Module 6: Single-Area OSPF

Routing

Module 6

6.1 Characteristics of OSPF

6.2 Configuring Single-area OSPFv2

Objectives

After completing this chapter, you will be able to:

- Explain the process by which link-state routers learn about other networks.
- Describe the types of packets used by Cisco IOS routers to establish and maintain an OSPF network.
- Explain how Cisco IOS routers achieve convergence in an OSPF network.
- Configure an OSPF router ID.
- Configure single-area OSPFv2 in a small, routed IPv4 network.
- Explain how OSPF uses cost to determine best path.
- Verify single-area OSPFv2 in a small, routed network.
- Compare the characteristics and operations of OSPFv2 to OSPFv3.
- Configure single-area OSPFv3 in a small, routed network.
- Verify single-area OSPFv3 in a small, routed network.

Open Shortest Path First

Evolution of OSPF

Interior Gateway Protocols

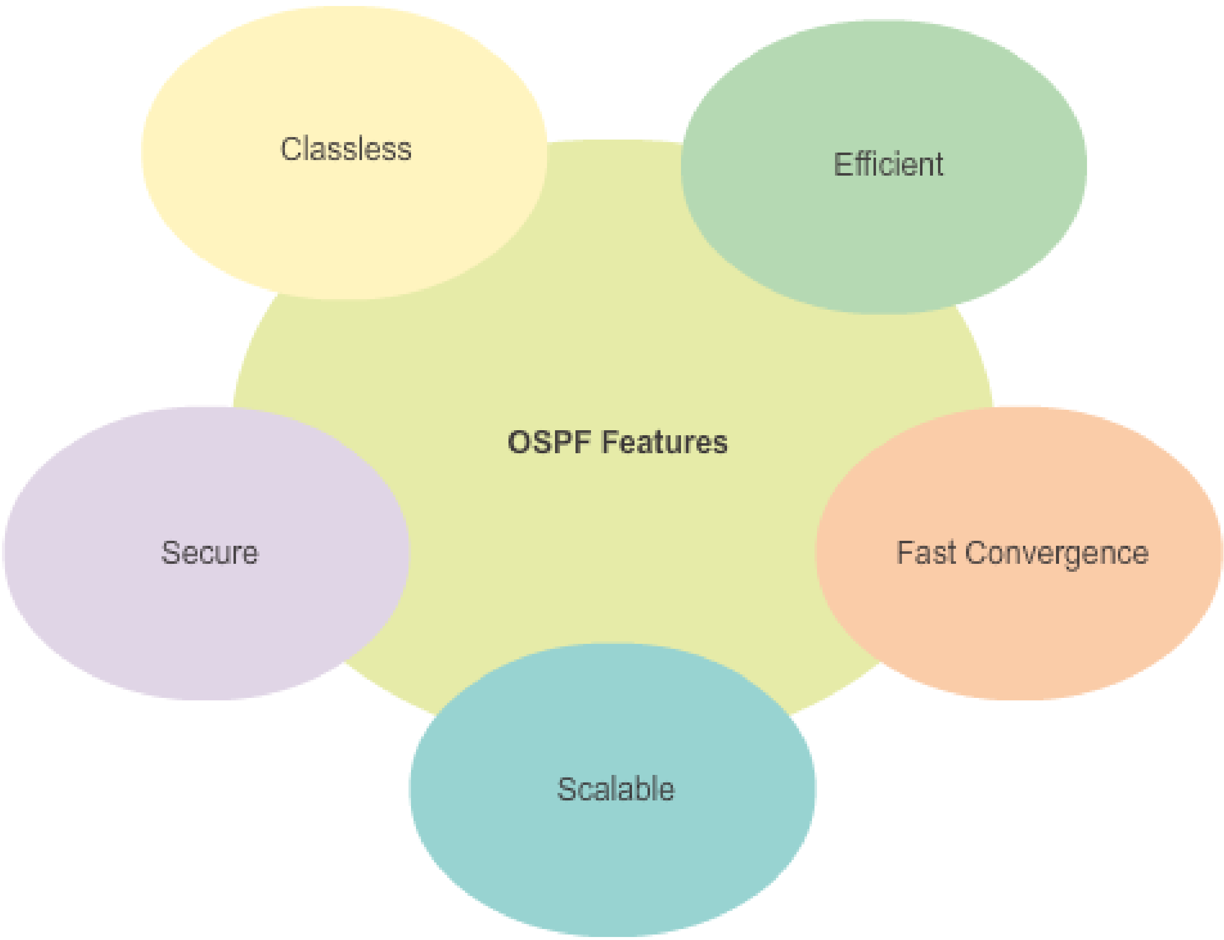
	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP

1988

1989
updated in
2008

Open Shortest Path First

Features of OSPF



Components of OSPF

OSPF Data Structures

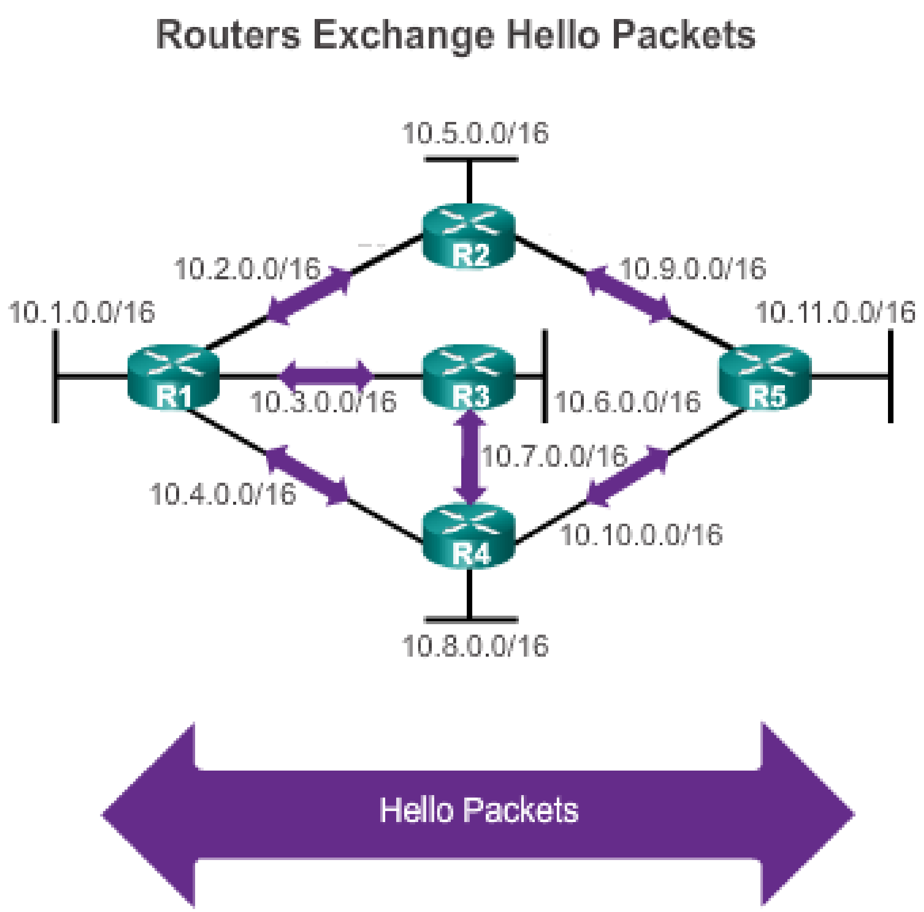
Database	Table	Description
Adjacency Database	Neighbor Table	• List of all neighbor routers to which a router has established bidirectional communication. • This table is unique for each router. • Can be viewed using the **`show ip ospf neighbor`** command.
Link-state Database (LSDB)	Topology Table	•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

