Chapter 2

Static Routing

Note for Instructors

- These presentations are the result of a collaboration among the instructors at St. Clair College in Windsor, Ontario.
- Thanks must go out to Rick Graziani of Cabrillo College. His material and additional information was used as a reference in their creation.
- If anyone finds any errors or omissions, please let me know at:
  - tdame@stclaircollege.ca.

Introduction to Routing and Packet Forwarding

Routers and the Network

2811 Router

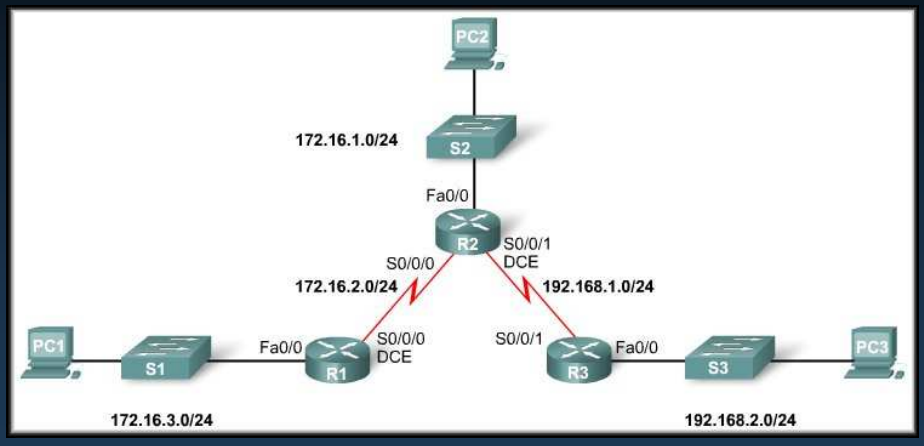
Role of the Router

2811 Router

- Routers are primarily responsible for interconnecting networks by:
  - Determining the best path for a packet.
  - Forwarding (switching) packets to the correct interface.

Introducing the Topology

- Chapter 2 Topology:

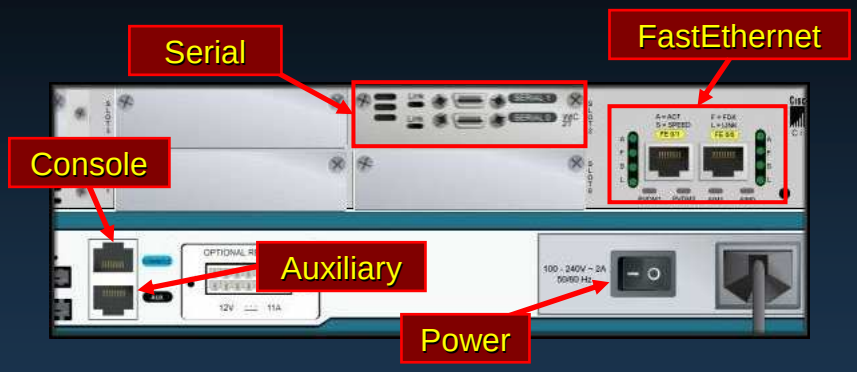


Introducing the Topology

- Chapter 2 Addressing Table:

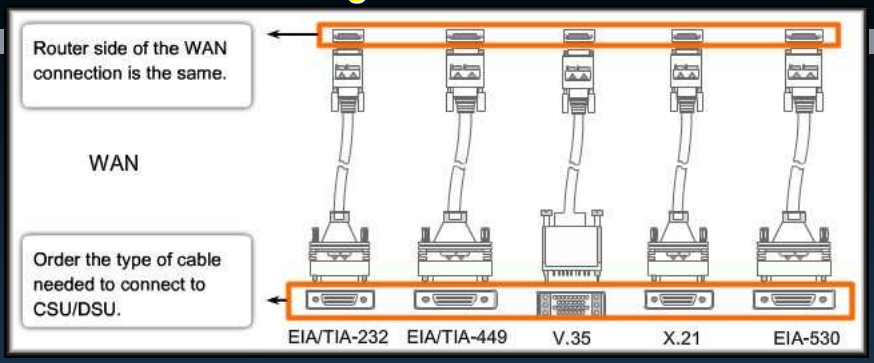
Device	Interface	IP Address	Subnet Mask	Default Gateway
R1	Fa0/0	172.16.3.1	255.255.255.0	N/A
	S0/0/0	172.16.2.1	255.255.255.0	N/A
R2	Fa0/0	172.16.1.1	255.255.255.0	N/A
	S0/0/0	172.16.2.2	255.255.255.0	N/A
	S0/0/1	192.168.1.2	255.255.255.0	N/A
R3	Fa0/0	192.168.2.1	255.255.255.0	N/A
	S0/0/1	192.168.1.1	255.255.255.0	N/A
PC1	NIC	172.16.3.10	255.255.255.0	172.16.3.1
PC2	NIC	172.16.1.10	255.255.255.0	172.16.1.1
PC3	NIC	192.168.2.10	255.255.255.0	192.168.2.1

Examining the Connections



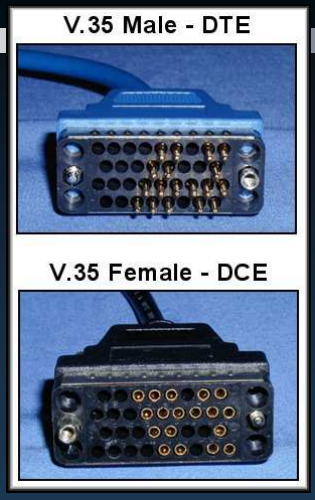
- Unlike most user PCs, a router will have multiple network interfaces.
- These interfaces can include a variety of connectors.

Examining the Connections



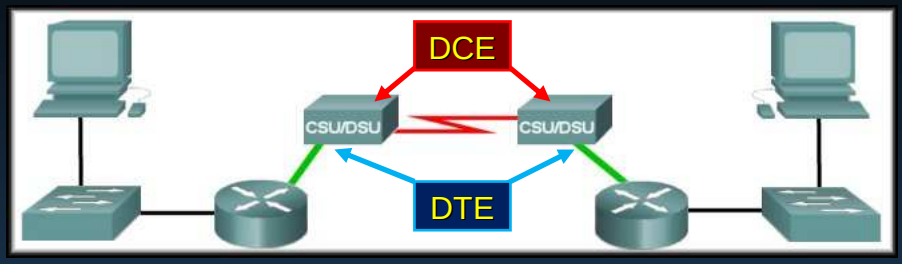
- Serial Connectors:
  - Cisco routers support the EIA/TIA-232, EIA/TIA-449, V.35, X.21, and EIA/TIA-530 standards.
  - *Memorizing these connection types is not important.*
  - Know that a router has a DB-60 port that can support five different cabling standards.

Examining the Connections



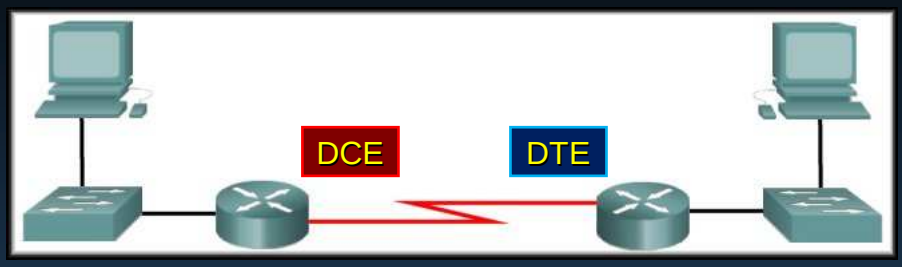
- Serial Connectors:
  - A router is typically a DTE device.
  - The DTE cable is connected to the serial interface on the router to a CSU/DSU device (DCE).

