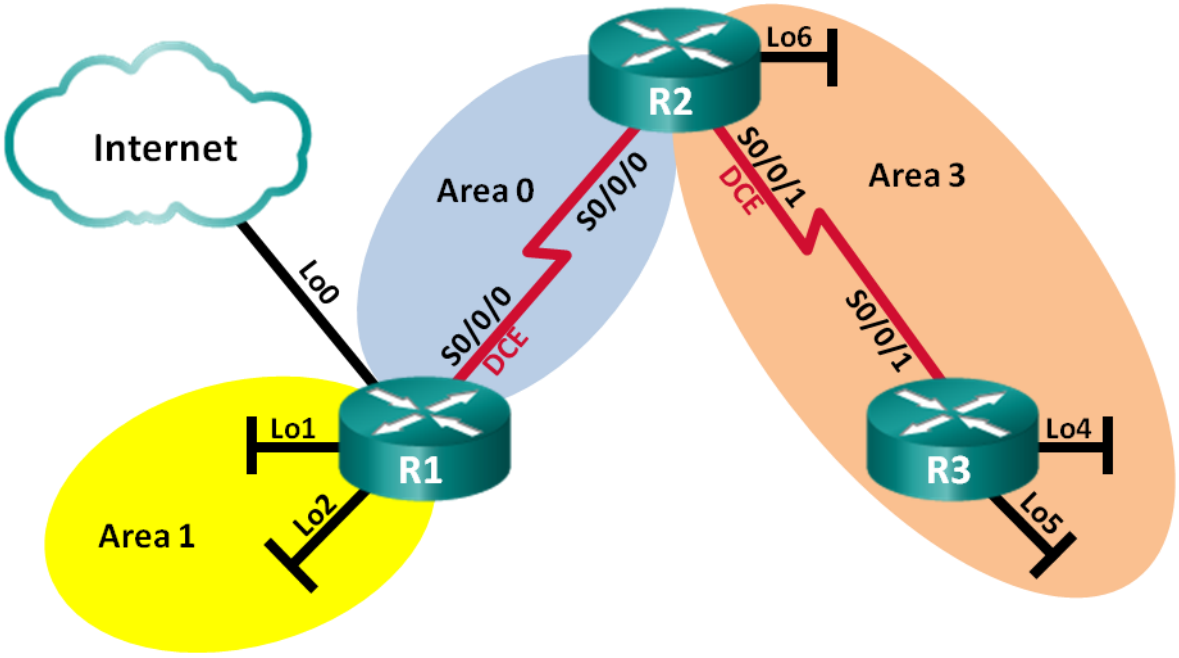
Lab - Configuring Multiarea OSPFv2 (Instructor Version)

Instructor Note: Red font color or Gray highlights indicate text that appears in the instructor copy only.

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

Objectives

Part 1: Build the Network and Configure Basic Device Settings

Part 2: Configure a Multiarea OSPFv2 Network

Part 3: Configure Interarea Summary Routes

Background / Scenario

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 multiarea OSPF. Multiarea OSPF is useful in larger network deployments to reduce processing and memory overhead.

In the lab, you will configure a multiarea OSPFv2 network with interarea summary routes.

Note: The routers used with CCNA hands-on labs are Cisco 1941 Integrated Services Routers (ISRs) with Cisco IOS Release 15.2(4)M3 (universalk9 image). Other routers and Cisco IOS versions can be used. Depending on the model and Cisco IOS version, the commands available and output produced might vary from what is shown in the labs. Refer to the Router Interface Summary Table at the end of this lab for the correct interface identifiers.

Note: Make sure that the routers have been erased and have no startup configurations. If you are unsure, contact your instructor.

Instructor Note: Refer to the Instructor Lab Manual for the procedures to initialize and reload devices.

Required Resources

- 3 Routers (Cisco 1941 with Cisco IOS Release 15.2(4)M3 universal image or comparable)
- Console cables to configure the Cisco IOS devices via the console ports
- Serial cables as shown in the topology

Part 1: Build the Network and Configure Basic Device Settings

In Part 1, you will set up the network topology and configure basic settings on the routers.

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

Step 2: Initialize and reload the routers as necessary.

