



# OSPF

## Routing Protocols and Concepts – Chapter 11



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## 11.0.1 Chapter Introduction

- Describe the background and basic features of OSPF
- Identify and apply the basic OSPF configuration commands
- Describe, modify and calculate the metric used by OSPF
- Describe the Designated Router/Backup Designated Router (DR/BDR) election process in multiaccess networks
- Describe the uses of additional configuration commands in OSPF

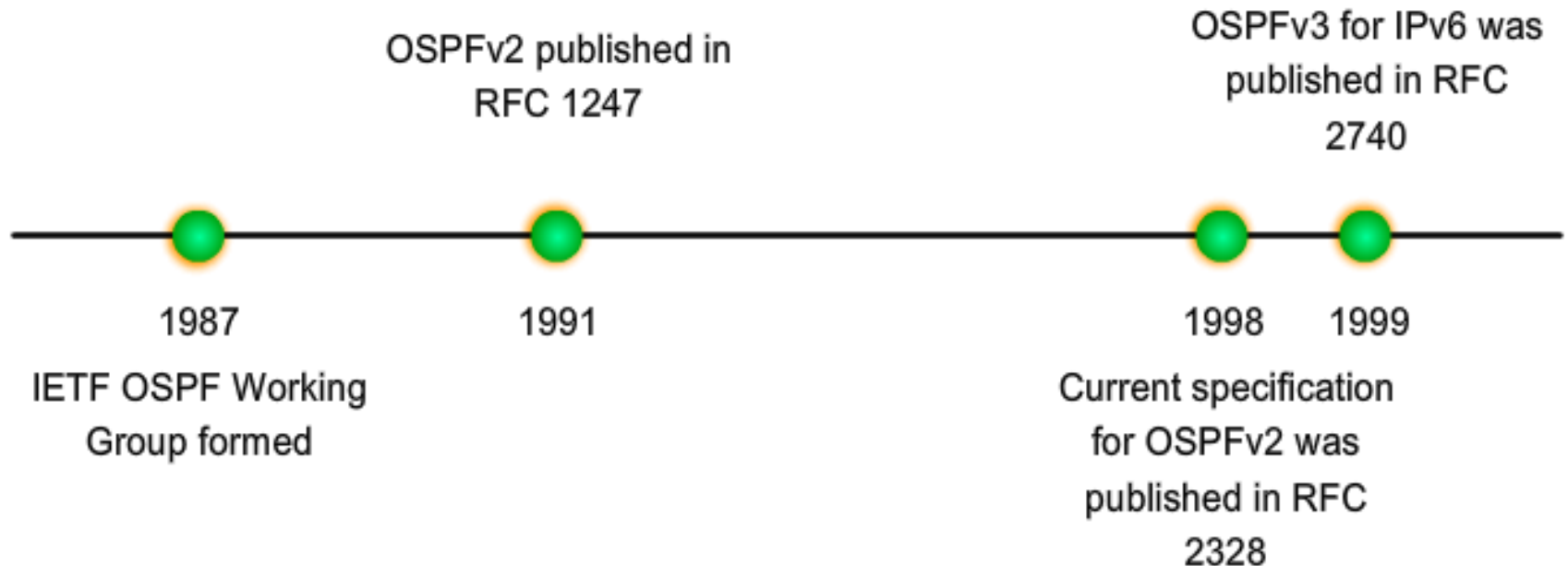
## 11.0.1 Chapter Introduction

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		Path Vector
Classful	<b>RIP</b>	<b>IGRP</b>			<b>EGP</b>
Classless	<b>RIPv2</b>	<b>EIGRP</b>	<b>OSPFv2</b>	<b>IS-IS</b>	<b>BGPv4</b>
IPv6	<b>RIPng</b>	<b>EIGRP for IPv6</b>	<b>OSPFv3</b>	<b>IS-IS for IPv6</b>	<b>BGPv4 for IPv6</b>

In this chapter, you will learn to:

- Describe the background and basic features of OSPF.
- Identify and apply the basic OSPF configuration commands.
- Describe, modify and calculate the metric used by OSPF.
- Describe the Designated Router/Backup Designated Router (DR/BDR) election process in multiaccess networks.
- Employ the `default-information originate` command to configure and propagate a default route in OSPF.

## 11.1.1 Background of OSPF



The initial development of OSPF began in 1987 by the Internet Engineering Task Force (IETF) OSPF Working Group. At that time the Internet was largely an academic and research network funded by the U.S. government.

## 11.1.2 OSPF Message Encapsulation

### OSPF Message Encapsulation

- OSPF packet type
  - There exist 5 types
- OSPF packet header
  - Contains** - Router ID and area ID **and** Type code for OSPF packet type
- IP packet header
  - Contains** - Source IP address, Destination IP address, & Protocol field set to 89
- Data link frame header
  - Contains** - Source MAC address and Destination MAC address

## 11.1.2 OSPF Message Encapsulation

### Encapsulated OSPF Message

Data Link Frame Header

IP Packet Header

OSPF Packet Header

OSPF Packet Type-Specific Data

#### Data Link Frame (Ethernet Fields shown here)

MAC Destination Address = Multicast: 01-00-5E-00-00-05 or 01-00-5E-00-00-06

MAC Source Address = Address of sending interface

#### IP Packet

IP Source Address = Address of sending interface

IP Destination Address = Multicast: 224.0.0.5 or 224.0.0.6

Protocol field = 89 for OSPF

#### OSPF Packet Header

Type Code for OSPF Packet Type

Router ID and Area ID

#### OSPF Packet Types

0x01 Hello

0x02 Database Description (DD)

0x03 Link State Request

0x04 Link State Update

0x05 Link State Acknowledgment

## 11.1.3 OSPF Packet Types

### Five Packet Types

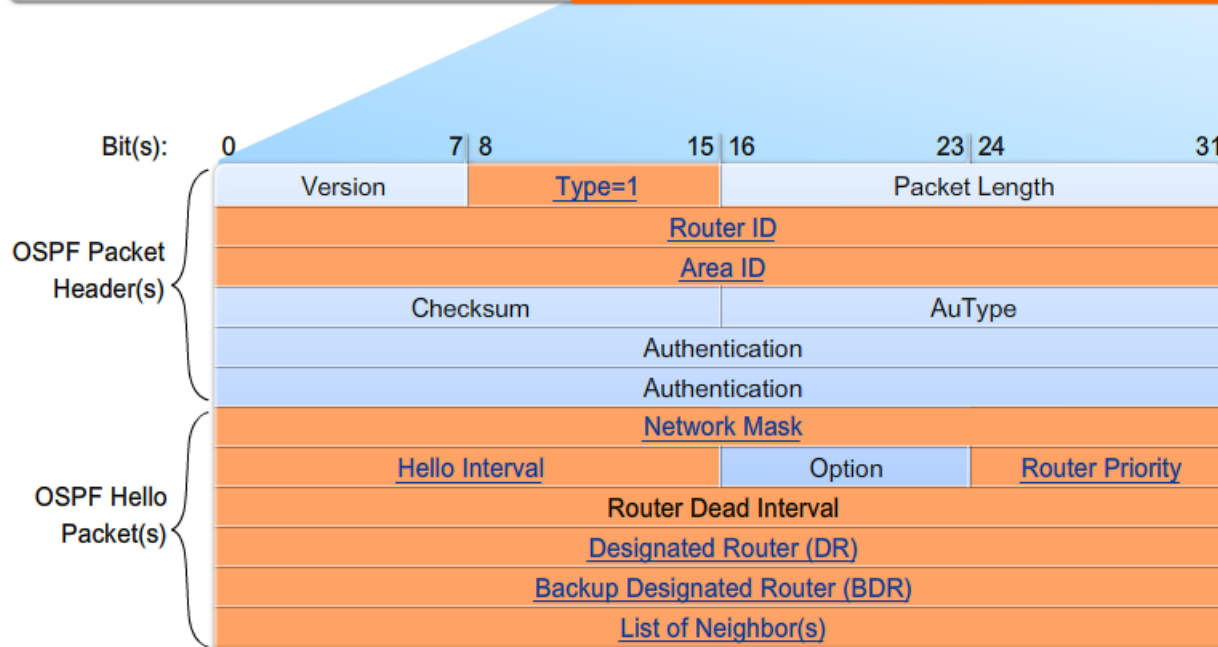
Type	Packet Name	Description
1	Hello	Discovers neighbors and builds adjacencies between them
2	Database Description (DBD)	Checks for database synchronization between routers
3	Link-State Request (LSR)	Requests specific link-state records from router to router
4	Link-State Update (LSU)	Sends specifically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

# 11.1.4 Hello Protocol

- OSPF Hello Packet

  - Purpose of Hello Packet

    - Discover OSPF neighbors & establish adjacencies
    - Advertise guidelines on which routers must agree to become neighbors
    - Used by multi-access networks to elect a **designated router** and a **backup designated router**

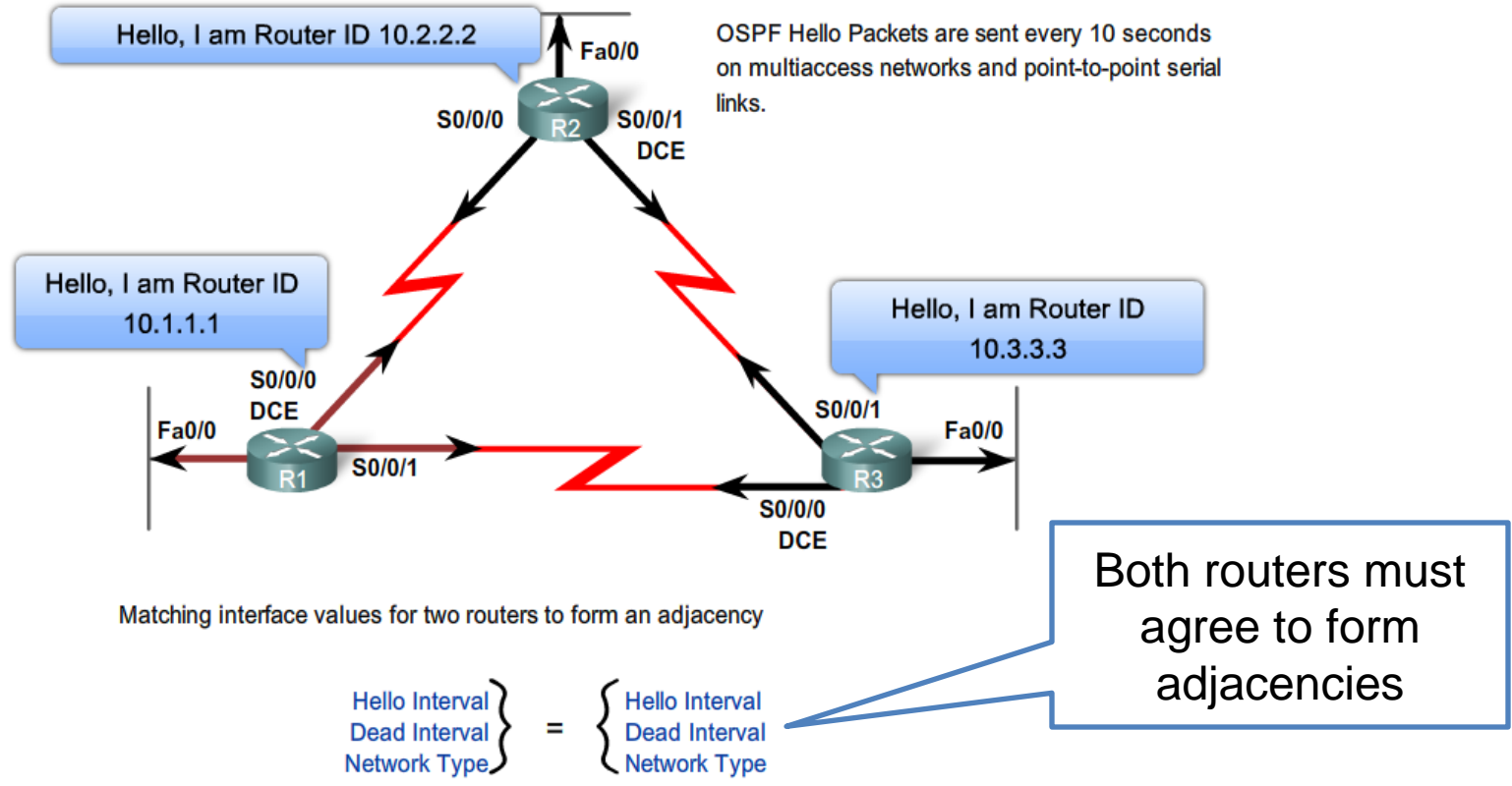


Roll over fields  
in the  
curriculum



# 11.1.4 Hello Protocol

- OSPF Hello Intervals
  - Usually multicast (224.0.0.5 reserved) sent every 10 seconds
  - Sent every 30 seconds for NBMA segments (Frame Relay – X25 – ATM)
- OSPF Dead Intervals
  - This is the time that must transpire before the neighbor is considered down
  - Default time is 4 times the hello interval



