



## Chapter 6: Network Layer



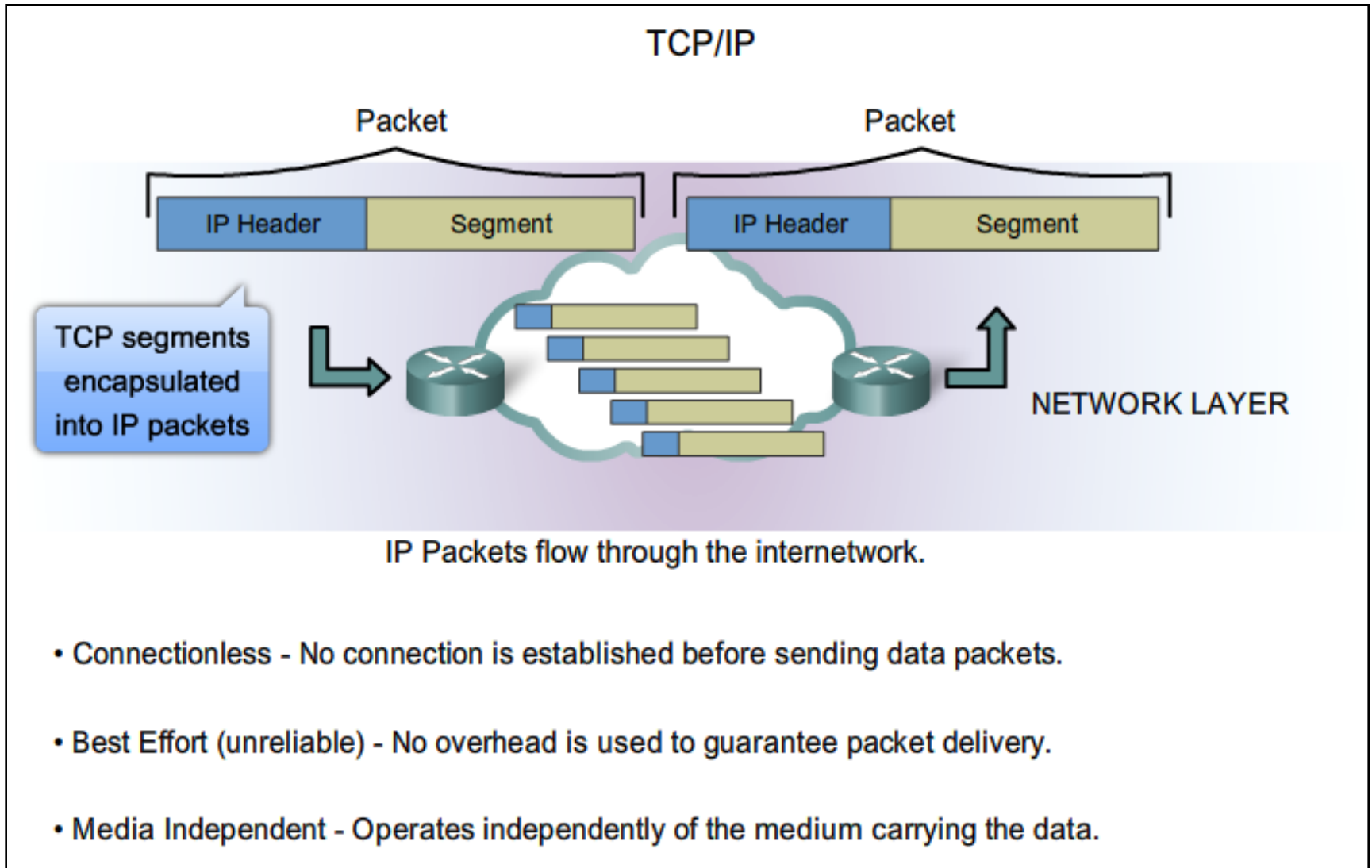
## Introduction to Networks

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## IP Characteristics

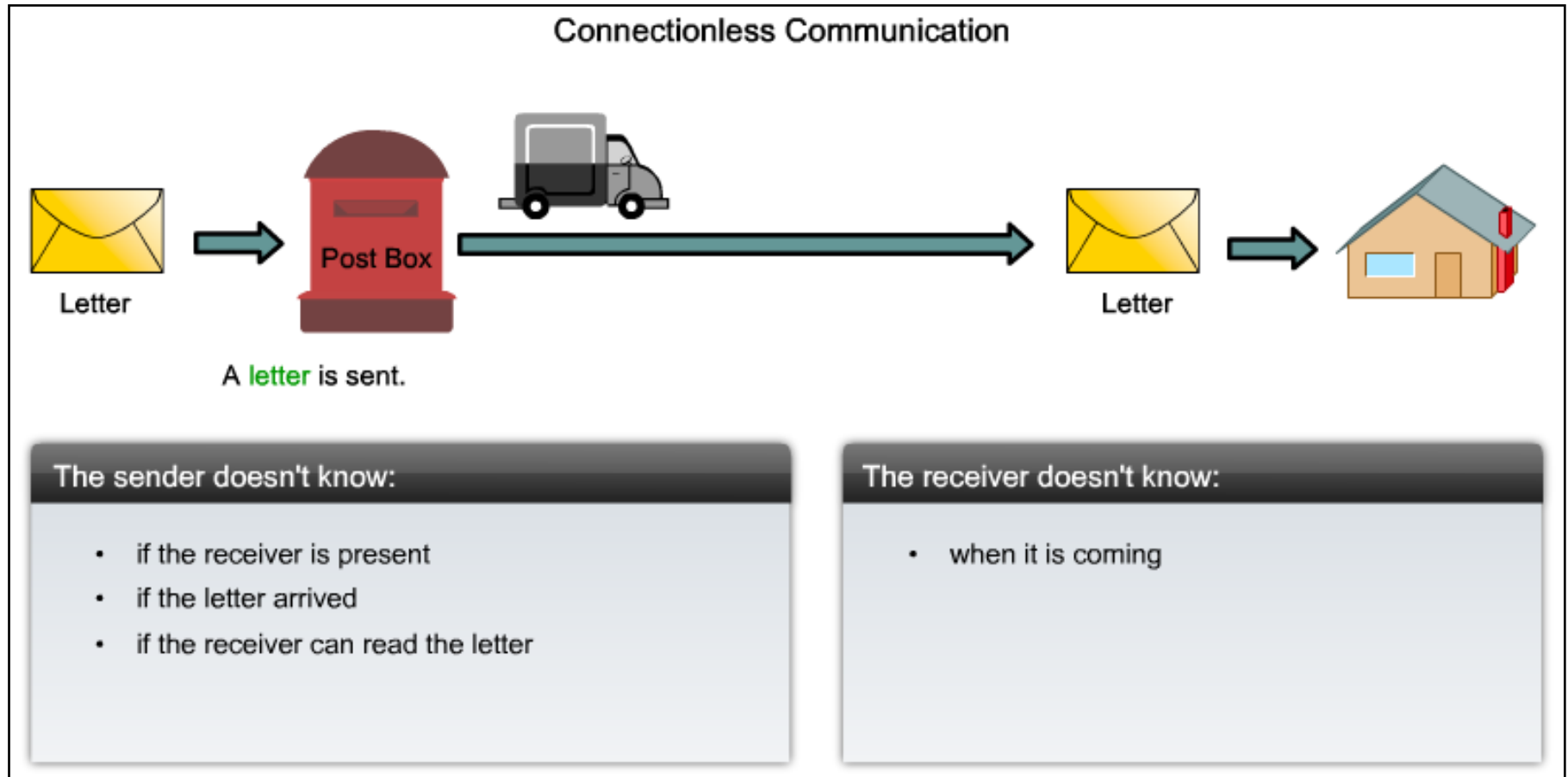
# IP Components





## Characteristics of the IP protocol

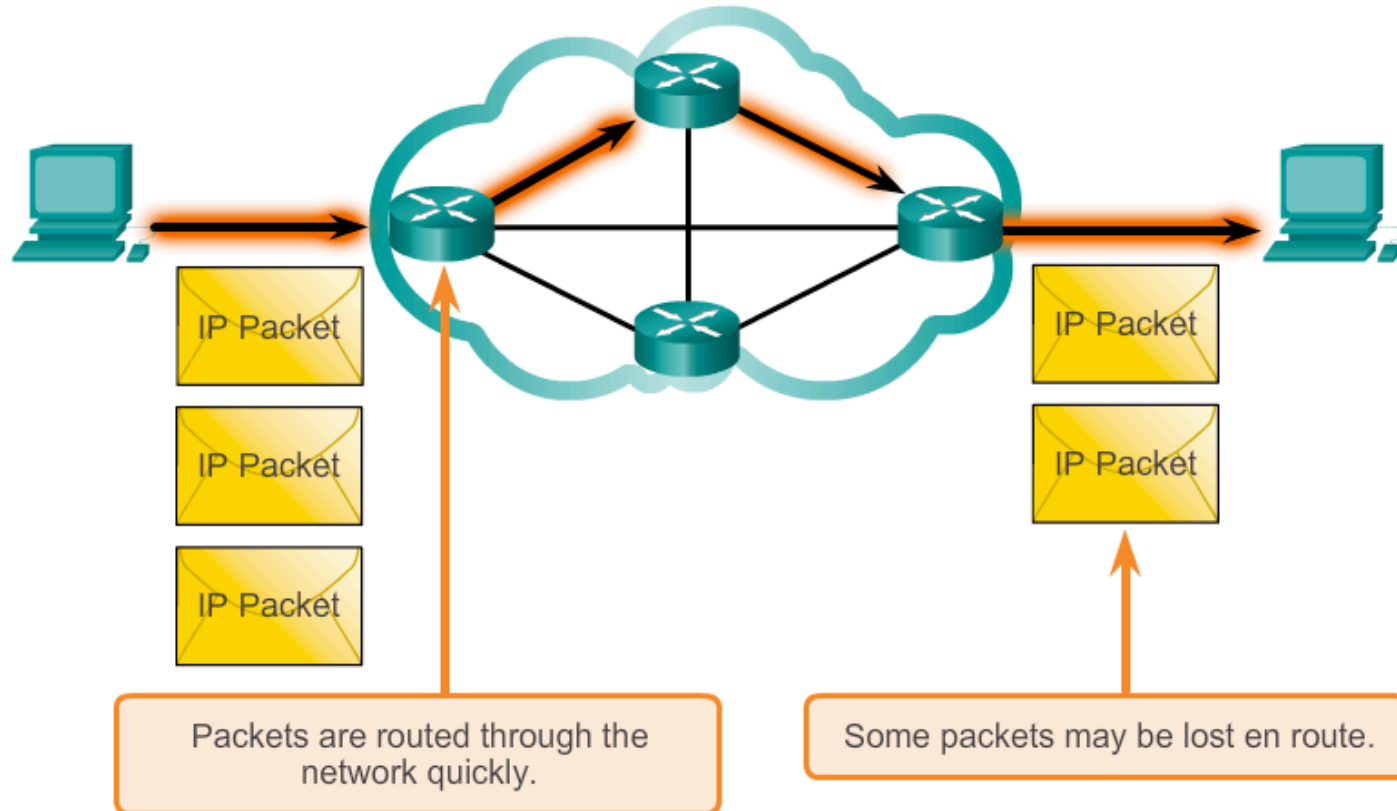