Step 3: 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 **logging synchronous** for the console line.

f. Configure an MOTD banner to warn users that unauthorized access is prohibited.

g. 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.

h. Copy the running configuration to the startup configuration.

Step 4: 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.

Part 2: Configure a Multiarea OSPFv2 Network

In Part 2, you will configure a multiarea OSPFv2 network with process ID of 1. All LAN loopback interfaces should be passive, and all serial interfaces should be configured with MD5 authentication using **Cisco123** as the key.

Step 1: Identify the OSPF router types in the topology.

Identify the Backbone router(s): _____ R1 and R2

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

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

Identify the Internal router(s): _____ R3

Step 2: Configure OSPF on R1.

a. Configure a router ID of 1.1.1.1 with OSPF process ID of 1.

```
R1(config)# router ospf 1
R1(config-router)# router-id 1.1.1.1
```

b. 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
```

c. Set all LAN loopback interfaces, Lo1 and Lo2, as passive.

```
R1(config-router)# passive-interface lo1
R1(config-router)# passive-interface lo2
R1(config-router)# exit
```

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

```
R1(config)# ip route 0.0.0.0 0.0.0.0 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.

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

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

Step 3: Configure OSPF on R2.

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

```
R2(config)# router ospf 1
R2(config-router)# router-id 2.2.2.2
```

b. 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
```

c. Set all LAN loopback interfaces as passive.

```
R2(config-router)# passive-interface lo6
```

Step 4: Configure OSPF on R3.

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

```
R3(config)# router ospf 1
R3(config-router)# router-id 3.3.3.3
```

b. 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
```

c. Set all LAN loopback interfaces as passive.

```
R3(config-router)# passive-interface lo4
R3(config-router)# passive-interface lo5
```

Step 5: Verify that OSPF settings are correct and adjacencies have been established between routers.

a. 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: _____

R2: _____

R3: _____

R1 - ABR and ASBR

R2 - ABR

R3 - No special OSPF router type

b. 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
```

c. 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
```

Step 6: Configure MD5 authentication on all serial interfaces.

Configure OSPF MD5 authentication at the interface level with an authentication key of **Cisco123**.

```
R1(config)# interface s0/0/0
R1(config-if)# ip ospf message-digest-key 1 md5 Cisco123
R1(config-if)# ip ospf authentication message-digest
```

```
R2(config)# int s0/0/0
R2(config-if)# ip ospf message-digest-key 1 md5 Cisco123
R2(config-if)# ip ospf authentication message-digest
R2(config-if)# interface s0/0/1
R2(config-if)# ip ospf message-digest-key 1 md5 Cisco123
R2(config-if)# ip ospf authentication message-digest

R3(config)# interface s0/0/1
R3(config-if)# ip ospf message-digest-key 1 md5 Cisco123
R3(config-if)# ip ospf authentication message-digest
```

Why is it a good idea to verify that OSPF is functioning correctly before configuring OSPF authentication?

_____

_____

Troubleshooting OSPF problems is much easier if OSPF adjacencies have been established and verified before implementing authentication. You then know that your authentication implementation is flawed, as adjacencies do not re-establish.

Step 7: Verify OSPF adjacencies have been re-established.

Issue the **show ip ospf neighbor** command again to verify that adjacencies have been re-established after MD5 authentication was implemented. Troubleshoot any issues found before moving on to Part 3.

Part 3: Configure Interarea Summary Routes

OSPF does not perform automatic summarization. Interarea summarization must be manually configured on ABRs. In Part 3, you will apply interarea summary routes on the ABRs. Using **show** commands, you will be able to observe how summarization affects the routing table and LSDBs.

