

# Chapter 6: Network Layer

Introduction to Networks v5.1

## Chapter Outline

- 6.0 Introduction
- 6.1 Network Layer Protocols
- 6.2 Routing
- 6.3 Routers
- 6.4 Configure a Cisco Router
- 6.5 Summary

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## Section 6.1: Network Layer Protocols

Upon completion of this section, you should be able to:

- Describe the purpose of the network layer in data communication.
- Explain why the IPv4 protocol requires other layers to provide reliability. (To include: media independent, unreliable, and connectionless.)
- Explain the role of the major header fields in the IPv4 packet.
- Explain the role of the major header fields in the IPv6 packet.

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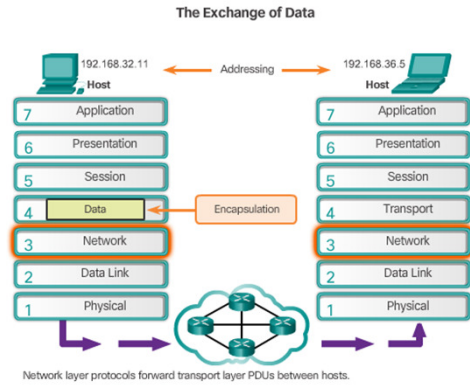
## Topic 6.1.1: Network Layer in Communication

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## The Network Layer

End to End Transport processes

- Addressing end devices
- Encapsulation
- Routing
- De-encapsulating



## Network Layer Protocols



- Internet Protocol version 4 (IPv4)
- Internet Protocol version 6 (IPv6)

## Topic 6.1.2: Characteristics of the IP Protocol



## Encapsulating IP

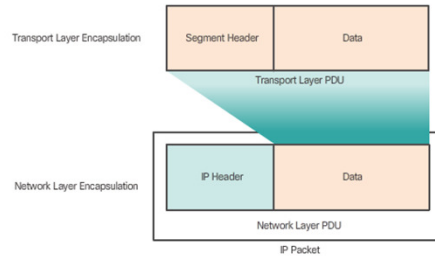
Transport Layer PDU = Segment



The transport layer adds a header so segments can be reassembled at the destination.

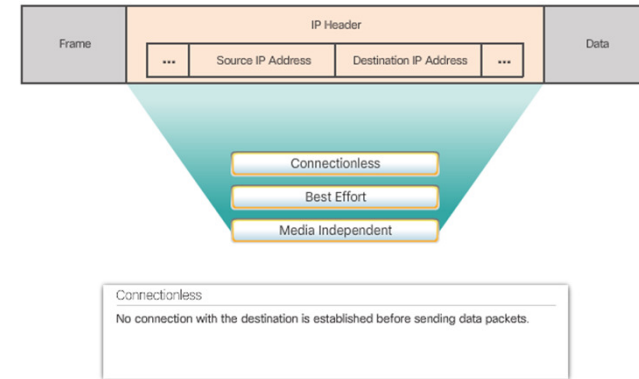
## Encapsulating IP (cont.)

Network Layer PDU = IP Packet



The network layer adds a header so packets can be routed through complex networks and reach their destination. In TCP/IP based networks, the network layer PDU is the IP Packet.

## Characteristics of IP



## IP - Connectionless



A letter is sent.

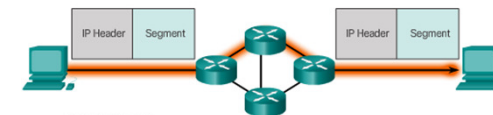
The sender doesn't know:

- If the receiver is present
- If the letter arrived
- If the receiver can read the letter

The receiver doesn't know:

- When it is coming

## IP - Connectionless (cont.)



A packet is sent.

The sender doesn't know:

- If the receiver is present
- If the packet arrived
- If the receiver can read the packet

The receiver doesn't know:

- When it is coming

### IP – Best Effort Delivery

Packets are routed through the network quickly.

Some packets may be lost en route.

As an unreliable network layer protocol, IP does not guarantee that all sent packets will be received. Other protocols manage the process of tracking packets and ensuring their delivery.

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### IP – Media Independent

IP packets can travel over different media.