## 11.1.4 Hello Protocol

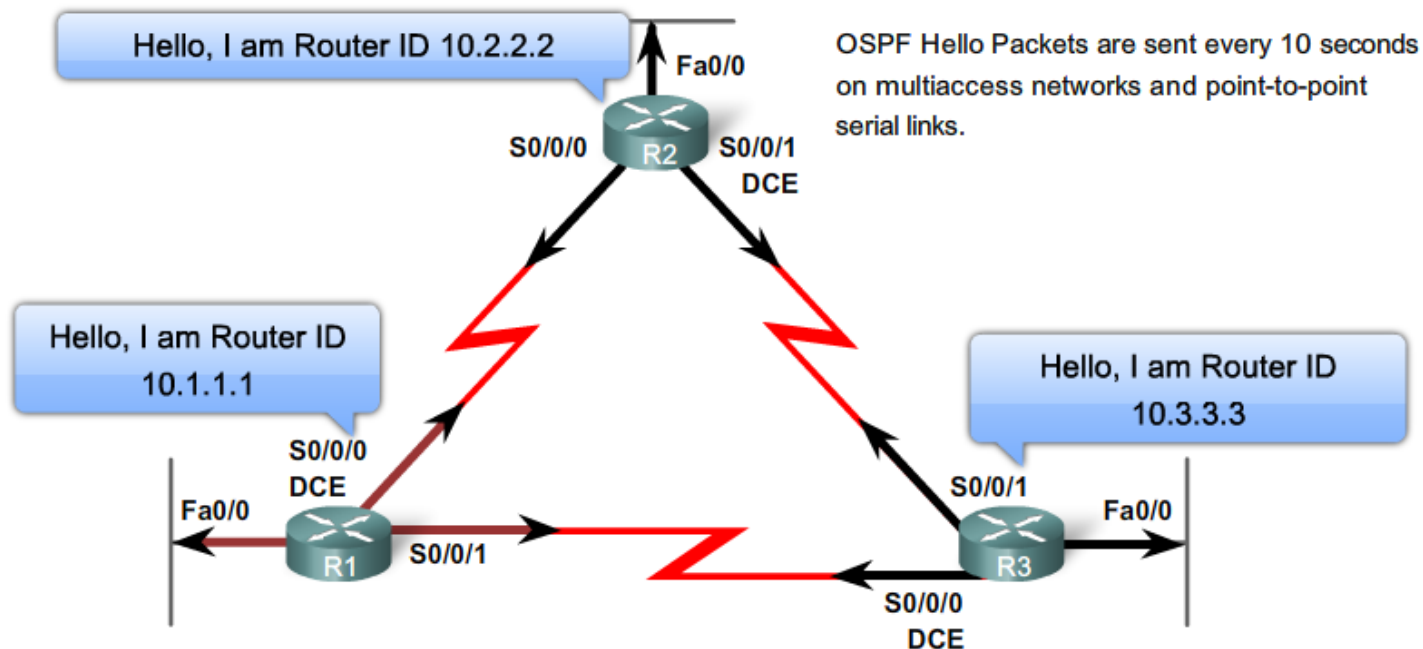
Hello protocol packets contain information that is used in electing:

### -Designated Router (DR)

- DR is responsible for updating all other OSPF routers

### -Backup Designated Router (BDR)

- This router takes over DR's responsibilities if DR fails
- No DR/BDR designations occur on point-to-point links



# 11.1.5 Link State Updates

- Purpose of a Link **State Update (LSU)**  
Used to deliver link state advertisements
- Purpose of a **Link State Advertisement (LSA)**  
Contains information about neighbors & path costs

NOTE

LSUs Contain Link-State Advertisements (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

- The acronyms LSA and LSU are often used interchangeably.
- An LSU contains one or more LSAs.
- LSAs contain route information for destination networks.
- LSA specifics are discussed in CCNP.

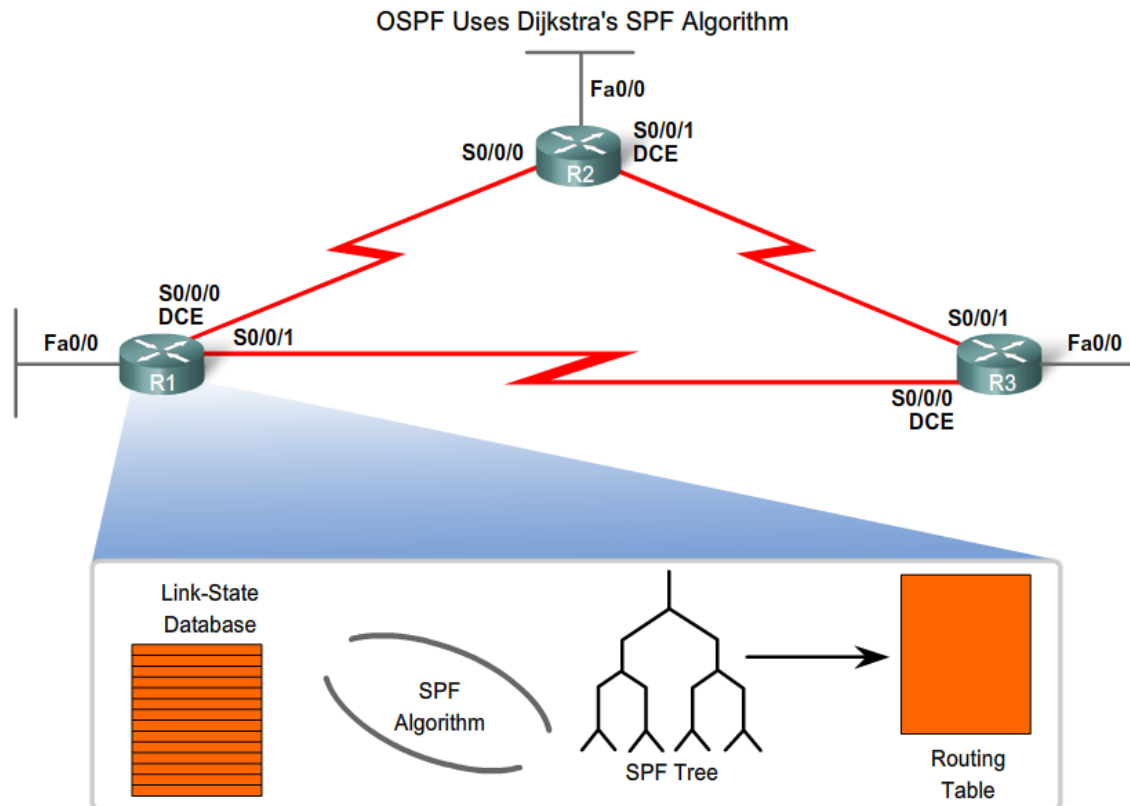
LSA Type
1
2
3 or 4
5
6
7
8
9, 10, 11

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 multiaccess networks like Ethernet and Frame Relay.

## 11.1.6 OSPF Algorithm

- OSPF routers build & maintain link-state database containing LSA received from other routers
- Information found in database is utilized upon execution of Dijkstra SPF algorithm
- SPF algorithm used to create SPF tree
- SPF tree used to populate routing table



## 11.1.7 Administrative Distances

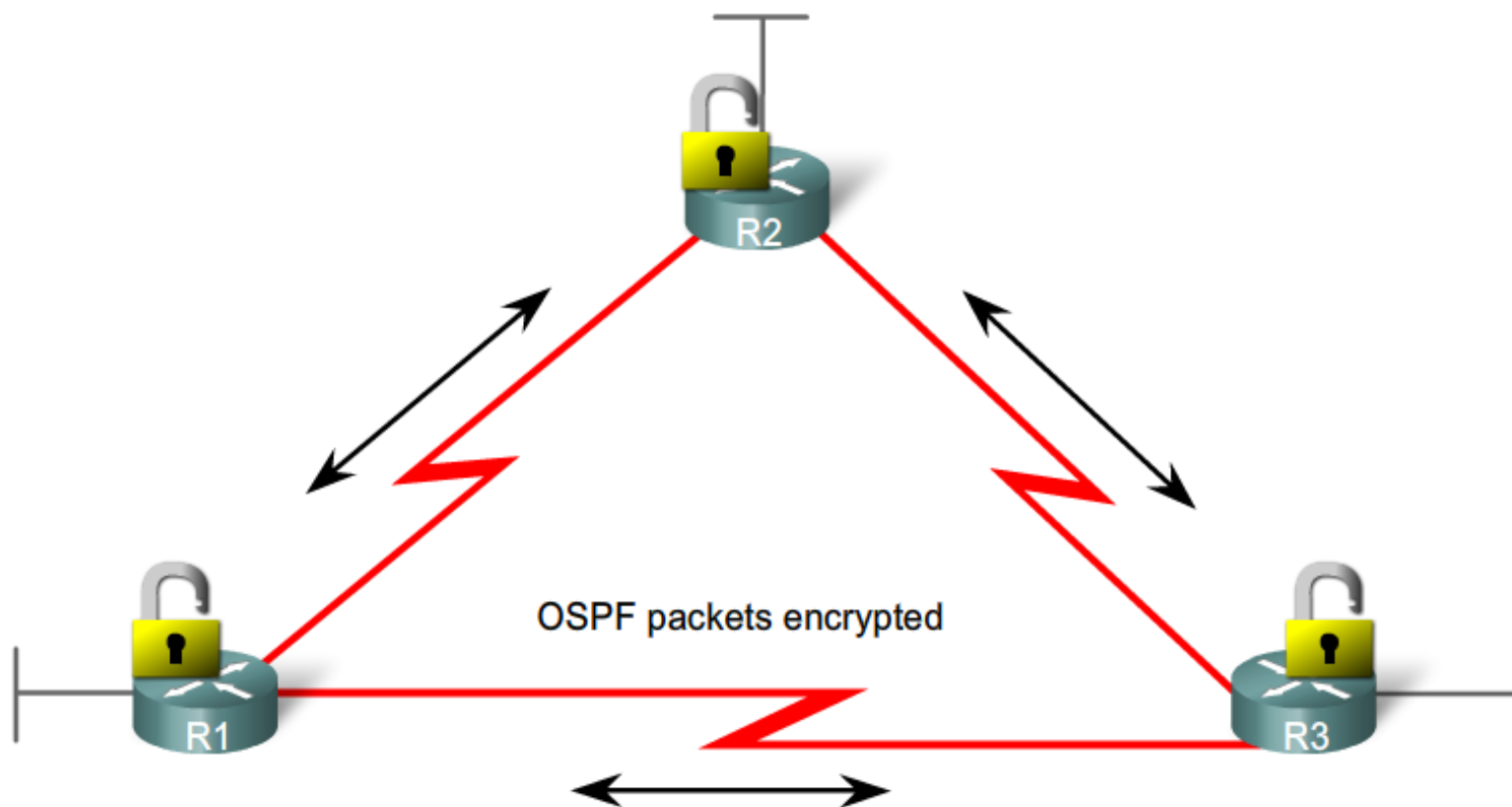
**Administrative distance (AD)** is the trustworthiness (or preference) of the route source. OSPF has a default administrative distance of 110. As you can see from the figure, when compared to other interior gateway protocols (IGPs), OSPF is preferred over IS-IS and RIP.

### Default Administrative Distances

Route Source	Administrative Distance
Connected	0
Static	1
EIGRP summary route	5
External BGP	20
Internal EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

## 11.1.8 Authentication

- OSPF Authentication
  - Purpose is to encrypt & authenticate routing information
  - This is an interface specific configuration
  - Routers will only accept routing information from other routers that have been configured with the same password or authentication information

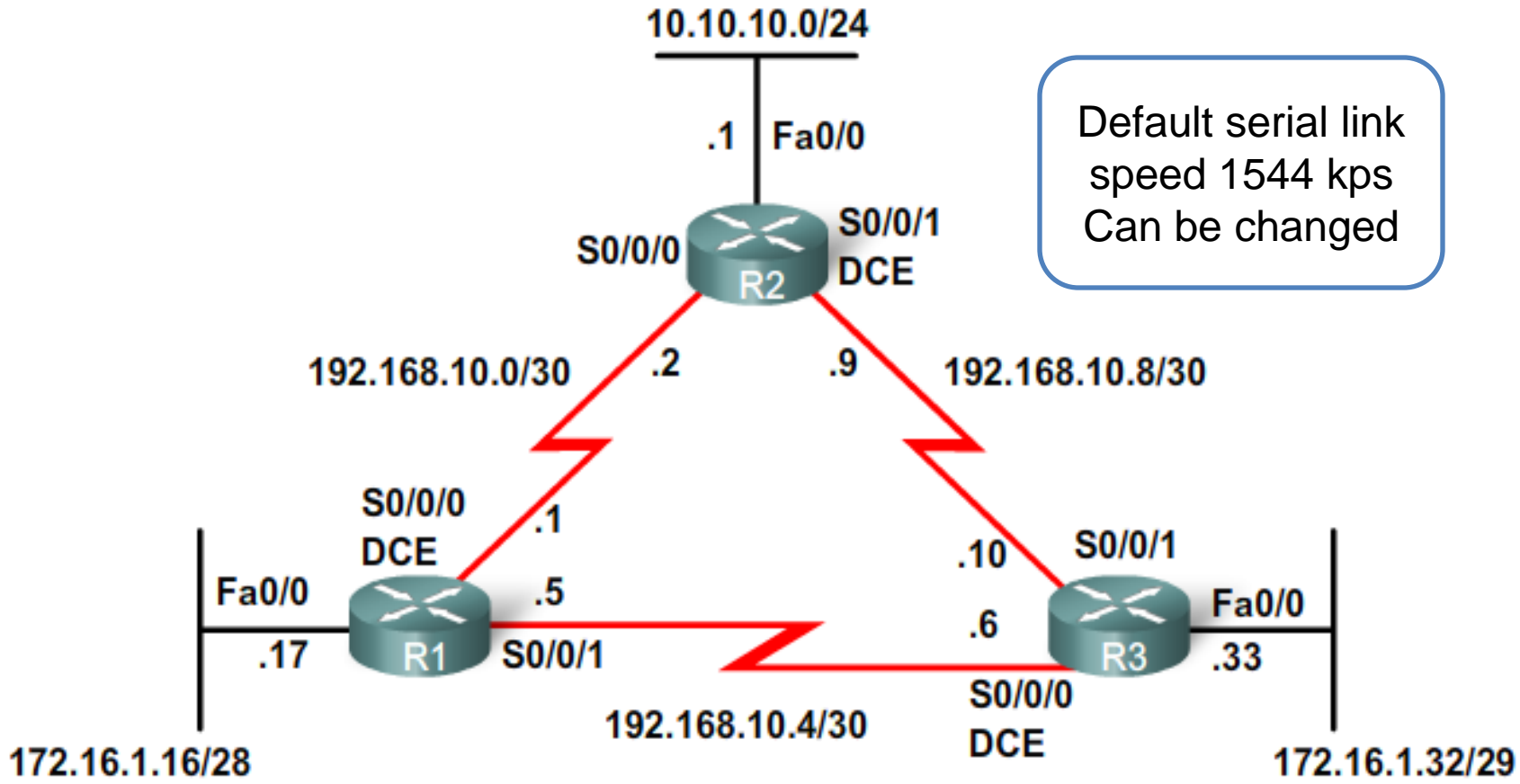


# 11.2.1 Lab Topology

- Topology used for this chapter

Discontiguous IP addressing scheme

Since OSPF is a classless routing protocol the subnet mask is configured in OSPF configuration