Components of OSPF (cont.)

OSPF Routers Exchange Packets - These packets are used to discover neighboring routers and also to exchange routing information to maintain accurate information about the network.

Open Shortest Path First

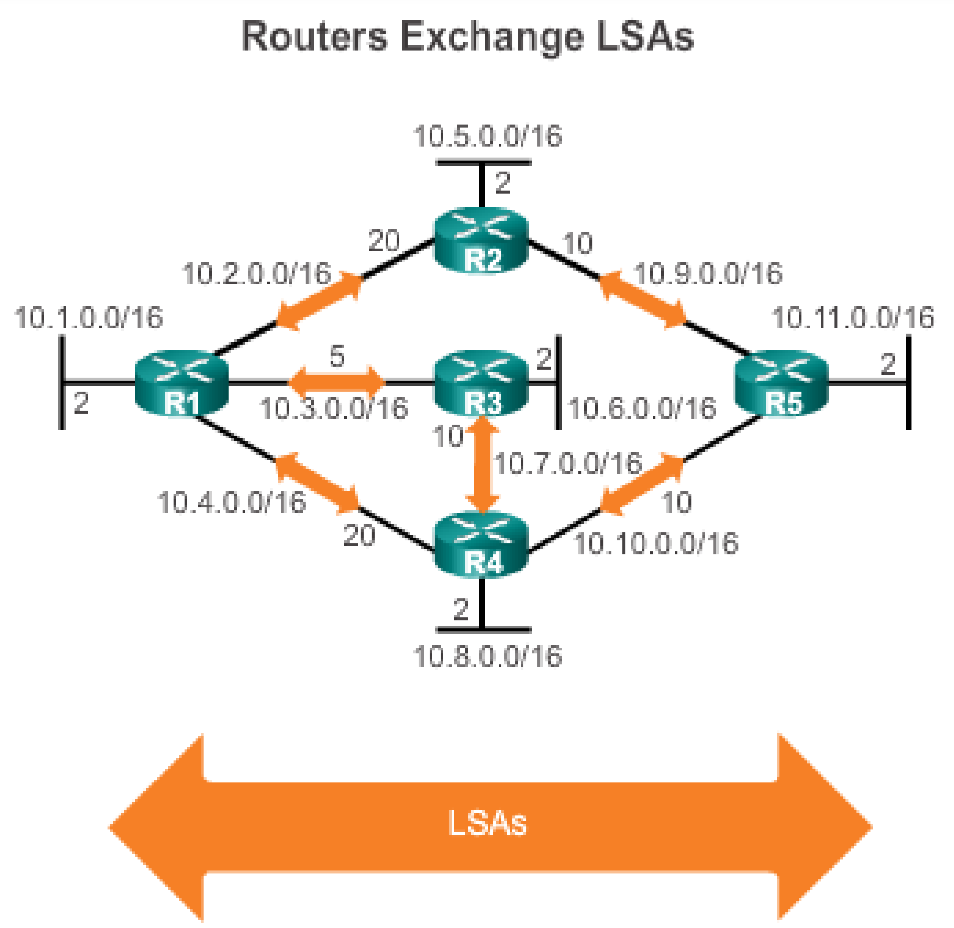
Link-State Operation



If a neighbor is present, the OSPF-enabled router attempts to establish a neighbor adjacency with that neighbor

