Chapter 8: Single-Area OSPF

Routing & Switching

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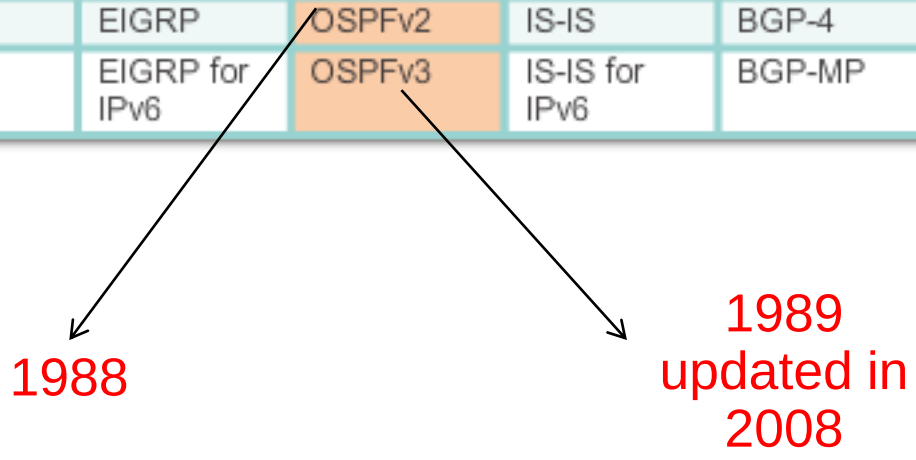
Evolution of OSPF

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



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

OSPF Routers Exchange Packets

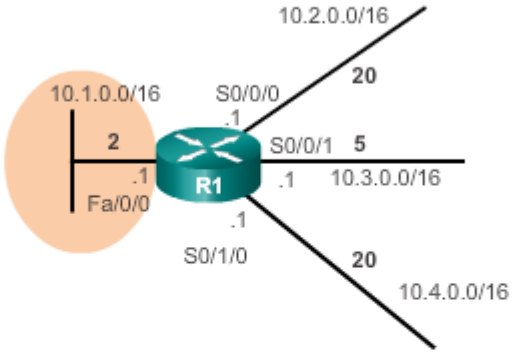
- These packets are used to discover neighboring routers and also to exchange routing information to maintain accurate information about the network.

- Hello-prosessi – naapuruus suhteet
- Exchange-prosessi – kannankuvaus, pyynnöt ja päivitykset
- Topologiakannan muodostus
- Reititystaulun muodostus
- Flooding-prosessi – päivityssanomien välitys

Link and Link-State

The first step in the link-state routing process is that each router learns about its own links and its own directly connected networks.

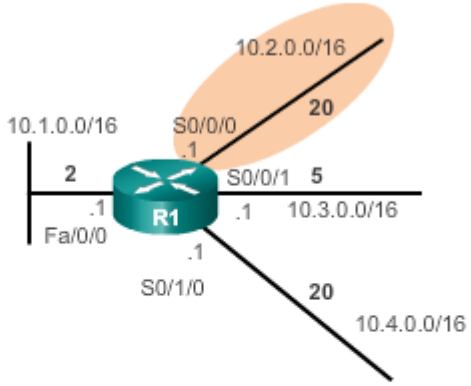
Link-State of Interface Fa0/0



Link 1

- Network: **10.1.0.0/16**
- IP address: **10.1.0.1**
- Type of network: **Ethernet**
- Cost of that link: **2**
- Neighbors: **None**

