



Cisco Certified Network Associate
CCNA 640-802
Routing Protocols and Concepts



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DAY 2


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Agenda

- Routing and Packet Forwarding
- Static Routing
- Dynamic Routing Protocol
- Dynamic Routing Protocol
- VLSM and CIDR
- RIPv2
- EIGRP
- OSPF

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ROUTING AND PACKET FORWARDING

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Router as a Computer

- Describe the basic purpose of a router
 - Computers that specialize in sending packets over the data network. They are responsible for interconnecting networks by selecting the best path for a packet to travel and forwarding packets to their destination
- Routers are the network center
 - Routers generally have 2 connections:
 - WAN connection (Connection to ISP)
 - LAN connection

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Router as a Computer

- Routers examine a packet's destination IP address and determine the best path by enlisting the aid of a routing table

```

R1#show ip route
Codes: C - connected, S - static, I - ISDP, O - OSPF, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, P - PBR, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       O1 - OSPF external type 1, O2 - OSPF external type 2, E - EGP
       I - IGP, L1 - L1-LS Level-1, L2 - L2-LS Level-2, Ia - IA-LS
inter area
       * - candidate default, D - per-user static route, s - OSPF
       P - periodic downloaded static route

Gateway of last resort is not set

C 192.168.1.0/24 is directly connected, FastEthernet0/0
C 192.168.2.0/24 is directly connected, Serial0/0/0
S 192.168.3.0/24 is directly connected, Serial0/0
  
```

← Routers use the routing table like a map to discover the best path for a given address.

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Router as a Computer

- Router components and their functions”
 - CPU** - Executes operating system instructions
 - Random access memory (RAM)** - Contains the running copy of configuration file. Stores routing table. RAM contents lost when power is off
 - Read-only memory (ROM)** - Holds diagnostic software used when router is powered up. Stores the router's bootstrap program.
 - Non-volatile RAM (NVRAM)** - Stores startup configuration. This may include IP addresses (Routing protocol, Hostname of router)
 - Flash memory** - Contains the operating system (Cisco IOS)
 - Interfaces** - There exist multiple physical interfaces that are used to connect network. Examples of interface types:
 - Ethernet / fast Ethernet interfaces
 - Serial interfaces
 - Management interfaces

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Router as a Computer

- Router components

Hardware components of a router

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Router as a Computer

- Major phases to the router boot-up process
 - Test router hardware
 - Power-On Self Test (POST)
 - Locate & load Cisco IOS software
 - Locate IOS
 - Load IOS
 - Locate & load startup configuration file or enter setup mode
 - Bootstrap program looks for configuration file

1.	ROM	POST	Perform POST
2.	ROM	Bootstrap	Load Bootstrap
3.	Flash	Cisco Internetwork Operating System	Locate and load Operating system
4.	TFTP Server		
5.	NVRAM		
6.	TFTP Server	Configuration	Locate and load configuration file or enter setup mode
7.	Console		

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Router as a Computer

- Verify the router boot-up process:
 - The show version command is used to view information about the router during the bootup process. Information includes:
 - Platform model number
 - Image name & IOS version
 - Bootstrap version stored in ROM
 - Image file name & where it was loaded from
 - Number & type of interfaces
 - Amount of NVRAM
 - Amount of flash
 - Configuration register

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Router as a Computer

How a Router Boots up

```

Router#show version
Cisco Internetwork Operating System Software
IOS (M) 12.0(0) Software (C26004M), Version 12.0(0)M, RELEASE SOFTWARE (FC1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2005 by Cisco Systems, Inc.
Compiled Wed 27-Apr-04 19:01 by mswang
Image text-base: 0x8000800C, data-base: 0x80A1FECC

ROM: System Bootstrap, Version 1.2(1)91Z, RELEASE SOFTWARE (fc1)
Copyright (c) 2000 by Cisco Systems, Inc.
ROM: C2600 Software (C26004M), Version 12.0(28), RELEASE SOFTWARE (fc5)
System returned to ROM by reload
System image file is "flash:c2600-i-mz:123-28.bin"

Cisco 2601 (MPC-850) processor (revision 0x200) with 16381856K bytes of memory

Processor board ID JAD06190612 (4292497450)
M890 processor, part number 0, mask 49
Bringing software...
X.25 software, Version 3.0.0.

2 FastEthernet/IEEE 802.3 interface(s)
2 Low-speed serial(sync/async) network interface(s)

52K bytes of non-volatile configuration memory.
16334K bytes of processor board System flash (Read/Write)


Configuration register is 0x2102
Router#
  
```

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Router as a Computer

- Router Interface is a physical connector that enables a router to send or receive packets
- Each interface connects to a separate network
- Consist of socket or jack found on the outside of a router
- Types of router interfaces:
 - Ethernet
 - Fastethernet
 - Serial
 - DSL
 - ISDN
 - Cable

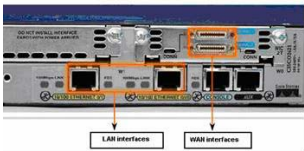
Each individual interface connects to a different network. Thus each interface has an IP address/mask from that network.



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Router as a Computer

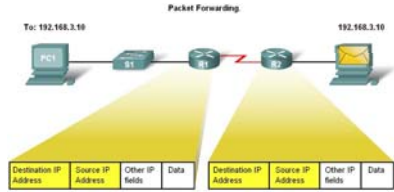
- Two major groups of Router Interfaces
 - LAN Interfaces:
 - Are used to connect router to LAN network
 - Has a layer 2 MAC address
 - Can be assigned a Layer 3 IP address
 - Usually consist of an RJ-45 jack
 - WAN Interfaces
 - Are used to connect routers to external networks that interconnect LANs.
 - Depending on the WAN technology, a layer 2 address may be used.
 - Uses a layer 3 IP address



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Router as a Computer

- Routers and the Network Layer
 - Routers use destination IP address to forward packets
 - The path a packet takes is determined after a router consults information in the routing table.
 - After router determines the best path
 - Packet is encapsulated into a frame
 - Frame is then placed on network medium in form of Bits

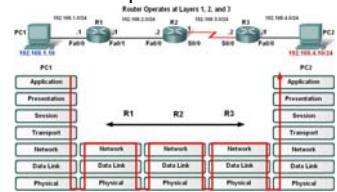


Each router examines the Destination IP address to correctly forward the packet.

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Router as a Computer

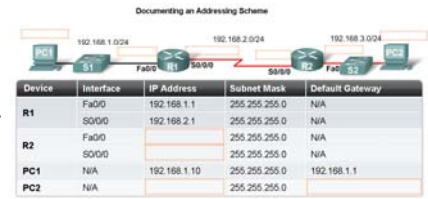
- Routers Operate at Layers 1, 2 & 3
 - Router receives a stream of encoded bits
 - Bits are decoded and passed to layer 2
 - Router de-encapsulates the frame
 - Remaining packet passed up to layer 3
 - Routing decision made at this layer by examining destination IP address
 - Packet is then re-encapsulated & sent out outbound interface



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Configure Devices and Apply Addresses

- Implementing Basic Addressing Schemes
 - When designing a new network or mapping an existing network you must provide the following information in the form of a document:
 - Topology drawing that illustrates physical connectivity
 - Address table that provides the following information:
 - Device name
 - Interfaces used
 - IP addresses
 - Default gateway



Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	192.168.1.1	255.255.255.0	N/A
	S0/0/0	192.168.2.1	255.255.255.0	N/A
R2	Fa0/0	192.168.3.1	255.255.255.0	N/A
	S0/0/0	192.168.2.2	255.255.255.0	N/A
PC1	N/A	192.168.1.10	255.255.255.0	192.168.1.1
PC2	N/A	192.168.3.10	255.255.255.0	N/A

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Configure Devices and Apply Addresses

- Basic Router Configuration
- A basic router configuration should contain the following:
 - Router name - Host name should be unique
 - Banner - At a minimum, banner should warn against unauthorized use
 - Passwords - Use strong passwords
 - Interface configurations - Specify interface type, IP address and subnet mask. Describe purpose of interface. Issue no shutdown command. If DCE serial interface issue clock rate command.
- After entering in the basic configuration the following tasks should be completed
 - Verify basic configuration and router operations.
 - Save the changes on a router

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Configure Devices and Apply Addresses

Basic router configuration command syntax

Naming the router	Router(config)# hostname name
Setting Passwords	Router(config)# enable secret password
	Router(config)# line console 0
	Router(config-line)# password password
	Router(config-line)# login
	Router(config)# line vty 0 4
	Router(config-line)# password password
	Router(config-line)# login
Configuring an interface	Router(config)# interface type number
	Router(config-if)# ip address address mask
	Router(config-if)# description description
	Router(config-if)# no shutdown
Configuring a message-of-the-day banner	Router(config)# banner motd # message #
Saving changes on a router	Router# copy running-config startup-config
Examining the output of show commands	Router# show running-config
	Router# show ip route
	Router# ip interface brief
	Router# interfaces

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Configure Devices and Apply Addresses

- Verify Basic Router Configuration
 - Issue the *show running-config* command
 - Save the basic router configuration by Issuing the *copy running-config startup-config* command
 - Additional commands that will enable you to further verify router configuration are:
 - *Show running-config* - Displays configuration currently in RAM
 - *Show startup-config* - Displays configuration file NVRAM
 - *Show IP route* - Displays routing table
 - *Show interfaces* - Displays all interface configurations
 - *Show IP int brief* - Displays abbreviated interface configuration information

