Instructor Materials
Chapter 8: Single-Area OSPF

CCNA Routing and Switching

Scaling Networks

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Chapter 8: Best Practices

- During this chapter, consider setting up an OSPF network as a Packet Tracer demonstration.
- Discuss with students the differences between single-area OSFP and multiarea OSPF. Give them an assignment to draw a picture of OSPF single areas and multiple areas.
- Make sure the students pay particular attention to the packet types on graphic 8.1.2.5. If they understand this graphic, multiarea OSPF discussion in Chapter 9 will flow smoother. Rote memorization of such things as packet type is a step that leads to comprehension.
- Provide wildcard mask worksheets.
- Give the student plenty of practice on hands-on OSPF configuration.
- Give the students assignments to memorize the steps of link-state operation.
- Give the students assignments to compare/contrast OSPF, EIGRP, and RIPv2.

Chapter 8: Best Practices (Cont.)

- It will be helpful to enlarge some of the graphics in this chapter and print out large examples for the classroom. Another option, give the students an assignment of making posters with concepts in this chapter.
- Using Wireshark and a topology of three routers connected to one switch, view the OSPF process of establishing adjacencies.
- Walk the students through all the commands in the chapter, but focus on the areas of possible confusion.
- Help students to analyze the nature of multi-access networks and the OSPF processes. Using Wireshark and a topology of three routers connected to one switch, view the OSPF process of establishing adjacencies. Look for the designated router, backup designated router and DROTHERS.
- Demonstrate both methods of modifying the OSPF cost. (bandwidth, cost)
- Walk the students through all the commands in the chapter, but focus on the areas of possible confusion.

Chapter 8: Single-Area OSPF

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Chapter 8 - Sections & Objectives

- 8.1 OSPF Characteristics
  - Explain how single-area OSPF operates.
- 8.2 Single-Area OSPFv2
  - Implement single-area OSPFv2.
- 8.3 Single-Area OSPFv3
  - Implement single-area OSPFv3.

8.1 OSPF Characteristics

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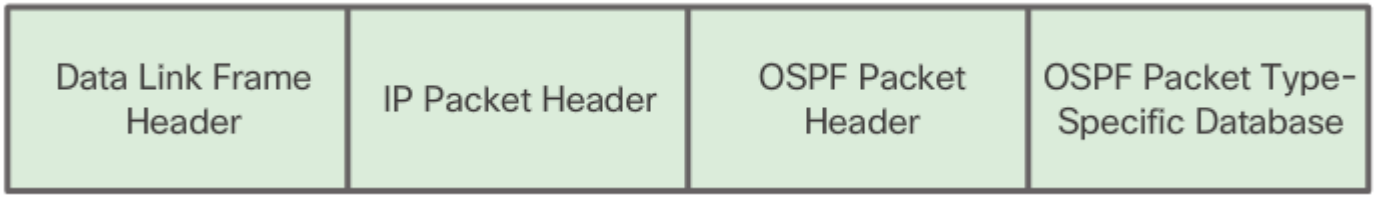
Open Shortest Path First

- OSPF
  - Version 2 (OSPFv2) is available for IPv4 while OSPF version 3 (OSPFv3) is available for IPv6.
- 3 Main Components
  - Data Structures, Routing Protocol Messages, and Algorithm
- Achieving Convergence:
  - Establish Neighbor Adjacencies
  - Exchange Link-State Advertisements
  - Build the Topology Table
  - Execute the SPF Algorithm
- OSPF can be implemented in one of two ways:
  - Single-Area OSPF
  - Multi-area OSPF

OSPF Messages

- OSPFv2 messages contain:



- LSP Types:
  - **Type 1: Hello packet**
  - **Type 2: Database Description (DBD) packet**
  - **Type 3: Link-State Request (LSR) packet**
  - **Type 4: Link-State Update (LSU) packet**
  - **Type 5: Link-State Acknowledgment (LSAck) packet**

OSPF Messages (Cont.)