# IP - Connectionless





# Characteristics of the IP protocol

## Best Effort Delivery

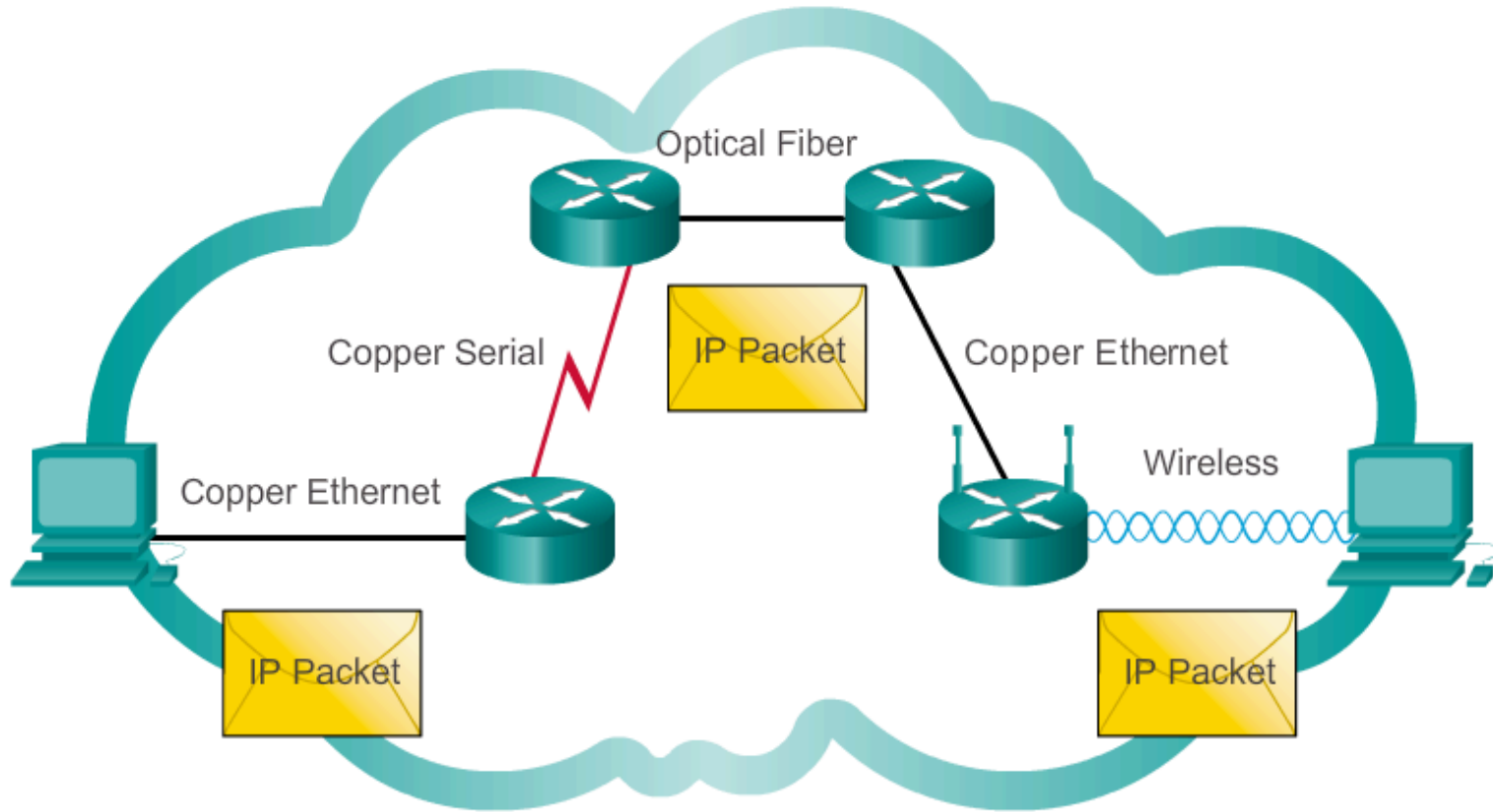


As an unreliable network layer protocol, IP does not guarantee that all sent packets will be received. Other