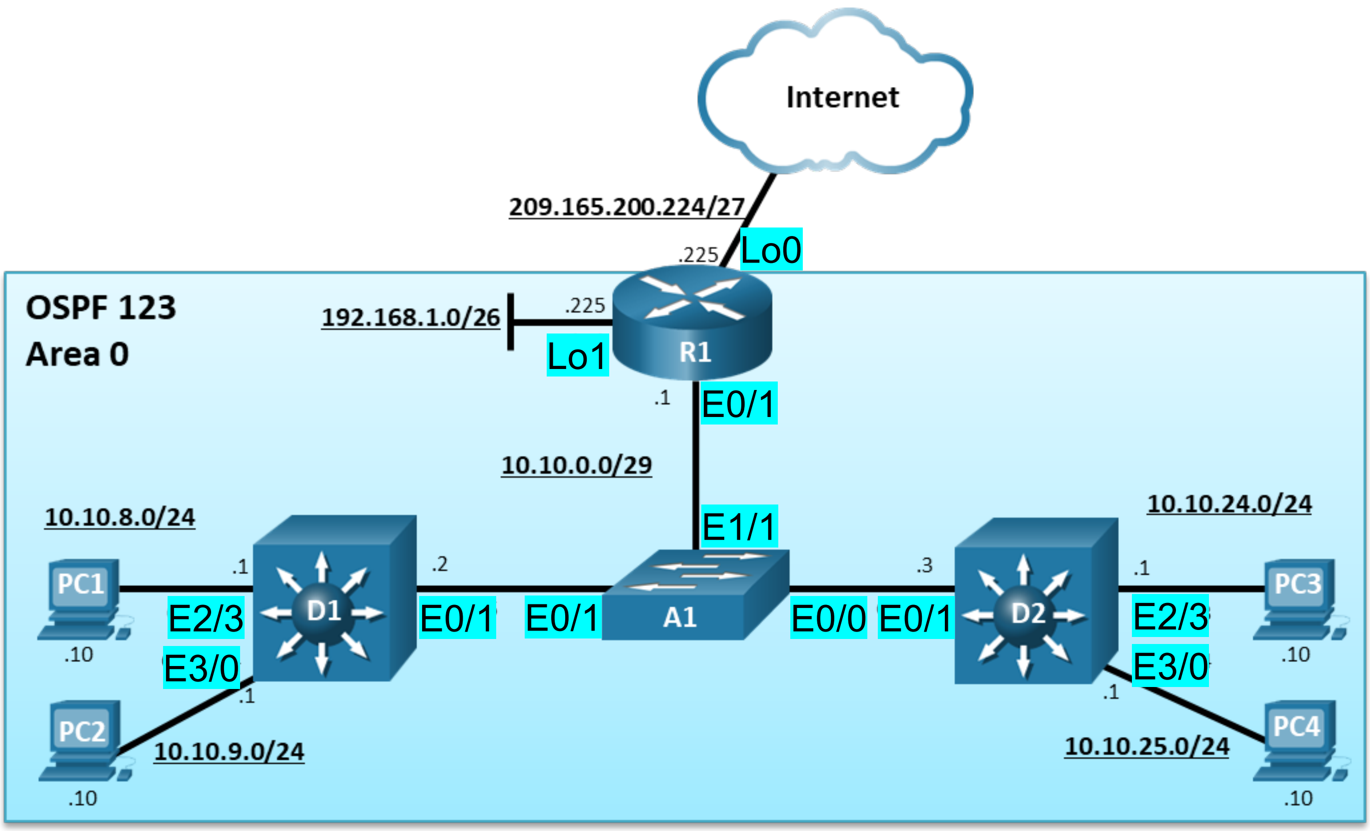
Lab - Implement Single-Area OSPFv2

Topology



Addressing Table

Device	Interface	IPv4 Address
R1	E0/1	10.10.0.1/29
	Loopback0	209.165.200.225/27
	Loopback1	192.168.1.1/26
D1	E0/1	10.10.0.2/29
	E2/3	10.10.8.1/24
	E3/0	10.10.9.1/24
D2	E0/1	10.10.0.3/29
	E2/3	10.10.24.1/24
	E3/0	10.10.25.1/24

Device	Interface	IPv4 Address
PC1	NIC	10.10.8.10/24
PC2	NIC	10.10.9.10/24
PC3	NIC	10.10.24.10/24
PC4	NIC	10.10.25.10/24

Objectives

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

Part 2: Configure and Verify Single Area OSPF for IPv4 on R1, D1, and D2

Part 3: Configure Default Route Propagation on R1 and Verify the Propagation

Part 4: Implement OSPF Network Optimizing Features

Part 5: DR and BDR Placement

Background / Scenario

In this lab, you will configure single-area OSPF version 2 for IPv4 on a multiaccess Ethernet LAN. This lab was specifically designed to use two Layer 3 switches instead of three routers to highlight how a Layer 3 switch can also be used to provide routing services.