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Routing Table Structure

- Routing Table is stored in ram and contains information about:
 - **Directly connected networks** - this occurs when a device is connected to another router interface
 - **Remotely connected networks** - this is a network that is not directly connected to a particular router
 - **Detailed information** about the networks include source of information, network address & subnet mask, and Ip address of next-hop router
- Show ip route* command is used to view a routing table

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Routing Table Structure

- Adding a connected network to the routing table
 - Router interfaces
 - Each router interface is a member of a **different** network
 - Activated using the *no shutdown* command
 - In order for static and dynamic routes to exist in routing table you must have **directly connected** networks

Connected and Static Routes

Static routes

```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, D - OSPF
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, FastEthernet0/0
C    192.168.2.0/24 is directly connected, Serial0/0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
  
```

Routing Table Structure

- Static routes in the routing table
 - Includes: network address and subnet mask and IP address of next hop router or exit interface
 - Denoted with the code **S** in the routing table
 - Routing tables must contain directly connected networks used to connect remote networks before static or dynamic routing can be used
- When to use static routes
 - When network only consists of a few routers
 - Network is connected to internet only through one ISP
 - Hub & spoke topology is used on a large network

Routing Table Structure

- Connected and Static routes

Connected and Static Routes

Static routes

```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.168.1.0/24 is directly connected, FastEthernet0/0
C    192.168.2.0/24 is directly connected, Serial0/0/0
S    192.168.3.0/24 [1/0] via 192.168.2.2
  
```

Routing Table Structure

- Dynamic routing protocols
 - Used to add remote networks to a routing table
 - Are used to discover networks
 - Are used to update and maintain routing tables
- Automatic network discovery
 - Routers are able discover new networks by sharing routing table information

Routing Table Structure

- Maintaining routing tables
 - Dynamic routing protocols are used to share routing information with other router & to maintain and up date their own routing table.
- IP routing protocols. Example of routing protocols include:
 - RIP
 - IGRP
 - EIGRP
 - OSPF

```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, E - EIGRP, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       N3 - OSPF external type 1, N4 - OSPF external type 2, O - BGP
       I - IS-IS level-1, IS - IS-IS level-1/2, IA - IS-IS inter
       area
       * - candidate default, U - per-user static route, s - OGM
       P - periodic downloaded static route
Gateway of last resort is not set
C 192.168.1.0/24 is directly connected, FastEthernet0/0
C 192.168.2.0/24 is directly connected, Serial0/0/0
I 192.168.1.0/24 [110/1] via 192.168.2.1
I 192.168.4.0/24 [110/1] via 192.168.2.2, Serial0/0/0
  
```

Router Paths and Packet Switching

- Path determination is a process used by a router to pick the best path to a destination
- One of 3 path determinations results from searching for the best path
 - Directly connected network
 - Remote network
 - No route determined

Router determine the best path to the destination

Router Paths and Packet Switching

- As a packet travels from one networking device to another
 - The Source and Destination IP addresses NEVER change
 - The Source & Destination MAC addresses CHANGE as packet is forwarded from one router to the next.
 - TTL field decrement by one until a value of zero is reached at which point router discards packet (prevents packets from endlessly traversing the network)

Layer	R1	R2	R3	PC1	PC2
Application	Application	Application	Application	Application	Application
Presentation	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data
Session	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data
Transport	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data	Source IP, Destination IP, Data
Network	Network	Network	Network	Network	Network
Data Link	Data Link	Data Link	Data Link	Data Link	Data Link
Physical	Physical	Physical	Physical	Physical	Physical

Router Paths and Packet Switching

- Path determination and switching function details. PC1 Wants to send something to PC 2 here is part of what happens

A Day in the Life of a Packet: Step 1

PC1's ARP Cache for R1

IP Address	MAC Address
192.168.1.0	08-10

Layer 2 Data Link Frame	Packet's Layer 3 data
Dest Mac: 08-10, Source Mac: 0A-10, Type: 800	Dest. IP: 192.168.4.10, Source IP: 192.168.1.10, IP Fields: Data, Trailer

Router Paths and Packet Switching
A day in a life of a packet: Step 2

Layer 2 Data Link Frame

Dest Mac	Type
0B-31	800

Packet's Layer 3 data

Dest IP	Source IP	IP Fields	Data	Trailer
192.168.4.10	192.168.1.10			

R1's ARP Cache

IP Address	MAC Address
192.168.2.2	0B-31

R1's Routing Table

Network	Hops	Next Hop IP	Exit Interface
192.168.1.0/24	0	Dir. Connect	Fa0/0
192.168.2.0/24	0	Dir. Connect	Fa0/1
192.168.3.0/24	1	192.168.2.2	Fa0/1
192.168.4.0/24	2	192.168.2.2	Fa0/1

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STATIC ROUTING

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General Role of the Router

- Functions of a Router
 - Best Path Selections
 - Forwarding packets to destination
- Introducing the Topology
 - 3 1800 series routers connected via WAN links
 - Each router connected to a LAN represented by a switch and a PC

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General Role of the Router

- Connections of a Router for WAN
 - A router has a DB-60 port that can support 5 different cabling standards
- Connections of a Router for Ethernet
 - 2 types of connectors can be used: Straight through and Cross-over
 - Straight through used to connect:
 - Switch-to-Router, Switch-to-PC, Router-to-Server, Hub-to-PC, Hub-to-Server
 - Cross-over used to connect:
 - Switch-to-Switch, PC-to-PC, Switch-to-Hub, Hub-to-Hub, Router-to-Router

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Interfaces

- Examining Router Interfaces
 - Show IP router command – used to view routing table
 - Show Interfaces command – used to show status of an interface
 - Show IP Interface brief command – used to show a portion of the interface information
 - Show running-config command – used to show configuration file in RAM

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Interfaces

- Configuring an Ethernet interface
 - By default all serial and Ethernet interfaces are down
 - To enable an interface use the No Shutdown command

```

R1#show ip route
Codes: C - connected, S - static, I - IGRP, B - BGP, M - mobile, W - NBP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2, S - SGP
i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
* - candidate default, U - per-user static route, o - ODR
P - periodic downloaded static route

Gateway of last resort is not set

R1#

```

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Interfaces

- Verifying Ethernet interface
 - Show interfaces for fastEthernet 0/0 – command used to show
 - Show ip interface brief
 - Show running-config
- Ethernet interfaces participate in ARP

Verifying MAC Addresses on Ethernet Interfaces

```

R1#show interfaces fastethernet 0/0
FastEthernet0/0 is up, line protocol is up
  Hardware is AmdFE, address is 000c.3010.9260 (bia 000c.3010.9260)
  Internet address is 172.16.3.1/24
  <output omitted>
R1#

```

Ethernet interfaces have MAC addresses.

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Interfaces

- Configuring a Serial interface
 - Enter interface configuration mode
 - Enter in the ip address and subnet mask
 - Enter in the no shutdown command
- Example:
 - R1(config)#interface serial 0/0
 - R1(config-if)#ip address 172.16.2.1 255.255.255.0
 - R1(config-if)#no shutdown

Serial interface with down and down

```

R1#show interfaces serial 0/0/0
Serial0/0/0 is administratively down, line protocol is down
  Hardware is PowerQUICC Serial
  Internet address is 172.16.2.1/24
  MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
  <output omitted>

```

Serial interface is down and down even though it has an IP address and was enabled with no shutdown command.

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Interfaces

- **Examining Router Interfaces**
 - Physically connecting a WAN Interface.
 - A WAN Physical Layer connection has sides:
 - Data Circuit-terminating Equipment (DCE) – This is the service provider. CSU/DSU is a DCE device.
 - Data Terminal Equipment (DTE) – Typically the router is the DTE device.

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Interfaces

- **Configuring serial links in a lab environment**
 - One side of a serial connection must be considered a DCE
 - This requires placing a clocking signal – use the clock rate command.
 - Example:
 - R1(config)#interface serial 0/0
 - R1(config-if)#clockrate 64000
 - Serial Interfaces require a clock signal to control the timing of the communications.

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Routing Table and CDP Protocol

- **Purpose of the debug ip routing command**
 - Allows you to view changes that the router performs when adding or removing routes
 - Example:
 - R2#debug ip routing
 - IP routing debugging is on

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Routing Table and CDP Protocol

- **To configure an Ethernet interface**
 - Example:
 - R2(config)#interface fastethernet 0/0
 - R2(config-if)#ip address 172.16.1.1 255.255.255.0
 - R2(config-if)#no shutdown

```

[show ip route]
Codes: C - connected, S - static, I - ISM, B - BGP, M - mobile, W - NBP
O - OSPF, OI - OSPF interarea, D - EIGRP, EX - EIGRP external
R1 - RIPv1, R2 - RIPv2, R3 - RIPv3, R4 - RIPv4, R5 - RIPv5, R6 - RIPv6
E - EIGRP summary, L1 - L1, L2 - L2, L3 - L3, L4 - L4, L5 - L5
I - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, L3 - IS-IS level-3
* - candidate default, U - per-user static route, s - SPM
P - periodic downloaded static route

Gateway of last resort is not set

R1#
  
```

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Routing Table and CDP Protocol

- When a router only has its interfaces configured & no other routing protocols are configured then:
 - The routing table contains only the directly connected networks
 - Only devices on the directly connected networks are reachable

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Routing Table and CDP Protocol