protocols manage the process of tracking packets and ensuring their delivery.



# Characteristics of the IP protocol

## IP – Media Independent



IP packets can travel over different media.

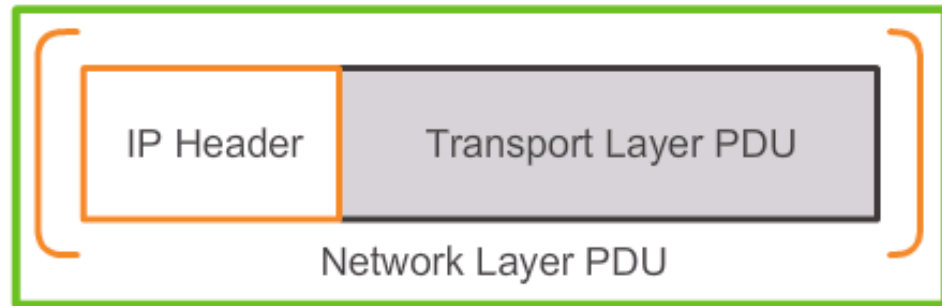


# IPv4 Packet Encapsulating IP

Transport Layer Encapsulation



Network Layer Encapsulation



IP Packet

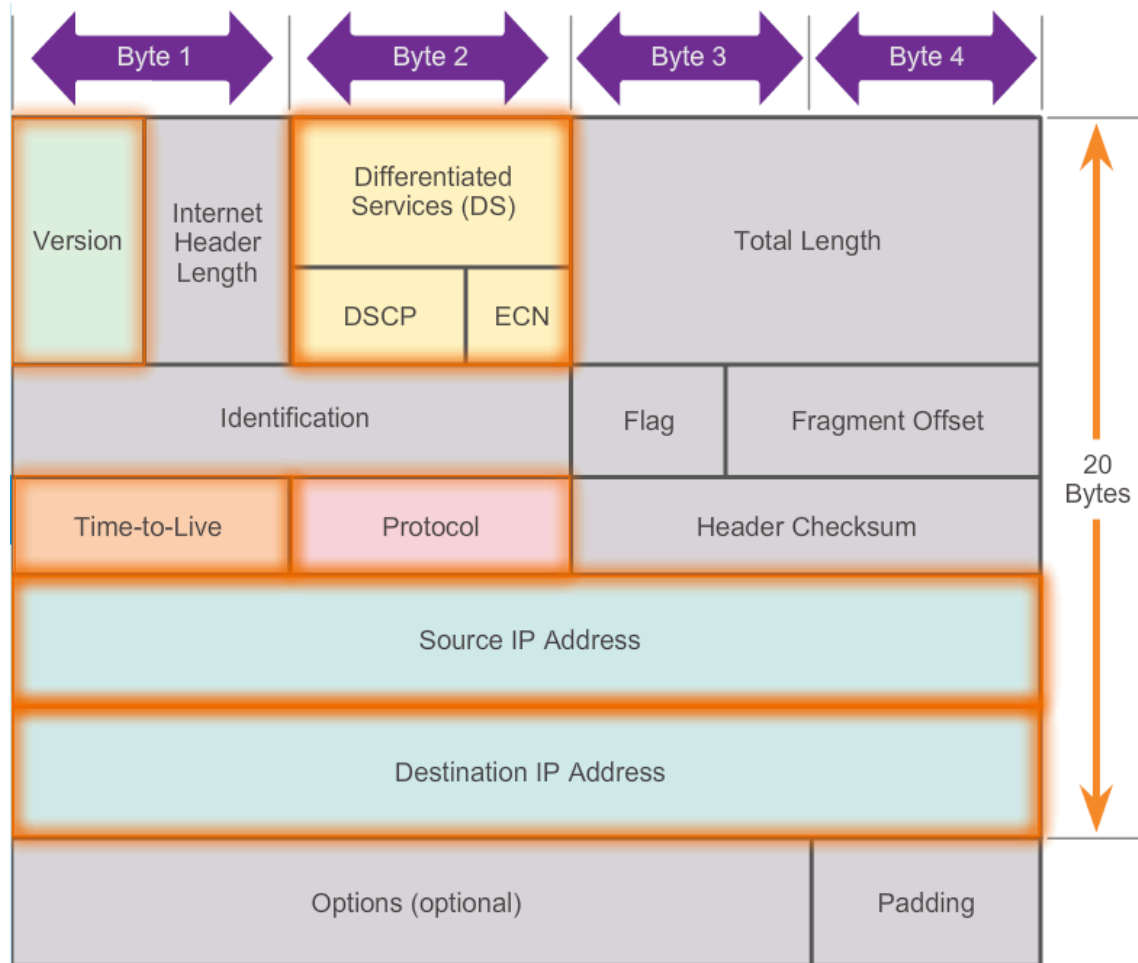
The network layer adds a header so packets can be routed through complex networks and reach their destination. In TCP/IP based networks, the network layer PDU is the IP packet.