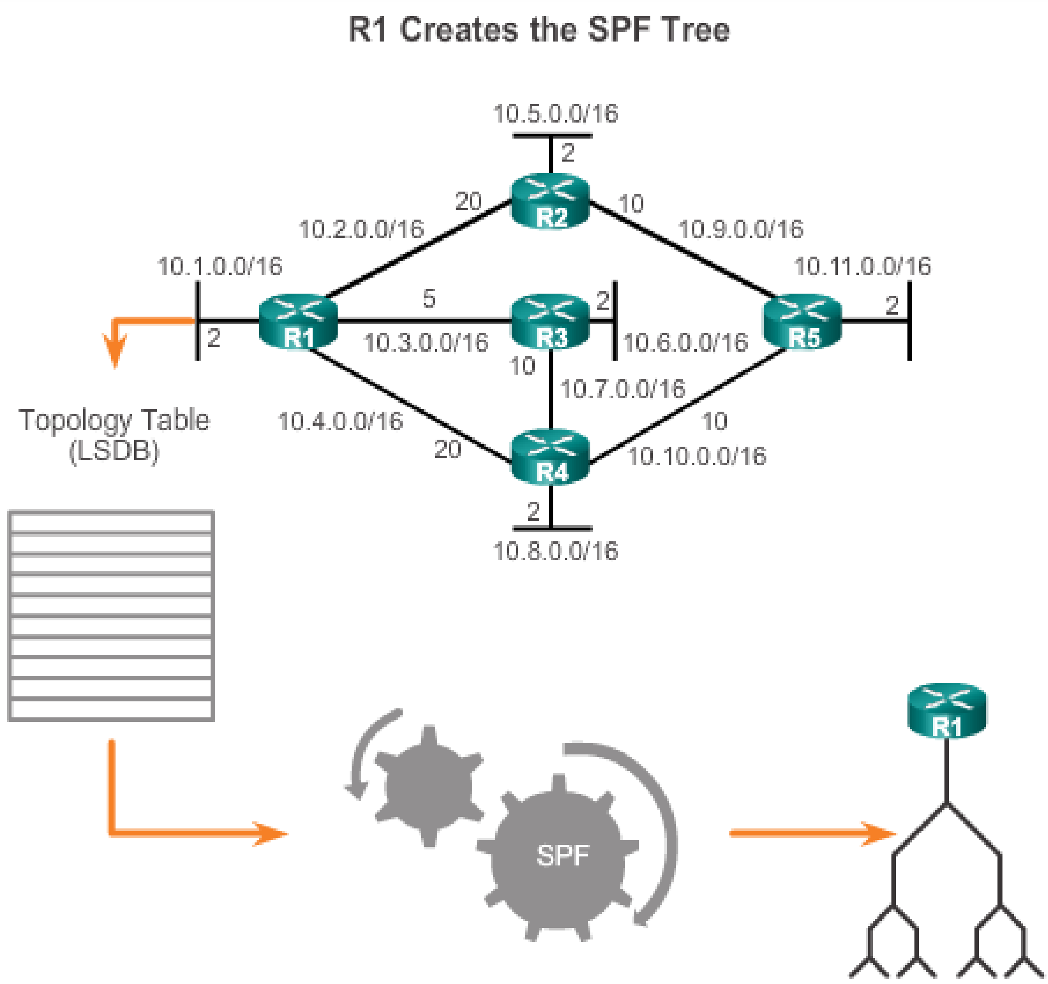
Open Shortest Path First

Link-State Operation (cont.)



- LSAs contain the state and cost of each directly connected link.
- Routers flood their LSAs to adjacent neighbors.
- Adjacent neighbors receiving the LSA immediately flood the LSA to other directly connected neighbors, until all routers in the area have all LSAs.

Link-State Operation

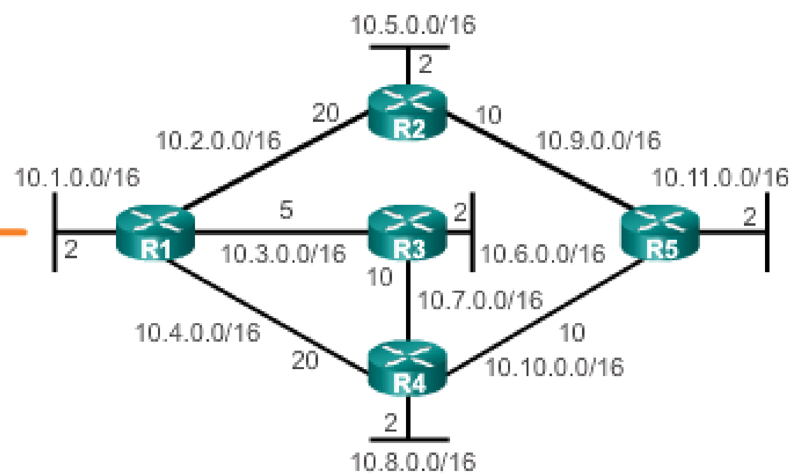


- Build the topology table based on the received LSAs.
- This database eventually holds all the information about the topology of the network.
- Execute the SPF Algorithm.

Open Shortest Path First

Link-State Operation (cont.)

Content of the R1 SPF Tree



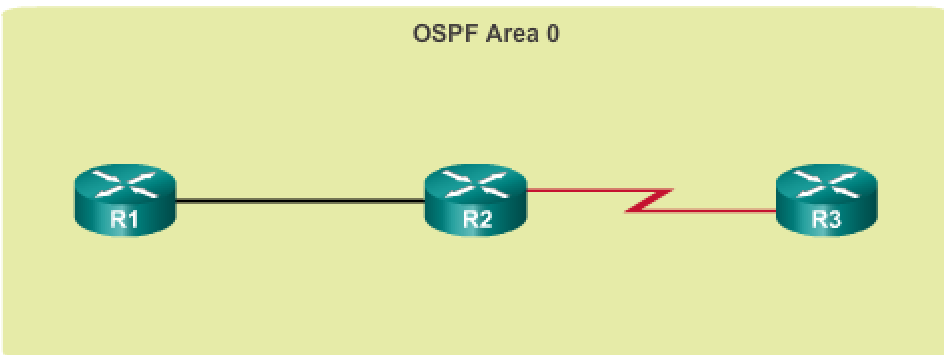
Destination	Shortest Path	Cost
10.5.0.0/16	R1 → R2	22
10.6.0.0/16	R1 → R3	7
10.7.0.0/16	R1 → R3	15
10.8.0.0/16	R1 → R3 → R4	17
10.9.0.0/16	R1 → R2	30
10.10.0.0/16	R1 → R3 → R4	25
10.11.0.0/16	R1 → R3 → R4 → R5	27

From the SPF tree, the best paths are inserted into the routing table.

Open Shortest Path First

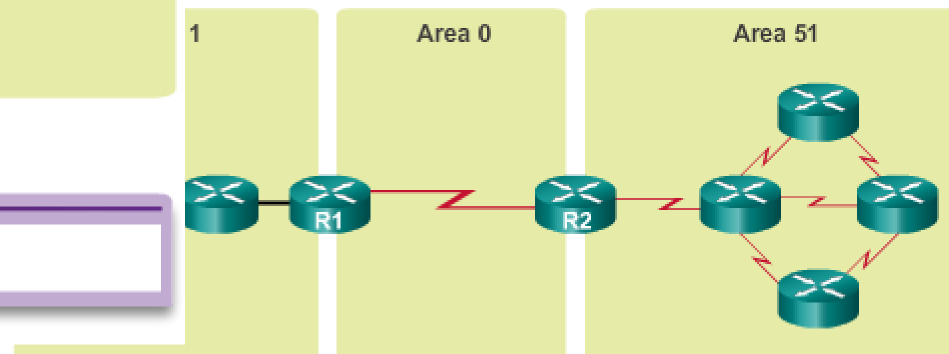
Single-area and Multiarea OSPF

Single-Area OSPF



- Area 0 is also called the backbone area.
- Single-area OSPF is useful in smaller networks with few routers.