Step 1: Display the OSPF routing tables on all routers.

a. Issue the **show ip route ospf** command on R1. OSPF routes that originate from a different area have a descriptor (O IA) indicating that these are interarea routes.

```
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 0.0.0.0 to network 0.0.0.0

      192.168.4.0/32 is subnetted, 1 subnets
O IA     192.168.4.1 [110/1563] via 192.168.12.2, 00:23:49, Serial0/0/0
      192.168.5.0/32 is subnetted, 1 subnets
O IA     192.168.5.1 [110/1563] via 192.168.12.2, 00:23:49, Serial0/0/0
```

```
      192.168.23.0/30 is subnetted, 1 subnets
O IA     192.168.6.1 [110/782] via 192.168.12.2, 00:02:01, Serial0/0/0
      192.168.23.0/30 is subnetted, 1 subnets
O IA     192.168.23.0 [110/1562] via 192.168.12.2, 00:23:49, Serial0/0/0
```

b. Repeat the **show ip route ospf** command for R2 and R3. Record the OSPF interarea routes for each router.

R2:

_____

_____

_____

```
O IA     192.168.1.1 [110/782] via 192.168.12.1, 00:25:22, Serial0/0/0
O IA     192.168.2.1 [110/782] via 192.168.12.1, 00:25:22, Serial0/0/0
```

R3:

_____

_____

_____

```
O IA     192.168.1.1 [110/1563] via 192.168.23.1, 00:30:41, Serial0/0/1
O IA     192.168.2.1 [110/1563] via 192.168.23.1, 00:30:41, Serial0/0/1
O IA     192.168.12.0 [110/1562] via 192.168.23.1, 01:40:46, Serial0/0/1
R2# 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 192.168.12.1 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 192.168.12.1, 00:25:22, Serial0/0/0
      192.168.1.0/32 is subnetted, 1 subnets
O IA     192.168.1.1 [110/782] via 192.168.12.1, 00:25:22, Serial0/0/0
      192.168.2.0/32 is subnetted, 1 subnets
O IA     192.168.2.1 [110/782] via 192.168.12.1, 00:25:22, Serial0/0/0
      192.168.4.0/32 is subnetted, 1 subnets
O        192.168.4.1 [110/782] via 192.168.23.2, 01:35:23, Serial0/0/1
      192.168.5.0/32 is subnetted, 1 subnets
O        192.168.5.1 [110/782] via 192.168.23.2, 01:35:23, Serial0/0/1

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 192.168.23.1 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 192.168.23.1, 00:30:36, Serial0/0/1
      192.168.1.0/32 is subnetted, 1 subnets
O IA     192.168.1.1 [110/1563] via 192.168.23.1, 00:30:41, Serial0/0/1
      192.168.2.0/32 is subnetted, 1 subnets
O IA     192.168.2.1 [110/1563] via 192.168.23.1, 00:30:41, Serial0/0/1
      192.168.12.0/30 is subnetted, 1 subnets
O        192.168.6.1 [110/782] via 192.168.23.1, 00:00:38, Serial0/0/1
      192.168.12.0/30 is subnetted, 1 subnets
O IA     192.168.12.0 [110/1562] via 192.168.23.1, 01:40:46, Serial0/0/1
```

Step 2: Display the LSDB on all routers.

a. Issue the **show ip ospf database** command on R1. A router maintains a separate LSDB for every area that it is a member.

```
R1# show ip ospf database

            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1295        0x80000003 0x0039CD 2
2.2.2.2         2.2.2.2         1282        0x80000002 0x00D430 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.1.1     1.1.1.1         1387        0x80000002 0x00AC1F
192.168.2.1     1.1.1.1         1387        0x80000002 0x00A129
192.168.4.1     2.2.2.2         761         0x80000001 0x000DA8
192.168.5.1     2.2.2.2         751         0x80000001 0x0002B2
192.168.6.1     2.2.2.2         1263        0x80000001 0x00596A
192.168.23.0    2.2.2.2         1273        0x80000001 0x00297E

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1342        0x80000006 0x0094A4 2

                Summary Net Link States (Area 1)
```

```
Link ID         ADV Router      Age         Seq#       Checksum
192.168.4.1     1.1.1.1         760         0x80000001 0x00C8E0
192.168.5.1     1.1.1.1         750         0x80000001 0x00BDEA
192.168.6.1     1.1.1.1         1262        0x80000001 0x0015A2
192.168.12.0    1.1.1.1         1387        0x80000001 0x00C0F5
192.168.23.0    1.1.1.1         1272        0x80000001 0x00E4B6

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1343        0x80000001 0x001D91 1
```

b. Repeat the **show ip ospf database** command for R2 and R3. Record the Link IDs for the Summary Net Link States for each area.

