Single-Area OSPFv2 Concepts

Introduction to OSPF

- OSPF is a link-state routing protocol that was developed as an alternative for the distance vector Routing Information Protocol (RIP).
- OSPF has significant advantages over RIP in that it offers faster convergence and scales to much larger network implementations.
- A link is an interface on a router, a network segment that connects two routers, or a stub network such as an Ethernet LAN that is connected to a single router.
- Information about the state of a link is known as a link-state. All link-state information includes the network prefix, prefix length, and cost.

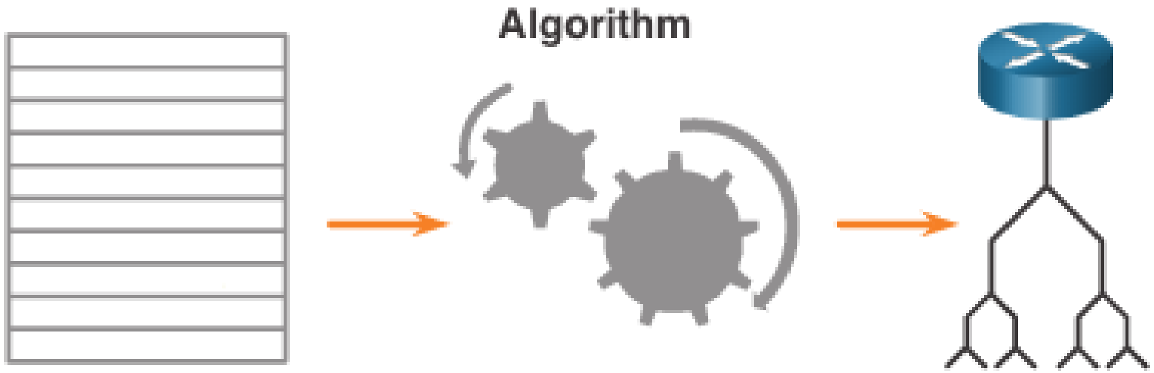
Components of OSPF

OSPF messages are used to create and maintain three OSPF databases, as follows:

Database	Table	Description
Adjacency Database	Neighbor Table	•List of all neighbor routers to which a router has established bi-directional communication. •This table is unique for each router. •Can be viewed using the **`show ip ospf neighbor`** command.
Link-state Database (LSDB)	Topology Table	•Lists information about all other routers in the network. •The database represents the network LSDB. •All routers within an area have identical LSDB. •Can be viewed using the **`show ip ospf database`** command.
Forwarding Database	Routing Table	•List of routes generated when an algorithm is run on the link-state database. •Each router's routing table is unique and contains information on how and where to send packets to other routers. •Can be viewed using the **`show ip route`** command.

Components of OSPF (Cont.)

- The router builds the topology table using results of calculations based on the Dijkstra shortest-path first (SPF) algorithm. The SPF algorithm is based on the cumulative cost to reach a destination.
- The SPF algorithm creates an SPF tree by placing each router at the root of the tree and calculating the shortest path to each node. The SPF tree is then used to calculate the best routes. OSPF places the best routes into the forwarding database, which is used to make the routing table.



Link-State Operation

To maintain routing information, OSPF routers complete a generic link-state routing process to reach a state of convergence. The following are the link-state routing steps that are completed by a router:

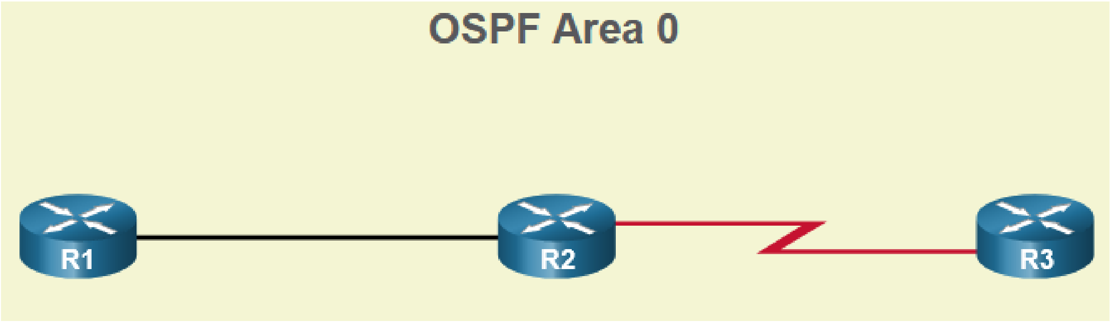
1. Establish Neighbor Adjacencies
2. Exchange Link-State Advertisements
3. Build the Link State Database
4. Execute the SPF Algorithm
5. Choose the Best Route

Single-Area and Multiarea OSPF

To make OSPF more efficient and scalable, OSPF supports hierarchical routing using areas. An OSPF area is a group of routers that share the same link-state information in their LSDBs. OSPF can be implemented in one of two ways, as follows:

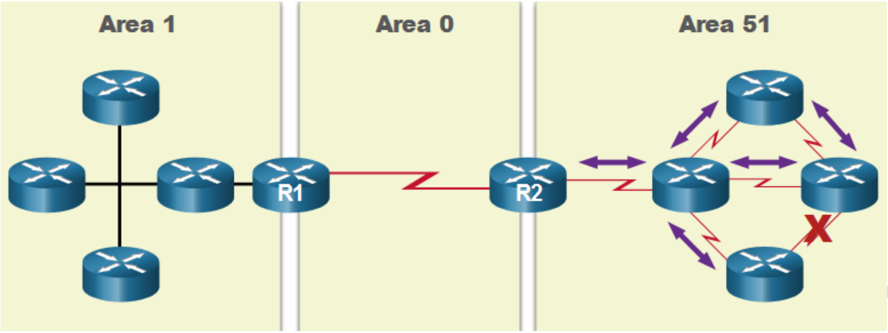
- **Single-Area OSPF** - All routers are in one area. Best practice is to use area 0.
- **Multiarea OSPF** - OSPF is implemented using multiple areas, in a hierarchical fashion. All areas must connect to the backbone area (area 0). Routers interconnecting the areas are referred to as Area Border Routers (ABRs).