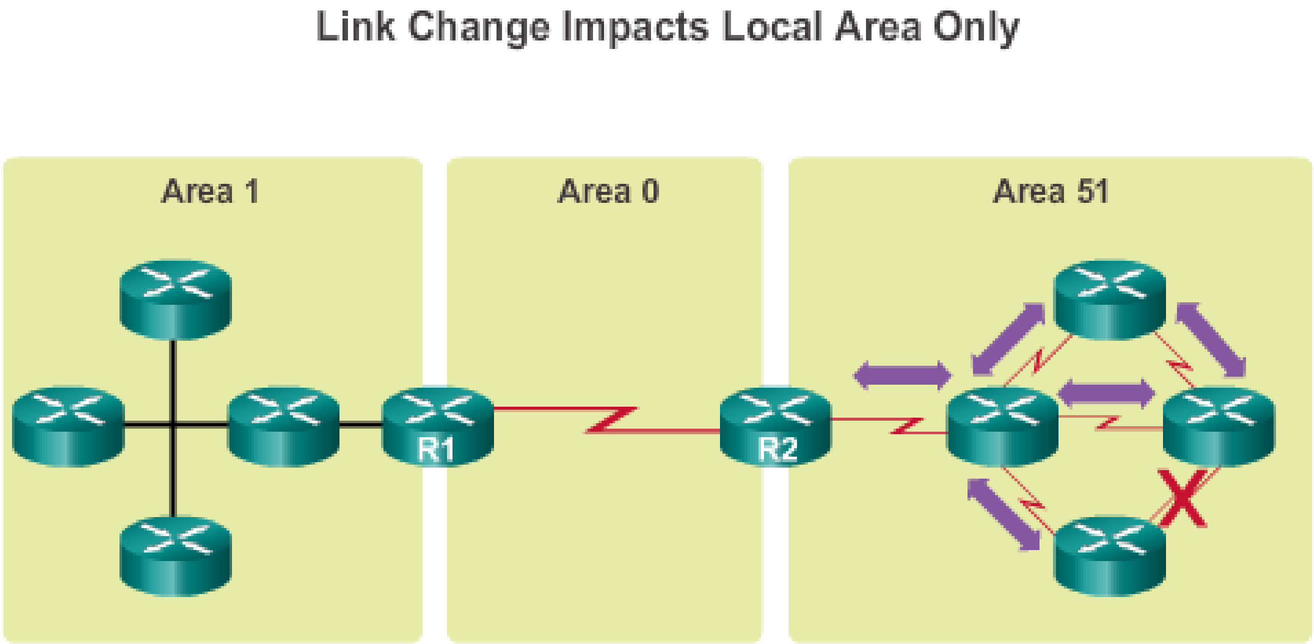
Multiarea OSPF



- Implemented using a two-layer area hierarchy as all areas must connect to the backbone area (area 0).
- Interconnecting routers are called Area Border Routers (ABR).
- Useful in larger network deployments to reduce processing and memory overhead.

Open Shortest Path First

Single-area and Multiarea OSPF (cont.)



- Link failure affects the local area only (area 51).
- The ABR (R2) isolates the fault to area 51 only.
- Routers in areas 0 and 1 do not need the run the SPF algorithm.

Encapsulating OSPF Messages

OSPF IPv4 Header Fields

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

OSPF Messages

Types of OSPF Packets

OSPF Packet Descriptions

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

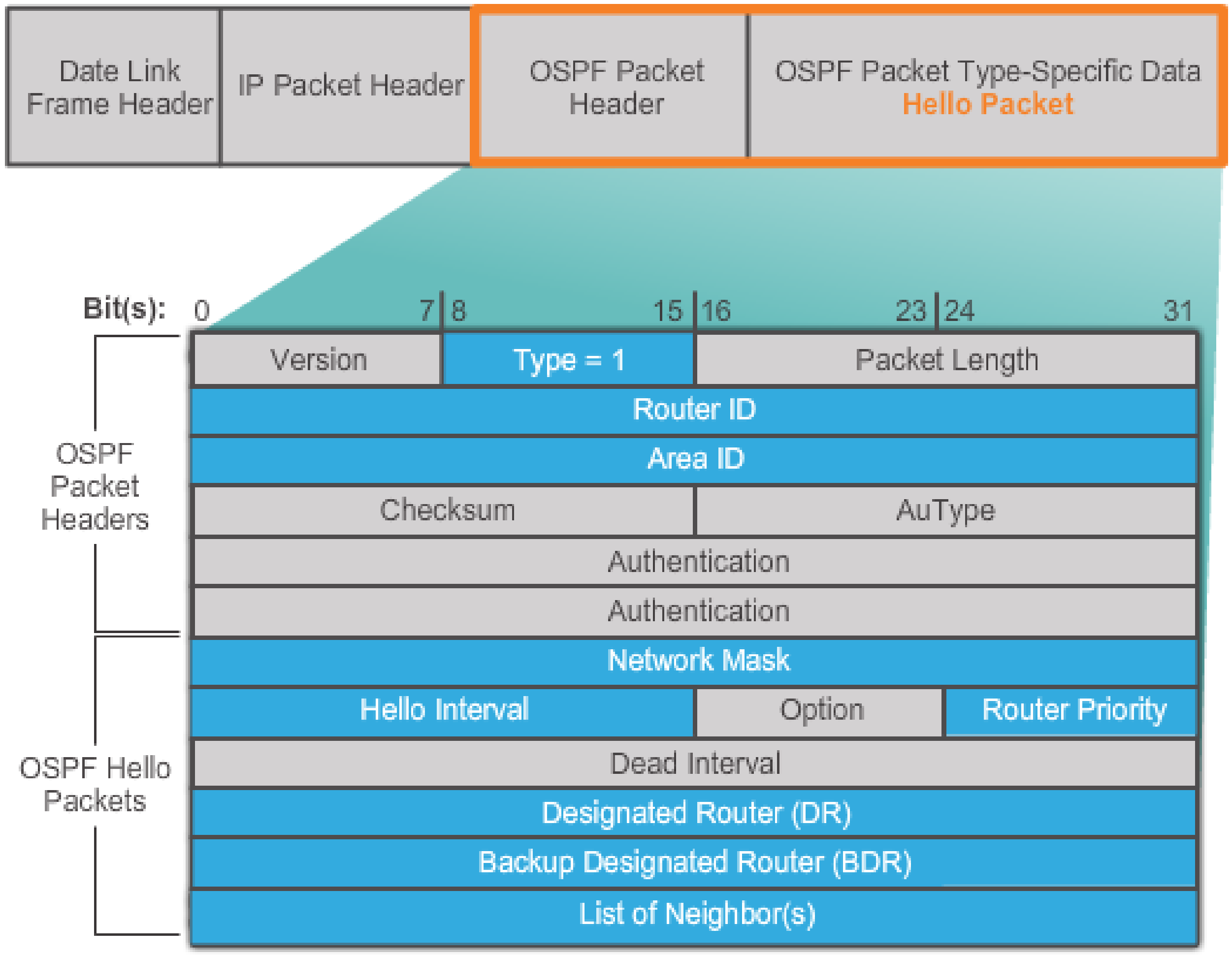
OSPF Type 1 packet = Hello packet:

- Discover OSPF neighbors and establish neighbor adjacencies.
- Advertise parameters on which two routers must agree to become neighbors.
- Elect the Designated Router (DR) and Backup Designated Router (BDR) on multiaccess networks like Ethernet and Frame Relay.

OSPF Messages

Hello Packet (cont.)

OSPF Hello Packet Content



OSPF Messages
Hello Packet Intervals

OSPF Hello packets are transmitted:

- To 224.0.0.5 in IPv4 and FF02::5 in IPv6 (all OSPF routers)
- Every 10 seconds (default on multiaccess and point-to-point networks)
- Every 30 seconds (default on non-broadcast multiaccess [NBMA] networks)
- Dead interval is the period that the router waits to receive a Hello packet before declaring the neighbor down
- Router floods the LSDB with information about down neighbors out all OSPF enabled interfaces
- Cisco’s default is 4 times the Hello interval

OSPF Messages

Link-State Updates

LSUs Contain LSAs

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

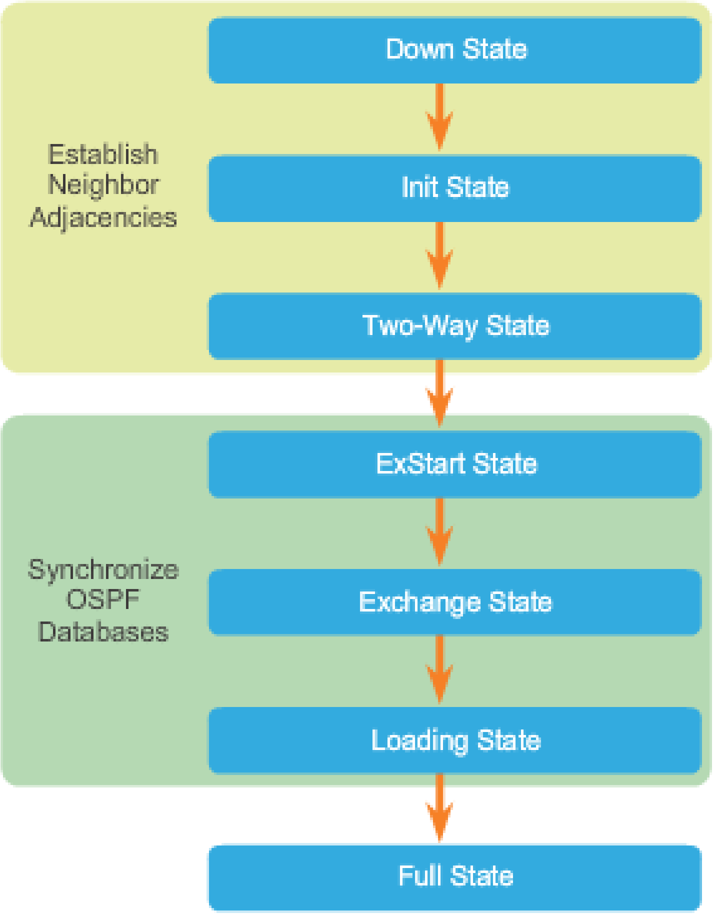
- An LSU contains one or more LSAs.
- LSAs contain route information for destination networks.

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

When an OSPF router is initially connected to a network, it attempts to:

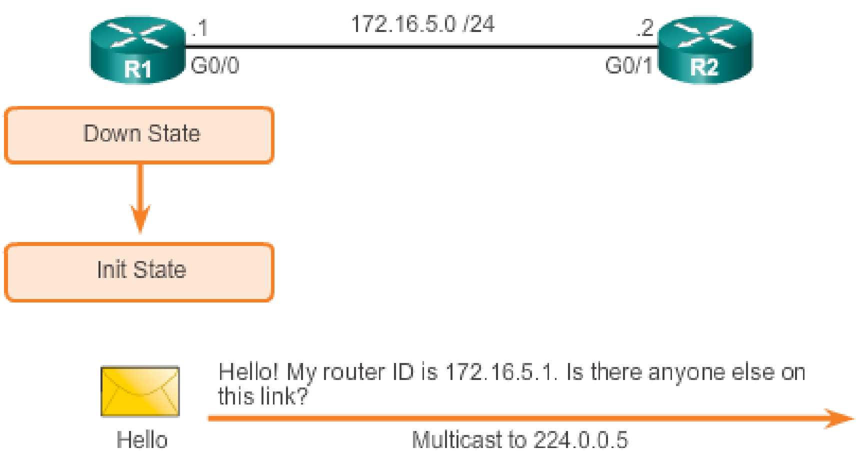
- Create adjacencies with neighbors
- Exchange routing information
- Calculate the best routes
- Reach convergence
- OSPF progresses through several states while attempting to reach convergence.