## IPv4 Packet

# IPv4 Packet Header

## Contents of the IPv4 packet header

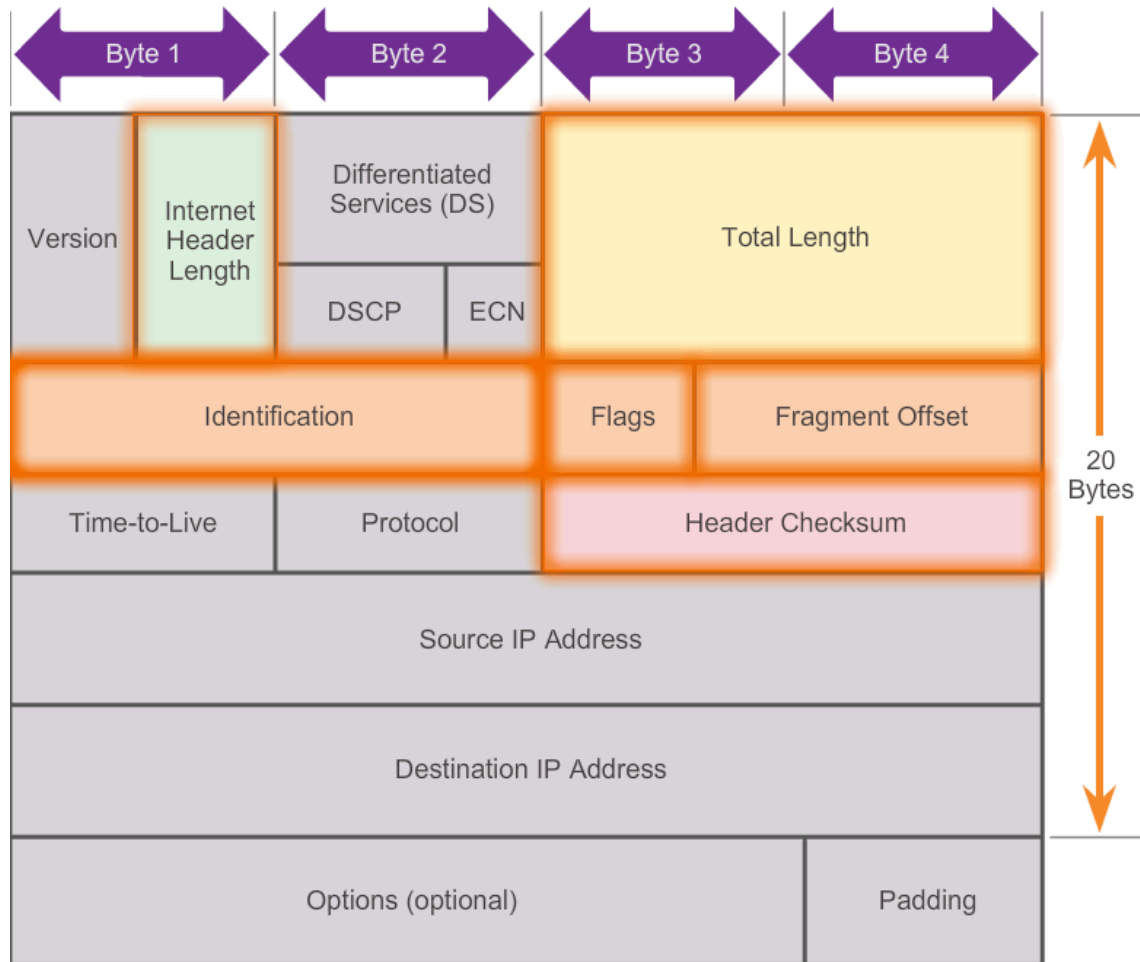




## IPv4 Packet

# IPv4 Header Fields

### Contents of the IPv4 header fields







# IPv4 Packet

## Sample IPv4 Headers

Microsoft: \Device\NPF\_{7BB3C130-30C5-4419-B79E-C0868085ABED} [Wireshark 1.8.2 (SVN Rev 44520 from /trunk-1.8)]

