 00:01:04, FastEthernet1/1
O 192.168.0.5/32 [110/1012] via 10.0.3.2, 00:01:04, FastEthernet1/1
```

10) Change this so that traffic from R1 to 10.1.2.0/24 will be load balanced via both R2 and R5.

Since we changed the reference bandwidth, all interfaces have a cost of 1000. The current path from R1 > R5 > R4 has a cost of 3000 (the cost of the destination interface itself is also counted in the total cost).

The path from R1 > R2 > R3 > R4 has a cost of 4000.

The easiest way to configure both paths to have the same cost is to configure the links from R1 > R5 and R5 > R4 to have a cost of 1500 each. (R1 > R5 = 1500, plus R5 > R4 = 1500, plus cost of 10.1.2.0/24 interface on R4 = 1000. Total = 4000).

```
R1(config)#int f1/1
R1(config-if)#ip ospf cost 1500

R5(config)#int f0/0
R5(config-if)# ip ospf cost 1500
R5(config)#int f0/1
R5(config-if)# ip ospf cost 1500

R4(config)#int f1/0
R4(config-if)# ip ospf cost 1500
```

11) Verify that traffic to the 10.1.2.0/24 network from R1 is load balanced via both R2 and R5.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:05:57, FastEthernet0/0
O 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:00:38, FastEthernet0/0
O 10.1.2.0/24 [110/4000] via 10.0.3.2, 00:00:25, FastEthernet1/1
              [110/4000] via 10.0.0.2, 00:00:25, FastEthernet0/0
O 10.1.3.0/24 [110/3000] via 10.0.3.2, 00:00:25, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:05:57, FastEthernet0/0
O 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:05:57, FastEthernet0/0
O 192.168.0.4/32 [110/3012] via 10.0.3.2, 00:00:25, FastEthernet1/1
                 [110/3012] via 10.0.0.2, 00:00:25, FastEthernet0/0
O 192.168.0.5/32 [110/1512] via 10.0.3.2, 00:00:38, FastEthernet1/1
```

Default Route Injection

12) Ensure that routers R1 to R5 have a route to the 203.0.113.0/24 network. Internal routes must not be advertised to the Service Provider at 203.0.113.2.

The 203.0.113.0/24 network must be added to the OSPF process on R4, and interface FastEthernet 1/1 facing the service provider configured as a passive interface to avoid sending out internal network information.

```
R4(config)#router ospf 1
R4(config-router)#passive-interface f1/1
R4(config-router)#network 203.0.113.0 0.0.0.255 area 0
```

13) Verify that routers R1 to R5 have a path to the 203.0.113.0/24 network.

```
R1#sh 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

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:08:40, FastEthernet0/0
O 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:03:21, FastEthernet0/0
O 10.1.2.0/24 [110/4000] via 10.0.3.2, 00:03:08, FastEthernet1/1
              [110/4000] via 10.0.0.2, 00:03:08, FastEthernet0/0
O 10.1.3.0/24 [110/3000] via 10.0.3.2, 00:03:08, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:08:40, FastEthernet0/0
O 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:08:40, FastEthernet0/0
O 192.168.0.4/32 [110/3012] via 10.0.3.2, 00:03:08, FastEthernet1/1
                 [110/3012] via 10.0.0.2, 00:03:08, FastEthernet0/0
O 192.168.0.5/32 [110/1512] via 10.0.3.2, 00:03:21, FastEthernet1/1
O 203.0.113.0/24 [110/3001] via 10.0.3.2, 00:00:03, FastEthernet1/1
                 [110/3001] via 10.0.0.2, 00:00:03, FastEthernet0/0
```

14) Configure a default static route on R4 to the Internet via the service provider at 203.0.113.2

```
R4(config)#ip route 0.0.0.0 0.0.0.0 203.0.113.2
```

15) Ensure that routers R1 to R5 learn via OSPF how to reach the Internet.

```
R4(config)#router ospf 1
R4(config-router)#default-information originate
```

16) Verify routers R1 to R5 have a route to the Internet.