Note: This lab is an exercise in developing, deploying, and verifying how OSPF operates and does not reflect networking best practices.

Note: The router used with CCNP hands-on labs is a Cisco 4221and the two Layer 3 switches are Catalyst 3560 switches. Other Layer 3 switches and Cisco IOS versions can be used. Depending on the model and Cisco IOS version, the commands available and the output produced might vary from what is shown in the labs.

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

Required Resources

- 1 Router (Cisco 4221 with Cisco IOS XE Release 16.9.4 universal image or comparable)
- 2 Switches (Cisco 3650 with Cisco IOS XE release 16.9.4 universal image or comparable)
- 1 Switch (Cisco 2960 with Cisco IOS Release 15.2(2) lanbasek9 image or comparable)
- 4 PCs (Windows with terminal emulation program, such as Tera Term)
- Console cables to configure the Cisco IOS devices via the console ports
- Ethernet cables as shown in the topology

Instructions

Part 1: Build the Network and Configure Basic Device Settings and Interface Addressing

In Part 1, you will set up the network topology and configure basic settings and interface addressing on the router and Layer 3 switches.

Note: The Layer 2 switch should only have a default configuration.

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

Attach the devices as shown in the topology diagram, and cable as necessary.

Step 2: Configure basic settings for the router and the two Layer 3 switches.

a. Console into each router and Layer 3 switch, enter global configuration mode, and apply the basic settings and interface addressing using the following startup configurations for each device.

Router R1

```
hostname R1
no ip domain lookup
line con 0
 logging sync
 exec-time 0 0
 exit
interface Loopback0
 ip address 209.165.200.225 255.255.255.224
 no shut
 exit
interface Loopback1
 ip address 192.168.1.1 255.255.255.192
 no shut
 exit
interface e0/1
 ip address 10.10.0.1 255.255.255.248
 no shut
 exit
```

Switch D1

```
hostname D1
no ip domain lookup
line con 0
 logging sync
 exec-time 0 0
 exit
interface e0/1
 no switchport
 ip address 10.10.0.2 255.255.255.248
 no shut
 exit
interface e2/3
 no switchport
 ip address 10.10.8.1 255.255.255.0
 no shut
 exit
interface e3/0
 no switchport
```

```
 ip address 10.10.9.1 255.255.255.0
 no shut
 exit
```

Switch D2

```
hostname D2
no ip domain lookup
line con 0
 logging sync
 exec-time 0 0
 exit
interface e0/1
 no switchport
 ip address 10.10.0.3 255.255.255.248
 no shut
 exit
interface e2/3
 no switchport
 ip address 10.10.24.1 255.255.255.0
 no shut
 exit
interface e3/0
 no switchport
 ip address 10.10.25.1 255.255.255.0
 no shut
 exit
```

b. Save the running configuration to startup-config.

c. Verify the interface status using the **show ip interface brief** command.

```
R1# show ip interface brief | include manual
Ethernet0/1            10.10.0.1       YES manual up                    up
Loopback0              209.165.200.225 YES manual up                    up
Loopback1              192.168.1.1     YES manual up                    up

D1# show ip interface brief | include manual
Ethernet0/1            10.10.0.2       YES manual up                    up
Ethernet2/3            10.10.8.1       YES manual up                    up
Ethernet3/0            10.10.9.1       YES manual up                    up

D2# show ip interface brief | include manual
Ethernet0/1            10.10.0.3       YES manual up                    up
Ethernet2/3            10.10.24.1      YES manual up                    up
Ethernet3/0            10.10.25.1      YES manual up                    up
```

d. Verify direct connectivity between the highlighted IP addresses of R1, D1, and D2.

```
R1# ping 10.10.0.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.0.2, timeout is 2 seconds:
```



```
..!!!
Success rate is 60 percent (3/5), round-trip min/avg/max = 2/2/3 ms

R1# ping 10.10.0.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.10.0.3, timeout is 2 seconds:
..!!!
Success rate is 60 percent (3/5), round-trip min/avg/max = 2/2/3 ms
```

All three devices should be able to reach the other directly connected networks (i.e., 10.10.0.0/29). Troubleshoot if necessary.

Part 2: Configure Single-Area OSPFv2

In this part, you will implement single-area OSPF on a multiaccess Ethernet network.

OSPF can be enabled using the traditional **network** router config command and wildcard mask. The wildcard mask enables the configuration to be as specific or vague as necessary. For example:

- **network** *ip-address* **0.0.0.0 area** *area-id* – Configuring the **network** statement with an IP address explicitly enables OSPF on that interface.
- **network** *network wildcard-mask* **area** *area-id* – The wildcard mask can explicitly match a subnet, or it can be less specific to match several subnets as required.
- **network 0.0.0.0 255.255.255.255 area** *area-id* – This is the vaguest method as the 0.0.0.0 network with 255.255.255.255 wildcard mask matches all enabled interfaces.