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### Topic 6.1.3: IPv4 Packet

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### IPv4 Packet Header

Byte 1	Byte 2		Byte 3		Byte 4	
Version	Internet Header Length	Differentiated Services (DS) DSCP   ECN		Total Length		
Identification		Flag	Fragment Offset			
Time-to-Live	Protocol	Header Checksum				
Source IP Address						
Destination IP Address						
...						

- Version = 0100
- DS = Packet Priority
- TTL = Limits life of Packet
- Protocol = Upper layer protocol such as TCP
- Source IP Address = source of packet
- Destination IP Address = destination of packet

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Topic 6.1.4:  
IPv6 Packet



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Limitations of IPv4

- IP address depletion
- Internet routing table expansion
- Lack of end-to-end connectivity



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Introducing IPv6

- Increased address space
- Improved packet handling
- Eliminates the need for NAT

4 billion IPv4 addresses

4,000,000,000

**vs.**

340 undecillion IPv6 addresses

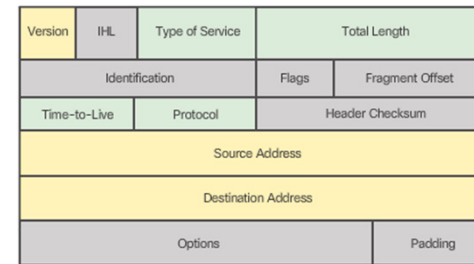
340,000,000,000,000,000,000,000,000,000,000,000,000,000

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Encapsulating IPv6

IPv4 Header



IPv6 has a simplified header

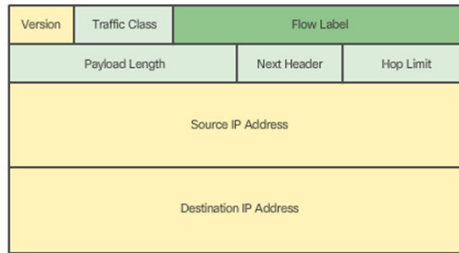
- - Field names kept from IPv4 to IPv6
- - Name and position changed in IPv6
- - Fields not kept in IPv6

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## Encapsulating IPv6 (cont.)

IPv6 Header



IPv6 has a simplified header

**Legend**

- Field names kept from IPv4 to IPv6
- Name and position changed in IPv6
- New field in IPv6

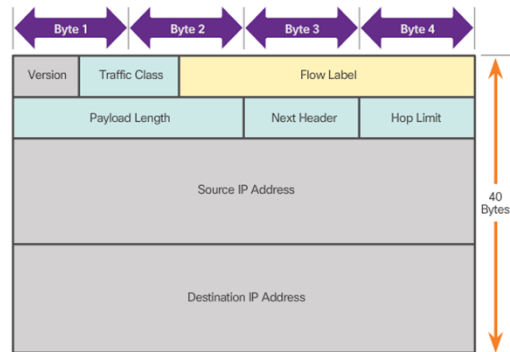
## Encapsulating IPv6 (cont.)

**IPv6 Advantages include:**

- Better routing efficiency for performance and forwarding-rate scalability
- No requirement for processing checksums
- Simplified and more efficient extension header mechanisms (as opposed to the IPv4 Options field)
- A Flow Label field for per-flow processing with no need to open the transport inner packet to identify the various traffic flows

## IPv6 Packet Header

Fields in the IPv6 Packet Header



- Version = 0110
- Traffic Class = Priority
- Flow Label = same flow will receive same handling
- Payload Length = same as total length
- Next Header = Layer 4 Protocol
- Hop Limit = Replaces TTL field

## Section 6.2: Routing

Upon completion of this section, you should be able to:

- Explain how a host device uses routing tables to direct packets to itself, a local destination, or a default gateway.
- Compare a host routing table to a routing table in a router.

### Topic 6.2.1: How a Host Routes

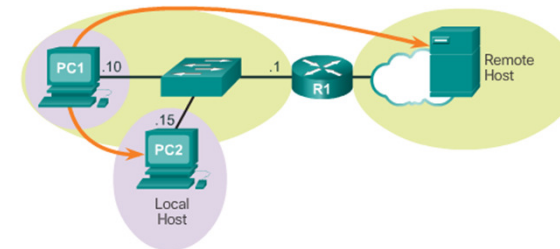


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### Host Forwarding Decision

