TRƯỜNG ĐẠI HỌC CÔNG NGHỆ THÔNG TIN – ĐHQG-HCM
Khoa Mạng máy tính & Truyền thông

Định tuyến động

NT132 – Quản trị mạng và hệ thống

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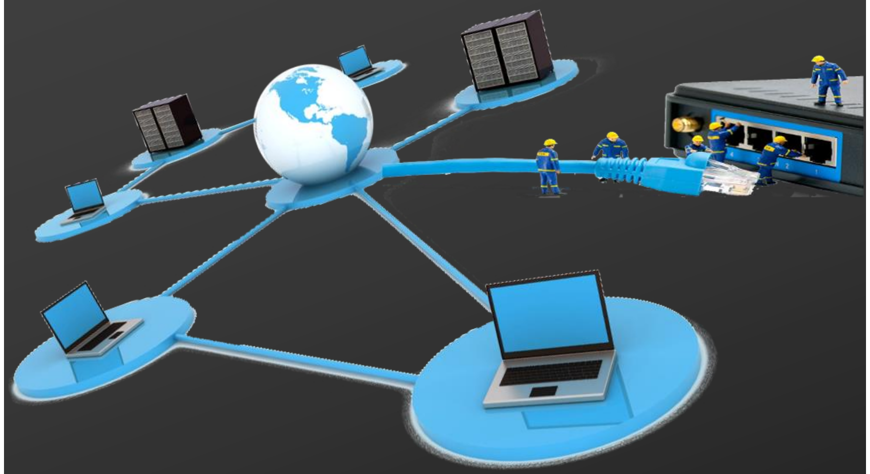


Nội dung

Định tuyến động

Hôm nay học gì?

1. Tổng quan về định tuyến động
2. OSPF

Dynamic Routing Overview

Dynamic Routing Evolution

The table classifies the current routing protocols. Interior Gateway Protocols (IGPs) are routing protocols used to exchange routing information within a routing domain administered by a single organization. There is only one EGP and it is BGP. BGP is used to exchange routing information between different organizations, known as autonomous systems (AS). BGP is used by ISPs to route packets over the internet. Distance vector, link-state, and path vector routing protocols refer to the type of routing algorithm used to determine best path.

	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

Dynamic Routing Protocol Concepts

A routing protocol is a set of processes, algorithms, and messages that are used to exchange routing information and populate the routing table with the choice of best paths. The purpose of dynamic routing protocols includes the following:

- Discovery of remote networks
- Maintaining up-to-date routing information
- Choosing the best path to destination networks
- Ability to find a new best path if the current path is no longer available

Dynamic Routing Protocol Concepts (Cont.)

The main components of dynamic routing protocols include the following:

- **Data structures -** Routing protocols typically use tables or databases for their operations. This information is kept in RAM.
- **Routing protocol messages -** Routing protocols use various types of messages to discover neighboring routers, exchange routing information, and other tasks to learn and maintain accurate information about the network.
- **Algorithm -** An algorithm is a finite list of steps used to accomplish a task. Routing protocols use algorithms for facilitating routing information and for the best path determination.

Routing protocols determine the best path, or route, to each network. That route is then offered to the routing table. The route will be installed in the routing table if there is not another routing source with a lower AD.

Best Path

The best path is selected by a routing protocol based on the value or metric it uses to determine the distance to reach a network. A metric is the quantitative value used to measure the distance to a given network. The best path to a network is the path with the lowest metric.

Dynamic routing protocols typically use their own rules and metrics to build and update routing tables. The following table lists common dynamic protocols and their metrics.

Routing Protocol	Metric
Routing Information Protocol (RIP)	•The metric is "hop count". •Each router along a path adds a hop to the hop count. •A maximum of 15 hops allowed.
Open Shortest Path First (OSPF)	•The metric is "cost" which is the based on the cumulative bandwidth from source to destination. •Faster links are assigned lower costs compared to slower (higher cost) links.
Enhanced Interior Gateway Routing Protocol (EIGRP)	•It calculates a metric based on the slowest bandwidth and delay values. •It could also include load and reliability into the metric calculation.

Load Balancing

When a router has two or more paths to a destination with equal cost metrics, then the router forwards the packets using both paths equally. This is called equal cost load balancing.

- The routing table contains the single destination network, but has multiple exit interfaces, one for each equal cost path. The router forwards packets using the multiple exit interfaces listed in the routing table.
- If configured correctly, load balancing can increase the effectiveness and performance of the network.
- Equal cost load balancing is implemented automatically by dynamic routing protocols. It is enabled with static routes when there are multiple static routes to the same destination network using different next-hop routers.

Note: Only EIGRP supports unequal cost load balancing.

OSPF Features and Characteristics

Introduction to OSPF

- OSPF is a **link-state routing protocol** that was developed as an alternative for the distance vector Routing Information Protocol (RIP). OSPF has significant advantages over RIP in that it offers **faster convergence and scales to much larger network** implementations.
- OSPF is a link-state routing protocol that uses the **concept of areas**. A network administrator can divide the **routing domain into distinct areas** that help control routing update traffic.
- A link is an interface on a router, a network segment that connects two routers, or a stub network such as an Ethernet LAN that is connected to a single router.
- Information about the state of a link is known as a link-state. All link-state information includes the network prefix, prefix length, and cost.
- This module covers basic, single-area OSPF implementations and configurations.

Components of OSPF

- All routing protocols share similar components. They all use routing protocol messages to exchange route information. The messages help build data structures, which are then processed using a routing algorithm.
- Routers running OSPF exchange messages to convey routing information using five types of packets:
  - Hello packet
  - Database description packet
  - Link-state request packet
  - Link-state update packet
  - Link-state acknowledgment packet
- These packets are used to discover neighboring routers and also to exchange routing information to maintain accurate information about the network.

OSPF Features and Characteristics

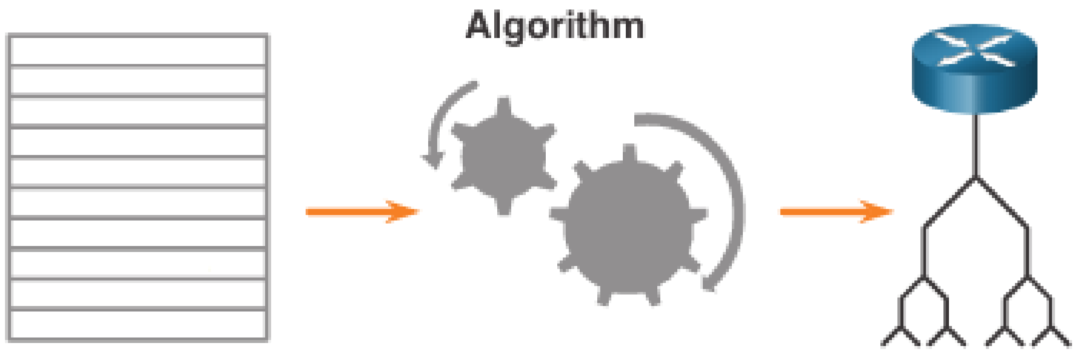
Components of OSPF (Cont.)

OSPF messages are used to create and maintain three OSPF databases, as follows:

Database	Table	Description
Adjacency Database	Neighbor Table	•List of all neighbor routers to which a router has established bi-directional 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 represents the network LSDB. •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.)

- The router builds the topology table using results of calculations based on the Dijkstra shortest-path first (SPF) algorithm. The SPF algorithm is based on the cumulative cost to reach a destination.
- The SPF algorithm creates an SPF tree by placing each router at the root of the tree and calculating the shortest path to each node. The SPF tree is then used to calculate the best routes. OSPF places the best routes into the forwarding database, which is used to make the routing table.



