Chapter 5

Routing & Switching

Outline

- Characteristics of OSPF
- Configuring Single-area OSPFv2
- Configure Single-area OSPFv3

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

Open Shortest Path First

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
- To exchange routing information
- To maintain accurate information about the network.

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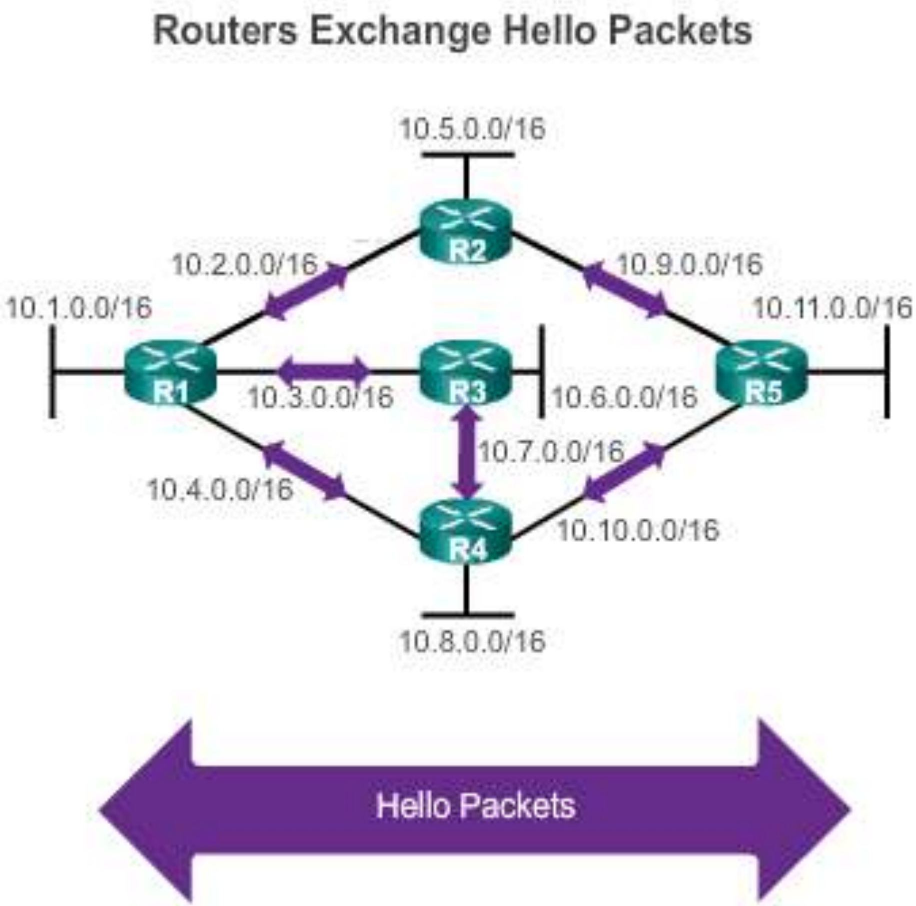
Link-State Operation



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

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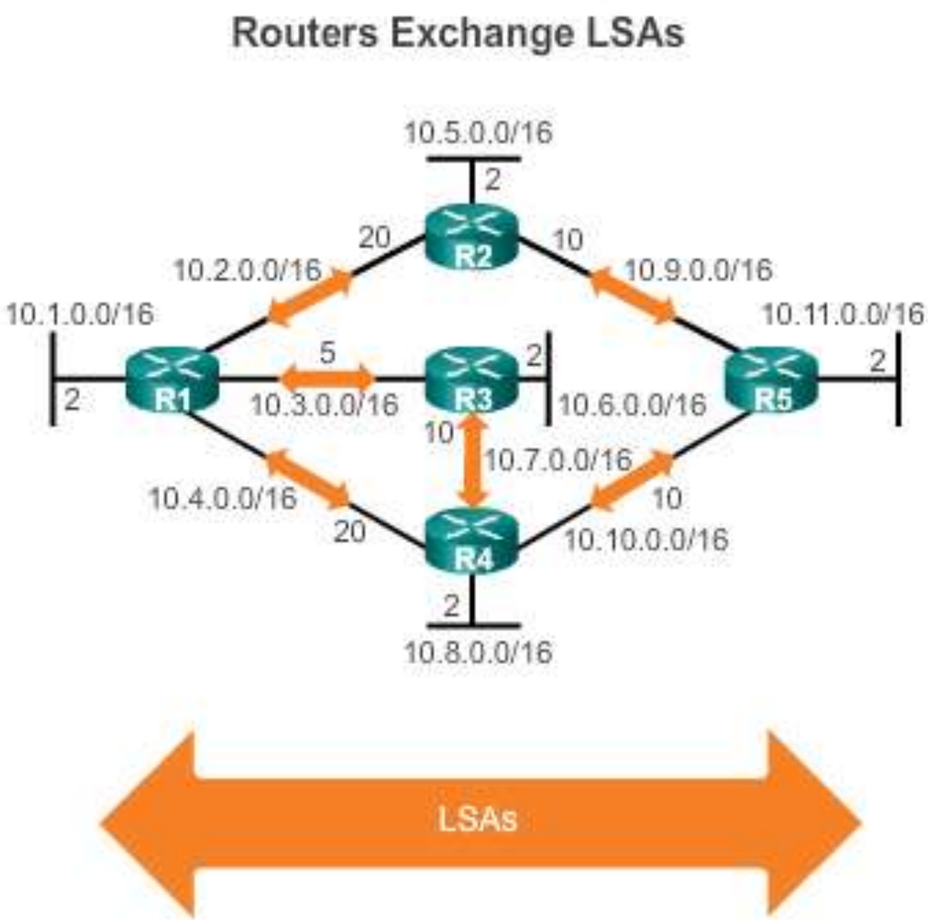
Link-State Operation (cont.)



- 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.