R2:

_____

_____

Area 0 - 192.168.1.1, 192.168.2.1, 192.168.4.1, 192.168.5.1, 192.168.6.1, 192.168.23.0

Area 3 – 192.168.1.1, 192.168.2.1, 192.168.12.0

R3:

_____

_____

Area 3 - 192.168.1.1, 192.168.2.1, 192.168.12.0

```
R2# show ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1444        0x80000003 0x0039CD 2
2.2.2.2         2.2.2.2         1429        0x80000002 0x00D430 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.1.1     1.1.1.1         1535        0x80000002 0x00AC1F
192.168.2.1     1.1.1.1         1535        0x80000002 0x00A129
192.168.4.1     2.2.2.2         908         0x80000001 0x000DA8
192.168.5.1     2.2.2.2         898         0x80000001 0x0002B2
192.168.6.1     2.2.2.2         1410        0x80000001 0x00596A
192.168.23.0    2.2.2.2         1420        0x80000001 0x00297E

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
2.2.2.2         2.2.2.2         1212        0x80000003 0x00DE86 3
```

```
3.3.3.3         3.3.3.3         892         0x80000005 0x00DB05 4

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.1.1     2.2.2.2         1420        0x80000002 0x002C8B
192.168.2.1     2.2.2.2         1420        0x80000002 0x002195
192.168.12.0    2.2.2.2         1420        0x80000002 0x00A011

                Summary ASB Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
1.1.1.1         2.2.2.2         1420        0x80000002 0x00AC72

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1492        0x80000001 0x001D91 1

R3# show ip ospf database

            OSPF Router with ID (3.3.3.3) (Process ID 1)

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
2.2.2.2         2.2.2.2         1251        0x80000003 0x00DE86 3
3.3.3.3         3.3.3.3         930         0x80000005 0x00DB05 4

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.1.1     2.2.2.2         1459        0x80000002 0x002C8B
192.168.2.1     2.2.2.2         1459        0x80000002 0x002195
192.168.12.0    2.2.2.2         1459        0x80000002 0x00A011

                Summary ASB Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
1.1.1.1         2.2.2.2         1459        0x80000002 0x00AC72

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1531        0x80000001 0x001D91 1
```

Step 3: Configure the interarea summary routes.

a. Calculate the summary route for the networks in area 1.

Networks 192.168.1.0 and 192.168.2.0 can be summarized as 192.168.0.0/22.

b. Configure the summary route for area 1 on R1.

```
R1(config)# router ospf 1
R1(config-router)# area 1 range 192.168.0.0 255.255.252.0
```

c. Calculate the summary route for the networks in area 3. Record your results.

_____

Networks 192.168.4.0, 192.168.5.0, and 192.168.6.0 can be summarized as 192.168.4.0/22.

d. Configure the summary route for area 3 on R2. Write the commands you used in the space below.

_____

_____

```
R2(config)# router ospf 1
R2(config-router)# area 3 range 192.168.4.0 255.255.252.0
```

Step 4: Re-display the OSPF routing tables on all routers.

Issue the **show ip route ospf** command on each router. Record the results for the summary and interarea routes.

R1:

_____

_____

```
O IA  192.168.4.0/22 [110/782] via 192.168.12.2, 00:04:04, Serial0/0/0
O IA     192.168.23.0 [110/1562] via 192.168.12.2, 00:06:31, Serial0/0/0
```

R2:

_____

_____

```
O IA  192.168.0.0/22 [110/782] via 192.168.12.1, 00:04:42, Serial0/0/0
O     192.168.4.0/22 is a summary, 00:04:42, Null0
```

R3:

_____

_____

```
O IA  192.168.0.0/22 [110/1563] via 192.168.23.1, 00:08:01, Serial0/0/1
O IA     192.168.12.0 [110/1562] via 192.168.23.1, 00:53:17, Serial0/0/1
```

```
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 0.0.0.0 to network 0.0.0.0
```

```
O     192.168.0.0/22 is a summary, 00:06:31, Null0
O IA  192.168.4.0/22 [110/782] via 192.168.12.2, 00:04:04, Serial0/0/0
      192.168.23.0/30 is subnetted, 1 subnets
O IA     192.168.23.0 [110/1562] via 192.168.12.2, 00:06:31, Serial0/0/0

R2# 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 192.168.12.1 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 192.168.12.1, 00:04:42, Serial0/0/0
O IA  192.168.0.0/22 [110/782] via 192.168.12.1, 00:04:42, Serial0/0/0
O     192.168.4.0/22 is a summary, 00:04:42, Null0
      192.168.4.0/32 is subnetted, 1 subnets
O        192.168.4.1 [110/782] via 192.168.23.2, 00:04:42, Serial0/0/1
      192.168.5.0/32 is subnetted, 1 subnets
O        192.168.5.1 [110/782] via 192.168.23.2, 00:04:42, Serial0/0/1

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 192.168.23.1 to network 0.0.0.0

O*E2  0.0.0.0/0 [110/1] via 192.168.23.1, 00:53:17, Serial0/0/1
O IA  192.168.0.0/22 [110/1563] via 192.168.23.1, 00:08:01, Serial0/0/1
      192.168.6.0/32 is subnetted, 1 subnets
O        192.168.6.1 [110/782] via 192.168.23.1, 00:53:17, Serial0/0/1
      192.168.12.0/30 is subnetted, 1 subnets
O IA     192.168.12.0 [110/1562] via 192.168.23.1, 00:53:17, Serial0/0/1
```

Step 5: Display the LSDB on all routers.

Issue the **show ip ospf database** command again on each router. Record the Link IDs for the Summary Net Link States for each area.

R1:

_____

_____

Area 0 - 192.168.0.0, 192.168.4.0, 192.168.23.0

Area 1 – 192.168.4.0, 192.168.12.0, 192.168.23.0

R2:

_____

_____

Area 0 - 192.168.0.0, 192.168.4.0, 192.168.23.0

Area 3 - 192.168.0.0, 192.168.12.0

R3:

_____

_____

Area 3 - 192.168.0.0, 192.168.12.0

```
R1# show ip ospf database

            OSPF Router with ID (1.1.1.1) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1452        0x80000006 0x0033D0 2
2.2.2.2         2.2.2.2         1451        0x80000005 0x00CE33 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     1.1.1.1         807         0x80000001 0x00B41D
192.168.4.0     2.2.2.2         660         0x80000001 0x006A5F
192.168.23.0    2.2.2.2         1753        0x80000002 0x00277F

                Router Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1871        0x80000007 0x0092A5 2

                Summary Net Link States (Area 1)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.4.0     1.1.1.1         659         0x80000001 0x002697
192.168.12.0    1.1.1.1         1871        0x80000002 0x00BEF6
192.168.23.0    1.1.1.1         1449        0x80000004 0x00DEB9

                Type-5 AS External Link States
```

```
Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1871        0x80000002 0x001B92 1

R2# show ip ospf database

            OSPF Router with ID (2.2.2.2) (Process ID 1)

                Router Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum Link count
1.1.1.1         1.1.1.1         1467        0x80000006 0x0033D0 2
2.2.2.2         2.2.2.2         1464        0x80000005 0x00CE33 2

                Summary Net Link States (Area 0)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     1.1.1.1         821         0x80000001 0x00B41D
192.168.4.0     2.2.2.2         673         0x80000001 0x006A5F
192.168.23.0    2.2.2.2         1766        0x80000002 0x00277F

                Router Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum Link count
2.2.2.2         2.2.2.2         1521        0x80000004 0x00DC87 3
3.3.3.3         3.3.3.3         1295        0x80000006 0x00D906 4

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     2.2.2.2         820         0x80000001 0x003489
192.168.12.0    2.2.2.2         1766        0x80000003 0x009E12

                Summary ASB Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
1.1.1.1         2.2.2.2         1766        0x80000003 0x00AA73

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1886        0x80000002 0x001B92 1

R3# show ip ospf database

            OSPF Router with ID (3.3.3.3) (Process ID 1)

                Router Link States (Area 3)
```

```
Link ID         ADV Router      Age         Seq#       Checksum Link count
2.2.2.2         2.2.2.2         1548        0x80000004 0x00DC87 3
3.3.3.3         3.3.3.3         1320        0x80000006 0x00D906 4

                Summary Net Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
192.168.0.0     2.2.2.2         847         0x80000001 0x003489
192.168.12.0    2.2.2.2         1793        0x80000003 0x009E12

                Summary ASB Link States (Area 3)

Link ID         ADV Router      Age         Seq#       Checksum
1.1.1.1         2.2.2.2         1793        0x80000003 0x00AA73

                Type-5 AS External Link States

Link ID         ADV Router      Age         Seq#       Checksum Tag
0.0.0.0         1.1.1.1         1913        0x80000002 0x001B92 1
```