OSPF Features and Characteristics

Link-State Operation

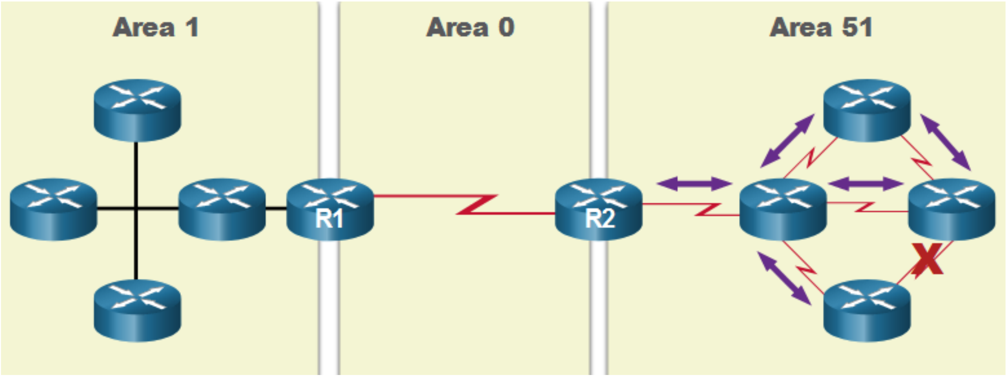
To maintain routing information, OSPF routers complete a generic link-state routing process to reach a state of convergence. The following are the link-state routing steps that are completed by a router:

1. Establish Neighbor Adjacencies
2. Exchange Link-State Advertisements
3. Build the Link State Database
4. Execute the SPF Algorithm
5. Choose the Best Route

Multiarea OSPF

The hierarchical-topology design options with multiarea OSPF can offer the following advantages.

- **Smaller routing tables** - Tables are smaller because there are fewer routing table entries. This is because network addresses can be summarized between areas. Route summarization is not enabled by default.
- **Reduced link-state update overhead** - Designing multiarea OSPF with smaller areas minimizes processing and memory requirements.
- **Reduced frequency of SPF calculations** - Multiarea OSPF localize the impact of a topology change within an area. For instance, it minimizes routing update impact because LSA flooding stops at the area boundary.



OSPF Packets

Types of OSPF Packets

The table summarizes the five different types of Link State Packets (LSPs) used by OSPFv2. OSPFv3 has similar packet types.

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

Link-State Updates

- LSUs are also used to forward OSPF routing updates. An LSU packet can contain 11 different types of OSPFv2 LSAs. OSPFv3 renamed several of these LSAs and also contains two additional LSAs.
- LSU and LSA are often used interchangeably, but the correct hierarchy is LSU packets contain LSA messages.

LSUs

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	LSU	Sends specifically requested link-state records
5	LSAck	Acknowledges the other packet types

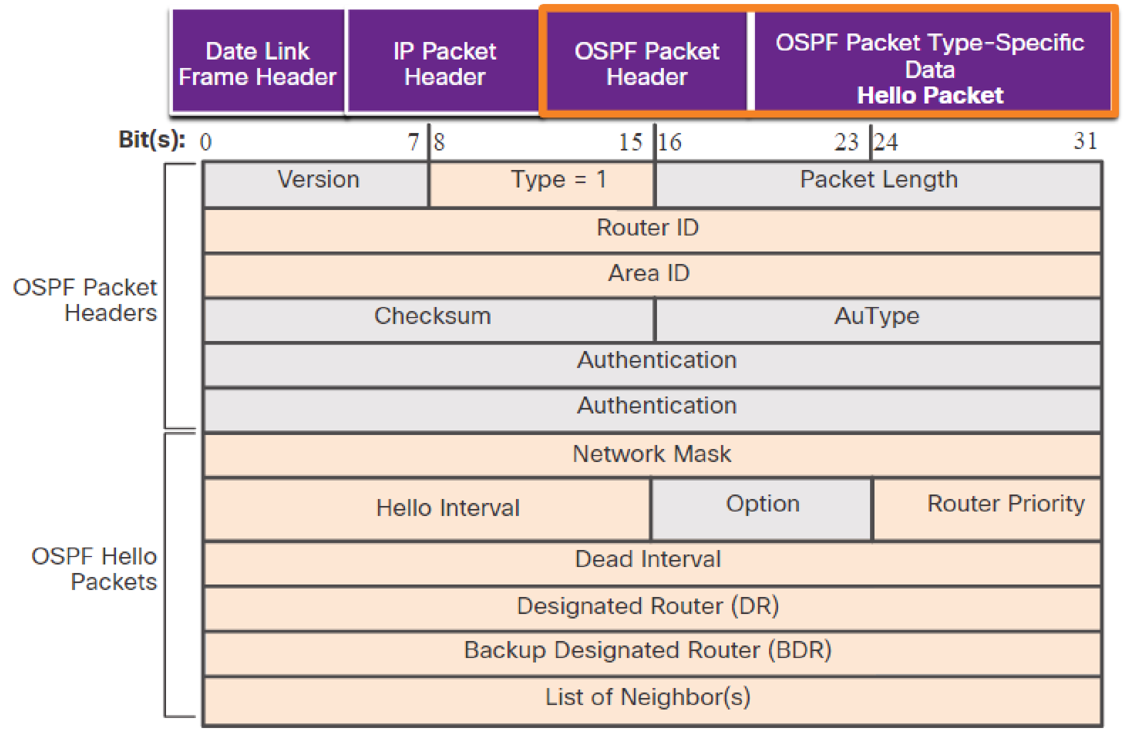
LSAs

LSA Type	Description
1	Router LSAs
2	Checks for database synchronization between routers
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 Patrol (BGPs)

OSPF Packets
Hello Packet

The OSPF Type 1 packet is the Hello packet. Hello packets are used to do the following:

- 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. Point-to-point links do not require DR or BDR.



OSPF Operation

OSPF Operational States

State	Description
Down State	• No Hello packets received = Down. • Router sends Hello packets. • Transition to Init state.
Init State	• Hello packets are received from the neighbor. • They contain the Router ID of the sending router. • Transition to Two-Way state.
Two-Way State	• In this state, communication between the two routers is bidirectional. • On multiaccess links, the routers elect a DR and a BDR. • Transition to ExStart state.

OSPF Operational States (Cont.)

State	Description
ExStart State	On point-to-point networks, the two routers decide which router will initiate the DBD packet exchange and decide upon the initial DBD packet sequence number.
Exchange State	•Routers exchange DBD packets. •If additional router information is required then transition to Loading; otherwise, transition to the Full state.
Loading State	•LSRs and LSUs are used to gain additional route information. •Routes are processed using the SPF algorithm. •Transition to the Full state.
Full State	The link-state database of the router is fully synchronized.

Establish Neighbor Adjacencies

- To determine if there is an OSPF neighbor on the link, the router sends a Hello packet that contains its router ID out all OSPF-enabled interfaces. The Hello packet is sent to the reserved All OSPF Routers **IPv4 multicast address 224.0.0.5**. Only OSPFv2 routers will process these packets.
- The OSPF router ID is used by the OSPF process to uniquely identify each router in the OSPF area. A **router ID is a 32-bit number** formatted like an IPv4 address and assigned to uniquely identify a router among OSPF peers.
- 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.

Establish Neighbor Adjacencies (Cont.)