Summary of interface status with show ip interface brief

```

show ip interface brief
Interface IP-Address MTU Method Status Protocol
FastEthernet0/0 unassigned 1500 manual administratively down down
Serial0/0/0 unassigned 1500 manual administratively down down
Serial0/0/1 unassigned 1500 manual administratively down down
  
```

Routing table has no routes

```

show ip route
Codes: C - connected, S - static, I - ISMP, M - mobile, W - wildcard, X - XDP
S - SPOF, S1 - SPOF external, S2 - SPOF IA - SPOF inter area
R1 - OSPF external type 1, R2 - OSPF external type 2, N - NBP
I - IS-IS, IS1 - IS-IS level-1, IS2 - IS-IS level-2, IA - IS-IS inter area
* - candidate default, U - per-user static route, o - ODR
E - EIGRP, EX - EIGRP external, R - RIP, O - OSPF, H - HSRP, B - BGP
D - DSDM, DS - DSDM external, D2 - DSDM IA - DSDM inter area
  
```

```

R1(config)#interface serial 0/0/1
R1(config-if)#ip address 192.168.1.2 255.255.255.0
R1(config-if)#clock rate 40000
R1(config-if)#no shutdown

R3(config)#interface fastethernet 0/0
R3(config-if)#ip address 192.168.2.1 255.255.255.0
R3(config-if)#no shutdown
R3(config-if)#interface serial 0/0/1
R3(config-if)#ip address 192.168.1.1 255.255.255.0
R3(config-if)#no shutdown
  
```

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Routing Table and CDP Protocol

- Checking each route in turn
 - The ping command is used to check end to end connectivity

```

R1#ping 172.16.3.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 172.16.3.1,
timeout is 2 seconds:
.....
Success rate is 0 percent (0/5)
RT#
  
```

```

R1#show ip route
Route output omitted
172.16.0.0/24 is subnetted, 2 subnets
C 172.16.1.0 is directly connected, FastEthernet0/0
C 172.16.2.0 is directly connected, Serial0/0
C 192.168.1.0/24 is directly connected, Serial0/1
RT#
  
```

Destination IP Address	172.16.3.1	0101100.00010000.00000001.00000001	
First route in routing table	172.16.1.0	10101100.00010000.00000001.00000000	No Match
Destination IP Address	172.16.3.1	10101100.00010000.00000001.00000001	
Second route in routing table	172.16.1.0	10101100.00010000.00000001.00000000	No Match
Destination IP Address	172.16.3.1	10101100.00010000.00000001.00000001	
Third route in routing table	172.16.1.0	10101100.00010000.00000001.00000000	No Match

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Routing Table and CDP Protocol

- Purpose of CDP
 - A layer 2 cisco proprietary tool used to gather information about other directly connected Cisco devices.
- Concept of neighbors
 - 2 types of neighbors
 - Layer 3 neighbors
 - Layer 2 neighbors

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Routing Table and CDP Protocol

- CDP show commands
 - Show cdp neighbors command
 - Displays the following information:
 - Neighbor device ID
 - Local interface
 - Holdtime value, in seconds
 - Neighbor device capability code
 - Neighbor hardware platform
 - Neighbor remote port ID
 - Show cdp neighbors detail command
 - Useful in determining if an IP address configuration error

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Routing Table and CDP Protocol

- Disabling CDP
 - To disable CDP globally use the following command
Router(config)#no cdp run

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Static Routes with Exit Interfaces

- Purpose of a static route
 - A manually configured route used when routing from a network to a stub network

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Static Routes with Exit Interfaces

- IP route command
 - To configure a static route use the following command: ip route
 - Example:
 - Router(config)# ip route network-address subnet-mask {ip-address | exit-interface }

Parameter	Description
network-address	Destination network address of the remote network to be added to the routing table.
subnet-mask	Subnet mask of the remote network to be added to the routing table. The subnet mask can be modified to summarize a group of networks.
ip-address	Commonly referred to as the next-hop router's IP address.
exit-interface	Outgoing interface that is used to forward packets to the destination network.

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Static Routes with Exit Interfaces

- Dissecting static route syntax
 - ip route - Static route command
 - 172.16.1.0 – Destination network address
 - 255.255.255.0 - Subnet mask of destination network
 - 172.16.2.2 - Serial 0/0/0 interface IP address on R2, which is the "next-hop" to this network

R1 static route to R2's LAN

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Static Routes with Exit Interfaces

- Configuring routes to 2 or more remote networks
 - Use the following commands for R1
 - R1(config)#ip route 192.168.1.0 255.255.255.0 172.16.2.2
 - R1(config)#ip route 192.168.2.0 255.255.255.0 172.16.2.2

R1 static route to R2's LAN

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Static Routes with Exit Interfaces

- Configuring a Static route with an Exit Interface
 - Static routes configured with an exit interface are more efficient because the routing
 - The routing table can resolve the exit interface in a single search instead of 2 searches
 - Example of syntax require to configure a static route with an exit interface

R1 routes depend on exit interface

```

R1#debug ip routing
IP routing debugging is on
R1#config t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#int s0/0/0
R1(config-if)#shutdown
R1(config-if)#no shutdown
R1(config-if)#exit
R1#sh ip route
ip route 0.0.0.0 0.0.0.0 Serial1/0/0
R1#
R1#show ip route
output omitted
Four routes are removed.
Only one route is left in the table.
  
```

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Static Routes with Exit Interfaces

- Modifying Static routes
 - Existing static routes cannot be modified. The old static route must be deleted by placing **no** in front of the **ip route**
 - Example:
 - no ip route 192.168.2.0 255.255.255.0 172.16.2.2
 - A new static route must be rewritten in the configuration

```

R1(config)#no ip route 172.16.1.0 255.255.255.0 172.16.2.2
R1(config)#ip route 172.16.1.0 255.255.255.0 serial 0/0/0
R1(config)#no ip route 192.168.1.0 255.255.255.0 172.16.2.2
R1(config)#ip route 192.168.1.0 255.255.255.0 serial 0/0/0

R2(config)#no ip route 172.16.3.0 255.255.255.0 172.16.2.1
R2(config)#ip route 172.16.3.0 255.255.255.0 serial 0/0/0
R2(config)#no ip route 192.168.2.0 255.255.255.0 192.168.1.1
R2(config)#ip route 192.168.2.0 255.255.255.0 serial 0/0/1

R3(config)#no ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)#ip route 172.16.1.0 255.255.255.0 serial 0/0/1
R3(config)#no ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)#ip route 172.16.2.0 255.255.255.0 serial 0/0/1
R3(config)#no ip route 172.16.3.0 255.255.255.0 192.168.1.2
R3(config)#ip route 172.16.3.0 255.255.255.0 serial 0/0/1
  
```

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Static Routes with Exit Interfaces

- **Verifying the Static Route Configuration**
 - Use the following commands
 - Step 1 **show running-config**
 - Step 2 **verify** static route has been entered correctly
 - Step 3 **show ip route**
 - Step 4 **verify** route was configured in routing table
 - Step 5 issue **ping** command to **verify** packets can reach destination and that Return path is working

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Summary and Default Route

- **Summarizing routes** **reduces** the size of the routing table.
- **Route summarization** is the process of combining a number of static routes into a single static route.

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Summary and Default Route

- **Configuring a summary route**
 - Step 1: Delete the current static route
 - Step 2: Configure the summary static route
 - Step 3: Verify the new static route

```

Router# show ip route
output omitted

Gateway of last resort is not set

172.16.0.0/24 is subnetted, 1 subnets
R       172.16.0.0 is directly connected, Serial0/0/1
R       172.16.2.0 is directly connected, Serial0/0/2
R       192.168.1.0/24 is directly connected, FastEthernet0/0
R       192.168.2.0/24 is directly connected, FastEthernet0/0

Router# show ip route
output omitted

Gateway of last resort is not set

172.16.0.0/22 is subnetted, 1 subnets
R       172.16.0.0 is directly connected, Serial0/0/1
R       192.168.1.0/24 is directly connected, Serial0/0/2
R       192.168.2.0/24 is directly connected, FastEthernet0/0
  
```

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Summary and Default Route

- **Default Static Route**
 - This is a route that will match all packets. Stub routers that have a number of static routes all exiting the same interface are good candidates for a default route.
 - Like route summarization this will help reduce the size of the routing table
- **Configuring a default static route**
 - Similar to configuring a static route. Except that **destination IP address and subnet mask are all zeros**
 - Example:
 - Router(config)#ip route 0.0.0.0 0.0.0.0 [exit-interface | ip-address]

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Static Routes and Packet Forwarding

- Packet forwarding with static routes.
- Router 1
 - Packet arrives on R1's FastEthernet 0/0 interface
 - R1 does not have a route to the destination network, 192.168.2.0/24
 - R1 uses the default static route.

```

R1#show ip route
<output omitted>
 172.16.0.0/24 is subnetted, 2 subnets
 C 172.16.2.0 is directly connected, Serial0/0
 C 172.16.3.0 is directly connected, FastEthernet0/0
 S* 0.0.0.0/0 is directly connected, Serial0/0
  
```

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Static Routes and Packet Forwarding

- Packet forwarding with static routes.
- Router 2
 - The packet arrives on the Serial 0/0/0 interface on R2.
 - R2 has a static route to 192.168.2.0/24 out Serial0/0/1.

```

R2#show ip route
<output omitted>
 172.16.0.0/24 is subnetted, 3 subnets
 C 172.16.1.0 is directly connected, FastEthernet0/0
 C 172.16.2.0 is directly connected, Serial0/0
 S 172.16.2.0 is directly connected, Serial0/0
 C 192.168.1.0/24 is directly connected, Serial0/1
 S 192.168.2.0/24 is directly connected, Serial0/1
  
```

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Static Routes and Packet Forwarding

- Packet forwarding with static routes.
- Router 3
 - The packet arrives on the Serial0/0/1 interface on R3.
 - R3 has a connected route to 192.168.2.0/24 out FastEthernet 0/1.

```

R3#show ip route
<output omitted>
 172.16.0.0/22 is subnetted, 1 subnets
 S 172.16.0.0 is directly connected, Serial0/1
 C 192.168.1.0/24 is directly connected, Serial0/1
 C 192.168.2.0/24 is directly connected, FastEthernet0/1
  
```

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DYNAMIC ROUTING PROTOCOL

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Dynamic Routing Protocols

- Function(s) of Dynamic Routing Protocols:
 - Dynamically share information between routers.
 - Automatically update routing table when topology changes.
 - Determine best path to a destination.

