Dynamic Routing

There are various routing protocols that are designed to exchange route information with neighbors. The most popular currently include OSPF and EIGRP. The network administrator does not configure dynamic routes. They are learned so that each router installs and selects routes for best path selection. The distinction between each routing protocol is how they learn, update and advertise routes between neighbors.

OSPFv2 Routing Protocol

OSPF is a link-state routing protocol that builds and maintains a global topology database. That is accomplished with the exchange of link-state advertisements (LSA) between OSPF routers. Topology and routing information is communicated to OSPF neighbors in LSAs. There are event-triggered updates that are sent only when a link failure occurs to conserve bandwidth.

OSPF Characteristics

- Link-state routing protocol
- Metric = link cost (bandwidth)
- Global view database topology table
- Shortest path to destination calculated
- Event-triggered routing updates
- Auto-summary disabled (default)
- Scalable to large enterprise domains
- Fast convergence when there is link failure
- Load balancing across four equal paths

OSPF is characterized by well-defined hierarchical layers that enable route summarization and smaller routing tables per router. The routing updates are minimized when there are link failures enabling faster convergence. In addition routing issues such as flapping and routing loops are limited to an OSPF area.

There is a mandatory common backbone area 0 only for multi-area OSPF. All other areas must connect to the OSPF backbone area. That is required to advertise routes between areas. OSPFv2 refers to the version of OSPF that only supports IPv4 addressing on network interfaces. It is the most widely deployed version of OSPF for dynamic routing. The area number for single-area OSPF does **not** have to be numbered area 0.

OSPF is an **IP-only** routing protocol that is well suited to current intranet and internet connectivity. Consider as well that internet and cloud-based services are IP-only connections. Single-area OSPF design reduces the routing tables and number of LSAs advertised between routers. All areas must be connected directly to the backbone.

OSPF Neighbor Adjacency

The purpose of OSPF hello packets are to discover neighbors and establish neighbor adjacency. Hello packets are also sent to maintain neighbor relationships and confirm that a neighbor is still active. OSPF routers establish adjacency with all connected neighbors for bidirectional communication. That enables all routers to synchronize database and routing tables.

Adjacency States

The following describe the sequence of OSPF states required to establish neighbor adjacency and exchange routing tables.

1. **Down** - No hello packets have been received from neighbor/s.

2. **Attempt** - NBMA routers only. Hello packet has not been received from NBMA neighbor. Hello packet is sent to neighbor.

3. **Init** - Hello packet is received from neighbor without the router ID listed. There are settings such as timers verified to match.

4. **Two-Way** - Hello packets sent between neighbor with router ID of local router. Neighbor adjacency is established and DR/BDR election occurs based on highest router ID.

5. **Exstart** - OSPF elected DR router starts exchanging LSAs with neighbors. The router with highest router ID remains DR unless priority was modified to influence selected router.

6. **Exchange** - Routers exchange database descriptor packets (DBD) and manage database synchronization to neighbor/s.

7. **Loading** - Routers complete exchange of all link-state advertisements (LSA) between neighbors.

8. **Full** - This is normal state where adjacency is established between OSPF neighbors and tables are updated for convergence.

There is a hello timer configured to send hello packets at fixed intervals. All timers must match between directly connected neighbor interfaces. OSPF neighbor adjacency is not formed when there is a mismatch of hello or dead timers. The following describe additional reasons why neighbor adjacency would not occur between neighbors.

- Subnet mismatch
- Network type mismatch
- Timers mismatch
- MTU mismatch
- Area ID mismatch

Metric Calculation

Each routing protocol has a unique method for calculating route metric (cost). OSPF calculates cost based on interface bandwidth. The default cost of an OSPF enabled interface = 1 (100 Mbps / 100 Mbps).

cost = 100 Mbps / interface bandwidth

Each link is comprised of the local interface and a neighbor interface. The lowest cost assignable to a link is 1 even though calculation could arrive at a lower number. The reference bandwidth of OSPF is configurable to account for faster Ethernet interfaces that start at Gigabit (1000 Mbps) speed today. The reference bandwidth is a global configuration command that must match for all routers in the same OSPF routing domain.

router ospf 1
auto-cost reference-bandwidth 1000

The alternative to reference bandwidth method is **ip ospf cost** command. It allows you to configure the cost directly on a network interface. The third option is to manually configure interface speed with the IOS interface **bandwidth** command. That would affect how OSPF calculates metric for that specific link. You would have to configure the bandwidth command on both local and neighbor interfaces.

OSPF Hello Packets

The hello packet is used to establish neighbor adjacencies and maintain neighbor relationships. It also detects the operational status of neighbors. and notifies when a link failure occurs. OSPF routes advertised from a neighbor with an interface that is down are deleted from the routing table. The following configuration settings are advertised in each OSPF hello packet to all connected neighbors.

- Hello and dead timer
- Router priority
- DR/BDR assigned
- Area assigned to neighbor interface
- Subnet mask of neighbor interface
- OSPF Authentication method
- OSPF network type

OSPF Router ID

OSPF routers must be assigned a router ID that is a unique identifier to all connected OSPF neighbors. The router ID is advertised in routing updates to identify where updates originated. Cisco default OSPF configuration has no router ID assigned. The following commands configure a router ID from router configuration mode.

router ospf 1
router-id 192.168.255.1

OSPF Router ID Selection

1. Unique 32-bit IPv4 dotted-decimal address.

2. Purpose is to identify each router for routing updates and adjacency.

3. Manually configured router ID is preferred first.

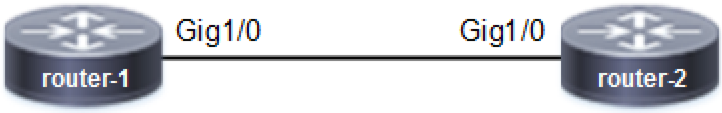
4. The highest IP address on a loopback interface is assigned when no router ID is configured.

