OSPF

CCNA Routing and Switching - Scaling Networks v6.0

- Chapter 8: Single-Area OSP
- Chapter 9: Multiarea OSPF
- Chapter 10: OSPF Tuning and Troubleshooting

Sections & Objectives

- Single Area OSPF Operation
  - Explain how single-area OSPF operates.
    - Explain the features and characteristics of the OSPF routing protocol.
    - Describe the types of packets used to establish and maintain an OSPF neighbor relationship.
    - Explain how OSPF achieves convergence.
- Implement single-area OSPFv2.
  - Configure an OSPF router ID.
  - Configure single-area OSPFv2.
  - Explain how OSPF uses cost to determine best path.
  - Verify single-area OSPFv2.

Sections & Objectives (Cont.)

- Implement single-area OSPFv3
  - Compare the characteristics and operations of OSPFv2 to OSPFv3.
  - Configure single-area OSPFv3.
  - Verify single-area OSPFv3.

- Advanced Single-Area OSPF Configurations
  - Configure the OSPF interface priority to influence the DR/BDR election.
  - Configure OSPF to propagate a default route.
  - Configure OSPF interface settings to improve network performance.

Sections & Objectives (Cont.)

- Multiarea OSPF Operation
  - Explain how multiarea OSPF operates in a small to medium-sized business network.
    - Explain why multiarea OSPF is used.
    - Explain how multiarea OSPFv2 uses link-state advertisements.
    - Explain how multiarea OSPF establishes neighbor adjacencies.
- Implement Multiarea OSPF
  - Implement multiarea OSPFv2 and OSPFv3.
    - Configure multiarea OSPFv2 and OSPFv3 in a routed network.
    - Verify multiarea OSPFv2 and OSPFv3 operation.

Sections & Objectives (Cont.)

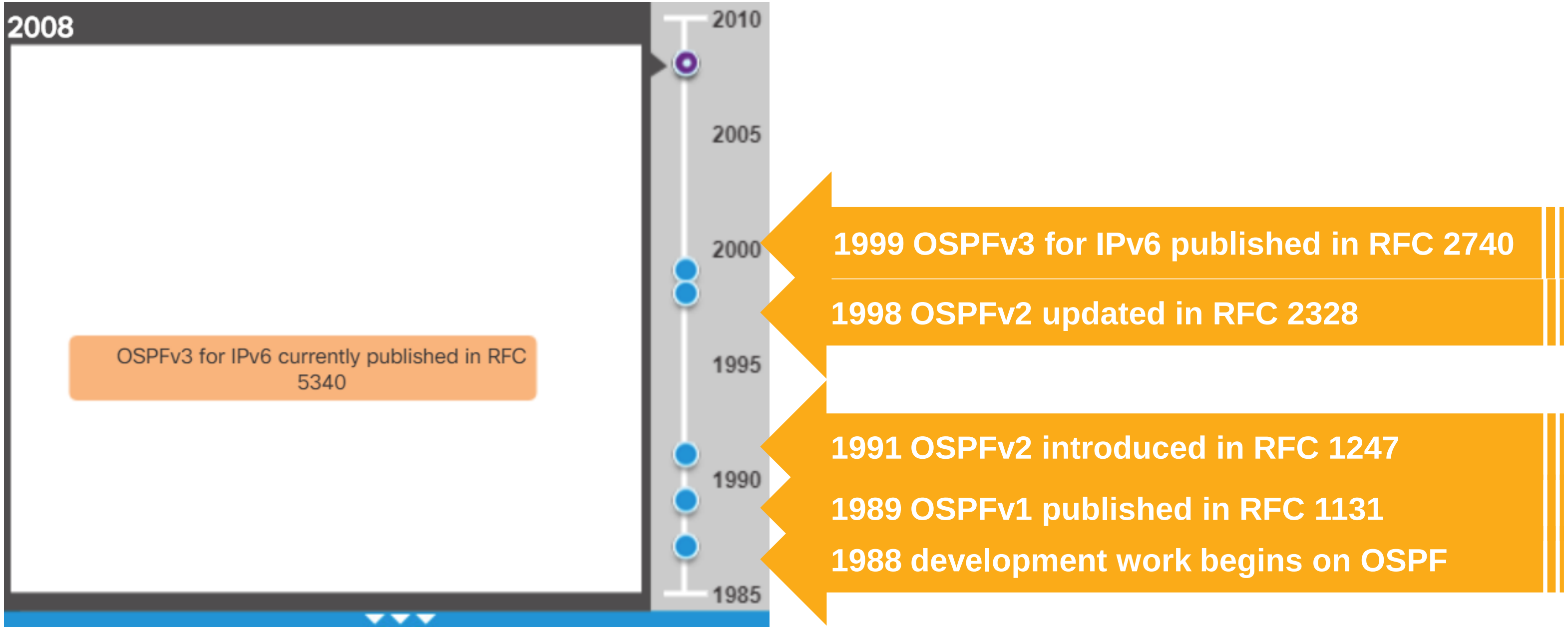
- Troubleshooting Single-Area OSPF Implementations
  - Explain the process and tools used to troubleshoot a single-area OSPF network.
  - Troubleshoot missing route entries in the single-area OSPFv2 routing table.
  - Troubleshoot missing route entries in a single-area OSPFv3 routing table.
  - Troubleshoot missing route entries in multiarea OSPFv2 and OSPFv3 routing tables.

Single area OSPF Characteristics

Evolution of OSPF

- OSPF is a link-state routing protocol

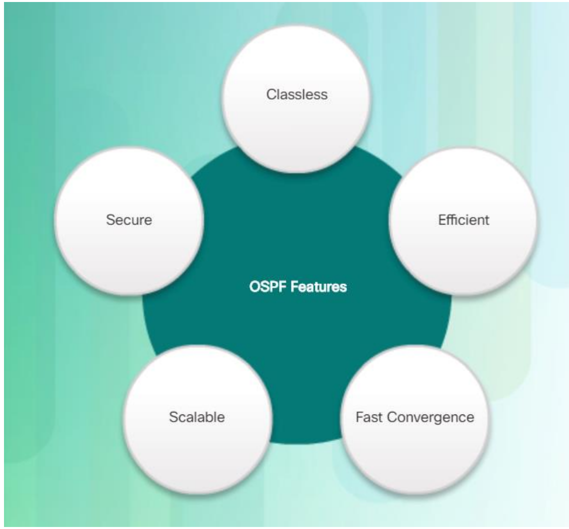
	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP



Features of OSPF

v2 supports MD5 and SHA authentication
v3 uses IPsec for authentication

Supports a hierarchical design system through the use of areas



Routing changes trigger routing updates

- OSPF uses the Dijkstra shortest path first (SPF) algorithm to choose the best path.
- Administrative distance is used in determining what route gets installed in the routing table when the route is learned from multiple sources.
  - The lowest administrative distance is the one added to the routing table.

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

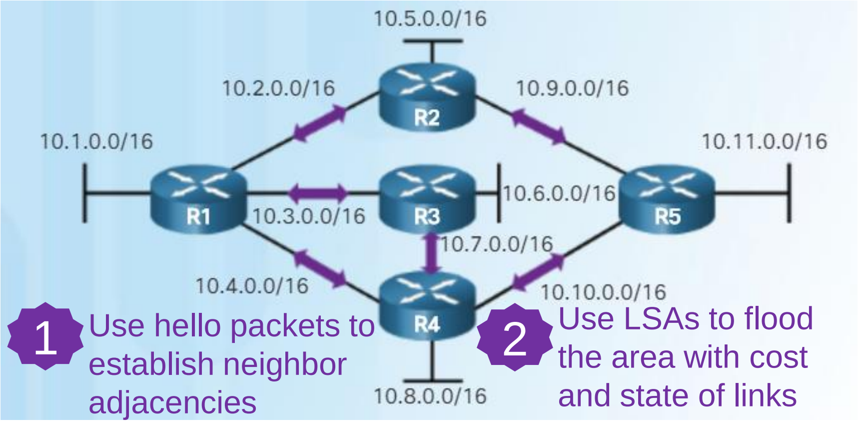
Components of OSPF

Database	Table	Description
Adjacency	Neighbor	• Lists all neighbor routers to which a router has established bidirectional communication • Unique for each router • View using the **show ip ospf neighbor** command
Link-state (LSDB)	Topology	• Lists information about all other routers • Represents the network topology • Contains the same LSDB as all other routers in the same area • View using the **show ip ospf database** command
Forwarding	Routing	• Lists routes generated when the SPF algorithm is run on the link-state database. • Unique to each router and contains information on how and where to send packets destined for remote networks • View using the **show ip route** command

- OSPF packet types: hello, database description, link-state request, link-state update, link-state acknowledgment

Open Shortest Path First

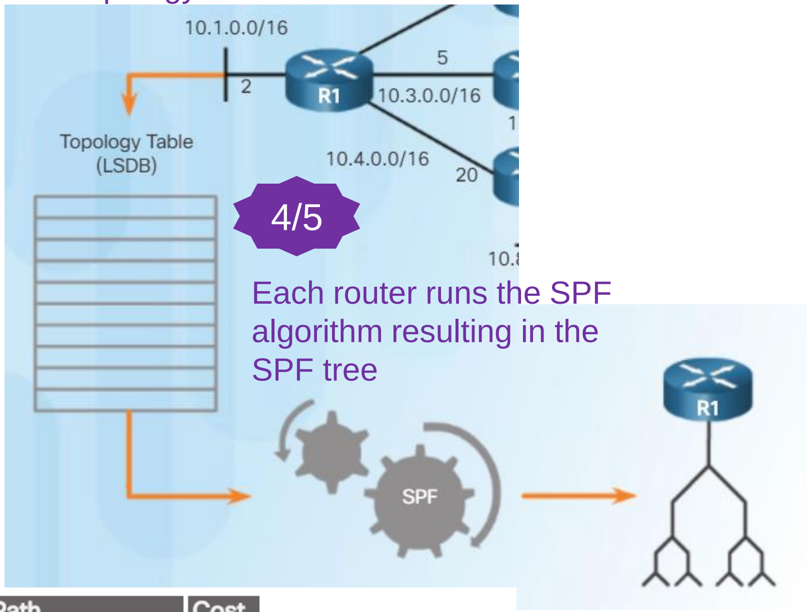
Link-State Operation



1 Use hello packets to establish neighbor adjacencies

2 Use LSAs to flood the area with cost and state of links

3 Each router builds a topology table



4/5 Each router runs the SPF algorithm resulting in the SPF tree

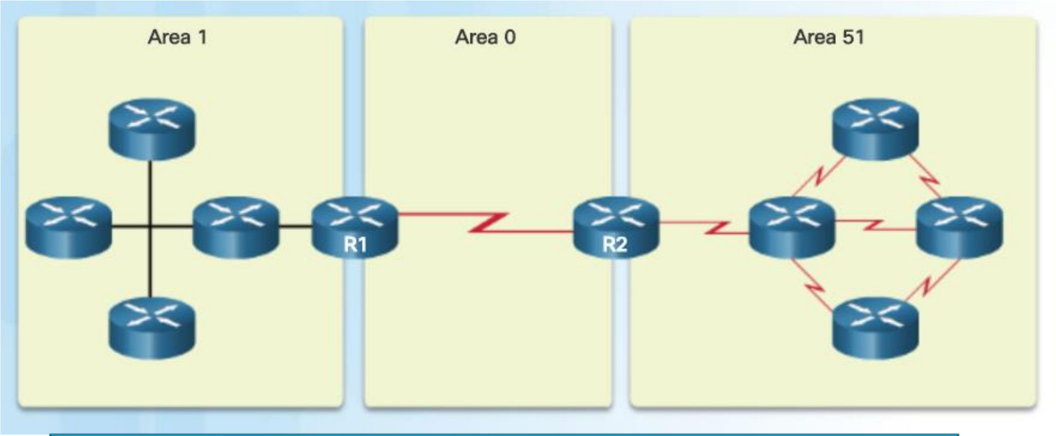
6 Each router builds a routing table that includes the path to get to the distant network and the cost to get there.

Destination	Shortest Path	Cost
10.5.0.0/16	R1→R2	22
10.6.0.0/16	R1→R3	7
10.7.0.0/16	R1→R3	15
10.8.0.0/16	R1→R3→R4	17
10.9.0.0/16	R1→R2	30
10.10.0.0/16	R1→R3→R4	25
10.11.0.0/16	R1→R3→R4→R5	27
10.5.0.0/16	R1→R2	22

Open Shortest Path First

Single-Area and Multiarea OSPF

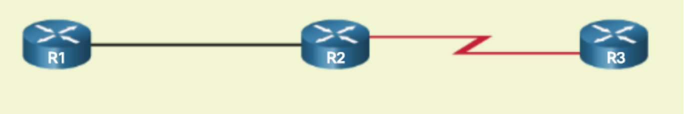
Multiarea OSPF



- Designed using a hierarchical scheme
- All areas connect to area 0
- More commonly seen with numerous areas around area 0 (like a daisy or aster)
- Routers that connect area 0 to another area is known as an Area Border Router (ABR)
- Used in large networks
- Multiple areas reduces processing and memory overhead
- A failure in one area does not affect other areas

The original uploader was Hugowolf at English Wikipedia - Transferred from en.wikipedia to Commons by DieBuche using CommonsHelper., CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=10285606

Single-Area OSPF



- All routers contained in one area
- Called the backbone area
- Known as Area 0
- Used in smaller networks with few routers

Encapsulating OSPF Messages

- OSPF adds its own Layer 3 header after the IP Layer 3 header.
  - The IP header contains the OSPF multicast address of either 224.0.0.5 or 224.0.0.6 and the protocol field of 89 which indicates it is an OSPF packet.
- OSPF Packet Header identifies the type of OSPF packet, the router ID, and the area ID
- OSPF Packet Type contains the specific OSPF packet type information

Data Link Frame Header	IP Packet Header	OSPF Packet Header	OSPF Packet Type-Specific Database

Data Link Frame (Ethernet Fields shown here)
MAC Destination Address = Multicast: 01-00-5E-00-00-05 or 01-00-5E-00-00-06
MAC Source Address = Address of sending interface

IP Packet
IP Source Address = Address of sending interface
IP Destination Address = Multicast: 224.0.0.5 or 224.0.0.6
Protocol Field = 89 for OSPF

OSPF Packet Header
Type code for OSPF packet type
Router ID and Area ID

OSPF Packet Types
0x01 Hello
0x02 Database Description (DD)
0X03 Link State Request
0X04 Link State Update
0X05 Link State Acknowledgment

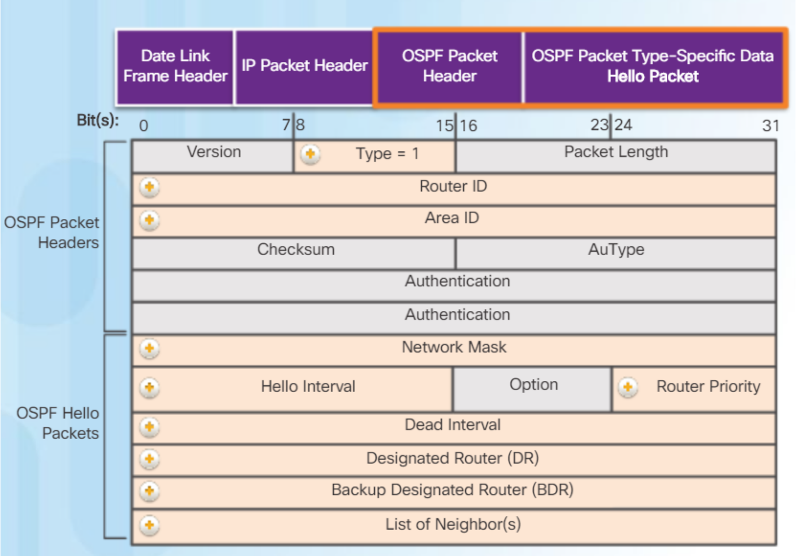
Encapsulating OSPF Messages (Cont.)

- OSPFv3 has similar packet types.

OSPF Packet 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

OSPF Messages

Hello Packet

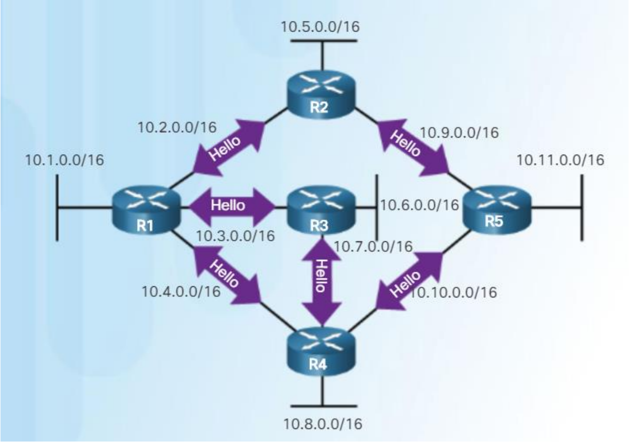


- Hello packets are used to discover neighbors, establish neighbor adjacencies, advertise parameters both routers must agree upon in order to become neighbors, and elect the Designated Router (DR) and Backup Designated Router (BDR) on multi-access networks like Ethernet and Frame Relay (not serial point-to-point links).
  - Type field – 1 = hello; 2 = DBD; 3 = LSR; 4 = LSU; 5 - LSAck
  - Hello interval – how often a router sends hello packets
  - Router priority (default is 1; 0-255 with the higher number influencing the DR/BDR election process)
  - Dead interval – how long a router waits to hear from a neighbor router before declaring the router out of service
  - DR and BDR fields contain the router ID for the DR and BDR
  - List of neighbors is the router ID for all adjacent neighbor routers

OSPF Messages

Hello Packet Intervals

- Hello and dead intervals must be the same interval setting on neighboring routers on the same link
- Transmitted to multicast address 224.0.0.5 in IPv4
- Transmitted to multicast address FF02::5 in IPv6
- Sent every 10 seconds by default on multi-access networks like Ethernet and point-to-point links
- Sent every 30 seconds by default on non-broadcast multiple access networks (NBMA) like Frame Relay
- Dead intervals by default are 4 times the hello interval
  - If the dead interval expires before the router receives a hello packet, OSPF removes that neighbor from its link state data base (LSDB). The router then floods the LSDB with info about the down neighbor.



