Cisco Networking Academy
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Chapter 6: Network Layer

Introduction to Networks v5.1

Chapter Outline

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.

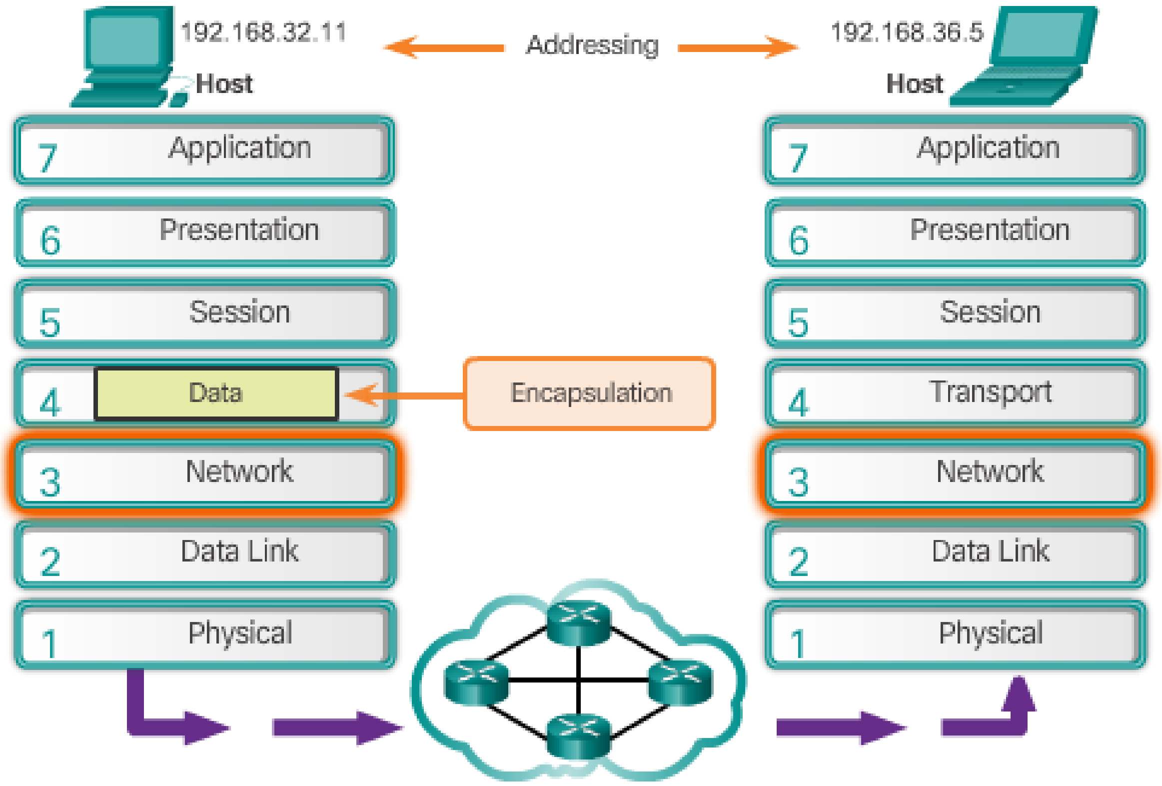
Topic 6.1.1:
Network Layer in Communication

The Network Layer

End to End Transport processes

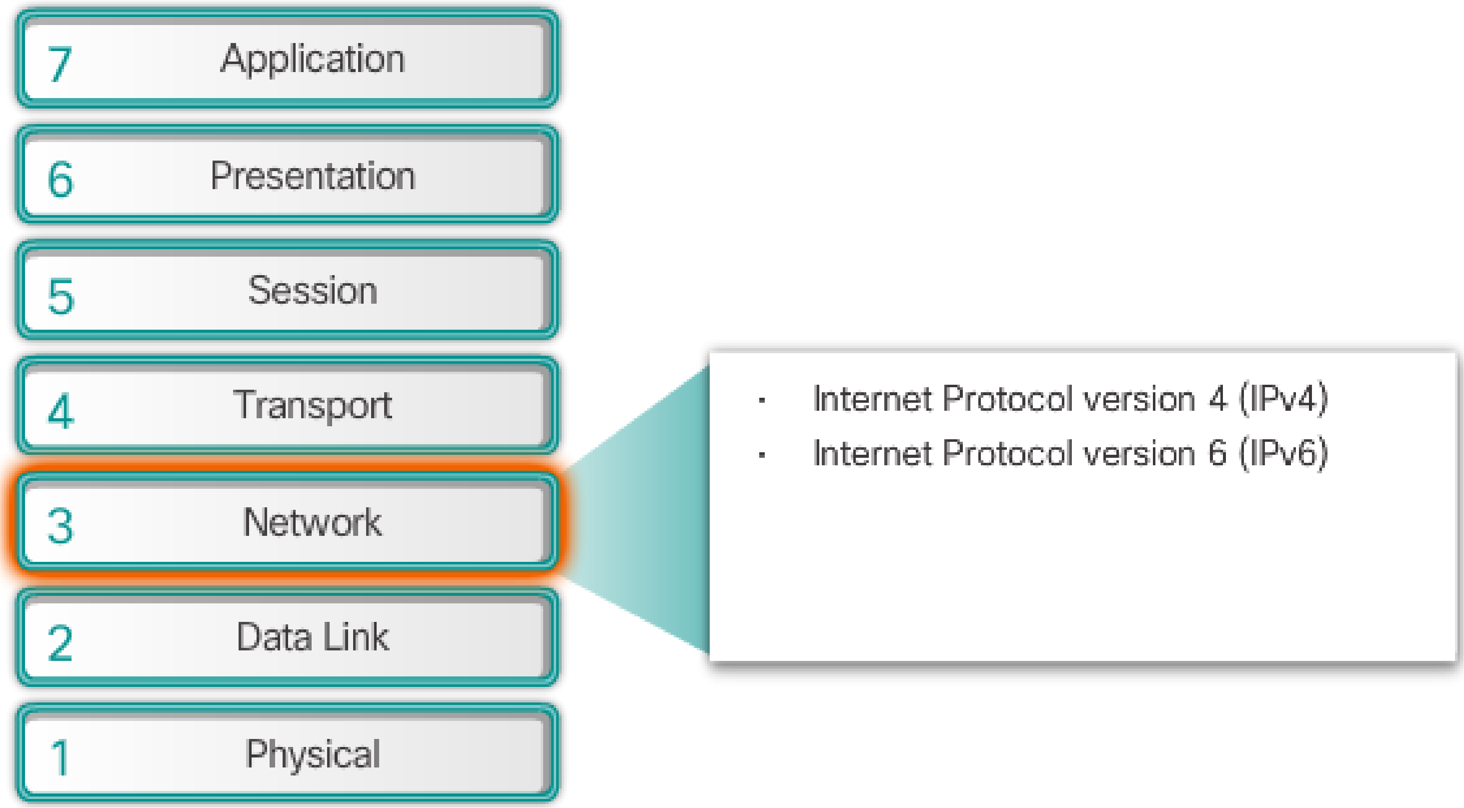
- Addressing end devices
- Encapsulation
- Routing
- De-encapsulating

The Exchange of Data



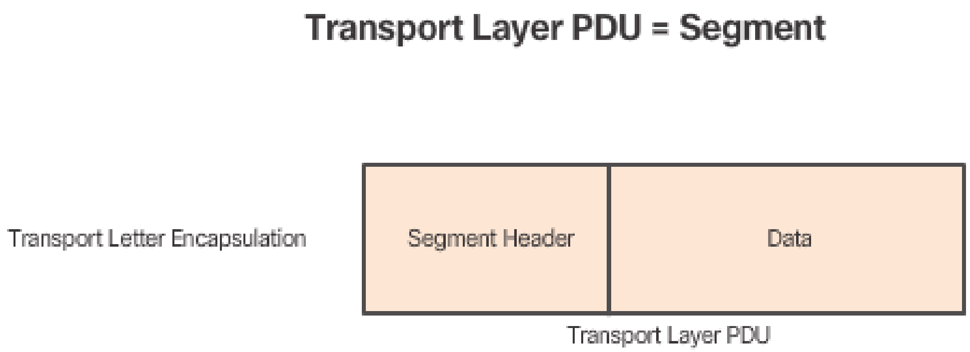
Network layer protocols forward transport layer PDUs between hosts.

Network Layer Protocols



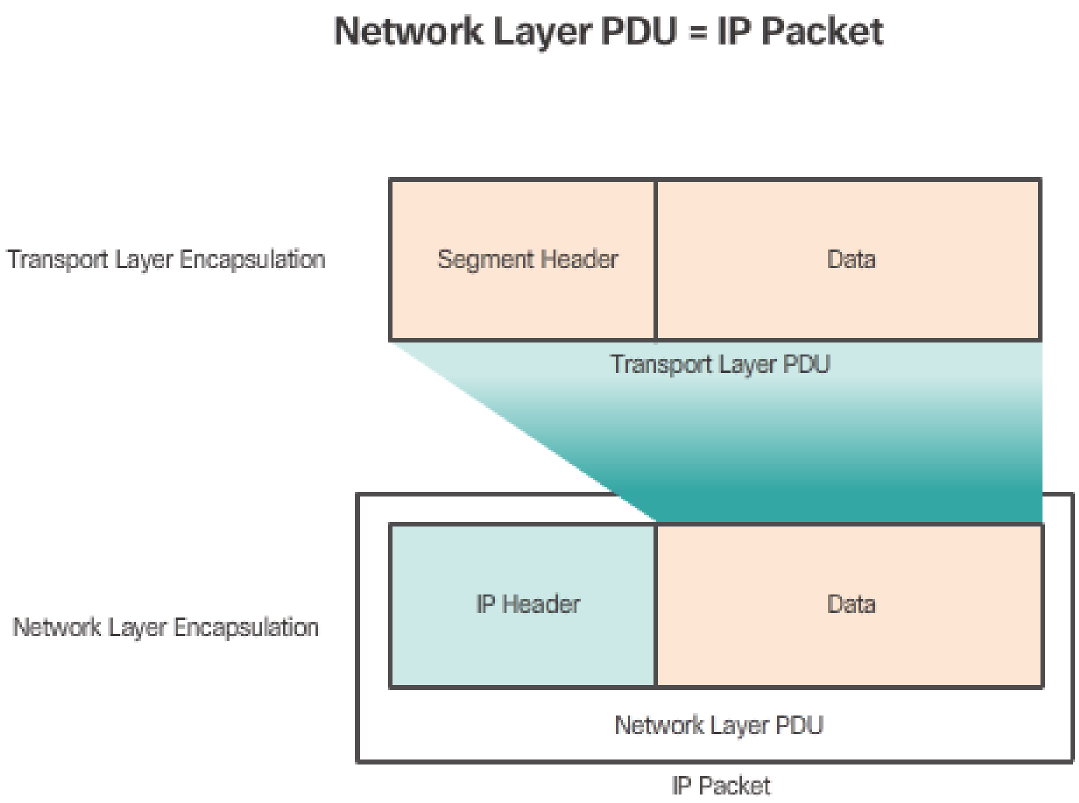
Topic 6.1.2:
Characteristics of the IP Protocol