Examining the Connections



- Serial Connectors:
  - In the real world, the serial line is connected to a Channel Service Unit/Data Service Unit (CSU/DSU).
  - The CSU/DSU controls the line and controls the clock rate for the bandwidth set by the service provider.

Examining the Connections



- Serial Connectors:
  - In the lab, the serial line is connected back-to-back.
  - The router that has the DCE cable connected provides the clock rate (bandwidth) by defining the specific clock rate to be used on the connection.

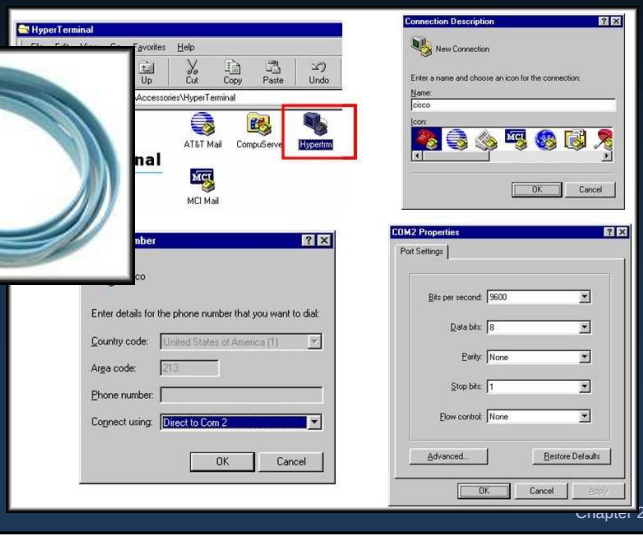
Examining the Connections

- Ethernet Connectors: Standard RJ45 UTP cables.

- Switch-to-Router
- Hub-to-Router
- Switch-to-PC/Server
- Hub-to-PC/Server
- Switch-to-Switch
- PC/Server-to-PC/Server
- Switch-to-Hub
- Hub-to-Hub
- Router-to-Router
- Router-to-PC/Server

Examining the Connections

- **Console Connection:** PC COM1 port using HyperTerminal



Introduction to Routing and Packet Forwarding

Router Configuration Review

```
RTR>enable
RTR#configure terminal
RTR(config)#hostname myrouter
RTR(config)#interface FastEthernet0/0
RTR(config-if)#ip address 192.168.1.1 255.255.255.0
RTR#show ip route
RTR#show interfaces
RTR#show ip interface brief
RTR#show version
RTR#show running-config
RTR#copy running-config startup-config
```

Examining Router Interfaces

- **`show ip route`:**
  - Displays the routing table.
- **`show interfaces`:**
  - Shows the status and gives a detailed description of all interfaces on the router.
- **`show interfaces [interface]`:**
  - Shows the status and gives a detailed description for a specific interface on the router.
- **`show ip interface brief`:**
  - Shows the status of all interfaces in a condensed format.

Configuring an Ethernet Interface

Indicates that physically, the connection is good. If you don't get this message, make sure that the interface is properly connected.

```
R1(config)#interface fastethernet0/0
R1(config-if)#ip address 172.16.3.1 255.255.255.0
R1(config-if)#no shutdown
*Mar  1 01:16:08.212: %LINK-3-UPDOWN: Interface Fastethernet0/0,
                                      changed state to up
*Mar  1 01:16:08.212: %LINEPROTO-5-UPDOWN: Line protocol
          on interface Fastethernet0/0, changed state to up
```

Indicates that the Data Link Layer is operational. On LAN interfaces, you do not normally change the Data Link layer parameters. In the Lab, you will be changing the WAN interface.

Unsolicited Messages from IOS

If you continue with configuration after entering a command that solicits a message from the IOS, the message can interfere with command entry.

```
R1(config)#interface fastethernet0/0
R1(config-if)#ip address 172.16.3.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#descri
*Mar  1 01:16:08.212: %LINK-3-UPDOWN: Interface Fastethernet0/0,
                                      changed state to up
*Mar  1 01:16:08.212: %LINEPROTO-5-UPDOWN: Line protocol
            on interface Fastethernet0/0, changed state to upption
R1(config-if)#
```


Unsolicited Messages from IOS

With the **logging synchronous** command, messages no longer interfere with command entry.

```
R1(config)#line console 0
R1(config-line)#logging synchronous

R1(config)#interface fastethernet0/0
R1(config-if)#ip address 172.16.3.1 255.255.255.0
R1(config-if)#no shutdown
R1(config-if)#descri
*Mar  1 01:16:08.212: %LINK-3-UPDOWN: Interface Fastethernet0/0,
                                      changed state to up
*Mar  1 01:16:08.212: %LINEPROTO-5-UPDOWN: Line protocol
            on interface Fastethernet0/0, changed state to up
R1(config-if)#description
```

Reading the Routing Table

```
R1#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP

  <output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
R1#
```

- The interface was configured with IP Address 172.16.3.1/24.
- That makes it a member of the 172.16.3.0/24 network.
- C = directly connected
  - R1 has an interface that belongs to this network.
- The /24 subnet mask for this route is displayed in the line above the actual route.

Routers Usually Store Network Addresses

```
R1#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP

  <output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.3.0 is directly connected, FastEthernet0/0
R1#
```

- Note that the entries in the routing table are the network address of the IP network.
  - Occasionally, a “host route” (individual host) is entered in the routing table.
  - The host route is listed with the host’s IP address and a /32 (255.255.255.255) subnet mask.
  - The topic of host routes is discussed in another course.

Ethernet Interfaces Participate in ARP

```
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>
```

- A router's Ethernet interface participates in a LAN network just like any other device on that network.
- This means that these interfaces:
  - Have Layer 2 MAC address.
  - Are recorded in a device's ARP Cache.
  - Issue ARP Requests when needed.
  - Issue ARP Replies when required.

Configuring a Serial Interface

```
R1(config)# interface serial 0/0/0
R1(config-if)# ip address 172.16.2.1 255.255.255.0
R1(config-if)# no shutdown

R1# show interfaces serial 0/0/0
Serial0/0/0 is 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>
```

- The serial interface will be in the up state only after the other end of the serial link has also been properly configured and activated.

Configuring a Serial Interface

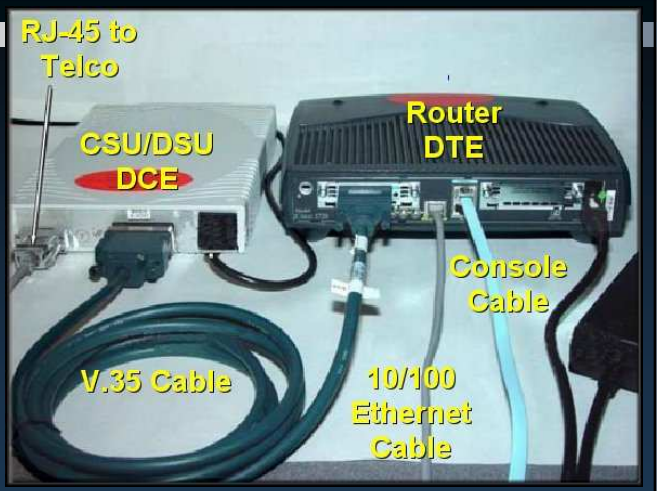
CAN be different interfaces on different routers.

```
R1(config)# interface serial 0/2/0
R1(config-if)# ip address 172.16.2.1 255.255.255.0
R1(config-if)# no shutdown

R2(config)# interface serial 0/0/0
R2(config-if)# ip address 172.16.2.2 255.255.255.0
R2(config-if)# no shutdown
```

MUST be members of the same network / subnetwork.