- Hello Packets are used to:
  - 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 multi-access networks like Ethernet and Frame Relay.
- OSPF Hello packets are transmitted to multicast address 224.0.0.5 in IPv4 and FF02::5 in IPv6

- 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 Operation

- OSPF progresses through several states while attempting to reach convergence
  - Down state, Init state, Two-Way state, ExStart state, Exchange state, Loading state, and Full state
- Establishing Adjacencies
  - When a neighboring OSPF-enabled router receives a Hello packet with a router ID that is not within its neighbor list, the receiving router attempts to establish an adjacency with the initiating router.
- OSPF DR and BDR
  - 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.
- After the Two-Way state, routers transition to database synchronization states.

8.2 Single-Area OSPFv2

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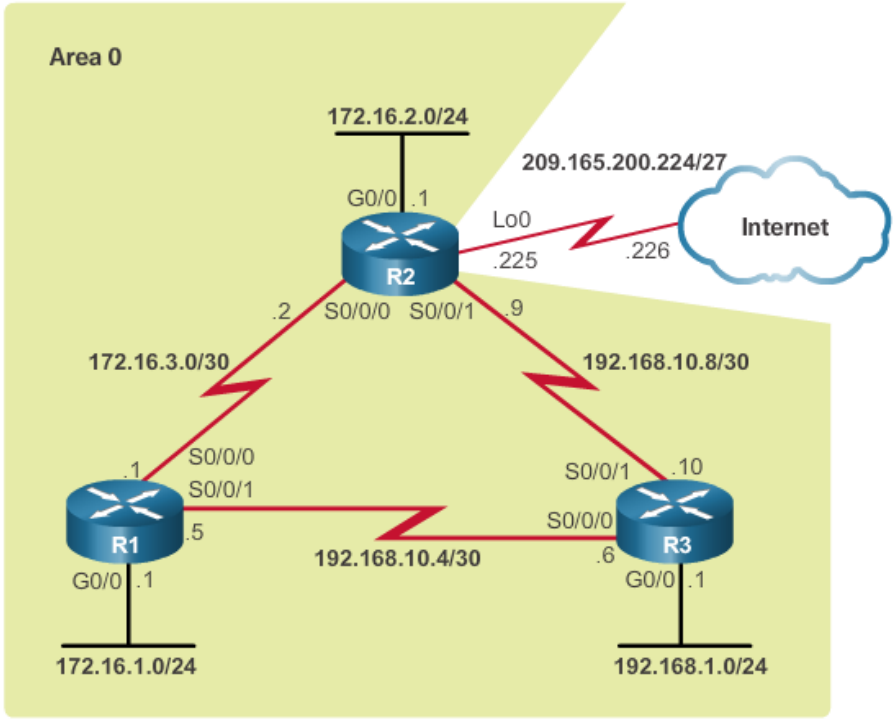
OSPF Router ID

- Enabling OSPFv2
  - OSPFv2 is enabled using the **router ospf** *process-id* global configuration mode command.
  - The *process-id* value represents a number between 1 and 65,535 and is selected by the network administrator.
  - The *process-id* value is locally significant, which means that it does not have to be the same value on the other OSPF routers to establish adjacencies with those neighbors.



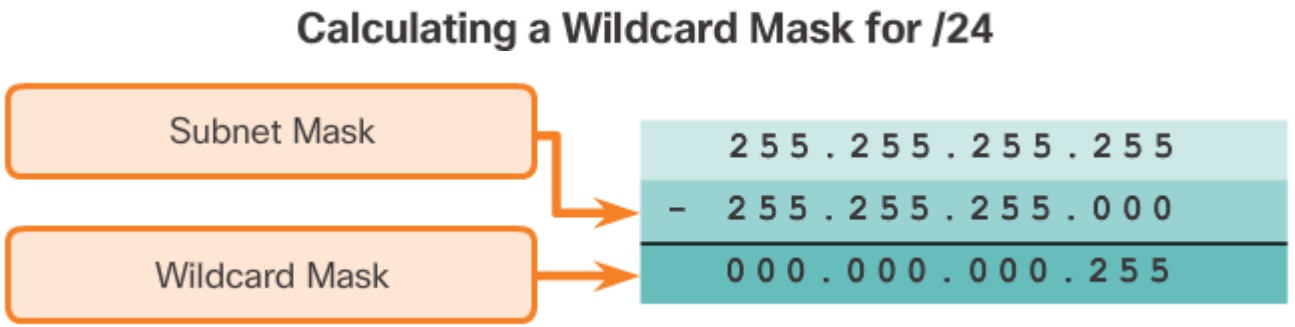
OSPF Router ID (Cont.)