An alternate method to using the **network** router configuration command is to use the interface specific method. Instead of the **network** statement, an interface is enabled for OSPF using the **ip ospf** *process-id* **area** *area-id* interface configuration command. Although simpler to use, the disadvantage is that the configuration is not centralized and increases in complexity as the number of interfaces on the routers increases.

Note: There is a newer method to configure OSPF using address families. Address families are covered in OSPFv3 and in CCNP Enterprise: Advanced Routing.

Step 1: Implement OSPF on D1 using Explicit IP addresses.

D1 will advertise its OSPF networks using the OSPF **network** *ip-address* **0.0.0.0 area** *area-id* command method and quad-zero wildcard mask. This enables OSPF for Area 0 only on the interfaces that explicitly match the IP addresses configured.

a. Layer 3 switches are not enabled to perform routing by default. Therefore, routing must be enabled using the **ip routing** global configuration command.

```
D1(config)# ip routing
```

b. Next, enter the OSPF router configuration mode using process ID 123.

```
D1(config)# router ospf 123
```

c. When using the quad-zero method, it is not necessary to calculate the actual wildcard mask. You simply advertise the IP address of the interface with a quad-zero wildcard mask and OSPF will advertise using the subnet mask of the interface. Configure OSPF to advertise the network address of the E0/1 interface (i.e., 10.10.0.2) with the quad-zero mask.

```
D1(config-router)# network 10.10.0.2 0.0.0.0 area 0
```

d. Next, enable OSPF on the E2/3 and E3/0 interfaces using a quad-zero mask.

```
D1(config-router)# network 10.10.8.1 0.0.0.0 area 0
```

```
D1(config-router)# network 10.10.9.1 0.0.0.0 area 0
```

These networks are now being advertised to other OSPF routers.

e. Verify the OSPF configuration on D1 using the **show ip protocols** command.

```
D1# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 123"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.10.9.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.2 0.0.0.0 area 0
    10.10.8.1 0.0.0.0 area 0
    10.10.9.1 0.0.0.0 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
  Distance: (default is 110)
```

The OSPF router ID chosen was the highest active IPv4 address configured on D1. The Routing for Networks section in the output above confirms that the configured statements are accurately advertising the D1 networks.

Step 2: Implement OSPF on D2 using Wildcard Masks.

D2 will advertise its OSPF networks using the **network** router configuration command and wildcard masks.

a. Like D1, D2 must be enabled for routing using the **ip routing** global configuration command.

```
D2(config)# ip routing
```

b. Next, enter the OSPF router configuration mode using process ID 123. Note that process IDs are only locally significant. Therefore, the process ID of other OSPF routers do not need to match. However, using the same process ID makes it simpler to remember and reduces potential configuration mistakes.

```
D2(config)# router ospf 123
```

c. Configure D2 to advertise the E0/1 /29 interface in OSPF area 0. The wildcard mask can be calculated using by deducting the subnet mask (i.e., /29 = 255.255.255.248) from 255.255.255.255, resulting in a wildcard mask of **0.0.0.7**.

```
D2(config-router)# network 10.10.0.0 0.0.0.7 area 0
D2(config-router)#
*Mar  1 00:16:46.465: %OSPF-5-ADJCHG: Process 123, Nbr 10.10.9.1 on Ethernet0/1 from
LOADING to FULL, Loading Done
```

Notice the informational message confirming that D2 has established a neighbor relationship with D1 (i.e., 10.10.9.1).

d. Next, configure D2 to advertise the two /24 networks in OSPF area 0. This can be accomplished using two **network** statements with specific wildcard mask for each subnet.

```
D2(config-router)# network 10.10.24.0 0.0.0.255 area 0
D2(config-router)# network 10.10.25.0 0.0.0.255 area 0
```

Note: The two networks could also be enabled using the **network 10.10.24.0 0.0.254.255** statement instead.

There are no informational messages this time because these interfaces are not connected to other OSPF-enabled routers. However, these networks are now being advertised to other OSPF routers.

e. Verify the OSPF configuration on D2 using the **show ip protocols** command.

```
D2# show ip protocols
*** IP Routing is NSF aware ***

Routing Protocol is "ospf 123"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.10.25.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.10.0.0 0.0.0.7 area 0
    10.10.24.0 0.0.0.255 area 0
    10.10.25.0 0.0.0.255 area 0
  Routing on Interfaces Configured Explicitly (Area 0):

  Routing Information Sources:
    Gateway         Distance      Last Update
    10.10.9.1            110      00:11:05
  Distance: (default is 110)
```

Again, the OSPF router ID chosen was the highest active IPv4 address configured on D2. The Routing for Networks section confirms that the configured statements are accurately advertising the D2 networks. We now also have another routing information source, 10.10.9.1 (i.e., D1).