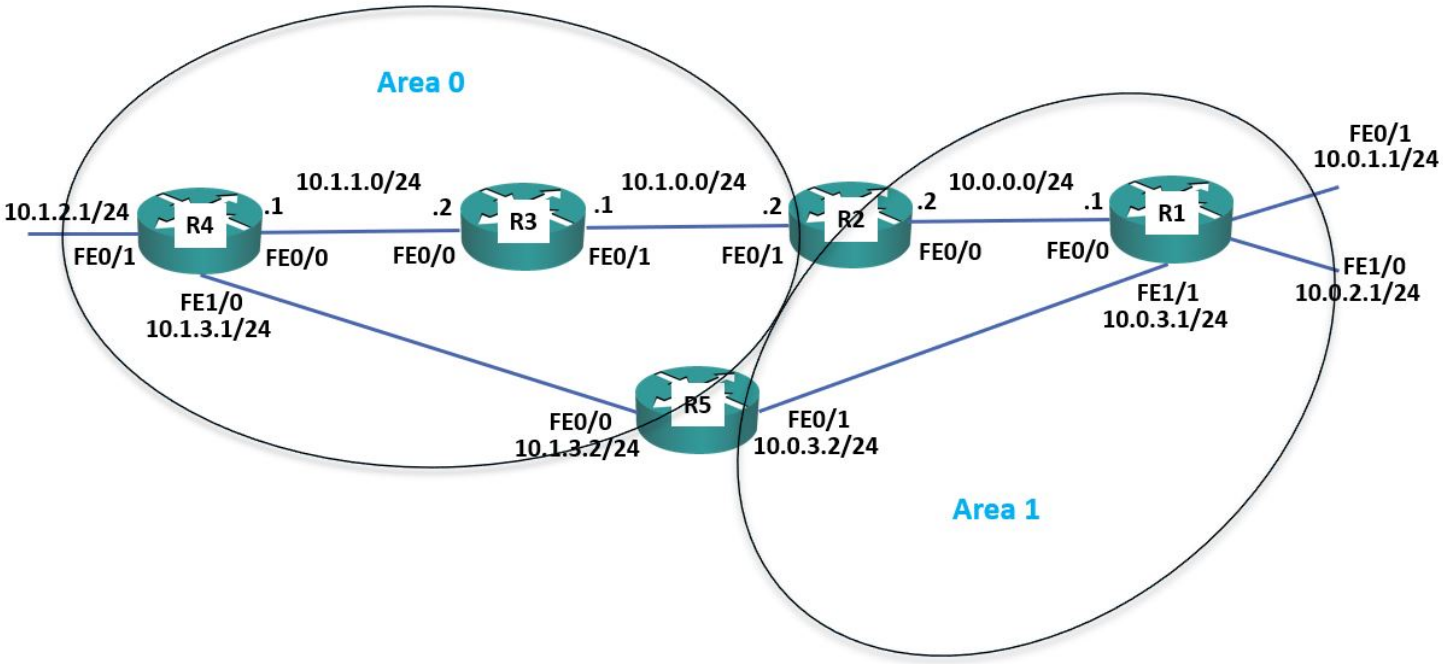
```
R1#sh ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - 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 10.0.3.2 to network 0.0.0.0

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:10:54, FastEthernet0/0
O 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:05:35, FastEthernet0/0
O 10.1.2.0/24 [110/4000] via 10.0.3.2, 00:05:22, FastEthernet1/1
              [110/4000] via 10.0.0.2, 00:05:22, FastEthernet0/0
O 10.1.3.0/24 [110/3000] via 10.0.3.2, 00:05:22, FastEthernet1/1
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:10:54, FastEthernet0/0
O 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:10:54, FastEthernet0/0
O 192.168.0.4/32 [110/3012] via 10.0.3.2, 00:05:22, FastEthernet1/1
                 [110/3012] via 10.0.0.2, 00:05:22, FastEthernet0/0
O 192.168.0.5/32 [110/1512] via 10.0.3.2, 00:05:35, FastEthernet1/1
O 203.0.113.0/24 [110/3001] via 10.0.3.2, 00:02:17, FastEthernet1/1
                 [110/3001] via 10.0.0.2, 00:02:17, FastEthernet0/0
O*E2 0.0.0.0/0 [110/1] via 10.0.3.2, 00:00:06, FastEthernet1/1
               [110/1] via 10.0.0.2, 00:00:06, FastEthernet0/0
```

Multi-Area OSPF

17) Convert the network to use multi-area OSPF. R3 and R4 should be backbone routers, R1 a normal router in Area 1, and R2 and R5 ABRs as shown in the diagram below.
Save your changes to the startup config and reboot the routers to ensure the changes take effect.