The focus of this module is on single-area OSPFv2.



Multiarea OSPF

- The hierarchical-topology design options with multiarea OSPF can offer the following advantages.
  - **Smaller routing tables** - Tables are smaller because there are fewer routing table entries. This is because network addresses can be summarized between areas. Route summarization is not enabled by default.
  - **Reduced link-state update overhead** - Designing multiarea OSPF with smaller areas minimizes processing and memory requirements.
  - **Reduced frequency of SPF calculations** -– Multiarea OSPF localize the impact of a topology change within an area. For instance, it minimizes routing update impact because LSA flooding stops at the area boundary.



OSPFv3

- OSPFv3 is the OSPFv2 equivalent for exchanging IPv6 prefixes. OSPFv3 exchanges routing information to populate the IPv6 routing table with remote prefixes.
  - **Note**: With the OSPFv3 Address Families feature, OSPFv3 includes support for both IPv4 and IPv6. OSPF Address Families is beyond the scope of this curriculum.
- OSPFv3 has the same functionality as OSPFv2, but uses IPv6 as the network layer transport, communicating with OSPFv3 peers and advertising IPv6 routes. OSPFv3 also uses the SPF algorithm as the computation engine to determine the best paths throughout the routing domain.
- OSPFv3 has separate processes from its IPv4 counterpart. The processes and operations are basically the same as in the IPv4 routing protocol, but run independently.

OSPF Packets

Types of OSPF Packets

The table summarizes the five different types of Link State Packets (LSPs) used by OSPFv2. OSPFv3 has similar packet types.

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	Database Description (DBD)	Checks for database synchronization between routers
3	Link-State Request (LSR)	Requests specific link-state records from router to router
4	Link-State Update (LSU)	Sends specifically requested link-state records
5	Link-State Acknowledgment (LSAck)	Acknowledges the other packet types

Link-State Updates

- LSUs are also used to forward OSPF routing updates. An LSU packet can contain 11 different types of OSPFv2 LSAs. OSPFv3 renamed several of these LSAs and also contains two additional LSAs.
- LSU and LSA are often used interchangeably, but the correct hierarchy is LSU packets contain LSA messages.

LSUs

Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	DBD	Checks for database synchronization between routers
3	LSR	Requests specific link-state records from router to router
4	LSU	Sends specifically requested link-state records
5	LSAck	Acknowledges the other packet types

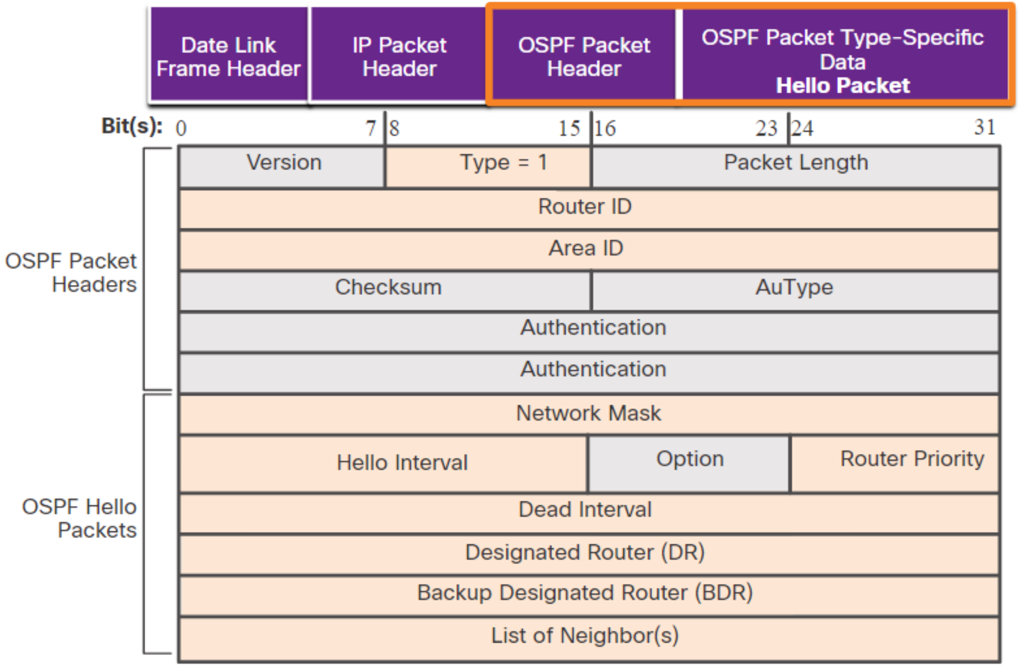
LSAs

LSA Type	Description
1	Router LSAs
2	Checks for database synchronization between routers
3 or 4	Summary LSAs
5	Autonomous System External LSAs
6	Multicast OSPF LSAs
7	Defined for Not-So-Stubby Areas
8	External Attributes LSA for Border Gateway Patrol (BGPs)

Hello Packet

The OSPF Type 1 packet is the Hello packet. Hello packets are used to do the following:

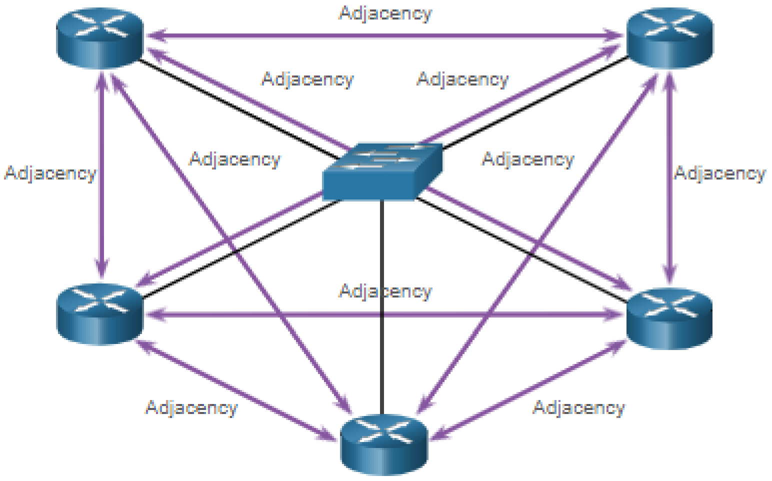
- Discover OSPF neighbors and establish neighbor adjacencies.
- Advertise parameters on which two routers must agree to become neighbors.
- Elect the Designated Router (DR) and Backup Designated Router (BDR) on multiaccess networks like Ethernet. Point-to-point links do not require DR or BDR.