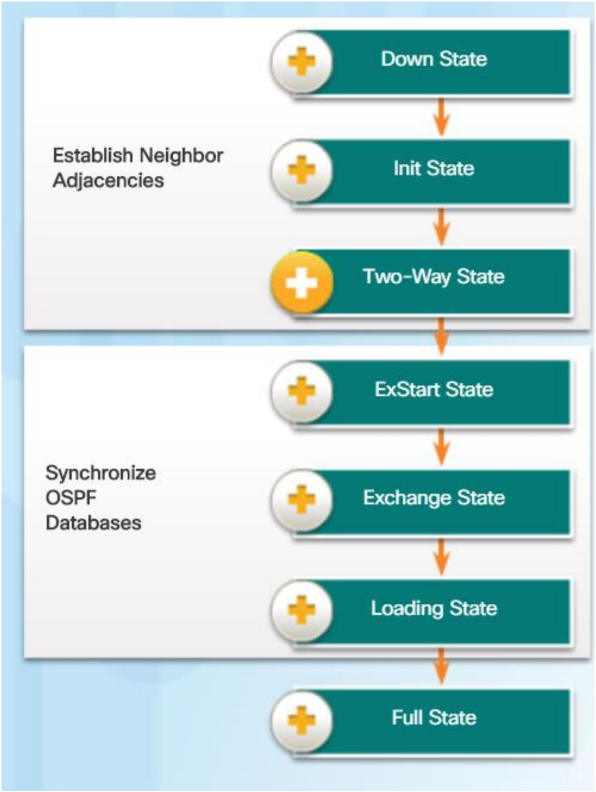
Link-State Updates

- A Link State Update (LSU) contains one or more LSAs; LSAs contain route information for destination networks
- Routers initially send Type 2 DBD packets – an abbreviated list of the sending routers LSDB
  - Receiving routers check against their own LSDB
- Type 3 LSR is used by the receiving router to request more information about an entry in the Database Description (DBD)
- Type 4 Link-state Update (LSU) is used to reply to an LSR packet

OSPF Packet 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	Link-State Update (LSU)	Sends specifically requested link-state records
5	LSAck	Acknowledges the other packet types

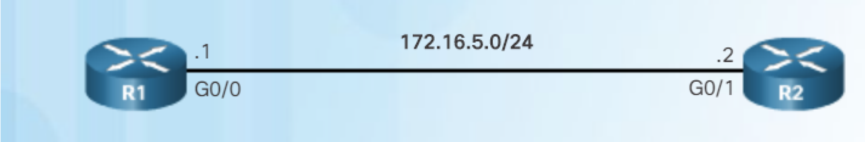
LSA Type	Description
1	Router LSAs
2	Network LSAs
3 or 4	Summary LSAs
5	Autonomous System External LSAs
6	Multicast OSPF LSAs
7	Defined for Not-So-Stubby Areas
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, 11	Opaque LSAs

OSPF Operational States

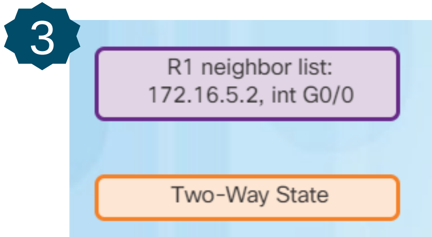


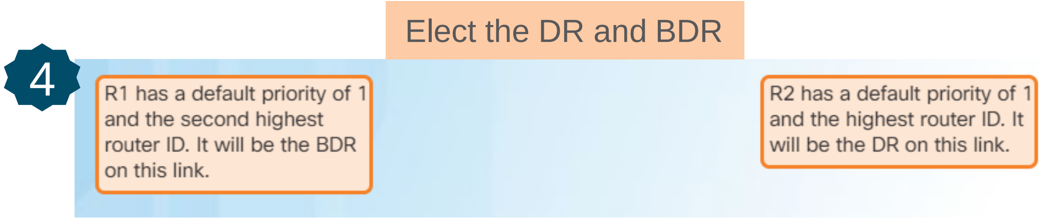
- OSPF progresses through several states while attempting to reach convergence:
  - Down – No Hello packets received; router sends Hello packets
  - Init – Hello packets are received that contain the sending router's Router ID
  - Two-Way – Used to elect a DR and BDR on an Ethernet link
  - ExStart – Negotiate master/slave relationship and DBD packet sequence number; the master initiates the DBD packet exchange
  - Exchange – Routers exchange DBD packets; if additional router information is required, then transition to the Loading State, otherwise, transition to the Full State
  - Loading – LSRs and LSUs are used to gain additional route information; routes are processed using the shortest path first (SPF) algorithm; transition to the Full State
  - Full – Routers have converged databases

Establish Neighbor Adjacencies



- Without a pre-configured router ID (RID) or loopback addresses, R1 has a RID of 172.16.5.1 and R2 has a RID of 172.16.5.2

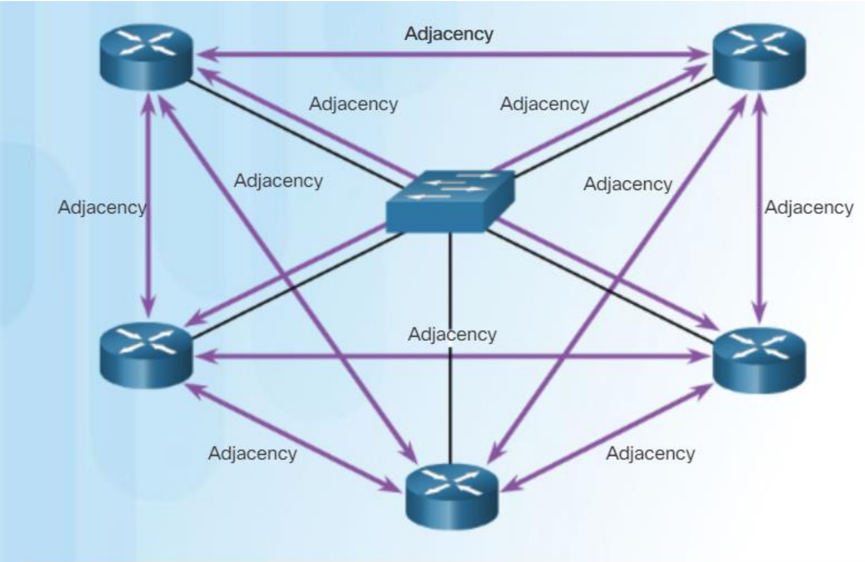




OSPF DR and BDR

- Why have a DR/BDR election?
- Reduce the number of LSAs sent – The DR is the only router used to send LSAs for the shared network
- Reduce the number of adjacencies over a multi-access network like Ethernet

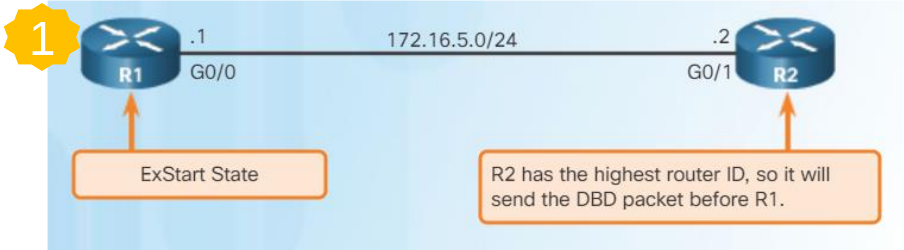
Routers	Adjacencies
n	n (n - 1) / 2
5	10
10	45
20	190
100	4,950

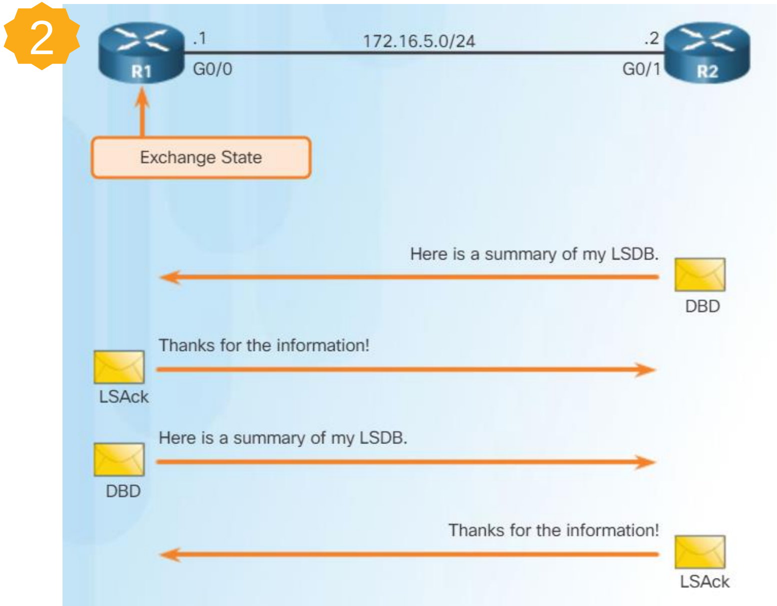


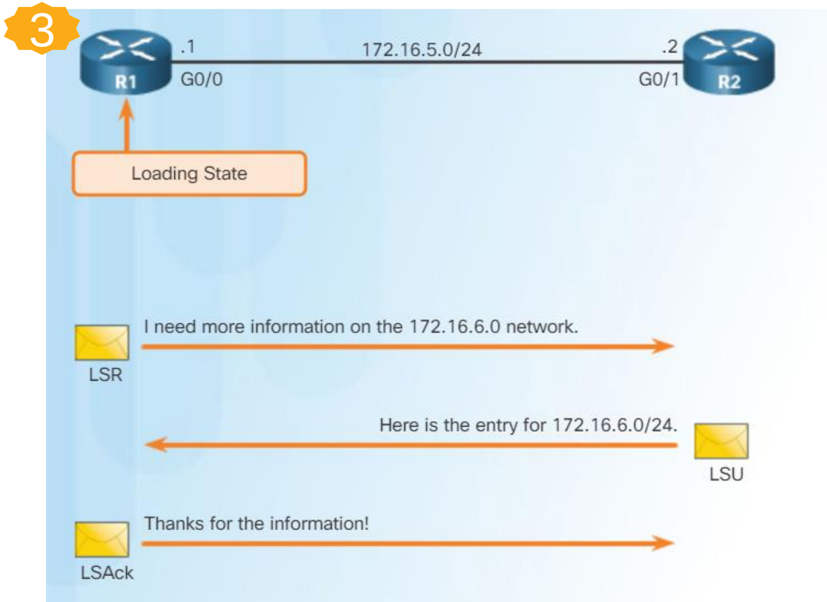
Number of Adjacencies = n (n - 1) / 2
n = number of routers
Example: 5 (5 - 1) / 2 = 10 adjacencies

Synchronizing OSPF Databases

- After the Two-Way state, routers need to synchronize their databases and use the other four types of OSPF packets to exchange information.



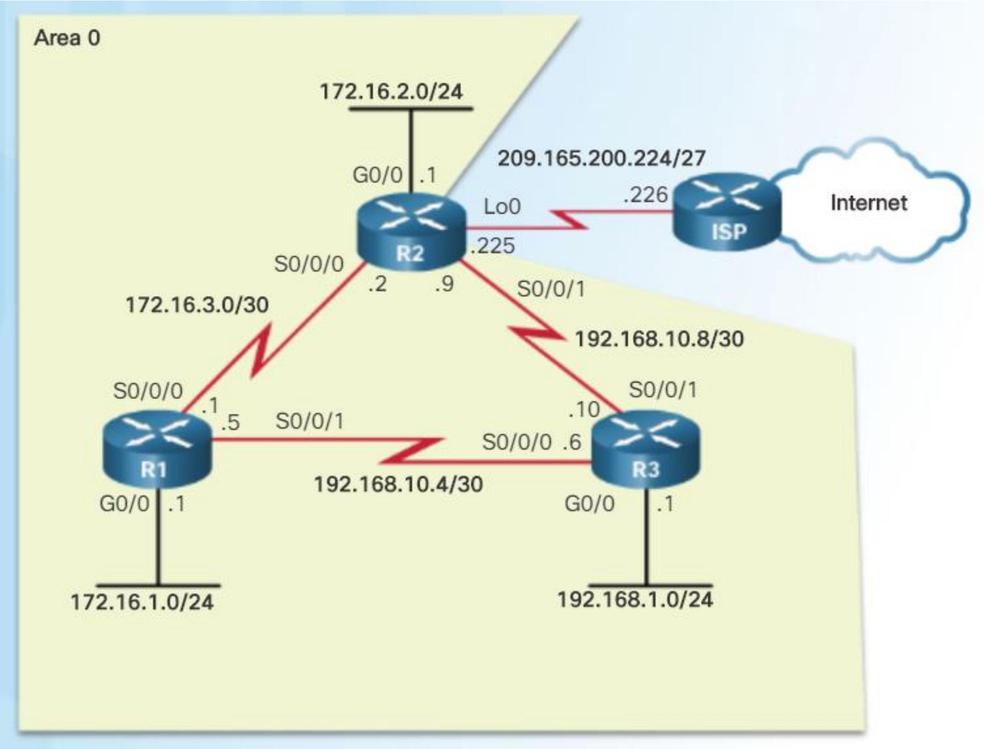




Single-Area OSPFv2

OSPF Network Topology

- Topology used to describe OSPF configuration



Router OSPF Configuration Mode

- OSPFv2 configuration uses the router ospf configuration mode
  - From global configuration mode, type **router ospf** *process-id* to enter commands

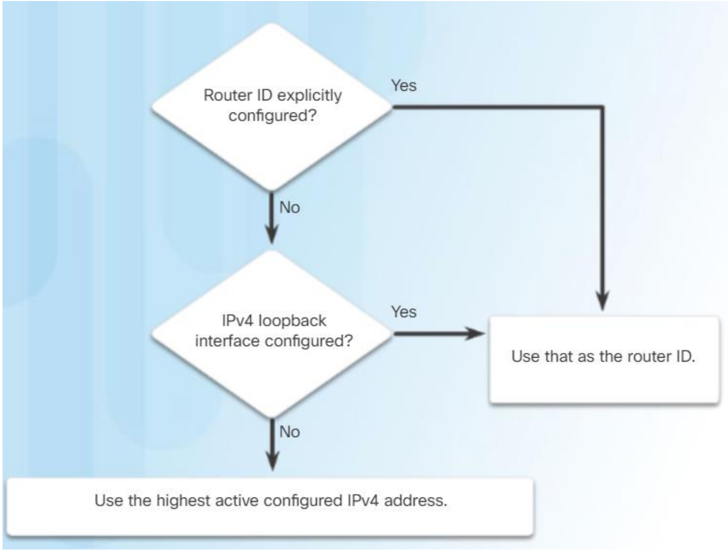
```
R1(config)# router ospf 10
R1(config-router)# ?
Router configuration commands:
 auto-cost              Calculate OSPF interface cost according to
                        bandwidth
 network                Enable routing on an IP network
 no                     Negate a command or set its defaults
 passive-interface      Suppress routing updates on an interface
 priority               OSPF topology priority
 router-id              router-id for this OSPF process
```

Note there are other commands used in this mode.

Router IDs

- Router IDs are used to uniquely identify an OSPF router
- Router IDs are 32 bits long in both OSPFv2 (IPv4) and OSPFv3 (IPv6)
- Used in the election of the DR if a priority number is not configured
- Ways a router gets a router ID

1. Configured using the **router-id *rid*** OSPF router configuration mode command
2. If a router ID is not configured, the highest configured loopback interface is used
3. If there are no configured loopback interfaces, then the highest active IPv4 address is used (not recommended because if the interface with the highest IPv4 address goes down, the router ID selection process starts over)



If a loopback address is used, do not route this network using a network statement!

Configuring an OSPF Router ID

- Use the **router-id** *x.x.x.x* command to configure a router ID.
- 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
R1#
*Mar 25 19:50:36.595: %SYS-5-CONFIG_I: Configured from console by console
R1#
R1# show ip protocols
*** IP Routing is NSF aware ***

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 0. 0 normal 0 stub 0 nssa
   Maximum path: 4
   Routing for Networks:
   Routing Information Sources:
   Gateway         Distance      Last Update
   Distance: (default is 110)
```

Modifying a Router ID

- Use the **clear ip ospf process** command after changing the router ID to make the change effective.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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 192.168.10.5
```

Original RID

```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
% OSPF: Reload or use "clear ip ospf process" command, for this to take effect
```

Change RID

Don't forget this command to make the router ID change effective.

```
R1# clear ip ospf process
Reset ALL OSPF processes? [no]: y
R1#
*Mar 25 19:46:22.423: %OSPF-5-ADJCHG: Process 10, Nbr
3.3.3.3 on Serial0/0/1 from FULL to DOWN, Neighbor Down:
 Interface down or detached
*Mar 25 19:46:22.423: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from FULL to DOWN, Neighbor Down:
 Interface down or detached
*Mar 25 19:46:22.475: %OSPF-5-ADJCHG: Process 10, Nbr
3.3.3.3 on Serial0/0/1 from LOADING to FULL, Loading Done
*Mar 25 19:46:22.475: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from LOADING to FULL, Loading Done
R1#
R1# show ip protocols | section Router ID
  Router ID 1.1.1.1
```

Applied RID Change

Using a Loopback Interface as the Router ID

- Older IOS version did not have the **router-id** OSPF configuration command.
- Loopback interfaces were used to provide a stable router ID.

Do NOT advertise this network! It is a common mistake made in OSPF configurations.

```
R1(config)# interface loopback 0
R1(config-if)# ip address 1.1.1.1 255.255.255.255
R1(config-if)# end
R1#
```

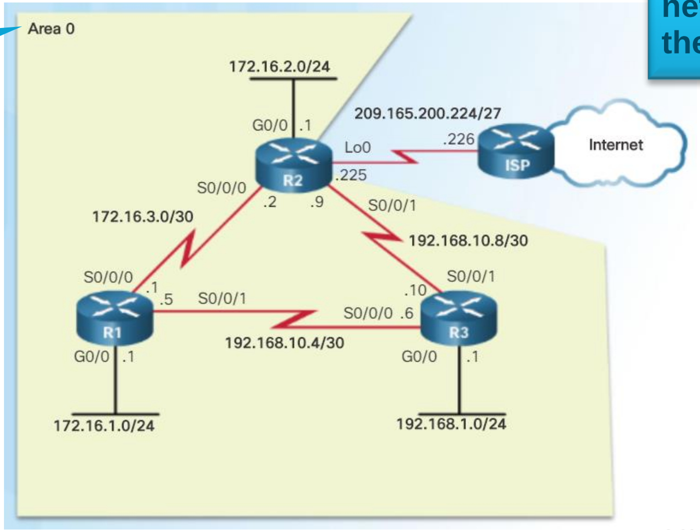

Enabling OSPF on Interfaces

- Use the **network** command to specify which interface(s) participate in the OSPFv2 area.
  - (config)# **router ospf** *x*
  - (config-router)# **network** *x.x.x.x wildcard_mask* **area** *area-id*

Common misconception!

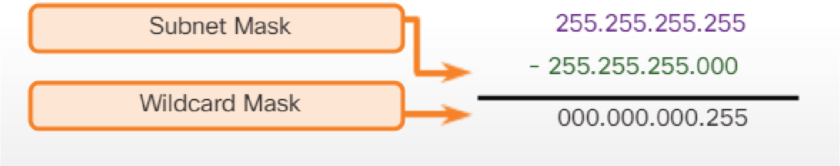
R2 has 3 interfaces in Area 0 so three network statements are used (not 6 network statements for all 6 networks in the entire area)

If a single-area topology is used, it is best to use Area 0

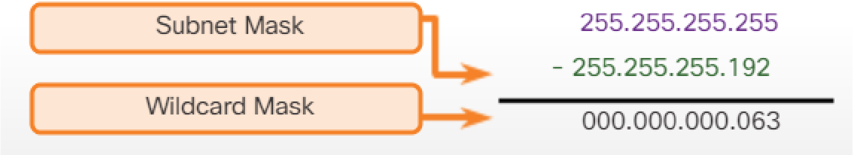


Wildcard Mask

- To determine the wildcard mask, subtract the normal mask from 255.255.255.255
- A wildcard mask bit of 0 – match the bit
- A wildcard mask bit of 1 – ignore the bit
- A wildcard mask is a series of 0s with the rest 1s (the 0s and 1s are not alternating like an IP address)



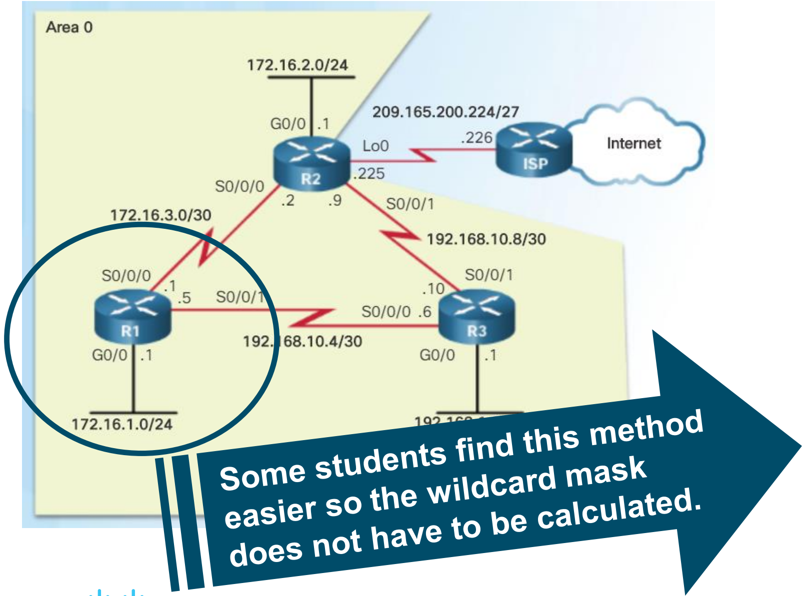
/24 mask



/26 mask

The **network** Command

- Two ways to use the **network** command
  - Advertise the particular network, calculating the wildcard mask
  - Advertise the IP address on the router interface with a 0.0.0.0 wildcard mask



Method 1 Traditional Method Network Number and Wildcard Mask

```
R1(config)# router ospf 10
R1(config-router)# network 172.16.1.0 0.0.0.255 area 0
R1(config-router)# network 172.16.3.0 0.0.0.3 area 0
R1(config-router)# network 192.168.10.4 0.0.0.3 area 0
```

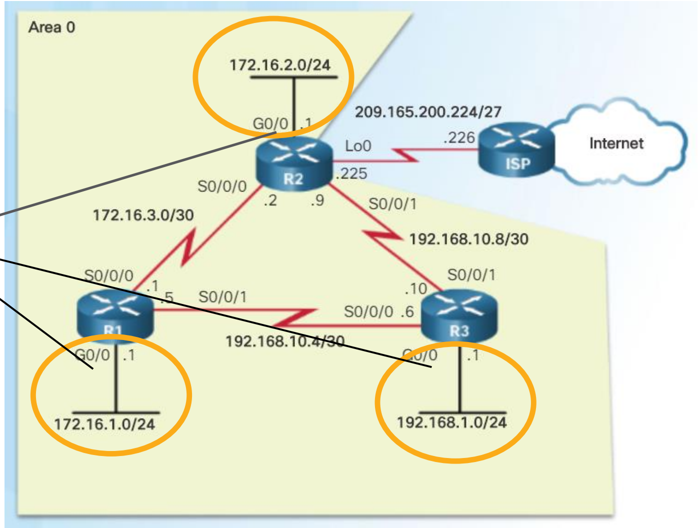
Method 2 Interface IP Address and 0.0.0.0

```
R1(config)# router ospf 10
R1(config-router)# network 172.16.1.1 0.0.0.0 area 0
R1(config-router)# network 172.16.3.1 0.0.0.0 area 0
R1(config-router)# network 192.168.10.5 0.0.0.0 area 0
```

Passive Interface

- An interface configured as a passive interface does not **SEND** OSPF messages.
- Best practice for interfaces that have users attached (security)
- Doesn't waste bandwidth sending messages out OSPF-enabled interfaces that don't have another router attached.