5. The highest IP address of any active physical interface is assigned if no loopback interface exists.

Example: Router ID

Refer to the network topology drawing and determine what router ID is assigned for router-1?

Figure 1 Router ID Configuration




```
interface Loopback0
ip address 192.168.255.1 255.255.255.255
!
interface Gigabitethernet1/0
ip address 192.168.1.1 255.255.255.0
```

There is no manually configured router ID on router-1. Based on OSPF rules, the highest loopback interface address configured is assigned as router ID. The router is borrowing the IP address only and does not affect loopback interface operation.

Table 1 OSPF Packet Types

Packet Type	Description
Hello	neighbor discovery, adjacency, and status
Database Descriptor	send database table update to neighbor
Link-State Request	LSA request for updates sent to neighbors
Link-State Update	flooding LSA (route) updates to neighbors
Link-State ACK	acknowledge LSA update from neighbor

OSPF Designated Router

OSPF designated router (DR) advertises routing updates to all connected spokes on a shared (broadcast) network. The most common example of a broadcast network type is Ethernet. OSPF DR minimizes routing updates between OSPF neighbors on a broadcast network. It is a hub router that advertises routing updates via 224.0.0.5 multicast address. Consider that a network broadcast segment refers to a common subnet or VLAN.

Designated Router (DR) Election

1. Router default OSPF priority = 1

2. Router with highest configured OSPF priority is elected DR

3. Router with highest router ID address is elected DR when priorities are equal. First preference is an explicitly configured router ID.

4. When no router ID is explicitly configured, the highest loopback address is assigned as router ID for a router. DR election then compares that router ID with neighbors for DR election.

5. Router assigns the highest physical interface address as router ID for OSPF when no loopback interface exists. DR election then compares that router ID with neighbors for DR election.

6. Router with second highest priority is elected BDR.

7. Router with second highest router ID is elected BDR.

All OSPF routers send routing updates via 224.0.0.6 multicast address to DR and BDR routers. The Cisco OSPF priority setting on a default router configuration has a value of 1. That is assigned to an OSPF enabled interface. The router priority is configurable to influence DR election.

Backup Designated Router

OSPF elects Backup Designated Router (BDR) on each broadcast domain. The purpose of BDR is to provide failover or redundancy to the elected DR. All routing updates from connected non-DR and non-BDR routers called spokes, are sent to the DR. The same routing updates are also sent to the elected BDR. The difference is that BDR never sends updates to spoke routers. That is only done from the elected DR as shown with Figure 3-19. Anytime there is a DR failure, then BDR is automatically assigned as DR for that subnet or VLAN.

Figure 2 OSPF DR/BDR Operation

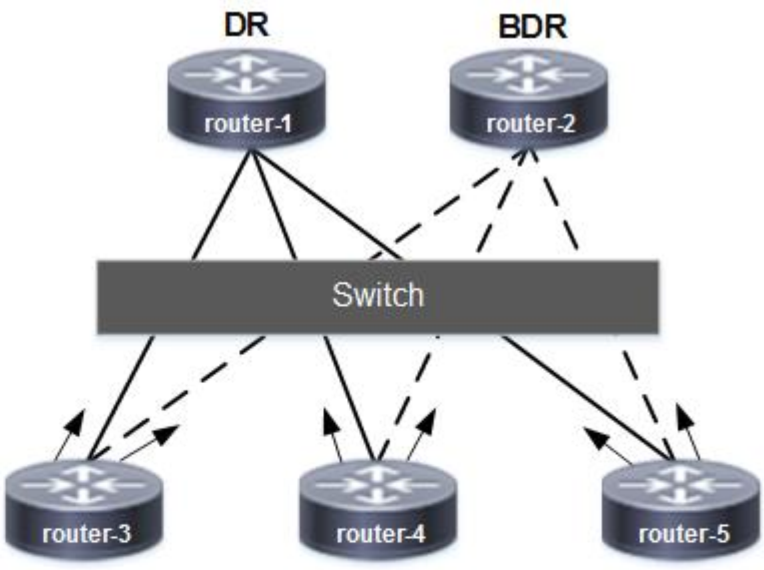


Table 2 OSPF Neighbor States

Neighbor State	Adjacency	DR Relationship	Description
Full/DR	FULL	Neighbor is DR	Neighbor_ID
Full/BDR	FULL	Neighbor is BDR	Neighbor_ID
Full/DROTHER	FULL	none	broadcast spoke
2-WAY/DROTHER	2-WAY	none	broadcast spoke

router-1# **show ip ospf neighbor**

Neighbor_ID	Pri	State	Dead Time	Address	Interface
172.16.4.1	1	**Full/DR**	00:00:12	172.16.1.2	Gig0/0

The results of **show ip ospf neighbor** command displays operational status information. The State column displays DR relationship with neighbor. For example, **Full/DR** indicates that the local router has full adjacency with 172.16.4.1 neighbor. That neighbor is elected DR for the broadcast domain. DROTHER indicates there is no exchange of routing updates between spoke neighbors. That is characteristic of a broadcast network where updates are only sent between DR and spoke routers .