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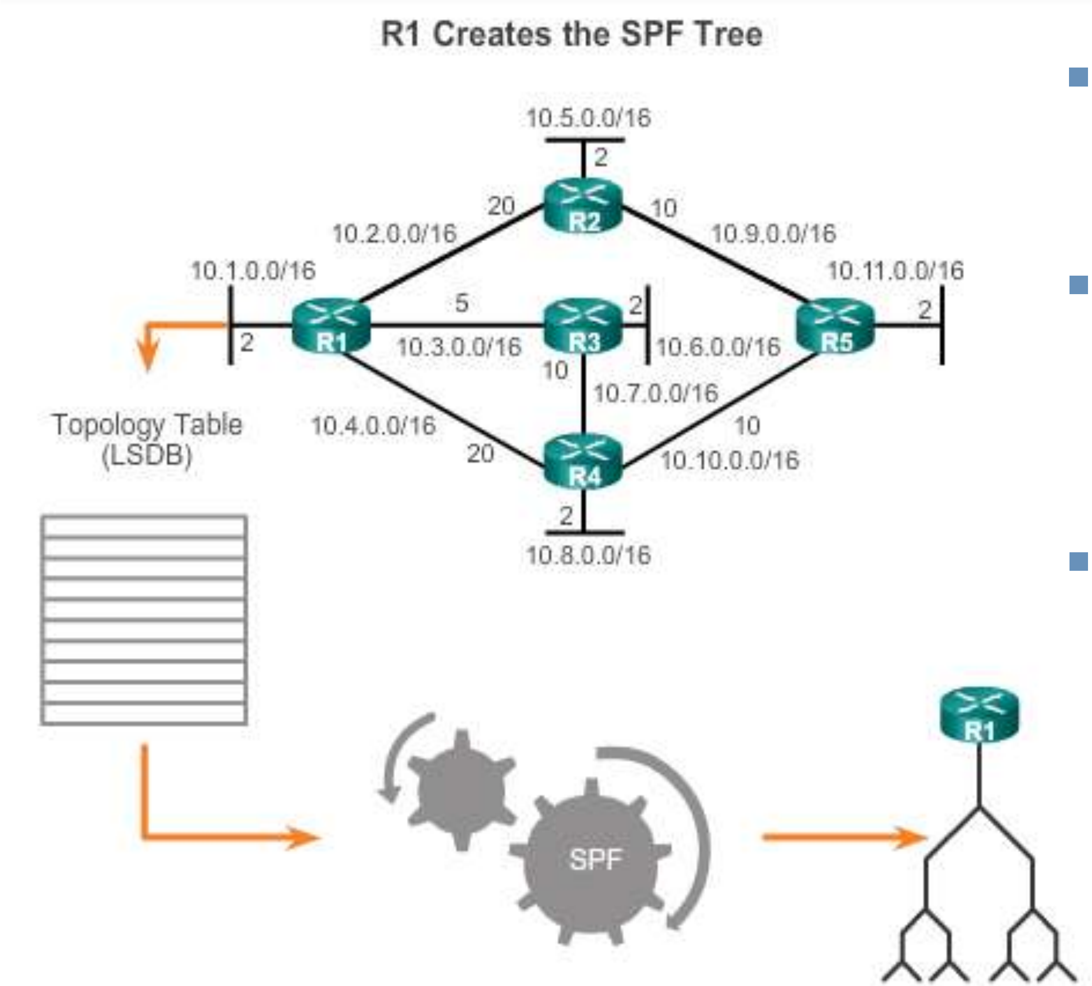
Link-State Operation

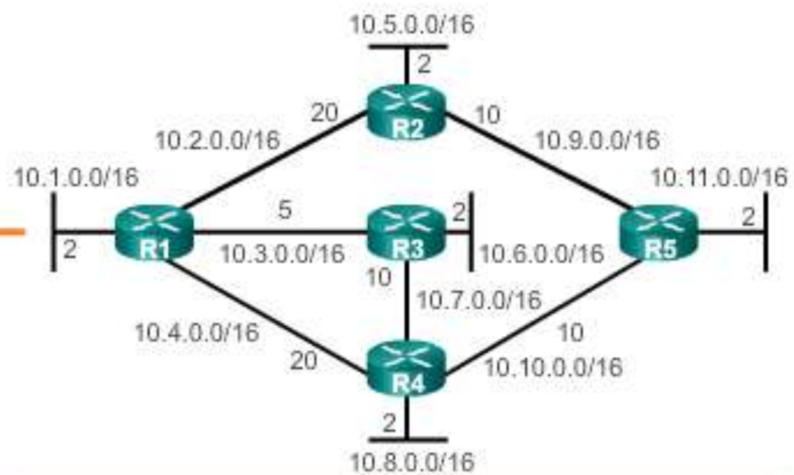


- Build the topology table based on the received LSAs.
- This database eventually holds all the information about the topology of the network.
- Execute the SPF Algorithm.

Open Shortest Path First

Link-State Operation (cont.)

Content of the R1 SPF Tree



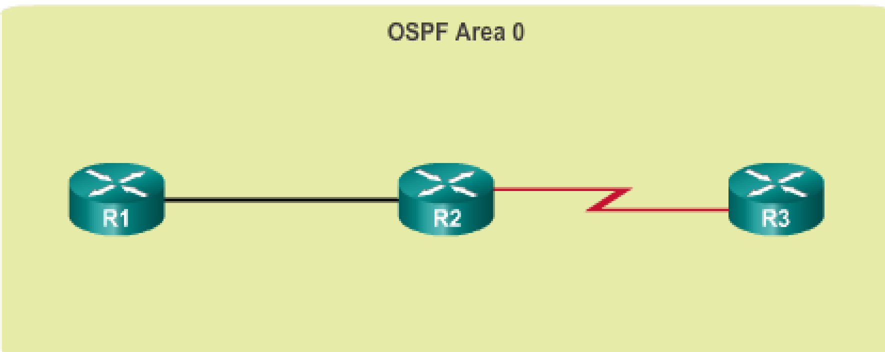
Destination	Shortest Path	Cost
10.5.0.0/16	R1 → R2	22
10.6.0.0/16	R1 → R3	7
10.7.0.0/16	R1 → R3	15
10.8.0.0/16	R1 → R3 → R4	17
10.9.0.0/16	R1 → R2	30
10.10.0.0/16	R1 → R3 → R4	25
10.11.0.0/16	R1 → R3 → R4 → R5	27