File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
16	3.64050300	192.168.1.109	192.168.1.1	ICMP	74	Echo (ping) request id=0x0001, seq=5/1280, ttl=128
17	3.64506800	192.168.1.1	192.168.1.109	ICMP	74	Echo (ping) reply id=0x0001, seq=5/1280, ttl=64
18	3.68215500	192.168.1.109	38.112.107.53	TCP	54	55502 > https [ACK] Seq=1 Ack=134 Win=16661 Len=0
19	4.19945400	fe80::15ff:98d8:d28ff02::c		SSDP	208	M-SEARCH * HTTP/1.1
20	4.60748800	fe80::15ff:98d8:d28ff02::b1ee:c4ae:a11		SSDP	453	HTTP/1.1 200 OK
21	4.64229900	192.168.1.109	192.168.1.1	ICMP	74	Echo (ping) request id=0x0001, seq=6/1536, ttl=128
22	4.64509200	192.168.1.1	192.168.1.109	ICMP	74	Echo (ping) reply id=0x0001, seq=6/1536, ttl=64
23	4.73605200	192.168.1.109	255.255.255.255	DB-LSP-	154	Droobox LAN svnc Discoverv Protocol

Frame 16: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0

Ethernet II, Src: IntelCor\_45:5d:c4 (24:77:03:45:5d:c4), Dst: Cisco-Li\_a0:d1:be (00:18:39:a0:d1:be)

Internet Protocol Version 4, Src: 192.168.1.109 (192.168.1.109), Dst: 192.168.1.1 (192.168.1.1)

Version: 4  
Header length: 20 bytes  
Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))  
Total Length: 60  
Identification: 0x3704 (14084)  
Flags: 0x00  
Fragment offset: 0  
Time to live: 128  
Protocol: ICMP (1)  
Header checksum: 0x7ffe [correct]  
Source: 192.168.1.109 (192.168.1.109)  
Destination: 192.168.1.1 (192.168.1.1)  
[Source GeoIP: Unknown]  
[Destination GeoIP: Unknown]

Internet Control Message Protocol

```

0000  00 18 39 a0 d1 be 24 77 03 45 5d c4 08 00 45 00  ..9...$w .E]...E.
0010  00 3c 37 04 00 00 80 01 7f fe c0 a8 01 6d c0 a8  .<7.....m..
0020  01 01 08 00 4d 56 00 01 00 05 61 62 63 64 65 66  ...MV.. ..abcdef
0030  67 68 69 6a 6b 6c 6d 6e 6f 70 71 72 73 74 75 76  ghijklmn opqrstuv
0040  77 61 62 63 64 65 66 67 68 69                    wabcdefg hi
  
```

Internet Protocol Version 4 (ip), 20 bytes      Packets: 35 Displayed: 35 Marked: 0 Dropped: 0      Profile: Default



## Network Layer in Communication

# Limitations of IPv4

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



# Network Layer in Communication Introducing IPv6

- [illegible]



# IPv6 Packet

## Encapsulating IPv6

### IPv4 and IPv6 Headers

#### IPv4 Header

Version	IHL	Type of Service	Total Length	
Identification			Flags	Fragment Offset
Time to Live	Protocol		Header Checksum	
Source Address				
Destination Address				
Options			Padding	

#### IPv6 Header

Version	Traffic Class	Flow Label	
Payload Length		Next Header	Hop Limit
Source Address			
Destination Address			