Link-State of Interface S0/0/0

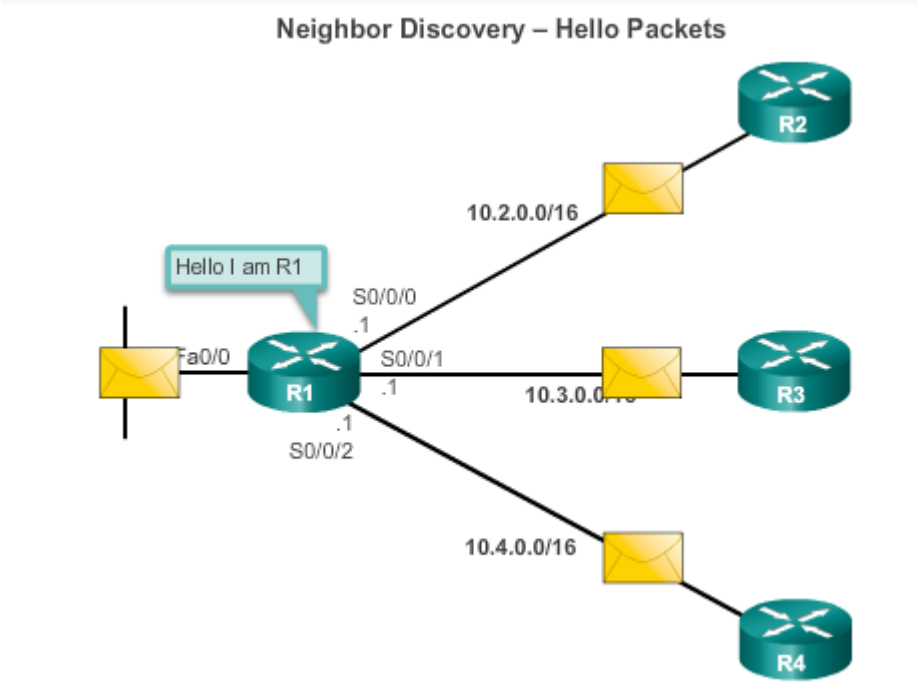


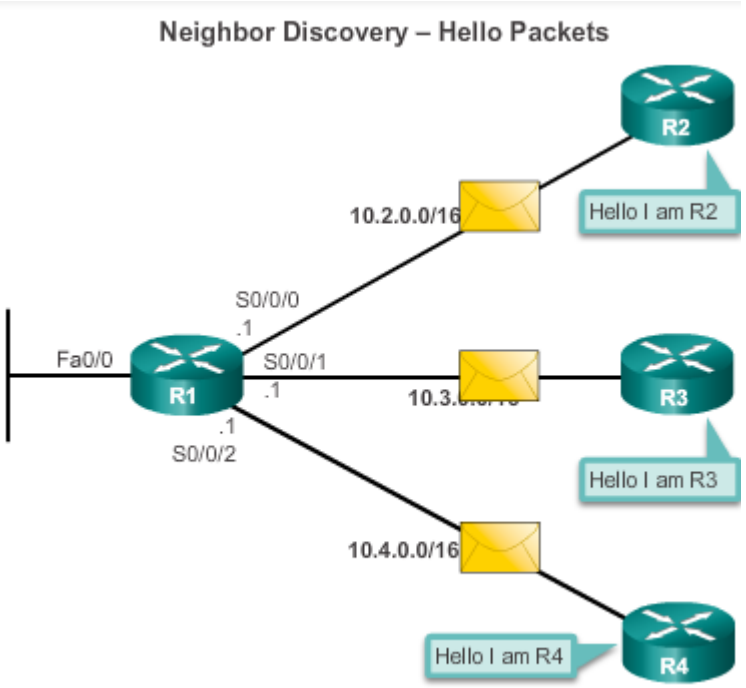
Link 2

- Network: **10.2.0.0/16**
- IP address: **10.2.0.1**
- Type of network: **Serial**
- Cost of that link: **20**
- Neighbors: **R2**

Hello

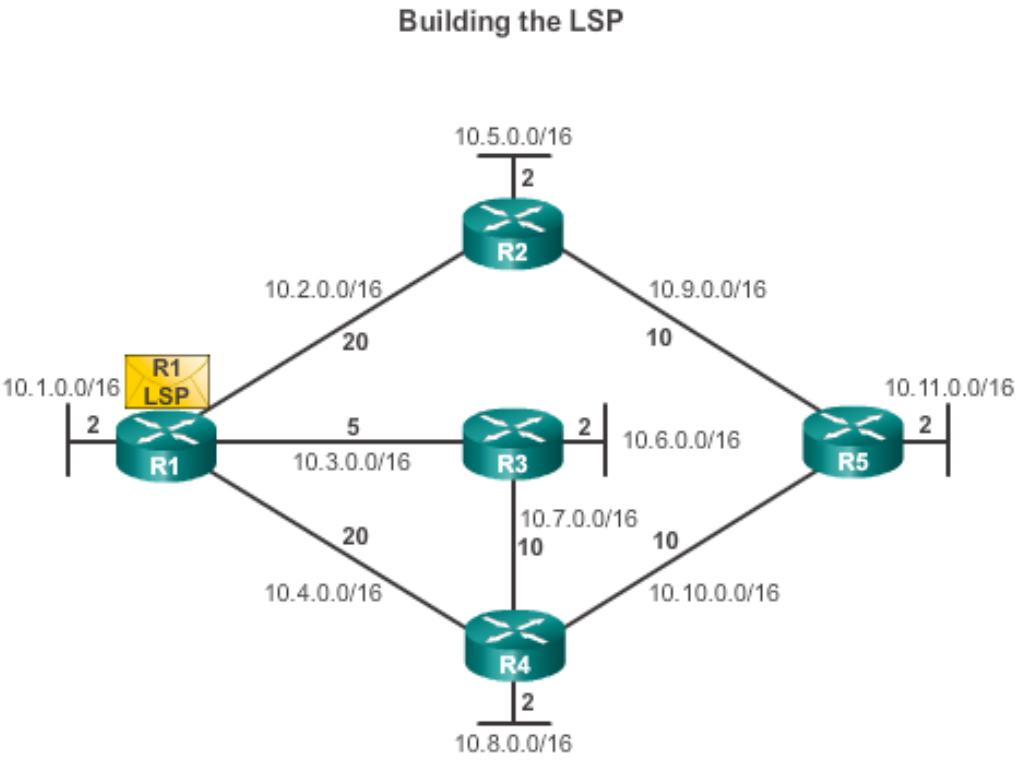
The second step in the link-state routing process is that each router is responsible for meeting its neighbors on directly connected networks.