Encapsulating IP



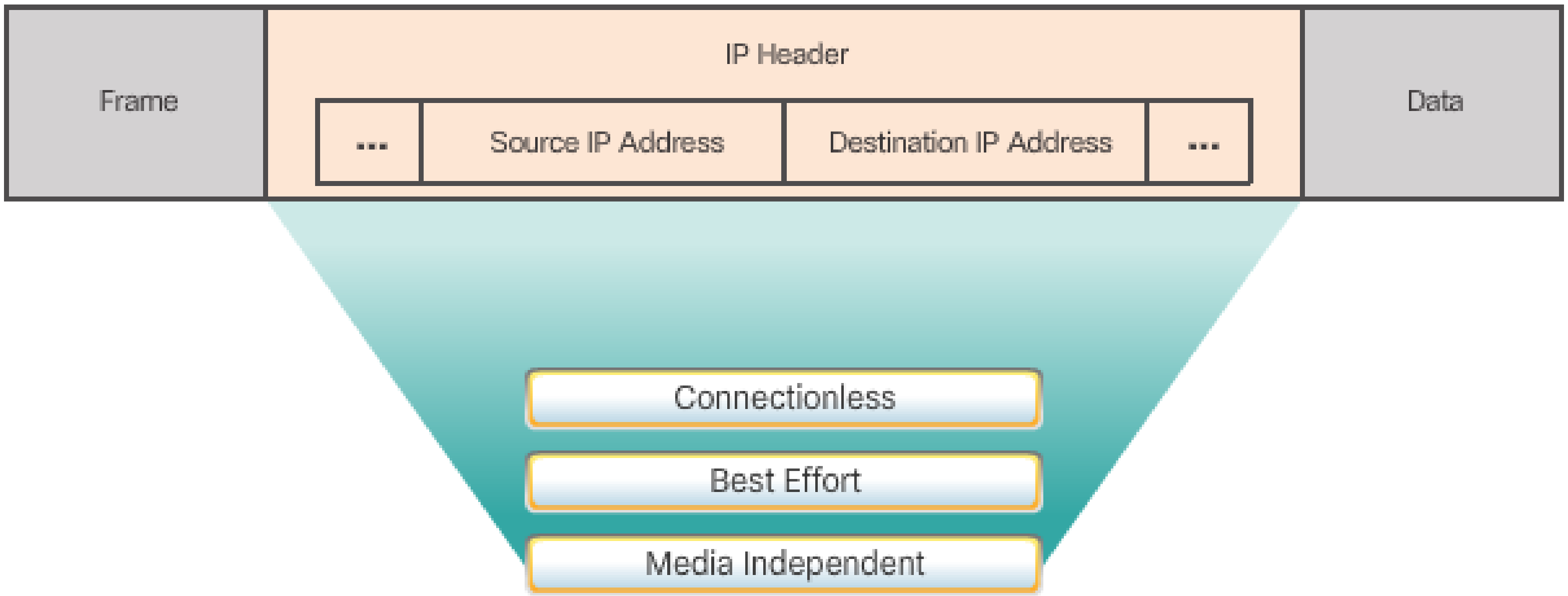
The transport layer adds a header so segments can be reassembled at the destination.

Encapsulating IP (cont.)



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



Connectionless

No connection with the destination is established before sending data packets.

IP - Connectionless

A letter is sent.

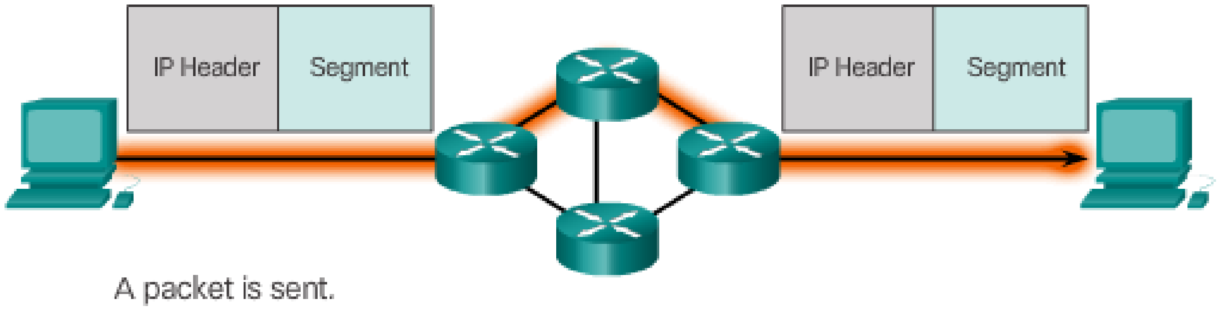
The sender doesn't know:

- 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.)



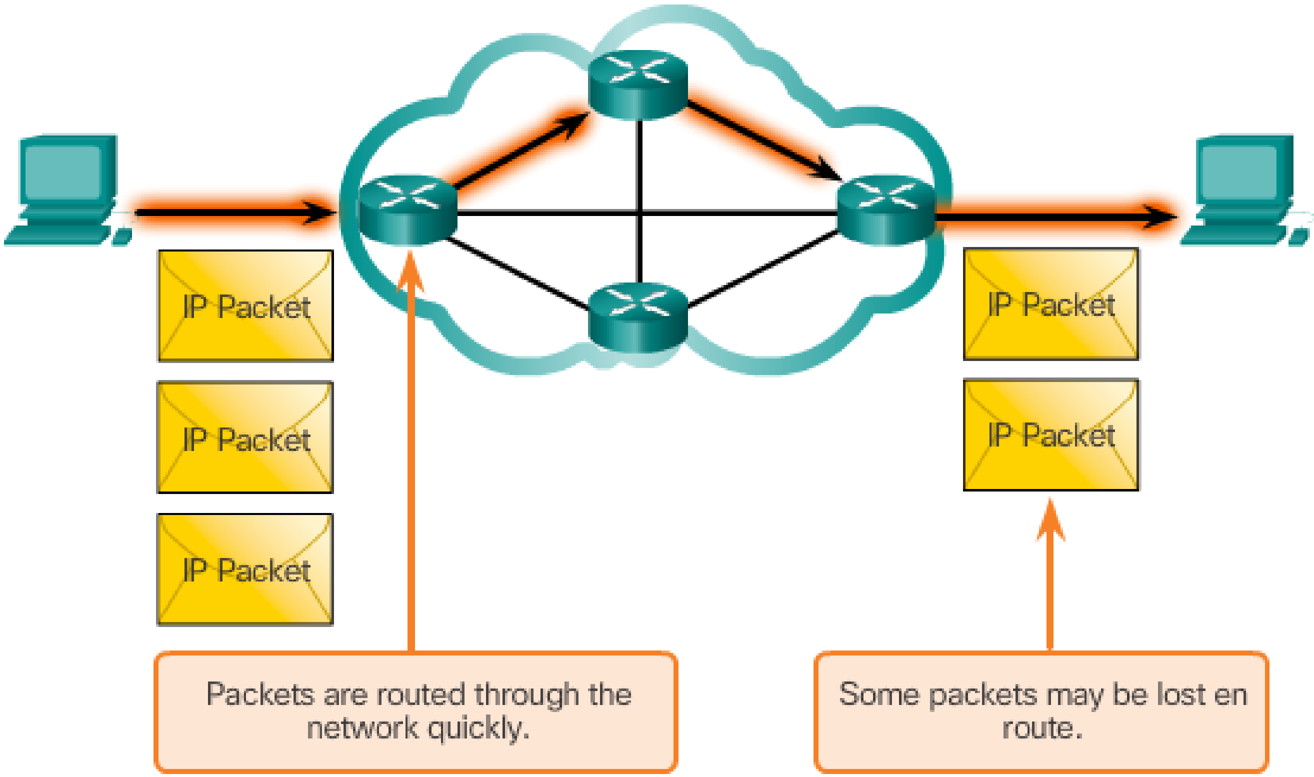
The sender doesn't know:

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

The receiver doesn't know:

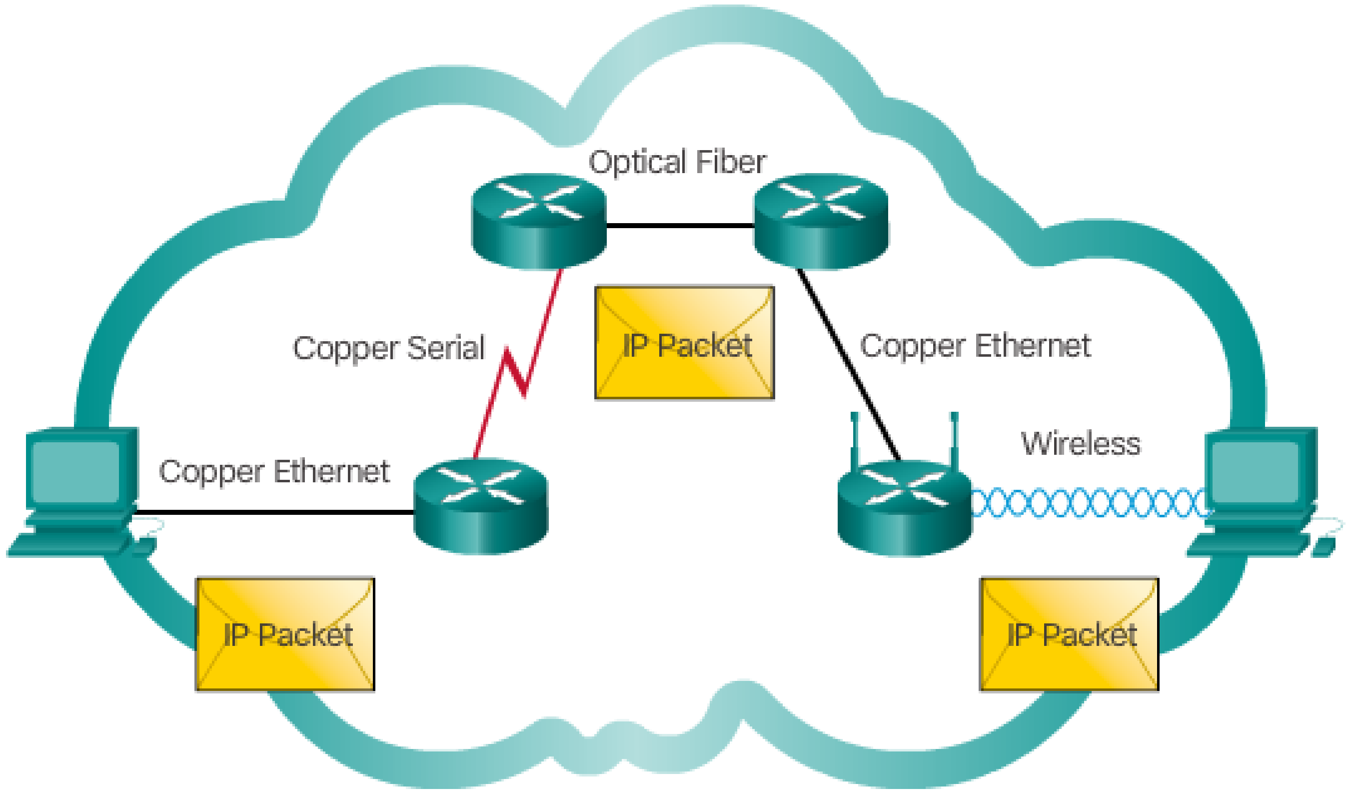
- When it is coming

IP – Best Effort Delivery



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.