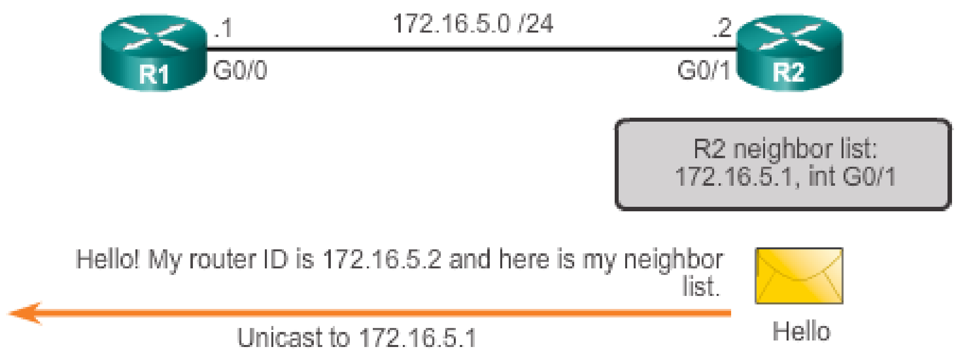
OSPF Operation

Establish Neighbor Adjacencies

Down State to Init State



The Init State



OSPF Operation

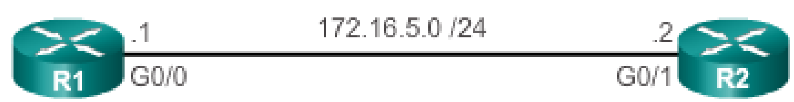
Establish Neighbor Adjacencies (cont.)

Two-Way State

R1 neighbor list:
172.16.5.2, int Fa0/0

Two-Way State

Elect the DR and BDR



R1 has a default priority of 1 and the second highest router ID. It will be the BDR on this link.

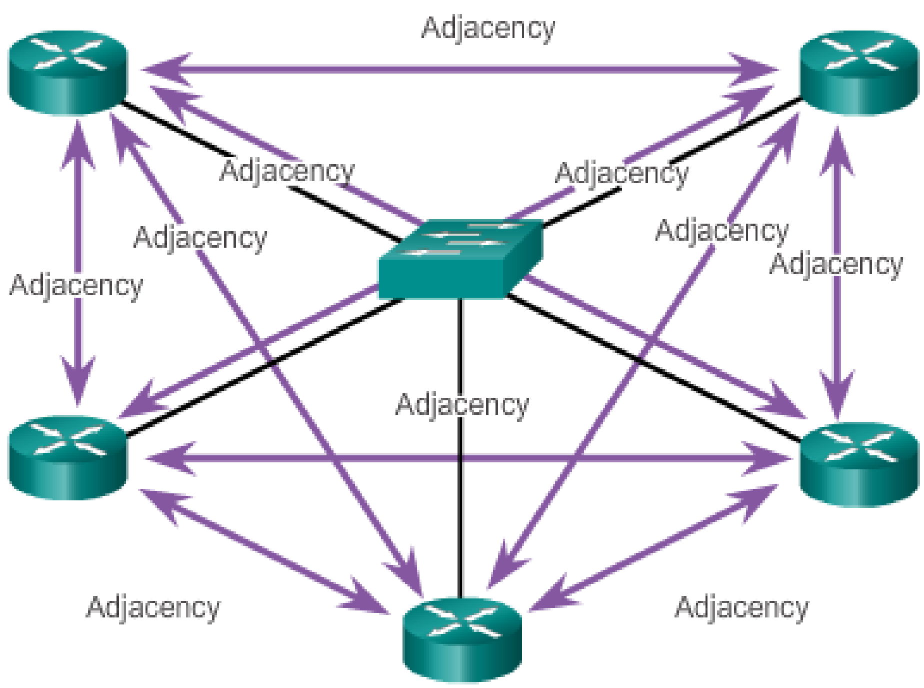
R2 has a default priority of 1 and the highest router ID. It will be the DR on this link.

DR and BDR election only occurs on multi-access networks such as Ethernet LANs.

OSPF Operation

OSPF DR and BDR

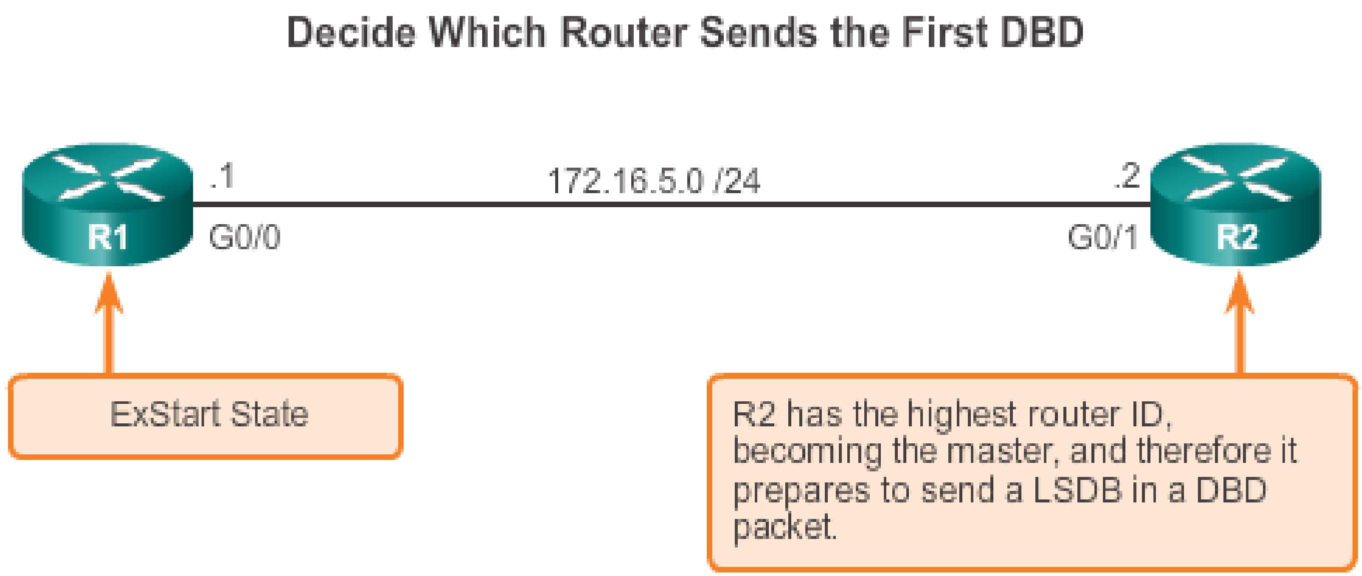
Creating Adjacencies With Every Neighbor