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

Open Shortest Path First

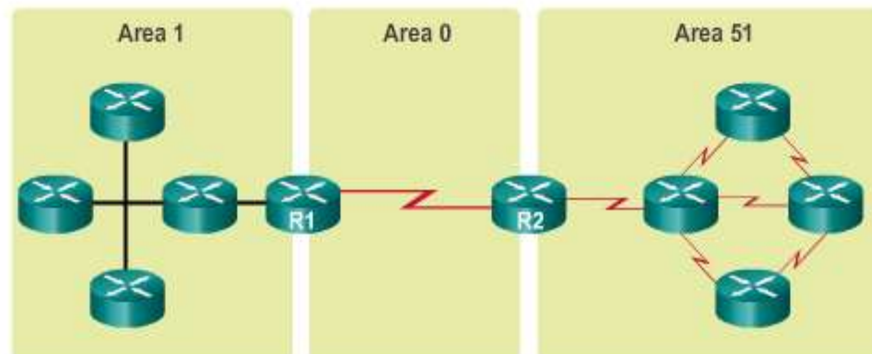
Single-area and Multiarea OSPF

Single-Area OSPF



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

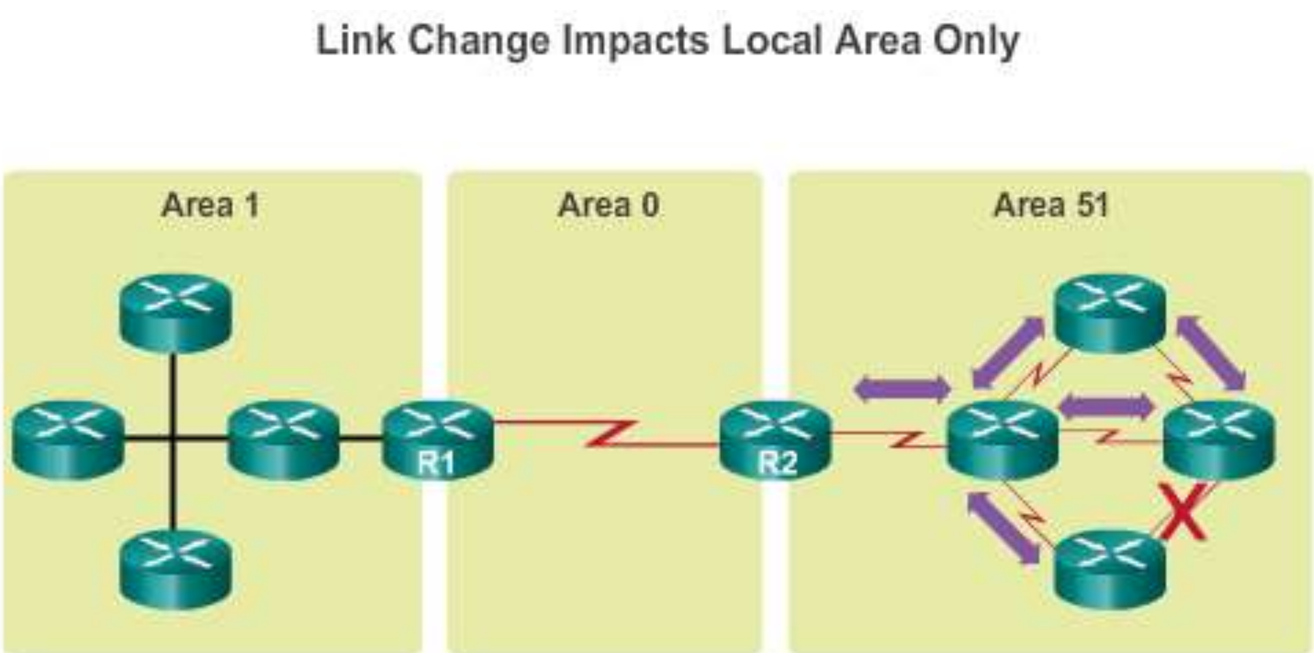
Multiarea OSPF



- 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

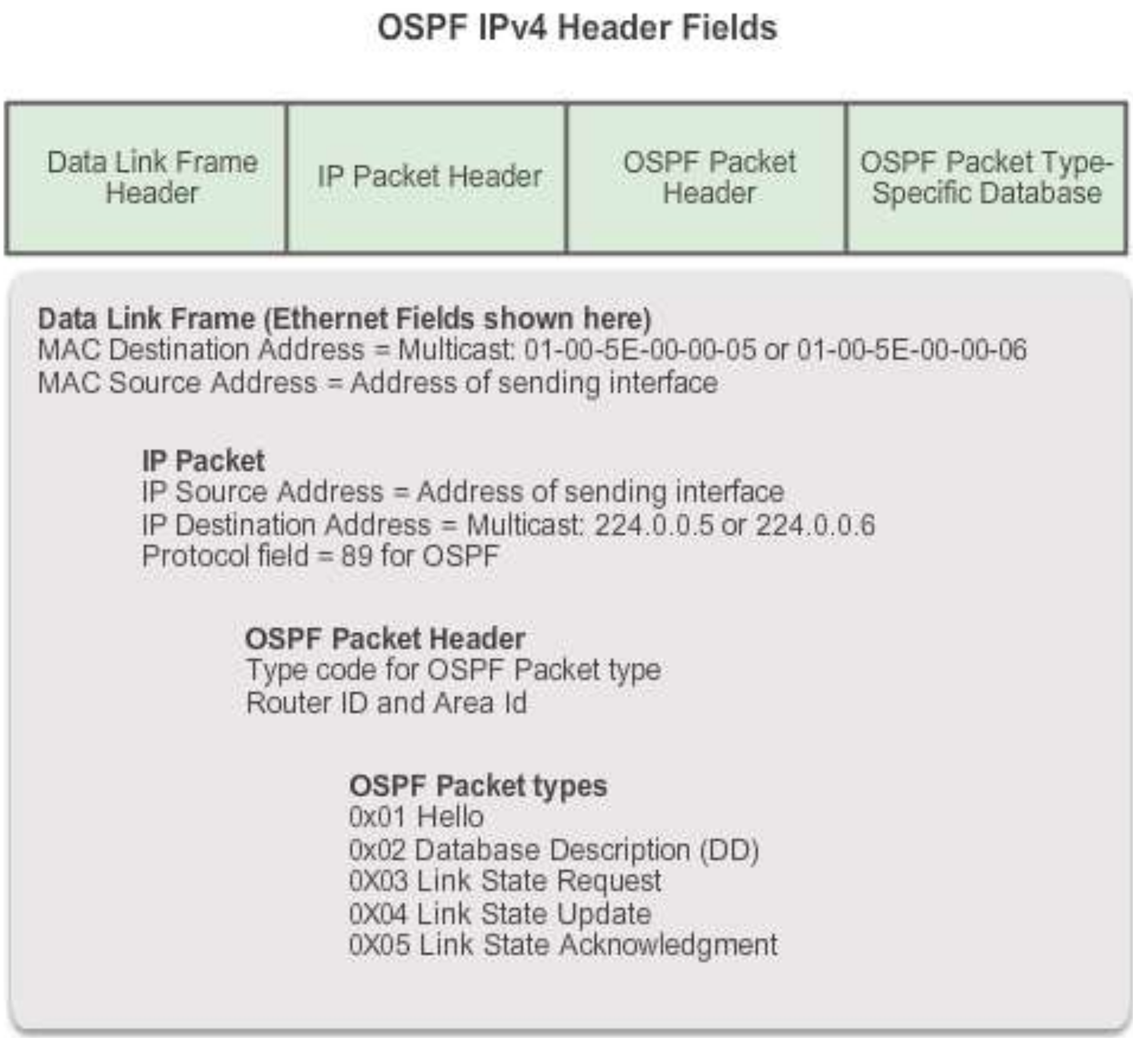
Single-area and Multiarea OSPF (cont.)



- 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.