Routers Dynamically Pass Updates

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Dynamic Routing Protocols

- The **purpose of a dynamic routing protocol** is to:
 - Discover 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

Routing Protocol Operation

Routing protocols are used to exchange routing information between the routers.

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Classifying Routing Protocols

- Dynamic routing protocols are grouped according to characteristics. Examples include:
 - RIP
 - IGRP
 - EIGRP
 - OSPF
 - IS-IS
 - BGP

Drag and drop each protocol into the correct category

- RIPv1
- IS-IS
- IGRP
- BGP
- OSPF
- EIGRP
- RIPv2

- Autonomous System is a group of routers under the control of a single authority.

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Classifying Routing Protocols

- Classful routing protocols**
 - Do NOT send subnet mask in routing updates
- Classless routing protocols**
 - Do send subnet mask in routing updates.

Classful vs. Classless Routing

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Routing Protocols Metrics

- The Metric Field in the Routing Table
- Metric** used for each routing protocol
 - RIP - hop count
 - IGRP & EIGRP - Bandwidth (used by default), Delay (used by default), Load, Reliability
 - IS-IS & OSPF – Cost, Bandwidth (Cisco's implementation)

Metric in the Routing Table

```

show ip route
<output omitted>
Gateway of last resort is not set
R 192.168.1.0/24 [120/1] via 192.168.2.1, 00:00:24, Serial0/0
C 192.168.2.0/24 is directly connected, Serial0/0
C 192.168.3.0/24 is directly connected, Vlan100/0/0
C 192.168.4.0/24 is directly connected, Serial0/1
R 192.168.5.0/24 [120/1] via 192.168.4.1, 00:00:24, Serial0/1
R 192.168.6.0/24 [120/1] via 192.168.2.1, 00:00:24, Serial0/0
[120/1] via 192.168.4.1, 00:00:24, Serial0/1
R 192.168.7.0/24 [120/1] via 192.168.4.1, 00:00:24, Serial0/1
R 192.168.8.0/24 [120/2] via 192.168.4.1, 00:00:24, Serial0/1

R is 2 hops from R2 to 192.168.8.0/24
  
```

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Routing Protocols Metrics

- Load balancing**
 - This is the ability of a router to distribute packets among multiple same cost paths

Load Balancing Across Equal Cost Paths

```

show ip route
<output omitted>
R 192.168.4.0/24 [120/2] via 192.168.2.1, 00:00:24, Serial0/0/0
[120/2] via 192.168.4.1, 00:00:24, Serial0/0/1
  
```

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Administrative Distance of a Route

- Dynamic Routing Protocols**

Default Administrative Distances

Route source	Default AD
Connected interface	0
Static	1
EIGRP summary route	5
eBGP	20
EIGRP (Internal)	90
IGRP	100
OSPF	110
IS - IS	115
RIP	120
EIGRP (External)	170
IBGP	200
Unknown	255

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VLSM AND CIDR

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Classful and Classless IP Addressing

- Classes of IP addresses are identified by the decimal number of the 1st octet
 - Class A** address begin with a **0** bit
 - Range of class A addresses = 0.0.0.0 to 127.255.255.255
 - Class B** address begin with a **1** bit and a **0** bit
 - Range of class B addresses = 128.0.0.0 to 191.255.255.255
 - Class C** addresses begin with **two 1** bits & a **0** bit
 - Range of class C addresses = 192.0.0.0 to 223.255.255.255.

Class	High Order Bits	Start	End
Class A	0	0.0.0.0	127.255.255.255
Class B	10	128.0.0.0	191.255.255.255
Class C	110	192.0.0.0	223.255.255.255
Multicast	1110	224.0.0.0	239.255.255.255
Experimental	1111	240.0.0.0	255.255.255.255

Classful and Classless IP Addressing

- The IPv4 Classful Addressing Structure (RFC 790)
 - An IP address has 2 parts:
 - The **network** portion
 - Found on the **left** side of an IP address
 - The **host** portion
 - Found on the **right** side of an IP address

Classful and Classless IP Addressing

Subnet Mask based on Class

	1st Octet	2st Octet	3st Octet	4st Octet	Subnet Mask
Class A	Network	Host	Host	Host	255.0.0.0 or /8
Class B	Network	Network	Host	Host	255.255.0.0 or /16
Class C	Network	Network	Network	Host	255.255.255.0 or /24

Number of Networks and Hosts per Network for Each Class

Address class	First Octet Range	Number of Possible Networks	Number of Host per Networks
Class A	0 to 127	128 (2 are reserved)	16,777,214
Class B	128 to 191	16,348	65,534
Class C	192 to 223	2,097,152	254

Classful and Classless IP Addressing

- Classful Routing Updates
 - Recall that **classful routing protocols** (i.e. RIPv1) **do not send subnet masks** in their routing updates
 - The reason is that the Subnet mask is directly related to the network address

Classful and Classless IP Addressing

- Classless Inter-domain Routing (CIDR – RFC 1517)
 - Advantage of CIDR :
 - More efficient use of IPv4 address space
 - Route summarization
 - Requires subnet mask to be included in routing update because address class is meaningless
 - Recall purpose of a subnet mask:
 - To determine the network and host portion of an IP address

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Classful and Classless IP Addressing

- Classless IP Addressing
- CIDR & Route Summarization
 - Variable Length Subnet Masking (VLSM)
 - Allows a subnet to be further sub-netted according to individual needs
 - Prefix Aggregation a.k.a. Route Summarization
 - CIDR allows for routes to be summarized as a single route

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Classful and Classless IP Addressing

- Classless Routing Protocol
- Characteristics of classless routing protocols:
 - Routing updates include the subnet mask
 - Supports VLSM
- Supports Route Summarization

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VLSM

- Classful routing
 - only allows for one subnet mask for all networks
- VLSM & classless routing
 - This is the process of subnetting a subnet
 - More than one subnet mask can be used
 - More efficient use of IP addresses as compared to classful IP addressing

In this example, 10.3.0.0/16 has been subnetted using the /28 mask and 10.4.0.0/16 has been subnetted using the /20 mask.

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VLSM

- **VLSM** – the process of **sub-netting a subnet** to fit your needs

-Example:

Subnet 10.1.0.0/16, 8 more bits are borrowed again, to create 256 subnets with a /24 mask.

-Mask allows for 254 host addresses per subnet

-Subnets range from:
10.1.0.0 / 24 to
10.1.255.0 / 24

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Classless Inter-Domain Routing (CIDR)

- Route summarization done by CIDR

- Routes are summarized with masks that are **less than** that of the **default classful mask**

-Example:

172.16.0.0 / 13 is the **summarized route** for the 172.16.0.0 / 16 to 172.23.0.0 / 16 classful networks

Route summarization

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RIPV2

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Introduction

- Chapter focus

- Difference between RIPv1 & RIPv2
 - RIPv1
 - A classful distance vector routing protocol
 - Does not support discontinuous subnets
 - Does not support VLSM
 - Does not send subnet mask in routing update
 - Routing updates are broadcast
 - RIPv2
 - A classless distance vector routing protocol that is an enhancement of RIPv1's features.
 - Next hop address is included in updates
 - Routing updates are multicast
 - The use of authentication is an option

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RIPv1 Limitations

- Lab Topology
- Scenario:
 - 3 router set up
 - Topology is discontinuous
 - There exists a static summary route
 - Static route information can be injected into routing table updates using redistribution.
 - Routers 1 & 3 contain VLSM networks

```

192.168.0.0/24
192.168.1.0/24
192.168.2.0/24
Summary Static Route to 192.168.0/16
  
```

```

R1 (config-router) rip
R1 (config-router) version 1
R1 (config-router) network 172.30.1.0/24
R1 (config-router) network 172.30.2.0/24
R1 (config-router) exit

R2 (config-router) rip
R2 (config-router) version 1
R2 (config-router) network 209.165.200.228/30
R2 (config-router) network 209.165.200.232/30
R2 (config-router) exit

R3 (config-router) rip
R3 (config-router) version 1
R3 (config-router) network 172.30.100.0/24
R3 (config-router) network 172.30.110.0/24
R3 (config-router) network 172.30.200.16/28
R3 (config-router) exit
  
```

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Configuring RIPv2

- Configuring RIPv2 on a Cisco router
 - Requires using the **version 2** command
 - RIPv2 ignores RIPv1 updates
- To verify RIPv2 is configured use the **show ip protocols** command

```

192.168.0.0/24
192.168.1.0/24
192.168.2.0/24
Summary Static Route to 192.168.0/16
  