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

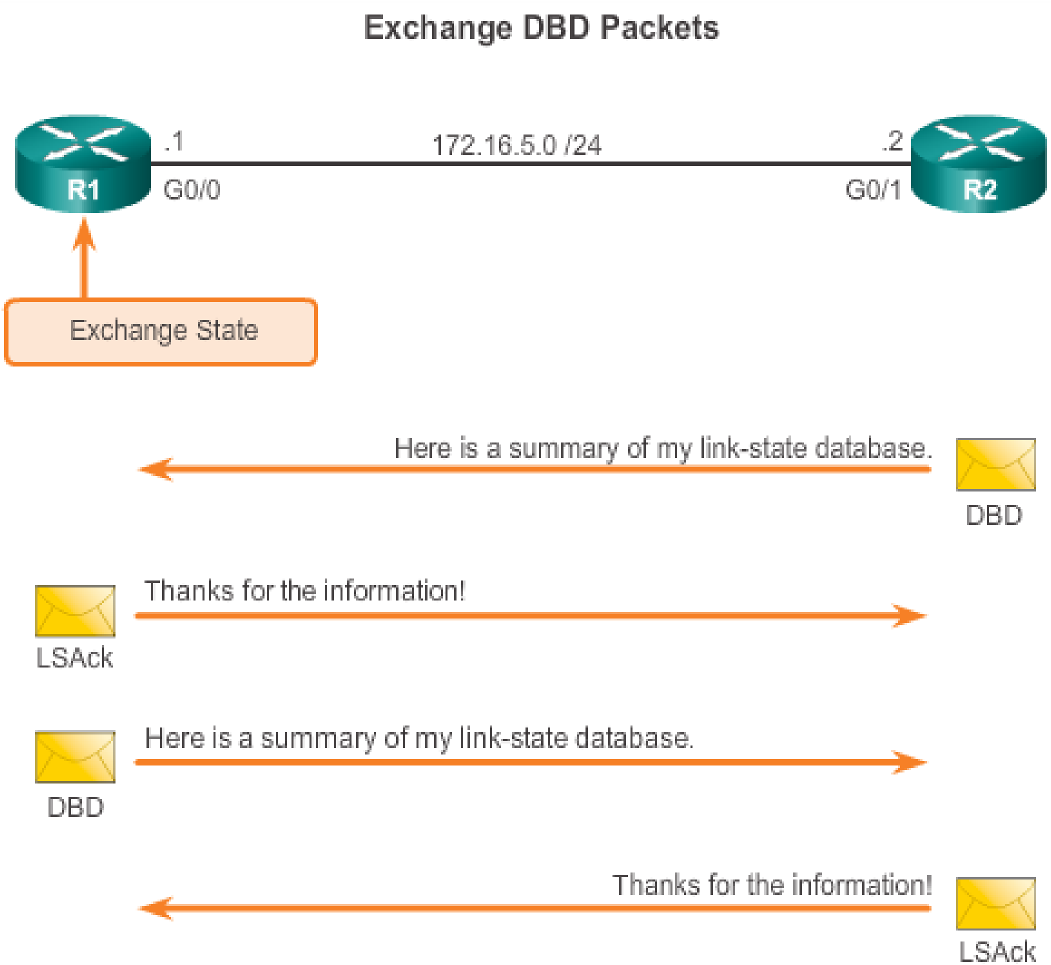
OSPF Operation

Synchronizing OSPF Database



OSPF Operation

Synchronizing OSPF Database (cont.)



OSPF Network Topology

Entering Router OSPF Configuration Mode on R1

```
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: Output has been altered to display only the commands that will be used in this chapter.

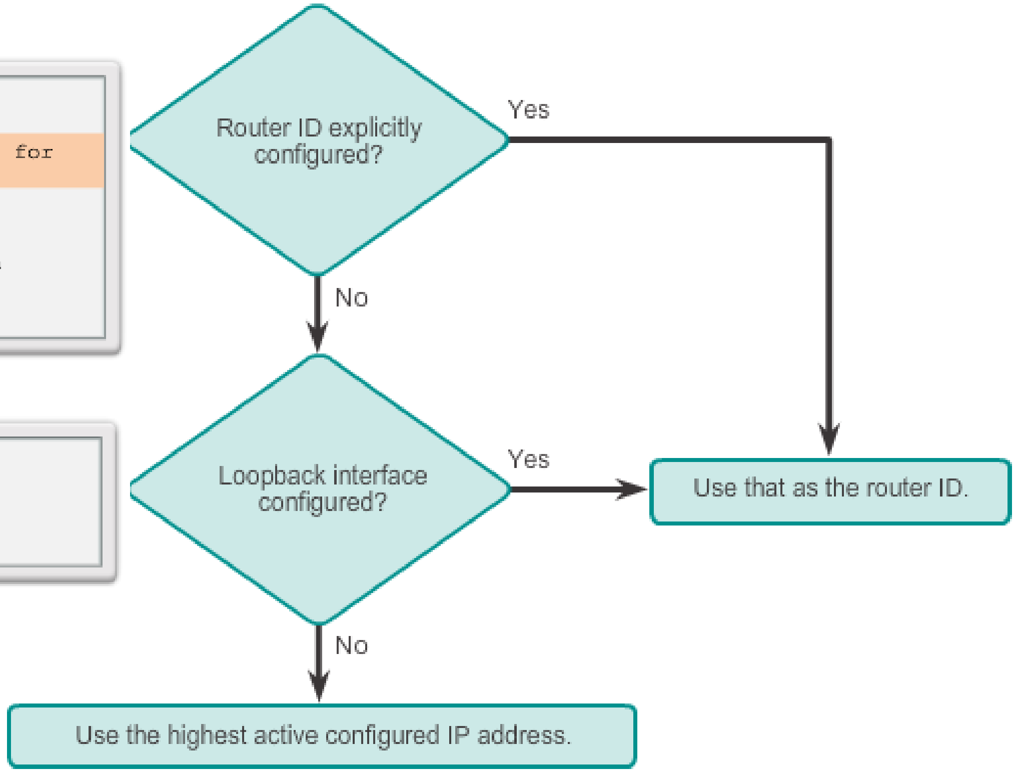
OSPF Router ID

Router IDs

```
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
R1(config-router)# end
R1#
*Mar 25 19:46:09.711: %SYS-5-CONFIG_I: Configured from
console by console
```

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

Router ID Order of Precedence



Clearing the OSPF Process

```
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
```

Configure Single-area OSPFv2

The network Command

Assigning Interfaces to an OSPF Area

```
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
R1(config-router)#
R1#
```

Assigning Interfaces to an OSPF Area with a Quad Zero