Examining Serial Interfaces

- Physically Connecting a WAN Interface:



- Serial interfaces require a clocking signal to control the timing of the interface.
- The CSU/DSU provides the clock rate.

Examining Serial Interfaces (In the Lab)

```
R2# show interfaces serial 0/0/0
Serial0/0/0 is up, line protocol is down
<output omitted>
```

- The physical link between R1 and R2 is up.
  - Both ends have been configured correctly with:
    - An IP Address and Subnet Mask
    - The **no shutdown** command has been issued.
- The line protocol is still down.
  - *The serial interface is not receiving a clock signal.*
  - Issue the **clock rate** command, on the router with the DCE cable.

Examining Serial Interfaces (In the Lab)

```
R1# show controllers serial 0/0/0
Interface Serial0/0/0
Hardware is PowerQUICC MPC860
DCE V.35, no clock
<output omitted>
```

- The **show controllers** command is useful in determining the DTE/DCE status of a serial link without having to physically check the cables.
  - If the cable connected to the router is listed as DCE, then the **clock rate** command must be issued for the interface.

Examining Serial Interfaces (In the Lab)

```
R1(config)# interface serial 0/0/0
R1(config-if)# clock rate 64000
01:10:28: %LINEPROTO-5-UPDOWN: Line protocol on
                    Interface Serial0/0/0, changed state to up
```

- Available clock rates, in bits per second, are 1200, 2400, 9600, 19200, 38400, 56000, 64000, 72000, 125000, 148000, 500000, 800000, 1000000, 1300000, 2000000, and 4000000.
- If a DTE interface is configured with the **clock rate** command, the IOS disregards it.

Verifying the Serial Interface Configuration

```
R1# show interfaces serial 0/0/0
Serial0/0/0 is up, line protocol is up
Hardware is PowerQUICC Serial
Internet address is 172.16.2.1/24
<output omitted>

R1# show ip interface brief
Interface        IP-Address OK? Method    Status Protocol
FastEthernet0/0 172.16.3.1 YES manual    up     up
Serial0/0/0      172.16.2.1 YES manual    up     up
<output omitted>

R1# ping 172.16.2.2
Sending 5, 100-byte ICMP Echos to 172.16.2.2, timeout is 2 seconds:
!!!!!
R1#
```

Verifying the Serial Interface Configuration

```
R1# show ip route

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

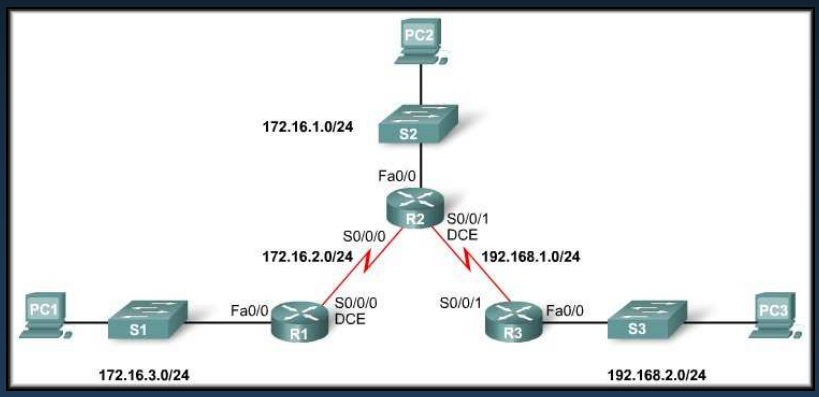
- If we use the **show ip route** command again, we can see that the serial link has been added to the routing table.

Verifying the Serial Interface Configuration

```
R1# show running-config
<output omitted>
!
interface FastEthernet0/0
description R1 LAN
ip address 172.16.3.1 255.255.255.0
!
interface Serial0/0/0
description Link to R2
ip address 172.16.2.1 255.255.255.0
clockrate 64000
!
<output omitted>
R1#
```

- Although the **clock rate** command is two words, IOS spells **clockrate** as a single word in the running configuration and startup configuration files.

Exploring Directly Connected Networks



Verifying Changes to the Routing Table

```
R1# show ip route
<output omitted>
Gateway of last resort is not set
     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

```
R2# show ip route
<output omitted>
Gateway of last resort is not set
     172.16.0.0/24 is subnetted, 1 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
```

- Routing Table Concepts:
  - The routing table consists of a list of "known" network addresses.
    - Those addresses that are directly connected, configured statically and/or learned dynamically.

Verifying Changes to the Routing Table

```
R2# debug ip routing
IP routing debugging is on
R2(config)# int fa0/0
R2(config-if)# ip address 172.16.1.1 255.255.255.0
R2(config-if)# no shutdown
%LINK-3-UPDOWN: Interface FastEthernet0/0, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0,
                                changed state to up
RT: add 172.16.1.0/24 via 0.0.0.0, connected metric [0/0]
RT: interface FastEthernet0/0 added to routing table
```

- Observing Routes as They Are Added:

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

- After `no shutdown` the interface is **up** and **up**
  - The network is added to the routing table.

Verifying Changes to the Routing Table

```
R2(config)# int fa0/0
R2(config-if)# shutdown
%LINK-5-CHANGED: Interface FastEthernet0/0,
                 changed state to administratively down
%LINEPROTO-5-UPDOWN: Line protocol on Interface FastEthernet0/0,
                 changed state to down
R2(config-if)# no ip address
R2(config-if)# ip address 172.16.1.1 255.255.255.0
R2(config-if)# no shutdown
R2(config-if)# end
```

- Changing an IP Address:
  - Disable the interface with the **`shutdown`** command.
  - Remove the current IP Address with the **`no ip address`** command.
  - *The route is removed from the routing table.*
  - Add the new IP address and enable the interface.

Verifying Changes to the Routing Table

- *Important notes on the debug command:*

- The debug commands, especially the **`debug all`** command, should be used sparingly.
  - Useful when configuring or troubleshooting a network.
  - Can disrupt router operations.
  - Intensive use of CPU and memory resources.
  - Run as few debug processes as necessary.
  - Disable them immediately when they are no longer needed.

Devices on Directly Connected Networks

```
R1# show ip interface brief
Interface        IP-Address OK? Method Status                Protocol
FastEthernet0/0 172.16.3.1 YES manual up                    up
Serial0/0/0      172.16.2.1 YES manual up                    up
FastEthernet0/1 unassigned YES manual administratively down down
Serial0/0/1      unassigned YES manual administratively down down

R2# show ip interface brief
Interface        IP-Address OK? Method Status                Protocol
FastEthernet0/0 172.16.1.1  YES manual up                    up
Serial0/0/0      172.16.2.2  YES manual up                    up
FastEthernet0/1 unassigned  YES manual administratively down down
Serial0/0/1      192.168.1.2 YES manual up                    up

R3# show ip interface brief
Interface        IP-Address  OK? Method Status                Protocol
FastEthernet0/0 192.168.2.1 YES manual up                    up
Serial0/0/0      unassigned  YES manual administratively down down
FastEthernet0/1 unassigned  YES manual administratively down down
Serial0/0/1      192.168.1.1 YES manual up                    up
```

Are all interfaces up and up?