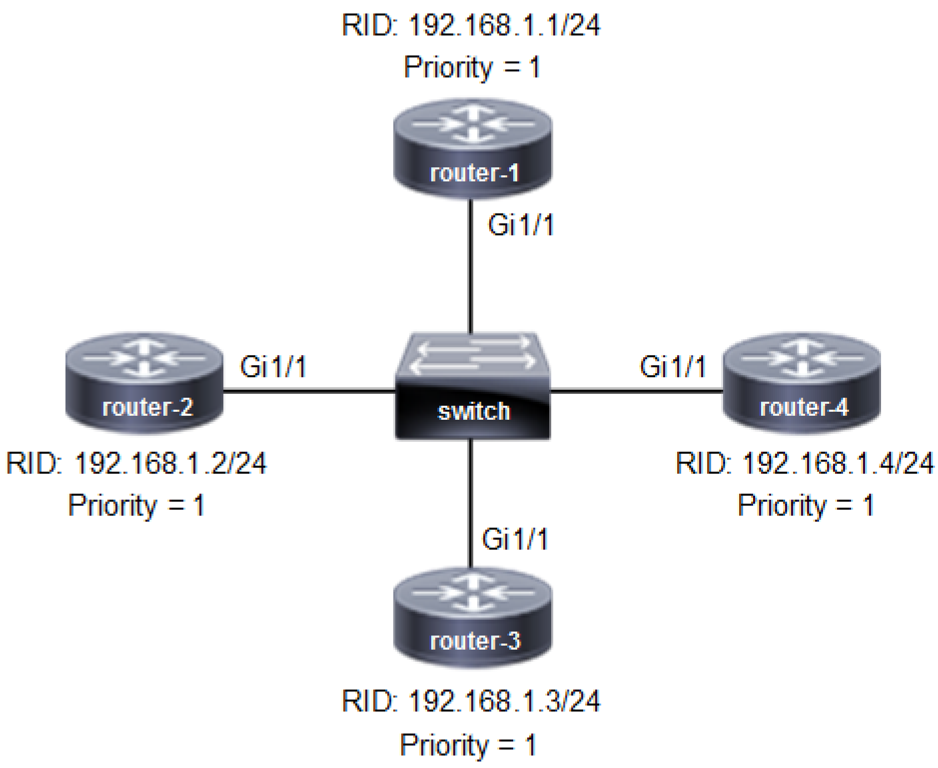
Neighbor Field Descriptions

- Neighbor_ID = Neighbor router ID
- Pri = Neighbor priority
- State = Neighbor adjacency + DR relationship
- Dead Time = Dead timer age
- Address = IP address of neighbor interface
- Interface = Ethernet interface of neighbor

Example: Designated Router

Refer to the network drawing. All routers are configured with the default OSPF priority (1). What router will be elected as designated router (DR)?

Figure 3 OSPF Designated Router Election



Answer

Ethernet interfaces within an OSPF broadcast domain are assigned to the same VLAN. There is a default configuration with the same priority on each router. The router with highest configured router ID (RID) is elected as DR for all routers connected to switch-1.

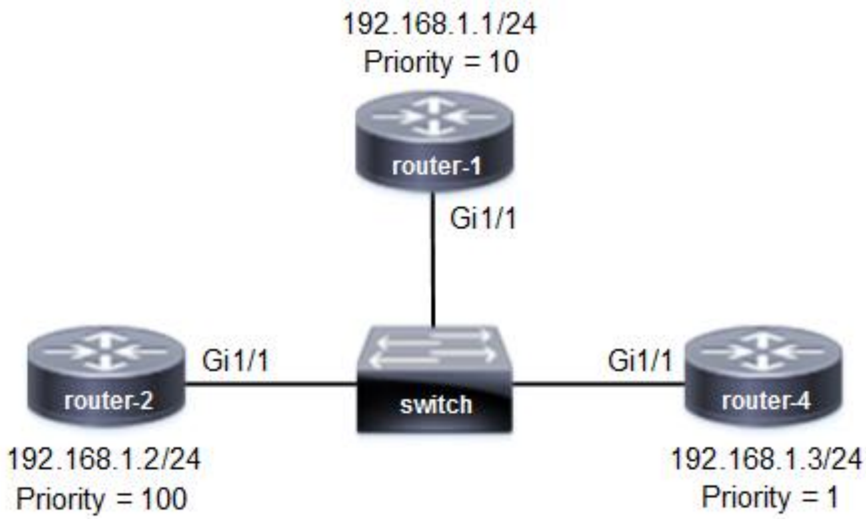
The elected DR is Router-4 with **192.168.1.4** configured as router ID. Router-3 has second highest configured router ID **192.168.1.3** and elected Backup DR (BDR). The highest IP address is calculated from left to right. The numbers for each IP address match until octet 3 where subnet 4 is higher. That is the IP address assigned to Router-4.

- 192.168.1.1
- 192.168.1.2
- 192.168.1.3
- 192.168.1.**4** = Router-4

Example: DR Priority

Refer to the network topology drawing. What router is elected DR based on the configuration?

Figure 4 Designated Router Priority



The router with highest configured priority is elected as Designated Router from a broadcast domain. In this example, router-2 is elected DR with priority 100. Configuring priority setting influences the election of a specific router as DR/BDR. The router with second highest priority is elected as Backup Designated Router for the broadcast domain. In this example, router-1 is elected BDR with priority 10. OSPF enabled router with a priority of zero (0) cannot be elected as DR or BDR. The following command assigns a priority of zero (0) to an OSPF interface.

router(config-if)# **ip ospf priority 0**

OSPF Network Type

You can enable OSPF globally or per interface, however both methods will enable OSPF routing on an interface. All dynamic routing protocols are based on interfaces as opposed to the physical device.