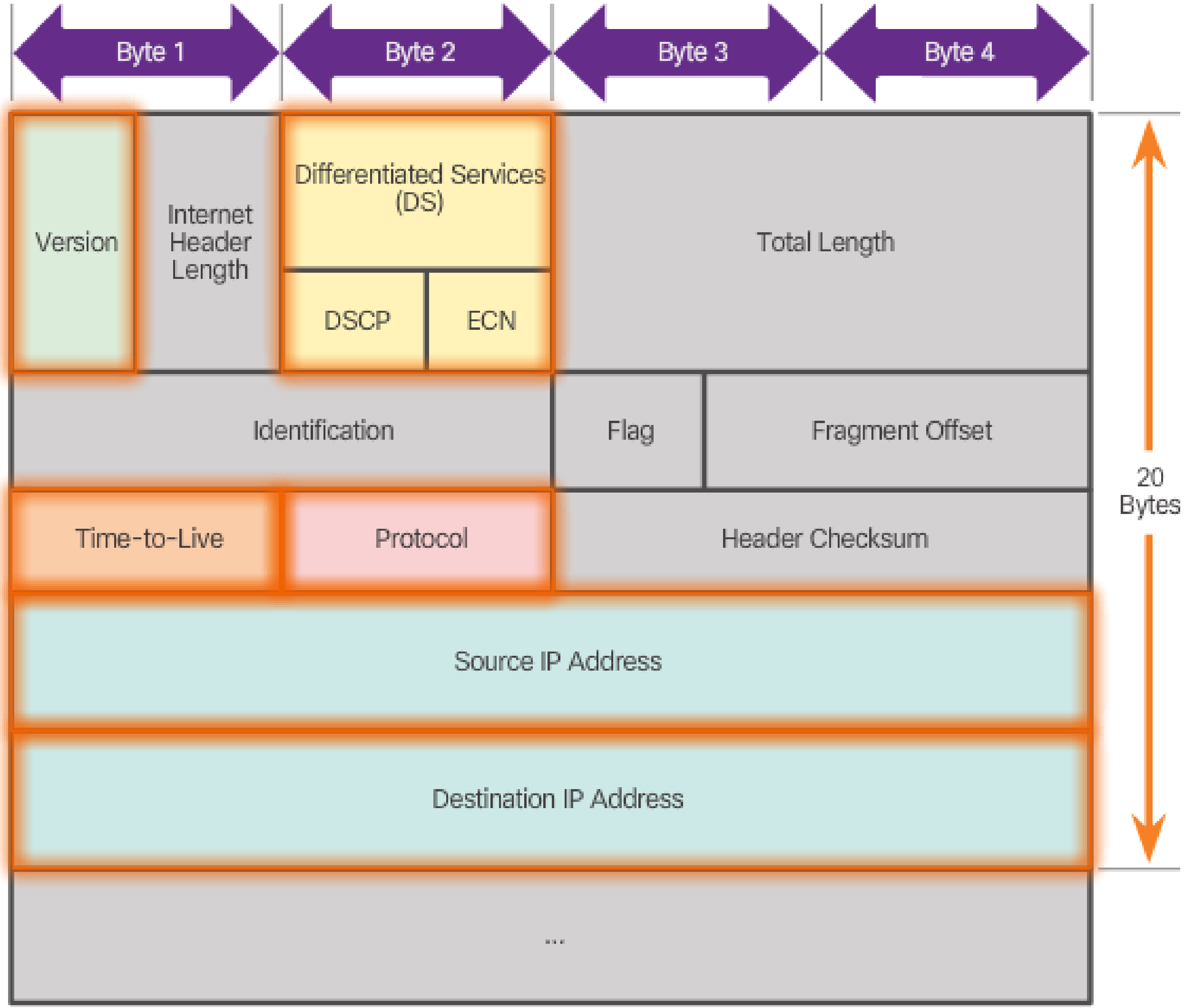
IP – Media Independent



IP packets can travel over different media.

Topic 6.1.3:
IPv4 Packet

IPv4 Packet Header



- 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

Topic 6.1.4:
IPv6 Packet

Limitations of IPv4

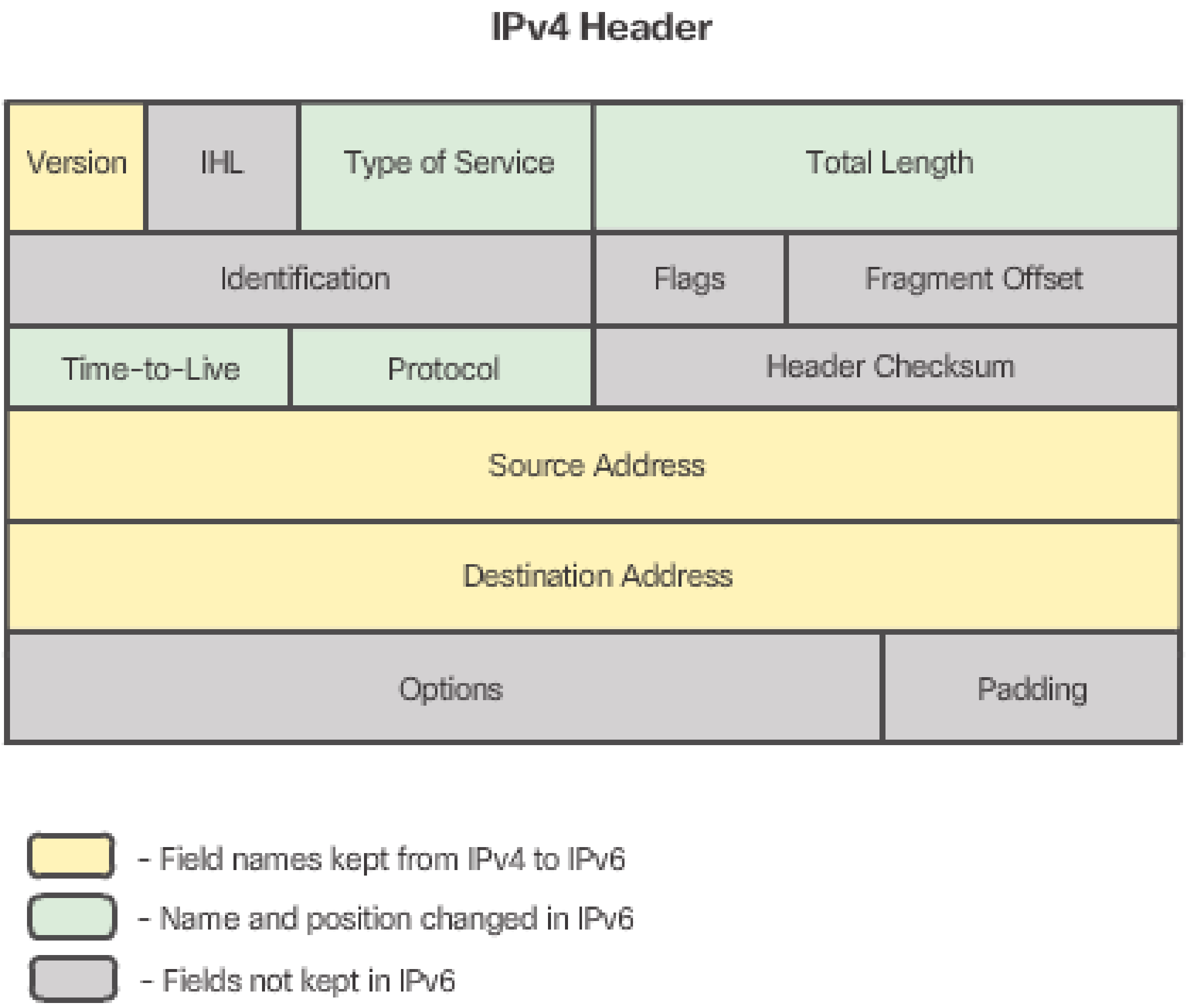
- IP address depletion
- Internet routing table expansion
- Lack of end-to-end connectivity