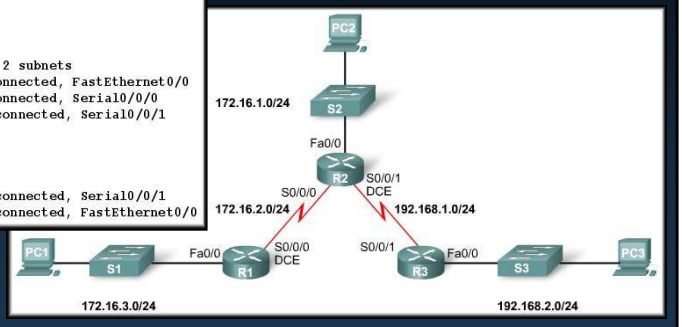
Devices on Directly Connected Networks

```
R1# show ip route

     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0

R2# show ip route

     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, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1

R3# show ip route

C    192.168.1.0/24 is directly connected, Serial0/0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/0
```

Are all directly connected networks in the routing tables?

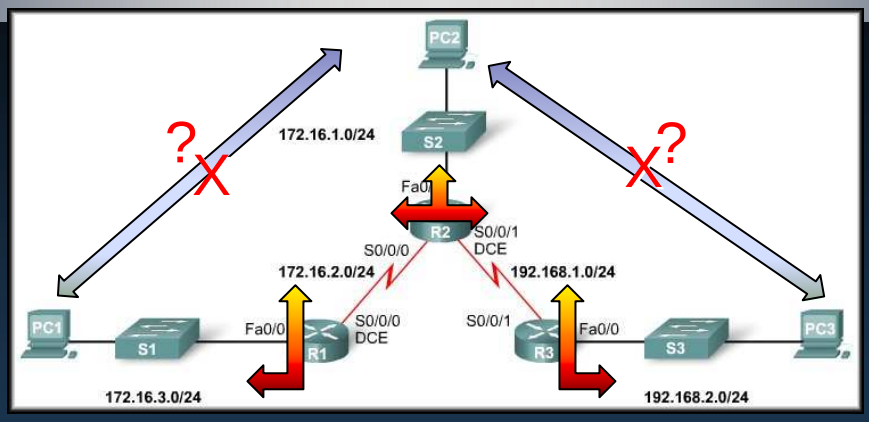
Devices on Directly Connected Networks

```
R1# show ip route

     172.16.0.0/24 is subnetted, 2 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0

R2# show ip route

     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, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1

R3# show ip route

C    192.168.1.0/24 is directly connected, Serial0/0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/0
```



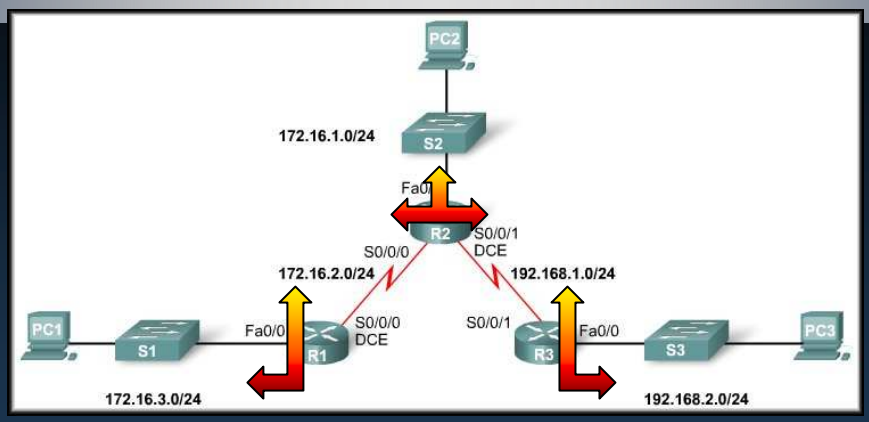
- When a router only has its interfaces configured, and the routing table contains the directly connected networks but no other routes, **only devices on those directly connected networks** are reachable.

Devices on Directly Connected Networks



- When a router only has its interfaces configured, and the routing table contains the directly connected networks but no other routes, only devices on those directly connected networks are reachable.

Devices on Directly Connected Networks



- Remote networks are unreachable.

```
R2# 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)
```

Devices on Directly Connected Networks

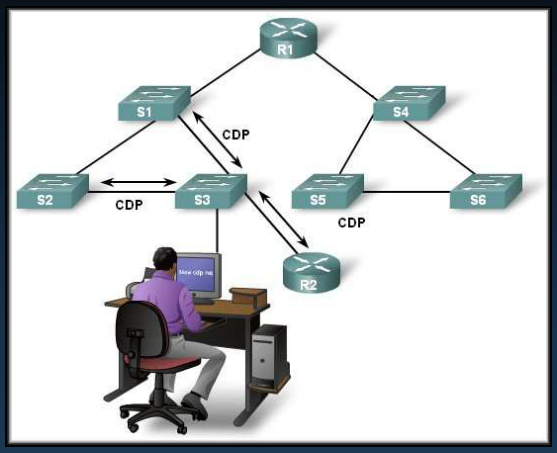
```
R2#show ip route
***ouput omitted***

     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, Serial0/0/0
C    192.168.1.0/24 is directly connected, Serial0/0/1
R2#
```

Destination IP Address	172.16.3.1	10101100.00010000.00000011.00000001	No Match
First route in routing table	172.16.1.0	10101100.00010000.00000001.00000000	
Destination IP Address	172.16.3.1	10101100.00010000.00000011.00000001	No Match
Second route in routing table	172.16.2.0	10101100.00010000.00000010.00000000	
Destination IP Address	172.16.3.1	10101100.00010000.00000011.00000001	No Match
Third route in routing table	192.168.1.0	11000000.10101000.00000001.00000000	

- The IOS routing table process checks to see whether the **24 leftmost bits** (subnet mask) of a packet's destination IP address (172.16.3.1) **match the entries in the routing table.**
  - **If so**, the packet is switched to that interface.
  - **If not**, the packet is dropped.

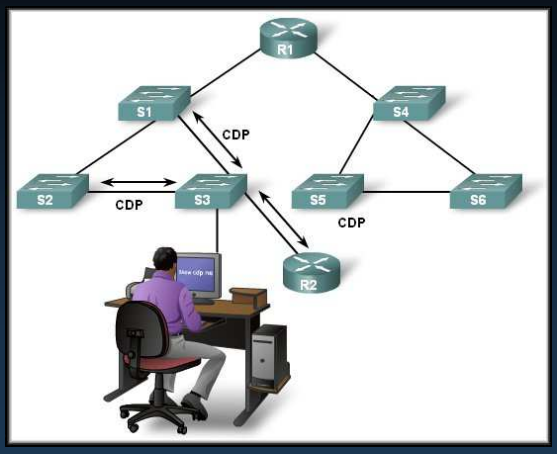
Cisco Discovery Protocol (CDP)

- CDP is a powerful network-monitoring and troubleshooting tool.
- Cisco proprietary.
- Enables you to access a **summary** of protocol and address information.
- **Directly connected** Cisco devices only.