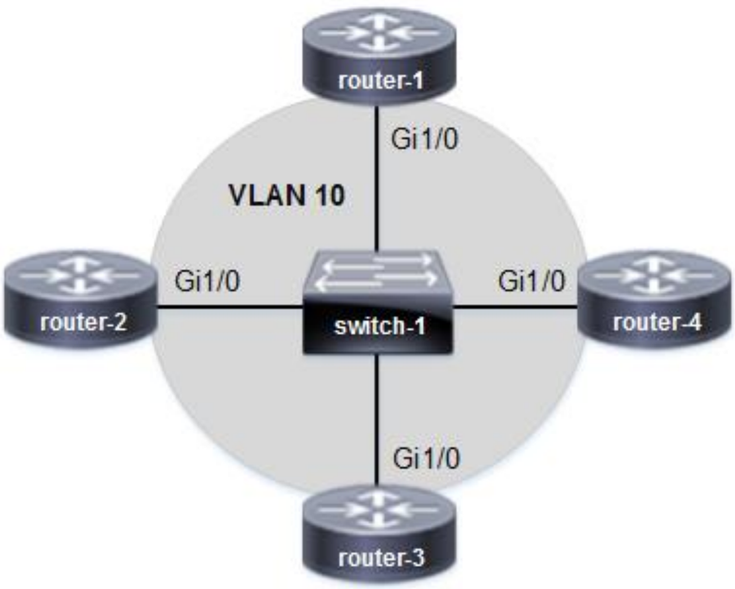
OSPF router interfaces all connect to an area. They also exchange routing updates with all directly connected OSPF neighbors. There are some exceptions where a configuration is per routing domain such as reference bandwidth.

OSPF network types are configured automatically based on the network interface media. For example, OSPF automatically assigns Broadcast network type to an Ethernet interface. There are serial interfaces as well that are assigned Point-to-Point network type. It is not a shared broadcast link as with an Ethernet segment. The OSPF serial interfaces connect only to a single neighbor.

Example: Network Type

Refer to the network topology drawing. What OSPF network type is assigned to the OSPF interfaces?

Figure 5 OSPF Network Type

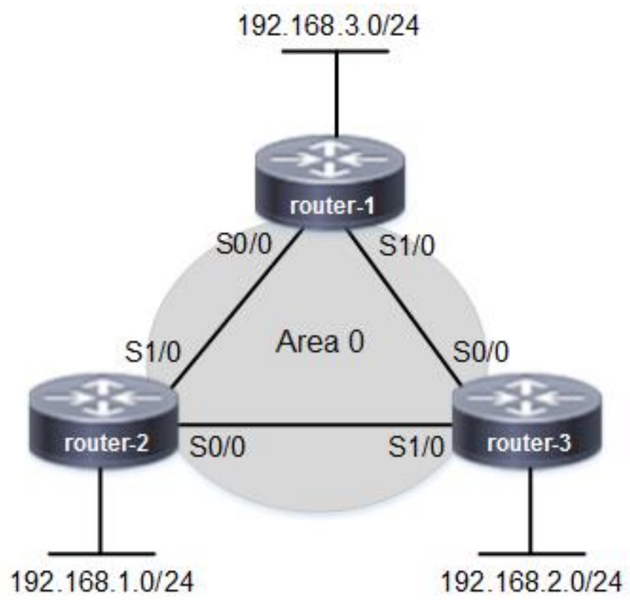


OSPF automatically assigns network type based on the interface media. In this example, OSPF interfaces are connected to an Ethernet switch. The network type assigned is Broadcast. Ethernet is a multi-access broadcast network where multiple routers are assigned to a broadcast domain. The purpose of a VLAN is to create a Layer 2 broadcast domain on a network switch. OSPF automatically elects DR/BDR routers on a broadcast network to send routing updates.

Example: Network Type

Refer to the network topology drawing. What OSPF network type is assigned to the OSPF interfaces?

Figure 6 OSPF Network Type



OSPF automatically assigns serial interfaces as point-to-point network type. There is no DR/BDR elected on a point-to-point network type. Each router advertises routing updates to the neighbor directly. In fact, there is a separate broadcast domain for each link on the same subnet. OSPF only advertises routing updates to neighbors within a common subnet. OSPF neighbors directly connected with Ethernet interfaces are manually configured as Point-to-Point network type. That is a common practice since OSPF will automatically configure Broadcast network type.

OSPF Operation

- OSPF is based on a hierarchical network topology where there is a backbone area. Any new area must be connected to the backbone area or have a virtual transit link through a connected area.

- Single-Area OSPF has only a single area where all routers are connected with at least one network interface.

- The OSPF process ID is a unique number assigned to an OSPF routing instance. It is only locally significant to the router. Multiple process ID can be assigned per interface.

- The valid range for a process ID is 1-65535. There is a separate OSPF database topology table per process ID.

- Cisco supports multiple OSPF instances per router defined with a process ID. There is a maximum of 32 processes permitted per router.

- All OSPF routers send hello packets to neighbors on the same segment (subnet) using multicast 224.0.0.5 destination IP address.

- Hello timer interval for broadcast and point-to-point network type is 10 seconds. The default dead timer is 4 hello intervals (40 seconds).

- There is no maximum hop count for OSPF so it is unlimited.

- OSPF router ID is manually configured or default to highest loopback IP address.

- Passive interfaces prevent router from sending hello messages to neighbors. There is no adjacency formed or routing updates sent.

- OSPF load balances up to four equal cost paths as a default. There is no support for unequal cost path load balancing.

- Path metric is cumulative and calculated based on interface cost (bandwidth). The default administrative distance is 110.

- There is a designated router election for broadcast network type. The router with highest router ID is elected for a default configuration.

- SPF algorithm calculates best path to each destination and loops are prevented with topology database.

OSPF Configuration

OSPF is a classless routing protocol and wildcard masks are required to define subnets for route advertisements. OSPF **network area** command enables OSPF routing on all local interfaces that are assigned an address within the subnet range specified. The routes are advertised to the area assigned and all neighbor/s assigned to that area.

For example, an interface assigned 192.168.1.1 is enabled for OSPF when **network area** command is configured with 192.168.0.0/16 or 192.168.1.0/24 network address. The subnet (route) is then advertised to the area assigned. OSPF supports either 32-bit dotted-decimal number or the equivalent decimal number to an area. The assignable range is from 0.0.0.0 - 255.255.255.255 or decimal equivalent of 0 to 255,255,255,255.