- Router ID
  - The router ID is used by the OSPF-enabled router to uniquely identify the router and participate in the election of the DR
  - Router ID based on one of three criteria
    - Explicitly configured using the OSPF **router-id** *rid* command
    - Router chooses the highest IPv4 address of any of configured loopback interfaces
    - If no loopback interfaces are configured, then the router chooses the highest active IPv4 address of any of its physical interfaces
  - Clearing the OSPF process is the preferred method to reset the router ID.

Note: The router ID looks like an IPv4 address, but it is not routable and, therefore, is not included in the routing table, unless the OSPF routing process chooses an interface (physical or loopback) that is appropriately defined by a **network** command.

Configure Single-Area OSPFv2

- Enabling OSPF
  - Any interfaces on a router that match the network address in the **network** command are enabled to send and receive OSPF packets.
- Wildcard Mask
  - In a wildcard mask, binary 0 is equal to a match and binary 1 is not a match.

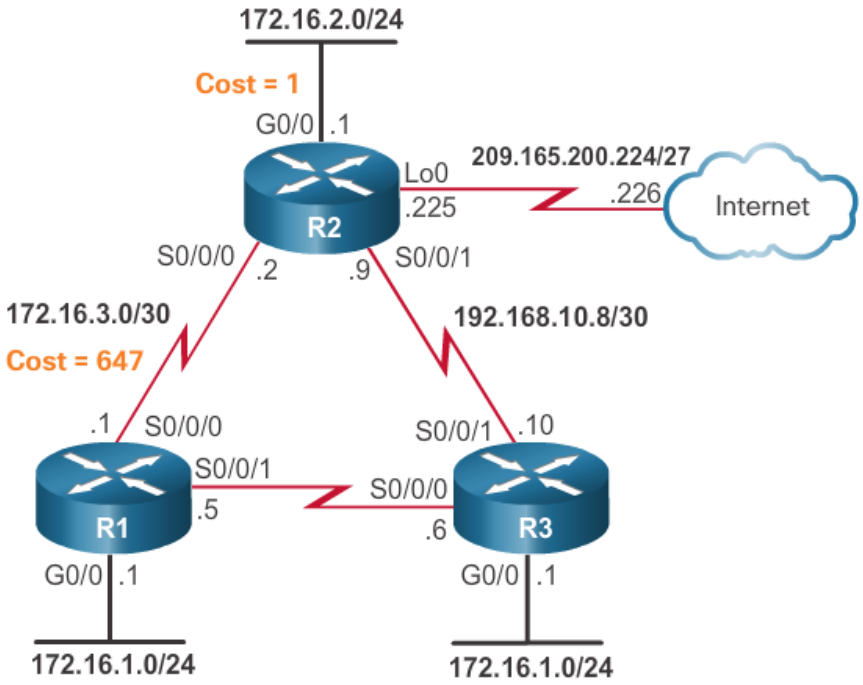


Configure Single-Area OSPFv2 (Cont.)

- The network Command
  - OSPFv2 can be enabled using the **network** *intf-ip-address* **0.0.0.0** ***area*** *area-id* router configuration mode command.
  - The advantage of specifying the interface is that the wildcard mask calculation is not necessary.
- Unneeded OSPFv2 messages affect the network:
  - Inefficient use of bandwidth, inefficient use of resources, and increased security risk
- Configure passive interfaces
  - 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.
  - A neighbor adjacency cannot be formed over a passive interface.

OSPF Cost

- OSPF Metric = Cost
  - The cost of an interface is inversely proportional to the bandwidth of the interface.
  - **Cost** = *reference bandwidth* / *interface bandwidth*
  - The cost of an OSPF route is the accumulated value from one router to the destination network.
  - To adjust the reference bandwidth, use the **auto-cost reference-bandwidth** *Mb/s* router configuration command.



OSPF Cost (Cont.)