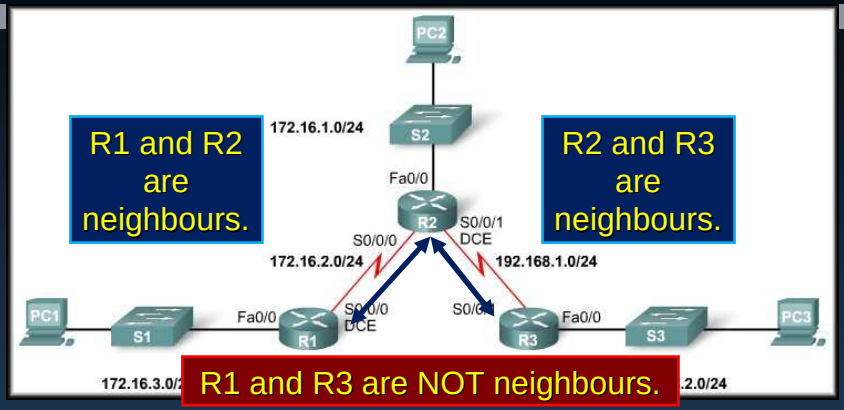


Cisco Discovery Protocol (CDP)

- By default, each Cisco device sends periodic messages to directly connected Cisco devices.
- These messages are known as CDP advertisements.
- Information gathered from other devices can assist you:
  - in making network design decisions, troubleshooting, making changes and network discovery.

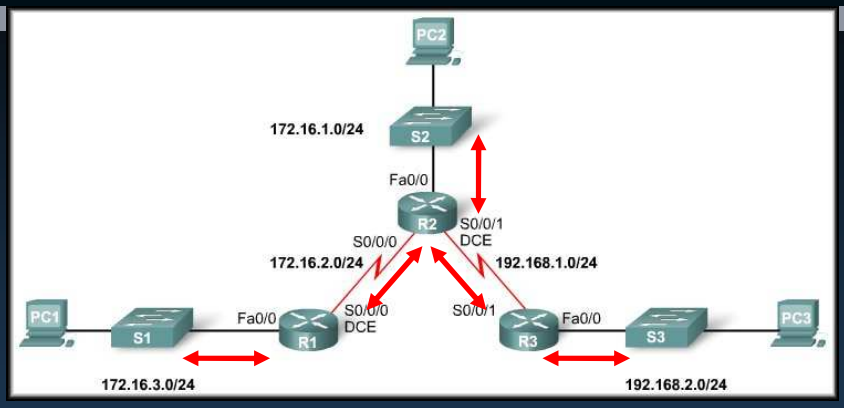


Cisco Discovery Protocol (CDP)



- Layer 3 Neighbours:
  - At Layer 3, routing protocols consider neighbors to be devices that share the same network address space.

Cisco Discovery Protocol (CDP)



- Layer 2 Neighbours:
  - CDP operates at Layer 2 only.
  - CDP neighbours are Cisco devices that share the same physical data connection.

Cisco Discovery Protocol (CDP)

- CDP Operation (**`show cdp neighbors`**):
  - Device ID: The configured host name of the device.
  - Port identifiers: The name of the local and remote ports that share the physical connection.
  - Capability: The type of device.
  - Platform: The hardware platform of the device.

```
R3#show cdp neighbors
Capability Codes: R - Router, T - Trans Bridge, B - Source Route Bridge
                  S - Switch, H - Host, I - IGMP, r - Repeater, P - Phone
Device ID    Local Intrfce   Holdtme    Capability   Platform    Port ID
S3           Fas 0/0          151            S       2960        Fas 0/1
R2           Ser 0/0/1        151            R       C1841       Ser 0/0/1
R3#
```

Cisco Discovery Protocol (CDP)

- CDP Operation (**show cdp neighbors detail**):

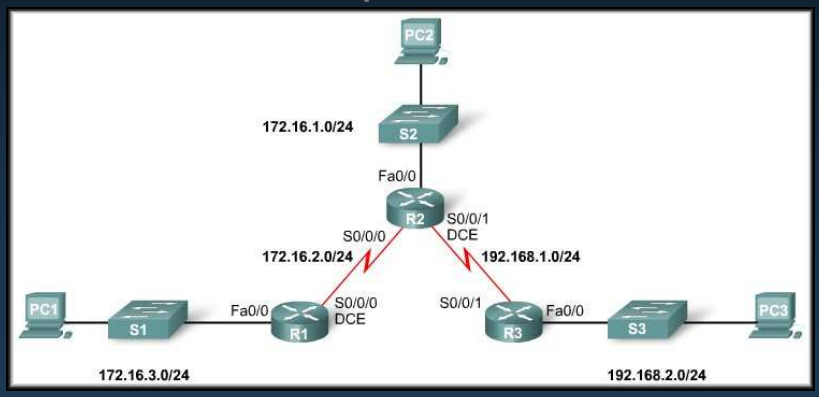
```
R3#show cdp neighbors detail

Device ID: R2
Entry address(es):
  IP address : 192.168.1.2
Platform: cisco C1841, Capabilities: Router
Interface: Serial0/0/1, Port ID (outgoing port): Serial0/0/1
Holdtime: 156

Version :
Cisco IOS Software, 1841 Software (C1841-IPBASE-M),
                Version 12.3(14)T7, RELEASE SOFTWARE (fc2)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2006 by Cisco Systems, Inc.
Compiled Mon 15-May-06 14:54 by pt_team

advertisement version: 2
Duplex: full

---------------------------

Device ID: S3
Entry address(es):
```


Cisco Discovery Protocol (CDP)

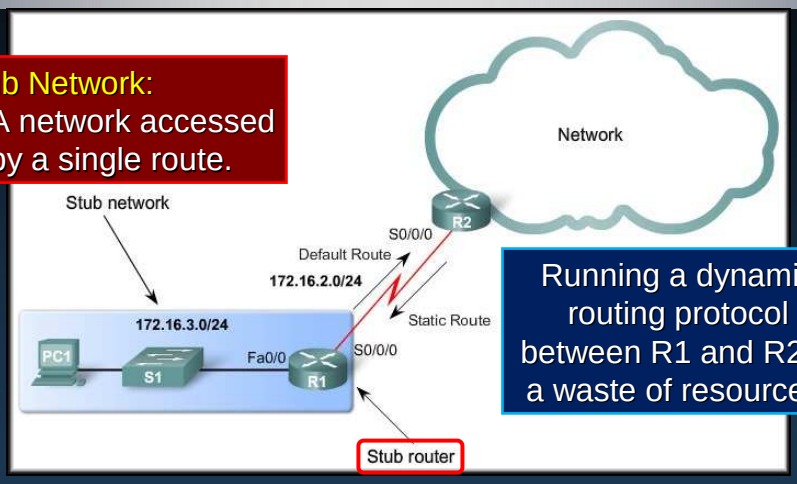
- CDP Operation:
  - Disabling CDP:
    - CDP can be a security risk.
    - To disable CDP globally, for the entire device, use the command **no cdp run**
    - To stop CDP advertisements on a particular interface, use the command **no cdp enable**

```
Router(config)# no cdp run

or

Router(config-if)# no cdp enable
```

Static Routes with "Next Hop" Addresses



Stub Network:
A network accessed by a single route.



Running a dynamic routing protocol between R1 and R2 is a waste of resources.