#### Three Types of Destinations

- Itself
- Local Host
- Remote Host



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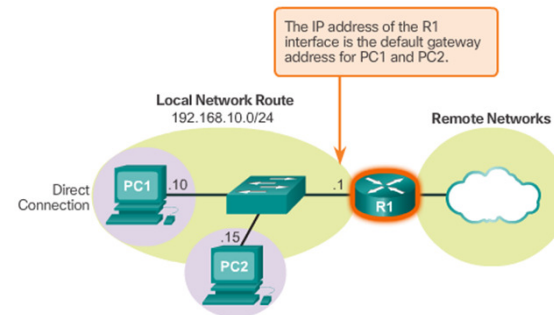
### Default Gateway

- Routes traffic to other networks
- Has a local IP address in the same address range as other hosts on the network
- Can take data in and forward data out

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### Using the Default Gateway

#### Host Default Gateway



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# Host Routing Tables

IPv4 Routing Table for PC1



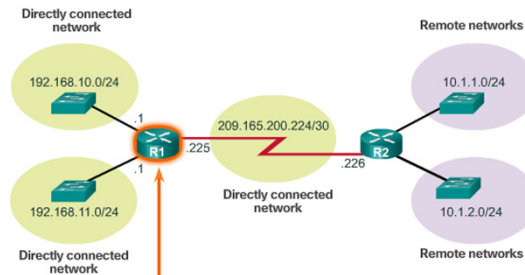
```
C:\Users\PC1>netstat -r
<output omitted>
IPv4 Route Table
-----
Active Routes:
Network  Destination     Netmask          Gateway         Interface  Metric
-----  -
0.0.0.0  0.0.0.0         0.0.0.0         192.168.10.1   192.168.10.10  25
127.0.0.0 255.0.0.0       255.0.0.0       On-Link        127.0.0.1     306
127.0.0.1 255.255.255.255 255.255.255.255 On-Link        127.0.0.1     306
127.255.255.255 255.255.255.255 255.255.255.255 On-Link        127.0.0.1     306
192.168.10.0 255.255.255.0   255.255.255.0   On-Link        192.168.10.10 281
192.168.10.10 255.255.255.255 255.255.255.255 On-Link        192.168.10.10 281
192.168.10.255 255.255.255.255 255.255.255.255 On-Link        192.168.10.10 281
224.0.0.0 240.0.0.0       240.0.0.0       On-Link        127.0.0.1     306
224.0.0.0 240.0.0.0       240.0.0.0       On-Link        192.168.10.10 281
255.255.255.255 255.255.255.255 255.255.255.255 On-Link        127.0.0.1     306
255.255.255.255 255.255.255.255 255.255.255.255 On-Link        192.168.10.10 281
<output omitted>
```

# Topic 6.2.2: Router Routing Tables



# Router Packet Forwarding Decision

Directly Connected and Remote Network Routes



R1 has three directly connected networks: 192.168.10.0/24, 192.168.11.0/24, and 209.165.200.224/30. R1 also has two remote networks that it can learn from R2: 10.1.1.0/24 and 10.1.2.0/24.

# IPv4 Router Routing Table

R1 IPv4 Routing Table



```
R1#show ip route
<output omitted>
Gateway of last resort is not set
10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D 10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05,
Serial0/0/0
D 10.1.2.0/24 [90/2170112] via 209.165.200.226, 00:00:05,
Serial0/0/0
192.168.10.0/24 is variably subnetted, 2 subnets, 3 masks
C 192.168.10.0/24 is directly connected, GigabitEthernet0/0
L 192.168.10.1/32 is directly connected, GigabitEthernet0/0
192.168.11.0/24 is variably subnetted, 2 subnets, 3 masks
C 192.168.11.0/24 is directly connected, GigabitEthernet0/1
L 192.168.11.1/32 is directly connected, GigabitEthernet0/1
209.165.200.0/24 is variably subnetted, 2 subnets, 3 masks
C 209.165.200.224/30 is directly connected, Serial0/0/0
L 209.165.200.225/32 is directly connected, Serial0/0/0
```



## Directly Connected Routing Table Entries

Understanding Local Route Entries

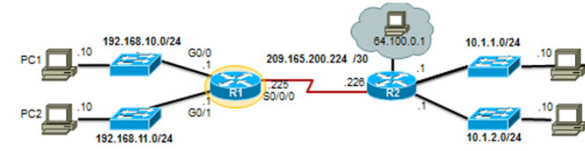


```

C   192.168.10.0/24 is directly connected, GigabitEthernet0/0
L   192.168.10.1/32 is directly connected, GigabitEthernet0/0
    
```

- Route source** – Identifies how the network was learned by the router.
- Destination network** – Identifies the destination network and how it was learned.
- Outgoing interface** – Identifies the exit interface to use to forward a packet toward the final destination.