The process routers use to establish adjacency on a multiaccess network:

1	Down to Init State	When OSPFv2 is enabled on the interface, R1 transitions from Down to Init and starts sending OSPFv2 Hellos out of the interface in an attempt to discover neighbors.
2	Init State	When a R2 receives a hello from the previously unknown router R1, it adds R1's router ID to the neighbor list and responds with a Hello packet containing its own router ID.
3	Two-Way State	R1 receives R2's hello and notices that the message contains the R1 router ID in the list of R2's neighbors. R1 adds R2's router ID to the neighbor list and transitions to the Two-Way State. If R1 and R2 are connected with a point-to-point link, they transition to ExStart If R1 and R2 are connected over a common Ethernet network, the DR/BDR election occurs.
4	Elect the DR & BDR	The DR and BDR election occurs, where the router with the highest router ID or highest priority is elected as the DR, and second highest is the BDR

OSPF Operation
Synchronizing OSPF Databases

After the Two-Way state, routers transition to database synchronization states. This is a three step process, as follows:

- Decide first router: The router with the highest router ID sends its DBD first.
- Exchange DBDs: As many as needed to convey the database. The other router must acknowledge each DBD with an LSAck packet.
- Send an LSR: Each router compares the DBD information with the local LSDB. If the DBD has more current link information, the router transitions to the loading state.

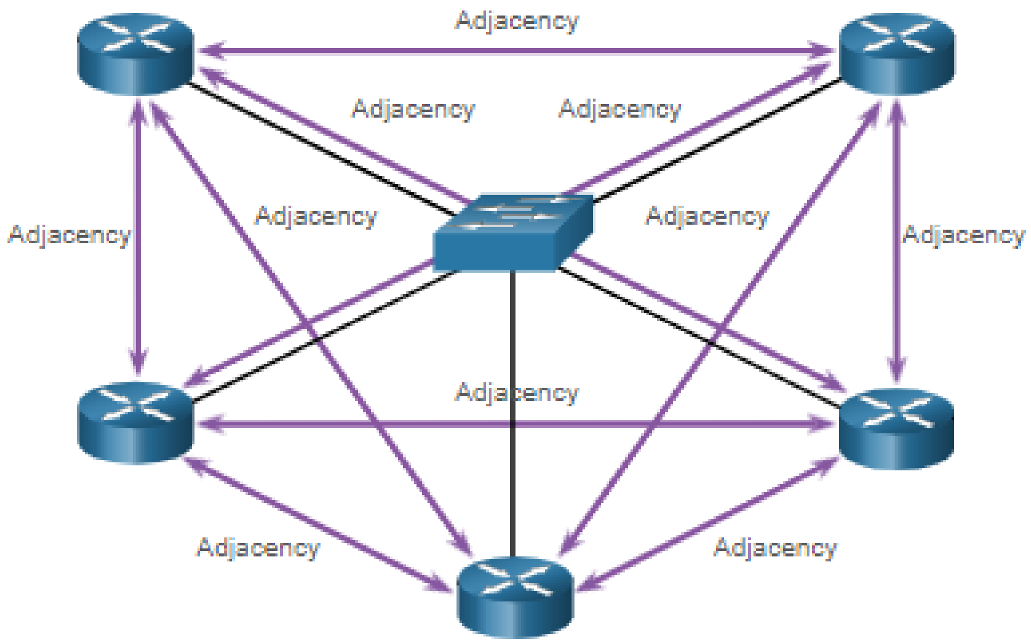
After all LSRs have been exchanged and satisfied, the routers are considered synchronized and in a full state. Updates (LSUs) are sent:

- When a change is perceived (incremental updates)
- Every 30 minutes

The Need for a DR

Multiaccess networks can create two challenges for OSPF regarding the flooding of LSAs, as follows:

- **Creation of multiple adjacencies** - Ethernet networks could potentially interconnect many OSPF routers over a common link. Creating adjacencies with every router would lead to an excessive number of LSAs exchanged between routers on the same network.
- **Extensive flooding of LSAs** - Link-state routers flood their LSAs any time OSPF is initialized, or when there is a change in the topology. This flooding can become excessive.



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

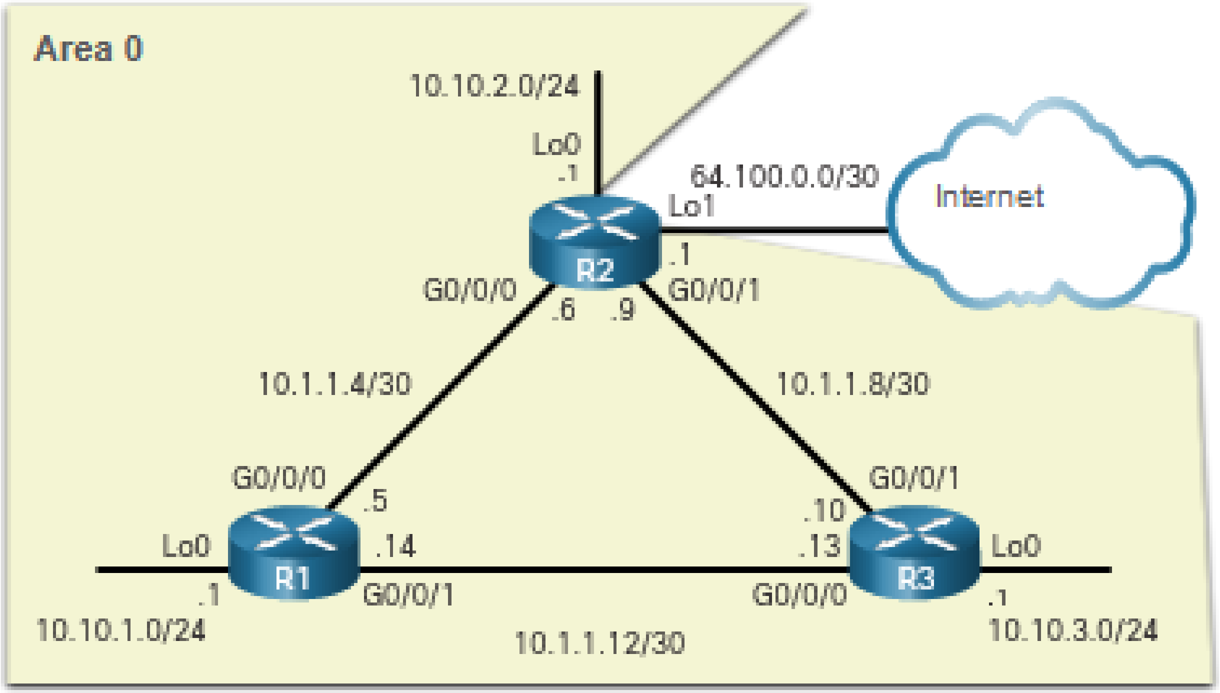
LSA Flooding with a DR

- An increase in the number of routers on a multiaccess network also increases the number of LSAs exchanged between the routers. This flooding of LSAs significantly impacts the operation of OSPF.
- If every router in a multiaccess network had to flood and acknowledge all received LSAs to all other routers on that same multiaccess network, the network traffic would become quite chaotic.
- 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. All other routers become DROTHERs. A DROTHER is a router that is neither the DR nor the BDR.
  - **Note**: The DR is only used for the dissemination of LSAs. The router will still use the best next-hop router indicated in the routing table for the forwarding of all other packets.

OSPF Router ID

OSPF Reference Topology

The figure shows the topology used for configuring OSPFv2 in this module. The routers in the topology have a starting configuration, including interface addresses. There is currently no static routing or dynamic routing configured on any of the routers. All interfaces on R1, R2, and R3 (except the loopback 1 on R2) are within the OSPF backbone area. The ISP router is used as the gateway to the internet of the routing domain.