## 11.2.2 Router OSPF Command

### The router ospf command

- To enable OSPF on a router use the following command

```
R1(config)#router ospf process-id
```

Process id

- **A locally significant** number between **1** and **65535**  
-this means it does not have to match other OSPF routers

```
R1(config)#router ospf 1  
R1(config-router)#
```

```
R2(config)#router ospf 1  
R2(config-router)#
```

```
R3(config)#router ospf 1  
R3(config-router)#
```



## 11.2.3 The Network Command

- **OSPF network command**
- Requires entering: **network address wildcard mask** - the inverse of the subnet mask
- **area-id** - area-id refers to the OSPF area.
- OSPF area is a group of routers that share link state information
  - Example: Router(config-router)#**network** network-address wildcard-mask **area** area-id

```
R1 (config)#router ospf 1  
R1 (config-router)#network 172.16.1.16 0.0.0.15 area 0  
R1 (config-router)#network 192.168.10.0 0.0.0.3 area 0  
R1 (config-router)#network 192.168.10.4 0.0.0.3 area 0
```

```
R2 (config)#router ospf 1  
R2 (config-router)#network 10.10.10.0 0.0.0.255 area 0  
R2 (config-router)#network 192.168.10.0 0.0.0.3 area 0  
R2 (config-router)#network 192.168.10.8 0.0.0.3 area 0
```

```
R3 (config)#router ospf 1  
R3 (config-router)#network 172.16.1.32 0.0.0.7 area 0  
R3 (config-router)#network 192.168.10.4 0.0.0.3 area 0  
R3 (config-router)#network 192.168.10.8 0.0.0.3 area 0
```

## 11.2.4 OSPF Router ID

Router ID is determined in the following order:

1. Use the IP address configured with the OSPF router-id command.
2. If the router-id is not configured, then the router chooses highest IP address of any of its loopback interfaces.
3. If no loopback interfaces are configured, then the router chooses highest active IP address of any of its physical interfaces.

### Router ID

This is an IP address used to identify a router

3 criteria for deriving the router ID

1. Use IP address configured with OSPF *router-id* command  
Takes precedence over loopback and physical interface addresses
2. If router-id command not used then router chooses highest IP address of any loopback interfaces
3. If no loopback interfaces are configured then the highest IP address on any active interface is used

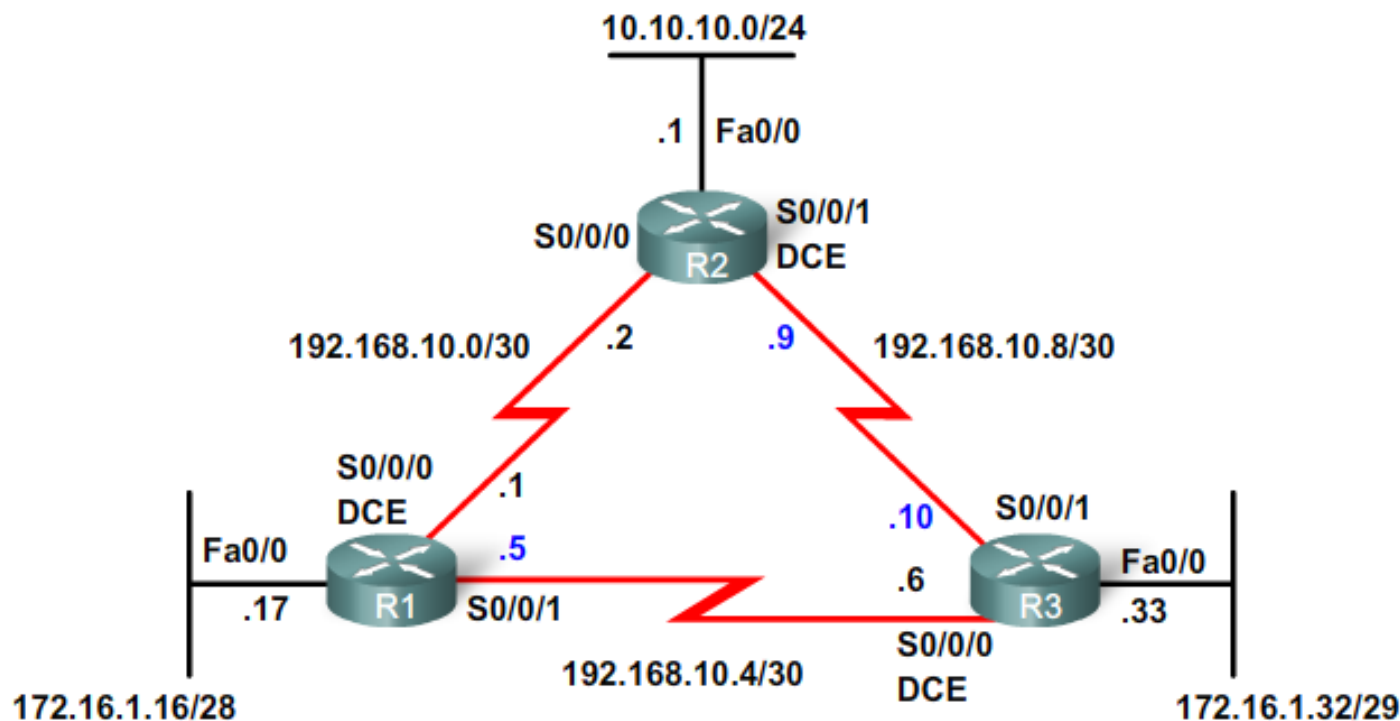
## 11.2.4 OSPF Router ID

Because we have not configured router IDs or loopback interfaces on our three routers, the router ID for each router is determined by the highest active IP address on any of the router's physical interfaces. As shown in the figure, the router ID for each router is:

R1: 192.168.10.5, which is higher than either 172.16.1.17 or 192.168.10.1

R2: 192.168.10.9, which is higher than either 10.10.10.1 or 192.168.10.2

R3: 192.168.10.10, which is higher than either 172.16.1.33 or 192.168.10.6



## 11.2.4 OSPF Router ID

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.5
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```

```
R2#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.9
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```

```
R3#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 192.168.10.10
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```

Commands used to verify current router ID

Show ip protocols

Show ip ospf

Show ip ospf interface

## 11.2.4 OSPF Router ID

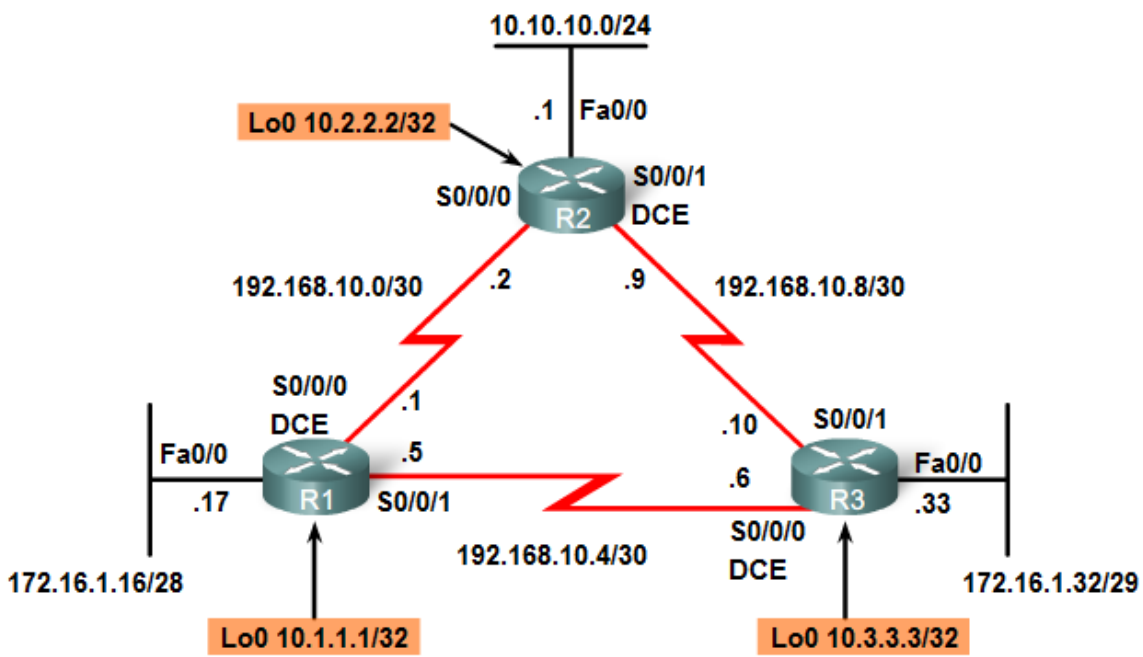
### OSPF Router ID

- Router ID & Loopback addresses
  - Highest loopback address will be used as router ID if router-id command isn't used
  - Advantage of using loopback address
    - the loopback interface cannot fail → OSPF stability
- The OSPF router-id command
  - Introduced in IOS 12.0
  - Command syntax
    - Router(config)#router ospfprocess-id
    - Router(config-router)#router-idip-address
- Modifying the Router ID
  - Use the command Router#clear ip ospf process

```
R1 (config) #interface loopback 0  
R1 (config-if) #ip add 10.1.1.1 255.255.255.255
```

# 11.2.4 OSPF Router ID

In this topology, all three routers have been configured with loopback addresses to represent the OSPF router IDs. The advantage of using a loopback interface is that - unlike physical interfaces - it cannot fail. There are no actual cables or adjacent devices on which the loopback interface depends for being in the up state. Therefore, using a loopback address for the router ID provides stability to the OSPF process. Because the OSPF router-id command, which is discussed next, is a fairly recent addition to IOS, it is more common to find loopback addresses used for configuring OSPF router ID



## 11.2.4 OSPF Router ID

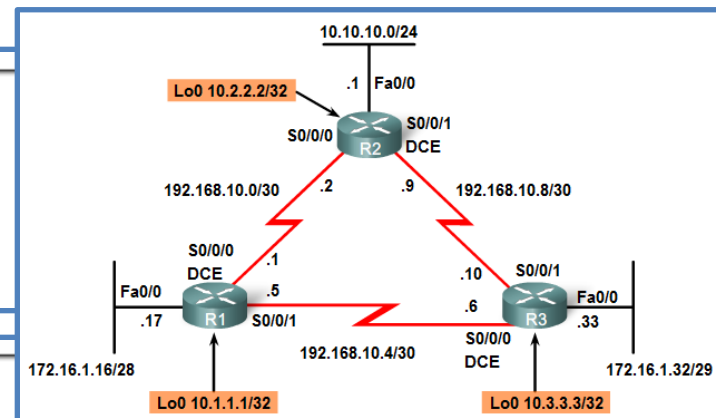
If the OSPF router-id command is not used and loopback interfaces are configured, OSPF will choose highest IP address of any of its loopback interfaces. A loopback address is a virtual interface and is automatically in the up state when configured. You already know the commands to configure a loopback interface:

```
Router(config)#interface loopback number
```

```
Router(config-if)#ip address ip-address subnet-mask
```

```
R1(config)#interface loopback 0
R1(config-if)#ip add 10.1.1.1 255.255.255.255
```

```
R1#show ip protocols
Routing Protocol is "ospf 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Router ID 10.1.1.1
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
***output omitted***
```



## 11.2.5 Verifying OSPF

### Verifying OSPF

- Use the show ip ospf command to verify & trouble shoot OSPF networks

Command will display the following:

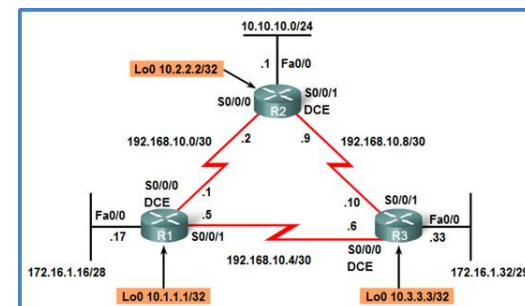
- Neighbor adjacency

-No adjacency indicated by -

- Neighboring router's Router ID is not displayed
- A state of **full** is not displayed

-Consequence of no adjacency-

- No link state information exchanged
- Inaccurate SPF trees & routing tables



```
R1#show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.3.3.3	1	FULL/ -	00:00:30	192.168.10.6	Serial0/0/1
10.2.2.2	1	FULL/ -	00:00:33	192.168.10.2	Serial0/0/0



## 11.2.5 Verifying OSPF

Command	Description
Show ip protocols	Displays OSPF process ID, router ID, networks router is advertising & administrative distance
Show ip ospf	Displays OSPF process ID, router ID, OSPF area information & the last time SPF algorithm calculated
Show ip ospf interface	Displays hello interval and dead interval

## 11.2.6 Examining the Routing Table

### Examining the routing table

- Use the show ip route command to display the routing table
  - An “O” at the beginning of a route indicates that the router source is OSPF
  - Note OSPF does not automatically summarize at major network boundaries

```
R3#show ip route
```

```
Codes: D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
```

```
***output omitted***
```

```
Gateway of last resort is not set
```

```
192.168.10.0/30 is subnetted, 3 subnets
```

```
O      192.168.10.4 [110/128] via 192.168.10.9, 14:31:52, Serial0/0/1  
      [110/128] via 192.168.10.5, 14:31:52, Serial0/0/0
```