## Remote Network Routing Table Entries



```

D   10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05, Serial10/0/0
    
```

<b>A</b>	Identifies how the network was learned by the router.
<b>B</b>	Identifies the destination network.
<b>C</b>	Identifies the administrative distance (trustworthiness) of the route source.
<b>D</b>	Identifies the metric to reach the remote network.
<b>E</b>	Identifies the next hop IP address to reach the remote network.
<b>F</b>	Identifies the amount of elapsed time since the network was discovered.
<b>G</b>	Identifies the outgoing interface on the router to reach the destination network.

## Next-Hop Address



```

R1# show ip route
Gateway of last resort is not set

10.0.0.0/8 is variably subnetted, 2 subnets, 2 masks
D   10.1.1.0/24 [90/2170112] via 209.165.200.226, 00:00:05,
    Serial10/0/0
D   10.1.2.0/24 [90/2170112] via 209.165.200.226, 00:00:05,
    Serial10/0/0
192.168.10.0/24 is variably subnetted, 2 subnets, 3 masks
C   192.168.10.0/24 is directly connected, GigabitEthernet0/0
L   192.168.10.1/32 is directly connected, GigabitEthernet0/0
192.168.11.0/24 is variably subnetted, 2 subnets, 3 masks
C   192.168.11.0/24 is directly connected, GigabitEthernet0/1
L   192.168.11.1/32 is directly connected, GigabitEthernet0/1
209.165.200.0/24 is variably subnetted, 2 subnets, 3 masks
C   209.165.200.224/30 is directly connected, Serial10/0/0
L   209.165.200.225/32 is directly connected, Serial10/0/0
R1#
    
```

## Section 6.3: Routers

Upon completion of this section, you should be able to:

- Describe the common components and interfaces of a router.
- Describe the boot-up process of a Cisco IOS router.

### Topic 6.3.1: Anatomy of a Router



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## A Router is a Computer/Router CPU and OS

Routers require:

- Central processing units (CPUs)
- Operating systems (OSs)

Memory consisting of:

- Random-access memory (RAM)
  - Read-only memory (ROM)
  - Nonvolatile random-access memory (NVRAM)
  - Flash
- The Cisco Internetwork Operating System (IOS) is the system software used for most Cisco devices regardless of the size and type of the device.

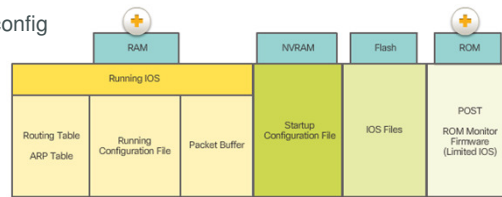
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## Router Memory

RAM uses the following applications and processes:

- IOS and running-config
- Routing table
- ARP cache
- Packet buffering



ROM stores the following:

- Bootup information that provides the startup instructions
- Power-on self-test (POST) that tests all the hardware components
- Limited IOS to provide a backup version of the IOS.

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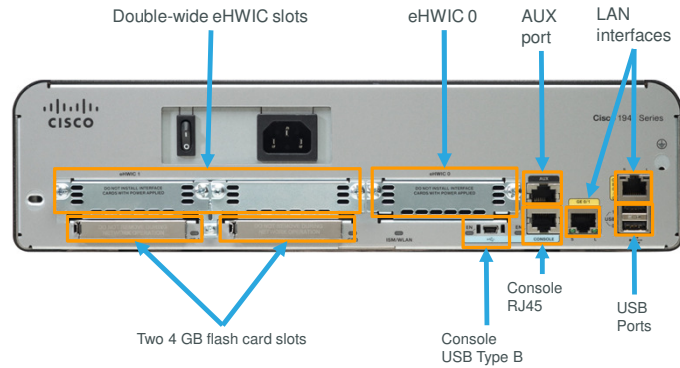
## Inside of a Router