Router Configuration Mode for OSPF

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. It is considered best practice to use the same *process-id* on all OSPF routers.

```
R1(config)# router ospf 10
R1(config-router)# ?
  area                           OSPF area parameters
  auto-cost                      Calculate OSPF interface cost according to bandwidth
  default-information            Control distribution of default information
  distance                       Define an administrative distance
  exit                           Exit from routing protocol configuration mode
  log-adjacency-changes          Log changes in adjacency state
  neighbor                       Specify a neighbor router
  network                        Enable routing on an IP network
  no                             Negate a command or set its defaults
  passive-interface              Suppress routing updates on an interface
  redistribute                   Redistribute information from another routing protocol
  router-id                      router-id for this OSPF process
R1(config-router)#
```

Router IDs

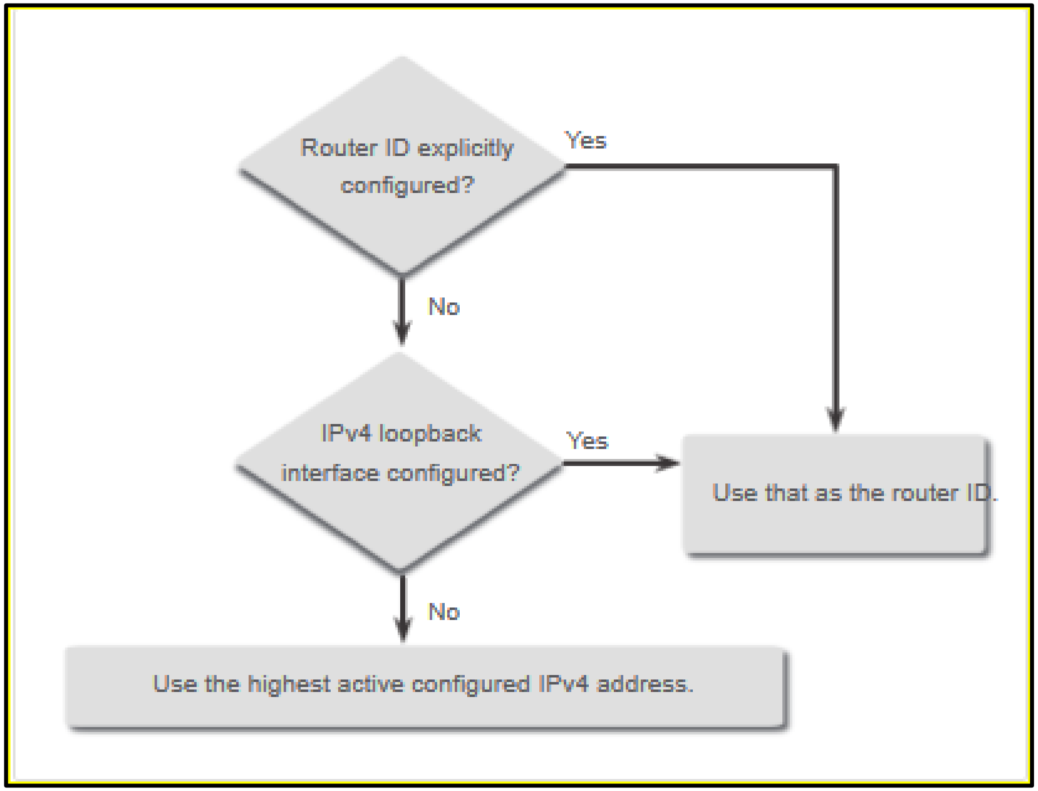
- An OSPF router ID is a 32-bit value, represented as an IPv4 address. It is used to uniquely identify an OSPF router, and all OSPF packets include the router ID of the originating router.
- Every router requires a router ID to participate in an OSPF domain. It can be defined by an administrator or automatically assigned by the router. The router ID is used by an OSPF-enabled router to do the following:
  - **Participate in the synchronization of OSPF databases –** During the Exchange State, the router with the highest router ID will send their database descriptor (DBD) packets first.
  - **Participate in the election of the designated router (DR)** - In a multiaccess LAN environment, the router with the highest router ID is elected the DR. The routing device with the second highest router ID is elected the backup designated router (BDR).

OSPF Router ID

Router ID Order of Precedence

Cisco routers derive the router ID based on one of three criteria, in the following preferential order:

1. The router ID is explicitly configured using the OSPF **router-id** *rid* router configuration mode command. This is the recommended method to assign a router ID.
2. The router chooses the highest IPv4 address of any of configured loopback interfaces.
3. The router chooses the highest active IPv4 address of any of its physical interfaces.



OSPF Router ID

Configure a Loopback Interface as the Router ID

Instead of relying on physical interface, the router ID can be assigned to a loopback interface. Typically, the IPv4 address for this type of loopback interface should be configured using a 32-bit subnet mask (255.255.255.255). This effectively creates a host route. A 32-bit host route would not get advertised as a route to other OSPF routers.

OSPF does not need to be enabled on an interface for that interface to be chosen as the router ID.

```
R1(config-if)# interface Loopback 1
R1(config-if)# ip address 1.1.1.1 255.255.255.255
R1(config-if)# end
R1# show ip protocols | include Router ID
  Router ID 1.1.1.1
R1#
```

Explicitly Configure a Router ID

- In our reference topology the router ID for each router is assigned as follows:
  - R1 uses router ID 1.1.1.1
  - R2 uses router ID 2.2.2.2
  - R3 uses router ID 3.3.3.3
- Use the **router-id** *rid* router configuration mode command to manually assign a router ID. In the example, the router ID 1.1.1.1 is assigned to R1. 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
*May 23 19:33:42.689: %SYS-5-CONFIG_I: Configured from console by console
R1# show ip protocols | include Router ID
  Router ID 1.1.1.1
R1#
```

Modify a Router ID

- After a router selects a router ID, an active OSPF router does not allow the router ID to be changed until the router is reloaded or the OSPF process is reset.
- Clearing the OSPF process is the preferred method to reset the router ID.