OSPF can be enabled directly on an interface as well. For example, assigning interface Fa0/1 to OSPF process 1 and area 0 would require interface command **ip ospf 1 area 0**. The result is OSPF will advertise the subnet assigned to that local interface to OSPF neighbors. It takes precedence as well when a subnet from the **network area** command is within the same range of an interface subnet address.

Example: OSPF Configuration

The following example will advertise 192.168.100.0/24 subnet from any local interface assigned within that same subnet to all connected OSPF neighbors in area 0.

network 192.168.100.0 0.0.0.255 area 0

OSPFv2 single-area global configuration that is advertising subnet 192.168.0.0/16 to area 0 and 172.16.1.0/24 to area 0.

router ospf 1
router-id 172.16.255.1
network 192.168.0.0 0.0.255.255 area 0
network 172.16.1.0 0.0.0.255 area 0

Default-Information Originate

The purpose of default-information originate is to advertise a default route to connected OSPF neighbors. There is a single route configured under a dynamic routing protocol. The traditional default route is configured locally on a router and used as a gateway of last resort. It is deployed as a backup to a primary link.

Table 3 OSPF Operational Commands

IOS Command	Description
show ip ospf database	Display all link states for areas where router has an interface and advertising routers
show ip ospf neighbors	Display all neighbors that have adjacency with local router and DR
show ip ospf interface	Display operational state of OSPF enabled interface, timers. process ID and router ID

IOS command **show ip ospf database** displays the database topology table. It is a global table comprised of all OSPF link-states for an OSPF domain. The local database table is exchanged between all OSPF neighbors. It creates a network topology used to calculate best path (shortest) to a destination.

The network topology and path cost for each link is considered as part of the calculation. The routing table is updated with the destination subnet and preferred next hop address.

Wildcard Masks

An often overlooked topic on the CCNA exam is wildcard masks. The wildcard mask is a technique for matching specific IP address or range of IP addresses. It is used by OSPF routing protocol to advertise routes to neighbors. In addition access control lists (ACL) filter based on the IP address range configured from a wildcard mask. The wildcard mask of 255.255.255.255 translates to any network address that can be advertised. As a result all/any network addresses assigned to an IP address are advertised to area 0.

The wildcard mask is an inverted mask where the matching IP address or range is based on zero (0) bits. The additional bits are set to 1 as no match required. The wildcard 0.0.0.0 is used to match a single IP address. The wildcard mask for 255.255.224.0 is 0.0.31.255 (invert the bits so zero=1 and one=0) noted with the following example.

11111111.11111111.111 00000.00000000 = subnet mask
00000000.00000000.000 11111.11111111 = wildcard mask

Example 1: Classful Wildcard

The following wildcard **0.0.0.255** will only match on the 192.168.3.0 subnet and not match on everything else. This could be used to define a single subnet to advertise from OSPF.

192 . 168 . 3 . 0

11000000.10101000.00000011.00000000

00000000.00000000.00000000.**11111111** = 0.0.0.255

192.168.3.0 0.0.0.255 = match on 192.168.3.0 subnet only

Example 2: Classless Wildcard

The classless wildcard can filter based on any network boundary. The following wildcard mask **0.0.0.3** matches on all of the addresses for 10.10.1.0/30 subnet only. It is equivalent to the 255.255.255.252 subnet mask. There is network address (10.10.1.0) and broadcast address (10.10.1.3) for that subnet that are not host assignable.

10 . 10 . 1 . 0

00001010.00001010.00000001.000000 00
00000000.00000000.00000000.000000 **11** = 0.0.0.3

10.10.1.0 0.0.0.3 = match 10.10.1.1 and 10.10.1.2

Question 1

Configure OSPF wildcard mask to advertise only 172.16.1.0 subnet to neighbor (zeros mask off subnet)

network 172.16.1.0 **0.0.0**.255 area 0

Question 2

Configure OSPF wildcard mask to advertise only 192.168.1.0 subnet for advertising to neighbor (zeros mask off subnet)

network 192.168.1.0 **0.0.0**.255 area 0

Question 3

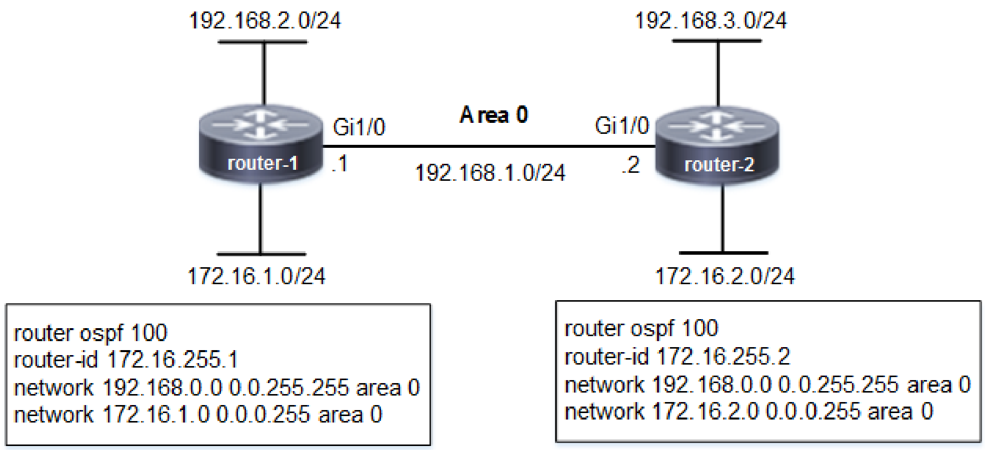
Configure OSPF wildcard mask to advertise all 172.16.0.0 subnets for advertising to neighbor (zeros mask off subnet)

network 172.16.0.0 **0.0**.255.255 area 0

Example 1: OSPF Wildcard Mask

Refer to the network topology drawing. What subnets are advertised between router-1 and router-2 based on the configuration? How does the current configuration affect OSPF normal operations?