Step 3: Implement OSPF on R1 using the Interface Specific method.

R1 will use the OSPF interface specific method to advertise the Lo1 interface and the G0/0/1 interface. Interface Lo0 will be advertised in Part 3. The interface specific method is simple because there is no need to enter **network** statements or calculate wildcard masks. You simply enter the **ip ospf** *process-id* **area** *area-id* interface configuration command on an interface.

Note: Alternatively, the **network 0.0.0.0 255.255.255.255 area 0** router configuration command would be simpler. However, it would enable OSPF on all interfaces including the Lo0 interface that will be advertised in Part 3.

a. The loopback interface on R1 is only configured to simulate another network for OSPF to advertise. However, the default behavior of OSPF for loopback interfaces is to advertise a 32-bit host route. To ensure that the /26 network is advertised, the **ip ospf network point-to-point** interface command must be configured on the loopback 1 interface. Change the network type on the loopback interfaces so that they are advertised with the correct subnet.

```
R1(config)# interface loopback 1
R1(config-if)# ip ospf network point-to-point
```

b. Next enable the loopback interface for OSPF using the **ip ospf 123 area 0** command as shown.

```
R1(config-if)# ip ospf 123 area 0
R1(config-if)# exit
```

c. Enter interface E0/1 and enable it for OSPF.

```
R1(config)# interface e0/1
R1(config-if)# ip ospf 123 area 0
R1(config-if)# end
R1#
R1#
*Dec 22 18:32:48.873: %OSPF-6-DFT_OPT: Protocol timers for fast convergence are
Enabled.
R1#
*Dec 22 18:32:49.683: %OSPF-5-ADJCHG: Process 123, Nbr 10.10.9.1 on Ethernet0/1 from
LOADING to FULL, Loading Done
*Dec 22 18:32:49.683: %OSPF-5-ADJCHG: Process 123, Nbr 10.10.25.1 on Ethernet0/1 from
LOADING to FULL, Loading Done
*Dec 22 18:32:49.755: %SYS-5-CONFIG_I: Configured from console by console
```

Notice how the informational messages are confirming that neighbor adjacencies have been established with D1 (i.e., 10.10.9.1) and D2 (i.e., 10.10.25.1).

d. Verify the OSPF configuration on R1 using the **show ip protocols** command.

```
R1# show ip protocols | section ospf
Routing Protocol is "ospf 123"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 209.165.200.225
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
  Routing on Interfaces Configured Explicitly (Area 0):
    Loopback1
    Ethernet0/1
  Routing Information Sources:
    Gateway         Distance      Last Update
    10.10.9.1            110      00:03:47
     10.10.25.1            110       00:03:47
    10.10.25.1           110      00:03:47
  Distance: (default is 110)
```

Again, the router ID chosen is the highest active IPv4 loopback address configured on R1. The Routing for Networks section confirms that routing was explicitly configured on the interfaces. It also displays a new routing source; 10.10.25.1.

Step 4: Assign Router IDs on R1, D1, and D2.

The OSPF router ID is dynamically assigned in order of preference:

- Manually configured using the **router-id** *router-id* router configuration command.
- If it is not manually assigned, then the highest enabled loopback IP address is used as the router ID.
- If there are no loopback interfaces configured, then the highest IP address of any active physical interfaces in the up state becomes the RID when the OSPF process initializes.

It is best to assign a static OSPF router ID for troubleshooting purposes.

To force an existing OSPF network to use the new router IP, the OSPF process must be reset using the **clear ip ospf process** privileged EXEC command.

a. Assign R1 the router ID 1.1.1.1 as shown.

```
R1(config)# router ospf 123
R1(config-router)# router-id 1.1.1.1
% OSPF: Reload or use "clear ip ospf process" command, for this to take effect
R1(config-router)# end
```

b. Next clear the OSPF process as shown.

```
R1# clear ip ospf process
Reset ALL OSPF processes? [no]: yes
```

c. Confirm that R1 is now using the new router ID as shown.

```
R1# show ip protocol | include Router ID
  Router ID 1.1.1.1
```

d. Repeat the process on D1 and D2. Use router ID 2.2.2.2 for D1 and 3.3.3.3 for D2. Also confirm that D1 and D2 are using the new router ID.

Step 5: Verify OSPF settings on R1, D1, and D2.

It is imperative to know how to validate that OSPF is operating as configured. The **show running-config** command only displays the initial OSPF configuration. It does not validate the operation and functionality of OSPF.