```
C      192.168.10.4 is directly connected, Serial0/0/0
```

```
C      192.168.10.8 is directly connected, Serial0/0/1
```

```
172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
```

```
C      172.16.1.32/29 is directly connected, FastEthernet0/0
```

```
O      172.16.1.16/28 [110/65] via 192.168.10.5, 14:31:52, Serial0/0/0
```

```
10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
```

```
C      10.3.3.3/32 is directly connected, Loopback0
```

```
O      10.10.10.0/24 [110/65] via 192.168.10.9, 14:31:52, Serial0/0/1
```

## 11.2.6 Examining the Routing Table



Packet Tracer Exploration:  
Configure and Verify OSPF Routing

Use the Packet Tracer Activity to  
configure and verify basic OSPF  
routing.

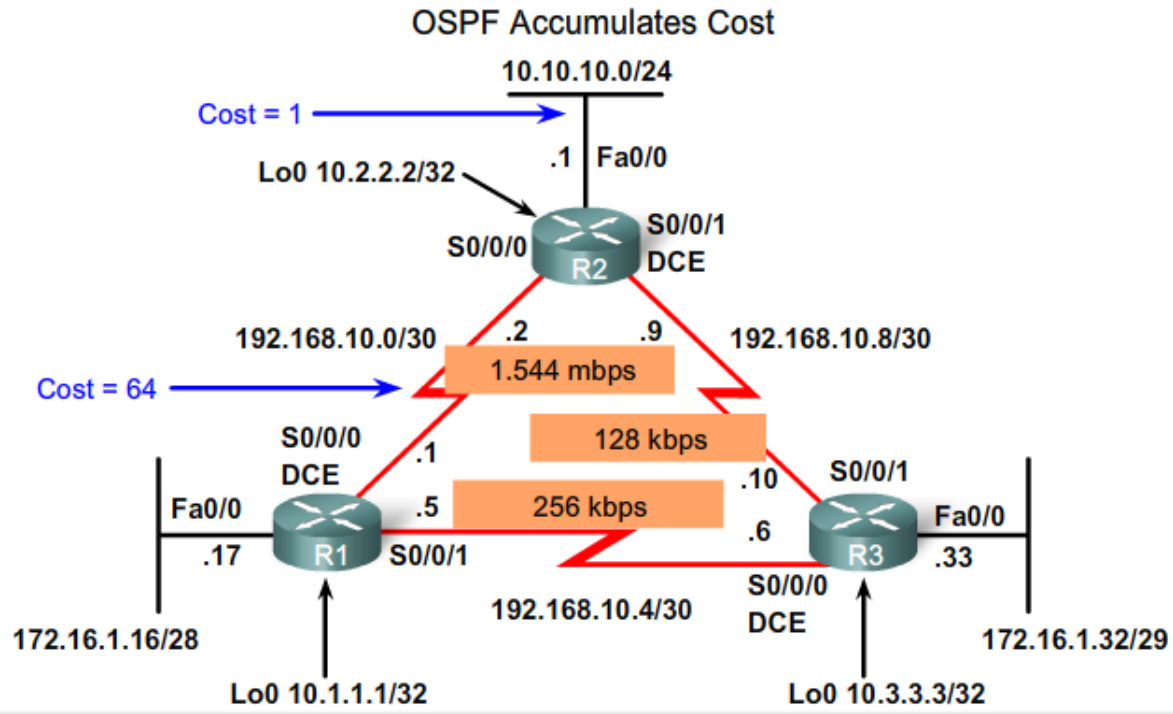


## 11.3.1 OSPF Metric

- OSPF uses **cost** as the metric for determining the best route
  - The best route will have the lowest cost
  - Cost** is based on bandwidth of an interface
    - Cost is calculated using the formula
$$10^8 / \text{bandwidth}$$
  - Reference bandwidth
    - defaults to 100Mbps
    - can be modified using
    - **auto-cost reference-bandwidth** command

Interface Type	$10^8 / \text{bps} = \text{Cost}$
Fast Ethernet and faster	$10^8 / 100,000,000 \text{ bps} = 1$
Ethernet	$10^8 / 10,000,000 \text{ bps} = 10$
E1	$10^8 / 2,048,000 \text{ bps} = 48$
T1	$10^8 / 1,544,000 \text{ bps} = 64$
128 kbps	$10^8 / 128,000 \text{ bps} = 781$
64 kbps	$10^8 / 64,000 \text{ bps} = 1562$
56 kbps	$10^8 / 56,000 \text{ bps} = 1785$

# 11.3.1 OSPF Metric



```
R1#show ip route
Codes: ***output omitted***
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area

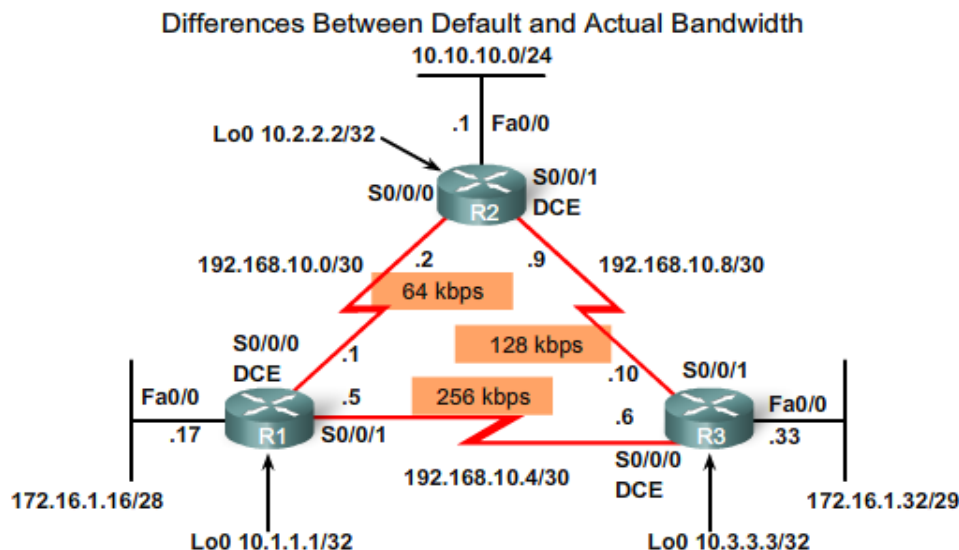
***output omitted***
O      10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0

Accumulated Cost = 65
```

- COST of an OSPF route
- Is the accumulated value from one router to the next

## 11.3.1 OSPF Metric

- Usually the actual speed of a link **is different** than the default bandwidth
  - This makes it imperative that the bandwidth value reflects link's actual speed
    - Reason: so routing table has best path information
- The **show interface** command will display interface's bandwidth
  - Most serial link default to 1.544Mbps



```
R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
Hardware is GT96K Serial
Description: Link to R2
Internet address is 192.168.10.1/30
MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
reliability 255/255, txload 1/255, rxload 1/255
```

Default Bandwidth = 1544 kbps

Actual Bandwidth = 64 kbps

## 11.3.2 Modifying the Cost of a Link

### Modifying the Cost of a link

- Both sides of a serial link should be configured with the same bandwidth
  - Commands used to modify bandwidth value
    - **Bandwidth** command
      - Example: Router(config-if)#**bandwidth** *bandwidth-kbps*
    - **ip ospf cost** command – allows you to directly specify interface cost
      - -Example: R1(config)#interface serial 0/0/0
      - R1(config-if)#ip ospf cost 1562

```
R1(config)#inter serial 0/0/0
R1(config-if) #bandwidth 64
R1(config-if)#inter serial 0/0/1
R1(config-if)#bandwidth 256
R1(config-if)#end
R1#show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
 Internet Address 192.168.10.1/30, Area 0
 Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
 Transmit Delay is 1 sec, State POINT_TO_POINT,
***output omitted***
```

$10^8 / 64,000 \text{ bps} = 1562$

## 11.3.2 Modifying the Cost of a Link

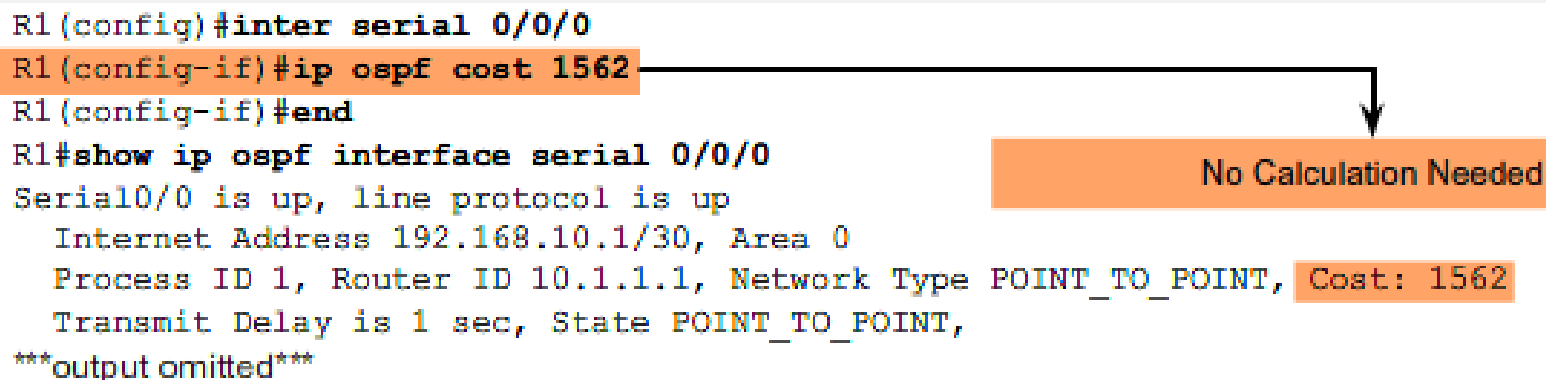
An alternative method to using the bandwidth command is to use the **ip ospf cost** command, which allows you to directly specify the cost of an interface.

For example, on R1 we could configure Serial 0/0/0 with the following command:

```
R1(config)#interface serial 0/0/0
```

```
R1(config-if)#ip ospf cost 1562
```

```
R1(config)#inter serial 0/0/0
R1(config-if)#ip ospf cost 1562
R1(config-if)#end
R1#show ip ospf interface serial 0/0/0
Serial0/0 is up, line protocol is up
  Internet Address 192.168.10.1/30, Area 0
  Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost: 1562
  Transmit Delay is 1 sec, State POINT_TO_POINT,
***output omitted***
```



The diagram illustrates the relationship between the configuration command and the resulting output. A black arrow originates from the command `R1(config-if)#ip ospf cost 1562` in the terminal output and points to an orange box containing the text `No Calculation Needed`. This indicates that the `ip ospf cost` command bypasses the standard bandwidth-based cost calculation.



## 11.3.2 Modifying the Cost of a Link

- Difference between bandwidth command & the ip ospf cost command
  - **ip ospf cost** command
    - Sets cost to a specific value
  - **Bandwidth** command
    - Link cost is calculated

### bandwidth Commands

```
Router R1
R1(config)#interface serial 0/0/0
R1(config-if)#bandwidth 64
```

```
R1(config)#interface serial 0/0/1
R1(config-if)#bandwidth 256
```

```
Router R2
R2(config)#interface serial 0/0/0
R2(config-if)#bandwidth 64
```

```
R2(config)#interface serial 0/0/1
R2(config-if)#bandwidth 128
```

```
Router R3
R3(config)#interface serial 0/0/0
R3(config-if)#bandwidth 256
```

```
R3(config)#interface serial 0/0/1
R3(config-if)#bandwidth 128
```

### ip ospf cost Commands

```
= Router R1
R1(config)#interface serial 0/0/0
R1(config-if)#ip ospf cost 1562
```

```
= R1(config)#interface serial 0/0/1
R1(config-if)#ip ospf cost 390
```

```
= Router R2
R2(config)#interface serial 0/0/0
R2(config-if)#ip ospf cost 1562
```

```
= R2(config)#interface serial 0/0/1
R2(config-if)#ip ospf cost 781
```

```
= Router R3
R3(config)#interface serial 0/0/0
R3(config-if)#ip ospf cost 390
```