The Need for a DR

Multiaccess networks can create two challenges for OSPF regarding the flooding of LSAs, as follows:

- **Creation of multiple adjacencies** - Ethernet networks could potentially interconnect many OSPF routers over a common link. Creating adjacencies with every router would lead to an excessive number of LSAs exchanged between routers on the same network.
- **Extensive flooding of LSAs** - Link-state routers flood their LSAs any time OSPF is initialized, or when there is a change in the topology. This flooding can become excessive.



- Number of Adjacencies = n (n - 1) / 2
- n = number of routers
- Example: 5 (5 - 1) / 2 = 10 adjacencies

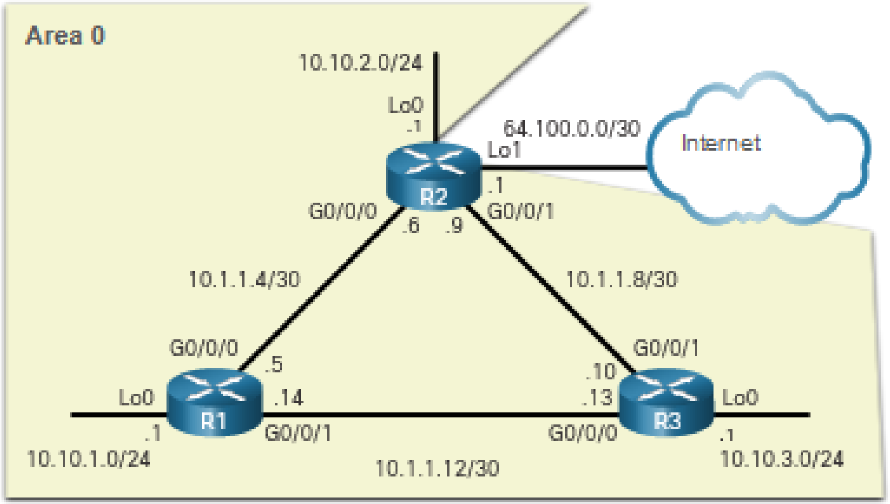
LSA Flooding with a DR

- An increase in the number of routers on a multiaccess network also increases the number of LSAs exchanged between the routers. This flooding of LSAs significantly impacts the operation of OSPF.
- If every router in a multiaccess network had to flood and acknowledge all received LSAs to all other routers on that same multiaccess network, the network traffic would become quite chaotic.
- On multiaccess networks, OSPF elects a DR to be the collection and distribution point for LSAs sent and received. A BDR is also elected in case the DR fails. All other routers become DROTHERs. A DROTHER is a router that is neither the DR nor the BDR.
- **Note**: The DR is only used for the dissemination of LSAs. The router will still use the best next-hop router indicated in the routing table for the forwarding of all other packets.

OSPF Router ID

OSPF Reference Topology

The figure shows the topology used for configuring OSPFv2 in this module. The routers in the topology have a starting configuration, including interface addresses. There is currently no static routing or dynamic routing configured on any of the routers. All interfaces on R1, R2, and R3 (except the loopback 1 on R2) are within the OSPF backbone area. The ISP router is used as the gateway to the internet of the routing domain.



Router IDs

- An OSPF router ID is a 32-bit value, represented as an IPv4 address. It is used to uniquely identify an OSPF router, and all OSPF packets include the router ID of the originating router.
- Every router requires a router ID to participate in an OSPF domain. It can be defined by an administrator or automatically assigned by the router. The router ID is used by an OSPF-enabled router to do the following:
  - **Participate in the synchronization of OSPF databases** – During the Exchange State, the router with the highest router ID will send their database descriptor (DBD) packets first.
  - **Participate in the election of the designated router (DR)** - In a multiaccess LAN environment, the router with the highest router ID is elected the DR. The routing device with the second highest router ID is elected the backup designated router (BDR).

Explicitly Configure a Router ID

In our reference topology the router ID for each router is assigned as follows:

- R1 uses router ID 1.1.1.1
- R2 uses router ID 2.2.2.2
- R3 uses router ID 3.3.3.3

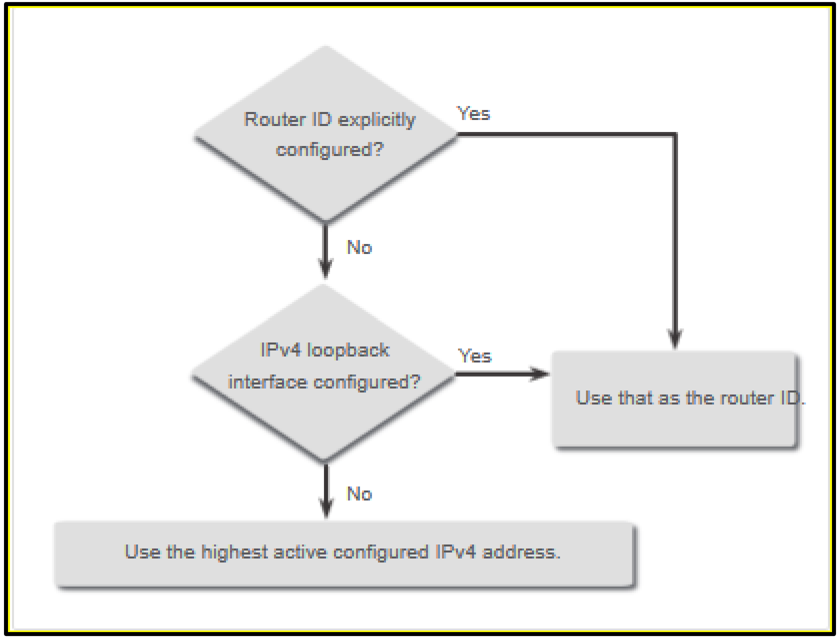
Use the **router-id** *rid* router configuration mode command to manually assign a router ID. In the example, the router ID 1.1.1.1 is assigned to R1. Use the **show ip protocols** command to verify the router ID.

```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
R1(config-router)# end
*May 23 19:33:42.689: %SYS-5-CONFIG_I: Configured from console by console
R1# show ip protocols | include Router ID
  Router ID 1.1.1.1
R1#
```

Router ID Order of Precedence

Cisco routers derive the router ID based on one of three criteria, in the following preferential order:

1. The router ID is explicitly configured using the OSPF **router-id** *rid* router configuration mode command. This is the recommended method to assign a router ID.
2. The router chooses the highest IPv4 address of any of configured loopback interfaces.
3. The router chooses the highest active IPv4 address of any of its physical interfaces.