```

```

R1 (config-router) rip
R1 (config-router) version 2
R1 (config-router) network 172.30.1.0/24
R1 (config-router) network 172.30.2.0/24
R1 (config-router) exit

R2 (config-router) rip
R2 (config-router) version 2
R2 (config-router) network 209.165.200.228/30
R2 (config-router) network 209.165.200.232/30
R2 (config-router) exit

R3 (config-router) rip
R3 (config-router) version 2
R3 (config-router) network 172.30.100.0/24
R3 (config-router) network 172.30.110.0/24
R3 (config-router) network 172.30.200.16/28
R3 (config-router) exit
  
```

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Configuring RIPv2

- Auto-Summary & RIPv2
- RIPv2 will automatically summarize routes at major network boundaries and can also summarize routes with a subnet mask that is smaller than the classful subnet mask

```

192.168.0.0/24
192.168.1.0/24
192.168.2.0/24
Summary Static Route to 192.168.0/16
  
```

```

R1 (config-router) rip
R1 (config-router) version 2
R1 (config-router) auto-summary
R1 (config-router) network 172.30.1.0/24
R1 (config-router) network 172.30.2.0/24
R1 (config-router) exit

R2 (config-router) rip
R2 (config-router) version 2
R2 (config-router) auto-summary
R2 (config-router) network 209.165.200.228/30
R2 (config-router) network 209.165.200.232/30
R2 (config-router) exit

R3 (config-router) rip
R3 (config-router) version 2
R3 (config-router) auto-summary
R3 (config-router) network 172.30.100.0/24
R3 (config-router) network 172.30.110.0/24
R3 (config-router) network 172.30.200.16/28
R3 (config-router) exit
  
```

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Configuring RIPv2

- Disabling Auto-Summary in RIPv2
- To disable automatic summarization issue the **no auto-summary** command

```

192.168.0.0/24
192.168.1.0/24
192.168.2.0/24
Summary Static Route to 192.168.0/16
  
```

```

R1 (config-router) rip
R1 (config-router) version 2
R1 (config-router) no auto-summary
R1 (config-router) network 172.30.1.0/24
R1 (config-router) network 172.30.2.0/24
R1 (config-router) exit

R2 (config-router) rip
R2 (config-router) version 2
R2 (config-router) no auto-summary
R2 (config-router) network 209.165.200.228/30
R2 (config-router) network 209.165.200.232/30
R2 (config-router) exit

R3 (config-router) rip
R3 (config-router) version 2
R3 (config-router) no auto-summary
R3 (config-router) network 172.30.100.0/24
R3 (config-router) network 172.30.110.0/24
R3 (config-router) network 172.30.200.16/28
R3 (config-router) exit
  
```

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VLSM & CIDR

- RIPv2 and VLSM
- Networks using a VLSM IP addressing scheme
 - Use **classless routing protocols** (i.e. RIPv2) to disseminate network addresses and their subnet masks

```

R1#debug ip rip
RIP protocol debugging is on
R1#
RIP: received v2 update from 209.165.200.233 on Serial0/0/1
10.1.0.0/16 via 0.0.0.0 in 1 hops
172.30.1.0/24 via 0.0.0.0 in 2 hops
172.30.2.0/24 via 0.0.0.0 in 2 hops
192.168.0.0/24 via 0.0.0.0 in 1 hops
209.165.200.228/30 via 0.0.0.0 in 1 hops
R1#
RIP: sending v2 update to 224.0.0.9 via FastEthernet0/0 (172.30.100.1)
RIP: build update entries
10.1.0.0/16 via 0.0.0.0, metric 2, tag 0
172.30.1.0/24 via 0.0.0.0, metric 3, tag 0
172.30.2.0/24 via 0.0.0.0, metric 3, tag 0
172.30.110.0/24 via 0.0.0.0, metric 1, tag 0
172.30.200.16/28 via 0.0.0.0, metric 1, tag 0
172.30.200.32/28 via 0.0.0.0, metric 1, tag 0
192.168.0.0/24 via 0.0.0.0, metric 3, tag 0
192.168.255.0/24 via 0.0.0.0, metric 3, tag 0
209.165.200.228/30 via 0.0.0.0, metric 2, tag 0
209.165.200.232/30 via 0.0.0.0, metric 1, tag 0
R1#
RIP: sending v2 update to 224.0.0.9 via Serial0/0/1 (209.165.200.234)
RIP: build update entries
172.30.100.0/24 via 0.0.0.0, metric 1, tag 0
172.30.110.0/24 via 0.0.0.0, metric 1, tag 0
172.30.200.16/28 via 0.0.0.0, metric 1, tag 0
172.30.200.32/28 via 0.0.0.0, metric 1, tag 0
  
```

RIPv2 supports VLSM

VLSM & CIDR

- CIDR uses Supernetting
 - Supernetting is a bunch of contiguous classful networks that is addressed as a single network.

VLSM & CIDR

- To **verify** that **supernets** are being sent and received use the following commands
 - Show ip route
 - Debug ip rip

```

R2 (config)#router rip
R2 (config-router)#network 10.0.0.0
R2 (config-router)#network 172.30.100.0
R2 (config-router)#network 209.165.200.0
R2 (config-router)#exit
R2 (config)#ip route 192.168.0.0 255.255.0.0 mull0 192.168.0.16 is a Supernet.
R2#debug ip rip
RIP protocol debugging is on
R2#
RIP: sending v2 update to 224.0.0.9 via Serial0/0/0 (209.165.200.229)
RIP: build update entries
10.1.0.0/16 via 0.0.0.0, metric 1, tag 0
172.30.100.0/24 via 0.0.0.0, metric 2, tag 0
172.30.110.0/24 via 0.0.0.0, metric 2, tag 0
172.30.200.16/28 via 0.0.0.0, metric 2, tag 0
172.30.200.32/28 via 0.0.0.0, metric 2, tag 0
192.168.0.0/24 via 0.0.0.0, metric 1, tag 0
209.165.200.232/30 via 0.0.0.0, metric 1, tag 0
  
```

Supernet is sent by R2.

Compare RIPv1 and RIPv2

Routing Protocol	Distance Vector	Classless Routing Protocol	Uses Hold-Down Timers	Use of Split Horizon or Split Horizon w/ Poison Reverse	Max Hop count = 15	Auto Summary	Support CIDR	Supports VLSM	Uses Authentication
RIPv1	Yes	No	Yes	Yes	Yes	Yes	No	No	No
RIPv2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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EIGRP

(ENHANCED INTERIOR GATEWAY ROUTING PROTOCOL)

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Introduction

In this chapter, you will learn to:

- Describe the background and history of EIGRP.
- Describe the features and operation of EIGRP.
- Examine the basic EIGRP configuration commands and identify their purposes.
- Calculate the composite metric used by EIGRP.
- Describe the concepts and operation of DUAL.
- Describe the uses of additional configuration commands in EIGRP.

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

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EIGRP

Protocol Dependent Modules (PDM)

- EIGRP uses PDM to route several different protocols i.e. IP, IPX & AppleTalk
- PDMs are responsible for the specific routing task for each network layer protocol

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EIGRP

Reliable Transport Protocol (RTP)

- Purpose of RTP**
 - Used by EIGRP to transmit and receive EIGRP packets
- Characteristics of RTP**
 - Involves both reliable & unreliable delivery of EIGRP packet
 - Reliable delivery requires acknowledgment from destination
 - Unreliable delivery does not require an acknowledgement from destination
 - Packets can be sent
 - Unicast
 - Multicast
 - Using address 224.0.0.10

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EIGRP

EIGRP's 5 Packet Types

- **Hello packets**
 - Used to discover & form adjacencies with neighbors

Hello packet

- Use to discover neighbors & form adjacencies
- Unreliable so no response required from recipient

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EIGRP

- **Update packets**
 - Used to propagate routing information
- **Acknowledgement packets**
 - Used to acknowledge receipt of update, query & reply packets

Update packet

- Used to propagate routing information after a change
- Automatically sent back when reliable RTP is used

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EIGRP

- **Query & Reply packets**
 - Used by DUAL for searching for networks
 - Query packets
 - Can use
 - Unicast
 - Multicast
 - Reply packet
 - Use only
 - unicast

Query packet

- Used by DUAL when searching for networks or other tasks
- Automatically sent in response to Query packet
- Automatically sent back when reliable RTP is used

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EIGRP

- **Purpose of Hello Protocol**
 - To discover & establish adjacencies with neighbor routers
- **Characteristics of hello protocol**
 - Time interval for sending hello packet
 - Most networks it is every **5 seconds**
 - Multipoint non broadcast multi-access networks
 - Unicast every 60 seconds
 - Holdtime
 - This is the maximum time router should wait before declaring a neighbor down
 - Default holdtime
 - 3 times hello interval

Default Hello Intervals and Hold Times for EIGRP

Bandwidth	Example Link	Default Hello Interval	Default Hold Time
≤ 1.544 Mbps	Multipoint Frame Relay	60 seconds	180 seconds
> 1.544 Mbps	T1, Ethernet	5 seconds	15 seconds

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EIGRP

EIGRP Bounded Updates

- EIGRP only sends update when there is a **change in route status**
- Partial update**
 - A partial update includes only the route information that has changed – the whole routing table is NOT sent
- Bounded update**
 - When a route changes, only those devices that are impacted will be notified of the change
- EIGRP's use of partial bounded updates minimizes use of bandwidth

EIGRP Updates

EIGRP Updates are partial and bounded:

Partial because the update only includes information about route changes.