OSPF Messages

Encapsulating OSPF Messages



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

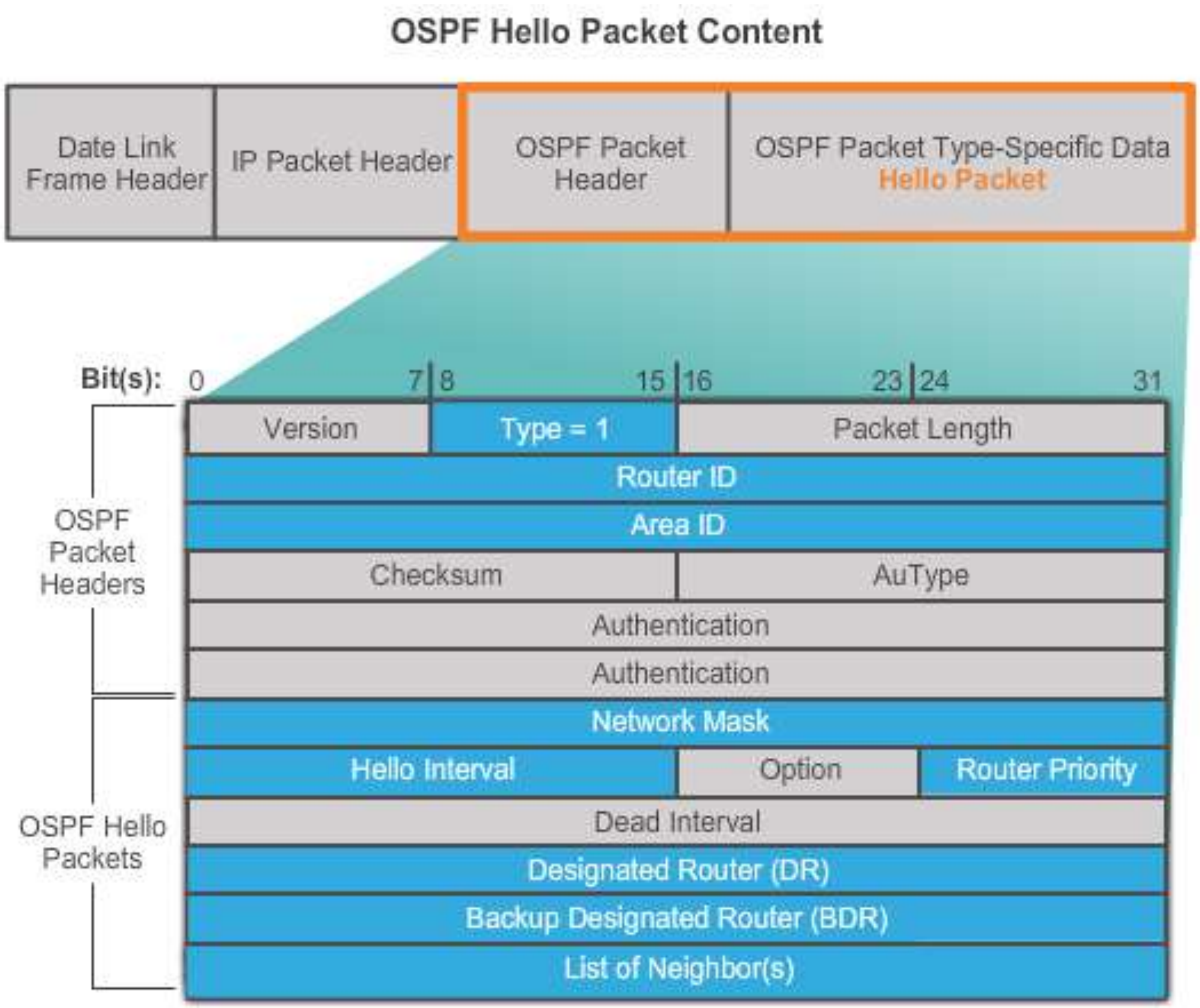
Hello Packet

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 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

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

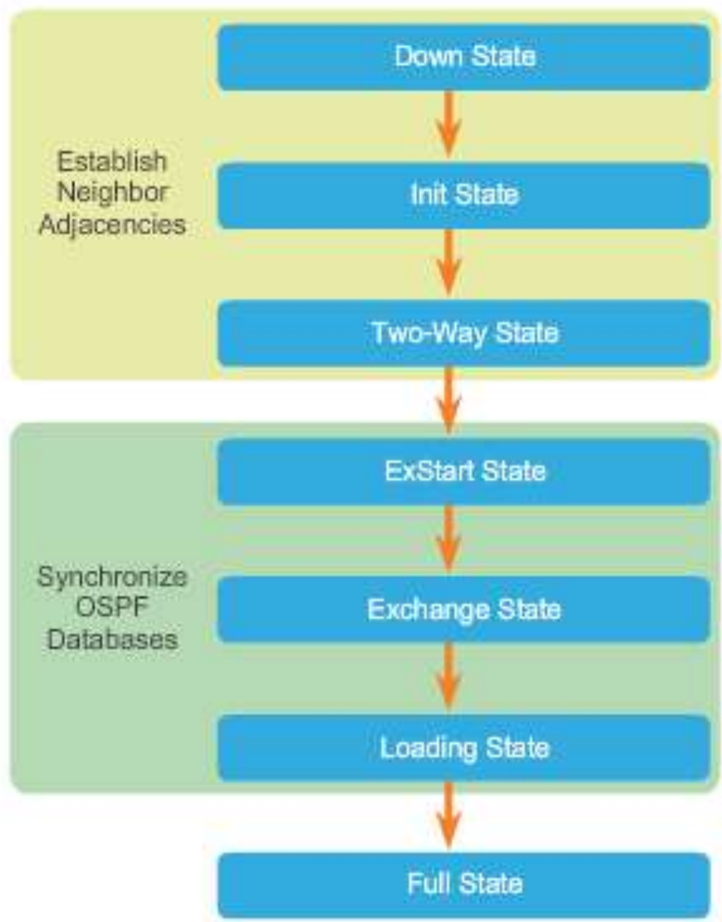
- An LSU contains one or more LSAs.
- LSAs contain route information for destination networks.