Hello

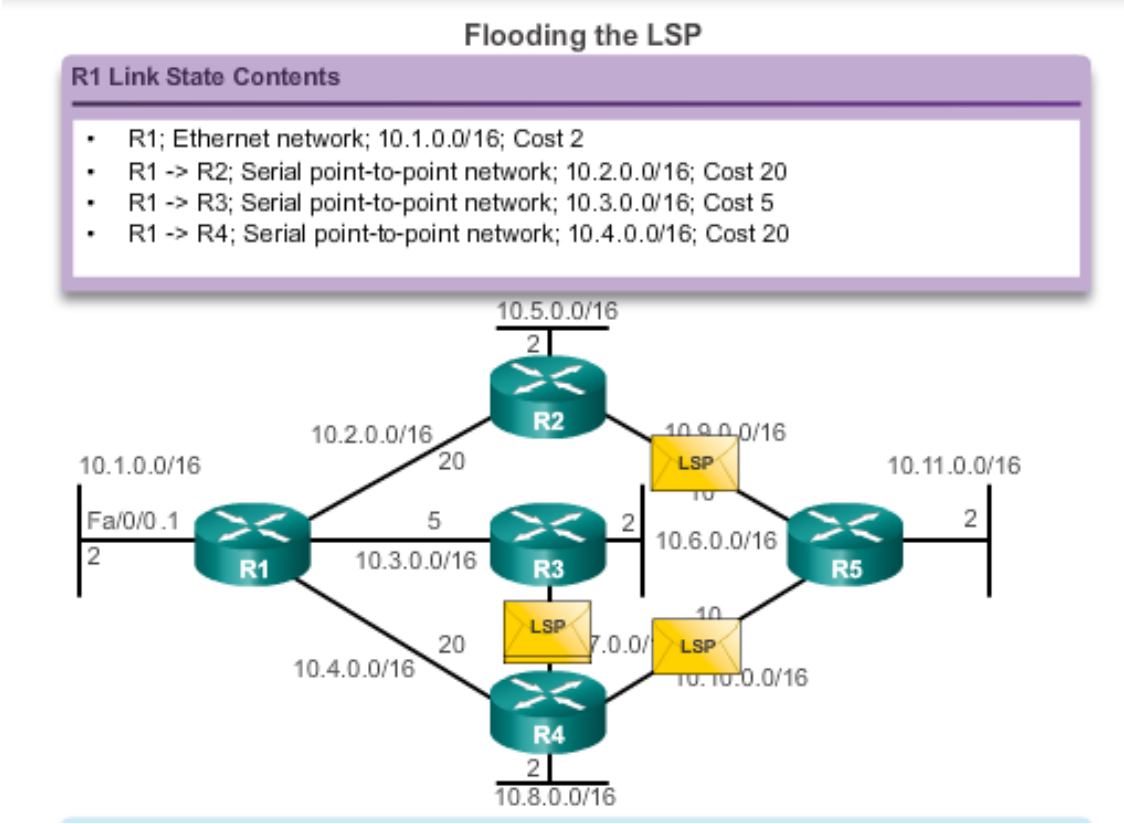
The third step in the link-state routing process is that each router builds a link-state packet (LSP) containing the state of each directly connected link.



1. R1; Ethernet network 10.1.0.0/16; Cost 2
2. R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
3. R1 -> R3; Serial point-to-point network; 10.7.0.0/16; Cost 5
4. R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20

Flooding the LSP

The fourth step in the link-state routing process is that each router floods the LSP to all neighbors, who then store all LSPs received in a database.



Building the Link-State Database

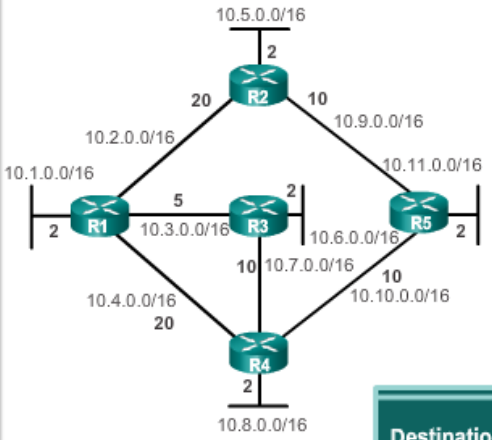
The final step in the link-state routing process is that each router uses the database to construct a complete map of the topology and computes the best path to each destination network.

Contents of the Link-State Database

R1 Link-State Database
R1 Link-states: • Connected to network 10.1.0.0/16, cost = 2 • Connected to R2 on network 10.2.0.0/16, cost = 20 • Connected to R3 on network 10.3.0.0/16, cost = 5 • Connected to R4 on network 10.4.0.0/16, cost = 20
R2 Link-states: • Connected to network 10.5.0.0/16, cost = 2 • Connected to R1 on network 10.2.0.0/16, cost = 20 • Connected to R5 on network 10.9.0.0/16, cost = 10
R3 Link-states: • Connected to network 10.6.0.0/16, cost = 2 • Connected to R1 on network 10.3.0.0/16, cost = 5 • Connected to R4 on network 10.7.0.0/16, cost = 10
R4 Link-states: • Connected to network 10.8.0.0/16, cost = 2 • Connected to R1 on network 10.4.0.0/16, cost = 20 • Connected to R3 on network 10.7.0.0/16, cost = 10 • Connected to R5 on network 10.10.0.0/16, cost = 10
R5 Link-states: • Connected to network 10.11.0.0/16, cost = 2 • Connected to R2 on network 10.9.0.0/16, cost = 10 • Connected to R4 on network 10.10.0.0/16, cost = 10

Building The SPF Tree and Adding OSPF Routes to the Routing Table

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



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

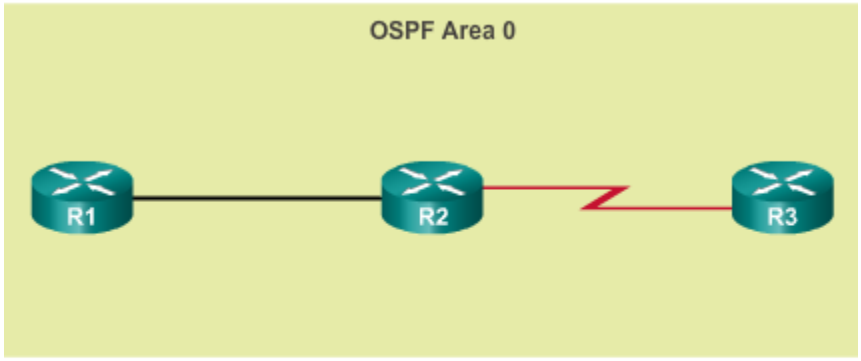
R1 Routing Table

Directly Connected Networks
- 10.1.0.0/16 Directly Connected Network
- 10.2.0.0/16 Directly Connected Network
- 10.3.0.0/16 Directly Connected Network
- 10.4.0.0/16 Directly Connected Network