Figure 7 Wildcard Mask Example 1



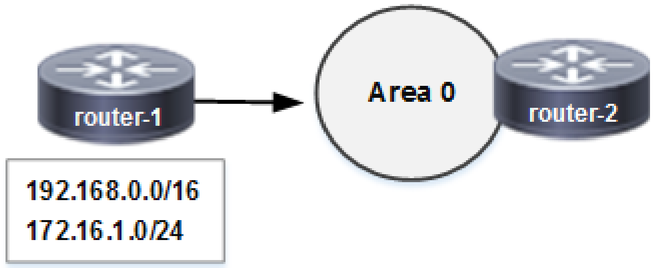
Router-1

This is OSPF global configuration instead of per interface. In this example the first network command advertises all 192.168.0.0/16 subnets from router-1 to area 0. Subnet connecting router-1 and router-2 (192.168.1.0/24) is called a connected route. It is automatically added to the routing table.

Remember that network interfaces advertise OSPF routes. The subnet assigned to router-1 interface Gi1/0 must be included in the subnet range of network command. The wildcard mask is used to configure subnet range. The interface address 192.168.1.1/24 (Gi1/0) of router-1 is within that range. In fact, any network interface that starts with **192.168**.x.x is enabled for OSPF. OSPF wont establish adjacency to router-2 unless Gi1/1 interface address is included.

The second network command advertises only 172.16.1.0/24 subnet from router-1 to area 0. If router-2 is connected to area 0, then by extension router-2 receives routes from router-1. The wildcard mask is the reverse of a subnet mask. For example, 0.0.0.255 = 255.255.255.0 (/24).

Figure 8 Router-1 OSPF Routes

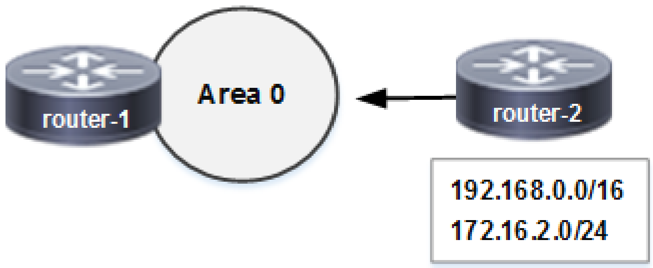


Router-2

This is OSPF global configuration instead of per interface as well. In this example, the first network command advertises all 192.168.0.0/16 subnets from router-2 to area 0.

The subnet connecting router-1 and router-2 (192.168.1.0/24) is called a connected route. It is automatically added to the routing table. The subnet assigned to router-2 interface Gi1/0 must be included in the subnet range of network command. The interface address 192.168.1.2/24 (Gi1/0) of router-2 is within that range. The second network command advertises only 172.16.2.0/24 subnet from router-2 to area 0. If router-1 is connected to area 0, then by extension router-1 receives routes from router-2.

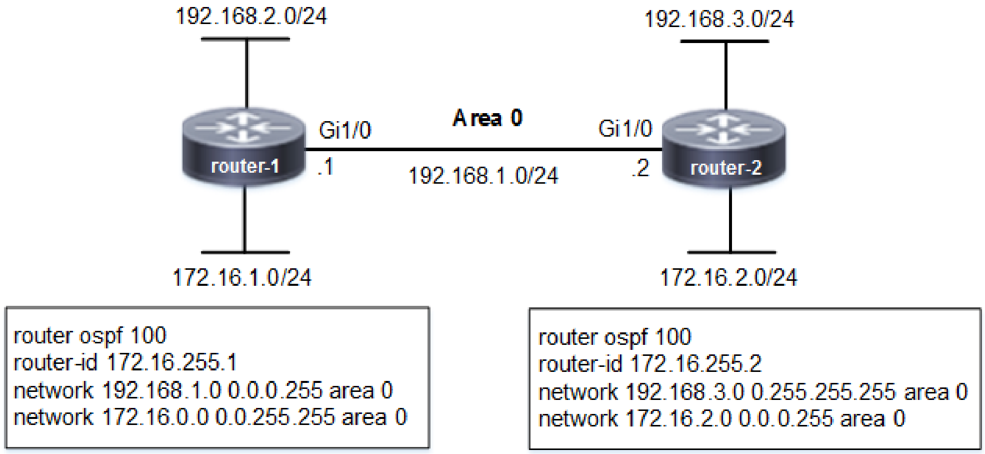
Figure 9 Router-2 OSPF Routes



Example 2: OSPF Wildcard Mask

Refer to the network topology drawing. What subnets are advertised between router-1 and router-2 based on the configuration? How does the current configuration affect OSPF normal operations?

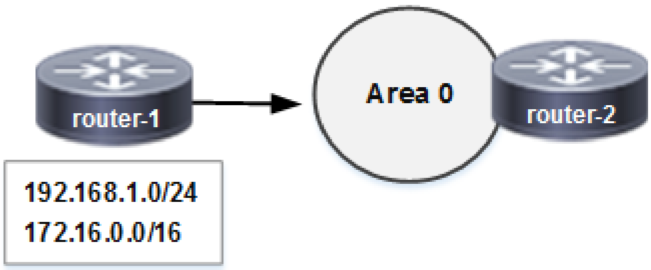
Figure 10 Wildcard Mask Example 2



Router-1

This is OSPF global configuration instead of per interface. The first network command enables only 192.168.1.0/24 subnet based on the wildcard mask. That prevents OSPF from advertising 192.168.2.0/24 subnet since it is out of range. The second network command enables OSPF on all interfaces configured with 172.16.0.0/16 as a subnet. Any network interface that starts with **172.16**.x.x will be enabled for OSPF.