Interfaces to configure as a passive interface

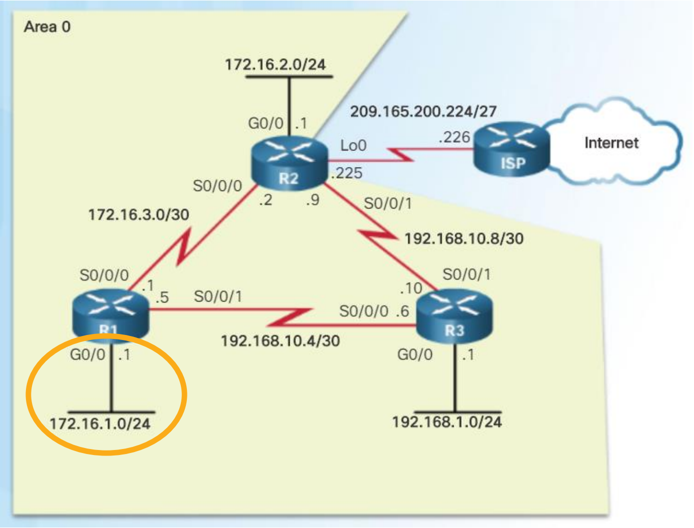


Configuring Passive Interfaces

- Use the **passive-interface** command to configure
- Use the **show ip protocols** to verify

```
R1(config)# router ospf 10
R1(config-router)# passive-interface GigabitEthernet 0/0
```

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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:
    172.16.1.1 0.0.0.0 area 0
    172.16.3.1 0.0.0.0 area 0
    192.168.10.5 0.0.0.0 area 0
  Passive Interface(s):
    GigabitEthernet0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:08:35
    2.2.2.2              110      00:08:35
  Distance: (default is 110)
```



OSPF Metric = Cost

- OSPF uses the metric of cost to determine the best path used to reach a destination network (Cost = reference bandwidth / interface bandwidth)
- Lowest cost is a better path
- The interface bandwidth influences the cost assigned
  - A lower bandwidth interface has a higher cost

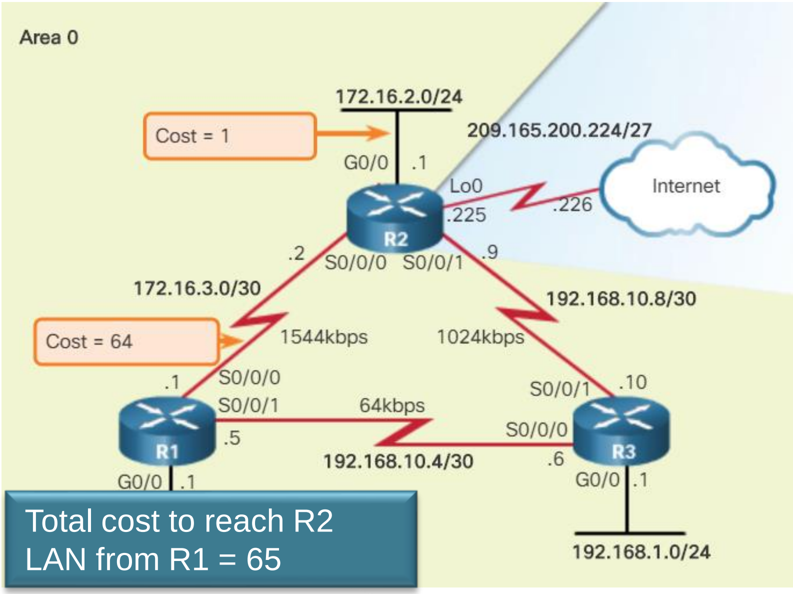
Important Concept!

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gbps Ethernet	100,000,000	÷	10,000,000,000	1
1 Gbps Ethernet	100,000,000	÷	1,000,000,000	1
100 Mbps Ethernet	100,000,000	÷	100,000,000	1
10 Mbps Ethernet	100,000,000	÷	10,000,000	10
1.544 Mbps Serial	100,000,000	÷	1,544,000	64
128 kbps Serial	100,000,000	÷	128,000	781
64 kbps Serial	100,000,000	÷	64,000	1562

This is an issue because it is the same cost due to the default reference bandwidth. Needs to be adjusted!

OSPF Accumulates Costs

- The “cost” for a destination network is an accumulation of all cost values from source to destination.
- The cost metric can be seen in the routing table as the second number within the brackets.



Cost metric to destination network 172.16.2.0 from R1

```
R1# show ip route | include 172.16.2.0
O        172.16.2.0/24 [110/65] via 172.16.3        39:07,
         Serial0/0/0
R1#
R1# show ip route 172.16.2.0
Routing entry for 172.16.2.0/24
  Known via "ospf 10", distance 110, metric 65, type intra
  area
  Last update from 172.16.3.2 on Serial0/0/0, 03:39:15 ago
  Routing Descriptor Blocks:
  * 172.16.3.2, from 2.2.2.2, 03:39:15 ago, via Serial0/0/0
      Route metric is 65, traffic share count is 1
```

Adjusting the Reference Bandwidth

- Changing the OSPF reference bandwidth affects only the OSPF calculation used to determine the metric, not the bandwidth of the interface.
- Use the **auto-cost reference-bandwidth** command to change the OSPF reference bandwidth.
- Default reference bandwidth is 100 Mbps.

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gbps Ethernet	100,000,000	÷	10,000,000,000	1
1 Gbps Ethernet	100,000,000	÷	1,000,000,000	1
100 Mbps Ethernet	100,000,000	÷	100,000,000	1
10 Mbps Ethernet	100,000,000	÷	10,000,000	10
1.544 Mbps Serial	100,000,000	÷	1,544,000	64
128 kbps Serial	100,000,000	÷	128,000	781
64 kbps Serial	100,000,000	÷	64,000	1562

With the default reference bandwidth applied makes 100Mbps Ethernet, 1 Gbps Ethernet, and 10 Gbps Ethernet appear to be the same bandwidth within the best path calculations.

OSPF Cost

Adjusting the Reference Bandwidth (Cont.)

- To adjust to distinguish between 100 Mbps Ethernet and Gigabit Ethernet, use the **auto-cost reference-bandwidth 1000** command.
- To adjust to distinguish between 1 Gigabit Ethernet and 10 Gigabit Ethernet, use the **auto-cost reference-bandwidth 10000** command.

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gbps Ethernet	1,000,000,000	÷	10,000,000,000	1
1 Gbps Ethernet	1,000,000,000	÷	1,000,000,000	1
100 Mbps Ethernet	1,000,000,000	÷	100,000,000	10
10 Mbps Ethernet	1,000,000,000	÷	10,000,000	100
1.544 Mbps Serial	1,000,000,000	÷	1,544,000	647
128 kbps Serial	1,000,000,000	÷	128,000	7812
64 kbps Serial	1,000,000,000	÷	64,000	15625

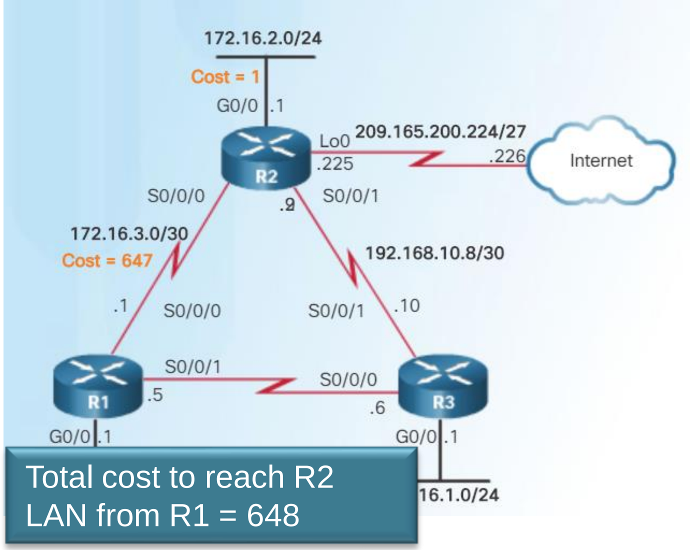
auto-cost reference-bandwidth 1000 command applied

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gbps Ethernet	10,000,000,000	÷	10,000,000,000	1
1 Gbps Ethernet	10,000,000,000	÷	1,000,000,000	10
100 Mbps Ethernet	10,000,000,000	÷	100,000,000	100
10 Mbps Ethernet	10,000,000,000	÷	10,000,000	1000
1.544 Mbps Serial	110,000,000,000	÷	1,544,000	6477
128 kbps Serial	10,000,000,000	÷	128,000	78126
64 kbps Serial	10,000,000,000	÷	64,000	156250

auto-cost reference-bandwidth 10000 command applied

Adjusting the Reference Bandwidth (Cont.)

- If the routers in the topology are adjusted to accommodate Gigabit links, the cost of the serial link is now 647 instead of 64. The total cost from R1 to the R2 LAN is now 648 instead of 65.
- If there were FastEthernet links in the topology, OSPF would make better choices.

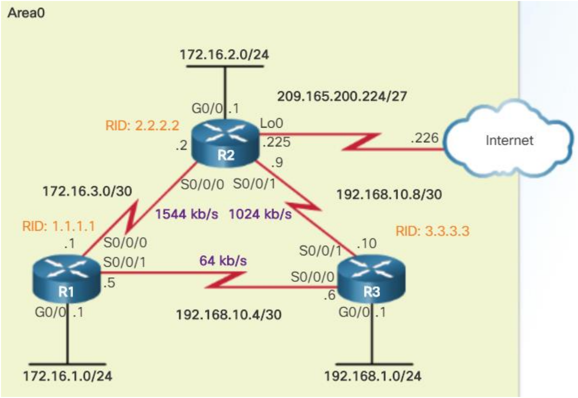



```
R1# show ip ospf interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
 Internet Address 172.16.3.1/30,Area 0,Attached via Network Statement
 Process ID 10,Router ID 1.1.1.1,Network Type POINT_TO_POINT,Cost:647
 Topology-MTID     Cost     Disabled     Shutdown      Topology Name
       0           647         no           no            Base
```

```
R1# show ip route | include 172.16.2.0
O        172.16.2.0/24 [110/648] via 172.16.3.2, 00:06:03, Serial0/0/0
R1#
R1# show ip route 172.16.2.0
Routing entry for 172.16.2.0/24
  Known via "ospf 10", distance 110, metric 648, type intra area
  Last update from 172.16.3.2 on Serial0/0/0, 00:06:17 ago
  Routing Descriptor Blocks:
  * 172.16.3.2, from 2.2.2.2, 00:06:17 ago, via Serial0/0/0
      Route metric is 648, traffic share count is 1
```

Default Interface Bandwidth

- Bandwidth values defined on an interface do not change the capacity of the interface.
- Bandwidth values defined on an interface are used by the EIGRP and OSPF routing protocols to compute the metric.
- Serial links default to 1.544 Mbps and that might not be an accurate bandwidth for the transmission rate.
- Use the **show interfaces** command to see the interface bandwidth..




```
R1# show interfaces serial 0/0/0
Serial0/0/0 is up, line protocol is up
    Hardware is WIC MBRD Serial
    Description: Link to R2
    Internet address is 172.16.3.1/30
    MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
       reliability 255/255, txload 1/255, rxload 1/255
```

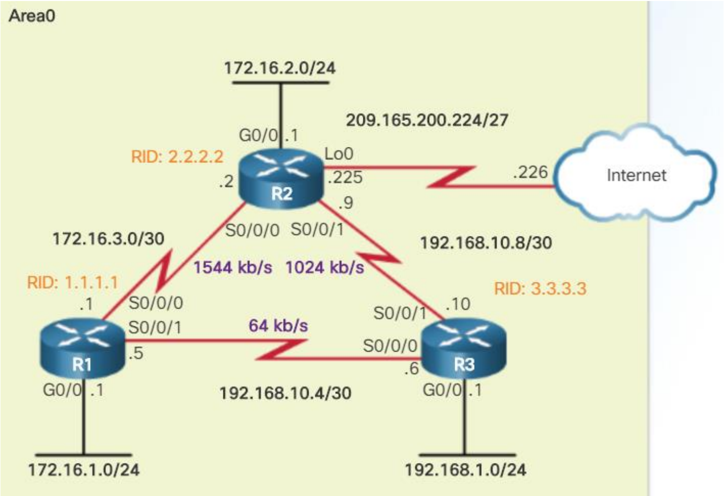
```
R1# show ip ospf interface serial 0/0/1
Serial0/0/1 is up, line protocol is up
    Internet Address 192.168.10.5/30, Area 0, Attached via
    Network Statement
    Process ID 10, Router ID 1.1.1.1, Network Type
    POINT_TO_POINT, Cost: 647
    Topology-MTID    Cost    Disabled    Shutdown    Topology Name
          0           647       no          no           Base
```

```
R1# show interfaces serial 0/0/1 | include BW
    MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
```

```
R1# show ip ospf interface serial 0/0/1 | include Cost:
    Process ID 10, Router ID 1.1.1.1, Network Type
POINT_TO_POINT, Cost: 647
```

OSPF Cost

Adjusting the Interface Bandwidth




```
R1(config)# int s0/0/1
R1(config-if)# bandwidth 64
R1(config-if)# end
R1#
*Mar 27 10:10:07.735: %SYS-5-CONFIG_I: Configured from console by c
R1#
R1#  show interfaces serial 0/0/1 | include BW
  MTU 1500 bytes, BW 64 Kbit/sec, DLY 20000 usec,
R1#
R1#  show ip ospf interface serial 0/0/1 | include Cost:
  Process ID 10, Router ID 1.1.1.1, Network Type
  POINT_TO_POINT, Cost: 15625
R1#
```

- The bandwidth must be adjusted at each end of the serial links, therefore:
  - R2 requires its S0/0/1 interface to be adjusted to 1,024 kb/s.
  - R3 requires its serial 0/0/0 to be adjusted to 64 kb/s and its serial 0/0/1 to be adjusted to 1,024 kb/s.
- Note: Command only modifies OSPF bandwidth metric. Does not modify the actual link bandwidth.

Manually Setting the OSPF Cost

- Instead of manually setting the interface bandwidth, the OSPF cost can be manually configured using the **ip ospf cost** *value* interface configuration mode command.

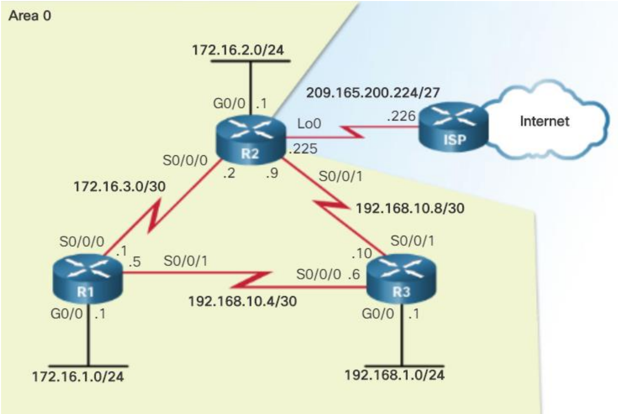
The **no bandwidth 64** is used to remove the command that was previously applied and reset the bandwidth back to the default.

```
R1(config)# int s0/0/1
R1(config-if)# no bandwidth 64
R1(config-if)# ip ospf cost 15625
R1(config-if)# end
R1#
R1# show interface serial 0/0/1 | include BW
    MTU 1500 bytes, BW 1544 Kbit/sec, DLY 20000 usec,
R1#
R1# show ip ospf interface serial 0/0/1 | include Cost:
    Process ID 10, Router ID 1.1.1.1, Network Type POINT_TO_POINT,
    Cost: 15625
```

Adjusting the Interface Bandwidth	= Manually Setting the OSPF Cost
R1(config)# **interface S0/0/1** R1(config-if)# **bandwidth 64**	= R1(config)# **interface S0/0/1** R1(config-if)# **ip ospf cost 15625**
R2(config)# **interface S0/0/1** R2(config-if)# **bandwidth 1024**	= R2(config)# **interface S0/0/1** R2(config-if)# **ip ospf cost 976**
R3(config)# **interface S0/0/0** R3(config-if)# **bandwidth 64**	= R3(config)# **interface S0/0/0** R3(config-if)# **ip ospf cost 15625**
R3(config)# **interface S0/0/1** R3(config-if)# **bandwidth 1024**	= R3(config)# **interface S0/0/1** R3(config-if)# **ip ospf cost 976**

Verify OSPF Neighbors

- Use the **show ip ospf neighbor** to verify the router has formed an adjacency with a directly-connected router.

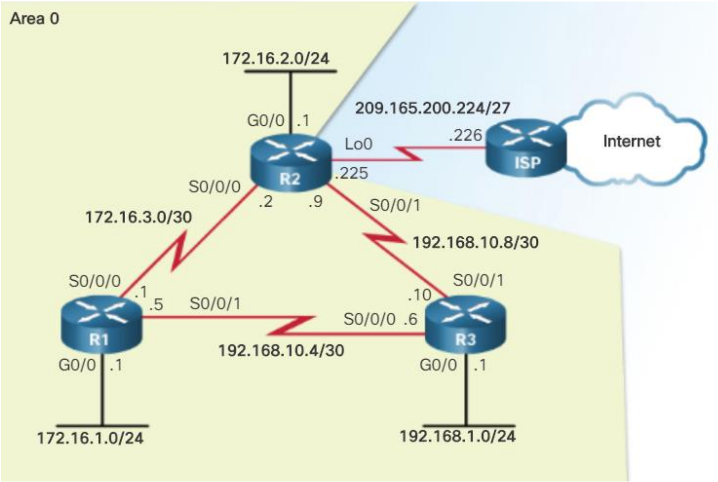



```
R1# show ip ospf neighbor

Neighbor ID  Pri State   Dead Time  Address       Interface
3.3.3.3        0  FULL/-  00:00:37  192.168.10.6  Serial0/0/1
2.2.2.2        0  FULL/-  00:00:30  172.16.3.2    Serial0/0/0
```

Output	Description
Neighbor ID	The router ID of the neighbor router
Pri	The OSPFv2 priority of the interface used in the DR/BDR election process
State	The OSPFv2 state – Full means that the link-state database has had the algorithm executed and the neighbor router and R1 have identical LSDBs. Ethernet multi-access interfaces may show as 2WAY. The dash indicates that no DR/BDR is required.
Dead time	Amount of time remaining before expecting to receive a hello packet from the neighbor before declaring the neighbor down. This value is reset when a hello packet is received.
Address	The address of the neighbor's directly-connected interface
Interface	The interface on R1 used to form an adjacency with the neighbor router

Verify OSPF Protocol Settings

- The **show ip protocols** command is used to verify the OSPFv2 process ID, router ID, networks being advertised by the router, neighbors that are sending OSPF updates, and the administrative distance (110 by default).