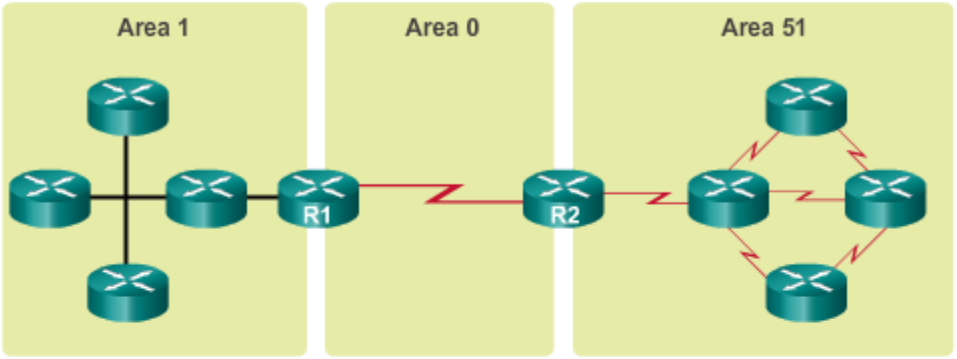
Remote Networks
- 10.5.0.0/16 via R2 serial 0/0/0,cost=22
- 10.6.0.0/16 via R3 serial 0/0/1,cost=7
- 10.7.0.0/16 via R3 serial 0/0/1,cost=15
- 10.8.0.0/16 via R3 serial 0/0/1,cost=17
- 10.9.0.0/16 via R2 serial 0/0/0,cost=30
- 10.10.0.0/16 via R3 serial 0/0/1,cost=25
- 10.11.0.0/16 via R3 serial 0/0/1,cost=27

Open Shortest Path First

Single-area and Multiarea OSPF



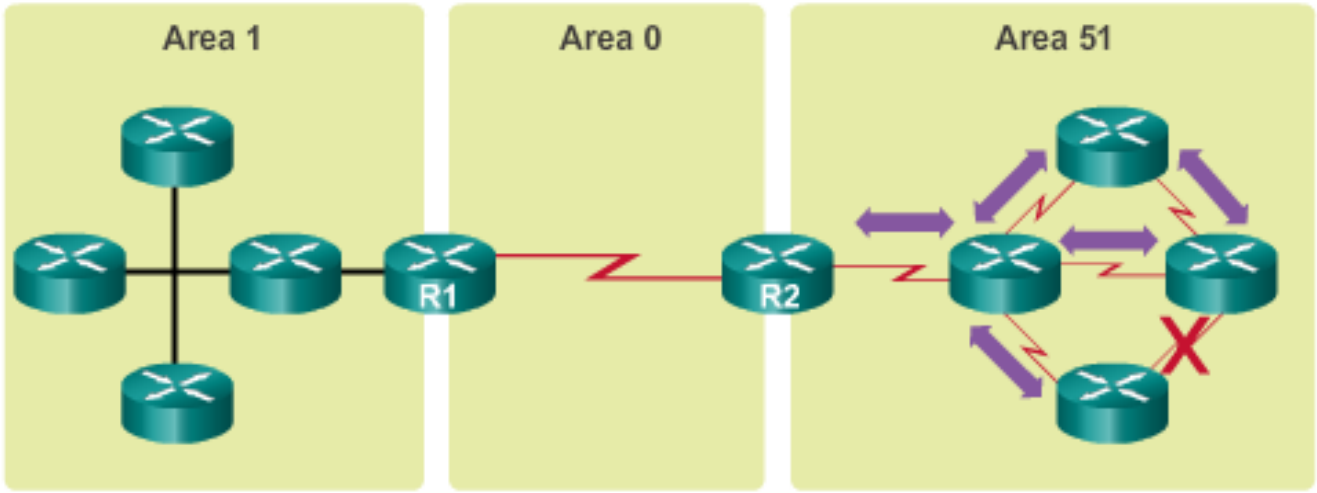
Area 0 is also called the backbone area.
Single-area OSPF is useful in smaller networks with few routers.



- 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.

Single-area and Multiarea OSPF

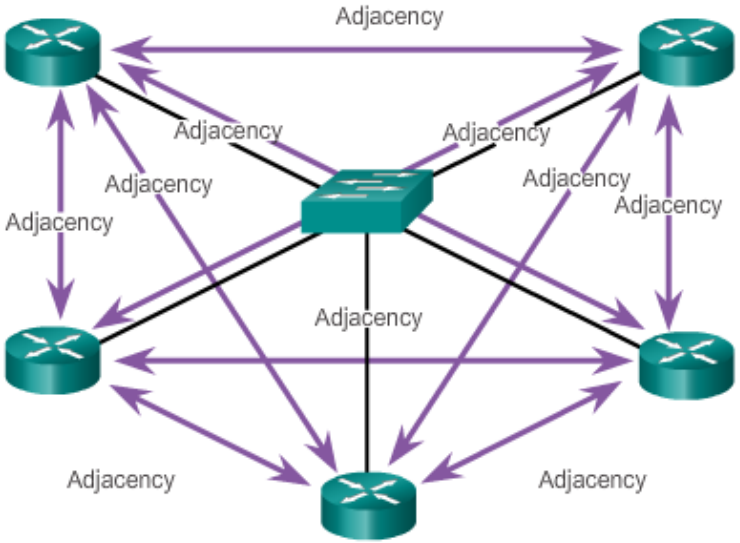
Link Change Impacts Local Area Only



- 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.