Configure a Loopback Interface as the Router ID

Instead of relying on physical interface, the router ID can be assigned to a loopback interface. Typically, the IPv4 address for this type of loopback interface should be configured using a 32-bit subnet mask (255.255.255.255). This effectively creates a host route. A 32-bit host route would not get advertised as a route to other OSPF routers.

OSPF does not need to be enabled on an interface for that interface to be chosen as the router ID.

```
R1(config-if)# interface Loopback 1
R1(config-if)# ip address 1.1.1.1 255.255.255.255
R1(config-if)# end
R1# show ip protocols | include Router ID
  Router ID 1.1.1.1
R1#
```

The network Command Syntax

- he basic syntax for the **network** command is as follows:

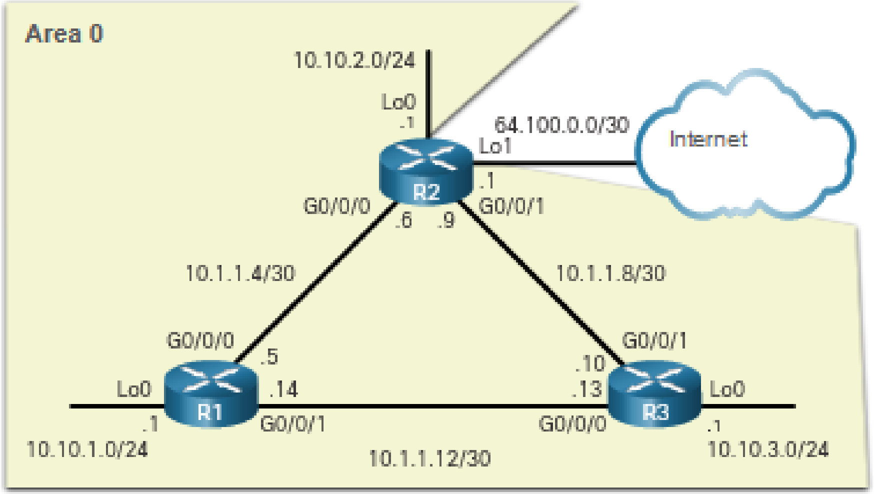
```
Router(config-router)# network network-address wildcard-mask area area-id
```

- The *network-address wildcard-mask* syntax is used to enable OSPF on interfaces.
- The **area** *area-id* syntax refers to the OSPF area. Although any area ID can be used, it is good practice to use an area ID of 0 with single-area OSPFv2.

Configure OSPF Using the network Command

Within routing configuration mode, there are two ways to identify the interfaces that will participate in the OSPFv2 routing process.

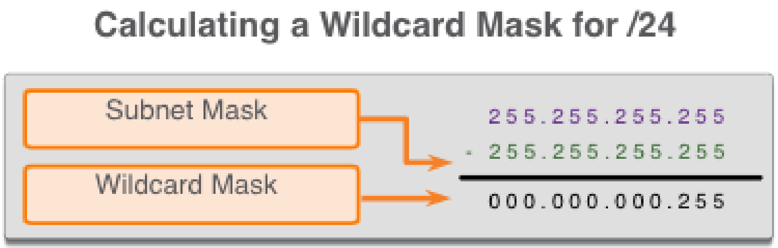
- In the first example, the wildcard mask identifies the interface based on the network addresses. Any active interface that is configured with an IPv4 address belonging to that network will participate in the OSPFv2 routing process.

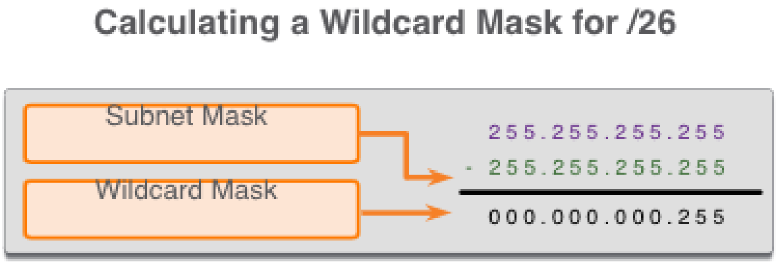



```
R1(config)# router ospf 10
R1(config-router)# network 10.10.1.0 0.0.0.255 area 0
R1(config-router)# network 10.1.1.4 0.0.0.3 area 0
R1(config-router)# network 10.1.1.12 0.0.0.3 area 0
R1(config-router)#
```

The Wildcard Mask

- The wildcard mask is typically the inverse of the subnet mask configured on that interface.
- The easiest method for calculating a wildcard mask is to subtract the network subnet mask from 255.255.255.255, as shown for /24 and /26 subnet masks in the figure.





Configure OSPF Using the ip ospf Command

To configure OSPF directly on the interface, use the **ip ospf** interface configuration mode command. The syntax is as follows:

Router(config-if)# **ip ospf** *process-id* **area** *area-id*

Remove the network commands using the **no** form of the command. Then go to each interface and configure the **ip ospf** command

```
R1(config)# router ospf 10
---------------------------
R1(config)# interface GigabitEthernet 0/0/0
R1(config-if)# ip ospf 10 area 0
R1(config-if)# interface GigabitEthernet 0/0/1
R1(config-if)# ip ospf 10 area 0
R1(config-if)# interface Loopback 0
R1(config-if)# ip ospf 10 area 0
R1(config-if)#
```

Passive Interface

By default, OSPF messages are forwarded out all OSPF-enabled interfaces. However, these messages only need to be sent out interfaces that are connecting to other OSPF-enabled routers.