Introducing IPv6

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

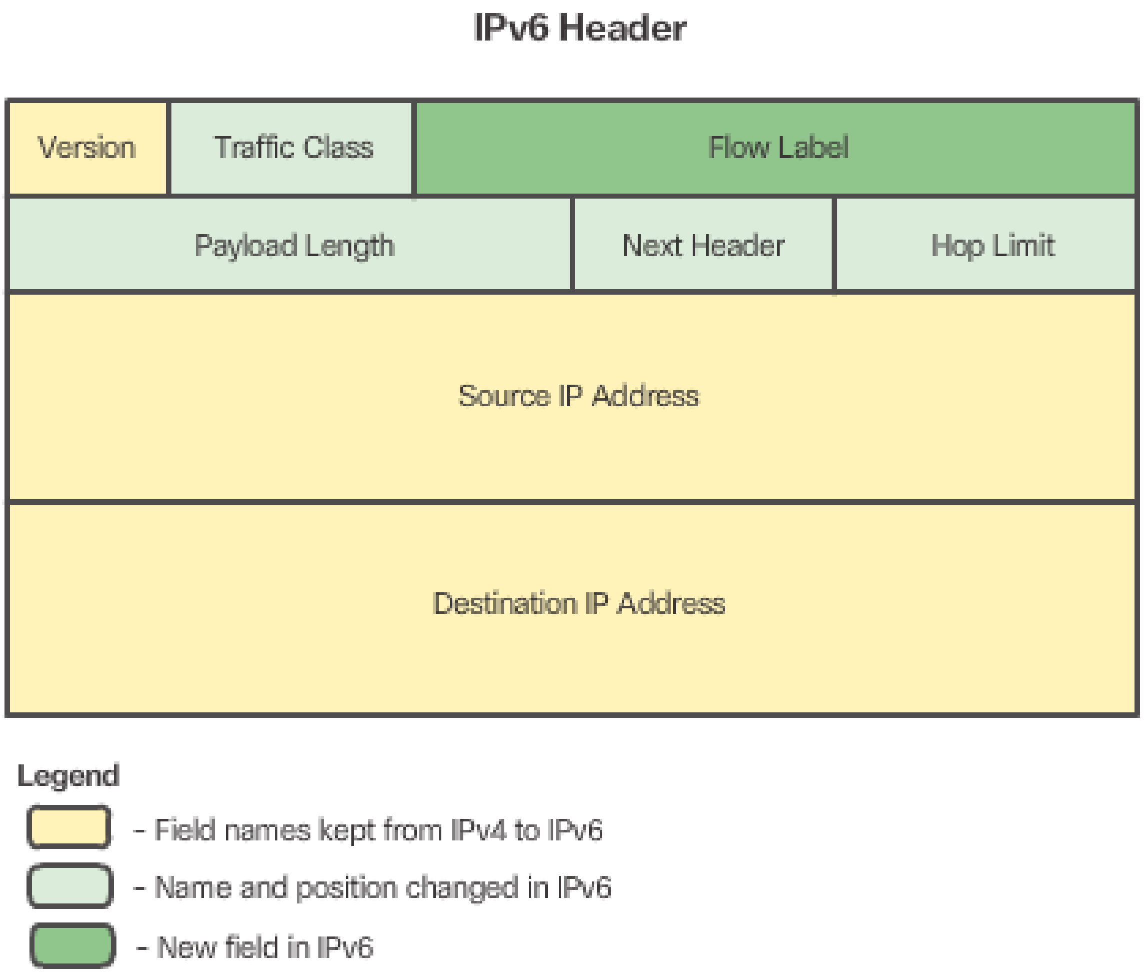
4 billion IPv4 addresses	**vs.**	340 undecillion IPv6 addresses
4,000,000,000		340,000,000,000,000,000,000,000,000,000,000,000,000

Encapsulating IPv6



IPv6 has a simplified header

Encapsulating IPv6 (cont.)