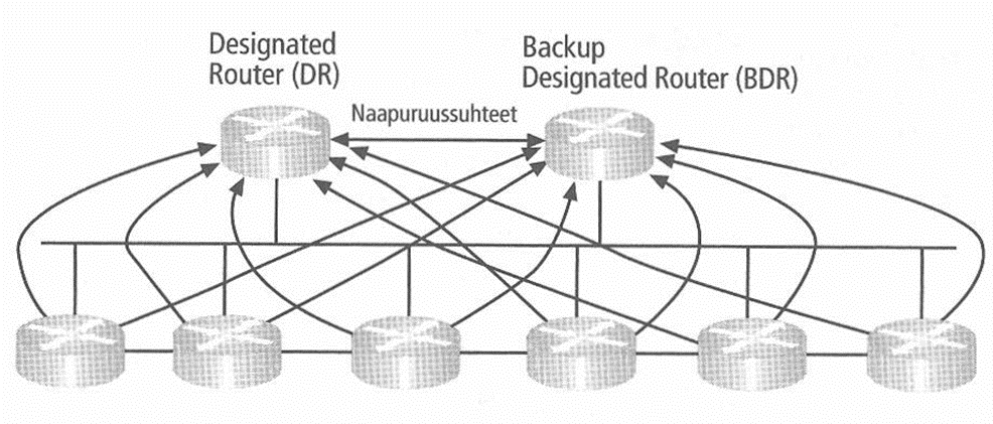
OSPF DR and BDR

Creating Adjacenncies with every Neighbour

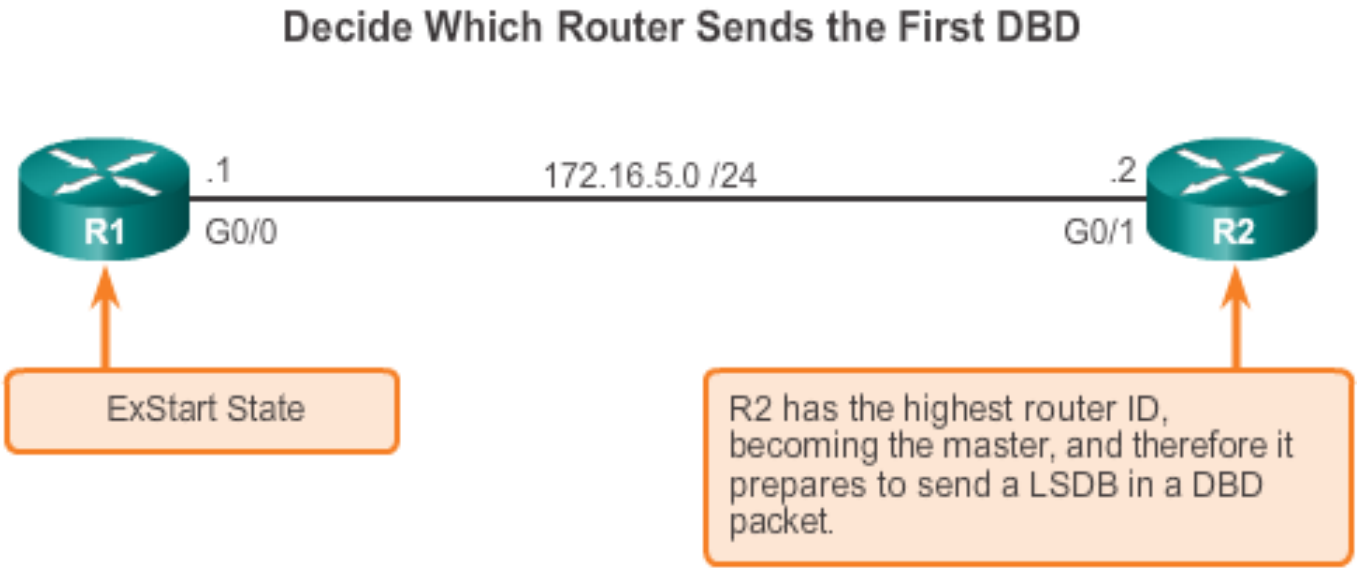


Number of Adjacencies=n(n-1)/2
n=number of routers
Example:5 routers (5-1)/2=10 adjacencies