Sending out unneeded messages on a LAN affects the network in three ways:

- **Inefficient Use of Bandwidth** - Available bandwidth is consumed transporting unnecessary messages.
- **Inefficient Use of Resources** - All devices on the LAN must process and eventually discard the message.
- **Increased Security Risk** - Without additional OSPF security configurations, OSPF messages can be intercepted with packet sniffing software. Routing updates can be modified and sent back to the router, corrupting the routing table with false metrics that misdirect traffic.

Configure Passive Interfaces

- Use the **passive-interface** router configuration mode command to prevent the transmission of routing messages through a router interface, but still allow that network to be advertised to other routers.
- The **show ip protocols** command is then used to verify that the interface is listed as passive.

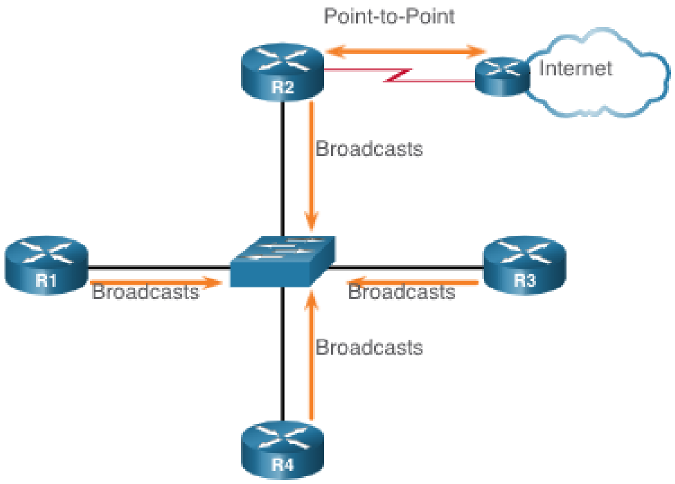
```
R1(config)# router ospf 10
R1(config-router)# passive-interface loopback 0
R1(config-router)# end
R1#
*May 23 20:24:39.309: %SYS-5-CONFIG_I: Configured from console by console
R1# show ip protocols
*** IP Routing is NSF aware ***
(output omitted)
Routing Protocol is "ospf 10"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
  Routing on Interfaces Configured Explicitly (Area 0):
    Loopback0
    GigabitEthernet0/0/1
    GigabitEthernet0/0/0
  Passive Interface(s):
    Loopback0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      01:01:48
    2.2.2.2              110      01:01:38
  Distance: (default is 110)
R1#
```

Multiaccess OSPF Networks

OPSF Network Types

Another type of network that uses OSPF is the multiaccess OSPF network. Multiaccess OSPF networks are unique in that one router controls the distribution of LSAs.

The router that is elected for this role should be determined by the network administrator through proper configuration.

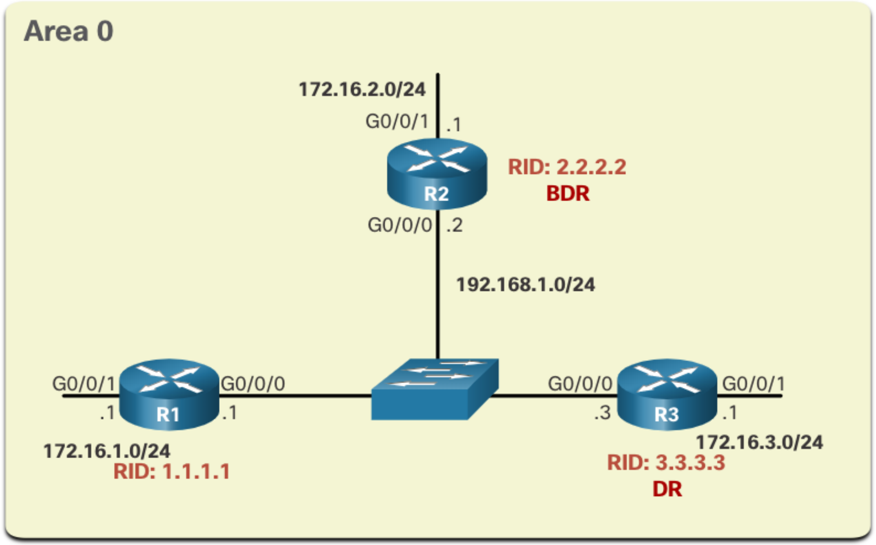


OPSF Designated Router

- In multiaccess networks, OSPF elects a DR and BDR. The DR is responsible for collecting and distributing LSAs sent and received. The DR uses the multicast IPv4 address 224.0.0.5 which is meant for all OSPF routers.
- A BDR is also elected in case the DR fails. The BDR listens passively and maintains a relationship with all the routers. If the DR stops producing Hello packets, the BDR promotes itself and assumes the role of DR.
- All other routers become a DROTHER (a router that is neither the DR nor the BDR). DROTHERs use the multiaccess address 224.0.0.6 (all designated routers) to send OSPF packets to the DR and BDR. Only the DR and BDR listen for 224.0.0.6.

OPSF Multiaccess Reference Topology

- In the multiaccess topology shown in the figure, there are three routers interconnected over a common Ethernet multiaccess network, 192.168.1.0/24.
- Because the routers are connected over a common multiaccess network, OSPF has automatically elected a DR and BDR. R3 has been elected as the DR because its router ID is 3.3.3.3, which is the highest in this network. R2 is the BDR because it has the second highest router ID in the network.



Verify OSPF Router Roles

To verify the roles of the OSPFv2 router, use the **show ip ospf interface** command.