- Static routes are commonly used when routing from a **stub network**.

ip route Command

- Complete Syntax:
  - **Router(config)#ip route**
    prefix
    mask
    {ip-address | interface-type interface-number [ip-address]}
    [distance]
    [name]
    [permanent]
    [tag tag]

ip route Command

- Simpler version of the Syntax:

Router(config)# ip route *network-address subnet-mask*
{ip-address | exit-interface }

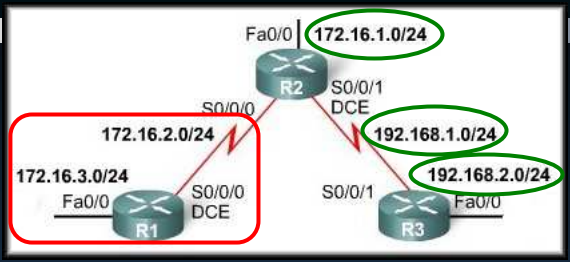
Parameter	Description
network-address	Destination network address of the remote network to be added to the routing table.
subnet-mask	Subnet mask of the remote network to be added to the routing table. The subnet mask can be modified to summarize a group of networks.
ip-address	Commonly referred to as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

ip route Command

- Simpler Syntax:
  - **ip route**
    [network address]
    [subnet mask]
    [ip address | exit interface]
  - Note:
    - The ***ip-address*** parameter is commonly referred to as the next-hop IP address.
    - The next hop IP Address is the IP Address *assigned to the interface of the destination router*.

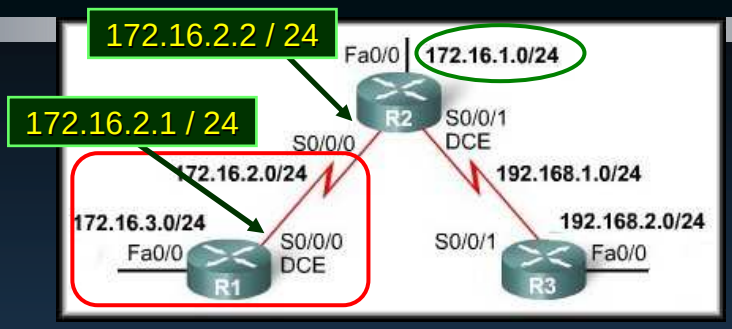
Configuring Static Routes

- R1 in our chapter topology knows about its directly connected networks.




```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

Configuring Static Routes



- Add a static route to R1 for the LAN on R2.

```
R1#conf t
R1(config)#ip route 172.16.1.0 255.255.255.0 172.16.2.2
```

Network

Subnet Mask

Next-Hop Address

Configuring Static Routes

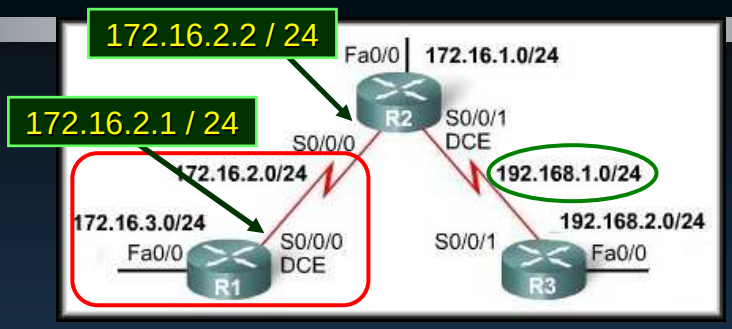
```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

BEFORE

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
```

AFTER

Configuring Routes to Two or More Networks



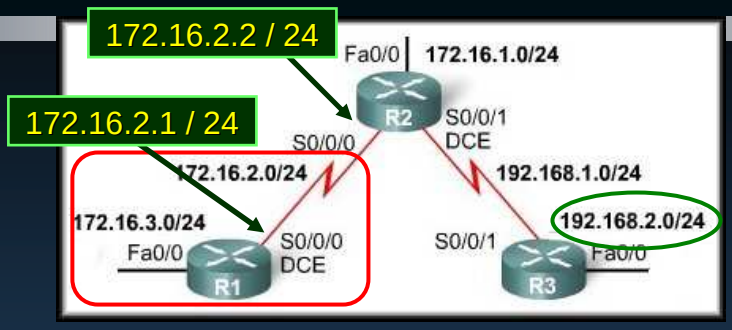
- Add a static route to R1 for the R2 to R3 WAN Link.

R1(config)#ip route Network = 192.168.1.0

Subnet Mask = 255.255.255.0

Next Hop Address = 172.16.2.2

Configuring Routes to Two or More Networks



- Add a static route to R1 for the R3 LAN.

R1(config)#ip route Network = 192.168.2.0

Subnet Mask = 255.255.255.0

Next Hop Address = 172.16.2.2

Configuring Routes to Two or More Networks

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
C       172.16.2.0 is directly connected, Serial0/0/0
```

BEFORE

```
R1#show ip route
Codes: C - connected, S - Static, I - IGRP, R - RIP,

<output omitted>

Gateway of last resort is not set

     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0 [1/0] via 172.16.2.2
S    192.168.1.0 [1/0] via 172.16.2.2
```

AFTER

Configuring Routes to Two or More Networks

- Verifying Static Routes:

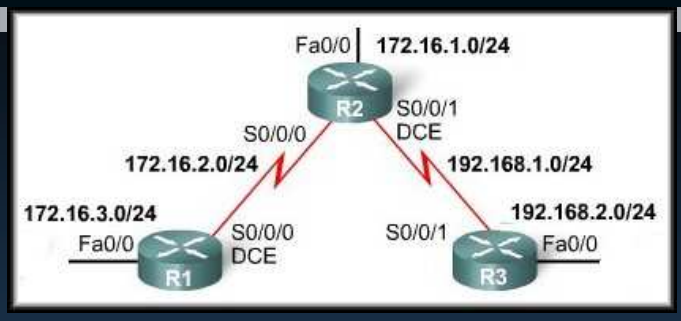
```
R1# show running-config
<output omitted>
!
ip route 172.16.1.0 255.255.255.0 172.16.2.2
ip route 192.168.1.0 255.255.255.0 172.16.2.2
ip route 192.168.2.0 255.255.255.0 172.16.2.2
!
<output omitted>
R1# copy running-config startup-config
```

Probably a good time to save your configuration.

Routing Table Principles and Static Routes

- Alex Zinin's Routing Table Principles:
  - Principle 1:
    - Every router makes its decision alone, based on the information it has in its own routing table.
  - Principle 2:
    - The fact that one router has certain information in its routing table does not mean that other routers have the same information.
  - Principle 3:
    - Routing information about a path from one network to another does not provide routing information about the reverse, or return, path.

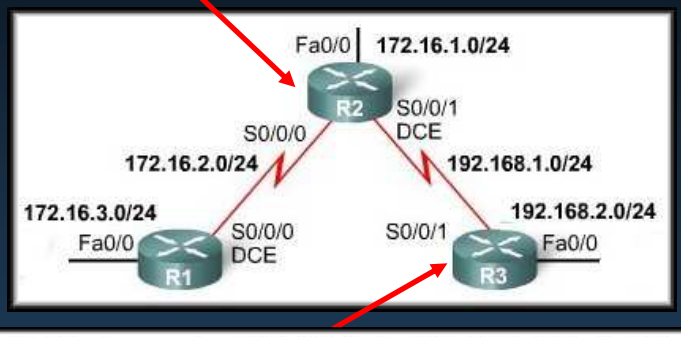
Routing Table Principles and Static Routes



- *Would a 'ping' from a PC on the LAN on R1 to a PC on the LAN on R3 work?*
  - NO……
    - According to the principles, each router makes its own decision based on its routing table.
    - There is no return path to R1 from R3.