Along with the **show ip protocols** command, there are several other useful OSPF-related **show** commands to verify that OSPF is operating as expected.

a. The **show ip route ospf** privileged EXEC command is used to verify the operation of OSPF. The command displays OSPF routes learned with an **O**, the administrative distance, the assigned metric, the next-hop IP address, and the local exit interface to reach the network.

```
R1# show ip route ospf | begin Gateway

D1# show ip route ospf | begin Gateway

D2# show ip route ospf | begin Gateway
```

b. Use the **show ip ospf interface** [**brief**] command to verify which interfaces are enabled for OSPF, process ID, Area ID, and state. A missing interface could be the result of an incorrect **network** statement, IP addressing problem, or a disabled interface.

```
R1# show ip ospf interface brief

D1# show ip ospf interface brief

D2# show ip ospf interface brief
```

Note: Omitting the “**brief**” keyword displays detailed information about the OSPF enabled interfaces.

This State field defines the state of the link and can be:

- **DR** - This is the Designated Router on the multiaccess network (i.e., Ethernet) to which this interface is connected. The DR establishes OSPF adjacencies with all other routers on the network.
- **BDR** - This is the Backup Designated Router on the multiaccess network to which this interface is connected. Like the DR, the BDR establishes adjacencies with all other routers on the broadcast network.

  - **DROTH** - This is a DROTHER. It is neither the DR nor the BDR on the multiaccess network. All non-DRs and BDRs on the broadcast network would be DROTHERs and establish adjacencies only with the DR and the BDR.
  - **P2P** - This is an OSPF point-to-point interface and does not require a DR or BDR. In this state, the interface is fully functional and starts exchanging hello packets with all of its neighbors.

c. Use the **show ip ospf neighbor** [**detail**] command to verify which OSPF neighbor your device has established adjacencies with, the state, the next-hop IP address, and the exit interface to use. A neighbor may not be appearing include RIDs that are not unique, interconnecting interfaces that are not on a common subnet, MTU values that do not match, Area ID that is not correct, Hello and dead interval timers that do not match, or authentication type / credentials that do not match. The following output confirms that our devices have correctly established adjacencies. The output for R1 is shown below. Repeat the command for D1 and D2.

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1   FULL/DR         00:00:33    10.10.0.2       Ethernet0/1
3.3.3.3           1   FULL/BDR        00:00:37    10.10.0.3       Ethernet0/1
```

d. Other OSPF validation commands include the **show ip ospf**, **show ip ospf topology-info**, **show ip ospf database** commands. Use these commands now and identify what types of information they generate which may be useful to know when troubleshooting a network.

Part 3: Configure and Verify the Advertising of a Default Route

In this part, you will configure a default static route to the internet on R1. R1 will then propagate the default route to other OSPF routers as an external Type 2 OSPF route (i.e., O*E2).

Propagating a default is the most efficient method to provide a consistent default gateway to all OSPF-enabled devices.

Step 1: Configure default route advertisement on R1.

a. R1 will be the gateway of last resort for the OSPF internetwork. In our sample topology, the internet is simulated using the Lo0 interface. Configure a static default route out of the Lo0 interface on R1.

```
R1(config)# ip route 0.0.0.0 0.0.0.0 lo0
%Default route without gateway, if not a point-to-point interface, may impact
performance
```

Note: Disregard the informational message. In a production environment, a valid physical interface would be used to provide default gateway services.

b. Enter OSPF router configuration mode and use the **default-information originate** [**always**] [**metric** *metric-value*] [**metric-type** *type-value*] command to enable default route propagation. The **always** keyword advertises a default route even if a static default route does not exist while the route metric and metric type can be changed. R1 is configured to propagate the default route.

```
R1(config)# router ospf 123
R1(config-router)# default-information originate
R1(config-router)# end
```

Step 2: Verify the default route advertisement.

a. Verify the routing table on R1.

```
R1# show ip route static | begin Gateway
```

```
Gateway of last resort is 0.0.0.0 to network 0.0.0.0

S*    0.0.0.0/0 is directly connected, Loopback0
```

b. Verify the routing table on D1 and D2.

```
D1# show ip route | include Gateway|0/0
Gateway of last resort is 10.10.0.1 to network 0.0.0.0
O*E2 0.0.0.0/0 [110/1] via 10.10.0.1, 00:06:55, Ethernet0/1

D2# show ip route | include Gateway|0/0
Gateway of last resort is 10.10.0.1 to network 0.0.0.0
O*E2 0.0.0.0/0 [110/1] via 10.10.0.1, 00:09:36, Ethernet0/1
```

Part 4: Implement OSPF Network Optimizing Features

In this part, you will configure OSPF optimizing features including:

- Passive interfaces
- Link costs
- Reference bandwidth
- Hello and Dead interval timers

Step 1: Configure passive interfaces on R1, D1 and D2.

A passive interface does not send out OSPF messages or process any received OSPF packets. However, the passive interface network segment is still added to the link state database (LSDB) and advertised out of non-passive interfaces. For security reasons, LAN interfaces which are not connected to other OSPF routers should be passive.

There are two approaches to identify passive interfaces.

- Use the **passive-interface** *interface-id* router configuration command to make an interface passive. This is a good approach to use when there are only a few interfaces to make passive.
- Use the **passive-interface default** router config command to make all interfaces passive, and then make some interfaces not passive using the **no passive-interface** *interface-id* command. This is a good approach to use when there are many interfaces to make passive, but only a few interfaces that should not be passive.

a. R1 only needs the Lo1 interface to be passive. The first approach is used to make the Loopback 1 interface passive. Enter OSPF router configuration mode and make the Lo1 interface passive as shown.