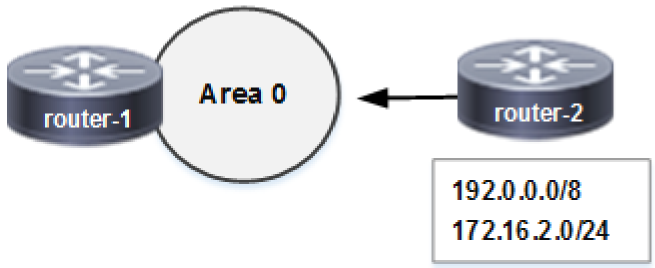
Figure 11 Router-1 OSPF Routes



Router-2

This is OSPF global configuration instead of per interface. The first network command enables all 192.0.0.0/8 subnets based on the wildcard mask. Any network interface that starts with **192**.x.x.x will be enabled for OSPF routing. As a result, interface 192.168.1.2/24 (Gi1/0) on router-2 is enabled for OSPF. That interface will advertise 192.168.1.0/24 and 192.168.3.0/24 subnets to area 0. The second network command only enables 172.16.2.0/24 subnet from router-2 to area 0.

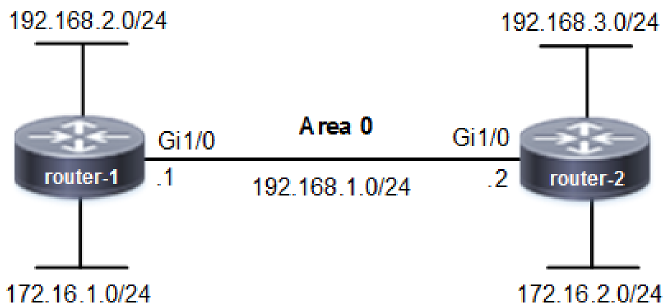
Figure 12 Router-2 OSPF Routes



Example 3: OSPF Wildcard Mask

Refer to the network topology drawing. What subnets are advertised between router-1 and router-2 based on the configuration?

Figure 13 Wildcard Mask Example 3



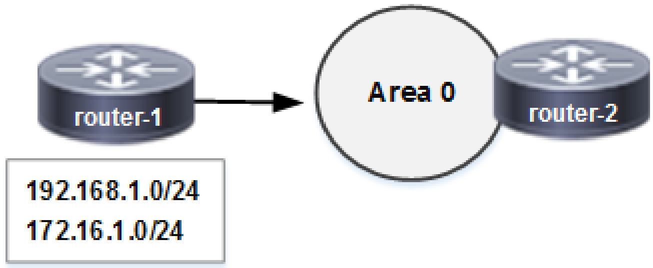

```
router ospf 1
router-id 172.16.255.1
network 172.16.1.0 0.0.0.255 area 0
!
interface GigabitEthernet1/0
ip address 192.168.1.1 255.255.255.0
ip ospf 1 area 0
```

```
router ospf 1
router-id 172.16.255.2
network 172.16.2.0 0.0.0.255 area 0
!
interface GigabitEthernet1/0
ip address 192.168.1.2 255.255.255.0
ip ospf 1 area 0
```

Router-1

This OSPF configuration is both global and per interface. The network command enables only 172.16.1.0/24 subnet based on the wildcard mask. The interface commands enable OSPF directly on router-1 interface Gi1/0. OSPF will advertise 192.168.1.0/24 subnet to area 0 for process ID 1. There is no global configuration or interface configuration for 192.168.2.0 subnet. That subnet is not enabled for OSPF or advertised to area 0.

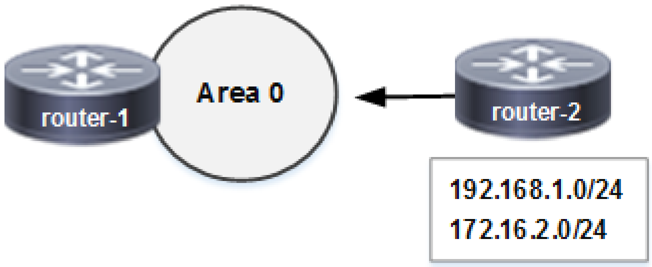
Figure 14 Router-1 OSPF Routes



Router-2

This OSPF configuration is both global and per interface. The network command enables only 172.16.2.0/24 subnet based on the wildcard mask. The interface commands enable OSPF directly on router-2 interface Gi1/0. OSPF will advertise 192.168.1.0/24 subnet to area 0 for process ID 1. There is no global configuration or interface configuration for 192.168.3.0 subnet. That subnet is not enabled for OSPF or advertised to area 0.

Figure 15 Router-2 OSPF Routes



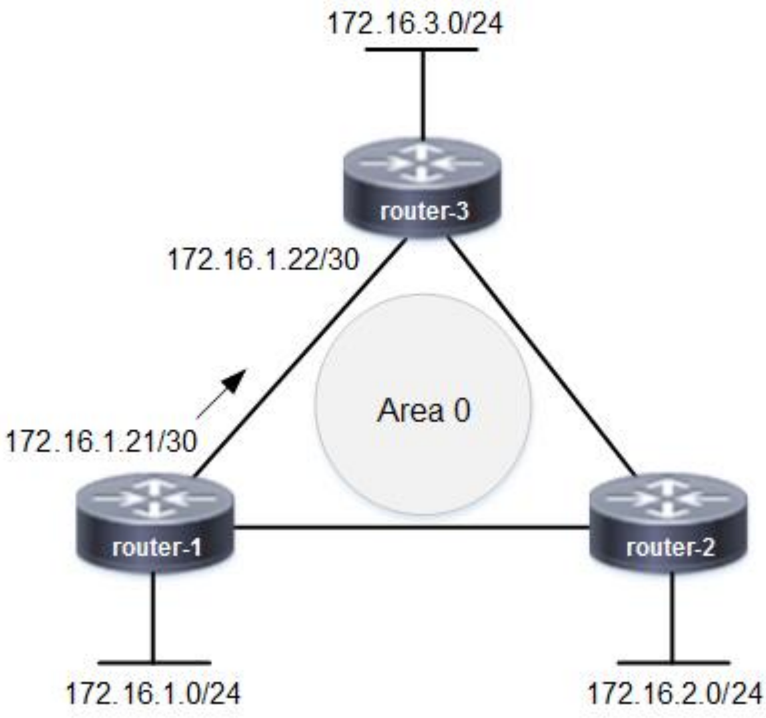
Example 4: OSPF Wildcard Mask

Refer to the network topology drawing. What wildcard mask will enable advertising of all connected routes via OSPF from router-1 to router-3?