Routing Table Principles and Static Routes

```
R2(config)# ip route 172.16.3.0 255.255.255.0 172.16.2.1
R2(config)# ip route 192.168.2.0 255.255.255.0 192.168.1.1
```




```
R3(config)# ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.3.0 255.255.255.0 192.168.1.2
```

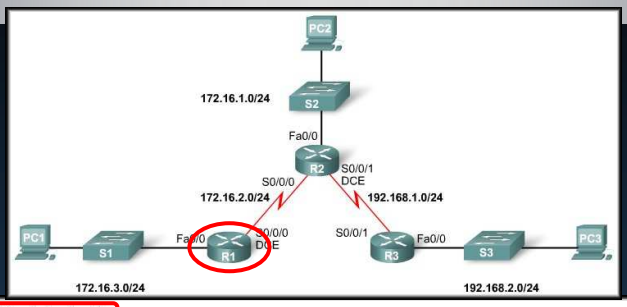

Verifying Static Routes

```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 [1/0] via 172.16.2.2
```

```
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, Serial0/0/0
S       172.16.3.0 [1/0] via 172.16.2.1
C    192.168.1.0/24 is directly connected, Serial0/0/1
S    192.168.2.0/24 [1/0] via 192.168.1.1
```

```
R3# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 192.168.1.2
S       172.16.2.0 [1/0] via 192.168.1.2
S       172.16.3.0 [1/0] via 192.168.1.2
C    192.168.1.0/24 is directly connected, Serial0/0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/0
```

Verifying Static Routes




```
R1# ping 172.16.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/28/32 ms
R1# ping 192.168.1.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/56 ms
R1# ping 192.168.1.2
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 28/29/32 ms
R1# ping 192.168.2.1
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 56/56/56 ms
R1#
```

Resolving to an Exit Interface

Packet for 192.168.2.20

```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 [1/0] via 172.16.2.2
```

- Before any packet is forwarded by a router, the routing table process must determine the exit interface to use to forward the packet.
- When the router has to perform multiple lookups in the routing table before forwarding a packet, it is performing a process known as a **Recursive Route Lookup**.

Exit Interface is Down

```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 [1/0] via 172.16.2.2
```

BEFORE

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

AFTER

- Cannot have a route if the exit interface does not exist.
- If an interface is manually taken down **(shutdown)** or a link fails, all routes that are resolved to that interface as the exit interface will be removed from the routing table.

Exit Interface is Down

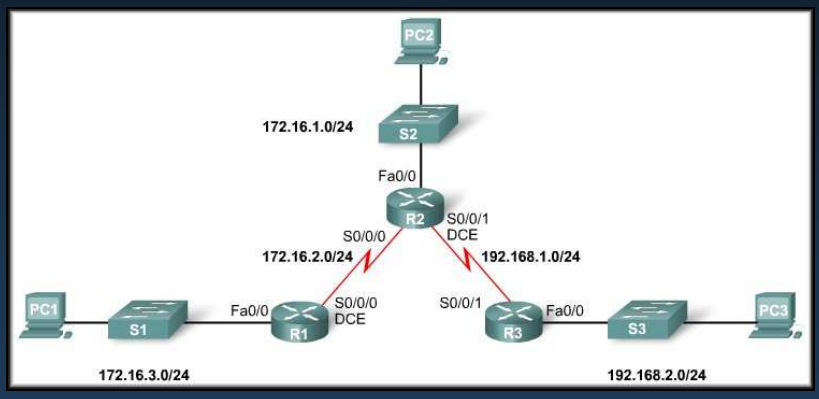
```
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 [1/0] via 172.16.2.2
```

REINSTATE

D

- If the interface is manually activated **(no shutdown)** or the link is restored, the static routes will be reinstated in the routing table.
  - The **ip route** commands still exist in the running configuration file.

Static Routes with Exit Interfaces




```
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.

- An alternative way of configuring static routes is to specify the exit interface instead of the next-hop address.

Configuring a Static Route with an Exit Interface

```
R1(config)# ip route 192.168.2.0 255.255.255.0 serial 0/0/0
R1(config)# end
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 is directly connected, Serial0/0/0
```

- Notice that the entry in the routing table no longer refers to the next-hop IP address but refers directly to the exit interface.
  - The table lookup will now resolve the route to the same Serial 0/0/0 interface in a single lookup.

Configuring a Static Route with an Exit Interface

```
R1(config)# ip route 192.168.2.0 255.255.255.0 serial 0/0/0
R1(config)# end
R1# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 172.16.2.2
C       172.16.2.0 is directly connected, Serial0/0/0
C       172.16.3.0 is directly connected, FastEthernet0/0
S    192.168.1.0/24 [1/0] via 172.16.2.2
S    192.168.2.0/24 is directly connected, Serial0/0/0
```

- Also note that the static route displays the route as **directly connected.**
- It is important to understand that this does not mean that this route is a directly connected network or a directly connected route.
- This route is still a static route.

Modifying Static Routes

- There is no way to modify a static route. **It must be deleted and reconfigured.**

You have entered this static route and testing fails.

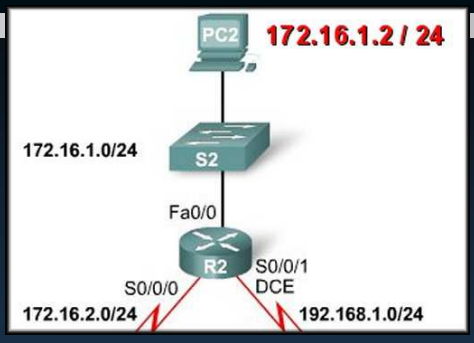
OOOPS! That's the wrong next-hop address!

```
R1(config)# ip route 192.168.2.0 255.255.255.0 192.168.2.2
```

The **no** form of the command is used to delete the invalid static route.

Re-enter the command line with the proper parameters.

Static Routes with Ethernet Interfaces



- R2 checks its ARP Cache for a matching MAC address for IP Address 172.16.1.2.
- If does not exist, R2 will send an ARP Request and PC2 sends an ARP Reply.
- R2 uses PC2's MAC address and IP Address 172.16.1.2 in the frame as the destination MAC and IP addresses.

Static Routes with Ethernet Interfaces

NOT Recommended

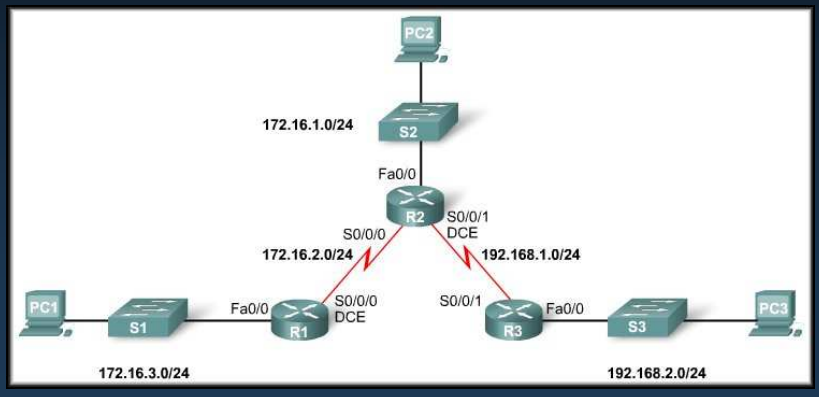
```
R1(config)# ip route 192.168.2.0 255.255.255.0 fastethernet0/1