Creating Adjacenncies only with DR and BDR



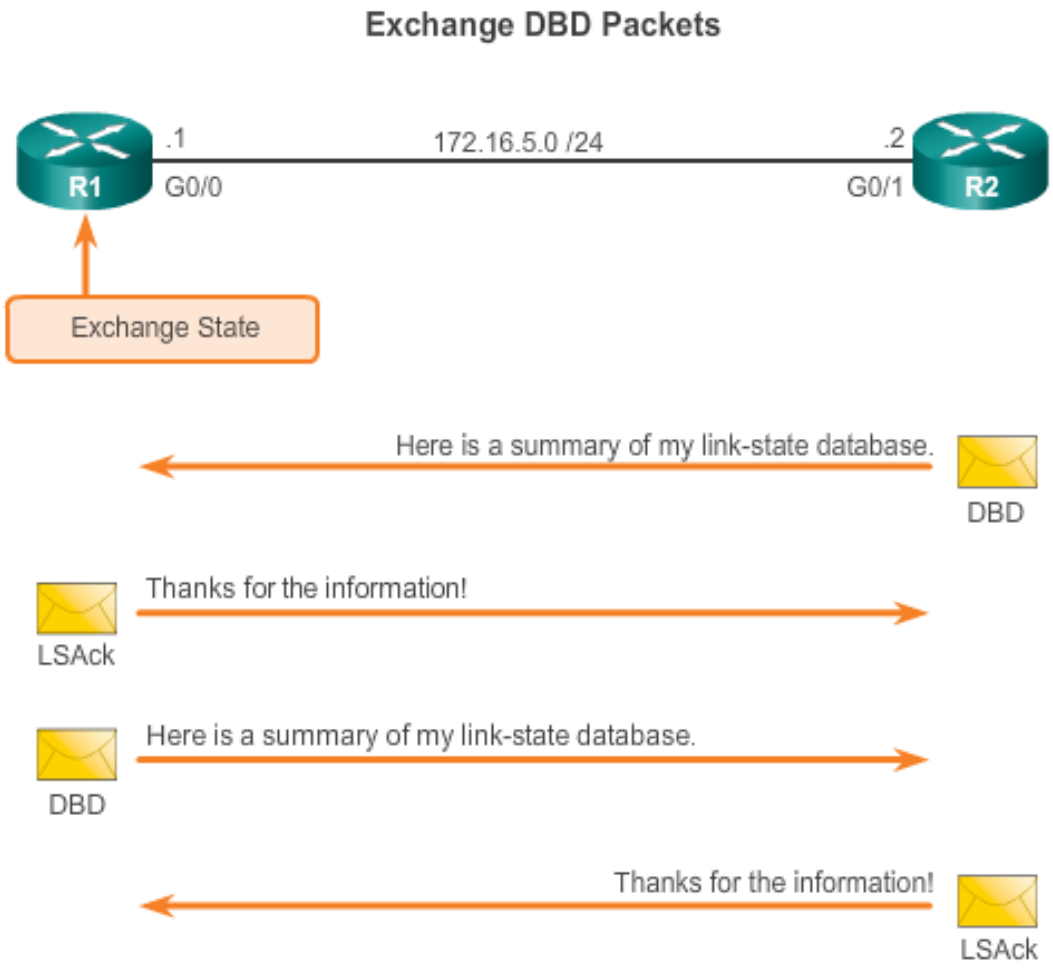
Synchronizing OSPF Database



LSDB=Link-State Database

DBD=Database Description

Synchronizing OSPF Database



Configuring OSPFv2

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OSPF Router ID

Router IDs

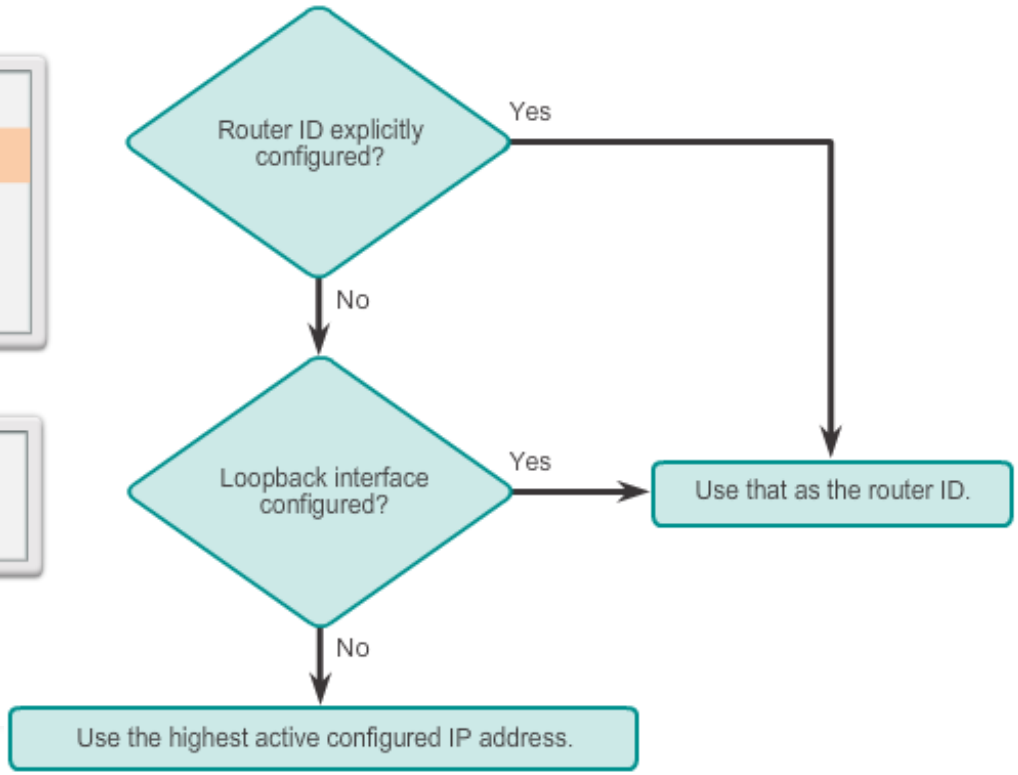
```
R1(config)# router ospf 10
R1(config-router)# router-id 1.1.1.1
% OSPF: Reload or use "clear ip ospf process" command, for
this to take effect
R1(config-router)# end
R1#
*Mar 25 19:46:09.711: %SYS-5-CONFIG_I: Configured from
console by console
```