Answer

The OSPF **network area** command specifies a subnet/s for an OSPF process and area. Any router interface assigned an IP address within that range is included in the OSPF process. There is support for multiple OSPF process numbers per router. Each OSPF process ID is assigned a number and becomes a separate OSPF instance.

Figure 16 Wildcard Mask Example 4



The **network area** command enables 172.16.1.16/30 - 172.16.1.31/30 subnet range. Interface serial0/0 (172.16.1.21/30) on router-1 is within that subnet range and enabled for OSPF.

router-1(config)# **router ospf 1**
router-1(config-router)# **network 172.16.1.16 0.0.0.15 area 0**

172 . 16 . 1 .16 17-31

00000000.00000000.00000000.**0000** **1111**

0 . 0 . 0 . 15

The wildcard mask zeros match on the first 3 octets (172.16.1) of the network address. The **15** causes a match on the leftmost 4 bits of the 4th octet. In addition it masks (1s) off the rightmost 4 bits of the 4th octet. It does the opposite of what a subnet mask does.

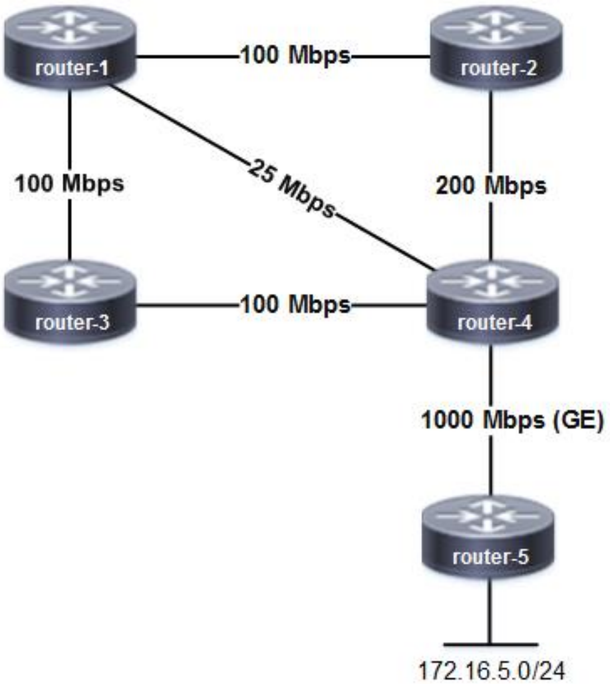
Example 5: OSPF Metric

Refer to the network topology drawing. All routers are enabled with OSPF and have default settings. What path/s will the router select to forward packets from router-1 to router-5?

Answer

OSPF selects a path based on interface cost (bandwidth) from source to destination. The cost of each link is calculated and added for a cumulative metric (path cost). The minimum cost assignable to any link is 1. The default OSPF reference bandwidth is 100 Mbps.

Figure 17 OSPF Metric



The following formula is used to calculate OSPF interface cost:

interface cost = 100 Mbps / interface bandwidth

OSPF default metric costs

- 10 Mbps = 10
- 100 Mbps = 1
- 200 Mbps = 1
- 1000 Mbps = 1

Example: 25 Mbps

Cost = 100 Mbps / 25 Mbps = 4

Path 1: Router-1 → Router-4 → Router-5 = 4+1 = 5

Path 2: Router-1 → Router-2 → Router-4 → Router-5 = 1+1+1 = 3

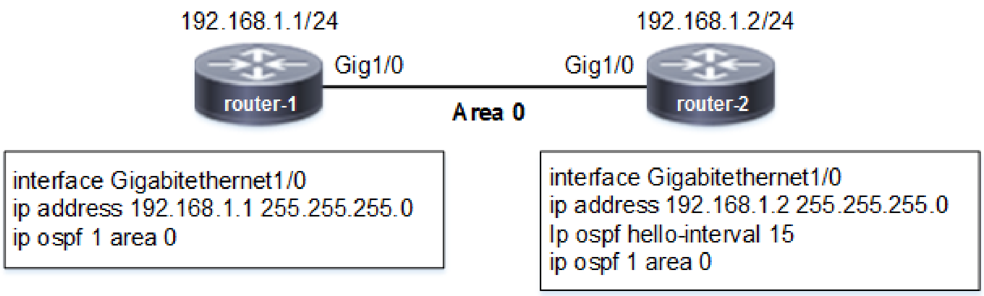
Path 3: Router-1 → Router-3 → Router-4 → Router-5 = 1+1+1 = 3

There are two equal **lowest cost** (highest bandwidth) paths to Router-5. The cost for Path 2 and Path 3 is 3. OSPF will load balance packets across each path as a result. There is no support for unequal-cost load balancing of OSPF routes.

Example: OSPF Timers

What is the OSPF hello timer setting on router-1 with a Cisco default configuration?

Figure 18 OSPF Hello Timer



The default OSPF hello timer interval for a point-to-point network type is 10 seconds. The dead timer is a default of 4 times the hello interval. Ethernet is an example of a broadcast network type that has the same timer settings.