```
= R3(config)#interface serial 0/0/1
R3(config-if)#ip ospf cost 781
```



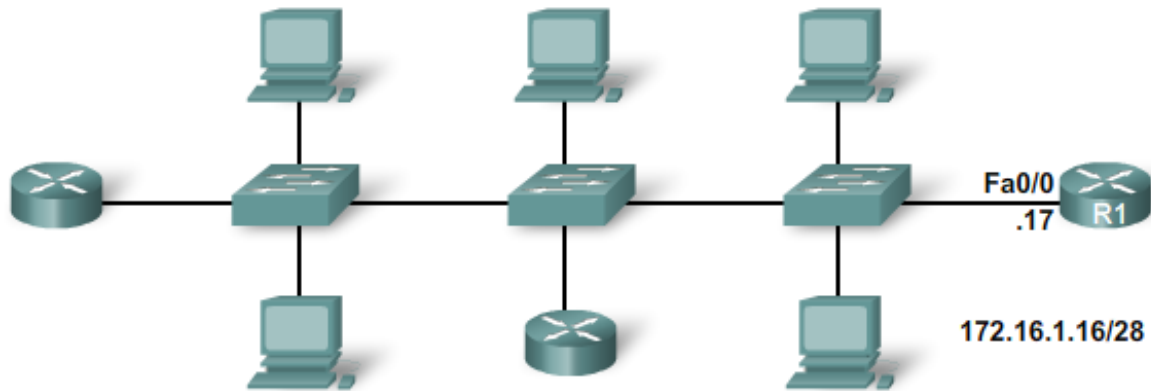
## Packet Tracer Exploration: Modifying the Cost of a Link

Use the Packet Tracer Activity to  
modify the cost values for OSPF.



## 11.4.1 Challenges in Multi-access Networks

Broadcast Multiaccess Network



Point-to-Point Network

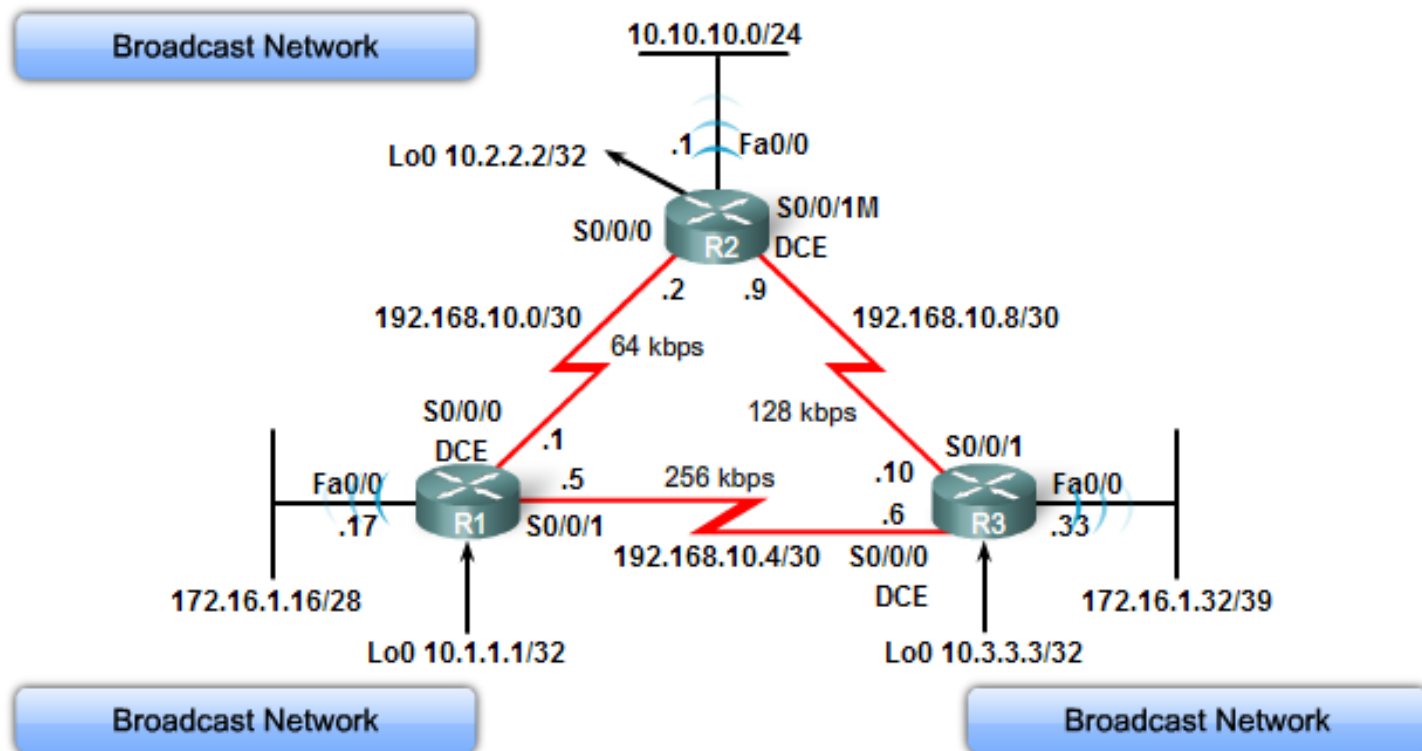


A point-to-point network there are only two devices on the network, one at each end. The WAN link between R1 and R3 is an example of a point-to-point link.

A multiaccess network is a network with more than two devices on the same shared media. In the top portion of the figure, the Ethernet LAN attached to R1 is extended to show possible devices that might be attached to the 172.16.1.16/28 network. Ethernet LANs are an example of a broadcast multiaccess network. They are broadcast networks because all devices on the network see all broadcast frames. They are multiaccess networks because there may be numerous hosts, printers, routers, and other devices that are all members of the same network.

## 11.4.1 Challenges in Multi-access Networks

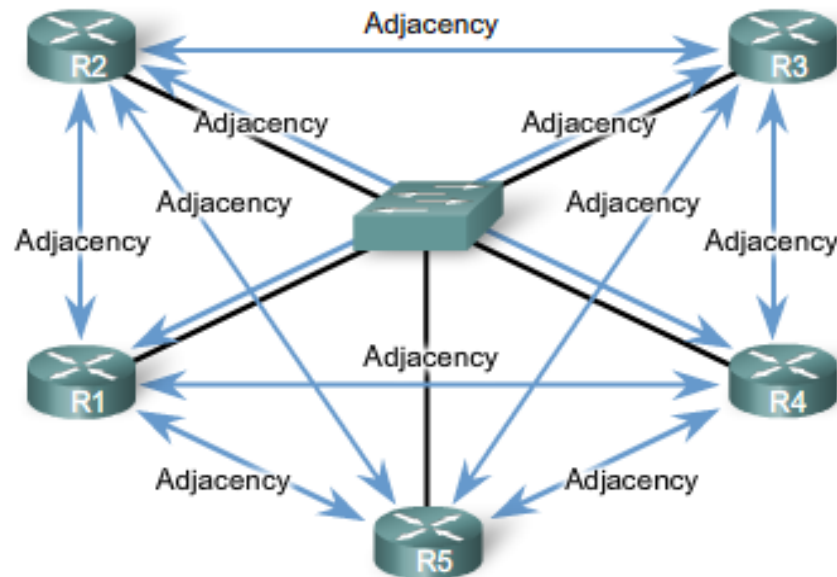
- OSPF defines five network types:
  - Point-to-point
  - Broadcast Multiaccess
  - Nonbroadcast Multiaccess (NBMA)
  - Point-to-multipoint
  - Virtual links



## 11.4.1 Challenges in Multi-access Networks

- 2 challenges presented by multiaccess networks
  - Multiple adjacencies
  - Extensive LSA flooding

Number of Adjacencies Grows Exponentially

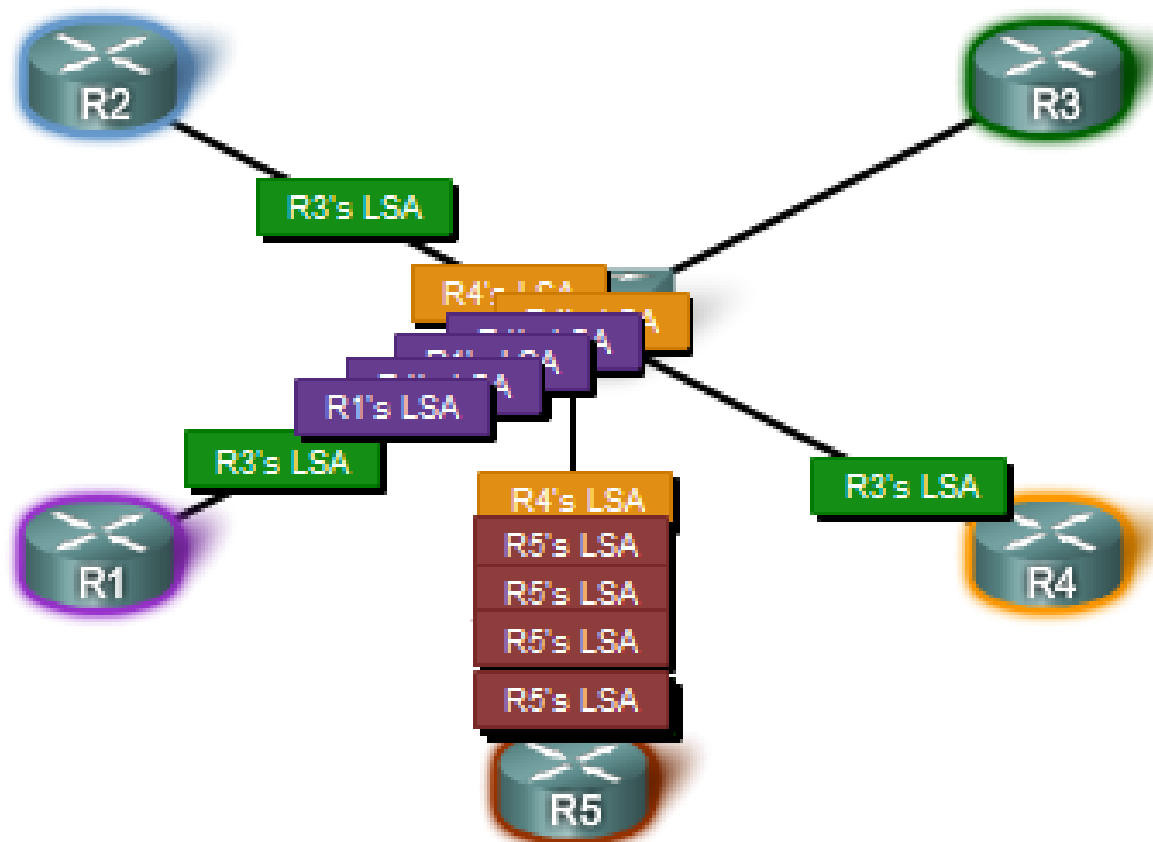


Routers	Adjacencies
$n$	$\frac{n(n-1)}{2}$
5	10
10	45
20	190
100	4,950

Number of Adjacencies =  $\frac{n(n-1)}{2}$   
 $n$  = number of routers  
Example: 5 routers  $(5 - 1)/2 = 10$  adjacencies

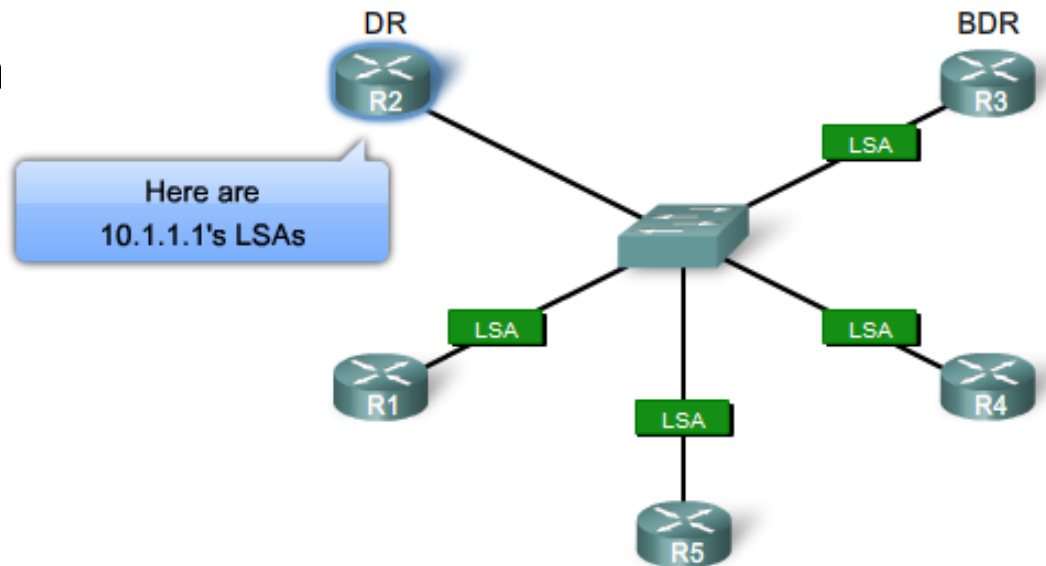
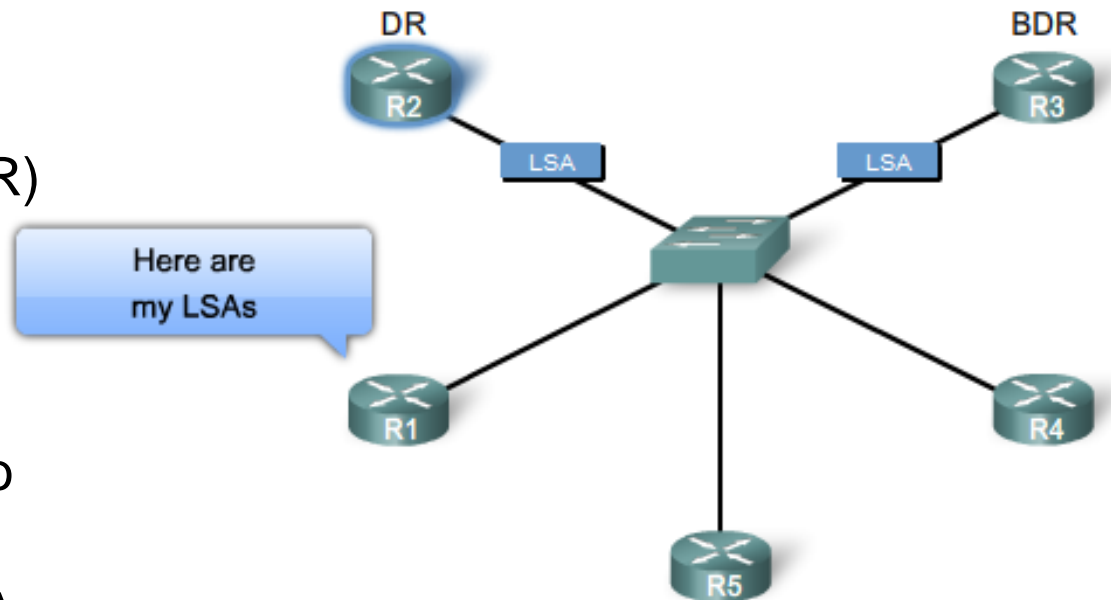
## 11.4.1 Challenges in Multi-access Networks

- **Extensive flooding of LSAs**
  - For every LSA sent out there must be an acknowledgement of receipt sent back to transmitting router.
  - consequence: lots of bandwidth consumed and chaotic traffic



## 11.4.1 Challenges in Multi-access Networks

- Solution to LSA flooding issue is the use of
  - Designated router (DR)
  - Backup designated router (BDR)
- DR & BDR selection
  - Routers are elected to send & receive LSA
- Sending & Receiving LSA
  - DRothers send LSAs via multicast 224.0.0.6 to DR & BDR
  - DR forward LSA via multicast address 224.0.0.5 to all other routers

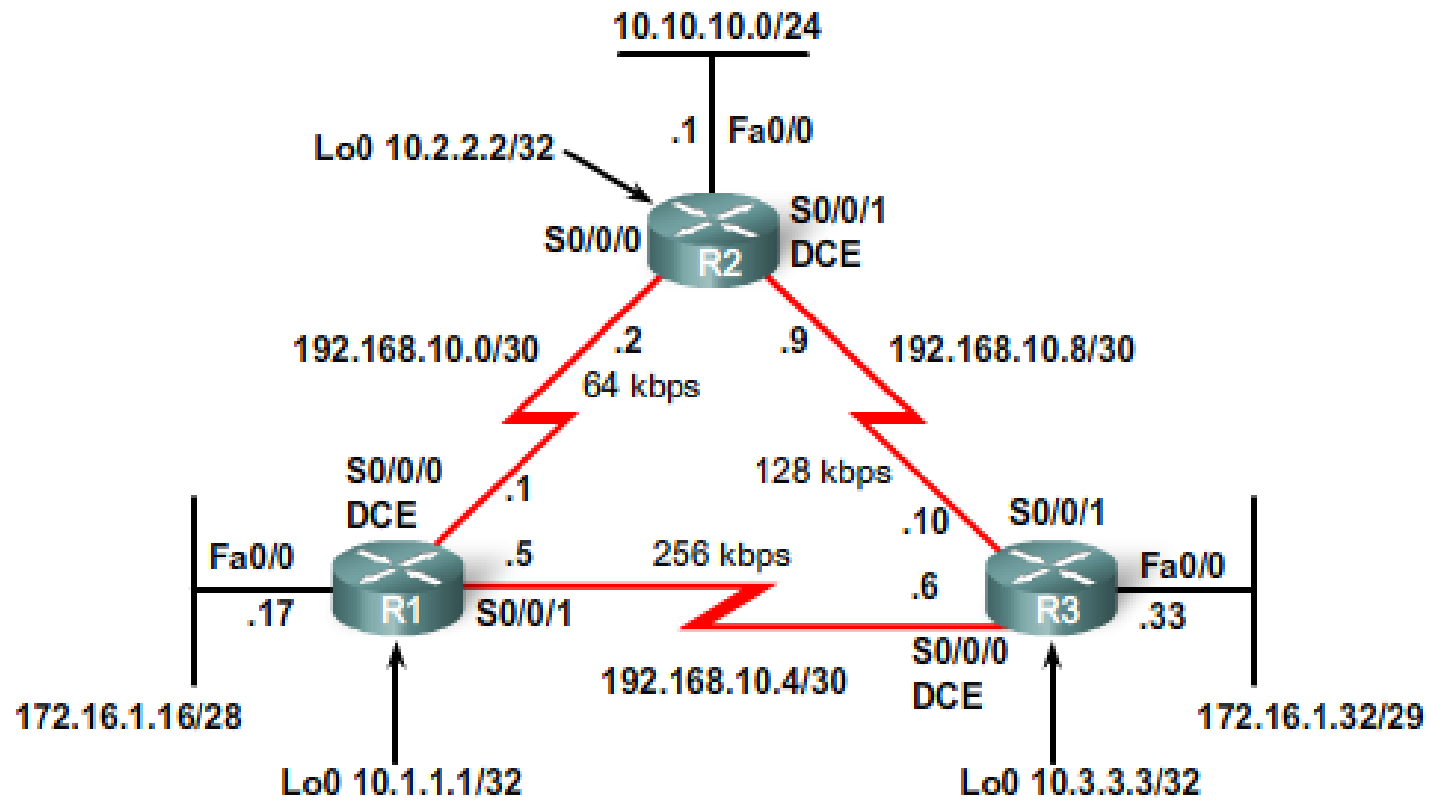


# 11.4.2 DR/BDR Election Process

## DR/BDR Election Process

- DR/BDR elections **DO NOT** occur in point to point networks

Point-to-Point Three Router Topology

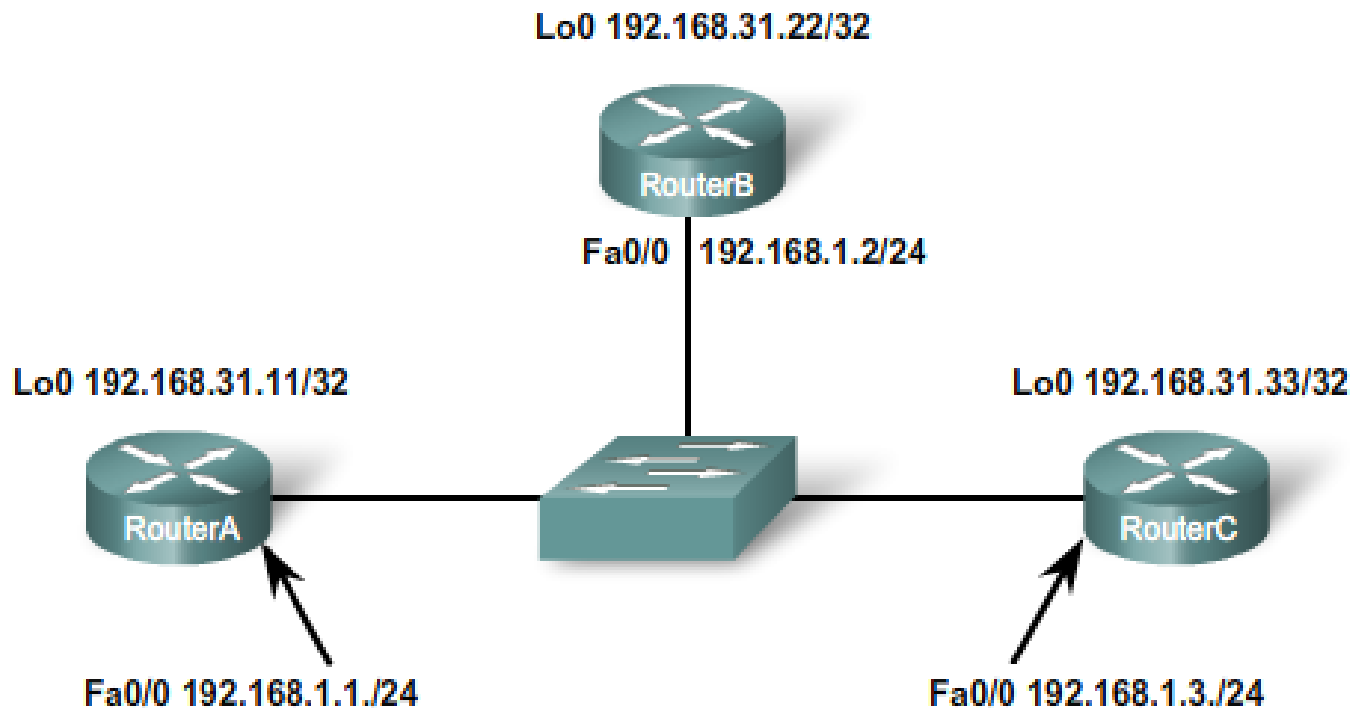




## 11.4.2 DR/BDR Election Process

DR/BDR elections **will take place on multiaccess networks** as shown below

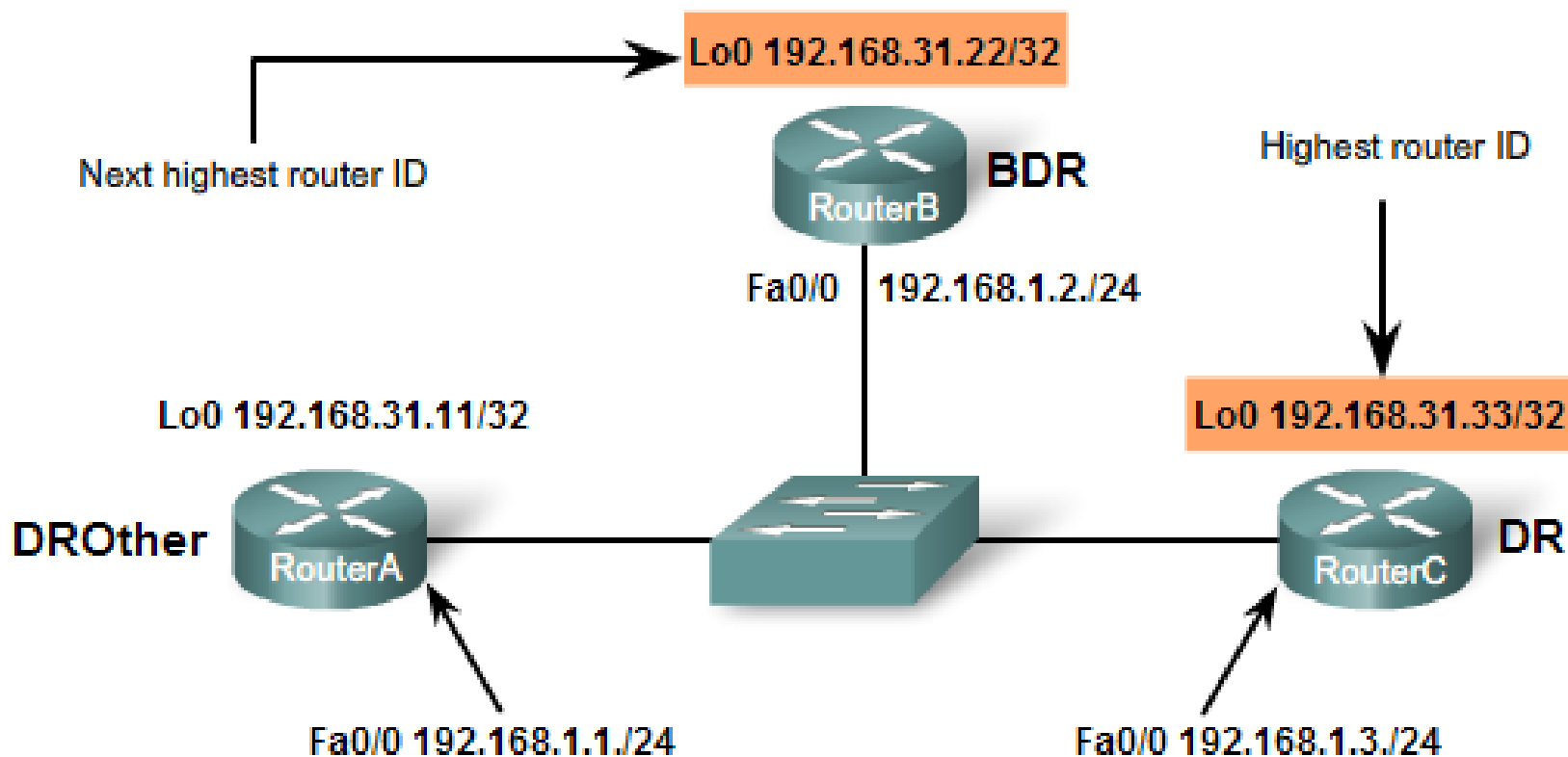
Multiaccess Three Router Topology



Notice that routers are now communicating via LAN interfaces.

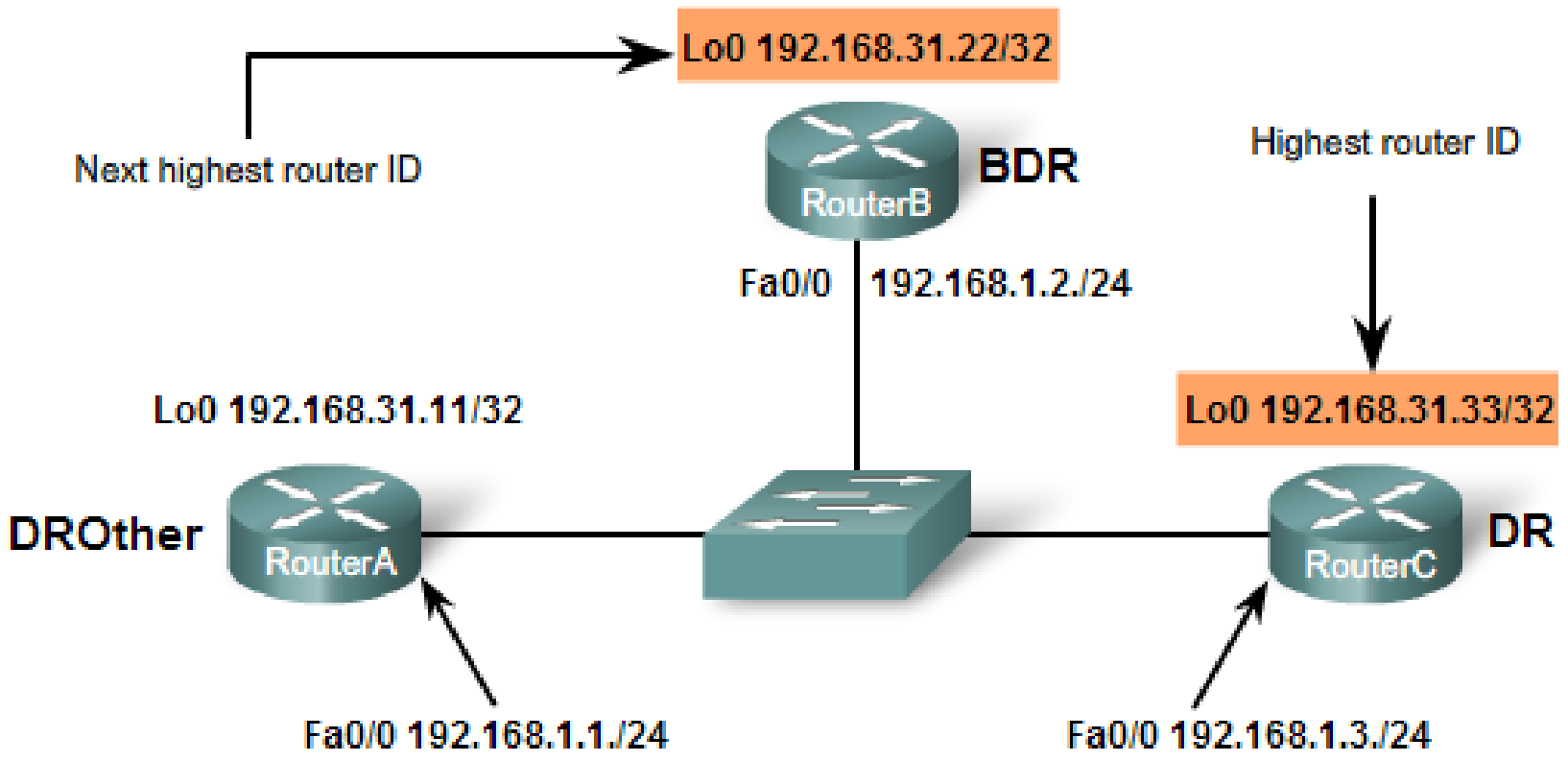
## 11.4.2 DR/BDR Election Process

- Criteria for getting elected DR/BDR
  - DR:** Router with the **highest** OSPF interface **priority**.
  - BDR:** Router with the **second highest** OSPF interface **priority**.
  - If OSPF interface **priorities are equal**, the
    - highest router ID** is used to break the tie.



# 11.4.2 DR/BDR Election Process