```
R1# show ip protocols
*** IP Routing is NSF aware ***

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:
    172.16.1.0 0.0.0.255 area 0
    172.16.3.0 0.0.0.3 area 0
    192.168.10.4 0.0.0.3 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    2.2.2.2              110      00:17:18
    3.3.3.3              110      00:14:49
  Distance: (default is 110)
```

Verify OSPF Process Information

- The **show ip ospf** command is another way to see the OSPFv2 process ID and router ID.

```
R1# show ip ospf
Routing Process "ospf 10" with ID 1.1.1.1
Start time: 01:37:15.156, Time elapsed: 01:32:57.776
Supports only single TOS(TOS0) routes
Supports opaque LSA
Supports Link-local Signaling (LLS)
Supports area transit capability
Supports NSSA (compatible with RFC 3101)
Event-log enabled, Maximum number of events: 1000, Mode:
cyclic
Router is not originating router-LSAs with maximum metric
Initial SPF schedule delay 5000 msecs
Minimum hold time between two consecutive SPFs 10000 msecs
Maximum wait time between two consecutive SPFs 10000 msecs
Incremental-SPF disabled
Minimum LSA interval 5 secs
Minimum LSA arrival 1000 msecs
LSA group pacing timer 240 secs
Interface flood pacing timer 33 msecs
Retransmission pacing timer 66 msecs
Number of external LSA 0. Checksum Sum 0x000000
Number of opaque AS LSA 0. Checksum Sum 0x000000
Number of DCbitless external and opaque AS LSA 0
Number of DoNotAge external and opaque AS LSA 0
Number of areas in this router is 1. 1 normal 0 stub 0
nssa
```

```
Number of areas transit capable is 0
External flood list length 0
IETF NSF helper support enabled
Cisco NSF helper support enabled
Reference bandwidth unit is 1000 mbps
       Area BACKBONE(0)
       Number of interfaces in this area is 3
       Area has no authentication
       SPF algorithm last executed 01:30:45.364 ago
       SPF algorithm executed 3 times
       Area ranges are
       Number of LSA 3. Checksum Sum 0x02033A
       Number of opaque link LSA 0. Checksum Sum 0x000000
       Number of DCbitless LSA 0
       Number of indication LSA 0
       Number of DoNotAge LSA 0
       Flood list length 0
```

Verify OSPF Interface Settings

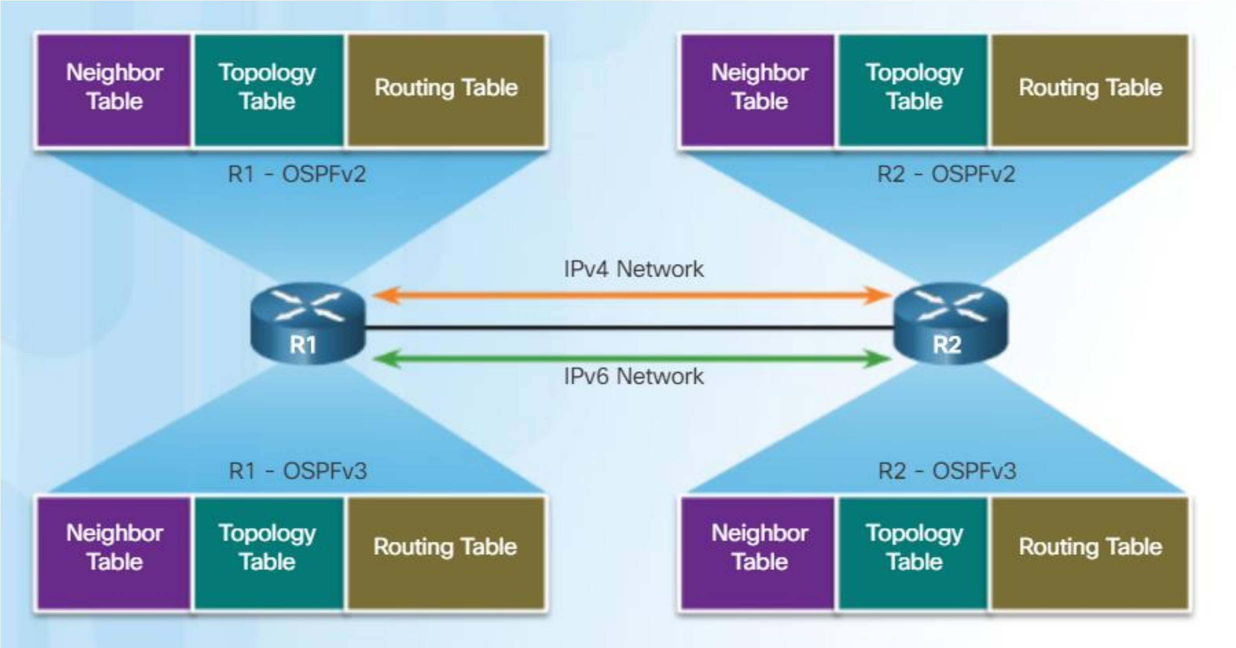
- Use the **show ip ospf interface** command to see details for every OSPFv2-enabled interface especially to see if the network statements were correctly composed.
- Use the **show ip ospf interface brief** command to see key information about OSPFv2-enabled interfaces on a particular router.

```
R1# show ip ospf interface brief
Interface  PID  Area  IP Address/Mask  Cost  State  Nbrs F/C
Se0/0/1    10   0     192.168.10.5/30  15625 P2P    1/1
Se0/0/0    10   0     172.16.3.1/30    647   P2P    1/1
Gi0/0      10   0     172.16.1.1/24    1     DR     0/0
```

Single-Area OSPFv3

OSPFv3

- OSPFv3 is used to exchange IPv6 prefixes and build an IPv6 routing table.
- OSPFv3 builds three OSPF tables – neighbor table, topology table, and routing table.



Similarities Between OSPFv2 and OSPFv3

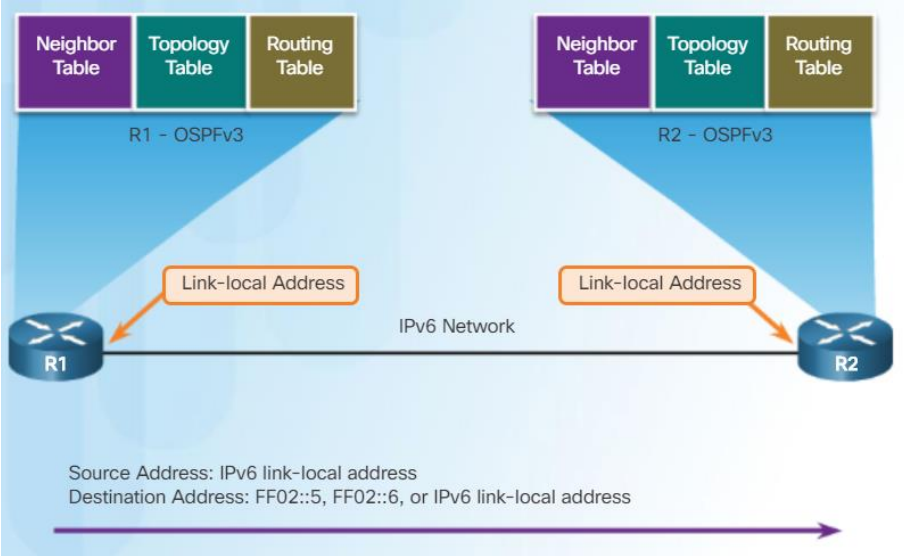
Feature	Comments
Link-State	Both are this type of routing protocol
Routing algorithm	Shortest Path First (SPF)
Metric	Cost
Areas	Both use and support a two-level hierarchy with areas connecting to Area 0
Packet types	Both use the same Hello, DBD, LSR, LSU, and LSAck packets
Neighbor discovery	Transitions through the same states using Hello packets
DR/BDR	Function and election process is the same
Router ID	Both use a 32-bit router ID; determined by the same process

Differences Between OSPFv2 and OSPFv3

Feature	OSPFv2	OSPFv3
Advertisements	IPv4 networks	IPv6 prefixes
Source address	IPv4 source address	IPv6 link-local address
Destination address	Choice of: • Neighbor IPv4 unicast address • 224.0.0.5 all-OSPF-routers multicast address • 224.0.0.6 DR/BDR multicast address	Choice of: • Neighbor IPv6 link-local address • FF02::5 all-OSPF-routers multicast address • FF02::6 DR/BDR multicast address
Advertise networks	Configured using the **network** router configuration command	Configured using the **ipv6 ospf** *process-id* **area** *area-id* interface configuration command
IP unicast routing	IPv4 unicast routing is enabled by default	IPv6 unicast forwarding is not enabled by default. Use the **ipv6 unicast-routing** global configuration command to enable.
Authentication	Plain text and MD5	IPv6 authentication (IPsec)

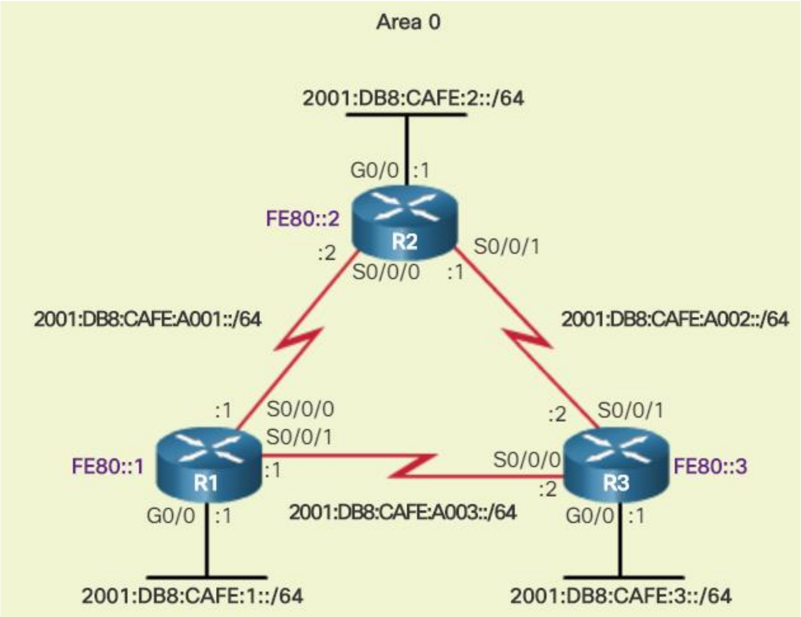
Link-Local Addresses

- An IPv6-link-local address enables a device to communicate with other IPv6-enabled devices on the same link and only on that link (subnet).
  - Packets with a source or destination link-local address cannot be routed beyond the link from where the packet originated.
- IPv6 link-local address are used to exchange OSPFv3 messages



OSPFv3 Network Topology

- Be sure to turn on IPv6 routing and assign IPv6 addresses to interfaces before enabling OSPFv3.




```
R1(config)# ipv6 unicast-routing
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# description R1 LAN
R1(config-if)# ipv6 address 2001:DB8:CAFE:1::1/64
R1(config-if)# no shut
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# description Link to R2
R1(config-if)# ipv6 address 2001:DB8:CAFE:A001::1/64
R1(config-if)# clock rate 128000
R1(config-if)# no shut
R1(config-if)#
R1(config-if)# interface Serial0/0/1
R1(config-if)# description Link to R3
R1(config-if)# ipv6 address 2001:DB8:CAFE:A003::1/64
R1(config-if)# no shut
```

The FE80 address on each router represents the link-local address assigned to each router.

OSPFv3 Network Topology (Cont.)

Steps to Configure OSPFv3

1. Enable IPv6 unicast routing in global configuration mode – **ipv6 unicast-routing**
2. (Optional) Configure link-local addresses.
3. Configure a 32-bit router ID in OSPFv3 router configuration mode – **router-id** *rid*
4. Configure optional routing specifics such as adjusting the reference bandwidth.
5. (Optional, but optimum) Configure OSPFv3 interface specific settings such as setting the interface bandwidth on serial links.
6. Enable OSPFv3 routing in interface configuration mode – **ipv6 ospf area**

Link-Local Addresses

- Verify IPv6 addresses on interfaces.
- Remember that link-local addresses are automatically created when an IPv6 global unicast address is assigned to an interface. However, IPv6 global unicast addresses are not required. Link-local addresses are required for OSPFv3.
- Unless configured manually, Cisco routers create a link-local address using FE80::/10 prefix and the EUI-64 process by manipulating the 48-bit Ethernet MAC address.

```
R1# show ipv6 interface brief
Em0/0                      [administratively down/down]
   unassigned
GigabitEthernet0/0         [up/up]
   FE80::32F7:DFF:FEA3:DA0
   2001:DB8:CAFE:1::1
GigabitEthernet0/1         [administratively down/down]
   unassigned
Serial0/0/0                [up/up]
   FE80::32F7:DFF:FEA3:DA0
   2001:DB8:CAFE:A001::1
Serial0/0/1                [up/up]
   FE80::32F7:DFF:FEA3:DA0
   2001:DB8:CAFE:A003::1
```

Assigning Link-Local Addresses

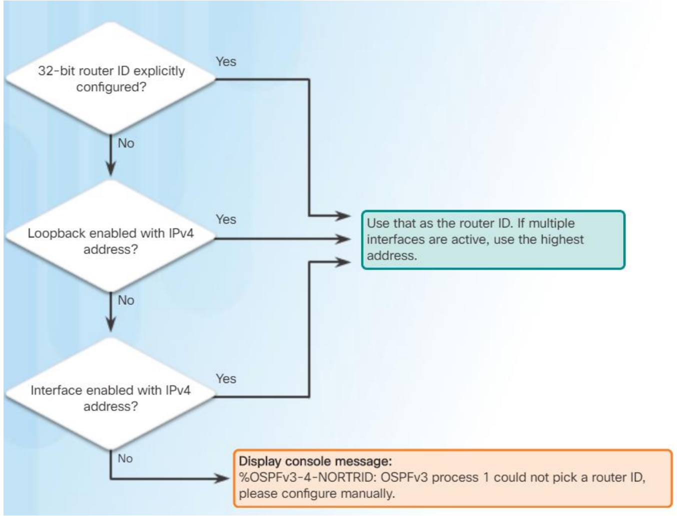
- Manually configuring link-local addresses make it easier to manage and verify OSPFv3 configurations.
  - Use the **ipv6 address link-local** interface command to apply.
  - Use the **show ipv6 interface brief** command to verify.

```
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# exit
R1(config)# interface Serial0/0/0
R1(config-if)# ipv6 address fe80::1 link-local
R1(config-if)# exit
R1(config)# interface Serial0/0/1
R1(config-if)# ipv6 address fe80::1 link-local
```

```
R1# show ipv6 interface brief
Em0/0                  [administratively down/down]
    unassigned
GigabitEthernet0/0     [up/up]
    FE80::1
    2001:DB8:CAFE:1::1
GigabitEthernet0/1     [administratively down/down]
    unassigned
Serial0/0/0            [up/up]
    FE80::1
    2001:DB8:CAFE:A001::1
Serial0/0/1            [up/up]
    FE80::1
    2001:DB8:CAFE:A003::1
```

Configuring the OSPFv3 Router ID

- Use the **ipv6 router ospf** *process-id* global configuration command to enter router configuration mode.
- Use the **router-id** *rid* command in router configuration mode to assign a router ID and use the **show ipv6 protocols** command to verify.



Same process as OSPFv2

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)#
*Mar 29 11:21:53.739: %OSPFv3-4-NORTRID: Process OSPFv3-1-
IPv6 could not pick a router-id, please configure manually
R1(config-rtr)#
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)#
R1(config-rtr)# auto-cost reference-bandwidth 1000
% OSPFv3-1-IPv6:  Reference bandwidth is changed. Please
ensure reference bandwidth is consistent across all routers.
R1(config-rtr)#
R1(config-rtr)# end
R1#
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
    None
```

Notice the message

Modifying an OSPFv3 Router ID

- Use the **clear ipv6 ospf process** privileged EXEC mode command after changing the router ID to complete the router ID change and force a router to renegotiate neighbor adjacencies using the new router ID.

Commonly forgotten step

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 10.1.1.1
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
   None
```

Original router ID

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# end
R1#
```

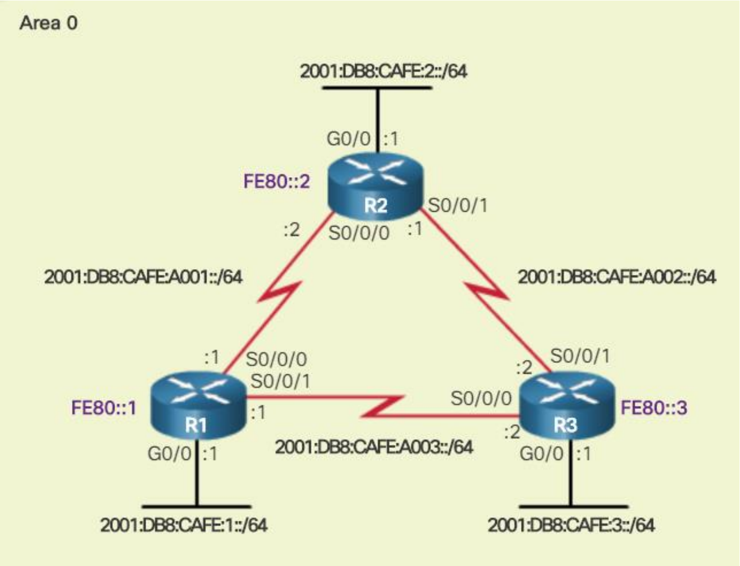
Change the router ID.

```
R1# clear ipv6 ospf process
Reset selected OSPFv3 processes? [no]: y
R1#
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Number of areas: 0 normal, 0 stub, 0 nssa
  Redistribution:
    None
```

Complete the router ID change.

Enabling OSPFv3 on Interfaces

- Use the **ipv6 ospf area** interface configuration mode command to enable OSPFv3 on a specific interface. Ensure the interface is within an OSPF area.
- Use the **show ipv6 ospf interfaces brief** command to verify.




```
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# interface Serial0/0/1
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)#
R1(config-if)# end
R1#
R1# show ipv6 ospf interfaces brief
Interface   PID   Area     Intf ID   Cost    State   Nbrs F/C
Se0/0/1     10     0         7       15625   P2P     0/0
Se0/0/0     10     0         6       647     P2P     0/0
Gi0/0       10     0         3         1     WAIT    0/0
R1#
```


Verifying OSPFv3 Neighbors

- Use the **show ipv6 ospf neighbor** command to verify neighbor connectivity with directly-connected routers.

```
R1# show ipv6 ospf neighbor

OSPFv3 Router with ID (1.1.1.1) (Process ID 10)

Neighbor ID    Pri   State     Dead Time   Interface ID Interface
3.3.3.3          0   FULL/  -   00:00:39   6            Serial0/0/1
2.2.2.2          0   FULL/  -   00:00:36   6            Serial0/0/0
```

Output	Description
Neighbor ID	The router ID of the neighbor router
Pri	The OSPFv3 priority of the interface used in the DR/BDR election process
State	The OSPFv3 state – Full means that the link-state database has had the algorithm executed and the neighbor router and R1 have identical LSDBs. Ethernet multi-access interfaces may show as 2WAY. The dash indicates that no DR/BDR is required.
Dead time	Amount of time remaining before expecting to receive an OSPFv3 Hello packet from the neighbor before declaring the neighbor down. This value is reset when a hello packet is received.
Address	The address of the neighbor's directly-connected interface
Interface	The interface on R1 used to form an adjacency with the neighbor router

Verifying OSPFv3 Protocol Settings

- Use the **show ipv6 protocols** command to verify vital OSPFv3 configuration information.