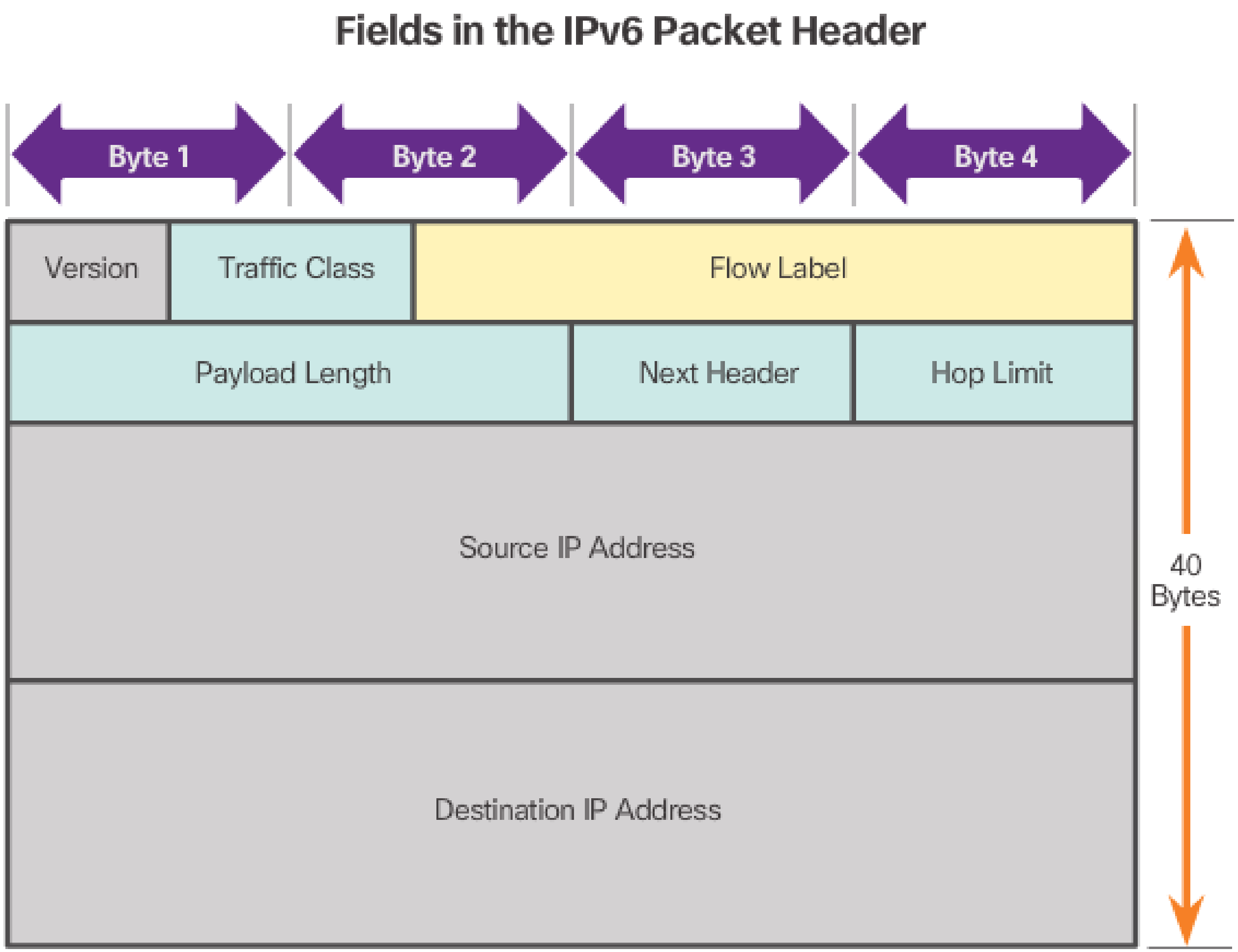
IPv6 has a simplified header

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



- 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

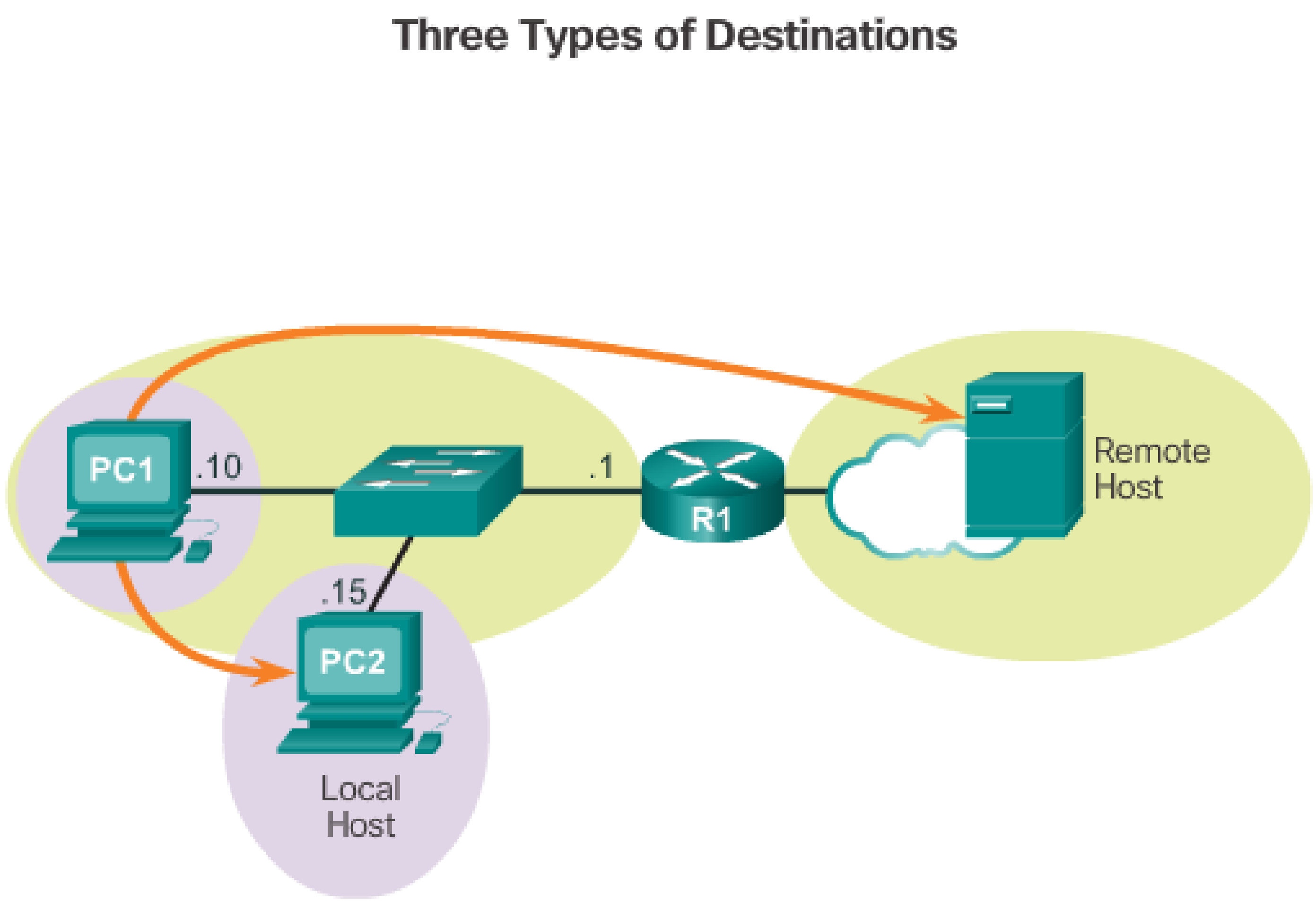
Section 6.2: Routing

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

Host Forwarding Decision

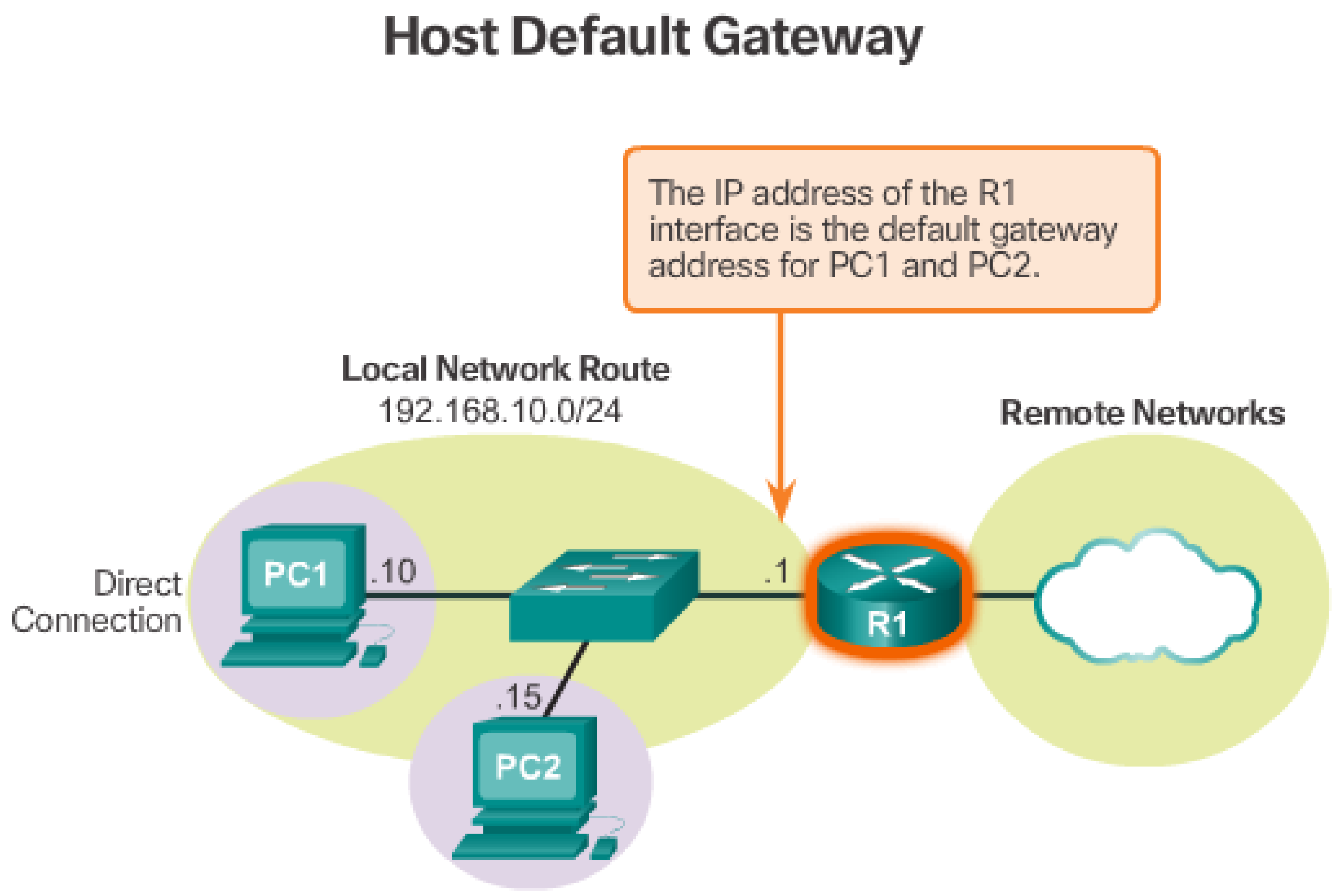


- Itself
- Local Host
- Remote Host

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

Using the Default Gateway



Host Routing Tables

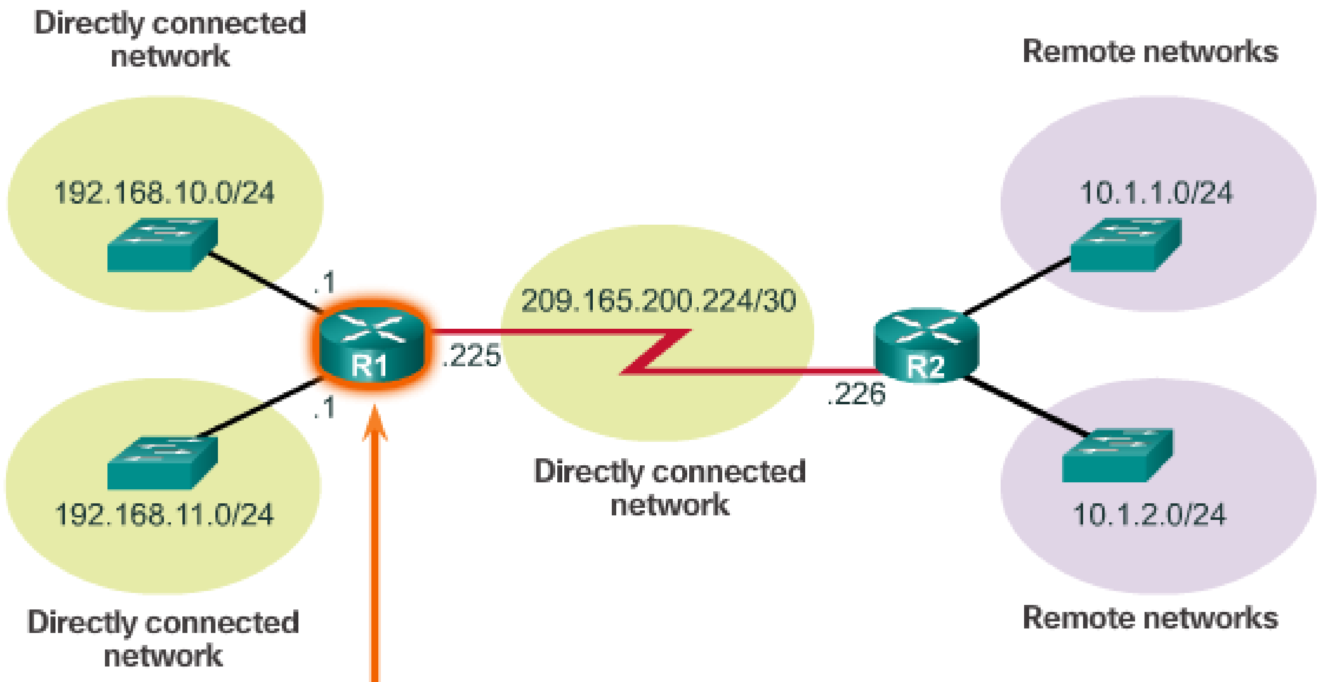
IPv4 Routing Table for PC1


```
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     192.168.10.1    192.168.10.10     25
        127.0.0.0        255.0.0.0         On-link         127.0.0.1    306
        127.0.0.1  255.255.255.255         On-link         127.0.0.1    306
  127.255.255.255  255.255.255.255         On-link         127.0.0.1    306
     192.168.10.0    255.255.255.0         On-link     192.168.10.10    281
    192.168.10.10  255.255.255.255         On-link     192.168.10.10    281
   192.168.10.255  255.255.255.255         On-link     192.168.10.10    281
        224.0.0.0        240.0.0.0         On-link         127.0.0.1    306
        224.0.0.0        240.0.0.0         On-link     192.168.10.10    281
  255.255.255.255  255.255.255.255         On-link         127.0.0.1    306
  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

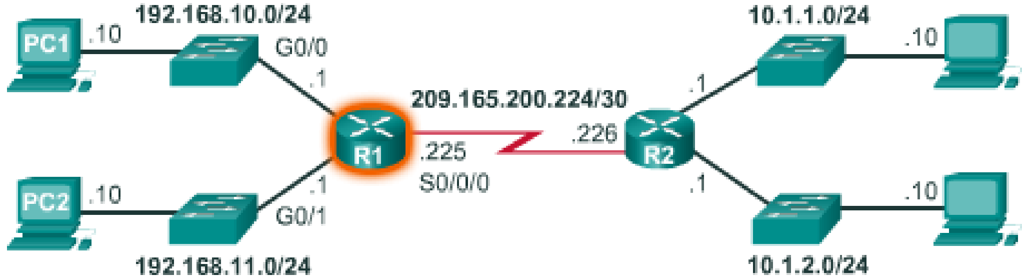
Directly Connected and Remote Network Routes



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 about from R2: 10.1.1.0/24 and 10.1.2.0/24.

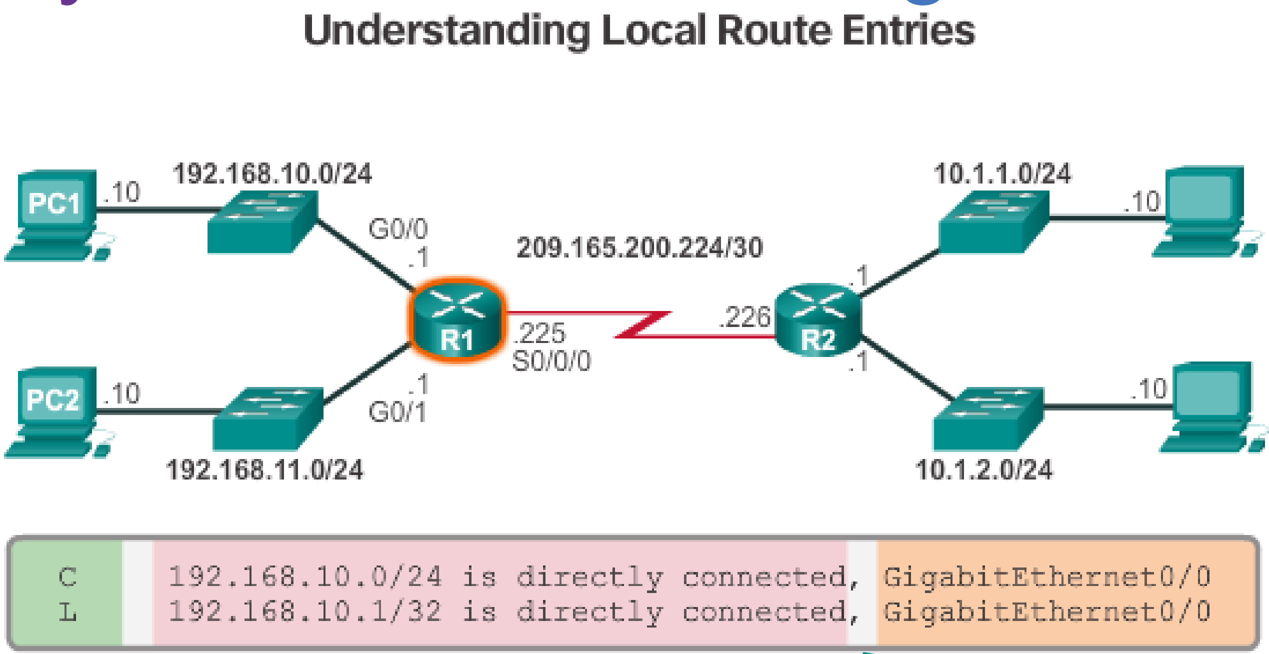
IPv4 Router Routing Table

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

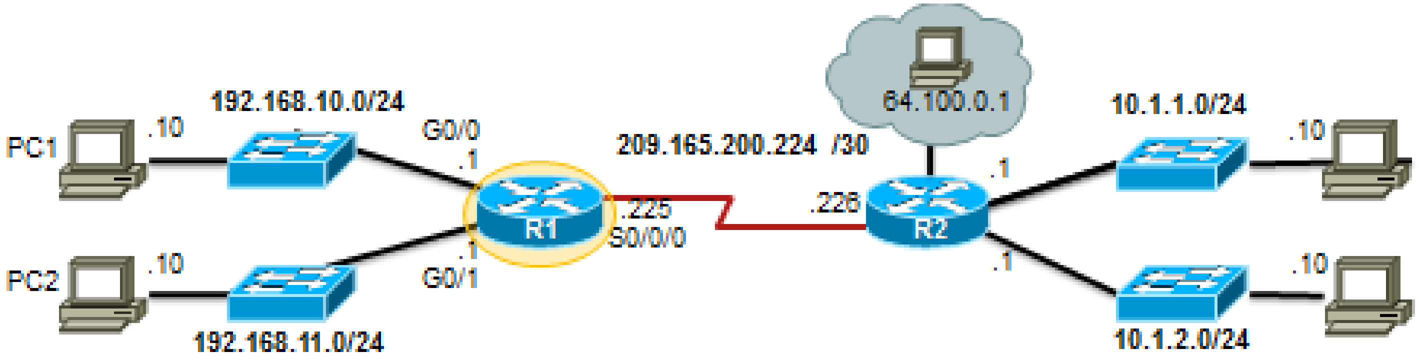


Route source – Identifies how the network was learned by the router.

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.

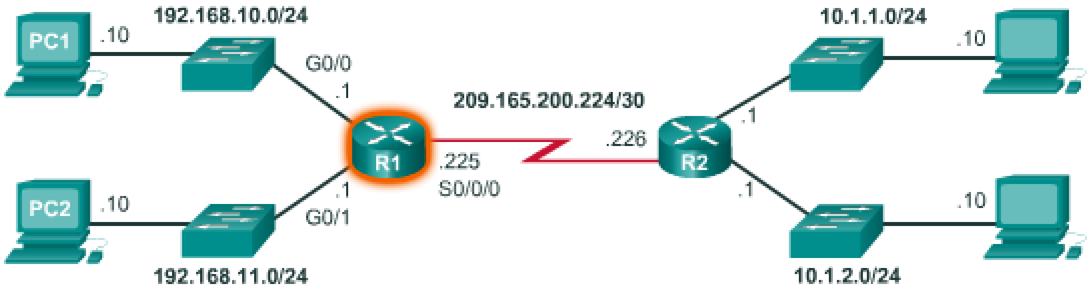
Remote Network Routing Table Entries



D		10.1.1.0/24	[90/	2170112]	via	209.165.200.226,	00:00:05,	Serial0/0/0

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

Next-Hop Address