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

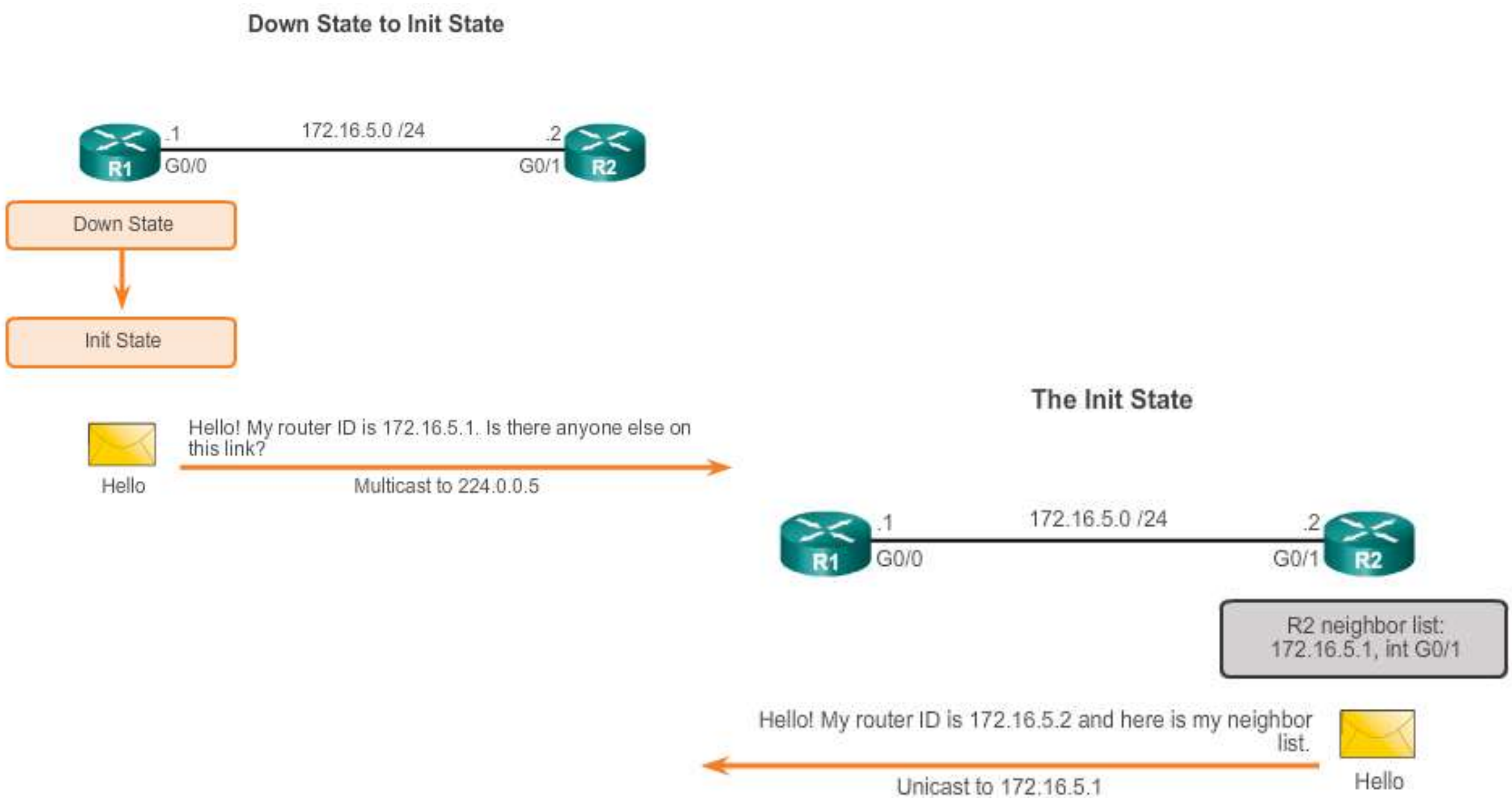
When an OSPF router is initially connected to a network, it attempts to:

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



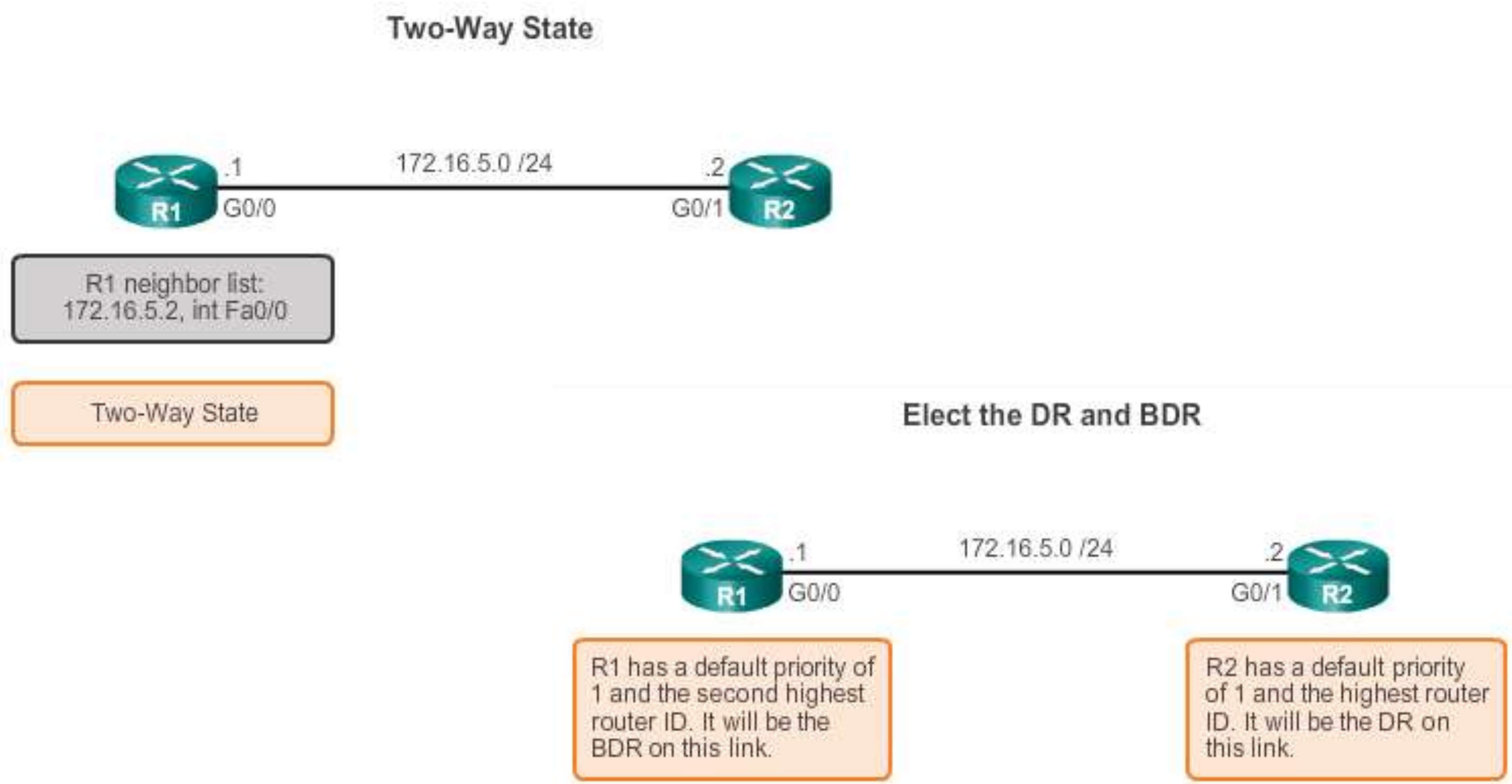
OSPF Operation

Establish Neighbor Adjacencies



OSPF Operation

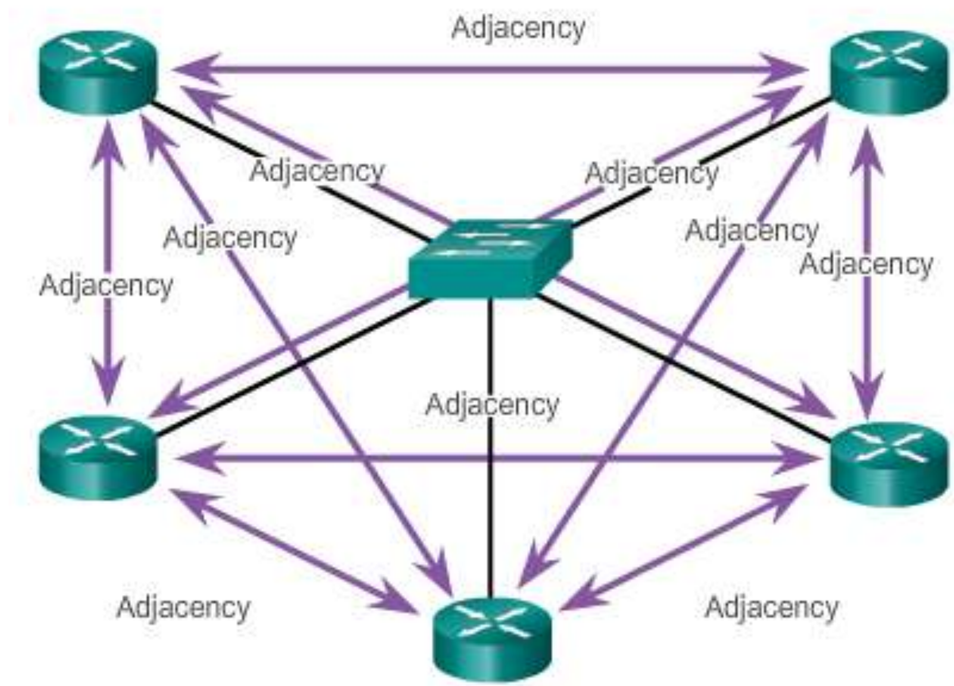
Establish Neighbor Adjacencies (cont.)



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

OSPF Operation
OSPF DR and BDR

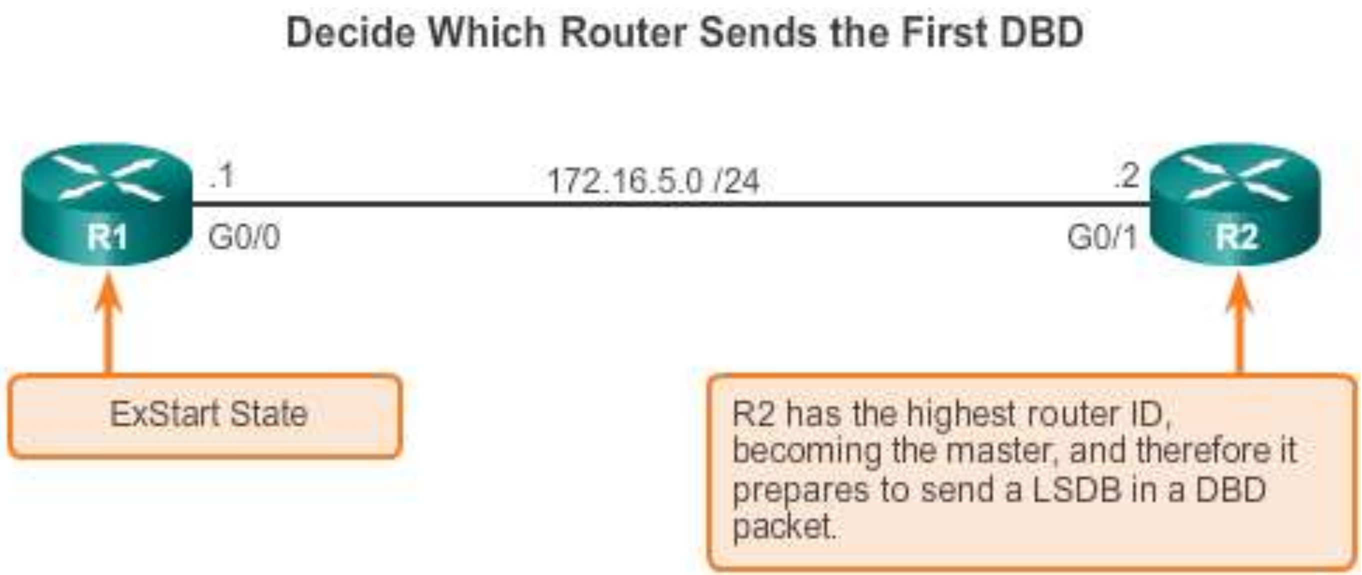
Creating Adjacencies With Every Neighbor