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
 Router ID 1.1.1.1
 Number of areas: 1 normal, 0 stub, 0 nssa
 Interfaces (Area 0):
   Serial0/0/1
   Serial0/0/0
   GigabitEthernet0/0
```

Verify OSPFv3 Interfaces

- Use the **show ipv6 ospf interface** command to display a detailed list for every OSPFv3-enabled interface.
- The **show ipv6 ospf interface brief** command is an easier output to verify which interfaces are being used with OSPFv3.

```
R1# show ipv6 ospf interface brief
Interface    PID   Area            Intf ID    Cost  State Nbrs F/C
Se0/0/1      10    0               7          15625 P2P   1/1
Se0/0/0      10    0               6          647   P2P   1/1
Gi0/0        10    0               3          1     DR    0/0
```

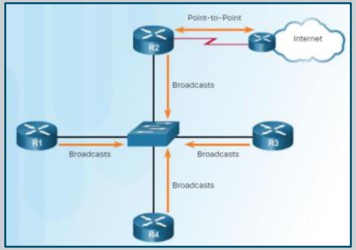
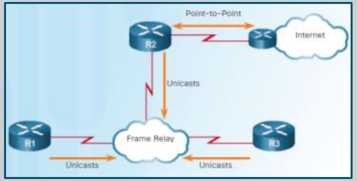
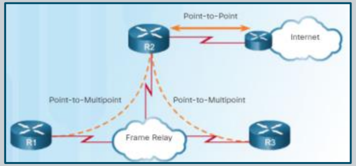
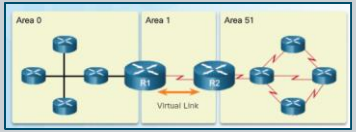
Verify The IPv6 Routing Table

- Use the **show ipv6 route** command to see an IPv6 routing table.
- Use the **show ipv6 route ospf** command to see just the OSPFv3 routes.

```
R1# show ipv6 route ospf
IPv6 Routing Table - default - 10 entries
Codes:C - Connected, L - Local, S - Static, U - Per-user Static route
      B - BGP, R - RIP, H - NHRP, I1 - ISIS L1
      I2 - ISIS L2, IA - ISIS interarea, IS - ISIS summary, D - EIGRP
      EX - EIGRP external, ND - ND Default, NDp - ND Prefix, DCE - Destination
      NDr - Redirect, O - OSPF Intra, OI - OSPF Inter, OE1 - OSPF ext 1
     OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
 O   2001:DB8:CAFE:2::/64 [110/657]
     via FE80::2, Serial0/0/0
 O   2001:DB8:CAFE:3::/64 [110/1304]
     via FE80::2, Serial0/0/0
 O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
```

Advanced Single-Area OSPF Configurations

OSPF Network Types

Point-to-point	Broadcast multiaccess	Nonbroadcast multiaccess (NBMA)	Point-to-multipoint	Virtual links
• Two routers interconnected over a common link. • No other routers are on the link. • Common configuration in WAN links.	• Multiple routers interconnected over an Ethernet network. • Ethernet LANs are the most common example of broadcast multiaccess networks.	• Multiple routers interconnected in a network that does not allow broadcasts. • The Frame Relay WAN protocol is an example NBMA network.	• Multiple routers interconnected in a hub-and-spoke topology over an NBMA network. • Often used to connect branch sites (spokes) to a central site (hub).	• Special OSPF network used to interconnect distant OSPF areas to the backbone area.
				

Challenges in Multiaccess Networks

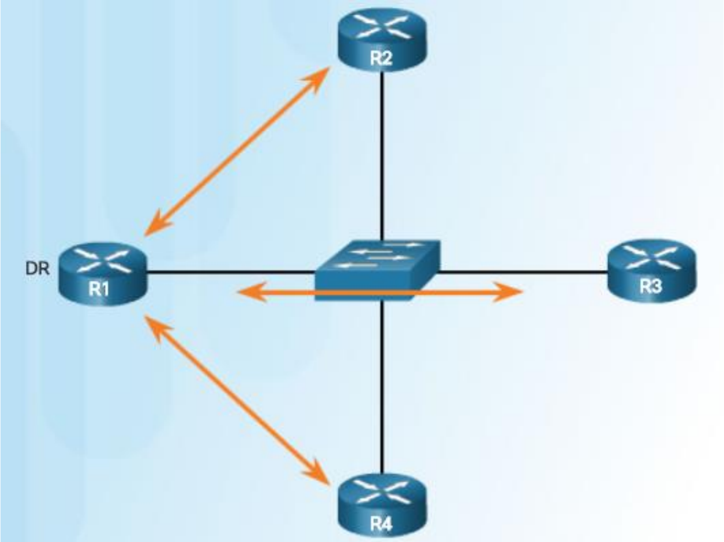
- Multiaccess networks create two challenges regarding the flooding of OSPF LSAs.

OSPF Challenges	Description	
Creation of multiple adjacencies	• Ethernet networks could potentially interconnect many OSPF routers creating numerous adjacencies with every router. • Use the ***n* (*n*-1) / 2** formula to calculate the number of adjacencies required for any number of routers (i.e., *n*) on a multiaccess network.	(see table below)
Extensive flooding of LSAs	• Link-state routers flood their link-state packets when OSPF is initialized, or when there is a change in the topology. • This flooding can become excessive.	

Routers *n*	Adjacencies *n* (*n*-1)/2
4	6
5	10
10	45
20	190
50	1225

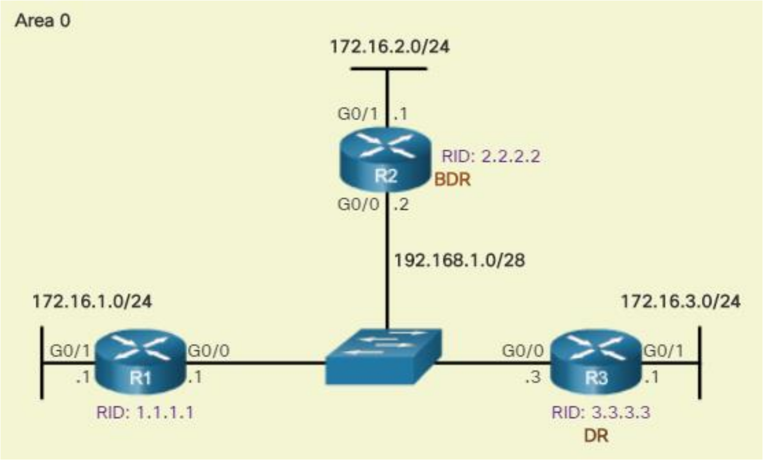
OSPF Designated Router

- 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. If the DR stops producing Hello packets, the BDR promotes itself and assumes the role of DR.
  - All other non-DR or BDR routers become DROTHER (a router that is neither the DR nor the BDR) and DROTHERs only form full adjacencies with the DR and BDR in the network.
  - Instead of flooding LSAs to all routers in the network, DROTHERs only send their LSAs to the DR and BDR using the multicast address 224.0.0.6 (all DR routers).



Verifying DR/BDR Roles

- OSPF has automatically elected a DR and BDR.



- R3 is the DR because of its higher router ID.
- R2 is the BDR because of its 2nd highest router ID.
- R1 is a DROTHER.

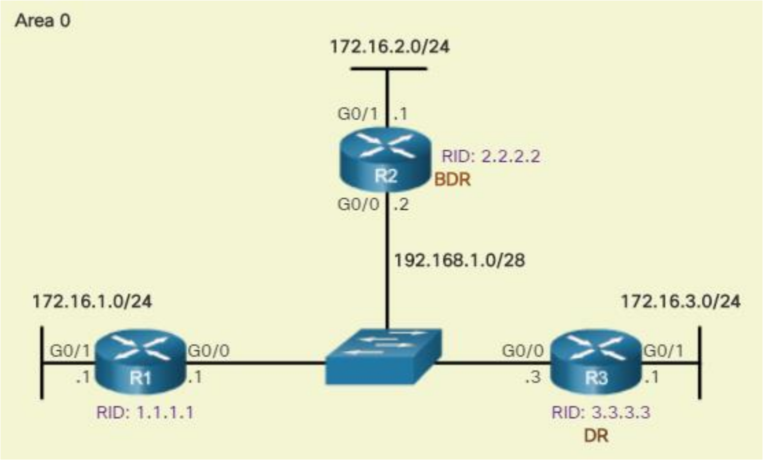
Verify the roles of the OSPFv2 router using the **show ip ospf interface** command.

```
R3# show ip ospf interface GigabitEthernet 0/0
GigabitEthernet0/0 is up, line protocol is up
 Internet Address 192.168.1.3/28,Area 0,Attached via Network Statement
 Process ID 10, Router ID 3.3.3.3, Network Type BROADCAST, Cost: 1
 Topology-MTID    Cost    Disabled    Shutdown      Topology Name
      0           1          no          no            Base
 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
 Timer intervals configured, Hello 10, Dead 40, Wait 40, 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
 Index 2/2, flood queue length 0
 Next 0x0(0)/0x0(0)
 Last flood scan length is 3, maximum is 3
 Last flood scan time is 0 msec, maximum is 0 msec
 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#
```

Note: For the equivalent OSPFv3 command, simply substitute **ip** with **ipv6**.

Verifying DR/BDR Adjacencies

- Verify OSPFv2 adjacencies using **show ip ospf neighbor**.




```
R1# show ip ospf neighbor

Neighbor ID Pri State        Dead Time  Address      Interface

2.2.2.2       1  FULL/BDR     00:00:36  192.168.1.2 GigabitEthernet0/0

3.3.3.3       1  FULL/DR      0:00:35   192.168.1.3 GigabitEthernet0/0

R1#
```

```
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

3.3.3.3       1  FULL/DR      00:00:39  192.168.1.3 GigabitEthernet0/0

R2#
```

```
R3# show ip ospf neighbor

Neighbor ID Pri State         Dead Time  Address      Interface

1.1.1.1       1  FULL/DROTHER 00:00:34  192.168.1.1 GigabitEthernet0/0

2.2.2.2       1  FULL/BDR     00:00:39  192.168.1.2 GigabitEthernet0/0

R3#
```

- Routers can be in the following states:
  - FULL/DROTHER
  - FULL/DR
  - FULL/BDR
  - 2-WAY/DROTHER

Note: For the equivalent OSPFv3 command, simply substitute **ip** with **ipv6**.

Default DR/BDR Election Process

- The OSPF DR and BDR election decision 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 elected as the BDR.
   - The priority can be configured to be any number between 0 – 255 but the default priority 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.

- Recall that the router ID is determined in one of three ways:
  - The router ID can be manually configured.
  - If no router IDs are configured, the router ID is determined by the highest loopback IPv4 address.
  - If no loopback interfaces are configured, the router ID is determined by the highest active IPv4 address.

Note: In an IPv6 network, if there are no IPv4 addresses configured on the router, then the router ID must be manually configured with the **router-id** *rid* router configuration command; otherwise, OSPFv3 does not start.

DR/BDR Election Process

- 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.

- OSPF DR and BDR elections are not pre-emptive.
  - If a new router with a higher priority is added to the network after the DR election, the newly added router does not take over the DR or the BDR role because those roles have already been assigned.
  - If the DR fails, the BDR is automatically promoted to DR even if another DROTHER with a higher priority or router ID is added to the network after the initial DR/BDR election.
  - After a BDR is promoted to DR, a new BDR election occurs and the DROTHER with the higher priority or router ID is elected as the new BDR.

The OSPF Priority

- To control the DR and BDR election, the priority of an interface can be configured using:
  - **ip ospf priority** *value* - OSPFv2 interface command
  - **ipv6 ospf priority** *value* - OSPFv3 interface command

- The *value* can be:
  - **0** - Does not become a DR or BDR.
  - **1 – 255** - The higher the priority value, the more likely the router becomes the DR or BDR on the interface.

Changing the OSPF Priority

- Changing the priority value on an interface from 1 to a higher value would enable the router to become a DR or BDR router during the next election.
  - Priority changes do not automatically take effect because the DR and BDR are already elected.

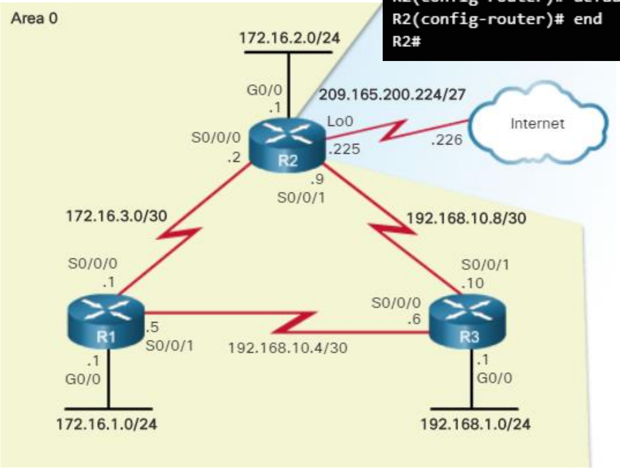
- To force an election, use one of the following methods:
  - Shutdown the router interfaces and then re-enable them starting with the desired DR, then the desired BDR, and then all other routers.
  - Reset the OSPF process using the **clear ip ospf process** privileged EXEC mode command on all routers.

Default Route Propagation

- An OSPF ASBR router (aka, edge, entrance, or the gateway router) connects to the Internet and can be configured to propagate a default route to other routers in the OSPF routing domain.

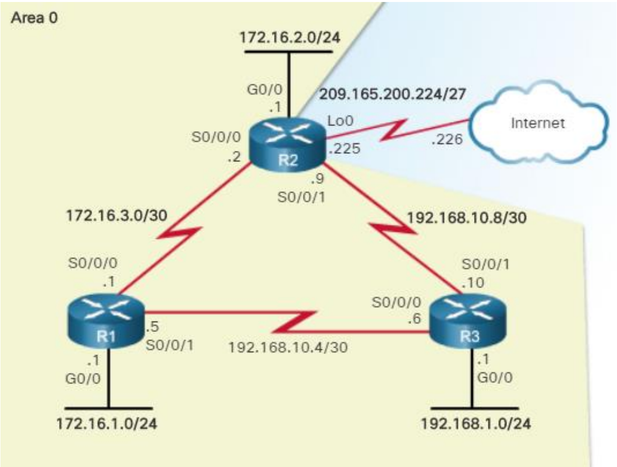
- To propagate a default route, R2 is configured with:
  - A default static route.
    - **ip route 0.0.0.0 0.0.0.0** {*ip-address* **|** *exit-intf*} command.
  - The **default-information originate** router config mode command to propagate the default route in OSPF updates.

```
R2(config)# ip route 0.0.0.0 0.0.0.0 209.165.200.226
R2(config)#
R2(config)# router ospf 10
R2(config-router)# default-information originate
R2(config-router)# end
R2#
```



Verifying the Propagated Default Route

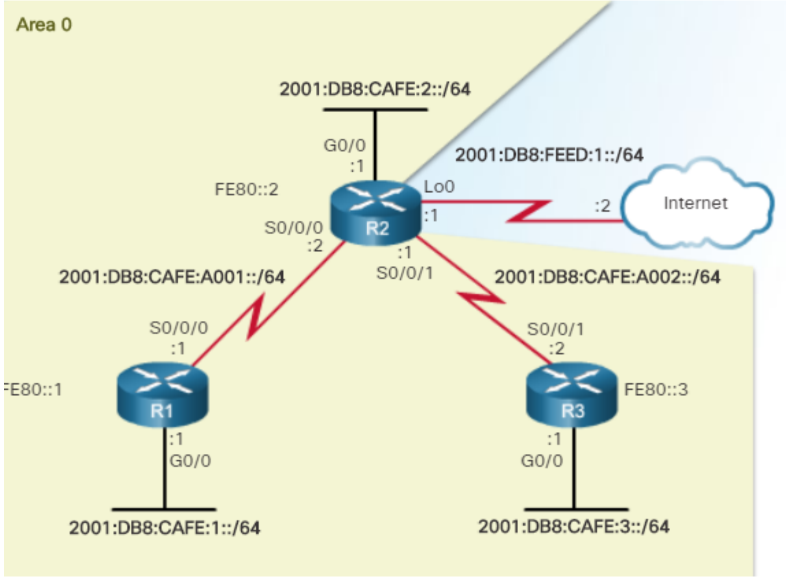
- Use the **show ip route** command to verify the default route settings..




```
R2# show ip route | begin Gateway

Gateway of last resort is 209.165.200.226 to network 0.0.0.0

S* 0.0.0.0/0 [1/0] via 209.165.200.226, Loopback0
   172.16.0.0/16 is variably subnetted, 5 subnets, 3 masks
O  172.16.1.0/24 [110/65] via 172.16.3.1, 00:01:44,
   Serial0/0/0
C  172.16.2.0/24 is directly connected, GigabitEthernet0/0
L  172.16.2.1/32 is directly connected, GigabitEthernet0/0
C  172.16.3.0/30 is directly connected, Serial0/0/0
L  172.16.3.2/32 is directly connected, Serial0/0/0
O  192.168.1.0/24 [110/65] via 192.168.10.10, 00:01:12,
   Serial0/0/1
   192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
O  192.168.10.4/30 [110/128] via 192.168.10.10, 00:01:12,
   Serial0/0/1
            [110/128] via 172.16.3.1, 00:01:12, Serial0/0/0
C  192.168.10.8/30 is directly connected, Serial0/0/1
L  192.168.10.9/32 is directly connected, Serial0/0/1
   209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C  209.165.200.224/30 is directly connected, Loopback0
L  209.165.200.225/32 is directly connected, Loopback0
R2#
```

Propagating a Default Static Route in OSPFv3

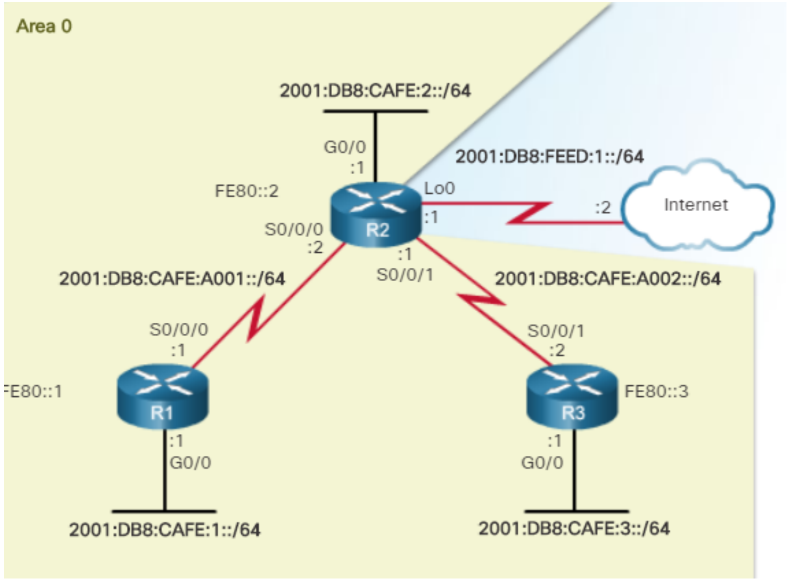
- To propagate a default route, the edge router (R2) must be configured with:
  - A default static route using the **ipv6 route ::/0 {***ipv6-address* **|** *exit-intf***}** command.
  - The **default-information originate** router configuration mode command.