```
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
R1(config-router)#
R1#
```

Configure Single-Area OSPFv2

Passive Interface

- By default, OSPF messages are forwarded out all OSPF-enabled interfaces. However, these messages really only need to be sent out interfaces connecting to other OSPF-enabled routers.
- Sending out unneeded messages on a LAN affects the network in three ways:
  - Inefficient Use of Bandwidth
  - Inefficient Use of Resources
  - Increased Security Risk
- The Passive Interface feature helps limiting the scope of routing updates advertisements.

Configure Single-area OSPFv2

Configuring Passive Interfaces

Configuring a Passive Interface on R1

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

Use the **passive-interface** router configuration mode command to prevent the transmission of routing messages through a router interface, but still allow that network to be advertised to other routers.

OSPF Cost

OSPF Metric = Cost

Cost = *reference bandwidth* / *interface bandwidth*
(default reference bandwidth is 10^8)
Cost = 100,000,000 bps / *interface bandwidth in bps*

Default Cisco OSPF Cost Values

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

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reference
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OSPF Cost

OSPF Accumulates Costs

Cost of an OSPF route is the accumulated value from one router to the destination network.

```
R1# show ip route | include 172.16.2.0
O        172.16.2.0/24 [110/65] via 172.16.3.2, 03:39:07,
         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
R1#
```

OSPF Cost

Adjusting the Reference Bandwidth

- Use the **command - auto-cost reference-bandwidth**
- Must be configured on every router in the OSPF domain
- Notice that the value is expressed in Mb/s:
  - **Gigabit Ethernet** - **auto-cost reference-bandwidth 1000**
  - **10 Gigabit Ethernet** - **auto-cost reference-bandwidth 10000**

Verifying the S0/0/0 Link Cost

```
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     Topol
       0           647       no          no           
 Transmit Delay is 1 sec, State POINT_TO_POINT
 Timer intervals configured, Hello 10, Dead 40, Wait 40,
   oob-resync timeout 40
   Hello due in 00:00:01
 Supports Link-local Signaling (LLS)
 Cisco NSF helper support enabled
 IETF NSF helper support enabled
 Index 3/3, 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#
```

Verifying the Metric to the R2 LAN

```
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
R1#
R1#
```

OSPF Cost

Default Interface Bandwidths

On Cisco routers, the default bandwidth on most serial interfaces is set to 1.544 Mb/s.

Verifying the Default Bandwidth Settings of R1 Serial 0/0/0

```
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
  Encapsulation HDLC, loopback not set
  Keepalive set (10 sec)
  Last input 00:00:05, output 00:00:03, output hang never
  Last clearing of "show interface" counters never
  Input queue: 0/75/0/0 (size/max/drops/flushes); Total
```

OSPF Cost

Adjusting the Interface Bandwidths

Adjusting the R1 Serial 0/0/1 Interface

```
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#
```

Manually Setting the OSPF Cost

Both the **bandwidth** interface command and the **ip ospf cost** interface command achieve the same result, which is to provide an accurate value for use by OSPF in determining the best route.

```
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
R1#
```

Verify OSPF

Verify OSPF Neighbors

Verify that the router has formed an adjacency with its neighboring routers.

```
R1# show ip ospf neighbor

Neighbor ID   Pri   State    Dead Time Address        Interface
3.3.3.3       0     FULL/-   00:00:37  192.168.10.6   Serial0/0/1
2.2.2.2       0     FULL/-   00:00:30  172.16.3.2     Serial0/0/0
R1#
```

Verify OSPF

Verify OSPF Protocol Settings

Verifying R1's OSPF 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:
    172.16.1.0 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)

R1#
```

Verify OSPF

Verify OSPF Process Information

Verifying R1's OSPF Process

```
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
```

Verify OSPF Interface Settings

Verifying R1's OSPF Interfaces

```
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
R1#
```

Summary

OSPF:

- For IPv4 is OSPFv2
- For IPv6 is OSPFv3
- Classless, link-state routing protocol with a default administrative distance of 110, and is denoted in the routing table with a route source code of **O**
- OSPFv2 is enabled with the **router ospf** *process-id* global configuration mode command. The *process-id* value is locally significant, which means that it does not need to match other OSPF routers to establish adjacencies with those neighbors.
- **Network** command uses the *wildcard-mask* value which is the inverse of the subnet mask, and the *area-id* value

Summary (cont.)

OSPF:

- By default, OSPF Hello packets are sent every 10 seconds on multiaccess and point-to-point segments and every 30 seconds on NBMA segments (Frame Relay, X.25, ATM), and are used by OSPF to establish neighbor adjacencies. The Dead interval is four times the Hello interval, by default.
- For routers to become adjacent, their Hello interval, Dead interval, network types, and subnet masks must match. Use the **show ip ospf neighbors**command to verify OSPF adjacencies.
- In a multiaccess network, OSPF elects a DR to act as collection and distribution point for LSAs sent and received. A BDR is elected to assume the role of the DR should the DR fail. All other routers are known as DROTHERs. All routers send their LSAs to the DR, which then floods the LSA to all other routers in the multiaccess network.

Summary (cont.)

OSPF:

- In multiaccess networks, the router with the highest router ID is the DR, and the router with the second highest router ID is the BDR. This can be superseded by the **ip ospf** *priority* command on that interface. The router with the highest priority value is the DR, and next-highest the BDR.
- The **show ip protocols** command is used to verify important OSPF configuration information, including the OSPF process ID, the router ID, and the networks the router is advertising.
- OSPFv3 is enabled on an interface and not under router configuration mode. OSPFv3 needs link-local addresses to be configured. IPv6 Unicast routing must be enabled for OSPFv3. A 32-bit router-ID is required before an interface can be enabled for OSPFv3.

Summary (cont.)

OSPF:

- The **show ip protocols** command is used to verify important OSPFv2 configuration information, including the OSPF process ID, the router ID, and the networks the router is advertising.
- OSPFv3
  - Enabled on an interface and not under router configuration mode
  - Needs link-local addresses to be configured. IPv6
  - Unicast routing must be enabled for OSPFv3
  - 32-bit router-ID is required before an interface can be enabled for OSPFv3
  - **show ipv6 protocols** command is a quick way to verify configuration information (OSPF process ID, the router ID, and the interfaces enabled for OSPFv3)