What type of LSA is injected into the backbone by the ABR when interarea summarization is enabled?

_____

A type-3 LSA or an interarea summary route.

Step 6: Verify end-to-end connectivity.

Verify that all networks can be reached from each router. If any issues exist, troubleshoot until they have been resolved.

Reflection

What are three advantages for designing a network with multiarea OSPF?

_____

_____

_____

1. Smaller routing tables. 2. Reduced link-state update overhead. 3. Reduced frequency of SPF calculations.

Router Interface Summary Table

Router Interface Summary				
Router Model	**Ethernet Interface #1**	**Ethernet Interface #2**	**Serial Interface #1**	**Serial Interface #2**
1800	Fast Ethernet 0/0 (F0/0)	Fast Ethernet 0/1 (F0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
1900	Gigabit Ethernet 0/0 (G0/0)	Gigabit Ethernet 0/1 (G0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2801	Fast Ethernet 0/0 (F0/0)	Fast Ethernet 0/1 (F0/1)	Serial 0/1/0 (S0/1/0)	Serial 0/1/1 (S0/1/1)
2811	Fast Ethernet 0/0 (F0/0)	Fast Ethernet 0/1 (F0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)
2900	Gigabit Ethernet 0/0 (G0/0)	Gigabit Ethernet 0/1 (G0/1)	Serial 0/0/0 (S0/0/0)	Serial 0/0/1 (S0/0/1)

Note: To find out how the router is configured, look at the interfaces to identify the type of router and how many interfaces the router has. There is no way to effectively list all the combinations of configurations for each router class. This table includes identifiers for the possible combinations of Ethernet and Serial interfaces in the device. The table does not include any other type of interface, even though a specific router may contain one. An example of this might be an ISDN BRI interface. The string in parenthesis is the legal abbreviation that can be used in Cisco IOS commands to represent the interface.

Device Configs - Final

Router R1

```
R1# show run
Building configuration...

Current configuration : 2062 bytes
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R1
!
boot-start-marker
boot-end-marker
!
enable secret 4 06YFDUHH61wAE/kLkDq9BGho1QM5EnRtoyr8cHAUg.2
!
no aaa new-model
memory-size iomem 15
!
ip cef
!
```

```
no ip domain lookup
no ipv6 cef
multilink bundle-name authenticated
!
interface Loopback0
 ip address 209.165.200.225 255.255.255.252
!
interface Loopback1
 ip address 192.168.1.1 255.255.255.0
!
interface Loopback2
 ip address 192.168.2.1 255.255.255.0
!
interface Embedded-Service-Engine0/0
 no ip address
 shutdown
!
interface GigabitEthernet0/0
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface GigabitEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface Serial0/0/0
 bandwidth 128
 ip address 192.168.12.1 255.255.255.252
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 Cisco123
 clock rate 128000
!
interface Serial0/0/1
 no ip address
 shutdown
!
router ospf 1
 router-id 1.1.1.1
 area 1 range 192.168.0.0 255.255.252.0
 passive-interface Loopback1
 passive-interface Loopback2
 network 192.168.1.0 0.0.0.255 area 1
 network 192.168.2.0 0.0.0.255 area 1
 network 192.168.12.0 0.0.0.3 area 0
 default-information originate
```

```
!
ip forward-protocol nd
!
no ip http server
no ip http secure-server
!
ip route 0.0.0.0 0.0.0.0 Loopback0
!
control-plane
!
!
banner motd @
  Unauthorized Access is Prohibited! @
!
line con 0
 password cisco
 logging synchronous
 login
line aux 0
line 2
 no activation-character
 no exec
 transport preferred none
 transport input all
 transport output pad telnet rlogin lapb-ta mop udptn v120 ssh
 stopbits 1
line vty 0 4
 password cisco
 login
 transport input all
!
scheduler allocate 20000 1000
!
end
```