```
R2(config)# ipv6 route ::/0 2001:DB8:FEED:1::2
R2(config)#
R2(config)# ipv6 router ospf 10
R2(config-rtr)# default-information originate
R2(config-rtr)# end
R2#
*Apr 10 11:36:21.995: %SYS-5-CONFIG_I: Configured from console by console
R2#
```

Verifying the Propagated IPv6 Default Route

- Verify the default static route setting on R2 using the **show ipv6 route static** command.




```
R2# show ipv6 route static
IPv6 Routing Table - default - 12 entries
Codes:C -Connected, L - Local, S - Static, U - Per-user Static route
      B -BGP, R - RIP, H - NHRP, I1 - ISIS L1
      I2 -ISIS L2, IA - ISIS interarea, IS-ISIS summary,D-EIGRP
      EX -EIGRP external, ND-ND Default,NDp-ND Prefix,DCE-Destination
      NDr -Redirect, O - OSPF Intra,OI-OSPF Inter,OE1-OSPF ext 1
      OE2 -OSPF ext 2, ON1 - OSPF NSSA ext 1, ON2 - OSPF NSSA ext 2
S   ::/0 [1/0]
     via 2001:DB8:FEED:1::2, Loopback0
R2#
```

OSPF Hello and Dead Intervals

- The OSPF Hello and Dead intervals used between two adjacent peers must match or a neighbor adjacency does not occur.
  - The OSPF Hello and Dead intervals are configurable on a per-interface basis.
  - The Serial 0/0/0 Hello and Dead intervals are set to the default 10 seconds and 40 seconds respectively.
- To verify the currently configured OSPFv2 interface intervals, use the **show ip ospf interface** command
- Use the **show ip ospf neighbor** command to verify that a router is adjacent with other routers.

```
R1# show ip ospf interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
  Internet Address 172.16.3.1/30, Area 0, Attached via
Network Statement
  Process ID 10, Router ID 1.1.1.1, Network Type
POINT_TO_POINT, Cost: 64
 Topology-MTID  Cost  Disabled   Shutdown   Topology Name
       0         64      no         no           Base
  Transmit Delay is 1 sec, State POINT_TO_POINT
  Timer intervals configured, Hello 10, Dead 40, Wait 40,
Retransmit 5
    oob-resync timeout 40
    Hello due in 00:00:03
  Supports Link-local Signaling (LLS)
  Cisco NSF helper support enabled
  IETF NSF helper support enabled
  Index 2/2, flood queue length 0
  Next 0x0(0)/0x0(0)
  Last flood scan length is 1, maximum is 1
  Last flood scan time is 0 msec, maximum is 0 msec
  Neighbor Count is 1, Adjacent neighbor count is 1
    Adjacent with neighbor 2.2.2.2
  Suppress hello for 0 neighbor(s)
R1#
R1# show ip ospf neighbor

Neighbor ID  Pri  State   Dead Time  Address       Interface
3.3.3.3       0   FULL/-  00:00:35   192.168.10.6 Serial0/0/1
2.2.2.2       0   FULL/-  00:00:33   172.16.3.2   Serial0/0/0
R1#
```

cisco

Modifying OSPFv2 Intervals

- OSPFv2 Hello and Dead intervals can be modified using the interface configuration mode commands:
  - **ip ospf hello-interval** *seconds*
  - **ip ospf dead-interval** *seconds*

```
R1(config)# interface serial 0/0/0
R1(config-if)# ip ospf hello-interval 5
R1(config-if)# ip ospf dead-interval 20
R1(config-if)# end
R1#
R1#
*Apr  7 17:28:21.529: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from FULL to DOWN, Neighbor Down: Dead timer expired
R1#
```

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

```
R2(config)# interface serial 0/0/0
R2(config-if)# ip ospf hello-interval 5
R2(config-if)#
*Apr  7 17:41:49.001: %OSPF-5-ADJCHG: Process 10, Nbr
1.1.1.1 on Serial0/0/0 from LOADING to FULL, Loading Done
R2(config-if)# end
R2#
```

```
R2# show ip ospf interface s0/0/0 | include Timer
  Timer intervals configured, Hello 5, Dead 20, Wait 20,
Retransmit 5
R2#
R2# show ip ospf neighbor

Neighbor ID   Pri  State  Dead Time  Address       Interface
3.3.3.3       0    FULL/- 00:00:35   192.168.10.10 Serial0/0/1
1.1.1.1       0    FULL/- 00:00:17   172.16.3.1    Serial0/0/0
R2#
```

Modifying OSPFv3 Intervals

- OSPFv3 Hello and Dead intervals can be modified using the interface configuration mode commands:
  - **ipv6 ospf hello-interval** *seconds*
  - **ipv6 ospf dead-interval** *seconds*

- Use the **no ipv6 ospf hello-interval** and **no ipv6 ospf dead-interval** interface configuration commands to reset the intervals to their default.

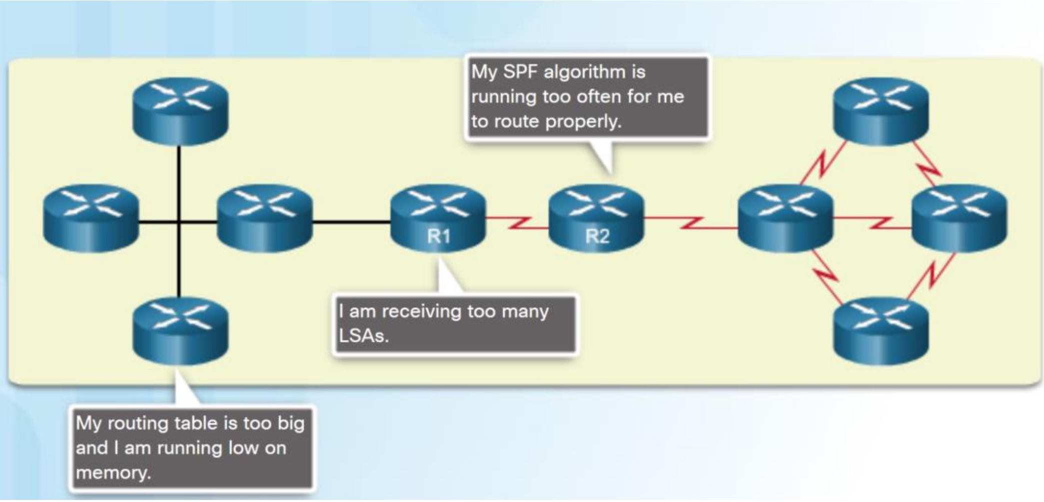
```
R1(config)# interface serial 0/0/0
R1(config-if)# ipv6 ospf hello-interval 5
R1(config-if)# ipv6 ospf dead-interval 20
R1(config-if)# end
R1#
*Apr 10 15:03:51.175: %OSPFv3-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from FULL to DOWN, Neighbor Down:
Dead timer expired
R1#
```

```
R2(config)# interface serial 0/0/0
R2(config-if)# ipv6 ospf hello-interval 5
R2(config-if)#
*Apr 10 15:07:28.815: %OSPFv3-5-ADJCHG: Process 10, Nbr
1.1.1.1 on Serial0/0/0 from LOADING to FULL, Loading Done
R2(config-if)# end
R2#
R2# show ipv6 ospf interface s0/0/0 | include Timer
  Timer intervals configured, Hello 5, Dead 20, Wait 20,
Retransmit 5
R2#
R2# show ipv6 ospf neighbor

          OSPFv3 Router with ID (2.2.2.2) (Process ID 10)

Neighbor ID Pri State  Dead Time Interface ID   Interface
3.3.3.3       0  FULL/- 00:00:38  7            Serial0/0/1
1.1.1.1       0  FULL/- 00:00:19  6            Serial0/0/0
R2#
```

Multiarea OSPF Operation

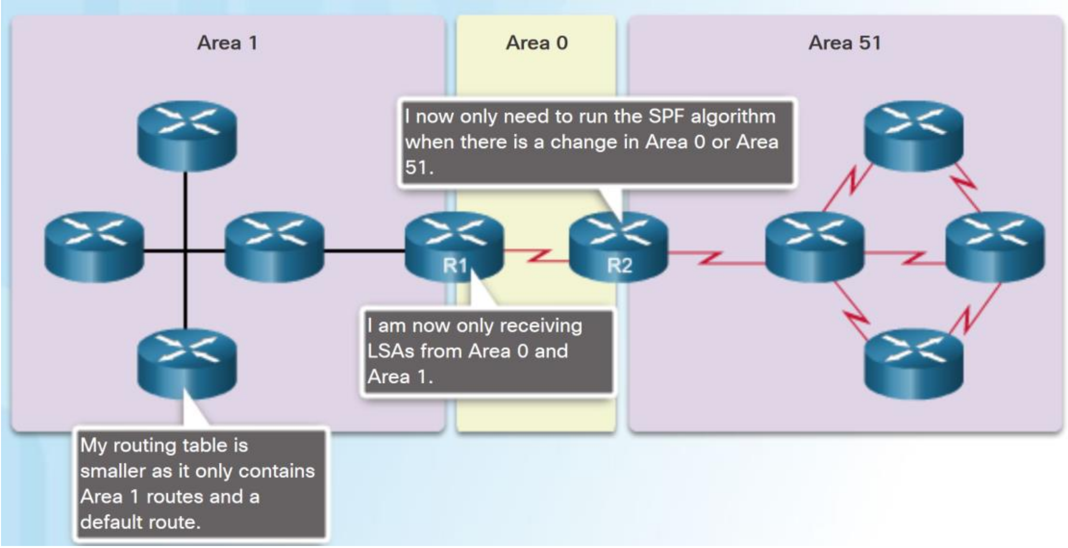
Single-Area OSPF

- Issues in a large single area OSPF:
  - Large routing table
  - Large link-state database (LSDB)
  - Frequent SPF algorithm calculations
- To make OSPF more efficient and scalable, OSPF supports hierarchical routing using areas.

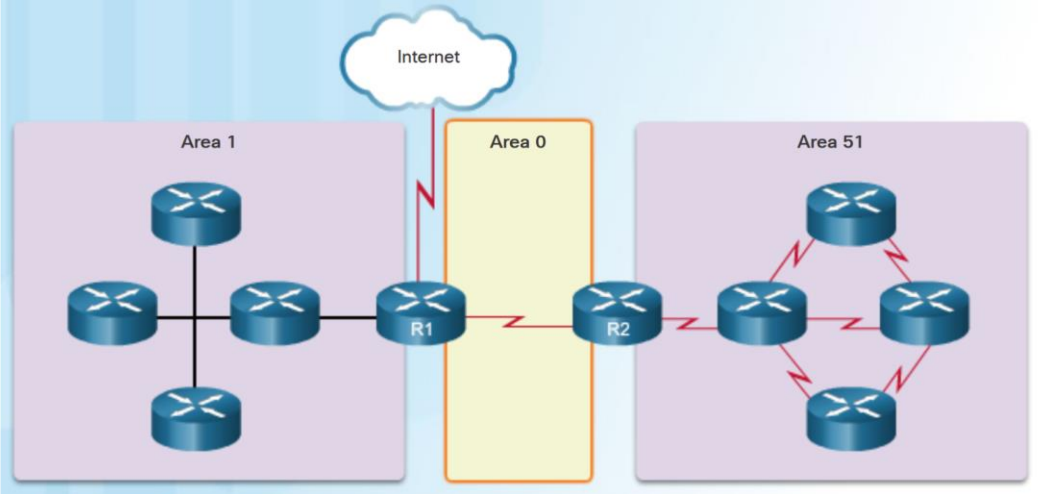


Multiarea OSPF

- Multiarea OSPF:
  - Large OSPF area is divided into smaller areas.
  - Reduces processing and memory overhead.
  - Requires a hierarchical network design.
  - The main area is the backbone area (area 0) and all other areas connect to it.
- Advantages of Multiarea OSPF:
  - Smaller routing tables - Fewer routing table entries as network addresses can be summarized between areas.
  - Reduced link-state update overhead.
  - Reduced frequency of SPF calculations.

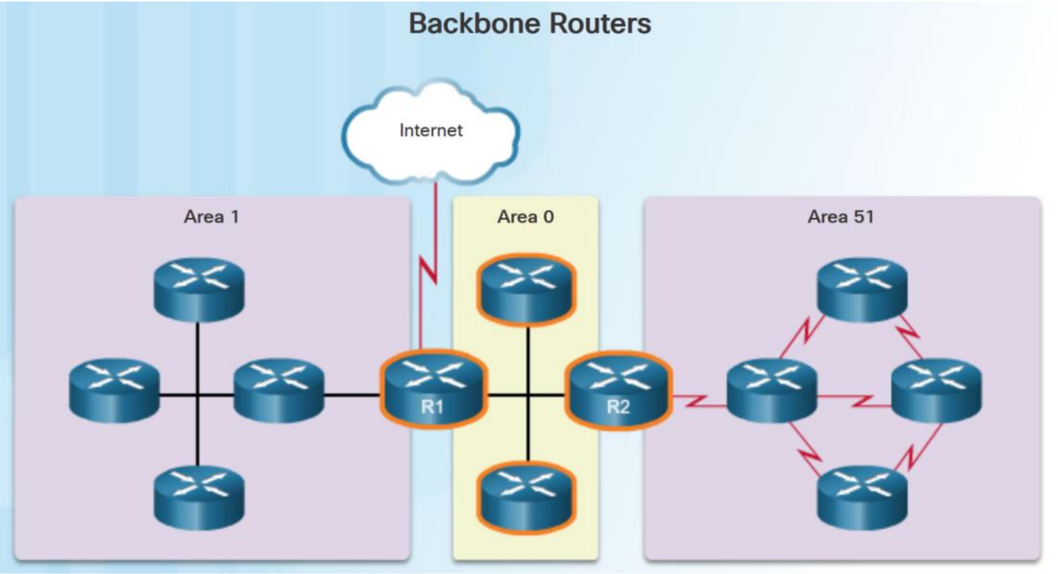


OSPF Two-Layer Area Hierarchy



- Multiarea OSPF is implemented in a two-layer area hierarchy.
- Backbone (Transit) area - An OSPF area whose primary function is the fast and efficient movement of IP packets:
  - Interconnects with other OSPF area types.
  - Also called OSPF area 0.
- Regular (nonbackbone) area - Connects users and resources:
  - Usually set up along functional or geographical groupings
  - All traffic from other areas must cross a transit area.

Types of OSPF Routers



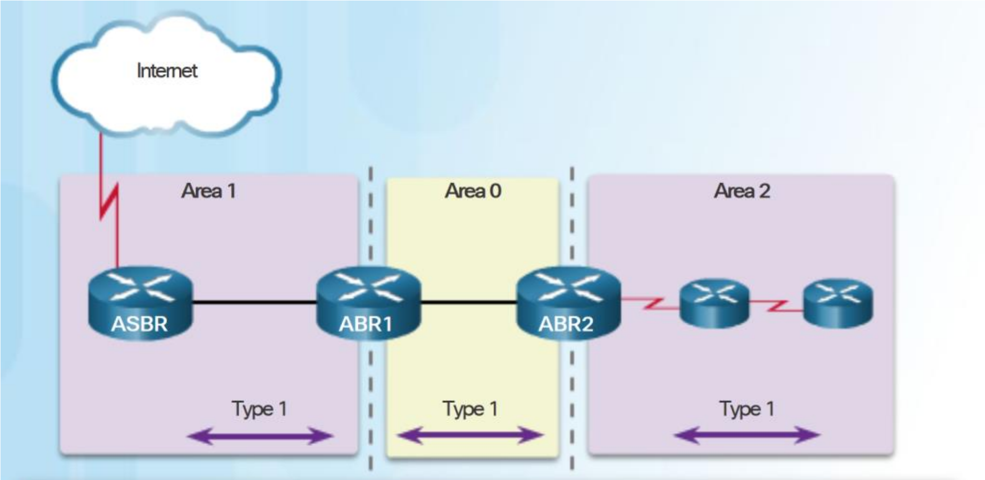
- There are four different types of OSPF routers:
  - Internal router –A router that has all of its interfaces in the same area.
  - Backbone router - A router in the backbone area. The backbone area is set to area 0
  - Area Border Router (ABR) – A router that has interfaces attached to multiple areas.
  - Autonomous System Boundary Router (ASBR) – A router that has at least one interface attached to an external internetwork.
- A router can be classified as more than one router type.

OSPF LSA Types

LSA Type	Description
1	Router LSA
2	Network LSA
3 and 4	Summary LSAs
5	AS External LSA
6	Multicast OSPF LSA
7	Defined for NSSAs
8	External Attributes LSA for Border Gateway Protocol (BGP)
9, 10, or 11	Opaque LSAs

- LSAs individually act as database records and provide specific OSPF network details.
- LSAs in combination describe the entire topology of an OSPF network or area.
- Any implementation of multiarea OSPF must support the first five LSAs

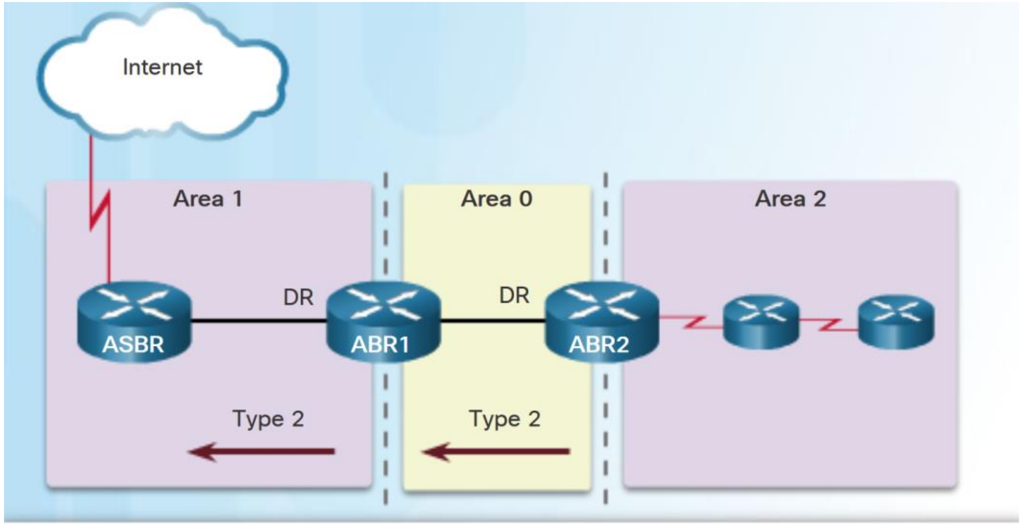
OSPF LSA Type 1



- Type 1 LSAs include a list of directly connected network prefixes and link types.
- All routers generate type 1 LSAs.
- Type 1 LSAs are flooded within the area and do not propagate beyond an ABR.
- A type 1 LSA link-state ID is identified by the router ID of the originating router.

- Routers advertise their directly connected OSPF-enabled links in a type 1 LSA .
- Type 1 LSAs are also referred to as router link entries.
- Type 1 LSAs are flooded only within the area in which they originated.
- ABRs advertise the networks learned from the type 1 LSAs to other areas as type 3 LSAs.
- The type 1 LSA link ID is identified by the router ID of the originating router.

OSPF LSA Type 2

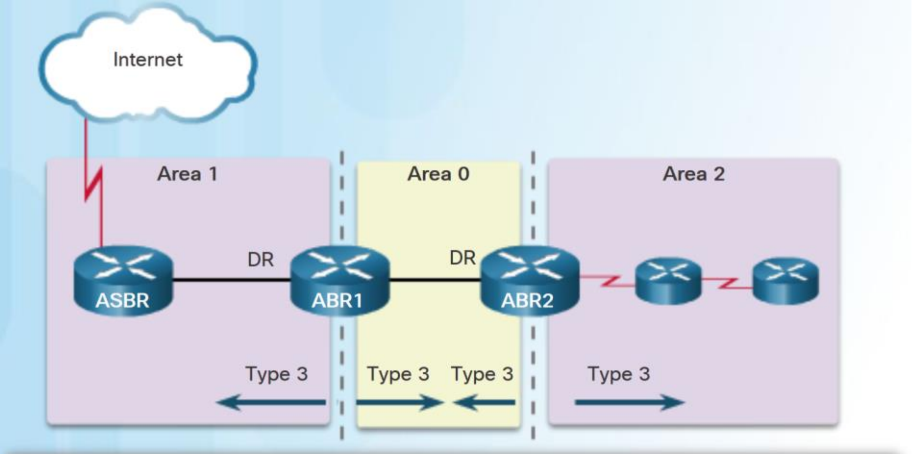


- Type 2 LSAs identify the routers and the network addresses of the multiaccess links.
- Only a DR generates a type 2 LSA.
- Type 2 LSAs are flooded within the multiaccess network and do not go beyond an ABR.
- A type 2 LSA link-state ID is identified by the DR router ID.

- Type 2 LSAs have the following characteristics:
  - Only found on multiaccess and nonbroadcast multiaccess (NBMA) networks
  - Contain the router ID and IP address of the DR, along with the router ID of all other routers on the multiaccess segment
  - Give other routers information about multiaccess networks within the same area
  - Not forwarded outside of an area
  - Also referred to as network link entries
  - Link-state ID is DR router ID

OSPF LSA Type 3

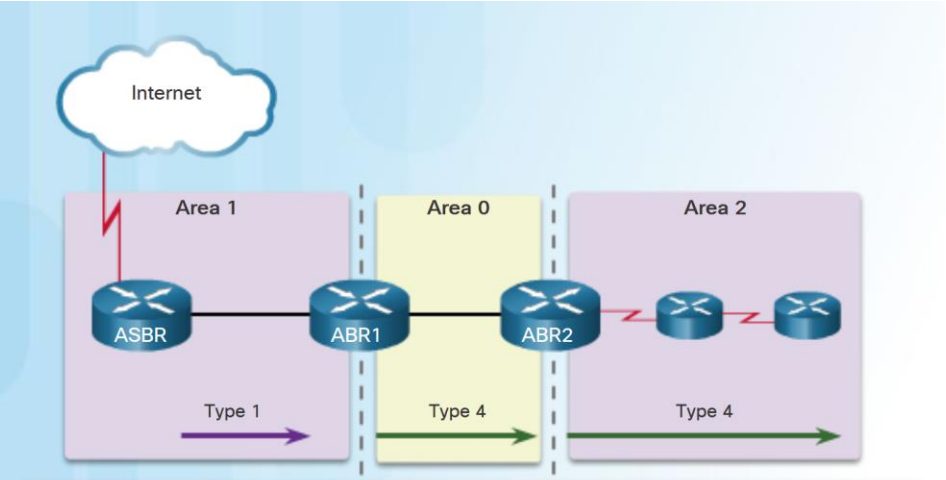
- Type 3 LSAs have the following characteristics:
  - They are used by ABRs to advertise networks from other areas.
  - The ABR creates a type 3 LSA for each of its learned OSPF networks.
  - ABRs flood type 3 LSAs from one area to other areas.
  - To reduce impact of flooding in a large OSPF deployment, configuration of manual route summarization on the ABR is recommended.
  - The link-state ID is set to the network address.



- A type 3 LSA describes a network address learned by type 1 LSAs.
- A type 3 LSA is required for every subnet.
- ABRs flood type 3 LSAs to other areas and are regenerated by other ABRs.
- A type 3 LSA link-state ID is identified by the network address.
- By default, routes are not summarized.

OSPF LSA Type 4

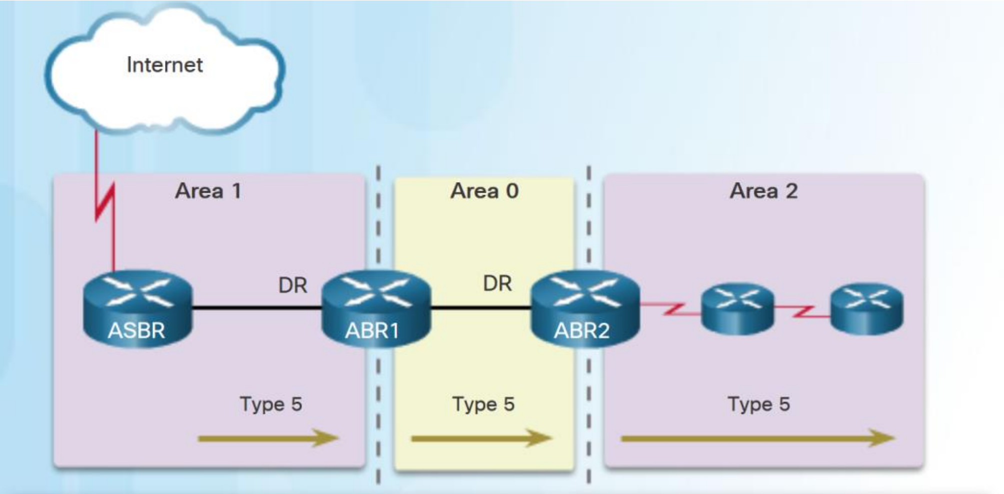
- Type 4 LSAs have the following characteristics:
  - They identify an ASBR and provide a route to it.
  - They are generated by an ABR only when an ASBR exists within an area.
  - They are flooded to other areas by ABRs.
  - The link-state ID is set to the ASBR router ID.



- Type 4 LSAs are used to advertise an ASBR to other areas and provide a route to the ASBR.
- ABRs generate type 4 LSAs.
- A type 4 LSA is generated by the originating ABR and regenerated by other ABRs.
- A type 4 LSA link-state ID is identified by the router ID of the ASBR.

Multiarea OSPF LSA Operation

OSPF LSA Type 5



- Type 5 LSAs are used to advertise external (i.e., non-OSPF) network addresses.
- An ASBR generates a type 5 LSA.
- Type 5 LSAs are flooded throughout the area and regenerated by other ABRs.
- A type 5 LSA link-state ID is the external network address.
- By default, routes are not summarized.

- Type 5 LSAs have the following characteristics:
  - They advertise external routes, also referred to as external LSA entries.
  - They are originated by the ASBR and flooded to the entire routing domain.
  - The link-state ID is the external network number.

OSPF Routing Table Entries