```
R1# show ip protocols | include Router ID
Router ID 10.10.1.1
R1# conf t
Enter configuration commands, one per line. End with CNTL/Z.
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# clear ip ospf process
Reset ALL OSPF processes? [no]: y
*Jun 6 01:09:46.975: %OSPF-5-ADJCHG: Process 10, Nbr 3.3.3.3 on GigabitEthernet0/0/1 from FULL to
DOWN, Neighbor Down: Interface down or detached
*Jun 6 01:09:46.981: %OSPF-5-ADJCHG: Process 10, Nbr 3.3.3.3 on GigabitEthernet0/0/1 from LOADING to
FULL, Loading Done *
R1# show ip protocols | include Router ID
  Router ID 1.1.1.1
R1#
```

Point-to-Point OSPF Networks

The network Command Syntax

- You can specify the interfaces that belong to a point-to-point network by configuring the **network** command. You can also configure OSPF directly on the interface with the **ip ospf** command.
- The basic syntax for the **network** command is as follows:

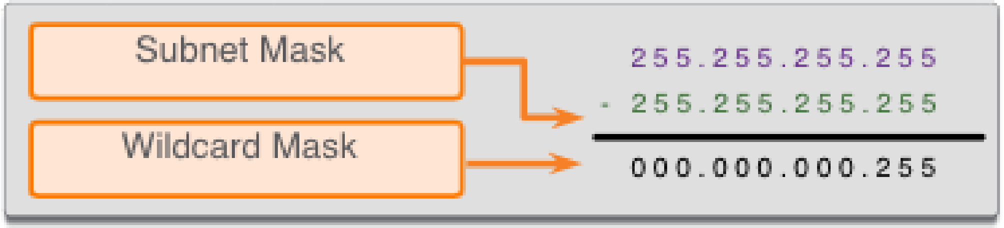
```
Router(config-router)# network network-address wildcard-mask area area-id
```

  - The *network-address wildcard-mask* syntax is used to enable OSPF on interfaces. Any interfaces on a router that match this part of the command are enabled to send and receive OSPF packets.
  - The **area** *area-id* syntax refers to the OSPF area. When configuring single-area OSPFv2, the **network** command must be configured with the same *area-id* value on all routers. Although any area ID can be used, it is good practice to use an area ID of 0 with single-area OSPFv2. This convention makes it easier if the network is later altered to support multiarea OSPFv2.

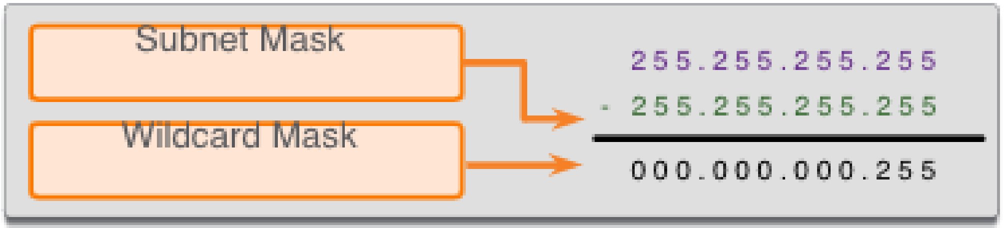
The Wildcard Mask

- The wildcard mask is typically the inverse of the subnet mask configured on that interface.
- The easiest method for calculating a wildcard mask is to subtract the network subnet mask from 255.255.255.255, as shown for /24 and /26 subnet masks in the figure.

Calculating a Wildcard Mask for /24



Calculating a Wildcard Mask for /26



Configure OSPF Using the network Command

Within routing configuration mode, there are two ways to identify the interfaces that will participate in the OSPFv2 routing process.

- In the first example, the wildcard mask identifies the interface based on the network addresses. Any active interface that is configured with an IPv4 address belonging to that network will participate in the OSPFv2 routing process.
- **Note**: Some IOS versions allow the subnet mask to be entered instead of the wildcard mask. The IOS then converts the subnet mask to the wildcard mask format.

```
R1(config)# router ospf 10
R1(config-router)# network 10.10.1.0 0.0.0.255 area 0
R1(config-router)# network 10.1.1.4 0.0.0.3 area 0
R1(config-router)# network 10.1.1.12 0.0.0.3 area 0
R1(config-router)#
```

Configure OSPF Using the network Command (Cont.)

- As an alternative, OSPFv2 can be enabled by specifying the exact interface IPv4 address using a quad zero wildcard mask. Entering **network 10.1.1.5 0.0.0.0 area 0** on R1 tells the router to enable interface Gigabit Ethernet 0/0/0 for the routing process.
- The advantage of specifying the interface is that the wildcard mask calculation is not necessary. Notice that in all cases, the **area** argument specifies area 0.

```
R1(config)# router ospf 10
R1(config-router)# network 10.10.1.1 0.0.0.0 area 0
R1(config-router)# network 10.1.1.5 0.0.0.0 area 0
R1(config-router)# network 10.1.1.14 0.0.0.0 area 0
R1(config-router)#
```

Point-to-Point OSPF Networks

Configure OSPF Using the ip ospf Command

To configure OSPF directly on the interface, use the **ip ospf** interface configuration mode command. The syntax is as follows:

```
Router(config-if)# ip ospf process-id area area-id
```

Remove the network commands using the **no** form of the command. Then go to each interface and configure the **ip ospf** command

```
R1(config)# router ospf 10
R1(config-router)# no network 10.10.1.1 0.0.0.0 area 0
R1(config-router)# no network 10.1.1.5 0.0.0.0 area 0
R1(config-router)# no network 10.1.1.14 0.0.0.0 area 0
R1(config-router)# interface GigabitEthernet 0/0/0
R1(config-if)# ip ospf 10 area 0
R1(config-if)# interface GigabitEthernet 0/0/1
R1(config-if)# ip ospf 10 area 0
R1(config-if)# interface Loopback 0
R1(config-if)# ip ospf 10 area 0
R1(config-if)#
```

Passive Interface

- By default, OSPF messages are forwarded out all OSPF-enabled interfaces. However, these messages only need to be sent out interfaces that are connecting to other OSPF-enabled routers.
- Sending out unneeded messages on a LAN affects the network in three ways:
  - **Inefficient Use of Bandwidth** - Available bandwidth is consumed transporting unnecessary messages.
  - **Inefficient Use of Resources** - All devices on the LAN must process and eventually discard the message.
  - **Increased Security Risk** - Without additional OSPF security configurations, OSPF messages can be intercepted with packet sniffing software. Routing updates can be modified and sent back to the router, corrupting the routing table with false metrics that misdirect traffic.

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.
- The **show ip protocols** command is then used to verify that the interface is listed as passive.

```
R1(config)# router ospf 10
R1(config-router)# passive-interface loopback 0
R1(config-router)# end
R1#
*May 23 20:24:39.309: %SYS-5-CONFIG_I: Configured from console by console
R1# show ip protocols
*** IP Routing is NSF aware ***
(output omitted)
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:
  Routing on Interfaces Configured Explicitly (Area 0):
    Loopback0
    GigabitEthernet0/0/1
    GigabitEthernet0/0/0
  Passive Interface(s):
    Loopback0
  Routing Information Sources:
    Gateway         Distance      Last Update
    3.3.3.3              110      01:01:48
    2.2.2.2              110      01:01:38
  Distance: (default is 110)
R1#
```

Multiaccess OSPF Networks

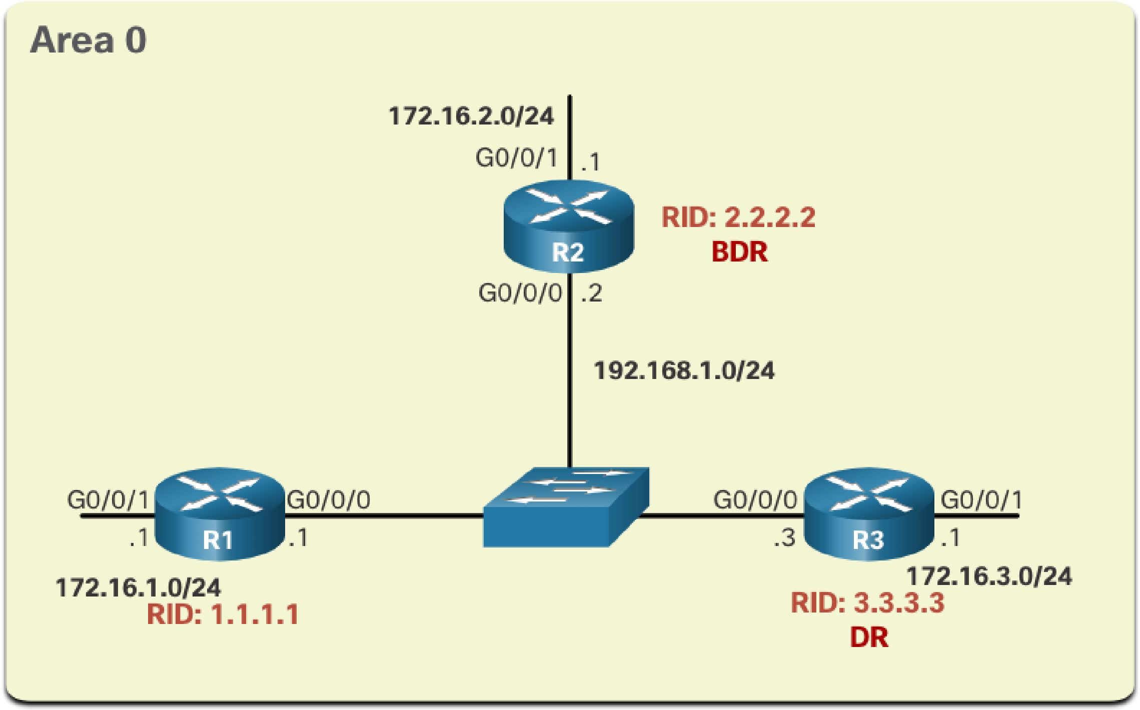
OPSF Designated Router

- In multiaccess networks, OSPF elects a DR and BDR. The DR is responsible for collecting and distributing LSAs sent and received. The DR uses the multicast IPv4 address 224.0.0.5 which is meant for all OSPF routers.
- A BDR is also elected in case the DR fails. The BDR listens passively and maintains a relationship with all the routers. If the DR stops producing Hello packets, the BDR promotes itself and assumes the role of DR.
- All other routers become a DROTHER (a router that is neither the DR nor the BDR). DROTHERs use the multiaccess address 224.0.0.6 (all designated routers) to send OSPF packets to the DR and BDR. Only the DR and BDR listen for 224.0.0.6.

Multiaccess OSPF Networks

OPSF Multiaccess Reference Topology

- In the multiaccess topology shown in the figure, there are three routers interconnected over a common Ethernet multiaccess network, 192.168.1.0/24.
- Because the routers are connected over a common multiaccess network, OSPF has automatically elected a DR and BDR. R3 has been elected as the DR because its router ID is 3.3.3.3, which is the highest in this network. R2 is the BDR because it has the second highest router ID in the network.



Multiaccess OSPF Networks

Verify OSPF Router Roles

- To verify the roles of the OSPFv2 router, use the **show ip ospf interface** command.
- The output generated by R1 confirms that the following:
  - R1 is not the DR or BDR, but is a DROTHER with a default priority of 1. (Line 7)
  - The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
  - R1 has two adjacencies: one with the BDR and one with the DR. (Lines 20-22)