```
R1(config-if)# router ospf 123
R1(config-router)# passive-interface lo1
R1(config-router)# end
```

b. Verify which interfaces are passive using the **show ip protocols** command.

```
R1# show ip protocols | section ospf
Routing Protocol is "ospf 123"
  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 autonomous system boundary router
 Redistributing External Routes from,
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
```



```
Maximum path: 4
Routing for Networks:
Routing on Interfaces Configured Explicitly (Area 0):
  Loopback1
  Ethernet0/1
Passive Interface(s):
  Loopback1
 Loopback1
Routing Information Sources:
  Gateway         Distance      Last Update
  3.3.3.3              110      10:45:59
  2.2.2.2              110      10:45:59
  10.10.9.1            110      10:54:49
  10.10.25.1           110      10:49:26
Distance: (default is 110)
```

c. A Layer 3 switch can potentially have many interfaces that should be passive. For example, assume that D1 and D2 only require their G1/0/5 interface to not be passive. However, all other interfaces should be passive. Using the first approach would be very time-consuming. For this reason, the second approach will be used. All active interfaces will be rendered passive and only interface E0/1 will be re-enabled.

```
D1(config)# router ospf 123
D1(config-router)# passive-interface default
D1(config-router)# no passive-interface e0/1
D1(config-router)# end
```

Notice the information messages stating that the OSPF adjacency with R1 and D2 transitioned to the DOWN state. Disabling the passive feature on interface E0/1 re-enabled the OSPF adjacency.

d. Repeat the process on D2.

Step 2: Adjust OSPF link costs.

The OSPF path metric is based on the cumulative interface cost to the network. OSPF assigns the OSPF link cost using the formula **Cost = Reference Bandwidth / Interface Bandwidth**. The default reference bandwidth is 100 Mbps, therefore, the default formula is **Cost = 100,000,000/Interface Bandwidth**. For example, a FastEthernet interface would be assigned a cost of 1 (i.e., 100,000,000 / 100,000,000).

However, the default reference bandwidth does not differentiate interfaces faster than FastEthernet. Therefore, OSPF assigns the identical cost of “1”to FastEthernet, Gigabit Ethernet, and 10 GE interfaces. OSPF makes no distinction that the Gig and 10GE interfaces are faster.

Use the **auto-cost reference-bandwidth** *bandwidth-mbps* router configuration command to change the reference bandwidth as follows:

- **auto-cost reference-bandwidth 100** – Assigns the default reference bandwidth to 100 Mbps which is the default setting. With this setting, FastEthernet = 1, GigabitEthernet = 1, and 10GE = 1.
- **auto-cost reference-bandwidth 1000** – Assigns the default reference bandwidth to 1 Gbps. With this setting, FastEthernet = 10, GigabitEthernet = 1, and 10GE = 1.
- **auto-cost reference-bandwidth 10000** – Assigns the default reference bandwidth to 10 Gbps. With this setting, FastEthernet = 100, GigabitEthernet = 10, and 10GE = 1.

Note: The **auto-cost reference-bandwidth** must be the same on all routers in the area. Otherwise suboptimal routing may occur.

a. On R1, change the reference bandwidth to account for the Gigabit interfaces as shown.

```
R1(config)# router ospf 123
R1(config-router)# auto-cost reference-bandwidth 1000
% OSPF: Reference bandwidth is changed.
      Please ensure reference bandwidth is consistent across all routers.
R1(config-router)# end
```

b. Verify that the reference bandwidth has changed to account for the Gigabit interfaces using the **show ip ospf** command.

```
R1# show ip ospf | include Ref
 Reference bandwidth unit is 1000 mbps
```

c. Repeat the steps on D1 and D2 to change the reference bandwidth to account for the Gigabit interfaces.

d. Verify the routing table on D2 to see if the route metrics have increased.