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

Clearing the OSPF Process

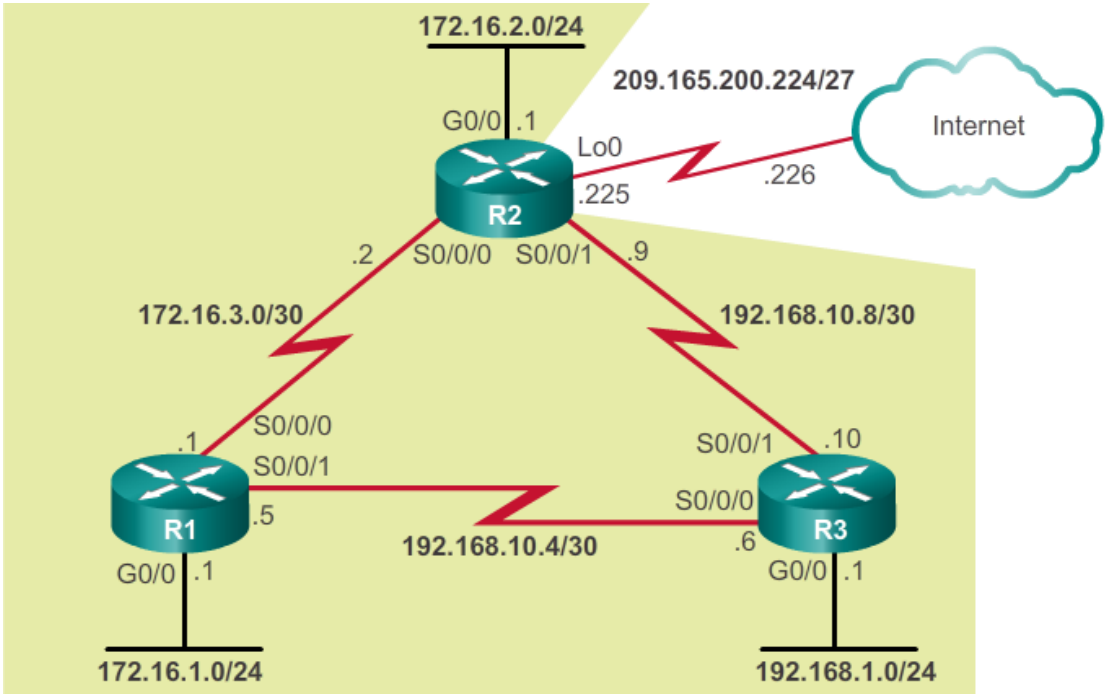
```
R1# clear ip ospf process
Reset ALL OSPF processes? [no]: y
R1#
*Mar 25 19:46:22.423: %OSPF-5-ADJCHG: Process 10, Nbr
3.3.3.3 on Serial0/0/1 from FULL to DOWN, Neighbor Down:
Interface down or detached
*Mar 25 19:46:22.423: %OSPF-5-ADJCHG: Process 10, Nbr
2.2.2.2 on Serial0/0/0 from FULL to DOWN,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

Router ID Order of Precedence



The network Command

```
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#
```



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.

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

OSPF Metric = Cost

Cost = *reference bandwidth* / *interface bandwidth*

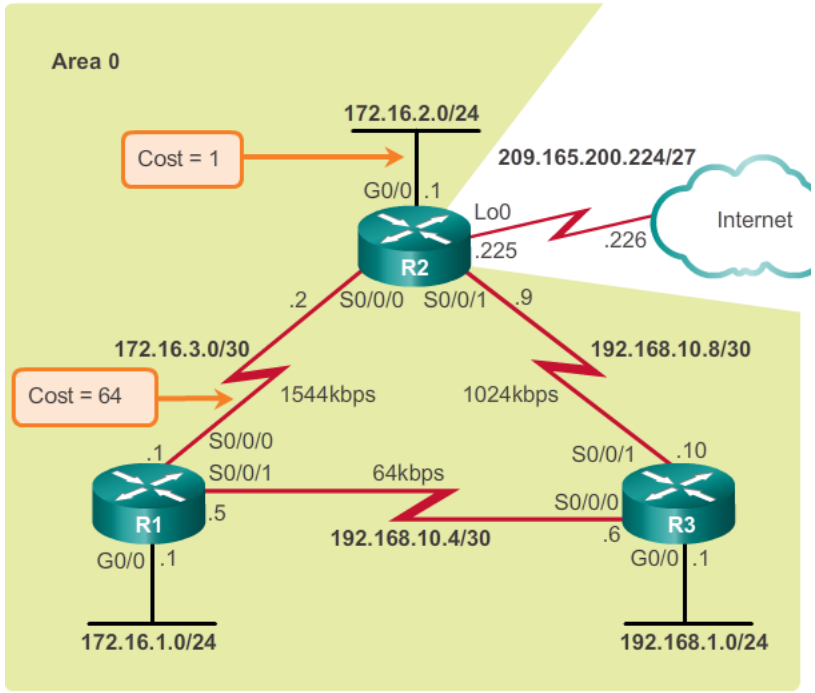
(default reference bandwidth is 10^8)

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

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 bandwidtl

OSPF Cost