Router R2

```
R2# show run
Building configuration...

Current configuration : 1905 bytes
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R2
!
boot-start-marker
```

```
boot-end-marker
!
enable secret 4 06YFDUHH61wAE/kLkDq9BGho1QM5EnRtoyr8cHAUg.2
!
no aaa new-model
memory-size iomem 15
!
ip cef
!
no ip domain lookup
no ipv6 cef
multilink bundle-name authenticated
!
interface Loopback6
 ip address 192.168.6.1 255.255.255.0
!
interface Embedded-Service-Engine0/0
 no ip address
 shutdown
!
interface GigabitEthernet0/0
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface GigabitEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface Serial0/0/0
 bandwidth 128
 ip address 192.168.12.2 255.255.255.252
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 Cisco123
!
interface Serial0/0/1
 bandwidth 128
 ip address 192.168.23.1 255.255.255.252
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 Cisco123
clock rate 128000
!
router ospf 1
 router-id 2.2.2.2
 area 3 range 192.168.4.0 255.255.252.0
 passive-interface Loopback6
```

```
 network 192.168.6.0 0.0.0.255 area 3
 network 192.168.12.0 0.0.0.3 area 0
 network 192.168.23.0 0.0.0.3 area 3
!
ip forward-protocol nd
!
no ip http server
no ip http secure-server
!
control-plane
!
banner motd @
  Unauthorized Access is Prohibited! @
!
line con 0
 password cisco
 logging synchronous
 login
line aux 0
line 2
 no activation-character
 no exec
 transport preferred none
 transport input all
 transport output pad telnet rlogin lapb-ta mop udptn v120 ssh
 stopbits 1
line vty 0 4
 password cisco
 login
 transport input all
!
scheduler allocate 20000 1000
!
end
```

Router R3

```
R3# show run
Building configuration...

Current configuration : 1958 bytes
!
version 15.2
service timestamps debug datetime msec
service timestamps log datetime msec
no service password-encryption
!
hostname R3
!
boot-start-marker
```

```
boot-end-marker
!
enable secret 4 06YFDUHH61wAE/kLkDq9BGho1QM5EnRtoyr8cHAUg.2
!
no aaa new-model
memory-size iomem 15
!
ip cef
!
no ip domain lookup
no ipv6 cef
!
multilink bundle-name authenticated
!
interface Loopback4
 ip address 192.168.4.1 255.255.255.0
!
interface Loopback5
 ip address 192.168.5.1 255.255.255.0
!
interface Embedded-Service-Engine0/0
 no ip address
 shutdown
!
interface GigabitEthernet0/0
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface GigabitEthernet0/1
 no ip address
 shutdown
 duplex auto
 speed auto
!
interface Serial0/0/0
 no ip address
 shutdown
 clock rate 2000000
!
interface Serial0/0/1
 bandwidth 128
 ip address 192.168.23.2 255.255.255.252
 ip ospf authentication message-digest
 ip ospf message-digest-key 1 md5 Cisco123
!
router ospf 1
 router-id 3.3.3.3
```

```
 passive-interface Loopback4
 passive-interface Loopback5
 network 192.168.4.0 0.0.0.255 area 3
 network 192.168.5.0 0.0.0.255 area 3
 network 192.168.23.0 0.0.0.3 area 3
!
ip forward-protocol nd
!
no ip http server
no ip http secure-server
!
control-plane
!
banner motd @
  Unauthorized Access is Prohibited! @
!
line con 0
 password cisco
 logging synchronous
 login
line aux 0
line 2
 no activation-character
 no exec
 transport preferred none
 transport input all
 transport output pad telnet rlogin lapb-ta mop udptn v120 ssh
 stopbits 1
line vty 0 4
 password cisco
 login
 transport input all
!
scheduler allocate 20000 1000
!
end
```