```
R1# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.1/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 1.1.1.1, Network Type BROADCAST, Cost: 1
  (output omitted)
  Transmit Delay is 1 sec, State DROTHER, 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
  (output omitted)
  Neighbor Count is 2, Adjacent neighbor count is 2
  Adjacent with neighbor 2.2.2.2 (Backup Designated Router)
  Adjacent with neighbor 3.3.3.3 (Designated Router)
  Suppress hello for 0 neighbor(s)
R1#
```

Verify OSPF Router Roles (Cont.)

The output generated by R2 confirms that:

- R2 is the BDR with a default priority of 1. (Line 7)
- The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
- R2 has two adjacencies; one with a neighbor with router ID 1.1.1.1 (R1) and the other with the DR. (Lines 20-22)

```
R2# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.2/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  (output omitted)
  Transmit Delay is 1 sec, State BDR, 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
  (output omitted)
  Neighbor Count is 2, Adjacent neighbor count is 2
  Adjacent with neighbor 1.1.1.1
  Adjacent with neighbor 3.3.3.3 (Designated Router)
  Suppress hello for 0 neighbor(s)
R2#
```

Multiaccess OSPF Networks

Verify OSPF Router Roles (Cont.)

The output generated by R3 confirms that:

- R3 is the DR with a default priority of 1. (Line 7)
- The DR is R3 with router ID 3.3.3.3 at IPv4 address 192.168.1.3, while the BDR is R2 with router ID 2.2.2.2 at IPv4 address 192.168.1.2. (Lines 8 and 9)
- R3 has two adjacencies: one with a neighbor with router ID 1.1.1.1 (R1) and the other with the BDR. (Lines 20-22)

```
R3# show ip ospf interface GigabitEthernet 0/0/0
GigabitEthernet0/0/0 is up, line protocol is up
  Internet Address 192.168.1.3/24, Area 0, Attached via Interface Enable
  Process ID 10, Router ID 2.2.2.2, Network Type BROADCAST, Cost: 1
  (output omitted)
  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
  (output omitted)
  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#
```

Multiaccess OSPF Networks

Verify DR/BDR Adjacencies

- To verify the OSPFv2 adjacencies, use the **show ip ospf neighbor** command. The state of neighbors in multiaccess networks can be as follows:
  - **FULL/DROTHER** - This is a DR or BDR router that is fully adjacent with a non-DR or BDR router. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
  - **FULL/DR** - The router is fully adjacent with the indicated DR neighbor. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
  - **FULL/BDR** - The router is fully adjacent with the indicated BDR neighbor. These two neighbors can exchange Hello packets, updates, queries, replies, and acknowledgments.
  - **2-WAY/DROTHER** - The non-DR or BDR router has a neighbor relationship with another non-DR or BDR router. These two neighbors exchange Hello packets.
- The normal state for an OSPF router is usually FULL. If a router is stuck in another state, it is an indication that there are problems in forming adjacencies. The only exception to this is the 2-WAY state, which is normal in a multiaccess broadcast network.

Multiaccess OSPF Networks
Verify DR/BDR Adjacencies (Cont.)

The output generated by R2 confirms that R2 has adjacencies with the following routers:

- R1 with router ID 1.1.1.1 is in a Full state and R1 is neither the DR nor BDR.
- R3 with router ID 3.3.3.3 is in a Full state and the role of R3 is DR.

```
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      GigabitEthernet0/0/0
3.3.3.3           1   FULL/DR         00:00:34      192.168.1.3      GigabitEthernet0/0/0
R2#
```

Default DR/BDR Election Process

The OSPF DR and BDR election 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 becomes the BDR.

- The priority can be configured to be any number between 0 – 255.
- If the interface priority value is set to 0, that interface cannot be elected as DR nor BDR.
- The default priority of multiaccess broadcast interfaces 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.

- The election process takes place when the first router with an OSPF-enabled interface is active on the network. If all of the routers on the network have not finished booting, it is possible that a router with a lower router ID becomes the DR.
- The addition of a new router does not initiate a new election process.

Multiaccess OSPF Networks
DR Failure and Recovery

- 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.

- If the DR fails, the BDR is automatically promoted to DR. This is the case even if another DROTHER with a higher priority or router ID is added to the network after the initial DR/BDR election. However, after a BDR is promoted to DR, a new BDR election occurs and the DROTHER with the highest priority or router ID is elected as the new BDR.

Multiaccess OSPF Networks

The ip ospf priority Command

If the interface priorities are equal on all routers, the router with the highest router ID is elected the DR.

Instead of relying on the router ID, it is better to control the election by setting interface priorities. This also allows a router to be the DR in one network and a DROTHER in another.

To set the priority of an interface, use the command **ip ospf priority** *value*, where value is 0 to 255.

- A value of 0 does not become a DR or a BDR.
- A value of 1 to 255 on the interface makes it more likely that the router becomes the DR or the BDR.

Configure OSPF Priority

The example shows the commands being used to change the R1 G0/0/0 interface priority from 1 to 255 and then reset the OSPF process.