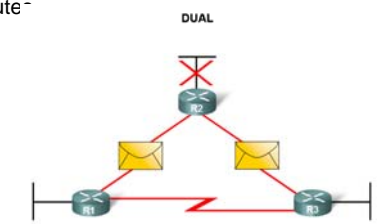
Bounded because only those routers affected by the change will receive the update.

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EIGRP

Diffusing Update Algorithm (DUAL)

- Purpose**
 - EIGRP's primary method for preventing routing loops
- Advantage of using DUAL**
 - Provides for fast convergence time by keeping a list of loop-free backup route



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EIGRP

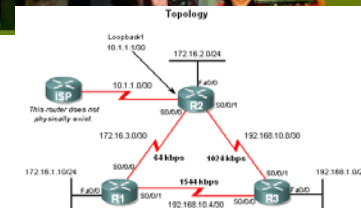
- Administrative Distance (AD)**
 - Defined as the trustworthiness of the source route
- EIGRP default administrative distances
 - Summary routes = 5
 - Internal routes = 90
 - Imported routes = 170

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
IG-IS	115
RIP	120
External EIGRP	170
Internal BGP	200

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EIGRP

- EIGRP will automatically summarize routes at classful boundaries



Device	Interface	IP Address	Subnet Mask
R1	FastEthernet0/0	172.16.1.1	255.255.255.0
	Serial0/0/0	192.168.10.5	255.255.255.252
R2	FastEthernet0/0	172.16.2.1	255.255.255.0
	Serial0/0/0	192.168.10.9	255.255.255.252
R3	FastEthernet0/0	192.168.10.1	255.255.255.0
	Serial0/0/1	192.168.10.10	255.255.255.252

```

R1#show startup-config
!
some output omitted
!
hostname R1
!
interface FastEthernet0/0
ip address 172.16.1.1 255.255.255.0
clock rate 40000
!
interface Serial0/0/0
ip address 192.168.10.5 255.255.255.252
clock rate 40000
!
end

R2#show startup-config
!
some output omitted
!
hostname R2
!
interface Loopback0
ip address 10.1.1.1 255.255.255.252
description Simulated IEP
!
interface FastEthernet0/0
ip address 172.16.2.1 255.255.255.0
!
interface Serial0/0/0
ip address 192.168.10.9 255.255.255.252
clock rate 40000
!
end

R3#show startup-config
!
some output omitted
!
hostname R3
!
interface FastEthernet0/0
ip address 192.168.10.1 255.255.255.0
!
interface Serial0/0/0
ip address 192.168.10.4 255.255.255.252
clock rate 40000
!
interface Serial0/0/1
ip address 192.168.10.10 255.255.255.252
clock rate 40000
!
end
  
```

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Basic EIGRP Configuration

- Autonomous System (AS) & Process IDs
 - This is a collection of networks under the control of a single authority (reference RFC 1930)
 - AS Numbers are assigned by IANA
 - Entities needing AS numbers
 - ISP
 - Internet Backbone providers
 - Institutions connecting to other institutions using AS numbers

```

R1(config)#router eigrp 1
R1(config-router)#network 172.16.0.0
R1(config-router)#network 192.168.10.0
R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
R2(config-router)#network 192.168.10.0
R3(config)#router eigrp 1
R3(config-router)#network 172.16.0.0
R3(config-router)#network 192.168.10.0
R4(config)#router eigrp 1
R4(config-router)#network 172.16.0.0
R4(config-router)#network 192.168.10.0
  
```

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Basic EIGRP Configuration

The `router eigrp` command

- The global command that enables eigrp is `router eigrp autonomous-system`
 - All routers in the EIGRP routing domain **must use the same process ID number** (autonomous-system number)

```

R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
R2(config-router)#network 192.168.10.0
R3(config)#router eigrp 1
R3(config-router)#network 172.16.0.0
R3(config-router)#network 192.168.10.0
R4(config)#router eigrp 1
R4(config-router)#network 172.16.0.0
R4(config-router)#network 192.168.10.0
  
```

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Basic EIGRP Configuration

The Network Command

- Functions of the network command
 - Enables interfaces to transmit & receive EIGRP updates
 - Includes network or subnet in EIGRP updates
- Example
 - `Router(config-router)#network`

```

R1(config)#router eigrp 1
R1(config-router)#network 172.16.0.0
R1(config-router)#network 192.168.10.0
R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
R2(config-router)#network 192.168.10.0
R3(config)#router eigrp 1
R3(config-router)#network 172.16.0.0
R3(config-router)#network 192.168.10.0
R4(config)#router eigrp 1
R4(config-router)#network 172.16.0.0
R4(config-router)#network 192.168.10.0
  
```

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Basic EIGRP Configuration

- The network Command with a Wildcard Mask
 - This option is used when you want to configure EIGRP to advertise specific subnets
 - Example
 - `Router(config-router)#network network-address [wildcard-mask]`

```

R1(config)#router eigrp 1
R1(config-router)#network 172.16.0.0
R1(config-router)#network 192.168.10.0

R2(config)#router eigrp 1
R2(config-router)#network 172.16.0.0
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 172.16.3.1 (Serial0/0/0) is up: new adjacency
R2(config-router)#network 192.168.10.0 0.0.0.3

R3(config)#router eigrp 1
R3(config-router)#network 192.168.10.0
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 192.168.10.5 (Serial0/0/0) is up: new adjacency
R3(config-router)#
%DUAL-5-NBRCHANGE: IP-EIGRP 1: Neighbor 192.168.10.9 (Serial0/0/1) is up: new adjacency
R3(config-router)#network 192.168.1.0
  
```

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Basic EIGRP Configuration

Verifying EIGRP

- EIGRP routers must establish adjacencies with their neighbors before any updates can be sent or received
- Command used to view neighbor table and verify that EIGRP has established adjacencies with neighbors is **show ip eigrp neighbors**

show ip eigrp neighbors

The Neighbor Table

```

R2#show ip eigrp neighbors
IP-EIGRP neighbors for process 1
H   Address          Interface         Hold  Uptime   SRTT  RTO   Seq  Seq Type
   1  192.168.10.10     Ser0/0/1         18    00:01:41  20    200   0    7
   0  172.16.3.1        Ser0/0/0         10    00:09:49  25    200   0    28
    
```

Address of neighbors Interface connected to neighbor Amount of time since adjacency was established Amount of time left before neighbor is considered "down"

Basic EIGRP Configuration

Examining the Routing Table

- The **show ip route** command is also used to verify EIGRP
- EIGRP routes are denoted in a routing table by the letter "D"
- By default, EIGRP automatically summarizes routes at major network boundary

```

R1#show ip route
Codes: C - connected, E - static, I - IGRP, B - BGP, M - mobile, N - NBP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       O*Output omitted

Gateway of last resort is not set

 192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
  D   192.168.10.0/24 is a summary, 00:03:10, Null0
  C   192.168.10.4/30 is directly connected, Serial0/0/1
  D   192.168.10.8/30 is directly connected, Serial0/0/1
  V   172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
  D   172.16.0.0/16 is a summary, 00:03:10, Null0
  D   172.16.1.0/24 is directly connected, FastEthernet0/0
  D   172.16.3.0/24 [90/2172416] via 192.168.10.3, 00:01:47, Serial0/0/0
  C   192.168.1.0/24 [90/2172416] via 192.168.10.4, 00:02:31, Serial0/0/1
    
```

Basic EIGRP Configuration

- R3's routing table shows that the 172.16.0.0/16 network is automatically summarized by R1 & R3

R3 Routing Table

```

R3#show ip route
Codes: C - connected, E - static, I - IGRP, B - BGP, M - mobile, N - NBP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       O*Output omitted

Gateway of last resort is not set

 192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
  D   192.168.10.0/24 is a summary, 00:03:11, Null0
  C   192.168.10.4/30 is directly connected, Serial0/0/0
  D   192.168.10.8/30 is directly connected, Serial0/0/1
  O   172.16.0.0/16 [90/2172416] via 192.168.10.3, 00:03:23, Serial0/0/0
       [90/2172416] via 192.168.10.9, 00:03:23, Serial0/0/1
  C   192.168.1.0/24 is directly connected, FastEthernet0/0

Equal cost routes to 172.16.0.0/16
    
```

EIGRP Metric Calculation

EIGRP Composite Metric & the K Values

- EIGRP uses the following values in its composite metric
 - Bandwidth, delay, reliability, and load
- The composite metric used by EIGRP
 - formula used has values K1 → K5

K1 & K3 = 1
all other K values = 0

EIGRP Composite Metric

Default Composite Formula:
metric = [K1*bandwidth + K3*delay]

Complete Composite Formula:
metric = [K1*bandwidth + (K2*bandwidth) / (256 - load) + K3*delay + [K5*reliability + K4]]
(Not used if "K" values are 0)

Default values:
K1 (bandwidth) = 1
K2 (load) = 0
K3 (delay) = 1
K4 (reliability) = 0
K5 (reliability) = 0

*K values can be changed with the **metric weights** command

```

Router(config-router)#metric weights top k1 k2 k3 k4 k5
    
```