R1(config)# ip route 192.168.2.0 255.255.255.0 fastethernet0/1 172.16.2.2
```

Recommended

- It is best not to use only an exit interface with Ethernet interfaces.
- Since many different devices can be sharing the same multi-access network, the Router will have difficulty determining the destination MAC address.
- Use both the exit interface and next-hop address for Ethernet exit interfaces.

Introduction to Routing and Packet Forwarding

Summary and Default Static Routes



Summary Static Routes

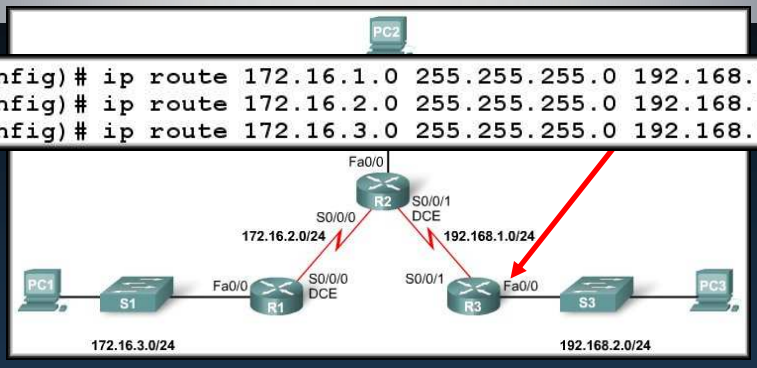
- Route Summarization:
  - A summary route is a single route that can be used to represent multiple routes.
    - Generally a set of contiguous networks.
    - Have the same exit interface or next-hop IP address.
    - Creates smaller routing tables
    - More efficient routing table lookup process.

FYI

As of March 2007, there are more than 200,000 routes in the Internet core routers. Most of these are summarized routes.

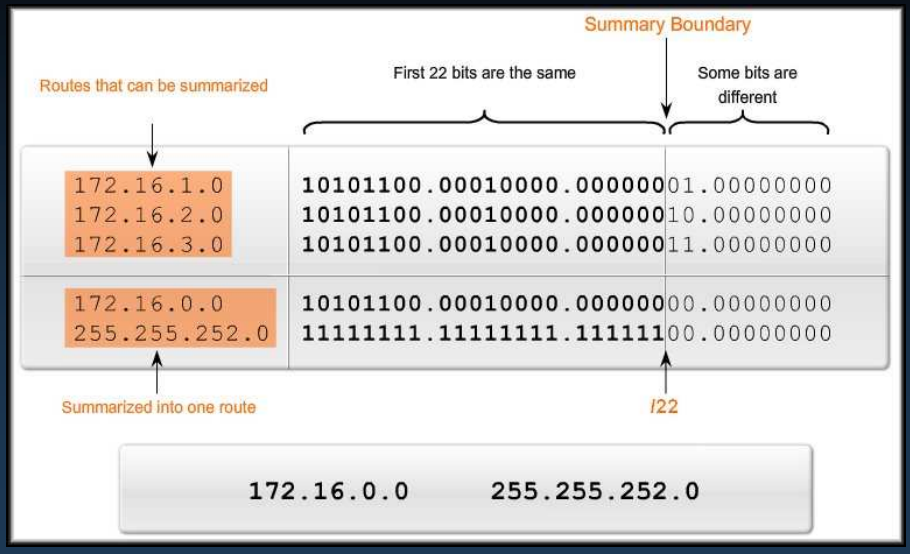
Summary Static Routes

```
R3(config)# ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)# ip route 172.16.3.0 255.255.255.0 192.168.1.2
```



- R3 has three static routes configured.
  - All three routes are forwarding traffic out the same Serial 0/0/1 interface.
  - Can be summarized to
    172.16.0.0 / 22 (255.255.252.0)

Summary Static Routes



Summary Static Routes

```
R3# show ip route
<output omitted>
     172.16.0.0/24 is subnetted, 3 subnets
S       172.16.1.0 [1/0] via 192.168.1.2
S       172.16.2.0 [1/0] via 192.168.1.2
```

BEFORE

```
R3(config)# no ip route 172.16.1.0 255.255.255.0 192.168.1.2
R3(config)# no ip route 172.16.2.0 255.255.255.0 192.168.1.2
R3(config)# no ip route 172.16.3.0 255.255.255.0 192.168.1.2

R3(config)# ip route 172.16.0.0 255.255.252.0 192.168.1.2
```

```
     172.16.0.0/22 is subnetted, 1 subnets
S       172.16.0.0 [1/0] via 192.168.1.2
C    192.168.1.0/24 is directly connected, Serial0/1
C    192.168.2.0/24 is directly connected, FastEthernet0/0
```

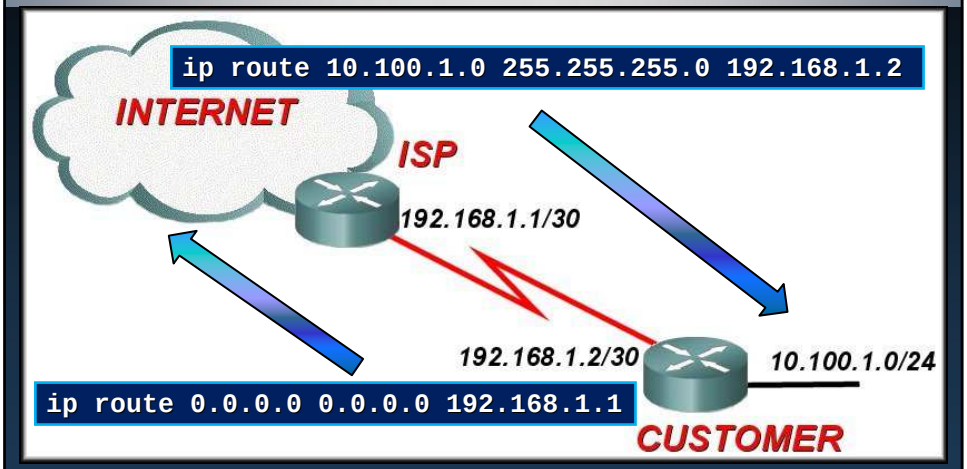
- Any packet with a destination IP address belonging to the 172.16.1.0/24, 172.16.2.0/24, or 172.16.3.0/24 network matches this summarized route.

Default Static Routes

- A default route is a static route that is used when there are no routes that have a specific match to the destination network.
- Default routes are used:
  - When a router has only one other router to which it is connected. This condition is known as a stub router.

```
ip route 0.0.0.0 0.0.0.0
            [ip address | interface]
```


Default Static Routes



- A common use for static routes is connecting a company's edge router to the ISP network.

Default Static Routes

```
CUSTOMER#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
<output omitted>
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is 192.168.1.1 to network 0.0.0.0

   10.0.0.0/8 is subnetted, 1 subnets
C     10.100.1.0/24 is directly connected, FastEthernet0/0
C     192.168.1.0/24 is directly connected, Serial0/0/1
S*    0.0.0.0/0 [1/0] via 192.168.1.1
```

- A common use for static routes is connecting a company's edge router to the ISP network.

Introduction to Routing and Packet Forwarding

Managing and Troubleshooting Static Routes