```
RouterA#show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
Internet Address 192.168.1.1/24, Area 0
Process ID 1, Router ID 192.168.31.11, Network Type BROADCAST, Cost: 1
Transmit Delay is 1 sec, State DROTHER, Priority 1
Designated Router (ID) 192.168.31.33, Interface address 192.168.1.3
Backup Designated router (ID) 192.168.31.22, Interface address 192.168.1.2
Timer intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
oob-resync timeout 40
Hello due in 00:00:06
```



## 11.4.2 DR/BDR Election Process

- **Timing of DR/BDR Election**

- Occurs as soon as 1<sup>st</sup> router has its interface enabled on multiaccess network
  - When a DR is elected it remains as the DR until one of the following occurs
    - -The DR fails.
    - -The OSPF process on the DR fails.
    - -The multiaccess interface on the DR fails.

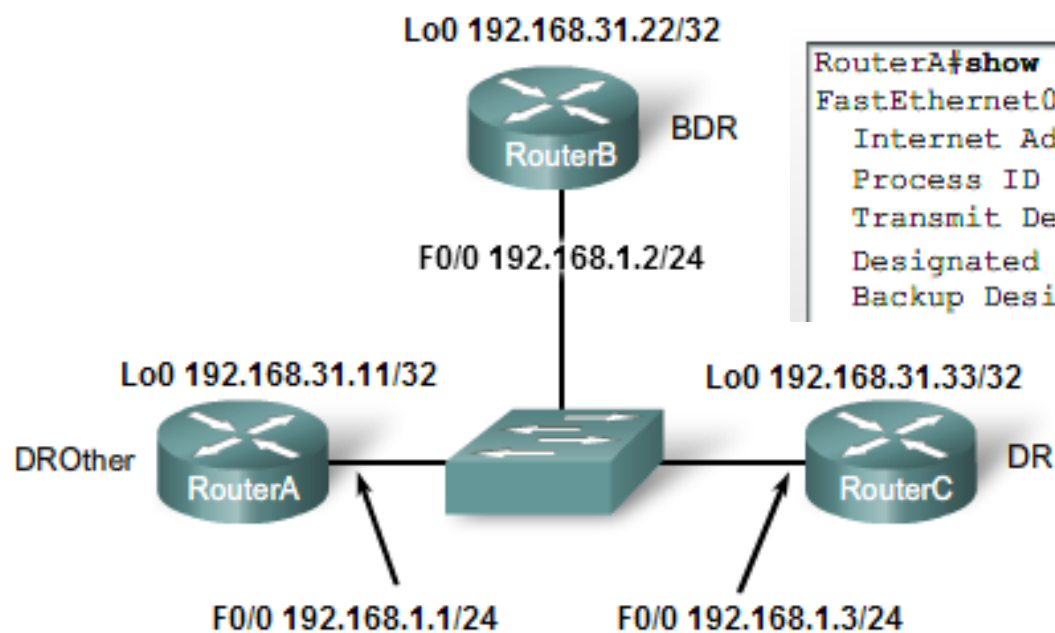
- **Manipulating the election process**

- -If you want to influence the election of DR & BDR then do one of the following
  - Boot up the DR first, followed by the BDR, and then boot all other routers, OR
  - Shut down the interface on all routers, followed by a **no shutdown** on the DR, then the BDR, and then all other routers.

## 11.4.3 OSPF Interface Priority

### OSPF Interface Priority

- Manipulating the DR/BDR election process continued
  - Use the `ip ospf priority interface` command.
  - Example: `Router(config-if)#ip ospf priority {0 - 255}`
    - Priority number range 0 to 255
      - 0 means the router cannot become the DR or BDR
      - 1 is the default priority value



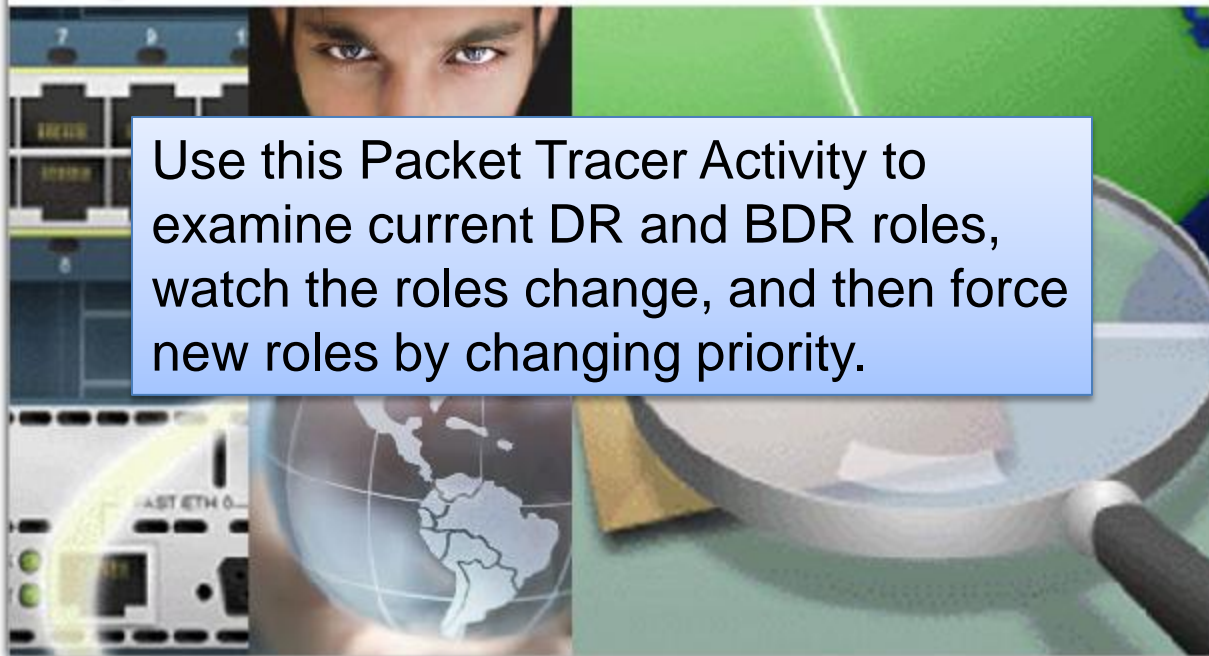
```
RouterA#show ip ospf interface fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
Internet Address 192.168.1.1/24, Area 0
Process ID 1, Router ID 192.168.31.11, Network Type E
Transmit Delay is 1 sec, State DROTHER, Priority 1
Designated Router (ID) 192.168.31.33, Interface address
Backup Designated router (ID) 192.168.31.22, Interface
```

## 11.4.3 OSPF Interface Priority



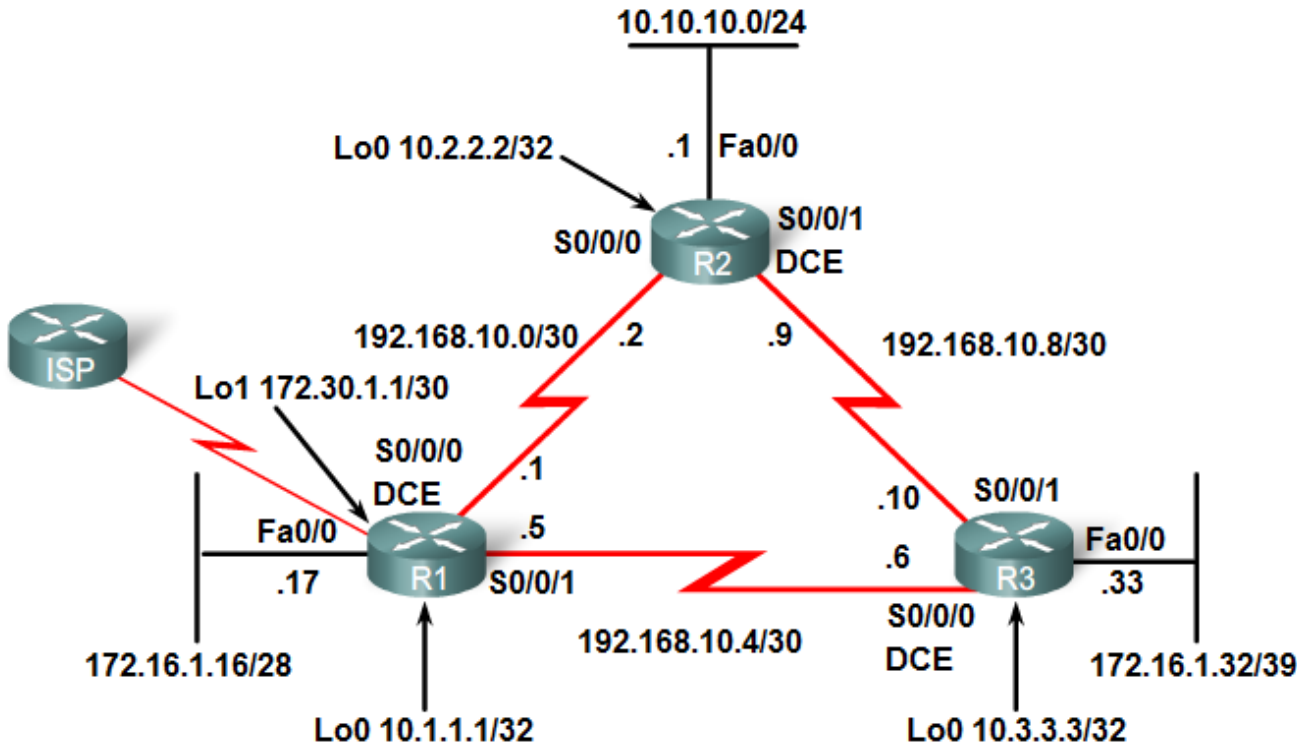
Packet Tracer Exploration:  
Determining the DR and BDR

Use this Packet Tracer Activity to examine current DR and BDR roles, watch the roles change, and then force new roles by changing priority.



# 11.5.1 Redistributing a Default OSPF Route

Let's return to the earlier topology, which now includes a new link to ISP. As with RIP and EIGRP, the router connected to the Internet is used to propagate a default route to other routers in the OSPF routing domain. This router is sometimes called the edge, entrance or gateway router. However, in OSPF terminology, the router located between an OSPF routing domain and a non-OSPF network is called the Autonomous System Boundary Router (ASBR). In this topology, the Loopback1 (Lo1) represents a link to a non-OSPF network. We will not configure the 172.30.1.1/30 network as part of the OSPF routing process



## 11.5.1 Redistributing the OSPF Default Route

- Topology includes a link to ISP
  - Router connected to ISP
    - Called an autonomous system border router
    - Used to propagate a default route
      - Example of static default route
      - R1(config)#**ip route 0.0.0.0 0.0.0.0 loopback 1**
      - Requires the use of the **default-information originate** command
      - Example of default-information originate command
      - R1(config-router)#**default-information originate**