```
R1# show ip route
Codes:L - local, C-connected, S-static, R-RIP, M-mobile, B-BGP
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      E1 - OSPF external type 1, E2 - OSPF external type 2
      i - IS-IS, su-IS-IS summary, L1-IS-IS level-1, L2-IS-IS level-2
      ia - IS-IS inter area,*-candidate default,U-per-user static route
      o - ODR, P-periodic downloaded static route, H-NHRP, l-LISP
      + - replicated route, % - next hop override

Gateway of last resort is 192.168.10.2 to network 0.0.0.0

O*E2 0.0.0.0/0 [110/1] via 192.168.10.2, 00:00:19, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C      10.1.1.0/24 is directly connected, GigabitEthernet0/0
L      10.1.1.1/32 is directly connected, GigabitEthernet0/0
C      10.1.2.0/24 is directly connected, GigabitEthernet0/1
L      10.1.2.1/32 is directly connected, GigabitEthernet0/1
O      10.2.1.0/24 [110/648] via 192.168.10.2, 00:04:34, Serial0/0/0
O IA 192.168.1.0/24 [110/1295] via 192.168.10.2, 00:01:48,Serial0/0/0
O IA 192.168.2.0/24 [110/1295] via 192.168.10.2, 00:01:48,Serial0/0/0
     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C    192.168.10.0/30 is directly connected, Serial0/0/0
L    192.168.10.1/32 is directly connected, Serial0/0/0
O    192.168.10.4/30 [110/1294] via 192.168.10.2, 00:01:55,Serial0/0/0
R1#
```

- OSPF routes in an IPv4 routing table are identified using the following descriptors:
  - O - The routing table reflects the link-state information with a designation of O, meaning that the route is intra-area
  - O IA - Summary LSAs appear in the routing table as IA (interarea routes).
  - O E1 or O E2 - External LSAs appear in the routing table marked as external type 1 (E1) or external type 2 (E2) routes.

OSPF Route Calculation

Steps to OSPF Convergence

```
R1# show ip route | begin Gateway
Gateway of last resort is 192.168.10.2 to network 0.0.0.0
O*E2 0.0.0.0/0 [110/1] via 192.168.10.2, 00:00:19, Serial0/0/0
     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
C     10.1.1.0/24 is directly connected, GigabitEthernet0/0
L     10.1.1.1/32 is directly connected, GigabitEthernet0/0
C     10.1.2.0/24 is directly connected, GigabitEthernet0/1
L     10.1.2.1/32 is directly connected, GigabitEthernet0/1
O     10.2.1.0/24 [110/648] via 192.168.10.2, 00:04:34,Serial0/0/0
O IA 192.168.1.0/24 [110/1295] via 192.168.10.2, 00:01:48,Serial0/0/0
O IA 192.168.2.0/24 [110/1295] via 192.168.10.2, 00:01:48,Serial0/0/0
     192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
C     192.168.10.0/30 is directly connected, Serial0/0/0
L     192.168.10.1/32 is directly connected, Serial0/0/0
O     192.168.10.4/30 [110/1294] via 192.168.10.2, 00:01:55,Serial0/0/0
R1#
```

- Calculate intra-area OSPF routes.
- Calculate best path to interarea OSPF routes.
- Calculate best path route to external non-OSPF networks.

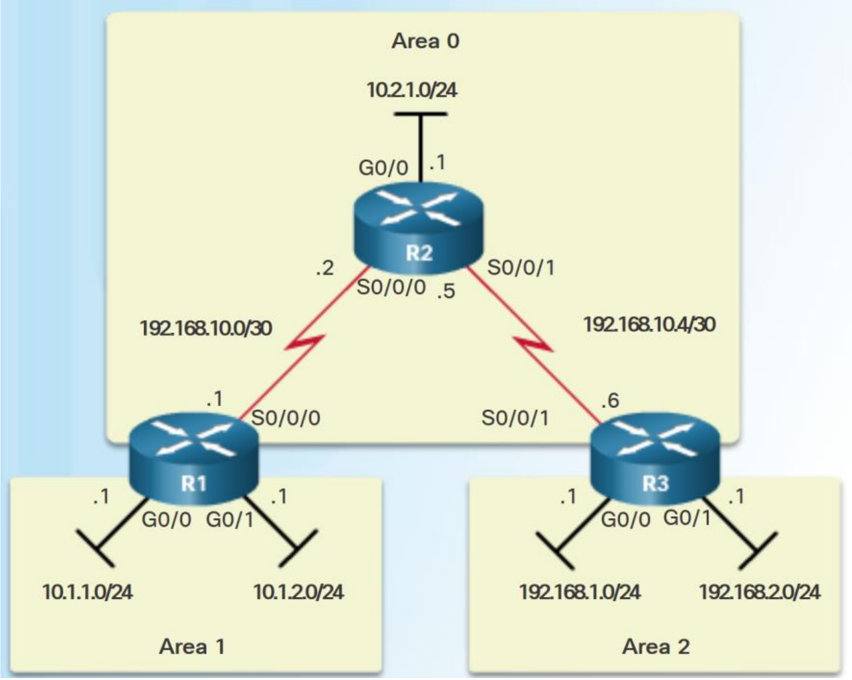
- The order in which the best paths are calculated is as follows:
  - All routers calculate the best path or paths to destinations within their area (intra-area). These are the type 1 and type 2 LSAs – O.
  - All routers calculate the best path or paths to the other areas within the internetwork. Type 3 LSAs - O IA.
  - All routers calculate the best path or paths to the external autonomous system (type 5) destinations - O E1 or an O E2 .

Configuring Multiarea OSPF

Implementing Multiarea OSPF

- There are 4 steps to implementing multiarea OSPF:
  - Step 1. Gather the network requirements and parameters
  - Step 2. Define the OSPF parameters
    - Single area or multiarea OSPF?
    - IP addressing plan
    - OSPF areas
    - Network topology
  - Step 3. Configure the multiarea OSPF implementation based on the parameters.
  - Step 4. Verify the multiarea OSPF implementation

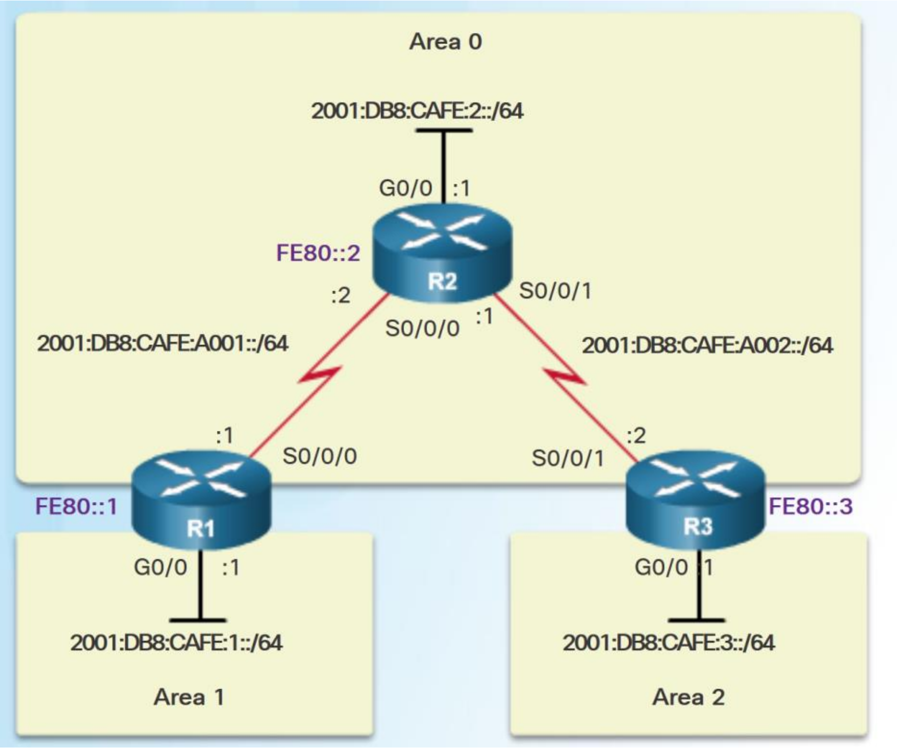
Configuring Multiarea OSPFv2




```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
R1(config-router)# network 10.1.1.1 0.0.0.0 area 1
R1(config-router)# network 10.1.2.1 0.0.0.0 area 1
R1(config-router)# network 192.168.10.1 0.0.0.0 area 0
R1(config-router)# end
R1#
```

- There are no special commands to implement multiarea OSPFv2.
- A router becomes an ABR when it has two network statements in different areas.
- R1 is an ABR because it has interfaces in area 1 and an interface in area 0.

Configuring Multiarea OSPFv3



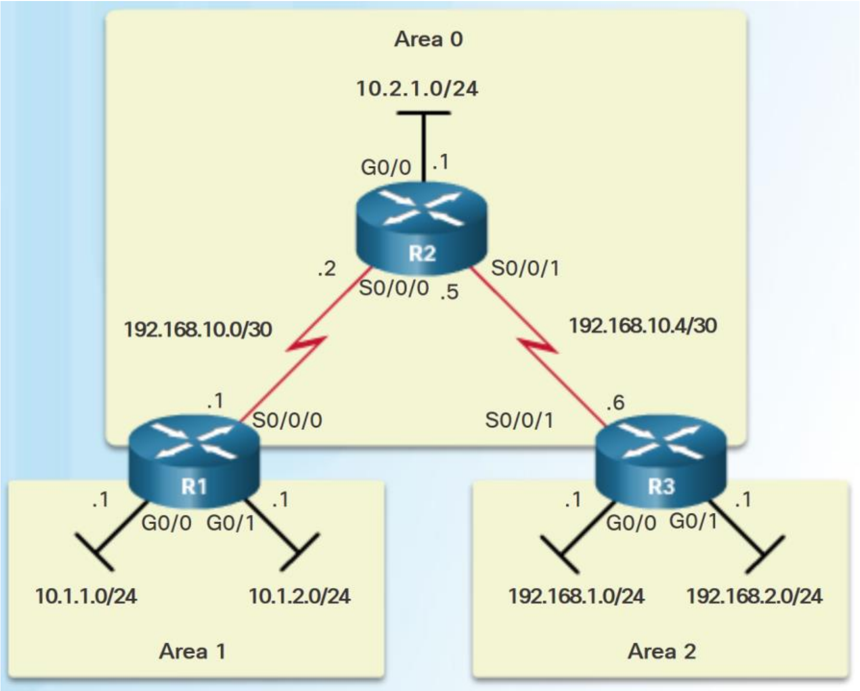

```
R1(config)# ipv6 router ospf 10
R1(config-rtr)# router-id 1.1.1.1
R1(config-rtr)# exit
R1(config)#
R1(config)# interface GigabitEthernet 0/0
R1(config-if)# ipv6 ospf 10 area 1
R1(config-if)#
R1(config-if)# interface Serial0/0/0
R1(config-if)# ipv6 ospf 10 area 0
R1(config-if)# end
R1#
```

- There are no special commands required to implement multiarea OSPFv3.
- A router becomes an ABR when it has two interfaces in different areas.

Verifying Multiarea OSPFv2

- Commands to verify multiarea OSPFv2
  - **show ip ospf neighbor**
  - **show ip ospf**
  - **show ip ospf interface**
  - **Show ip protocols**
  - **show ip ospf interface brief**
  - **show ip route ospf**
  - **show ip ospf database**

Note: For the equivalent OSPFv3 command, simply substitute ipv6 for ip.



Verify General Multiarea OSPFv2 Settings

- Use the **show ip protocols** command to verify the OSPFv2 status.
  - Lists routing protocols configured on router, number of areas, router ID and networks included in routing protocol.
- Use the **show ip ospf interface brief** command to display OSPFv2-related information for OSPFv2-enabled interfaces.
  - Lists the OSPFv2 process ID, area that the interfaces are in, and interface cost.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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
  It is an area border router
  Number of areas in this router is 2. 2 normal 0 stub 0 nssa
  Maximum path: 4
  Routing for Networks:
    10.1.1.1 0.0.0.0 area 1
    10.1.2.1 0.0.0.0 area 1
    192.168.10.1 0.0.0.0 area 0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      02:20:36
    2.2.2.2              110      02:20:39
  Distance: (default is 110)
```

```
R1# show ip ospf interface brief
Interface    PID   Area   IP Address/Mask    Cost   State   Nbrs F/C
Se0/0/0      10    0      192.168.10.1/30    64     P2P     1/1
Gi0/1        10    1      10.1.2.1/24        1      DR      0/0
Gi0/0        10    1      10.1.1.1/24        1      DR      0/0
R1#
```

Verify the OSPFv2 Routes

```
R1# show ip route ospf | begin Gateway
Gateway of last resort is not set

     10.0.0.0/8 is variably subnetted, 5 subnets, 2 masks
O    10.2.1.0/24 [110/648] via 192.168.10.2, 00:26:03, Serial0/0/0
O IA 192.168.1.0/24 [110/1295] via 192.168.10.2, 00:26:03, Serial0/0/0
O IA 192.168.2.0/24 [110/1295] via 192.168.10.2, 00:26:03, Serial0/0/0
     192.168.10.0/24 is variably subnetted,3 subnets,2 masks
O    192.168.10.4/30 [110/1294] via 192.168.10.2, 00:26:03, Serial0/0/0
R1#
```

- Use the **show ip route ospf** command to verify the muliarea OSPFv2 configuration..
  - O represents OSPFv2 routes and IA represents interarea, which means that the route originated from another area.