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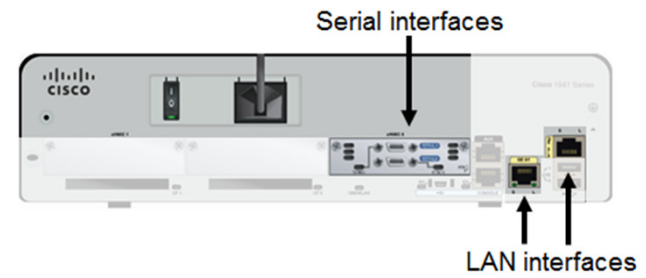
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## Connect to a Router



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## LAN and WAN Interfaces



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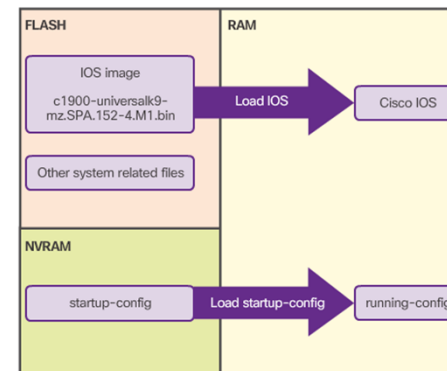
## Topic 6.3.2: Router Boot-up



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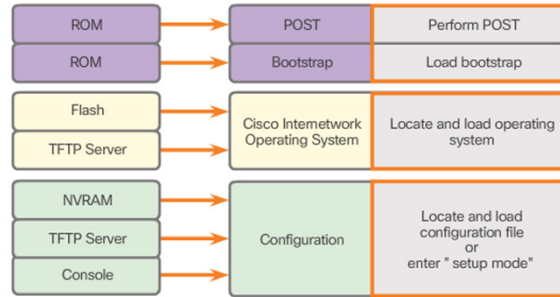
## Bootset Files

Files Copied to RAM During Bootup



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## Router Bootup Process



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## Show version output

```

Router#show version
Cisco IOS Software, C1900 Software (C1900-UNIVERSALK9-M),
Version 15.2(4)M1, RELEASE SOFTWARE (fc1)
Technical Support: http://www.cisco.com/techsupport
Copyright (c) 1986-2012 by Cisco Systems, Inc.
Compiled Thu 26-Jul-12 19:34 by prod_rel_team

ROM: System Bootstrap, Version 15.0(1r)M15,
RELEASE SOFTWARE (fc1)

Router uptime is 10 hours, 9 minutes
System returned to ROM by power-on
System image file is
"flash0:c1900-universalk9-mz.SPA.152-4.M1.bin"
Last reload type: Normal Reload
Last reload reason: power-on

<output omitted>

Cisco CISC01941/K9 (revision 1.0)
with 446464K/77824K bytes of memory.
Power-on-Reset ID: F0X1C3682B
  
```

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## Show version output (cont.)

```

2 Gigabit Ethernet interfaces
2 Serial(sync/async) interfaces
1 terminal line
DRAM configuration is 64 bits wide with parity disabled.
255K bytes of non-volatile configuration memory.
250880K bytes of ATA System CompactFlash 0 (Read/Write)

<output omitted>

Technology Package License Information for Module: 'c1900'

-----
Technology   Technology-package   Technology-package
Current      Type                 Next reboot
-----
ipbase       ipbasek9             Permanent           ipbasek9
security     None                 None                None
data         None                 None                None

Configuration register is 0x2142
(will be 0x2102 at next reload)
  
```

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## Section 6.4: Configure a Cisco Router

Upon completion of this section, you should be able to:

- Configure initial settings on a Cisco IOS router.
- Configure two active interfaces on a Cisco IOS router.
- Configure devices to use the default gateway.