```
R1 (config) #interface loopback 1
R1 (config-if) #ip add 172.30.1.1 255.255.255.252
R1 (config-if) #exit
R1 (config) #ip route 0.0.0.0 0.0.0.0 loopback 1
R1 (config) #router ospf 1
R1 (config-router) #default-information originate
```

OSPF requires the use of the default-information originate command to advertise the 0.0.0.0/0 static default route to the other routers in the area.



## 11.5.2 Fine Tuning OSPF

### Reference Bandwidth

As you remember, Cisco OSPF cost uses accumulated bandwidth. The bandwidth value of each interface is calculated using  $100,000,000/\text{bandwidth}$ . 100,000,000 or 10 to the 8th is known as the reference bandwidth.

Therefore, 100,000,000 is the default bandwidth referenced when the actual bandwidth is converted into a cost metric.

In order to obtain more accurate cost calculations, it may be necessary to adjust the reference bandwidth value. The reference bandwidth can be modified to accommodate these faster links by using the OSPF command **auto-cost reference-bandwidth**. When this command is necessary, use it on all routers so that the OSPF routing metric remains consistent.

**R1(config-router)#auto-cost reference-bandwidth ?**

**1-4294967 The reference bandwidth in terms of Mbits per second**

## 11.5.2 Fine Tuning OSPF

- Since link speeds are getting faster it may be necessary to change reference bandwidth values
  - Do this using the **auto-cost reference-bandwidth** command
  - Example:
    - **R1(config-router)#auto-cost reference-bandwidth 10000**

```
R1(config-if)#router ospf 1
R1(config-router)#auto-cost reference-bandwidth ?
  <1-4294967> The reference bandwidth in terms of Mbits per second

R1(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
  Please ensure reference bandwidth is consistent across all routers

R2(config-if)#router ospf 1
R2(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
  Please ensure reference bandwidth is consistent across all routers.