The output generated by R1 confirms that the following:

- R1 is not the DR or BDR, but is a DROTHER with a default priority of 1. (Line 7)
- The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
- R1 has two adjacencies: one with the BDR and one with the DR. (Lines 20-22)

```
R1# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  (output omitted)
  Transmit Delay is 1 sec, State DROTHER, Priority 1
  Designated Router (ID) 3.3.3.3, Interface address 192.168.1.3
  Backup Designated router (ID) 2.2.2.2, Interface address 192.168.1.2
  (output omitted)
  Neighbor Count is 2, Adjacent neighbor count is 2
  Adjacent with neighbor 2.2.2.2 (Backup Designated Router)
  Adjacent with neighbor 3.3.3.3 (Designated Router)
  Suppress hello for 0 neighbor(s)
R1#
```

Verify OSPF Router Roles (Cont.)

The output generated by R2 confirms that:

- R2 is the BDR with a default priority of 1. (Line 7)
- The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
- R2 has two adjacencies; one with a neighbor with router ID 1.1.1.1 (R1) and the other with the DR. (Lines 20-22)

```
R2# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.2/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  (output omitted)
  Transmit Delay is 1 sec, State BDR, Priority 1
  Designated Router (ID) 3.3.3.3, Interface address 192.168.1.3
  Backup Designated Router (ID) 2.2.2.2, Interface address 192.168.1.2
  (output omitted)
  Neighbor Count is 2, Adjacent neighbor count is 2
  Adjacent with neighbor 1.1.1.1
  Adjacent with neighbor 3.3.3.3 (Designated Router)
  Suppress hello for 0 neighbor(s)
R2#
```

Verify OSPF Router Roles (Cont.)

The output generated by R3 confirms that:

- R3 is the DR with a default priority of 1. (Line 7)
- The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
- R3 has two adjacencies: one with a neighbor with router ID 1.1.1.1 (R1) and the other with the BDR. (Lines 20-22)

```
R3# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.3/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  (output omitted)
  Transmit Delay is 1 sec, State DR, Priority 1
  Designated Router (ID) 3.3.3.3, Interface address 192.168.1.3
  Backup Designated Router (ID) 2.2.2.2, Interface address 192.168.1.2
  (output omitted)
  Neighbor Count is 2, Adjacent neighbor count is 2
  Adjacent with neighbor 1.1.1.1
  Adjacent with neighbor 2.2.2.2 (Backup Designated Router)
  Suppress hello for 0 neighbor(s)
R3#
```

Verify DR/BDR Adjacencies

To verify the OSPFv2 adjacencies, use the **show ip ospf neighbor** command. The state of neighbors in multiaccess networks can be as follows:

- **FULL/DROTHER** - This is a DR or BDR router that is fully adjacent with a non-DR or BDR router. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
- **FULL/DR** - The router is fully adjacent with the indicated DR neighbor. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
- **FULL/BDR** - The router is fully adjacent with the indicated BDR neighbor. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
- **2-WAY/DROTHER** - The non-DR or BDR router has a neighbor relationship with another non-DR or BDR router. These two neighbors exchange Hello packets.

The normal state for an OSPF router is usually FULL. If a router is stuck in another state, it is an indication that there are problems in forming adjacencies. The only exception to this is the 2-WAY state, which is normal in a multiaccess broadcast network.

Verify DR/BDR Adjacencies (Cont.)

The output generated by R2 confirms that R2 has adjacencies with the following routers:

- R1 with router ID 1.1.1.1 is in a Full state and R1 is neither the DR nor BDR.
- R3 with router ID 3.3.3.3 is in a Full state and the role of R3 is DR.

```
R2# show ip ospf neighbor
Neighbor ID     Pri   State           Dead Time       Address         Interface
1.1.1.1           1     FULL/DROTHER 00:00:31     192.168.1.1     GigabitEthernet0/0/0
3.3.3.3           1     FULL/DR         00:00:34   192.168.1.3     GigabitEthernet0/0/0 R2#
```

Default DR/BDR Election Process

The OSPF DR and BDR election is based on the following criteria, in sequential order:

1. The routers in the network elect the router with the highest interface priority as the DR. The router with the second highest interface priority is becomes the BDR.
   - The priority can be configured to be any number between 0 – 255.
   - If the interface priority value is set to 0, that interface cannot be elected as DR nor BDR.
   - The default priority of multiaccess broadcast interfaces is 1.
2. If the interface priorities are equal, then the router with the highest router ID is elected the DR. The router with the second highest router ID is the BDR.

- The election process takes place when the first router with an OSPF-enabled interface is active on the network. If all of the routers on the network have not finished booting, it is possible that a router with a lower router ID becomes the DR.
- The addition of a new router does not initiate a new election process.

Multiaccess OSPF Networks

DR Failure and Recovery

After the DR is elected, it remains the DR until one of the following events occurs:

- The DR fails.
- The OSPF process on the DR fails or is stopped.
- The multiaccess interface on the DR fails or is shutdown.

If the DR fails, the BDR is automatically promoted to DR. This is the case even if another DROTHER with a higher priority or router ID is added to the network after the initial DR/BDR election. However, after a BDR is promoted to DR, a new BDR election occurs and the DROTHER with the highest priority or router ID is elected as the new BDR.

The ip ospf priority Command

- If the interface priorities are equal on all routers, the router with the highest router ID is elected the DR.
- Instead of relying on the router ID, it is better to control the election by setting interface priorities. This also allows a router to be the DR in one network and a DROTHER in another.
- To set the priority of an interface, use the command **ip ospf priority** *value*, where value is 0 to 255.
  - A value of 0 does not become a DR or a BDR.
  - A value of 1 to 255 on the interface makes it more likely that the router becomes the DR or the BDR.