R3 and R4 require no change as all their interfaces are already in Area 0.

R1's interfaces need to be reconfigured to be in Area 1 rather than Area 0.

```
R1#show run | section ospf
 ip ospf cost 1500
router ospf 1
 log-adjacency-changes
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R1(config)#router ospf 1
R1(config-router)#network 10.0.0.0 0.255.255.255 area 1
R1(config-router)#network 192.168.0.0 0.0.0.255 area 1
R1#copy run start
R1#reload
```

R2 interface FastEthernet 0/1 should remain in Area 0. FastEthernet 0/0 needs to be reconfigured to be in Area 1. I used a 10.0.0.0/8 network statement originally so I need to remove that and add more granular statements.

```
R2#sh run | section ospf
router ospf 1
 log-adjacency-changes
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R2(config)#router ospf 1
R2(config-router)#no network 10.0.0.0 0.255.255.255 area 0
R2(config-router)#network 10.1.0.0 0.0.0.255 area 0
R2(config-router)#network 10.0.0.0 0.0.0.255 area 1
R2#copy run start
R2#reload
```

R5 interface FastEthernet 0/0 should remain in Area 0. FastEthernet 0/1 needs to be reconfigured to be in Area 1.

```
R5#sh run | section ospf
 ip ospf cost 1500
 ip ospf cost 1500
router ospf 1
 log-adjacency-changes
 auto-cost reference-bandwidth 100000
 network 10.0.0.0 0.255.255.255 area 0
 network 192.168.0.0 0.0.0.255 area 0

R5(config)#router ospf 1
R5(config-router)#no network 10.0.0.0 0.255.255.255 area 0
R5(config-router)#network 10.1.3.0 0.0.0.255 area 0
R5(config-router)#network 10.0.3.0 0.0.0.255 area 1
R5#copy run start
R5#reload
```

18) Verify the router's interfaces are in the correct areas.

```
R2#show ip ospf interface

Loopback0 is up, line protocol is up
 Internet address is 192.168.0.2/32, Area 0
FastEthernet0/1 is up, line protocol is up
 Internet address is 10.1.0.2/24, Area 0
FastEthernet0/0 is up, line protocol is up
 Internet address is 10.0.0.2/24, Area 1
```

! Output truncated

19) Verify routers R1 to R5 have formed adjacencies with each other.

```
R1#sh ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.5       1   FULL/DR         00:00:33    10.0.3.2        FastEthernet1/1
192.168.0.2       1   FULL/DR         00:00:31    10.0.0.2        FastEthernet0/0
```

20) What change do you expect to see on R1's routing table? Verify this (give the routing table a few seconds to converge).

The networks beyond R2 and R5 will appear as Inter Area routes (apart from the default route which will appear as an external route as it was redistributed into OSPF).

```
R1#sh 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 10.0.0.2 to network 0.0.0.0

      10.0.0.0/8 is variably subnetted, 12 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O IA 10.1.0.0/24 [110/2000] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 10.1.1.0/24 [110/3000] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 10.1.2.0/24 [110/4000] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 10.1.3.0/24 [110/4500] via 10.0.0.2, 00:02:59, FastEthernet0/0
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O IA 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 192.168.0.4/32 [110/3012] via 10.0.0.2, 00:03:10, FastEthernet0/0
O IA 192.168.0.5/32 [110/4512] via 10.0.0.2, 00:02:59, FastEthernet0/0
O IA 203.0.113.0/24 [110/3001] via 10.0.0.2, 00:03:10, FastEthernet0/0
O*E2 0.0.0.0/0 [110/1] via 10.0.0.2, 00:02:59, FastEthernet0/0
```

21) Do you see less routes in R1's routing table? Why or why not?

R1 has the same amount of routes in its routing table because OSPF does not perform automatic summarisation. You must configure manual summarisation to reduce the size of the routing table.