```
R1# show ip route ospf | begin Gateway

D1# show ip route ospf | begin Gateway

D2# show ip route ospf | begin Gateway
```

Step 3: Alter Hello and Dead interval timers.

OSPF Hello messages are exchanged to establish a neighbor relationship and to ensure that adjacent OSPF neighbors are still available. OSPF uses a hello timer and a dead interval timer which is four times the hello timer.

When a router receives a Hello packet, the dead interval resets and starts to decrement again. If subsequent hello packets are not received before the OSPF dead interval timer reaches 0, the neighbor state is changed to down. The router then sends out the appropriate topology change LSA to all other peers and the SPF algorithm must be recalculated on all routers in the area.

The default OSPF hello timer interval varies based on the OSPF network type. On broadcast and point-to-point links, the default hello timer interval is 10 seconds and dead timer interval is 40 seconds. On non-broadcast multiaccess (NBMA) and point-to-multipoint networks, the default hello interval is 30 seconds with a dead timer interval of 120 seconds.

You can alter the hello timer interval with values between 1 and 65,535 seconds using the **ip ospf hello-interval** *seconds* interface configuration command.

The dead interval can be modified using the **ip ospf dead-interval** *seconds* interface configuration command. However, the command is really not required because changing the hello timer interval automatically modifies the default dead interval.

a. On R1, change the hello interval on the E0/1 interface to 5 seconds and a dead interval time to 20 seconds.

```
R1(config)# interface e0/1
R1(config-if)# ip ospf hello-interval 5
R1(config-if)# ip ospf dead-interval 20
R1(config-if)# end
```

Notice how R1 has received OSPF adjacency change messages for D1 and D2. The reason is because OSPF timers must match between interconnecting peers. Therefore, the D1 and D2 Ethernet0/1 interface must also be configured with the identical timers.

b. Verify that the timers have changed on E0/1 using the **show ip ospf interface** command.

```
R1# show ip ospf interface e0/1 | include Timer
```

```
  Timer intervals configured, Hello 5, Dead 20, Wait 20, Retransmit 5
```

c. Configure D1 with the identical hello and dead interval timers on Ethernet0/1 and verify.

```
D1(config)# interface e0/1
D1(config-if)# ip ospf hello-interval 5
D1(config-if)# ip ospf dead-interval 20
D1(config-if)# end

D1# show ip ospf interface g1/0/5 | include Timer
  Timer intervals configured, Hello 5, Dead 20, Wait 20, Retransmit 5
```

Notice the first OSPF adjacency change message indicating that D1 had lost adjacency with R1. After the commands are entered, the next OSPF adjacency change message indicates that the adjacency with R1 has been re-established. However, the second adjacency change message indicates that the adjacency with D2 has been lost because its timers are not matching.

Also notice that the dead interval was automatically adjusted without having to configure the **ip ospf dead-interval 20** command on the interface.

d. Configure D2 with the identical hello and dead interval timers on Ethernet0/1 and verify.

```
D2#
D2# conf t
D2(config)# interface e0/1
D2(config-if)# ip ospf hello-interval 5
D2(config-if)# ip ospf dead-interval 20
D2(config-if)# end

D2# show ip ospf interface e0/1 | include Timer
  Timer intervals configured, Hello 5, Dead 20, Wait 20, Retransmit 5
```

Again, notice the existing OSPF adjacency change messages indicating that D2 had lost adjacency with R1 and D1.

After the commands are entered, the next OSPF adjacency change messages indicate adjacencies with R1 and D1 have been re-established. And again, the dead interval was automatically adjusted without having to configure the **ip ospf dead-interval 20** command on the interface.

Part 5: DR and BDR Placement

In this part, you will configure OSPF DR and BDR placement on the multiaccess network.

By default, an OSPF router tries to establish neighbor adjacencies with all other OSPF routers. This is a concern with large multiaccess (i.e. Ethernet) networks. For instance, 10 routers interconnected to the same Layer 2 switch would require a total of 45 adjacencies to be established. This can cause excessive OSPF traffic and waste router resources.

For this reason, OSPF routers interconnected to the same multiaccess network elect a designated router (DR) and a backup designated router (BDR). All non-DR and BDR routers are referred to as DROTHERS and only form adjacencies with DR and BDR routers. This reduces the total number of adjacencies and improves network operations.

DR and BDR are automatically elected during the last phase of the 2-Way OSPF neighbor state, before the ExStart state.

DR and BDR elections are conducted as follows:

1) An OSPF router interface with a priority greater than 0 attempts to become BDR on the link.

2) If no BDR exists, then it elects itself the BDR. If there is a tie with another router, the highest router ID is used.

3) If there is no DR, the BDR promotes itself as DR.

4) The neighbor with the next highest priority is elected BDR.

The DR and BDR are the central focal points on a multiaccess network. In a large network, it is advantageous to choose which router should be DR and BDR.

When all OSPF routers have the same OSPF priority, the election is based on the higher router ID. Altering router ID to choose DR/BDR routers may not be convenient. A better alternative is to alter the interface priority.

By default, all OSPF routers on a multiaccess network have a priority of 1 assigned. An interface priority can be changed using the **ip ospf priority** *value* interface configuration command. The value can be between 0 and 255. Setting the value to 0 ensures the router will never become a DR or BDR. Setting the value greater than the default value of 1, makes the router a candidate to become the DR or BDR.

Note: It may be necessary to use the **clear ip ospf process** to ensure the proper devices are elected.

Step 1: Verify current DR and BDR selection.

In the topology, R1, D1, and D2 are interconnected on the same Ethernet network. Therefore, a DR/BDR election has already transpired. The easiest way to determine the interface role is by viewing the OSPF interface with the **show ip ospf neighbor** command.

a. On R1, verify the current DR/BDR status using the **show ip ospf neighbor** command.