Configure OSPF Priority

The example shows the commands being used to change the R1 G0/0/0 interface priority from 1 to 255 and then reset the OSPF process.

```
R1(config)# interface GigabitEthernet 0/0/0
R1(config-if)# ip ospf priority 255
R1(config-if)# end
R1# clear ip ospf process
Reset ALL OSPF processes? [no]: y
R1# *Jun 5 03:47:41.563: %OSPF-5-ADJCHG: Process 10, Nbr 2.2.2.2 on GigabitEthernet0/0/0
from FULL to DOWN, Neighbor Down: Interface down or detached
```

Modify Single-Area OSPFv2

Cisco OSPF Cost Metric

- Routing protocols use a metric to determine the best path of a packet across a network. OSPF uses cost as a metric. A lower cost indicates a better path.
- The Cisco cost of an interface is inversely proportional to the bandwidth of the interface. Therefore, a higher bandwidth indicates a lower cost. The formula used to calculate the OSPF cost is:

Cost = reference bandwidth / interface bandwidth

- The default reference bandwidth is 10^8 (100,000,000); therefore, the formula is:

Cost = 100,000,000 bps / interface bandwidth in bps

- Because the OSPF cost value must be an integer, FastEthernet, Gigabit Ethernet, and 10 GigE interfaces share the same cost. To correct this situation, you can:
  - Adjust the reference bandwidth with the **auto-cost reference-bandwidth** command on each OSPF router.
  - Manually set the OSPF cost value with the **ip ospf cost** command on necessary interfaces.

Cisco OSPF Cost Metric (Cont.)

Refer to the table for a breakdown of the cost calculation

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gigabit Ethernet 10 Gbps	100,000,000	÷	10,000,000,000	0.01 = 1
Gigabit Ethernet 1 Gbps	100,000,000	÷	1,000,000,000	0.1 = 1
Fast Ethernet 100 Mbps	100,000,000	÷	100,000,000	1
Ethernet 10 Mbps	100,000,000	÷	10,000,000	10

Same Costs due to reference bandwidth

Adjust the Reference Bandwidth

- The cost value must be an integer. If something less than an integer is calculated, OSPF rounds up to the nearest integer. Therefore, the OSPF cost assigned to a Gigabit Ethernet interface with the default reference bandwidth of 100,000,000 bps would equal 1, because the nearest integer for 0.1 is 0 instead of 1.

  Cost = 100,000,000 bps / 1,000,000,000 = 1

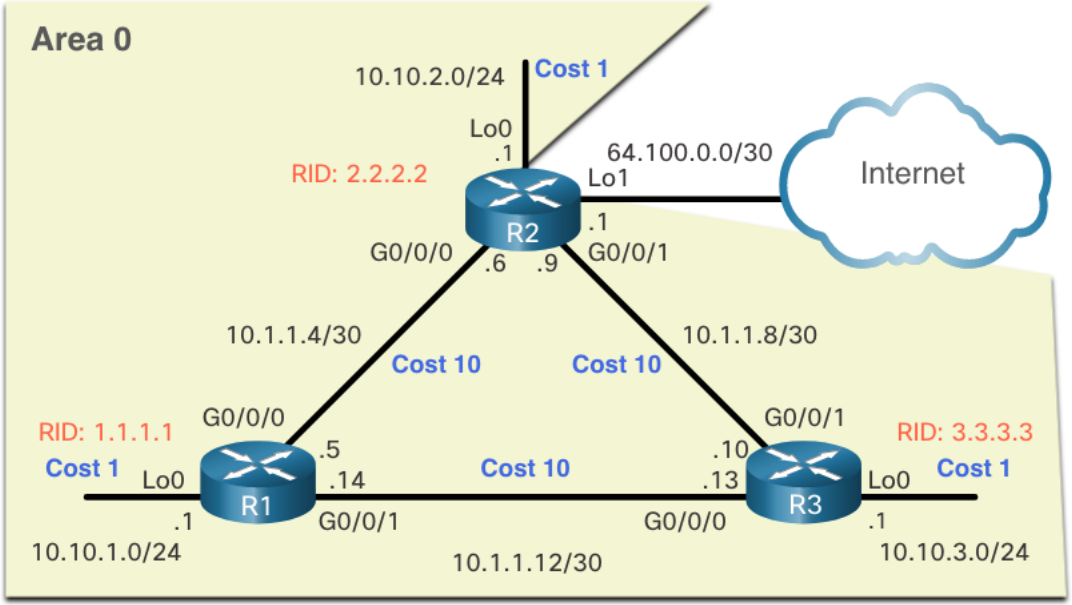
- For this reason, all interfaces faster than Fast Ethernet will have the same cost value of 1 as a Fast Ethernet interface.
- To assist OSPF in making the correct path determination, the reference bandwidth must be changed to a higher value to accommodate networks with links faster than 100 Mbps.

Adjust the Reference Bandwidth (Cont.)

- Changing the reference bandwidth does not actually affect the bandwidth capacity on the link; rather, it simply affects the calculation used to determine the metric.
  - This command must be configured on every router in the OSPF domain.
  - Notice in the command that the value is expressed in Mbps; therefore, to adjust the costs for Gigabit Ethernet, use the command **auto-cost reference-bandwidth 1000.** For 10 Gigabit Ethernet, use the command **auto-cost reference-bandwidth 10000.**
  - To return to the default reference bandwidth, use the **auto-cost reference-bandwidth 100** command.
- Another option is to change the cost on one specific interface using the following command: **ip ospf cost** *cost*

OSPF Accumulates Cost (Cont.)

- You can calculate the cost for each router to reach each network.
- For example, the total cost for R1 to reach the 10.10.2.0/24 network is 11. This is because the link to R2 cost = 10 and the loopback default cost = 1. 10 + 1 = 11.
- You can verify this with the **show ip route** command.



OSPF Accumulates Cost (Cont.)

Verifying the accumulated cost for the path to the 10.10.2.0/24 network:

```
R1# show ip route | include 10.10.2.0
O         10.10.2.0/24 [110/11] via 10.1.1.6, 01:05:02, GigabitEthernet0/0/0
R1# show ip route 10.10.2.0
Routing entry for 10.10.2.0/24
  Known via "ospf 10", distance 110, metric 11, type intra area
  Last update from 10.1.1.6 on GigabitEthernet0/0/0, 01:05:13 ago
  Routing Descriptor Blocks:
  * 10.1.1.6, from 2.2.2.2, 01:05:13 ago, via GigabitEthernet0/0/0
       Route metric is 11, traffic share count is 1
R1#
```

Manually Set OSPF Cost Value

Reasons to manually set the cost value include:

- The Administrator may want to influence path selection within OSPF, causing different paths to be selected than what normally would given default costs and cost accumulation.
- Connections to equipment from other vendors who use a different formula to calculate OSPF cost.