22) Configure summary routes on the Area Border Routers for the 10.0.0.0/16 and 10.1.0.0/16 networks.

```
R2(config)#router ospf 1
R2(config-router)#area 0 range 10.1.0.0 255.255.0.0
R2(config-router)#area 1 range 10.0.0.0 255.255.0.0

R5(config-if)#router ospf 1
R5(config-router)#area 0 range 10.1.0.0 255.255.0.0
R5(config-router)#area 1 range 10.0.0.0 255.255.0.0
```

23) Verify R1 now sees a single summary route for 10.1.0.0/16 rather than individual routes for the 10.1.x.x networks.

```
R1#sh 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 10.0.0.2 to network 0.0.0.0

      10.0.0.0/8 is variably subnetted, 9 subnets, 2 masks
C 10.0.0.0/24 is directly connected, FastEthernet0/0
L 10.0.0.1/32 is directly connected, FastEthernet0/0
C 10.0.1.0/24 is directly connected, FastEthernet0/1
L 10.0.1.1/32 is directly connected, FastEthernet0/1
C 10.0.2.0/24 is directly connected, FastEthernet1/0
L 10.0.2.1/32 is directly connected, FastEthernet1/0
C 10.0.3.0/24 is directly connected, FastEthernet1/1
L 10.0.3.1/32 is directly connected, FastEthernet1/1
O IA 10.1.0.0/16 [110/2000] via 10.0.0.2, 00:00:04, FastEthernet0/0
      192.168.0.0/32 is subnetted, 5 subnets
C 192.168.0.1/32 is directly connected, Loopback0
O IA 192.168.0.2/32 [110/1012] via 10.0.0.2, 00:05:27, FastEthernet0/0
O IA 192.168.0.3/32 [110/2012] via 10.0.0.2, 00:05:27, FastEthernet0/0
O IA 192.168.0.4/32 [110/3012] via 10.0.0.2, 00:05:27, FastEthernet0/0
O IA 192.168.0.5/32 [110/4512] via 10.0.0.2, 00:05:16, FastEthernet0/0
O IA 203.0.113.0/24 [110/3001] via 10.0.0.2, 00:05:27, FastEthernet0/0
O*E2 0.0.0.0/0 [110/1] via 10.0.0.2, 00:05:16, FastEthernet0/0
```

24) Verify R1 is receiving a summary route for the 10.1.0.0/16 network from both R2 and R5.

```
R1#sh ip ospf database

            OSPF Router with ID (192.168.0.1) (Process ID 1)

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link
count
192.168.0.1     192.168.0.1     18          0x80000005 0x00536E 5
192.168.0.2     192.168.0.2     27          0x80000003 0x0069ED 1
192.168.0.5     192.168.0.5     1890        0x80000003 0x00C490 1

                Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
10.0.0.1        192.168.0.1     18          0x80000002 0x00DF0E
10.0.3.1        192.168.0.1     18          0x80000002 0x00E8FE

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.5     192.168.0.5     408         0x80000006 0x00e987
10.0.3.0        192.168.0.5     408         0x80000007 0x007e7d
192.168.0.4     192.168.0.5     408         0x80000009 0x00bbd1
203.0.113.0     192.168.0.5     408         0x8000000a 0x00ebdb
192.168.0.3     192.168.0.5     408         0x8000000b 0x00f4ab
192.168.0.2     192.168.0.5     408         0x8000000c 0x003084
10.0.0.0        192.168.0.5     408         0x8000000d 0x002c09
192.168.0.2     192.168.0.2     1079        0x80000005 0x001c5c
192.168.0.3     192.168.0.2     1079        0x80000006 0x004446
192.168.0.4     192.168.0.2     1079        0x80000008 0x006932
203.0.113.0     192.168.0.2     1079        0x80000009 0x00993c
192.168.0.5     192.168.0.2     398         0x80000006 0x00308a
10.0.3.0        192.168.0.2     398         0x80000007 0x00c282
192.168.0.1     192.168.0.5     393         0x80000010 0x003c74
10.1.0.0        192.168.0.5     82          0x80000015 0x007679
10.1.0.0        192.168.0.2     67          0x8000001f 0x000ee4

                Summary ASB Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.4     192.168.0.2     27          0x80000002 0x00EE9B
192.168.0.4     192.168.0.5     1889        0x80000002 0x00433A

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         192.168.0.4     207         0x80000002 0x00152F 1
```

25) R1 is routing traffic to 10.1.0.0/16 via R2 only. Why is it not load balancing the traffic through both R2 and R5?