```
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
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

A Router is a Computer/Router CPU and OS

Routers require:

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

Memory consisting of:

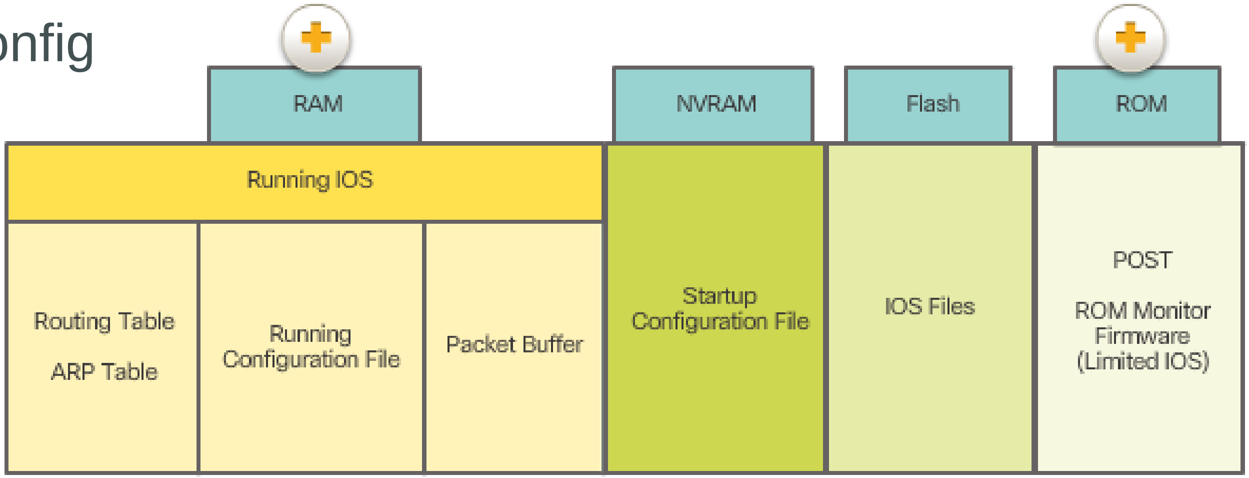
  - Random-access memory (RAM)
  - Read-only memory (ROM)
  - Nonvolatile random-access memory (NVRAM)
  - Flash

- The Cisco Internetwork Operating System (IOS) is the system software used for most Cisco devices regardless of the size and type of the device.

Router Memory

RAM uses the following applications and processes:

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

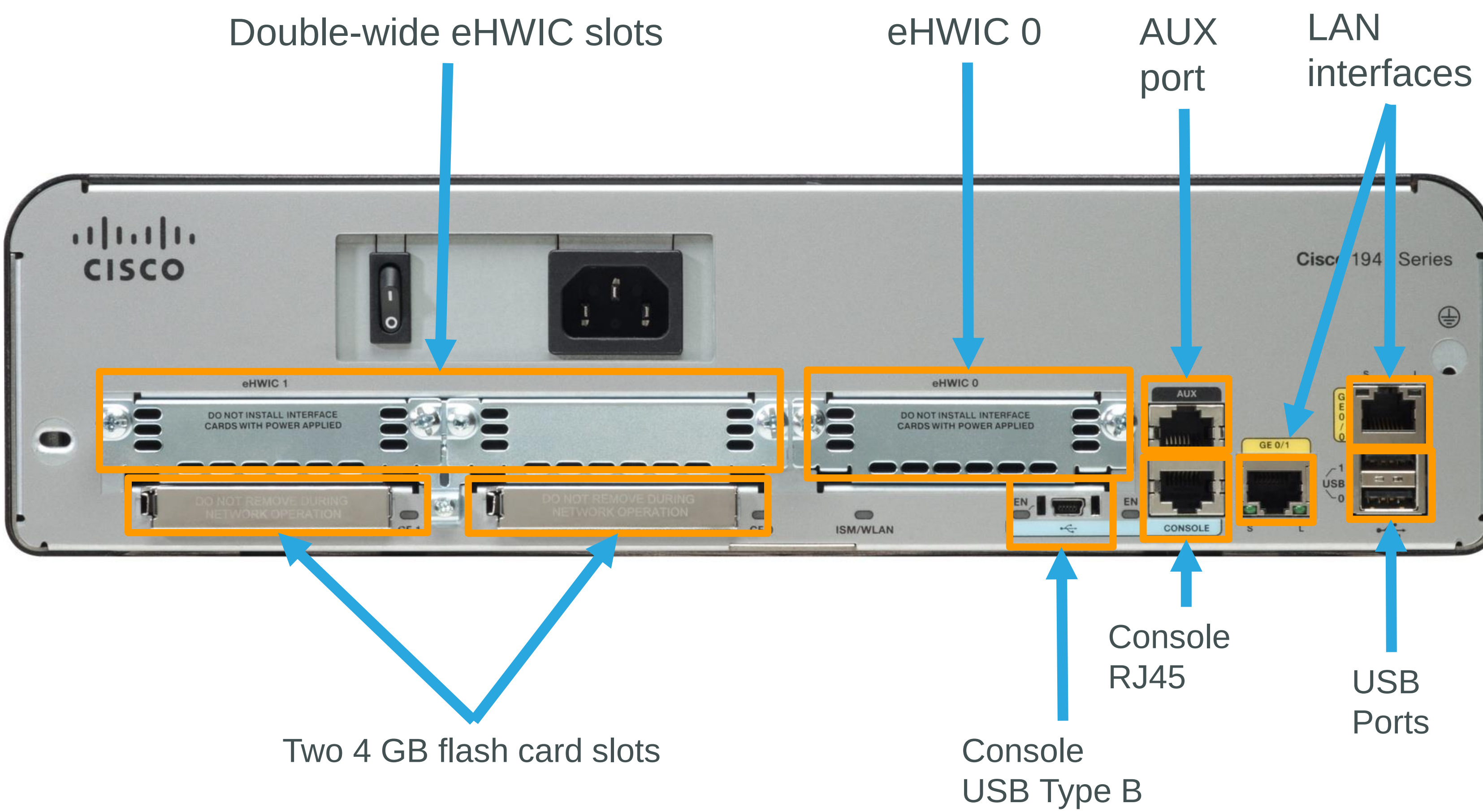


ROM stores the following:

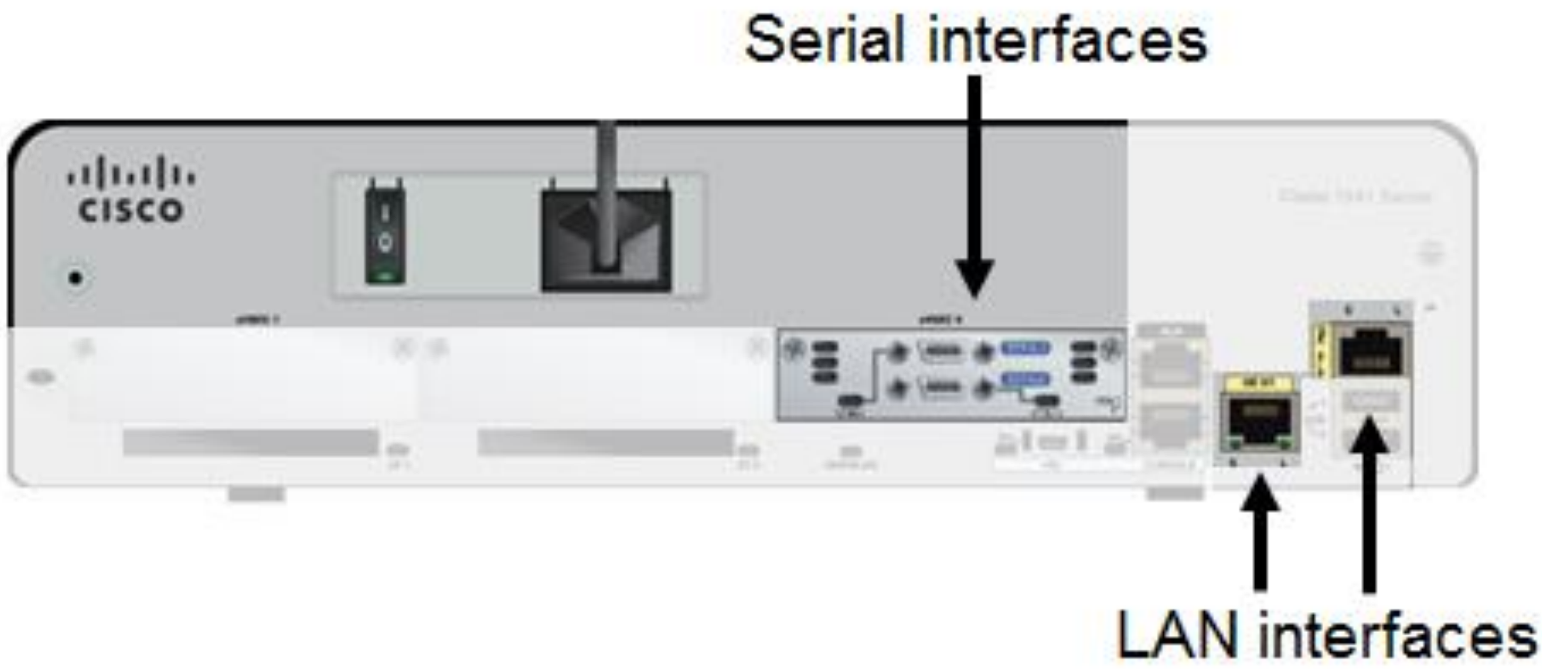
- Bootup information that provides the startup instructions
- Power-on self-test (POST) that tests all the hardware components
- Limited IOS to provide a backup version of the IOS.

Inside of a Router

Connect to a Router

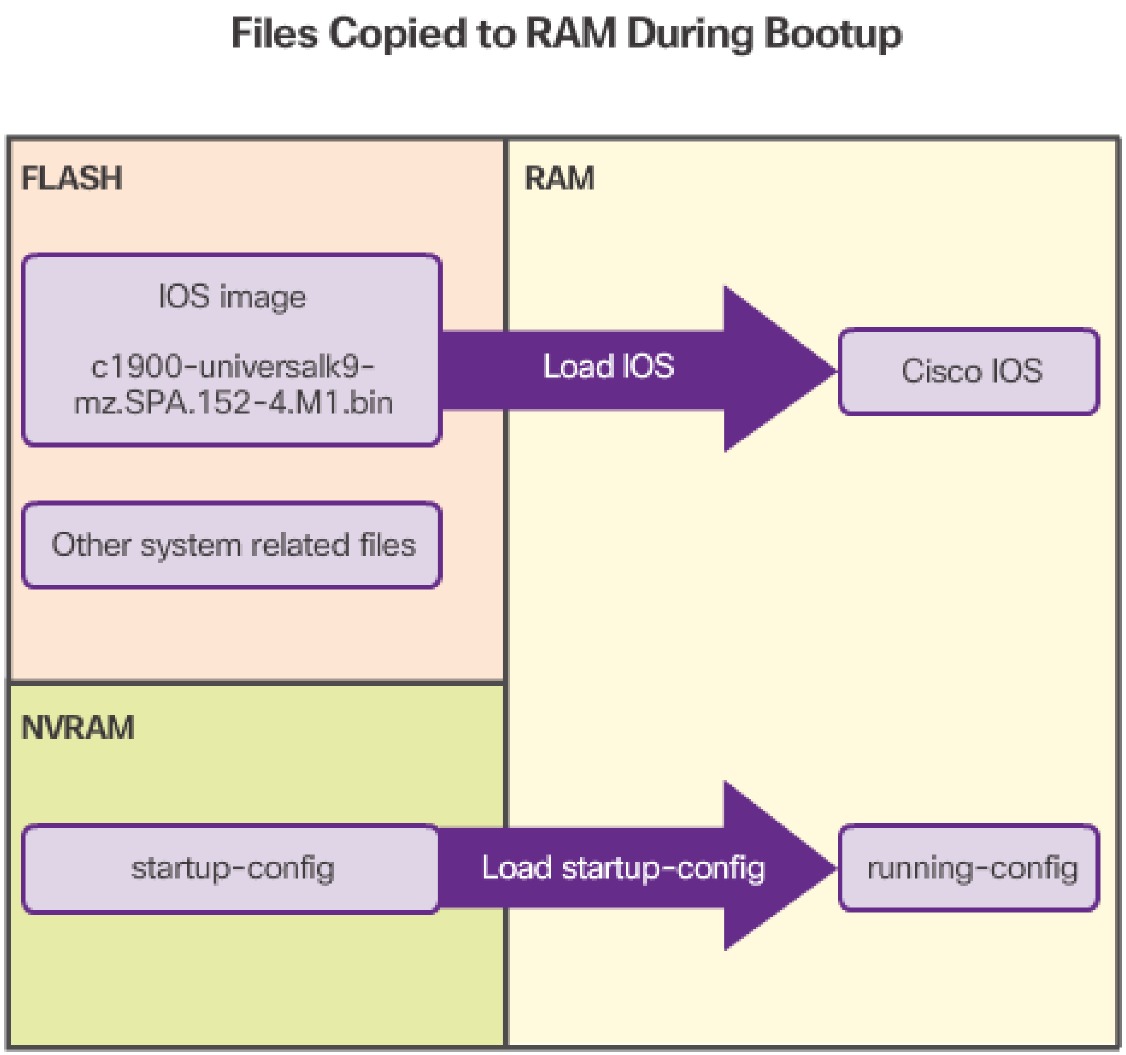


LAN and WAN Interfaces

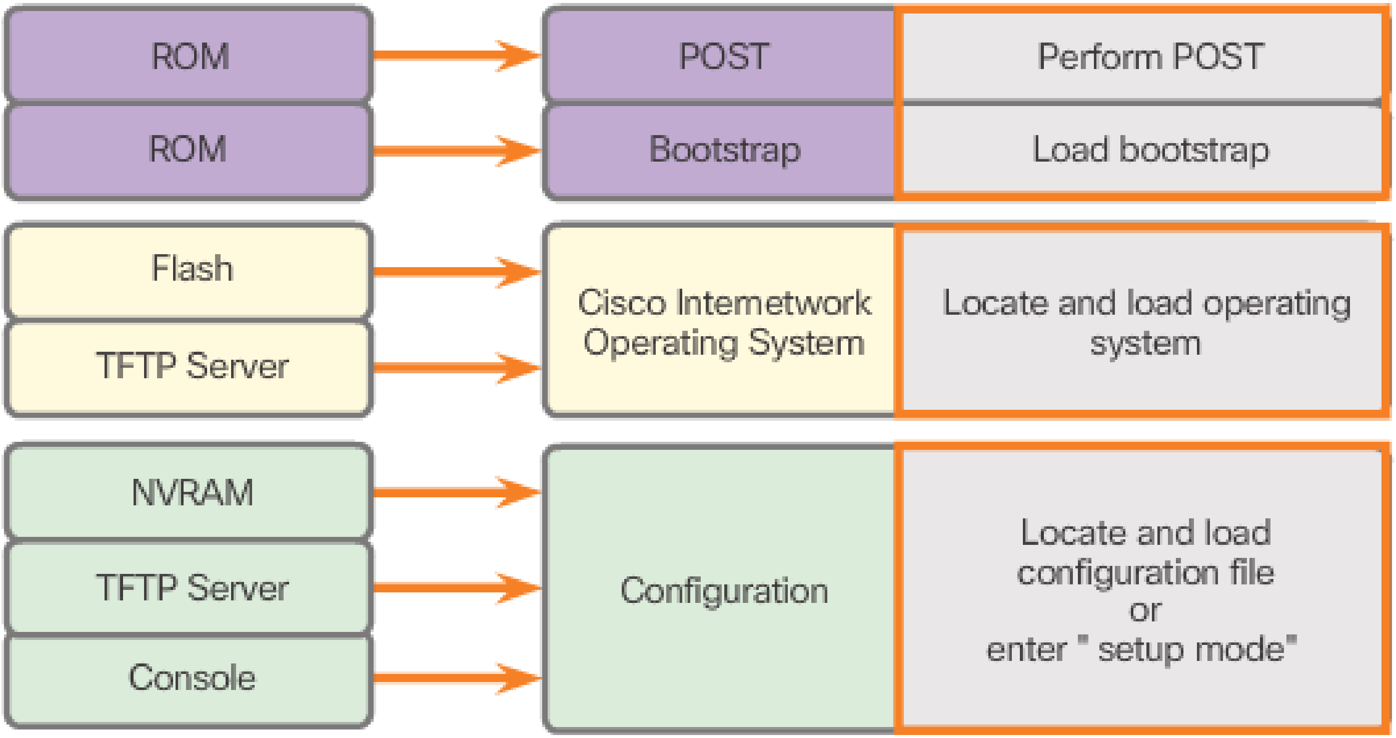


Topic 6.3.2:
Router Boot-up

Bootset Files



Router Bootup Process



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 CISCO1941/K9 (revision 1.0)
with 446464K/77824K bytes of memory.
Processor board ID FTX1636848Z
```

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)
```

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.