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## Topic 6.4.1: Configure Initial Settings



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## Basic Switch Configuration Steps

- Configure the device name
  - hostname *name*
- Secure user EXEC mode
  - line console 0
  - password *password*
  - login
- Secure remote Telnet / SSH access
  - line vty 0 15
  - password *password*
  - login
- Secure privilege EXEC mode
  - enable secret *password*
- Secure all passwords in the config file
  - service password-encryption
- Provide legal notification
  - banner motd *delimiter message delimiter*
- Configure the management SVI
  - interface *vlan 1*
  - ip address *ip-address subnet-mask*
  - no shutdown
- Save the configuration
  - copy *running-config startup-config*

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## Basic Router Configuration Steps

### Limiting Device Access

- Configure the device name
  - hostname *name*
- Secure user EXEC mode
  - line console 0
  - password *password*
  - login
- Secure remote Telnet / SSH access
  - line vty 0 15
  - password *password*
  - login
- Secure privilege EXEC mode
  - enable secret *password*
- Secure all passwords in the config file
  - service password-encryption
- Provide legal notification
  - banner motd *delimiter message delimiter*
- Save the configuration
  - copy *running-config startup-config*

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## Topic 6.4.2: Configure Interfaces



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## Configure Router Interfaces

- Configure the interface
  - interface type-and-number
  - description description-text
  - ip address ipv4-address subnet-mask
  - no shutdown

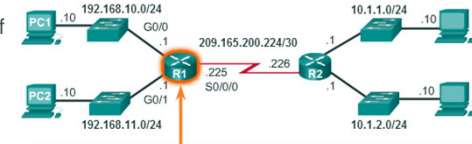


```

R1>conf t
Enter configuration commands, one per line.
End with CNTRL-Z.
R1 (config)#
R1 (config)#interface gigabitEthernet 0/0
R1 (config-if)#ip address 192.168.10.1 255.255.255.0
R1 (config-if)#description Link to LAN-10
R1 (config-if)#no shutdown
%LINE-5-CHANGED: Interface GigabitEthernet0/0,
changed state to up
%LINK-5-UPDOWN: Line protocol on Interface
GigabitEthernet0/0, changed state to up
    
```

## Verify Interface Configuration

- show ip route** - Displays the contents of the IPv4 routing table stored in RAM.
- show interfaces** - Displays statistics for all interfaces on the device.
- show ip interface** - Displays the IPv4 statistics for all interfaces on a router.



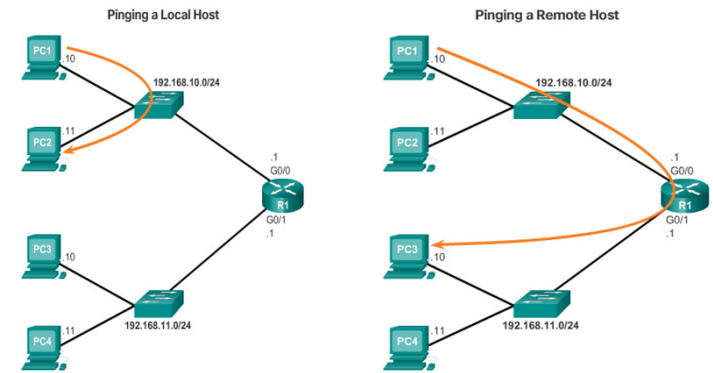
```

R1#show ip interface brief
Interface      IP-Address      OK? Method Status
GigabitEthernet0/0  192.168.10.1    YES manual up
GigabitEthernet0/1  192.168.11.1    YES manual up
Serial0/0/0       209.165.200.225 YES manual up
Serial0/0/1       unassigned      YES NVRAM administratively down
Vlan1             unassigned      YES NVRAM administratively down
R1#
R1#ping 209.165.200.226
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.226:
    
```

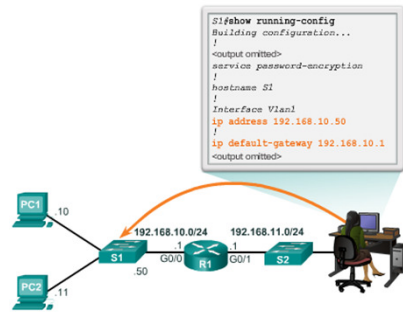
## Topic 6.4.3: Configure the Default Gateway



## Default Gateway for a Host



## Default Gateway for a Switch



If the default gateway was not configured on S1, response packets from S1 would not be able to reach the administrator at 192.168.11.10. The administrator would not be able to manage the device remotely.

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## Section 6.5: Summary

Chapter Objectives:

- Explain how network layer protocols and services support communications across data networks.
- Explain how routers enable end-to-end connectivity in a small to medium-sized business network.
- Explain how devices route traffic in a small to medium-sized business network.
- Configure a router with basic configurations.

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Thank you.

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