```
R1# show ip ospf neighbor

Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1   FULL/DROTHER    00:00:19    10.10.0.2       Ethernet0/1
3.3.3.3           1   FULL/DR         00:00:18    10.10.0.3       Ethernet0/1
```

From the perspective of R1, D1 (i.e., 2.2.2.2) is a DROTHER and D2 (i.e., router ID 3.3.3.3) is the DR. We must then assume that R1 is the BDR.

b. Verify the current status of R1 using the **show ip ospf interface e0/1** command.

```
R1# show ip ospf interface e0/1
Ethernet0/1 is up, line protocol is up
  Internet Address 10.10.0.1/29, Interface ID 7, Area 0
  Attached via Interface Enable
  Process ID 123, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 10
  Topology-MTID    Cost    Disabled    Shutdown      Topology Name
        0           10        no          no            Base
  Enabled by interface config, including secondary ip addresses
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 3.3.3.3, Interface address 10.10.0.3
  Backup Designated router (ID) 1.1.1.1, Interface address 10.10.0.1
  Timer intervals configured, Hello 5, Dead 20, Wait 20, 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
  Can be protected by per-prefix Loop-Free FastReroute
```

```
  Can be used for per-prefix Loop-Free FastReroute repair paths
  Not Protected by per-prefix TI-LFA
  Index 1/2/2, flood queue length 0
  Next 0x0(0)/0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 2
  Last flood scan time is 0 msec, maximum is 1 msec
  Neighbor Count is 2, Adjacent neighbor count is 2
    Adjacent with neighbor 2.2.2.2
    Adjacent with neighbor 3.3.3.3  (Designated Router)
  Suppress hello for 0 neighbor(s)
```

The output confirms that R1 is the BDR and that D2 (i.e., 3.3.3.3) is the DR.

c. Verify the current DR/BDR status on D1 and D2 using the **show ip ospf neighbor** command.

Step 2: Change DR and BDR selection.

It is sometimes advantageous to choose which router is selected as DR and BDR. For example, we will change the DR and BDR assignment as follows:

- R1 is currently the BDR but should be the DR using a priority of 255.
- D1 is currently a DROTHER but should be the BDR using the default priority.
- D2 is currently DR but should never become DR or BDR using a priority of 0.

a. Starting on D2, enter interface E0/1 and set the priority to 0 as shown.

```
D2(config)# interface e0/1
D2(config-if)# ip ospf priority 0
D2(config-if)#
D2(config-if)# end
```

Notice the OSPF message. The reason is because D1 (i.e., 2.2.2.2) just assumed either the DR or BDR role and has established an adjacency with D2.

b. Verify the current DR / BDR placement.

```
D2# show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time   Address         Interface
1.1.1.1           1   FULL/DR         00:00:18    10.10.0.1       Ethernet0/1
2.2.2.2           1   FULL/BDR        00:00:18    10.10.0.2       Ethernet0/1
```

The output confirms that R1 (i.e., 1.1.1.1) is now the DR and D1 (i.e., 2.2.2.2) is the BDR.

The reason R1 became the DR is because it had already been elected as BDR. When a DR fails, the elected BDR is automatically elected as DR to avoid network instability.

c. Although R1 is already the DR, change the interface priority to ensure it is always a candidate to be DR.

```
R1(config)# interface e0/1
R1(config-if)# ip ospf priority 255
R1(config-if)# end
```

d. Verify that R1 is now the DR.

```
R1# show ip ospf interface e0/1 | include State
  Transmit Delay is 1 sec, State DR, Priority 255
```

e. Verify the roles of D1 and D2.

```
R1# show ip ospf neighbor
```

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1   FULL/BDR        00:00:19    10.10.0.2       Ethernet0/1
3.3.3.3           0   FULL/DROTHER    00:00:15    10.10.0.3       Ethernet0/1
```

Router Interface Summary Table

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)
4221	Gigabit Ethernet 0/0/0 (G0/0/0)	Gigabit Ethernet 0/0/1 (G0/0/1)	Serial 0/1/0 (S0/1/0)	Serial 0/1/1 (S0/1/1)
4300	Gigabit Ethernet 0/0/0 (G0/0/0)	Gigabit Ethernet 0/0/1 (G0/0/1)	Serial 0/1/0 (S0/1/0)	Serial 0/1/1 (S0/1/1)

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.