We configured the link from R1 to R5 to have a higher cost than the link from R1 to R2 earlier.

```
R1#sh run | begin interface FastEthernet1/1
Building configuration...

Current configuration : 100 bytes
!
interface FastEthernet1/1
 ip address 10.0.3.1 255.255.255.0
 ip ospf cost 1500
```

DR and BDR Designated Routers

26) Enable a loopback interface on routers R6 to R9. Use the IP address 192.168.0.x/32, where 'x' is the router number. For example 192.168.0.6/32 on R6.

On routers R6 to R9:

```
R6(config)#interface loopback0
R6(config-if)#ip address 192.168.0.6 255.255.255.255
```

27) Enable OSPF for Area 0 on the Loopback 0 and FastEthernet 0/0 interfaces on routers R6 to R9.

On routers R6 to R9:

```
R6(config)#router ospf 1
R6(config-router)#network 172.16.0.0 0.0.0.255 area 0
R6(config-router)# network 192.168.0.0 0.0.0.255 area 0
```

You can use different network statements, as long as they cover the range of IP addresses configured on the router interfaces.

28) Set the reference bandwidth on routers R6 to R9 so that a 100 Gbps interface will have a cost of 1.

Remember to do this on all routers R6 to R9.

```
R6(config)#router ospf 1
R6(config-router)#auto-cost reference-bandwidth 100000
```

29) Which routers do you expect to be the DR and BDR on the Ethernet segment? Verify this.

OSPF priority has not been set so all routers will have the default of 1.
R9 and R8 will be elected as the DR and BDR respectively because the have the highest Router IDs (because they have the highest IP addresses on their loopback interfaces).

```
R6#show ip ospf interface FastEthernet 0/0

FastEthernet0/0 is up, line protocol is up
  Internet address is 172.16.0.6/24, Area 0
  Process ID 1, Router ID 192.168.0.6, Network Type BROADCAST, Cost: 1000
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 192.168.0.9, Interface address 172.16.0.9
  Backup Designated Router (ID) 192.168.0.8, Interface address 172.16.0.8

R6#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.8       1   FULL/BDR        00:00:31    172.16.0.8      FastEthernet0/0
192.168.0.7       1   2WAY/DROTHER    00:00:39    172.16.0.7      FastEthernet0/0
192.168.0.9       1   FULL/DR         00:00:39    172.16.0.9      FastEthernet0/0

R9#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.8       1   FULL/BDR        00:00:31    172.16.0.8      FastEthernet0/0
192.168.0.7       1   2WAY/DROTHER    00:00:39    172.16.0.7      FastEthernet0/0
192.168.0.6       1   FULL/DROTHER    00:00:39    172.16.0.6      FastEthernet0/0
```

30) Set R6 as the Designated Router without changing any IP addresses.

Configure a higher OSPF priority on R6.

```
R6(config)#interface FastEthernet0/0
R6(config-if)#ip ospf priority 100
R6(config-if)#end
R6#clear ip ospf process
```

31) Verify R6 is the Designated Router.

```
R6#show ip ospf interface FastEthernet 0/0
```

```
FastEthernet0/0 is up, line protocol is up
Internet address is 172.16.0.6/24, Area 0
Process ID 1, Router ID 192.168.0.6, Network Type BROADCAST, Cost: 1000
Transmit Delay is 1 sec, State DR, Priority 100
Designated Router (ID) 192.168.0.6, Interface address 172.16.0.6
Backup Designated Router (ID) 192.168.0.8, Interface address 172.16.0.8
```

```
R6#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.8       1   FULL/BDR        00:00:31    172.16.0.8      FastEthernet0/0
192.168.0.7       1   2WAY/DROTHER    00:00:39    172.16.0.7      FastEthernet0/0
192.168.0.9       1   FULL/DROTHER    00:00:39    172.16.0.9      FastEthernet0/0
```

```
R9#show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
192.168.0.8       1   FULL/BDR        00:00:31    172.16.0.8      FastEthernet0/0
192.168.0.7       1   2WAY/DROTHER    00:00:39    172.16.0.7      FastEthernet0/0
192.168.0.6       1   FULL/DR         00:00:39    172.16.0.6      FastEthernet0/0
```