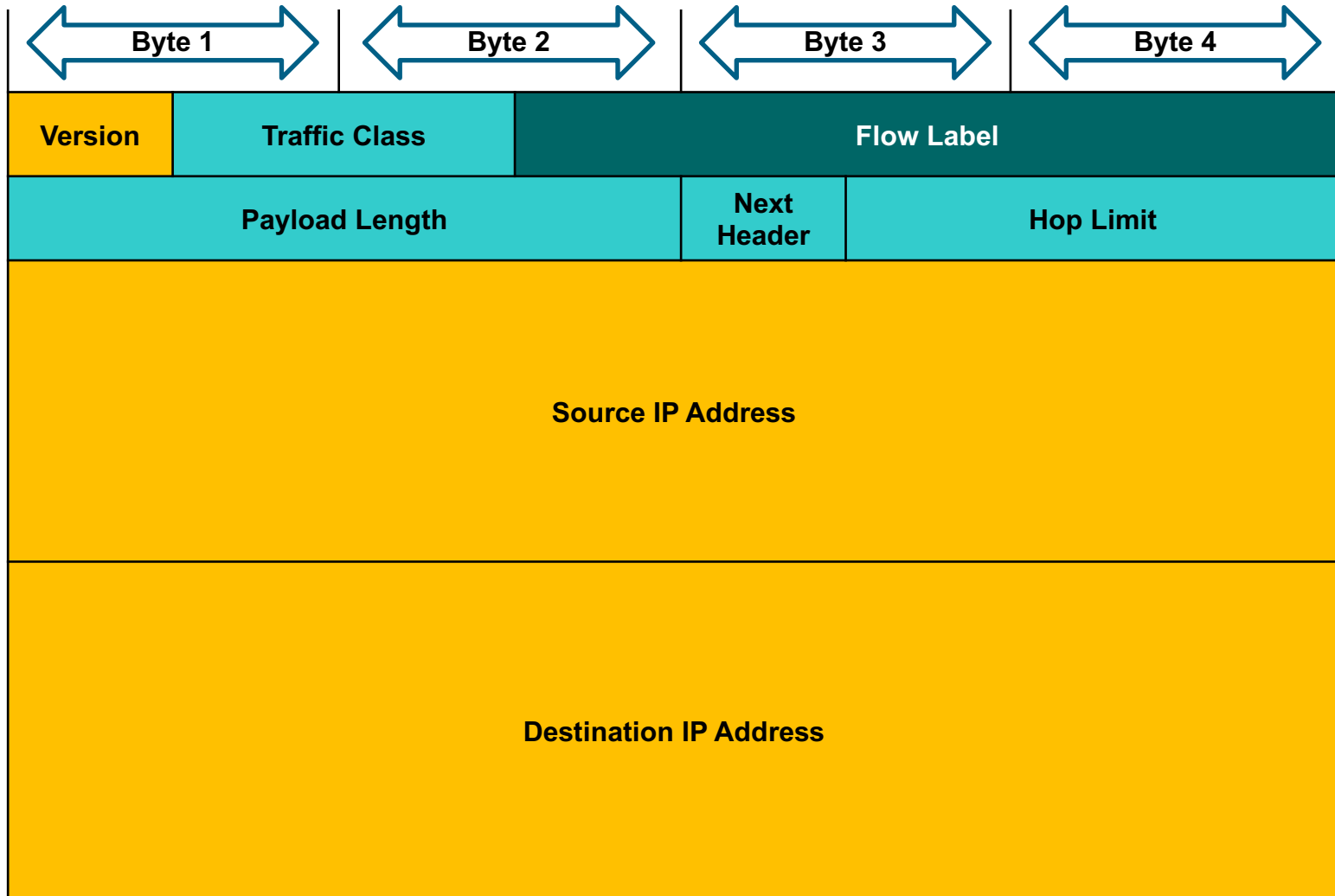
#### Legend

- Field names kept from IPv4 to IPv6
- Fields not kept in IPv6
- Name & position changed in IPv6
- New field in IPv6



## IPv6 Packet

# IPv6 Packet Header





# IPv6 Packet

## Sample IPv6 Header

Wireshark 1.8.2 (SVN Rev 44520 from /trunk-1.8)

Filter: Expression... Clear Apply Save

No.	Time	Source	Destination	Protocol	Length	Info
47	325.030878	2001:6f8:900:7c0::2	2001:6f8:102d:0:2d0:9ff:fee3:e8de	TCP	82	59201 > http [ACK] Seq=1 Ack=1 win=5760
48	325.031166	2001:6f8:102d:0:2d0:9ff:fee3:e8de	2001:6f8:900:7c0::2	TCP	74	59201 > http [ACK] Seq=1 Ack=1 win=5760
49	325.040411	2001:6f8:102d:0:2d0:9ff:fee3:e8de	2001:6f8:900:7c0::2	HTTP	314	GET / HTTP/1.0
50	325.045496	2001:6f8:900:7c0::2	2001:6f8:102d:0:2d0:9ff:fee3:e8de	TCP	1506	[TCP segment of a reassembled PDU]
51	325.045525	2001:6f8:900:7c0::2	2001:6f8:102d:0:2d0:9ff:fee3:e8de	HTTP	901	HTTP/1.1 200 OK (text/html)
52	325.045627	2001:6f8:900:7c0::2	2001:6f8:102d:0:2d0:9ff:fee3:e8de	TCP	74	http > 59201 [FIN, ACK] Seq=2260 Ack=241

Frame 49: 314 bytes on wire (2512 bits), 314 bytes captured (2512 bits)

Ethernet II, Src: HsingTec\_e3:e8:de (00:d0:09:e3:e8:de), Dst: Ibm\_82:95:b5 (00:11:25:82:95:b5)

Internet Protocol Version 6, Src: 2001:6f8:102d:0:2d0:9ff:fee3:e8de (2001:6f8:102d:0:2d0:9ff:fee3:e8de), Dst: 2001:6f8:900:7c0::2 (2001:6f8:900:7c0::2)

0110 .... = Version: 6

.... 0000 0000 .... = Traffic class: 0x00000000

.... 0000 0000 0000 0000 = Flowlabel: 0x00000000

Payload length: 260

Next header: TCP (6)

Hop limit: 64

Source: 2001:6f8:102d:0:2d0:9ff:fee3:e8de (2001:6f8:102d:0:2d0:9ff:fee3:e8de)

[Source SA MAC: HsingTec\_e3:e8:de (00:d0:09:e3:e8:de)]

Destination: 2001:6f8:900:7c0::2 (2001:6f8:900:7c0::2)

[Source GeoIP: Unknown]

[Destination GeoIP: Unknown]

Transmission Control Protocol, Src Port: 59201 (59201), Dst Port: http (80), Seq: 1, Ack: 1, Len: 240

Hypertext Transfer Protocol

0000 00 11 25 82 95 b5 00 d0 09 e3 e8 de 86 dd 60 00 ..%.....