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

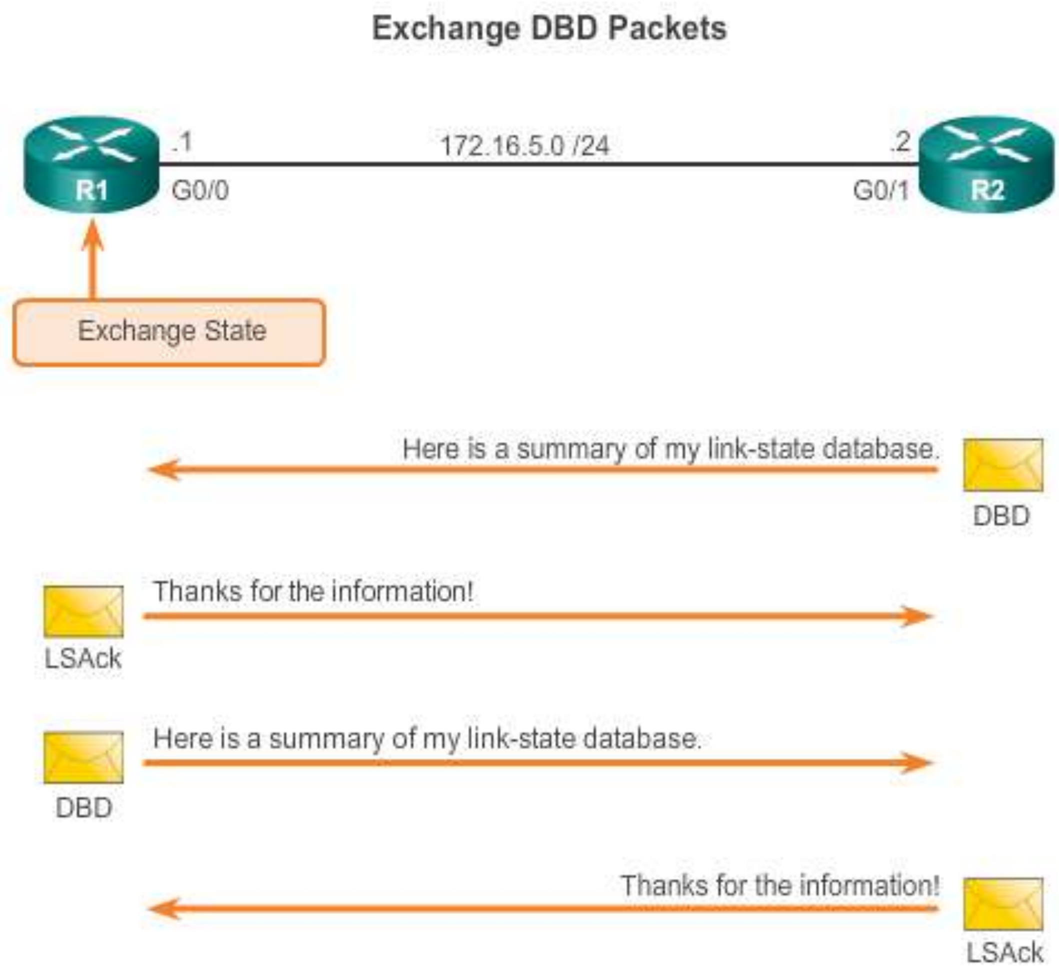
OSPF Operation

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
```

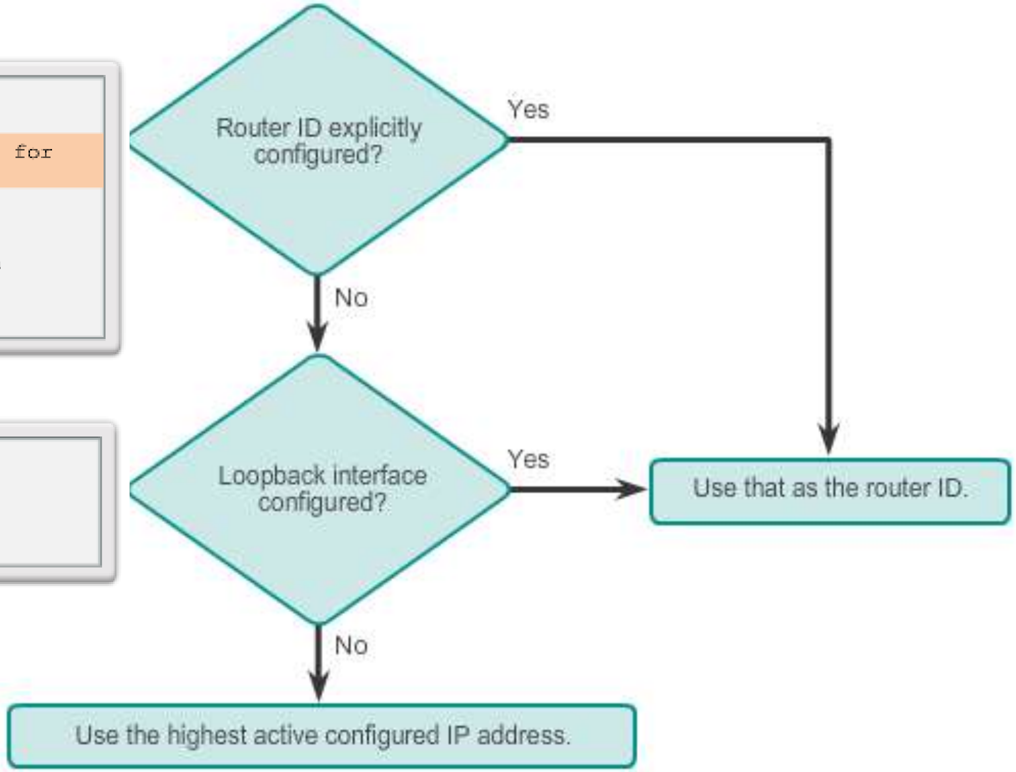
Note: Output has been altered to display only the commands that will be used in this chapter.

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

Same Cos
due to
reference
bandwidt

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#
```

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 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 Protocol Settings

Verifying R1's OSPF Neighbors

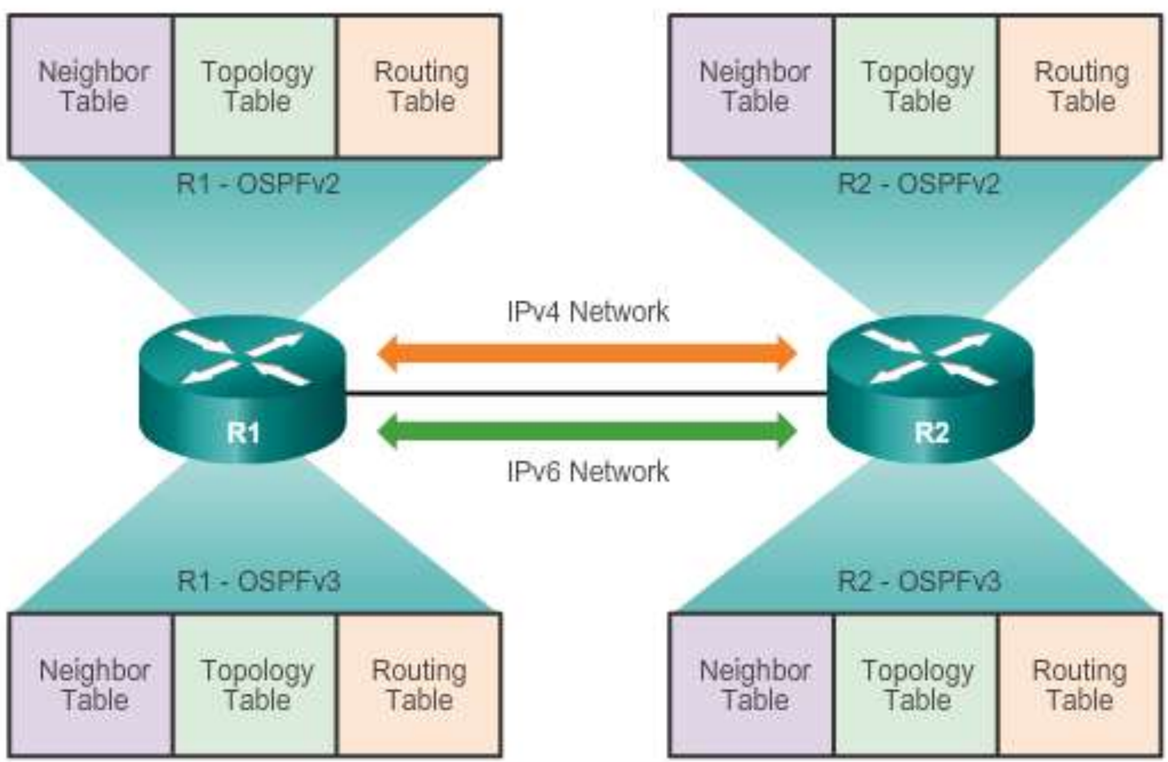
```
R1# show ip protocols
*** IP Routing is NSF aware ***

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#
```

OSPFv2 vs. OSPFv3
OSPFv3

OSPFv2 and OSPFv3 Data Structures



OSPFv2 vs. OSPFv3

Similarities Between OSPFv2 to OSPFv3

OSPFv2 and OSPFv3	
Link-State	Yes
Routing Algorithm	SPF
Metric	Cost
Areas	Supports the same two-level hierarchy
Packet Types	Same Hello, DBD, LSR, LSU and LSAck packets
Neighbor Discovery	Transitions through the same states using Hello packets
DR and BDR	Function and election process is the same
Router ID	32-bit router ID: determined by the same process in both protocols