```
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#
```

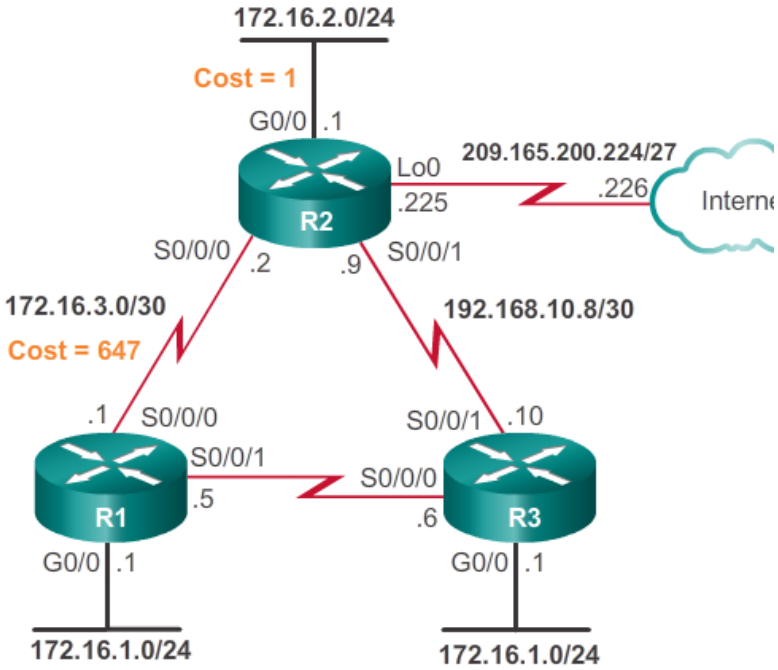
OSPF Cost

Adjusting the Reference Bandwidth

- 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

```
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
 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 00:00:01
```

```
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#
```



OSPF Cost

Interface Bandwidths

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
```

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

```
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

```
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#
```

```
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#
```

```
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
```

```
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#
```

OSPFv3

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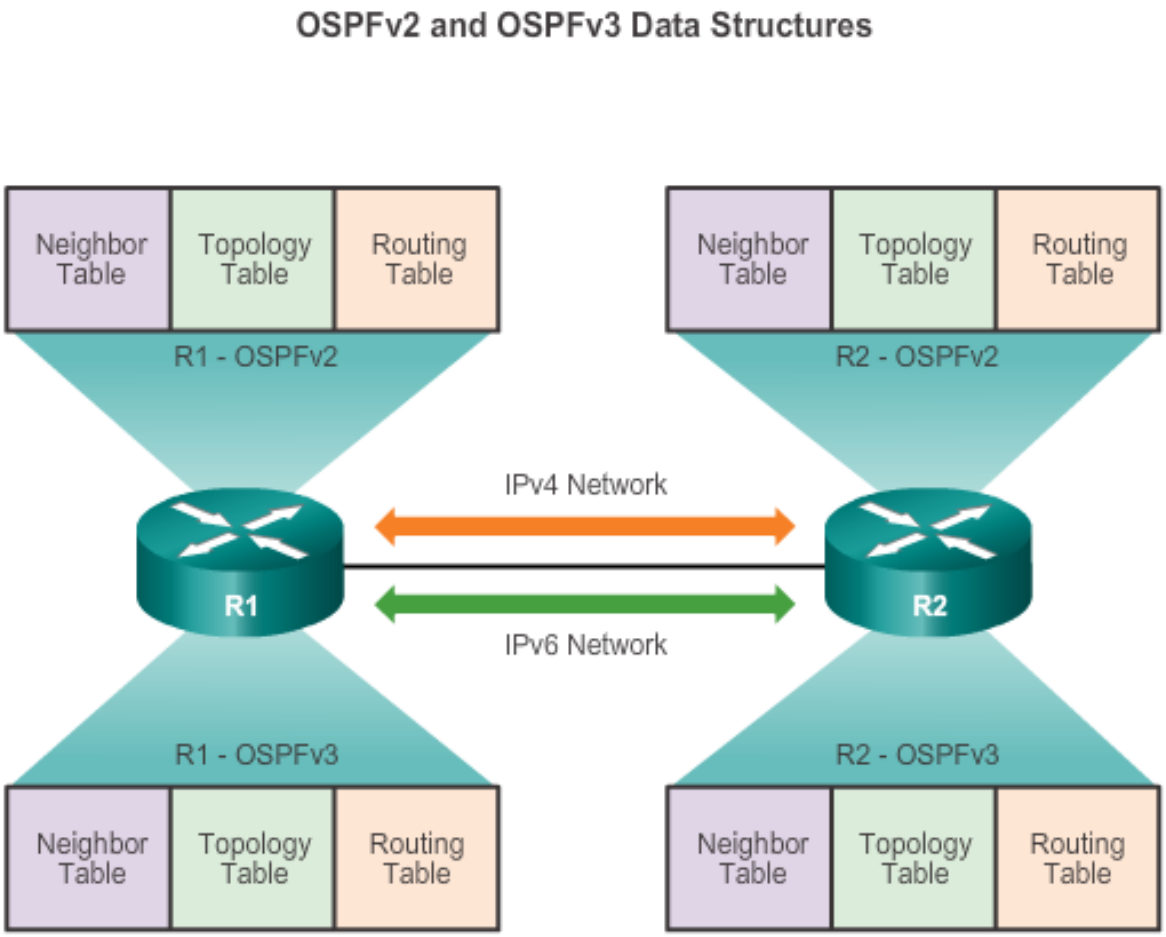
OSPFv2 vs. OSPFv3

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

OSPFv3 Network Topology

Steps to Configure OSPFv3

Step 1: Enable IPv6 unicast routing: **`ipv6 unicast-routing`**.

Step 2: (Optional) Configure link-local addresses.

Step 3: Configure a 32-bit router ID in OSPFv3 router configuration mode using the **`router-id`** `rid` command.

Step 4: Configure optional routing specifics such as adjusting the reference bandwidth.

Step 5: (Optional) Configure OSPFv3 interface specific settings. For example, adjust the interface bandwidth.

Step 6: Enable IPv6 routing by using the **`ipv6 ospf area`** command.

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

```
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
R1#
```

```
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#
```

```
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
  Redistribution:
    None
R1#
```

Verify OSPFv3

Verify IPv6 Routing Table

```
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
R1#
```