EIGRP Metric Calculation

- Use the **sh ip protocols** command to verify the K values

```

R1#show ip protocols
Routing Protocol is "eigrp 1"
  Outgoing update filter list for all interfaces is not set
  Incoming update filter list for all interfaces is not set
  Default networks flagged in outgoing updates
  Default networks accepted from incoming updates
  EIGRP metric weight K1=1, K2=0, K3=1, K4=0, K5=0
  EIGRP maximum hopcount 100
  EIGRP maximum metric variance 1
  Redistributing: eigrp 1
  Automatic network summarization is in effect
  Automatic address summarization:
    192.168.10.0/24 for FastEthernet0/0, Serial0/0/0
    Summarizing with metric 2169856
    172.16.0.0/16 for Serial0/0/1
    Summarizing with metric 28160
  Maximum paths: 4
  Routing for Networks:
    172.16.0.0
    192.168.10.0
  Routing Information Sources:
    Gateway         Distance      Last Update
  (this router)      90            00:03:29
  192.168.10.6       90            00:02:09
  Gateway           Distance      Last Update
  172.16.3.2         90            00:02:12
  Distance: internal 90 external 170
  
```

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EIGRP Metric Calculation

EIGRP Metrics

- Use the **show interfaces** command to view metrics
- EIGRP Metrics
 - Bandwidth** – EIGRP uses a static bandwidth to calculate metric
 - Most serial interfaces use a default bandwidth value of 1.544Mbos (T1)

```

R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
Hardware is C7303 Serial
Description: Link to R2
Internet address is 172.16.3.1/30
MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,
Encapsulation HDLC, loopback not set
Keepalive set (15 sec)
last input: 00:00:49, output: 00:00:41, output hung never
last clearing of "show interface" counters 28230
Input queue: 0/72/0/0 (size/max/drops/flushes); Total output drops: 0
Queueing strategy: fifo
Output queue: 0/40 (size/max)
5 minute input rate: 0 bits/sec, 0 packets/sec
5 minute output rate: 0 bits/sec, 0 packets/sec
112922 packets input, 189752 bytes, 0 no buffer
Received 45016 bytes/4241, 0 runs, 0 giants, 0 throttles
5 input errors, 0 CRC, 2 frame, 0 overrun, 0 ignored, 0 abort
112611 packets output, 128133 bytes, 0 underruns
0 output errors, 0 collisions, 2 interface resets
0 output buffer failures, 0 output buffers swapped out
12 carrier transitions
DCE-up DCR-up DTR-up DTE-up CTR-up
  
```

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EIGRP Metric Calculation

EIGRP Metrics

- Delay** is defined as the measure of time it takes for a packet to traverse a route
 - it is a static value based on link type to which interface is connected

Delay Values in Microseconds

Media	Delay
100M ATM	100 µs
Fast Ethernet	100 µs
FDDI	100 µs
1HSSI	20,000 µs
16M Token Ring	630 µs
Ethernet	1,000 µs
T1 (Serial Default)	20,000 µs
512K	20,000 µs
DSO	20,000 µs
56K	20,000 µs

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EIGRP Metric Calculation

- Reliability** (not a default EIGRP metric)
 - A measure of the likelihood that a link will fail
 - Measure dynamically & expressed as a fraction of 255 the higher the fraction the better the reliability
- Load** (not a default EIGRP metric)
 - A number that reflects how much traffic is using a link
 - Number is determined dynamically and is expressed as a fraction of 255
 - The lower the fraction the less the load on the link

Reliability and Load Values

MTU 1500 bytes, BW 1544 Kbit, DLY 20000 usec,

reliability 255/255, txload 1/255, rxload 1/255

Reliability Value Load Value

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EIGRP Metric Calculation

Using the Bandwidth Command

- Modifying the interface bandwidth
 - Use the **bandwidth** command
 - Example
Router(config-if)#**bandwidth** kilobits
- Verifying bandwidth
 - Use the **show interface** command
- Note – bandwidth command **does not change** the link's physical bandwidth

The bandwidth Command

```

R1(config-if)# bandwidth 1000
R1(config-if)# bandwidth 100000
R1(config-if)# bandwidth 1000000
R1(config-if)# bandwidth 10000000

```

Verifying Bandwidth Value

```

R1# show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
Hardware is T3E100
Internet address is 192.168.10.10
MTU 1500 bytes, BW 1000000 kbps, DLE 0,
keepalive 0, hold 100, receive 1000,
send 1000, reliability 255/100, tx queue 1000,
broadcast 0, multicast 0, loopback not set,
code 0x00000000

```

Note: The actual bandwidth of the link between R1 and R2 matches the default value for serial interfaces (1000 kbps).

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EIGRP Metric Calculation

- The EIGRP metric can be determined by examining the bandwidth delay

Calculating the EIGRP Default Metric

Default metric = [K1*bandwidth + K3*delay]

Since K1 and K3 both equal 1, the formula simplifies to: **bandwidth + delay**

bandwidth = speed of slowest link in route to the destination
 delay = sum of the delays of each link in route to the destination

```

Slowest bandwidth:      (10,000,000/bandwidth kbps) * 256
Plus the sum of the delays + (sum of delay/10) * 256
-----
= EIGRP metric

```

```

R2#show ip route
<output omitted>
D 192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:02:14, Serial0/0/1

```

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DUAL Concepts

- The Diffusing Update Algorithm (DUAL) is used to prevent looping

DUAL Concepts

DUAL provides:

- Loop-free paths
- Loop-free backup paths which can be used immediately
- Fast convergence
- Minimum bandwidth usage with bounded updates

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DUAL Concepts

- Successor
 - The **best least cost route** to a destination found in the routing table
- Feasible distance
 - The **lowest calculated metric** along a path to a destination network

Feasible Distance and Successor

```

R2#show ip route
<code output omitted>
Gateway of last resort is not set

192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
D 192.168.10.0/24 is a summary, 00:00:15, Null0
D 192.168.10.4/30 [90/21624000] via 192.168.10.10, 00:00:15,
Serial0/0/1
C 192.168.10.8/30 is directly connected, Serial0/0/1
172.16.0.0/16 is variably subnetted, 4 subnets, 3 masks
D 172.16.0.0/16 is a summary, 00:00:15, Null0
D 172.16.1.0/24 [90/40514560] via 172.16.3.1, 00:00:15, Serial0/0/0
C 172.16.2.0/24 is directly connected, FastEthernet0/0
D 172.15.3.0/30 is directly connected, Serial0/0/0
C 10.0.0.0/30 is subnetted, 1 subnets
D 10.1.1.0 is directly connected, loopback0
D 192.168.1.0/24 [90/3014400] via 192.168.10.10, 00:00:15, Serial0/0/1

```

feasible distance successor

R3 at 192.168.10.10 is the successor for network 192.168.1.0/24. This route has a feasible distance of 3014400.

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DUAL Concepts

Feasible Successors, Feasibility Condition & Reported Distance

- Feasible Successor
 - This is a **loop free backup route** to same destination as successor route

Finding the Feasible Successor

```

R1#show ip route
Code output omitted>
Gateway of last resort is not set.

D 192.168.10.0/24 is variably subnetted, 3 subnets, 2 masks
D 192.168.10.0/24 is a summary, 00:00:00, Null0
D 192.168.10.4/30 [90/2024000] via 192.168.10.10, 00:00:15, Serial0/0/1
D 192.168.10.8/30 is directly connected, Serial0/0/1
D 192.16.1.0/24 is variably subnetted, 4 subnets, 3 masks
D 192.16.1.0/24 is a summary, 00:00:13, Null0
D 192.16.1.0/24 [90/4034400] via 192.16.1.1, 00:00:15, Serial0/0/0
D 192.16.2.0/24 is directly connected, FastEthernet0/0
D 192.16.2.0/24 is directly connected, Serial0/0/0
D 10.1.1.0/24 is subnetted, 1 subnet
D 10.1.1.0 is directly connected, Loopback1
D 192.169.1.0/24 [90/3914400] via 192.169.1.10, 00:00:15, Serial0/0/1
  
```

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DUAL Concepts

Feasible Successors, Feasibility Condition & Reported Distance

- Reported distance (RD)
 - The metric that a router reports to a neighbor about its own cost to that network

RT satisfies the feasibility condition.

```

R1#show ip route
Code output omitted for brevity>
D 192.168.1.0/24 [90/3024000] via 192.168.10.10, 00:00:15, Serial0/0/1
-----
R2#show ip route
Code output omitted for brevity>
D 192.168.1.0/24 [90/372416] via 192.168.10.6, 01:12:26, Serial0/0/1
  
```

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DUAL Concepts

- Feasibility Condition (FC)
 - Met when a neighbor's RD is less than the local router's FD to the same destination network

Does R1 satisfy the feasibility condition?

```

R1#show ip route
Code output omitted for brevity>
D 192.168.1.0/24 [90/372416] via 192.168.10.6, 01:12:26, Serial0/0/1

R1 reports to R2 that its feasible distance to 192.168.1.0/24 is 372416
  
```

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DUAL Concepts

- Topology Table: Successor & Feasible Successor
- EIGRP Topology table
 - Viewed using the *show ip eigrp topology* command
 - Contents of table include:
 - all successor routes
 - all feasible successor routes

EIGRP Topology Table

```

R1#show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(0.0.0.0)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status

Code output omitted>
P 192.168.1.0/24: 1 successors, FD is 3014400
   via 192.168.10.10 (3014400/28160), Serial0/0/1
   via 192.16.2.1 (4102400/2172416), Serial0/0/0
P 192.16.1.0/24: 1 successor, FD is 3014400
   via Connected, Serial0/0/1

Routes for 192.168.1.0/24
  