Verify the Multiarea OSPFv2 LSDB

```
R1# show ip ospf database
                    OSPF Router with ID (1.1.1.1) (Process ID 10)

                        Router Link States (Area 0)
Link ID         ADV Router      Age    Seq#          Checksum    Link  count
1.1.1.1         1.1.1.1         725    0x80000005    0x00F9B0    2
2.2.2.2         2.2.2.2         695    0x80000007    0x003DB1    5
3.3.3.3         3.3.3.3         681    0x80000005    0x00FF91    2
                      Summary Net Link States (Area 0)
Link ID         ADV Router      Age    Seq#          Checksum
10.1.1.0        1.1.1.1         725    0x80000006    0x00D155
10.1.2.0        1.1.1.1         725    0x80000005    0x00C85E
192.168.1.0     3.3.3.3         681    0x80000006    0x00724E
192.168.2.0     3.3.3.3         681    0x80000005    0x006957

                        Router Link States (Area 1)
Link ID          ADV Router      Age    Seq#          Checksum    Link  count
1.1.1.1          1.1.1.1         725    0x80000006    0x007D7C    2
                      Summary Net Link States (Area 1)
Link ID          ADV Router      Age    Seq#          Checksum
10.2.1.0         1.1.1.1         725    0x80000005    0x004A9C
192.168.1.0      1.1.1.1         725    0x80000005    0x00B593
192.168.2.0      1.1.1.1         725    0x80000005    0x00AA9D
192.168.10.0     1.1.1.1         725    0x80000005    0x00B3D0
192.168.10.4     1.1.1.1         725    0x80000005    0x000E32
R1#
```

- Use the **show ip ospf database** command to verify the contents of the OSPFv2 LSDB.

Verify Multiarea OSPFv3

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Area border router
  Number of areas: 2 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Serial0/0/0
  Interfaces (Area 1):
    GigabitEthernet0/0
  Redistribution:
    None
R1#
```

```
R1# show ipv6 ospf interface brief
Interface    PID   Area        Intf ID    Cost   State Nbrs F/C
Se0/0/0      10    0           6          647    P2P   1/1
Gi0/0        10    1           3          1      DR    0/0
R1#
```

- Use the **show ipv6 protocols** command to verifyOSPFv3.
- Use the **show ipv6 interface brief** to verify the OSPFv3-enabled interfaces and the area to which they belong.
- Use **show ipv6 route ospf** to display the routing table.
- Use **show ipv6 ospf database** to display the contents of the LSDB.

```
R1# show ipv6 route ospf
IPv6 Routing Table - default - 8 entries
Codes: C - Connected, L - Local, S - Static, U - Per-user Static route,B - BGP,
       R - RIP, H - NHRP, I1 - ISIS L1, I2 - ISIS L2, IA - ISIS interarea,
       IS - ISIS summary, D - EIGRP, EX - EIGRP external, ND - ND Default,
       NDp - ND Prefix, DCE - Destination, NDr - Redirect, O - OSPF Intra,
       OI - OSPF Inter, OE1 - OSPF ext 1, OE2 - OSPF ext 2, ON1 - OSPF NSSA ext 1,
       ON2 - OSPF NSSA ext 2
O   2001:DB8:CAFE:2::/64 [110/648]
     via FE80::2, Serial0/0/0
OI  2001:DB8:CAFE:3::/64 [110/1295]
     via FE80::2, Serial0/0/0
O   2001:DB8:CAFE:A002::/64 [110/1294]
     via FE80::2, Serial0/0/0
```


Troubleshooting Single-Area OSPF Implementations

Components of Troubleshooting Single-Area OSPF

- OSPF is a popular routing protocol in large enterprise networks.

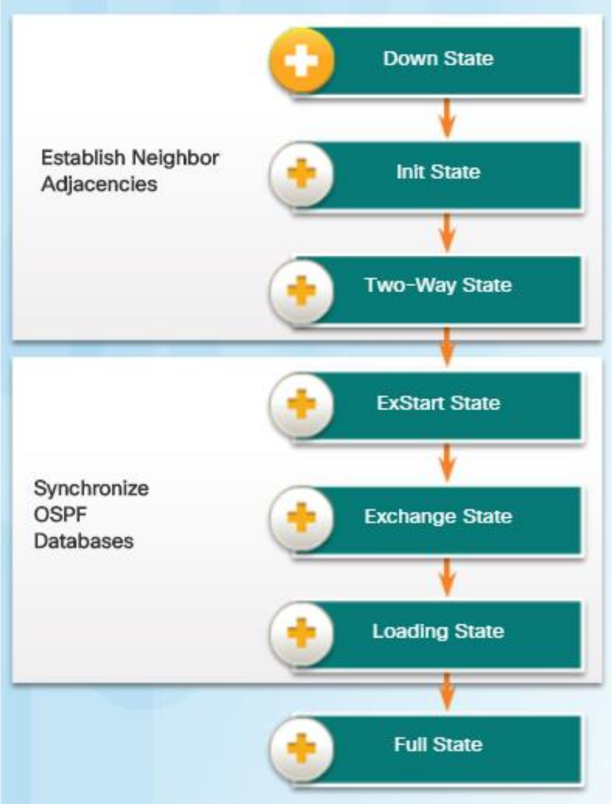
- Troubleshooting problems related to the exchange of routing information is one of the most essential skills for a network administrator.

OSPF Adjacencies Will Not Form If

- The interfaces are not on the same network.
- OSPF network types do not match.
- OSPF Hello or Dead Timers do not match.
- Interface to neighbor is incorrectly configured as passive.
- There is a missing or incorrect OSPF **network** command.
- Authentication is misconfigured.
- Each interface must be properly addressed and in the "up and up" condition.

OSPF States

- To troubleshoot OSPF, it is important to understand how OSPF routers traverse different OSPF states when adjacencies are being established.
- When troubleshooting OSPF neighbors, be aware that the FULL or 2WAY states are normal.
  - All other states are transitory and the router should not remain in those states for extended periods of time.



OSPF Troubleshooting Commands

- Common OSPFv2 troubleshooting commands include:
  - **show ip protocols** - Used to verify vital OSPFv2 configuration information.
  - **show ip ospf neighbor** - Used to verify that the router has formed an OSPFv2 adjacency with its neighboring routers.
  - **show ip ospf interface** - Used to display the OSPFv2 parameters configured on an interface.
  - **show ip ospf** - Used to examine the OSPFv2 process ID and router ID.
  - **show ip route ospf** - Used to display only the OSPFv2 learned routes in the IPv4 routing table. T
  - **clear ip ospf** [*process-id*] **process** - Used to reset the OSPFv2 neighbor adjacencies

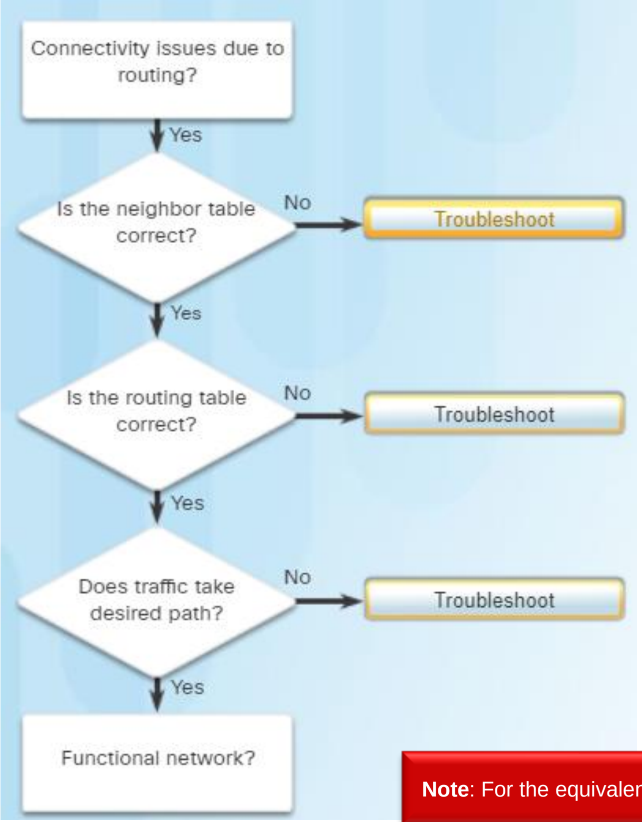
```
R1# show ip protocols
*** IP Routing is NSF aware ***

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:
   172.16.1.1 0.0.0.0 area 0
   172.16.3.1 0.0.0.0 area 0
   192.168.10.5 0.0.0.0 area 0
 Passive Interface(s):
   GigabitEthernet0/0
 Routing Information Sources:
   Gateway         Distance      Last Update
   3.3.3.3              110      00:08:35
   2.2.2.2              110      00:08:35
 Distance: (default is 110)

R1# show ip ospf neighbor

Neighbor ID Pri State         Dead Time Address     Interface
2.2.2.2       1 FULL/BDR      00:00:30  192.168.1.2 GigabitEthernet0/0
3.3.3.3       0 FULL/DROTHER  00:00:38  192.168.1.3 GigabitEthernet0/0
R1#
```

Note: For the equivalent OSPFv3 command, simply substitute **ip** with **ipv6**.

Components of Troubleshooting OSPF

OSPF problems usually relate to:

- Neighbor adjacencies
- Missing routes
- Path selection



Use:
- **show ip ospf neighbor**
- **show ip interface brief**
- **show ip ospf interface**

Use:
- **show ip protocols**
- **show ip route ospf**

Use:
- **show ip route ospf**
- **show ip ospf interface**

Note: For the equivalent OSPFv3 command, simply substitute **ip** with **ipv6**.

Troubleshooting Neighbor Issues

- When troubleshooting neighbor issues:
  - Verify the routing table using the **show ip route ospf** command.
  - Verify that interfaces are active using the **show ip interface brief** command.
  - Verify active OSPF interfaces using the **show ip ospf interface** command.
  - Verify the OSPFv2 settings using the **show ip protocols** command.
- Recall that the **passive-interface** command stops both outgoing and incoming routing updates and for that reason, routers will not become neighbors.

```
R1# show ip protocols
*** IP Routing is NSF aware ***

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:
    172.16.1.1 0.0.0.0 area 0
    172.16.3.1 0.0.0.0 area 0
  Passive Interface(s):
    GigabitEthernet0/0
    Serial0/0/0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      00:50:03
    2.2.2.2              110      04:27:25
  Distance: (default is 110)

R1#
```

```
R1(config)# router ospf 10
R1(config-router)# no passive-interface s0/0/0
R1(config-router)#
*Apr  9 13:14:15.454: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from LOADING to FULL, Loading Done
R1(config-router)# end
R1#
```

Troubleshooting OSPFv2 Routing Table Issues

- When troubleshooting routing table issues:
  - Verify the routing table using the **show ip route ospf** command.
  - Verify the OSPFv2 settings using the **show ip protocols** command.
  - Verify the OSPF configuration using the **show running-config | section router ospf** command.

```
R3# show running-config | section router ospf
router ospf 10
 router-id 3.3.3.3
 passive-interface default
 no passive-interface Serial0/0/1
 network 192.168.10.8 0.0.0.3 area 0
R3#
R3# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)# router ospf 10
R3(config-router)# network 192.168.1.0 0.0.0.255 area 0
R3(config-router)# end
R3#
*Apr 10 11:03:11.115: %SYS-5-CONFIG_I: Configured from
console by console
R3#
```

OSPFv3 Troubleshooting Commands

- Common OSPFv3 troubleshooting commands include:
  - **show ipv6 protocols** - Used to verify vital OSPFv3 configuration information.
  - **show ipv6 ospf neighbor** - Used to verify that the router has formed an OSPFv3 adjacency with its neighboring routers.
  - **show ipv6 ospf interface** - Used to display the OSPFv3 parameters configured on an interface.
  - **show ipv6 ospf** - Used to examine the OSPFv3 process ID and router ID.
  - **show ipv6 route ospf** - Used to display only the OSPFv3 learned routes in the IPv4 routing table. T
  - **clear ipv6 ospf** [*process-id*] **process** - Used to reset the OSPFv3 neighbor adjacencies
- .

```
R1# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 1.1.1.1
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
    Serial0/0/0
    GigabitEthernet0/0
  Redistribution:
    None
R1#
R1# show ipv6 ospf neighbor

Neighbor ID   Pri  State   Dead Time  Interface ID  Interface
2.2.2.2        0   FULL/-  00:00:33       7         Serial0/0/0
R1#
```

Troubleshooting OSPFv3

- In this example, R1 is not receiving the R3 LAN OSPFv3 route (2001:DB8:CAFE:3::/64).
- Verifying the R3 routing protocol settings reveals that R3 is not enabled on the G0/0 R3 interface.
- Enable OSPFv3 on the R3 Gigabit Ethernet 0/0 interface.
- The R3 LAN is now in the routing table of R1.

```
R3# show ipv6 protocols
IPv6 Routing Protocol is "connected"
IPv6 Routing Protocol is "ND"
IPv6 Routing Protocol is "ospf 10"
  Router ID 3.3.3.3
  Number of areas: 1 normal, 0 stub, 0 nssa
  Interfaces (Area 0):
  Serial0/0/1
  Redistribution:
    None
R3#
```

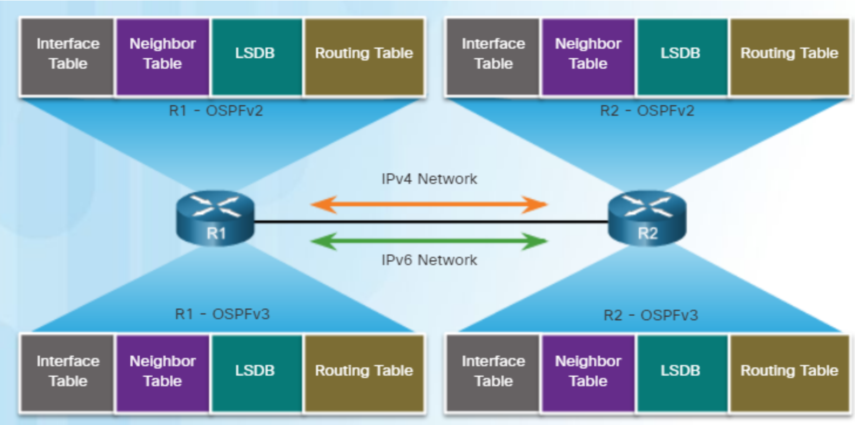
```
R3# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R3(config)# interface g0/0
R3(config-if)# ipv6 ospf 10 area 0
R3(config-if)# end
R3#
```

Multiarea OSPF Troubleshooting Skills

- Before you can begin to diagnose and resolve problems related to a multiarea OSPF implementation, you must be able to do the following:
  - Understand the processes OSPF uses to distribute, store, and select routing information.
  - Understand how OSPF information flows within and between areas.
  - Use Cisco IOS commands to gather and interpret the information necessary to troubleshoot OSPF operation.

Multiarea OSPF Troubleshooting Data Structures

- OSPF stores routing information in four main data structures:



OSPF Data Structures	Description
Interface table	• Includes a list of all active OSPF interfaces. • Type 1 LSAs include the subnets associated with each active interface.
Neighbor table	• Used to manage neighbor adjacencies through hello timers and dead timers. • Neighbor entries are added and refreshed when a hello is received. • Neighbors are removed when dead timer expires.
Link-state database (LSDB)	• This is the primary data structure used by OSPF to store network topology information. • It includes full topological information about each area that the OSPF router is connected to and any paths that are available to reach other networks.
Routing table	• After the SPF algorithm is calculated, the best routes are offered to the routing table

Chapter Summary

Conclusion

Single-Area OSPF

- Explain how single-area OSPF operates.
- Implement single-area OSPFv2.
- Implement single-area OSPFv3.

Conclusion

Multiarea OSPF

- Explain how multiarea OSPF operates in a small to medium-sized business network.
- Implement multiarea OSPFv2 and OSPFv3.

Conclusion

OSPF Tuning and Troubleshooting (Cont.)

- OSPF defines five network types: point-to-point, broadcast multiaccess, nonbroadcast multiaccess, point-to-multipoint, and virtual links.
- Multiaccess networks can create two challenges for OSPF regarding the flooding of LSAs: creation of multiple adjacencies and extensive flooding of LSAs. The solution to managing the number of adjacencies and the flooding of LSAs on a multiaccess network is the DR and BDR. If the DR stops producing Hellos, the BDR promotes itself and assumes the role of DR.
- The routers in the network elect the router with the highest interface priority as DR. The router with the second highest interface priority is elected the BDR. The higher the priority, the likelier the router will be selected as the DR. If set to 0, the router is not capable of becoming the DR. The default priority of multiaccess broadcast interfaces is 1. Therefore, unless otherwise configured, all routers have an equal priority value and must rely on another tie breaking method during the DR/BDR election. 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 addition of a new router does not initiate a new election process.

OSPF Tuning and Troubleshooting (Cont.)

- To propagate a default route in OSPF, the router must be configured with a default static route and the **default-information originate** command must be added to the configuration. Verify routes with the **show ip route** or **show ipv6 route** command.
- 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. To adjust the reference bandwidth, use the **auto-cost reference-bandwidth** *Mbps* router configuration mode command. To adjust the interface bandwidth, use the **bandwidth** *kilobits* interface configuration mode command. The cost can be manually configured on an interface using the **ip ospf cost** *value* interface configuration mode command.
- The OSPF Hello and Dead intervals must match or a neighbor adjacency does not occur. To modify these intervals, use the following interface commands:
  - **ip ospf hello-interval** *seconds*
  - **ip ospf dead-interval** *seconds*
  - **ipv6 ospf hello-interval** *seconds*
  - **ipv6 ospf dead-interval** *seconds*

OSPF Tuning and Troubleshooting (Cont.)

- When troubleshooting OSPF neighbors, be aware that the FULL or 2WAY states are normal. The following commands summarize OSPFv2 troubleshooting:
  - **show ip protocols**
  - **show ip ospf neighbor**
  - **show ip ospf interface**
  - **show ip ospf**
  - **show ip route ospf**
  - **clear ip ospf** [*process-id*] **process**
- Troubleshooting OSPFv3 is similar to OSPFv2. The following commands are the equivalent commands used with OSPFv3: **show ipv6 protocols**, **show ipv6 ospf neighbor**, **show ipv6 ospf interface**, **show ipv6 ospf**, **show ipv6 route ospf**, and **clear ipv6 ospf** [*process-id*] **process**.

New Terms and Commands

• OSPFv2 • OSPFv3 • Classless • MD5 authentication • IPsec authentication • Administrative distance • Adjacency database • Neighbor table • Link-state database • Topology table • Forwarding database • Routing table • Hello packet • Database description packet • Link-state request packet • Link-state update packet	• Link-state acknowledgment packet • Dijkstra algorithm • SPF algorithm • SPF tree • Single-area OSPF • Multiarea OSPF • Backbone area • ABRs • Router priority • Hello/dead intervals • DR/BDR • Router ID • LSU • LSA • Init state	• Two-Way state • ExStart state • Exchange state • Loading state • Full state • **router ospf** • **router-id** • **show ip protocols** • **clear ip ospf process** • **interface loopback** • **network area** • Wildcard mask • Passive interface • **passive-interface** • **passive-interface default** • Cost

New Terms and Commands (Cont.)

• Reference bandwidth • Default bandwidth • Metric • Cost accumulation • **auto-cost reference-bandwidth** • **show ip ospf interface** • **show interfaces** • **bandwidth** • **no bandwidth** • **ip ospf cost** • **show ip ospf neighbor** • **neighbor ID** • **show ip ospf** • **show ip ospf interface** • **show ip ospf interface brief**	• Link-local address • All OSPF router multicast address • IPv6 unicast routing • Source IPv6 address • Destination IPv6 address • **show ipv6 interface brief** • **ipv6 address link-local** • **show ipv6 interface brief** • **ipv6 router ospf** • **show ipv6 protocols** • **clear ipv6 protocols** • **ipv6 ospf area** • **show ipv6 ospf neighbor** • **show ipv6 ospf**	• **show ipv6 ospf interface** • **show ipv6 ospf interface brief** • **show ipv6 route** • **show ipv6 route ospf**

New Terms and Commands (Cont.)

- Broadcast multiaccess
- Point-to-multipoint
- Virtual links
- OSPF Hello and Dead intervals

New Terms and Commands (Cont.)

- Internal router
- Backbone router
- Autonomous System Boundary Router (ASBR)
- route redistribution
- LSA Type 1
- LSA Type 2
- LSA Type 3
- LSA Type 4
- LSA Type 5

CISCO