```
R1(config)# interface GigabitEthernet 0/0/0
R1(config-if)# ip ospf priority 255
R1(config-if)# end
R1# clear ip ospf process
Reset ALL OSPF processes? [no]: y
R1# *Jun 5 03:47:41.563: %OSPF-5-ADJCHG: Process 10, Nbr 2.2.2.2 on GigabitEthernet0/0/0
from FULL to DOWN, Neighbor Down: Interface down or detached
```

Modify Single-Area OSPFv2

Modify Single-Area OSPFv2

Cisco OSPF Cost Metric

- Routing protocols use a metric to determine the best path of a packet across a network. OSPF uses cost as a metric. A lower cost indicates a better path.
- The Cisco cost of an interface is inversely proportional to the bandwidth of the interface. Therefore, a higher bandwidth indicates a lower cost. The formula used to calculate the OSPF cost is:

  Cost = reference bandwidth / interface bandwidth

- The default reference bandwidth is 10^8 (100,000,000); therefore, the formula is:

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

- Because the OSPF cost value must be an integer, FastEthernet, Gigabit Ethernet, and 10 GigE interfaces share the same cost. To correct this situation, you can:
  - Adjust the reference bandwidth with the **auto-cost reference-bandwidth** command on each OSPF router.
  - Manually set the OSPF cost value with the **ip ospf cost** command on necessary interfaces.

Modify Single-Area OSPFv2

Cisco OSPF Cost Metric (Cont.)

Refer to the table for a breakdown of the cost calculation

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gigabit Ethernet 10 Gbps	100,000,000	÷	10,000,000,000	0.01 = 1
Gigabit Ethernet 1 Gbps	100,000,000	÷	1,000,000,000	0.1 = 1
Fast Ethernet 100 Mbps	100,000,000	÷	100,000,000	1
Ethernet 10 Mbps	100,000,000	÷	10,000,000	1

Same Costs due to reference bandwidth

Adjust the Reference Bandwidth

- The cost value must be an integer. If something less than an integer is calculated, OSPF rounds up to the nearest integer. Therefore, the OSPF cost assigned to a Gigabit Ethernet interface with the default reference bandwidth of 100,000,000 bps would equal 1, because the nearest integer for 0.1 is 0 instead of 1.

Cost = 100,000,000 bps / 1,000,000,000 = 1

- For this reason, all interfaces faster than Fast Ethernet will have the same cost value of 1 as a Fast Ethernet interface.
- 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.

Adjust the Reference Bandwidth (Cont.)

- Changing the reference bandwidth does not actually affect the bandwidth capacity on the link; rather, it simply affects the calculation used to determine the metric.
- To adjust the reference bandwidth, use the **auto-cost reference-bandwidth** *Mbps* router configuration command.
  - This command must be configured on every router in the OSPF domain.
  - Notice in the command that the value is expressed in Mbps; therefore, to adjust the costs for Gigabit Ethernet, use the command **auto-cost reference-bandwidth 1000.** For 10 Gigabit Ethernet, use the command **auto-cost reference-bandwidth 10000.**
  - To return to the default reference bandwidth, use the **auto-cost reference-bandwidth 100** command.
- Another option is to change the cost on one specific interface using the **ip ospf cost** *cost* command.

Modify Single-Area OSPFv2

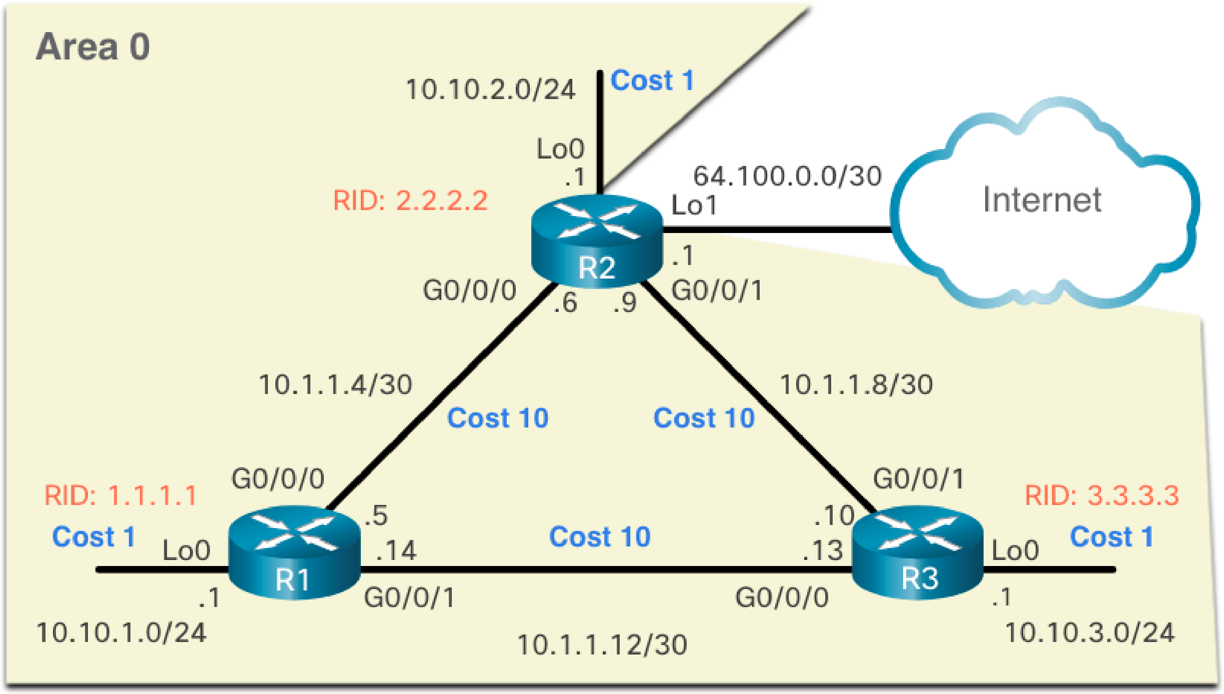
Adjust the Reference Bandwidth (Cont.)

- Whichever method is used, it is important to apply the configuration to all routers in the OSPF routing domain.
- The table shows the OSPF cost if the reference bandwidth is adjusted to accommodate 10 Gigabit Ethernet links. The reference bandwidth should be adjusted anytime there are links faster than FastEthernet (100 Mbps).
- Use the **show ip ospf interface** command to verify the current OSPFv2 cost assigned to the interface.

Interface Type	Reference Bandwidth in bps		Default Bandwidth in bps	Cost
10 Gigabit Ethernet 10 Gbps	10,000,000,000	÷	10,000,000,000	1
Gigabit Ethernet 1 Gbps	10,000,000,000	÷	1,000,000,000	10
Fast Ethernet 100 Mbps	10,000,000,000	÷	100,000,000	100
Ethernet 10 Mbps	10,000,000,000	÷	10,000,000	1000

OSPF Accumulates Cost

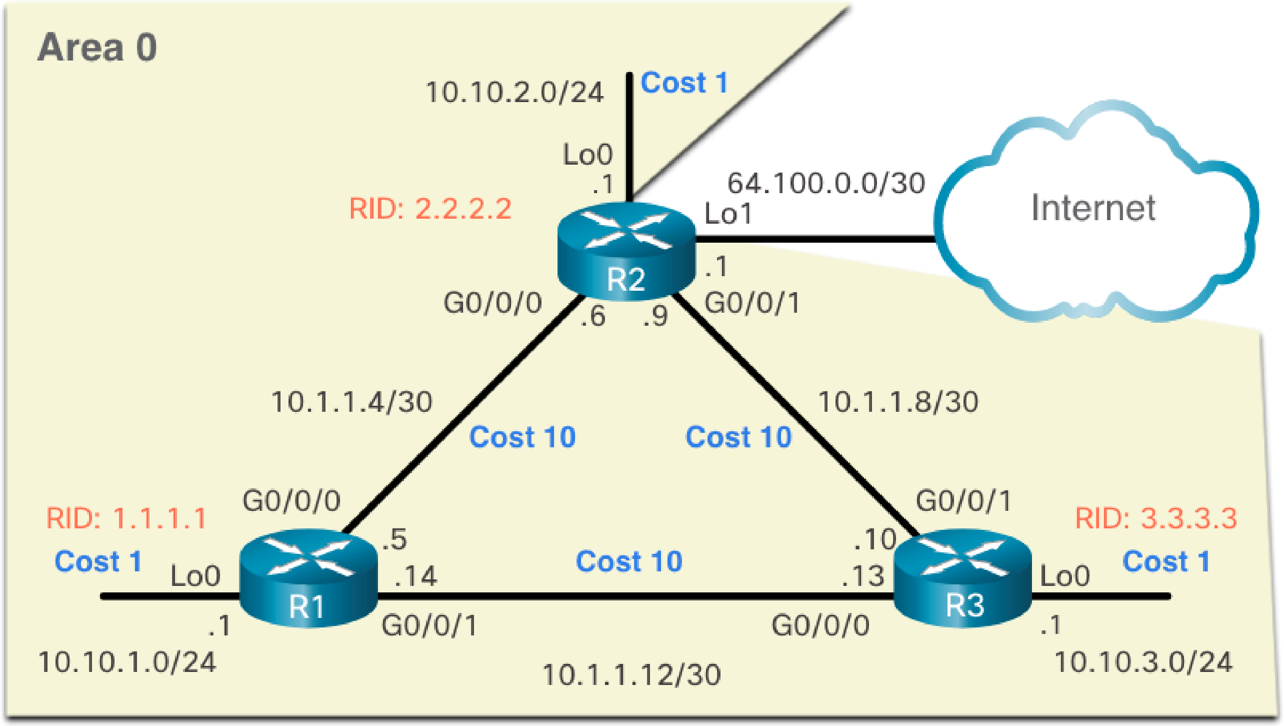
- The cost of an OSPF route is the accumulated value from one router to the destination network.
- Assuming the **auto-cost reference-bandwidth 10000** command has been configured on all three routers, the cost of the links between each router is now 10. The loopback interfaces have a default cost of 1.



Modify Single-Area OSPFv2

OSPF Accumulates Cost (Cont.)

- You can calculate the cost for each router to reach each network.
- For example, the total cost for R1 to reach the 10.10.2.0/24 network is 11. This is because the link to R2 cost = 10 and the loopback default cost = 1. 10 + 1 = 11.
- You can verify this with the **show ip route** command.



OSPF Accumulates Cost (Cont.)

Verifying the accumulated cost for the path to the 10.10.2.0/24 network:

```
R1# show ip route | include 10.10.2.0
O 10.10.2.0/24 [110/11] via 10.1.1.6, 01:05:02, GigabitEthernet0/0/0
R1# show ip route 10.10.2.0
Routing entry for 10.10.2.0/24
  Known via "ospf 10", distance 110, metric 11, type intra area
  Last update from 10.1.1.6 on GigabitEthernet0/0/0, 01:05:13 ago
  Routing Descriptor Blocks:
  * 10.1.1.6, from 2.2.2.2, 01:05:13 ago, via GigabitEthernet0/0/0
            Route metric is 11, traffic share count is 1
R1#
```

Manually Set OSPF Cost Value

- Reasons to manually set the cost value include:
  - The Administrator may want to influence path selection within OSPF, causing different paths to be selected than what normally would given default costs and cost accumulation.
  - Connections to equipment from other vendors who use a different formula to calculate OSPF cost.

- To change the cost value reported by the local OSPF router to other OSPF routers, use the interface configuration command **ip ospf cost** *value*.

```
R1(config)# interface g0/0/1
R1(config-if)# ip ospf cost 30
R1(config-if)# interface lo0
R1(config-if)# ip ospf cost 10
R1(config-if)# end
R1#
```

Modify Single-Area OSPFv2

Test Failover to Backup Route

What happens if the link between R1 and R2 goes down? You can simulate that by shutting down the Gigabit Ethernet 0/0/0 interface and verifying the routing table is updated to use R3 as the next-hop router. Notice that R1 can now reach the 10.1.1.4/30 network through R3 with a cost value of 50.

```
R1# show ip route ospf | begin 10
          10.0.0.0/8 is variably subnetted, 8 subnets, 3 masks
O         10.1.1.4/30 [110/50] via 10.1.1.13, 00:00:14, GigabitEthernet0/0/1
O         10.1.1.8/30 [110/40] via 10.1.1.13, 00:00:14, GigabitEthernet0/0/1
O         10.10.2.0/24 [110/50] via 10.1.1.13, 00:00:14, GigabitEthernet0/0/1
O         10.10.3.0/24 [110/40] via 10.1.1.13, 00:00:14, GigabitEthernet0/0/1
R1#
```

Default Route Propagation

Propagate a Default Static Route in OSPFv2

- To propagate a default route, the edge router must be configured with the following:
  - A default static route using the **ip route 0.0.0.0 0.0.0.0** [*next-hop-address* **|** *exit-intf*] command.
  - The **default-information originate** router configuration command. This instructs R2 to be the source of the default route information and propagate the default static route in OSPF updates.
- In the example, R2 is configured with a loopback to simulate a connection to the internet. A default route is configured and propagated to all other OSPF routers in the routing domain.

Note: When configuring static routes, best practice is to use the next-hop IP address. However, when simulating a connection to the internet, there is no next-hop IP address. Therefore, we use the *exit-intf* argument.

```
R2(config)# interface lo1
R2(config-if)# ip address 64.100.0.1 255.255.255.252
R2(config-if)# exit
R2(config)# ip route 0.0.0.0 0.0.0.0 loopback 1
%Default route without gateway, if not a point-to-point interface, may impact performance
R2(config)# router ospf 10
R2(config-router)# default-information originate
R2(config-router)# end
R2#
```

Verify the Propagated Default Route

- You can verify the default route settings on R2 using the **show ip route** command. You can also verify that R1 and R3 received a default route.
- Notice that the route source on R1 is **O*E2**, signifying that it was learned using OSPFv2. The asterisk identifies this as a good candidate for the default route. The E2 designation identifies that it is an external route. The meaning of E1 and E2 is beyond the scope of this module.

```
R2# show ip route | begin Gateway
Gateway of last resort is 0.0.0.0 to network 0.0.0.0
S*         0.0.0.0/0 is directly connected, Loopback1
      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
(output omitted)
```

```
R1# show ip route | begin Gateway
Gateway of last resort is 10.1.1.6 to network 0.0.0.0
O*E2  0.0.0.0/0 [110/1] via 10.1.1.6, 00:11:08, GigabitEthernet0/0/0
      10.0.0.0/8 is variably subnetted, 9 subnets, 3 masks
(output omitted)
```

Verify Single-Area OSPFv2

Verify OSPF Neighbors

- After configuring single-area OSPFv2, you will need to verify your configurations. The following two commands are particularly useful for verifying routing:
  - **show ip interface brief** - This verifies that the desired interfaces are active with correct IP addressing.
  - **show ip route**- This verifies that the routing table contains all the expected routes.
- Additional commands for determining that OSPF is operating as expected include the following:
  - **show ip ospf neighbor**
  - **show ip protocols**
  - **show ip ospf**
  - **show ip ospf interface**

Today end,

See you next week!