Topic 6.4.1:
Configure Initial Settings

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

Basic Router Configuration Steps

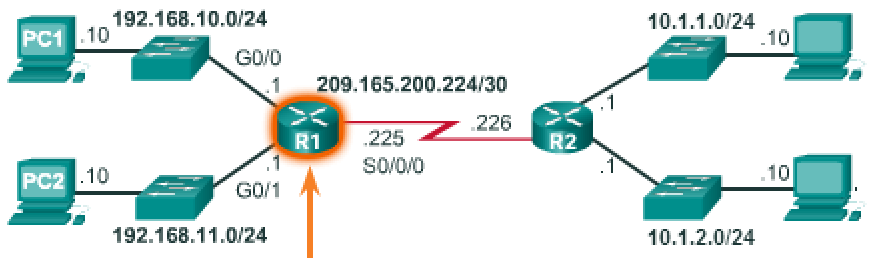
Limiting Device Access

- 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

Topic 6.4.2:
Configure Interfaces

Configure Router Interfaces

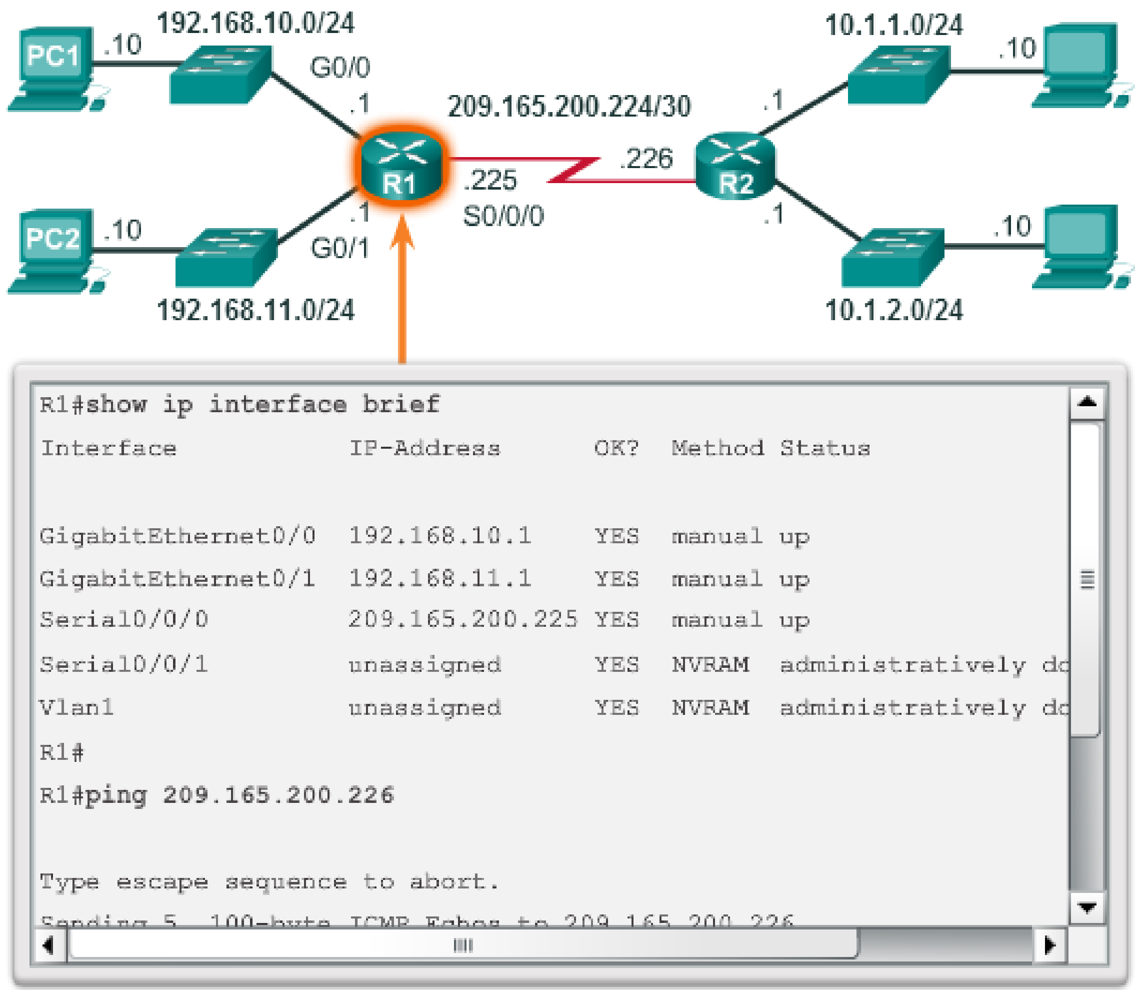
- Configure the interface
  - **interface** *type-and-number*
  - **description** *description-text*
  - **ip address** *ipv4-address subnet-mask*
  - **no shutdown**




```
R1#conf t
Enter configuration commands, one per line.
End with CNTL/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
%LINK-5-CHANGED: Interface GigabitEthernet0/0,
changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface
GigabitEthernet0/0,changed state to up
```

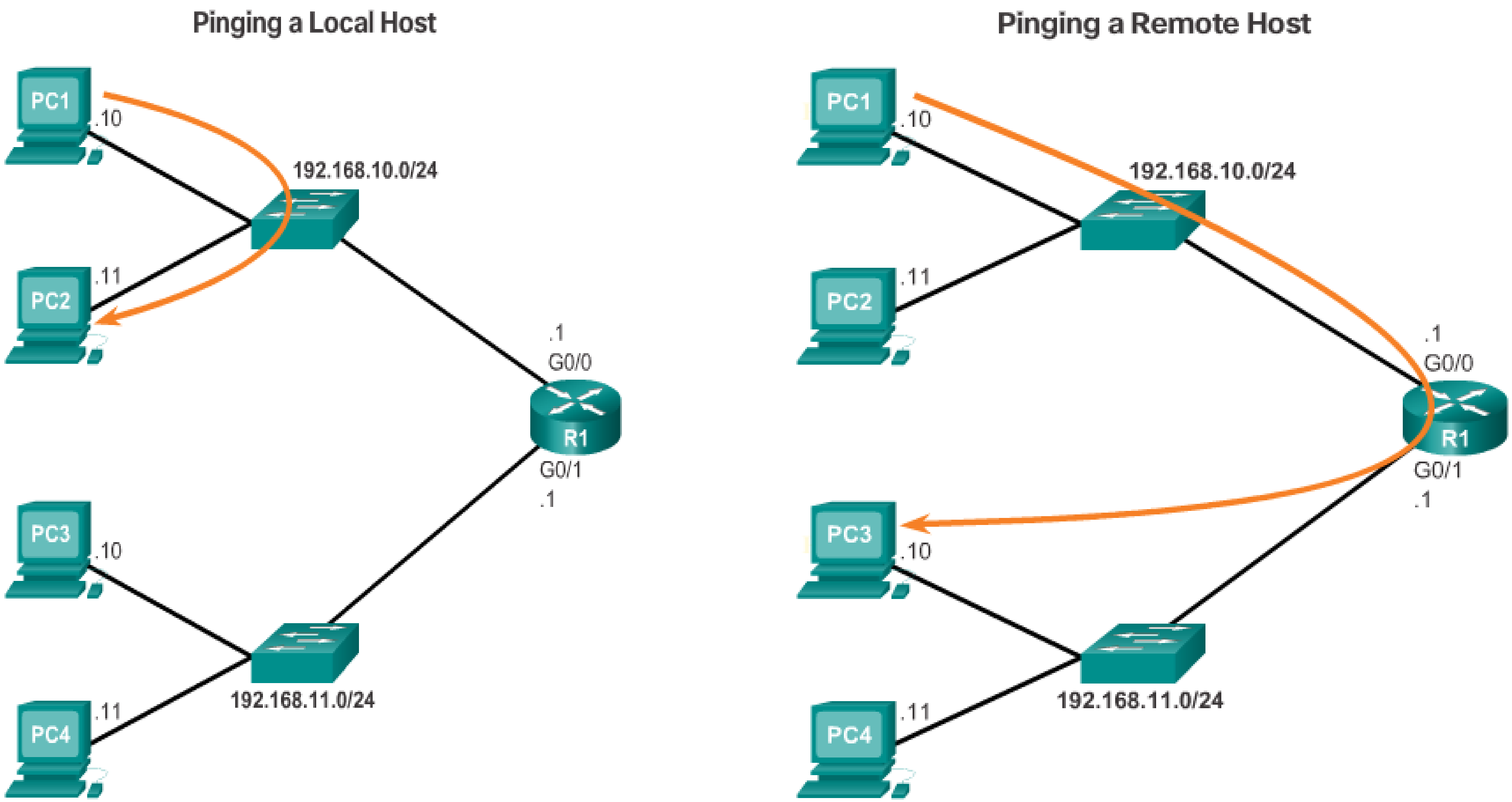
Verify Interface Configuration

- **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.

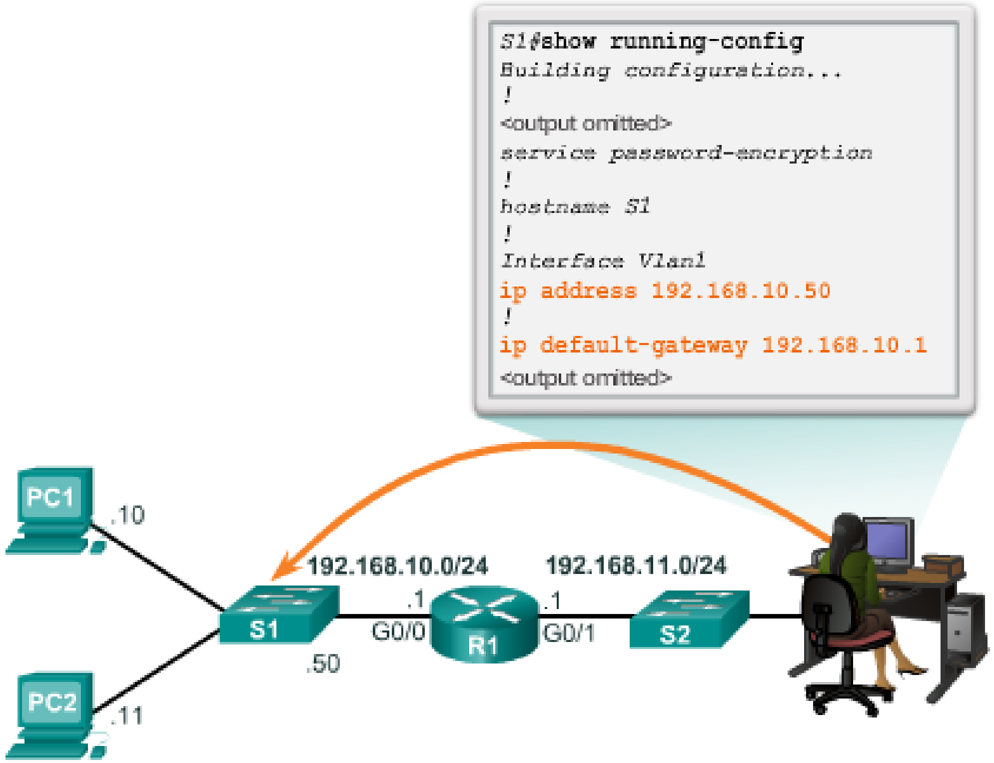


Topic 6.4.3: Configure the Default Gateway

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.

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.

Thank you.

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