To change the cost value reported by the local OSPF router to other OSPF routers, use the interface configuration command **ip ospf cost** *value*.

```
R1(config)# interface g0/0/1
R1(config-if)# ip ospf cost 30
R1(config-if)# interface lo0
R1(config-if)# ip ospf cost 10
R1(config-if)# end
R1#
```

Hello Packet Intervals

- OSPFv2 Hello packets are transmitted to multicast address 224.0.0.5 (all OSPF routers) every 10 seconds. This is the default timer value on multiaccess and point-to-point networks.

Note: Hello packets are not sent on interfaces set to passive by the **passive-interface** command.

- The Dead interval is the period that the router waits to receive a Hello packet before declaring the neighbor down. If the Dead interval expires before the routers receive a Hello packet, OSPF removes that neighbor from its link-state database (LSDB). The router floods the LSDB with information about the down neighbor out all OSPF-enabled interfaces.
- Cisco uses a default of 4 times the Hello interval. This is 40 seconds on multiaccess and point-to-point networks.
- The OSPF Hello and Dead intervals are configurable on a per-interface basis.

Modify OSPFv2 Intervals

- It may be desirable to change the OSPF timers so that routers detect network failures in less time. Doing this increases traffic, but sometimes the need for quick convergence is more important than the extra traffic it creates.

Note: The default Hello and Dead intervals are based on best practices and should only be altered in rare situations.

- OSPFv2 Hello and Dead intervals can be modified manually using the following interface configuration mode commands:

```
Router(config-if)# ip ospf hello-interval seconds
Router(config-if)# ip ospf dead-interval seconds
```

- Use the **no ip ospf hello-interval** and **no ip ospf dead-interval** commands to reset the intervals to their default.

Modify OSPFv2 Intervals (Cont.)

```
R1(config)# interface g0/0/0
R1(config-if)# ip ospf hello-interval 5
R1(config-if)# ip ospf dead-interval 20
R1(config-if)#
*Jun 7 04:56:07.571: %OSPF-5-ADJCHG: Process 10, Nbr 2.2.2.2 on GigabitEthernet0/0/0
from FULL to DOWN, Neighbor Down: Dead timer expired
R1(config-if)# end
R1# show ip ospf neighbor
Neighbor ID     Pri   State      Dead Time       Address         Interface
3.3.3.3           0   FULL/ -    00:00:37        10.1.1.13       GigabitEthernet0/0/1
R1#
```

Default Route Propagation

Propagate a Default Static Route in OSPFv2

To propagate a default route, the edge router must be configured with the following:

- A default static route using the **ip route 0.0.0.0 0.0.0.0** [*next-hop-address* | *exit-intf*] command.
- The **default-information originate** router configuration command. This instructs R2 to be the source of the default route information and propagate the default static route in OSPF updates.

In the example, R2 is configured with a loopback to simulate a connection to the internet. A default route is configured and propagated to all other OSPF routers in the routing domain.

Note: When configuring static routes, best practice is to use the next-hop IP address. However, when simulating a connection to the internet, there is no next-hop IP address. Therefore, we use the *exit-intf* argument.

```
R2(config)# interface lo1
R2(config-if)# ip address 64.100.0.1 255.255.255.252
R2(config-if)# exit
R2(config)# ip route 0.0.0.0 0.0.0.0 loopback 1
%Default route without gateway, if not a point-to-point interface, may impact performance
R2(config)# router ospf 10
R2(config-router)# default-information originate
R2(config-router)# end
R2#
```

→ inform others about default way

Verify the Propagated Default Route

- You can verify the default route settings on R2 using the **show ip route** command. You can also verify that R1 and R3 received a default route.

```
R2# show ip route | 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, Loopback1
      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
(output omitted)
```

Verify Single-Area OSPFv2

Verify OSPF Neighbors

After configuring single-area OSPFv2, you will need to verify your configurations. The following two commands are particularly useful for verifying routing:

- **show ip interface brief** - This verifies that the desired interfaces are active with correct IP addressing.
- **show ip route**- This verifies that the routing table contains all the expected routes.

Other useful commnands for OSPF is as follows:

- **show ip ospf neighbor**
- **show ip protocols**
- **show ip ospf**
- **show ip ospf interface**

Verify OSPF Neighbors (Cont.)

- Use the **show ip ospf neighbor** command to verify that the router has formed an adjacency with its neighboring routers.

```
R1# show ip ospf neighbor
Neighbor ID     Pri   State        Dead Time       Address         Interface
3.3.3.3           0     FULL/  -   00:00:35    10.1.1.13      GigabitEthernet0/0/1
2.2.2.2           0     FULL/  -    00:00:31   10.1.1.6  GigabitEthernet0/0/0
R1#
```

Verify OSPF Protocol Settings

The **show ip protocols** command is a quick way to verify vital OSPF configuration information, as shown in the command output. This includes the OSPFv2 process ID, the router ID, interfaces explicitly configured to advertise OSPF routes, the neighbors the router is receiving updates from, and the default administrative distance, which is 110 for OSPF.

```
R1# show ip protocols
*** IP Routing is NSF aware ***
(output omitted)
Routing Protocol is "ospf 10"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 1.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
  Routing on Interfaces Configured Explicitly (Area 0):
     Loopback0
     GigabitEthernet0/0/1
     GigabitEthernet0/0/0
  Routing Information Sources:
     Gateway    Distance       Last Update
     3.3.3.3    110            00:09:30
     2.2.2.2    110            00:09:58
  Distance: (default is 110)
R1#
```

Verify OSPF Interface Settings

The **show ip ospf interface** command provides a detailed list for every OSPFv2-enabled interface. Specify an interface to display the settings of just that interface. This command shows the process ID, the local router ID, the type of network, OSPF cost, DR and BDR information on multiaccess links (not shown), and adjacent neighbors.

```
R1# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 10.1.1.5/30, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 1.1.1.1, Network Type POINT_TO_POINT, Cost: 10

<output omitted>

  Neighbor Count is 1, Adjacent neighbor count is 1
     Adjacent with neighbor 2.2.2.2
  Suppress hello for 0 neighbor(s)
R1#
```