```

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DUAL Concepts

- EIGRP Topology Table dissected

```

R2#show ip eigrp topology
IP-EIGRP Topology Table for AS(1)/ID(10.1.1.1)
Codes: P - Passive, A - Active, U - Update, Q - Query, R - Reply,
       r - reply Status, s - sia Status
<output omitted>
P 192.168.1.0/24, 1 successors, FD is 3014400
  via 192.168.10.10 (3014400/28160), Serial0/0/1
  via 172.16.3.1 (41026560/2172416), Serial0/0/0
  
```

Table Entry for 192.168.1.0/24

More EIGRP Configurations

Disabling Automatic Summarization

- The **auto-summary** command permits EIGRP to automatically summarize at major network boundaries
- The **no auto-summary** command is used to disable automatic summarization
 - This causes all EIGRP neighbors to send updates that will not be automatically summarized
 - this will cause changes to appear in both
 - routing tables
 - topology tables

More EIGRP Configurations

Manual Summarization

- Manual summarization can include supernets
 - Reason: EIGRP is a classless routing protocol & include subnet mask in update
- Command used to configure manual summarization
 - Router(config-if)#ip summary-address eigrp as-number network-address subnet-mask

More EIGRP Configurations

- Configuring a summary route in EIGRP

```

R3(config)#interface serial 0/0/0
R3(config-if)#ip summary-address eigrp 1 192.168.0.0 255.255.252.0
R3(config-if)#interface serial 0/0/1
R3(config-if)#ip summary-address eigrp 1 192.168.0.0 255.255.252.0
  
```

Configure the summary route on all interfaces that send EIGRP packets.

Cisco Networking Academy

OSPF

(OPEN SHORT-TEST PATH FIRST)

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Cisco Networking Academy

Introduction

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

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.

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Cisco Networking Academy

Introduction to OSPF

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

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 Source Address = Address of sending interface			
MAC Destination Address = Multicast: 01:00:5E:00:00:05 or 01:00:5E:00:00:00			
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			
0000 Hello			
0001 Database Description (DD)			
0002 Link State Request			
0003 Link State Update			
0004 Link State Acknowledgment			

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Cisco Networking Academy

Introduction to OSPF

- Hello Packets continued
 - Contents of a Hello Packet
 - router ID of transmitting router
- OSPF Hello Intervals
 - Usually multicast (224.0.0.5)
 - Sent every 30 seconds for NBMA segments
- OSPF Dead Intervals
 - This is the time that must transpire before the neighbor is considered down
 - Default time is 4 times the hello interval

Matching interface values for two routers to form an adjacency

Hello Interval } Hello Interval
Dead Interval } Dead Interval
Network Type } Network Type

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Introduction to OSPF

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

OSPF Uses Dijkstra's SPF Algorithm

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Introduction to OSPF

Administrative Distance

- Default Administrative Distance for OSPF is 110

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

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Basic OSPF Configuration

Lab Topology

- Topology used for this chapter
 - Discontiguous IP addressing scheme
 - Since OSPF is a classless routing protocol the subnet mask is configured in

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Basic OSPF Configuration

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)#

```

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Basic OSPF Configuration

- 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
  
```

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Basic OSPF Configuration

- Router ID
 - This is an IP address used to identify a router
 - 3 criteria for deriving the router ID
 - Use IP address configured with OSPF **router-id** command
 - Takes precedence over loopback and physical interface addresses
 - If **router-id** command not used then router chooses highest IP address of any loopback interfaces
 - If no loopback interfaces are configured then the highest IP address on any active interface is used

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Basic OSPF Configuration

OSPF Router ID

- Commands used to verify current router ID
 - Show ip protocols
 - Show ip ospf
 - Show ip ospf interface

```

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

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

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 192.168.10.3
  Number of areas in this router is 1. 1 normal 0 stub 0 nssa
  
```

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Basic OSPF Configuration

OSPF Router ID

```

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

- 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 ospf process-id
 - Router(config-router)#router-id ip-address
- Modifying the Router ID
 - Use the command Router#clear ip ospf process

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Basic OSPF Configuration

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
```

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Basic OSPF Configuration

Verifying OSPF - Additional Commands

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

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Basic OSPF Configuration

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

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

Gateway of last resort is not set

192.168.10.0/30 is subnetted, 3 subnets
C    192.168.10.0 is directly connected, Serial0/0/0
C    192.168.10.4 is directly connected, Serial0/0/1
O    192.168.10.8 [110/128] via 192.168.10.2, 14:27:57, Serial0/0/0
O    172.16.0.0/16 is variably subnetted, 2 subnets, 2 masks
O    172.16.1.32/29 [110/65] via 192.168.10.6, 14:27:57, Serial0/0/1
C    172.16.1.16/28 is directly connected, FastEthernet0/0
O    10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
O    10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0
C    10.1.1.1/32 is directly connected, Loopback0
```

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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 bps = Cost
Fast Ethernet and faster	10 ⁸ /100,000,000 bps = 1
Ethernet	10 ⁸ /10,000,000 bps = 10
E1	10 ⁸ /2,048,000 bps = 48
T1	10 ⁸ /1,544,000 bps = 64
128 kbps	10 ⁸ /128,000 bps = 781
64 kbps	10 ⁸ /64,000 bps = 1562
56 kbps	10 ⁸ /56,000 bps = 1785

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OSPF Metric

- COST of an OSPF route

Is the accumulated value from one router to the next

OSPF Accumulates Cost

```

R1#show ip route
Codes: <same code output omitted>
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF Inter area
<route output omitted>
O    10.10.10.0/24 [110/65] via 192.168.10.2, 14:27:57, Serial0/0/0
    Accumulated Cost = 65
  
```

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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

Differences Between Default and Actual Bandwidth

```

R1#show interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
Hardware is GT700 Serial
Description: Link to R2
Internet address is 192.168.10.2/30
MTU 1500 bytes, BW 1544 Kbit, DLY 2000 usec,
encapsulation HDLC, loopback 0, speed 1544
Default Bandwidth is 1544 Kbps
Actual Bandwidth is 64 Kbps
  
```

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Basic OSPF Configuration

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)#interface serial 0/0/0
R1(config-if)#bandwidth 1544
R1(config-if)#ip ospf cost 1562
R1(config-if)#end
R1#show ip ospf interface serial 0/0/0
Serial0/0/0 is up, line protocol is up
Internet Address 192.168.10.2/30, Area 0
Process ID 1, Router ID 10.1.1.1, Network Type POINT_TO_POINT, Cost1: 1562
Transmit Delay is 1 sec, State POINT_TO_POINT,
<output omitted>
  
```

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Basic OSPF Configuration

Modifying the Cost of the 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

Equivalent Commands

bandwidth Commands	ip ospf cost Commands
Router R1 R1(config)#interface serial 0/0/0 R1(config-if)#bandwidth 64	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)#bandwidth 256	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)#bandwidth 44	Router R2 R2(config)#interface serial 0/0/0 R2(config-if)#ip ospf cost 1542
R2(config)#interface serial 0/0/1 R2(config-if)#bandwidth 128	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)#bandwidth 356	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)#bandwidth 128	R3(config)#interface serial 0/0/1 R3(config-if)#ip ospf cost 781

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OSPF and Multiaccess Networks

Challenges in Multiaccess Networks

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

OSPF Network Types Used in the Topology

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OSPF in Multiaccess 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
 - DRouters 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

Adjacencies are formed with DR and BDR only. LSAs are sent to the DR. BDR listens.

Here are my LSAs

DR sends out any LSAs to all other routers.

Here are 10.1.1.1's LSAs

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OSPF in Multiaccess Networks

DR/BDR Election Process

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

Point-to-Point Three Router Topology

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OSPF in Multiaccess Networks

- 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.

```

Router#show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface
192.168.31.33 1 FULL/DR 00:00:39 192.168.1.3 FastEthernet0/0
192.168.31.22 1 FULL/BDR 00:00:34 192.168.1.2 FastEthernet0/0

Router#show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface
192.168.31.29 1 FULL/DR 00:00:34 192.168.1.3 FastEthernet0/0
192.168.31.31 1 FULL/BDR 00:00:36 192.168.1.1 FastEthernet0/0

Router#show ip ospf neighbor
Neighbor ID Pri State Dead Time Address Interface
192.168.31.29 1 FULL/DR 00:00:39 192.168.1.3 FastEthernet0/0
192.168.31.11 1 FULL/BDR 00:00:32 192.168.1.1 FastEthernet0/0
  
```

```

Router#show ip ospf interface FastEthernet0/0
FastEthernet0/0 is up, line protocol is up
Interface 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 DR/OTHER
Designated Router (ID) 192.168.31.29, 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
ob-resync-timerout 60
Hello due in 00:00:06
Suppress LSA/LSack signaling (LSR)
Index 1/1, Flood queue length 0
Next 00:00:04(0)
Last flood scan length is 0, maximum is 1
Last flood scan time is 0 msec, maximum is 0 msec
Neighbor count is 2, Adjacent neighbor count is 2
Adjacent with neighbor 192.168.31.22 (Backup Designated Router)
Adjacent with neighbor 192.168.31.33 (Designated Router)
Suppress hello for 0 neighbor(s)
  
```

Priority is equal at the default value of 1.

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OSPF in Multiaccess Networks

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 is 1, Router ID 192.168.31.1, 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 192.168.1.3
Timer Intervals configured, Hello 10, Dead 40, Wait 40, Retransmit 5
oob-resync timeout 40
  
```

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More OSPF Configuration

Redistributing an 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`

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