R3(config-if)#router ospf 1
R3(config-router)#auto-cost reference-bandwidth 10000
% OSPF: Reference bandwidth is changed.
  Please ensure reference bandwidth is consistent across all routers.
```

## 11.5.2 Fine Tuning OSPF

```
R1#show ip ospf neighbor
```

Neighbor ID	Pri	State	Dead Time	Address	Interface
10.3.3.3	0	FULL/ -	00:00:35	192.168.10.6	Serial0/0/1
10.2.2.2	0	FULL/ -	00:00:36	192.168.10.2	Serial0/0/0

### Modifying OSPF Intervals

The `show ip ospf neighbor` command on R1 verifies that R1 is adjacent to R2 and R3. Notice in the output that the Dead Time is counting down from 40 seconds. By default, this value is refreshed every 10 seconds when R1 receives a Hello from the neighbor.

It may be desirable to change the OSPF timers so that routers will detect network failures in less time. Doing this will increase traffic, but sometimes there is a need for quick convergence that outweighs the extra traffic.

OSPF Hello and Dead intervals can be modified manually using the following interface commands:

```
Router(config-if)#ip ospf hello-interval seconds
```

```
Router(config-if)#ip ospf dead-interval seconds
```

## 11.5.2 Fine Tuning OSPF

- Modifying OSPF timers
  - Reason to modify timers
    - Faster detection of network failures
  - Manually modifying Hello & Dead intervals
    - Router(config-if)#**ip ospf hello-interval seconds**
    - Router(config-if)#**ip ospf dead-interval seconds**
  - Point to be made
    - Hello & Dead intervals must be the same between neighbors

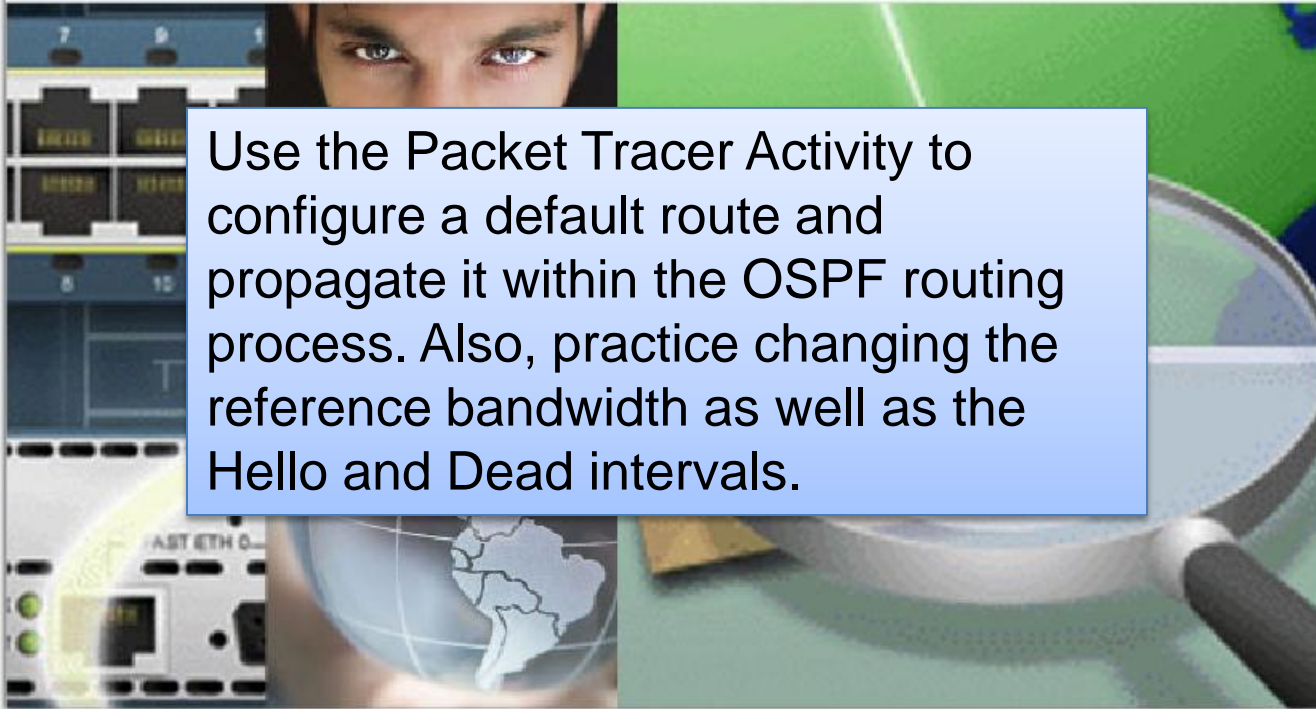
```
R1 (config) #interface serial 0/0/0  
R1 (config-if) #ip ospf hello-interval 5  
R1 (config-if) #ip ospf dead-interval 20  
R1 (config-if) #end
```

## 11.5.2 Fine Tuning OSPF



### Packet Tracer Exploration: Default Routing and Fine-tuning OSPF

Use the Packet Tracer Activity to configure a default route and propagate it within the OSPF routing process. Also, practice changing the reference bandwidth as well as the Hello and Dead intervals.



## 11.6.1 Basic OSPF Configuration Lab



### Hands-on Lab: Basic OSPF Configuration Lab

In this lab activity, there are two separate scenarios. In the first scenario, you will learn how to configure the routing protocol OSPF using the network shown in the Topology Diagram in Scenario A. The segments of the network have been subnetted using VLSM. OSPF is a classless routing protocol that can be used to provide subnet mask information in the routing updates. This will allow VLSM subnet information to be propagated throughout the network.

In the second scenario, you will learn to configure OSPF on a multi-access network. You will also learn to use the OSPF election process to determine the designated router (DR), backup designated router (BDR), and DRother states.

## 11.6.1 Basic OSPF Configuration Lab



### Packet Tracer Exploration: Basic OSPF Configuration Lab

Use this Packet Tracer Activity to repeat a simulation of Lab 11.6.1. Remember, however, that Packet Tracer is not a substitute for a hands-on lab experience with real equipment.

A summary of the instructions is provided within the activity. Use the Lab PDF for more details.



## 11.6.2 Challenge OSPF Configuration Lab



### Hands-on Lab: Challenge OSPF Configuration Lab

In this lab activity, you will be given a network address that must be subnetted using VLSM to complete the addressing of the network shown in the Topology Diagram. A combination OSPF routing and static routing will be required so that hosts on networks that are not directly connected will be able to communicate with each other. OSPF area ID of 0 and process ID of 1 will be used in all OSPF configurations.



## 11.6.2 Challenge OSPF Configuration Lab



### Packet Tracer Exploration: Challenge OSPF Configuration Lab

Use this Packet Tracer Activity to repeat a simulation of Lab 11.6.2. Remember, however, that Packet Tracer is not a substitute for a hands-on lab experience with real equipment.

A summary of the instructions is provided within the activity. Use the Lab PDF for more details.

## 11.6.3 OSPF Troubleshooting Lab



### Hands-on Lab: OSPF Troubleshooting Lab

In this lab, you will begin by loading configuration scripts on each of the routers. These scripts contain errors that will prevent end-to-end communication across the network.

You will need to troubleshoot each router to determine the configuration errors, and then use the appropriate commands to correct the configurations.

When you have corrected all of the configuration errors, all of the hosts on the network should be able to communicate with each other.

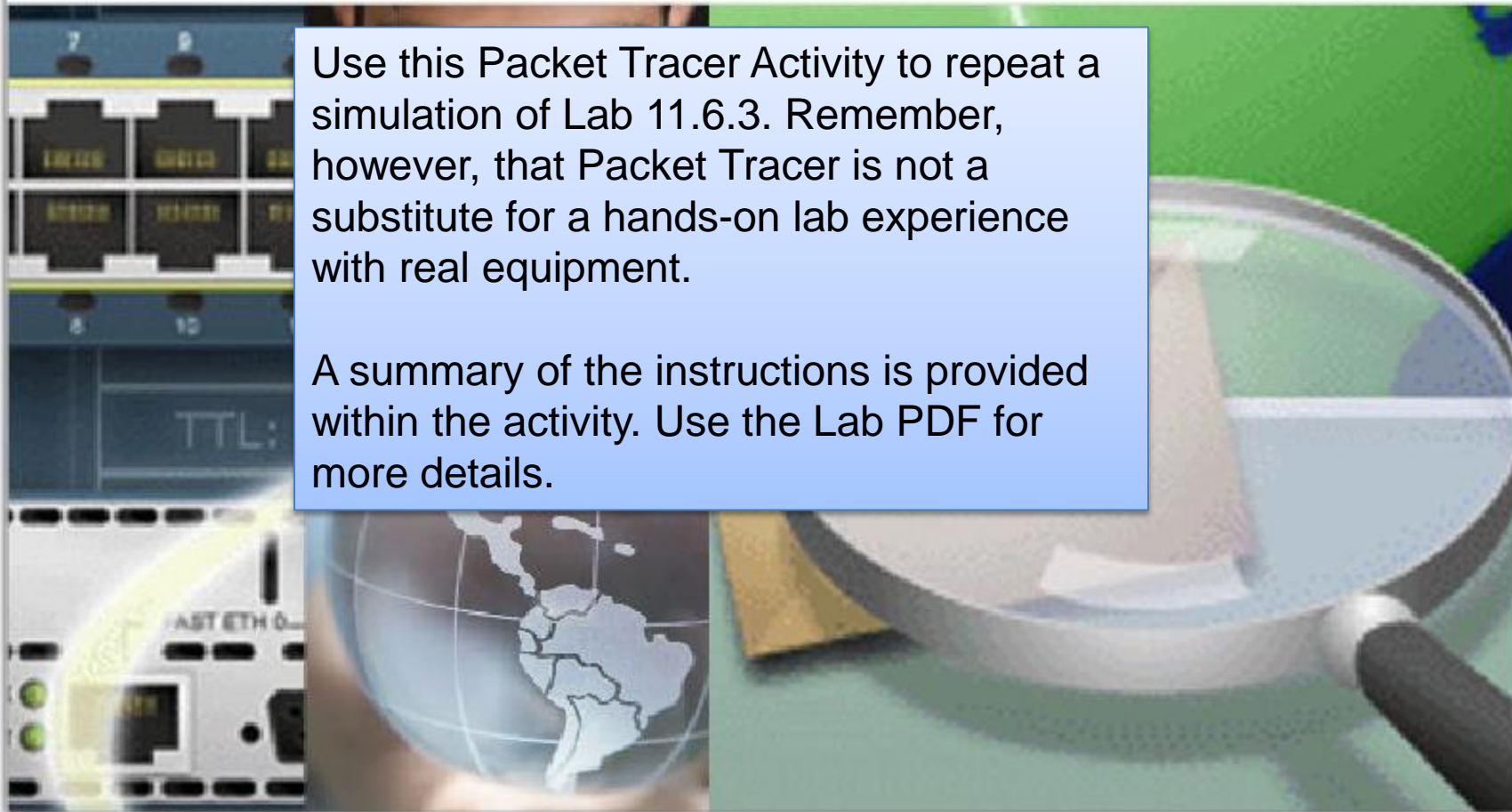
## 11.6.3 Troubleshooting an OSPF Configuration Lab



### Packet Tracer Exploration: OSPF Troubleshooting Lab

Use this Packet Tracer Activity to repeat a simulation of Lab 11.6.3. Remember, however, that Packet Tracer is not a substitute for a hands-on lab experience with real equipment.

A summary of the instructions is provided within the activity. Use the Lab PDF for more details.



## 11.7.1 Summary and Review

- RFC 2328 describes OSPF link state concepts and operations
- OSPF Characteristics
  - A commonly deployed link state routing protocol
  - Employs **DRs** & **BDRs** on multi-access networks
    - DRs & BDRs are elected
    - DR & BDRs are used to transmit and receive LSAs
  - Uses 5 packet types:
    - 1: HELLO**
    - 2: DATABASE DESCRIPTION**
    - 3: LINK STATE REQUEST**
    - 4: LINK STATE UPDATE**
    - 5: LINK STATE ACKNOWLEDGEMENT**

## 11.7.1 Summary and Review

- OSPF Characteristics

- Metric = cost

- Lowest cost = best path

- Configuration

- Enable OSPF on a router using the following command

- R1(config)#**router ospf process-id**

- use the network command to define which interfaces will participate in a given OSPF process

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

## 11.7.1 Summary and Review

- Verifying OSPF configuration
  - Use the following commands
    - show ip protocol
    - show ip route
    - show ip ospf interface
    - show ip ospf neighbor

## 11.7.1 Summary and Review

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector Routing Protocols		Link State Routing Protocols		Path Vector
Classful	<b>RIP</b>	<b>IGRP</b>			<b>EGP</b>
Classless	<b>RIPv2</b>	<b>EIGRP</b>	<b>OSPFv2</b>	<b>IS-IS</b>	<b>BGPv4</b>
IPv6	<b>RIPng</b>	<b>EIGRP for IPv6</b>	<b>OSPFv3</b>	<b>IS-IS for IPv6</b>	<b>BGPv4 for IPv6</b>

In this chapter, you have learned to:

- Describe the background and basic features of OSPF.
- Identify and apply the basic OSPF configuration commands.
- Describe, modify and calculate the metric used by OSPF.
- Describe the Designated Router/Backup Designated Router (DR/BDR) election process in multiaccess networks.
- Employ the **default-information originate** command to configure and propagate a default route in OSPF.

## 11.7.1 Summary and Review



### Packet Tracer Exploration:

#### Ch11 - Packet Tracer Skills Integration Challenge

The Packet Tracer Skills Integration Challenge Activity integrates all the knowledge and skills you acquired in previous chapters of this course and prior courses. Skills related to this chapter's discussion of OSPF are also included.

In this activity, you build a network from the ground up. Starting with an addressing space and network requirements, you must implement a network design that satisfies the specifications. Next, you implement an effective OSPF routing configuration with integrated default routing. Detailed instructions are provided within the activity.