- Default Interface Bandwidths
  - As with reference bandwidth, interface bandwidth values do not actually affect the speed or capacity of the link.
  - Use the **show interfaces** command to view the interface bandwidth setting.
- Adjust Interface Bandwidth
  - To adjust the interface bandwidth use the **bandwidth** *kilobits* interface configuration command.
  - Use the **no bandwidth** command to restore the default value.
- Set OSPF Cost Manually
  - The cost can be manually configured on an interface using the **ip ospf cost** *value* interface configuration command.

Verify OSPF

- Verify OSPF Neighbors
  - Use the **show ip ospf neighbor** command to verify that the router has formed an adjacency with its neighboring routers.
- Verify OSPF Protocol Settings
  - The **show ip protocols** command is a quick way to verify vital OSPF configuration information.
- Verify OSPF Process Information
  - The **show ip ospf** command can also be used to examine the OSPFv2 process ID and router ID

```
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 (Cont.)

- Verify OSPF Interface Settings
  - The quickest way to verify OSPFv2 interface settings is to use the **show ip ospf interface** command.
  - To get a summary of OSPFv2-enabled interfaces, use the **show ip ospf interface brief** command.

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#
```

8.3 Single-Area OSPFv3

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OSPFv2 vs. OSPFv3

- OSPFv3
  - Similar to its IPv4 counterpart, OSPFv3 exchanges routing information to populate the IPv6 routing table with remote prefixes
  - Packets with a source or destination link-local address cannot be routed beyond the link from where the packet originated.

Differences Between OSPFv2 vs. 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`** *`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 (Cont.)

- Link-Local Addresses
  - Link-local addresses are automatically created when an IPv6 global unicast address is assigned to the interface.
- Assigning Link-Local Addresses
  - Link-local addresses can be configured manually using the same interface command used to create IPv6 global unicast addresses, but appending the **link-local** keyword to the **ipv6 address** command.
- Configuring the OSPFv3 Router ID
  - OSPFv3 requires a 32-bit router ID to be assigned before OSPF can be enabled on an interface.
  - The **router-id** *rid* command is used to assign a router ID in OSPFv3.
  - Clearing the OSPF process is the preferred method to reset the router ID.

Configuring OSPFv3

- Enabling OSPFv3 on Interfaces
  - To enable OSPFv3 on an interface, use the **ipv6 ospf** *process-id* **area** *area-id* interface configuration mode command.

```
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

- Verify OSPFv3 Neighbors
  - Use the **show ipv6 ospf neighbor** command to verify that the router has formed an adjacency with its neighboring routers.
- Verify OSPFv3 Protocol Settings
  - The **show ipv6 protocols** command is a quick way to verify vital OSPFv3 configuration information, including the OSPFv3 process ID, the router ID, and the interfaces enabled for OSPFv3.
- Verify OSPFv3 Interfaces
  - The quickest way to verify OSPFv3 interface settings is to use the **show ipv6 ospf interface** command.
  - To retrieve and view a summary of OSPFv3-enabled interfaces on R1, use the **show ipv6 ospf interface brief** command

Verify OSPFv3 (Cont.)

- Verify the IPv6 Routing Table
  - The **show ipv6 route ospf** command provides specifics about OSPFv3 routes in the 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#
```

8.4 Chapter Summary

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Chapter Summary

Summary

- The current version of OSPF for IPv4 is OSPFv2 introduced in RFC 1247 and updated in RFC 2328 by John Moy. In 1999, OSPFv3 for IPv6 was published in RFC 2740.
- OSPF is a 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 OSPFv2 routers to establish adjacencies with those neighbors.
- The **network** command used with OSPFv2 has the same function as when used with other IGP routing protocols, but with slightly different syntax. The *wildcard-mask* value is the inverse of the subnet mask, and the *area-id* value should be set to **0**.
- By default, OSPF Hello packets are sent every 10 seconds on multi-access 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 OSPFv2 adjacencies.
- OSPF elects a DR to act as collection and distribution point for LSAs sent and received in the multi-access network. 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 multi-access network.
- 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 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. Similar verification commands used for OSPFv2 are used for OSPFv3.