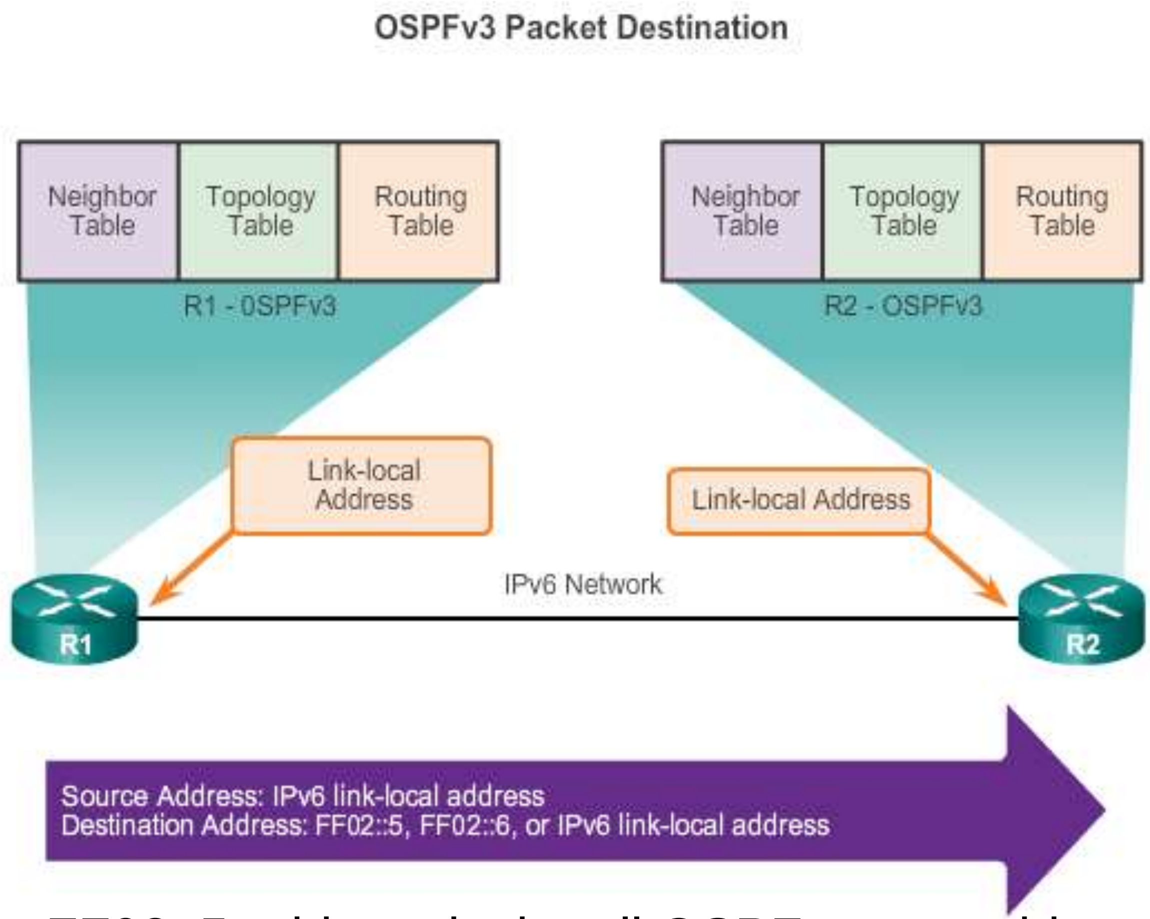
OSPFv2 vs. OSPFv3

Differences Between OSPFv2 to OSPFv3

	OSPFv2	OSPFv3
Advertises	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-OSPFv3-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-id`** interface configuration command
IP Unicast Routing	IPv4 unicast routing is enabled by default.	IPv6 unicast forwarding is not enabled by default. The **`ipv6 unicast-routing`** global configuration command must be configured.
Authentication	Plain text and MD5	IPv6 authentication

OSPFv2 vs. OSPFv3

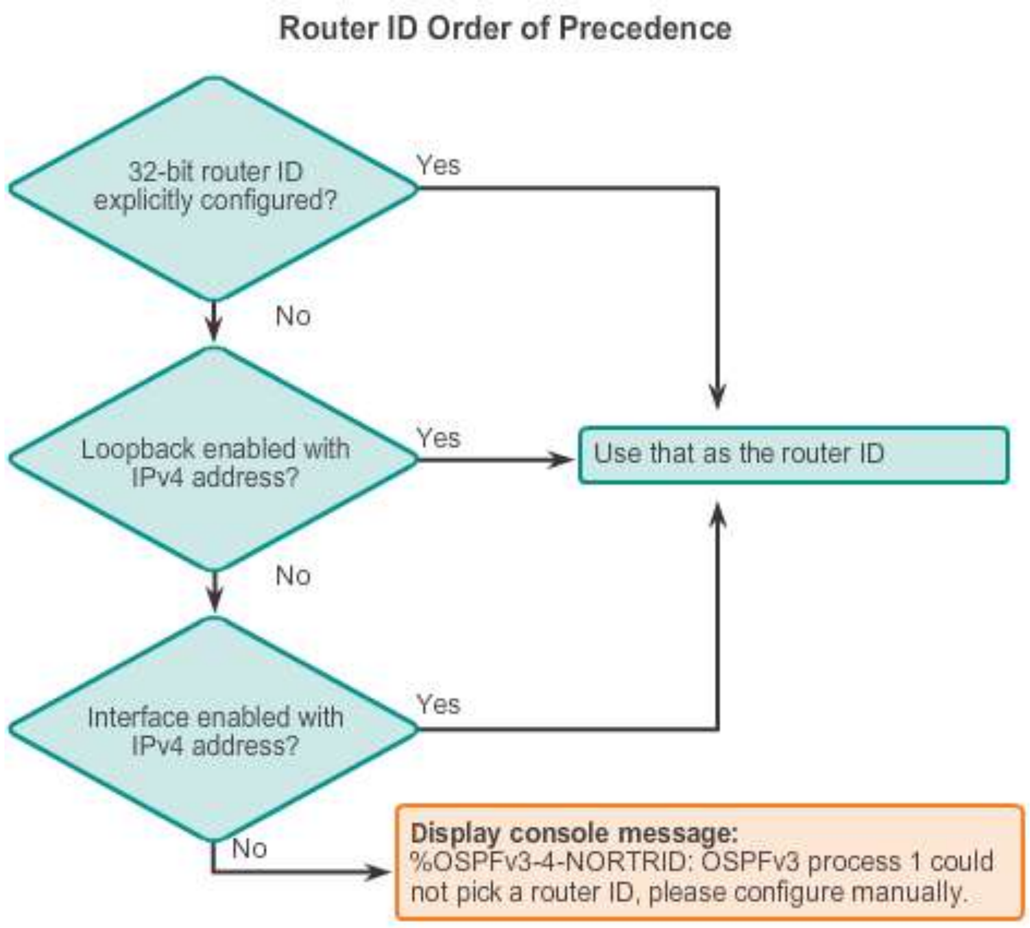
Link-Local Addresses



FF02::5 address is the all OSPF router address
FF02::6 is the DR/BDR multicast address

Configuring OSPFv3

Configuring the OSPFv3 Router ID



Enabling OSPFv3 on Interfaces

Instead of using the **network** router configuration mode command to specify matching interface addresses, OSPFv3 is configured directly on the interface.

```
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#
```

Verify OSPFv3 Interfaces

```
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
R1#
```