0010 00 00 01 04 06 40 20 01 06 f8 10 2d 00 00 02 d0 .....@.....

0020 09 ff fe e3 e8 de 20 01 06 f8 09 00 07 c0 00 00 .....A.P...a.J

0030 00 00 00 00 00 02 e7 41 00 50 ab dc d6 61 01 4a s.P....H..GET /

0040 73 9f 50 18 16 80 f4 48 00 00 47 45 54 20 2f 20 HTTP/1.0 ..Host:

0050 48 54 54 50 2f 31 2e 30 0d 0a 48 6f 73 74 3a 20 c1-1985. ham-01.d

0060 63 6c 2d 31 39 38 35 2e 68 61 6d 2d 30 31 2e 64 e.sixxs. net..Acc

0070 65 2e 73 69 78 78 73 2e 6e 65 74 0d 0a 41 63 63

Internet Protocol Version 6 (IPv6), 40 bytes

Packets: 55 Displayed: 55 Mark...

Profile: Default



## 6.2 Routing



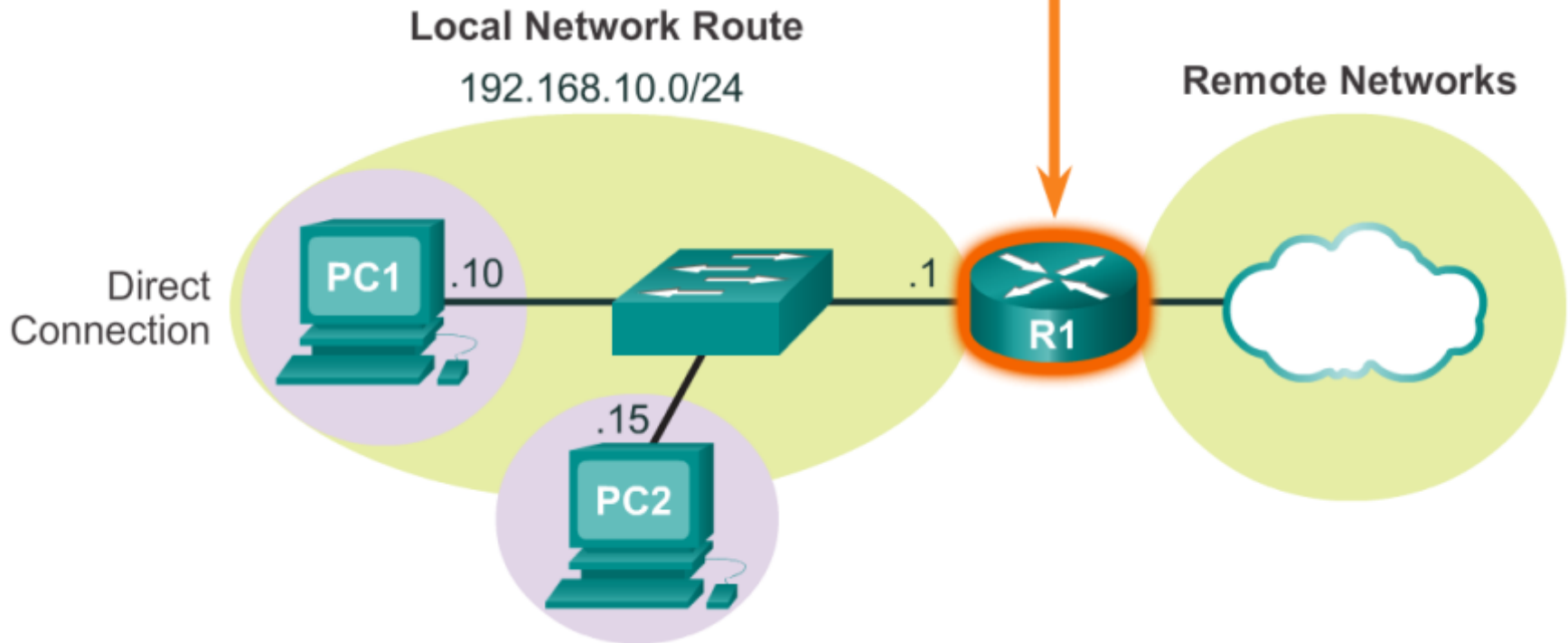
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## Host Routing Tables

# Host Packet Forwarding Decision

The IP address of the R1 interface is the default gateway address for PC1 and PC2.

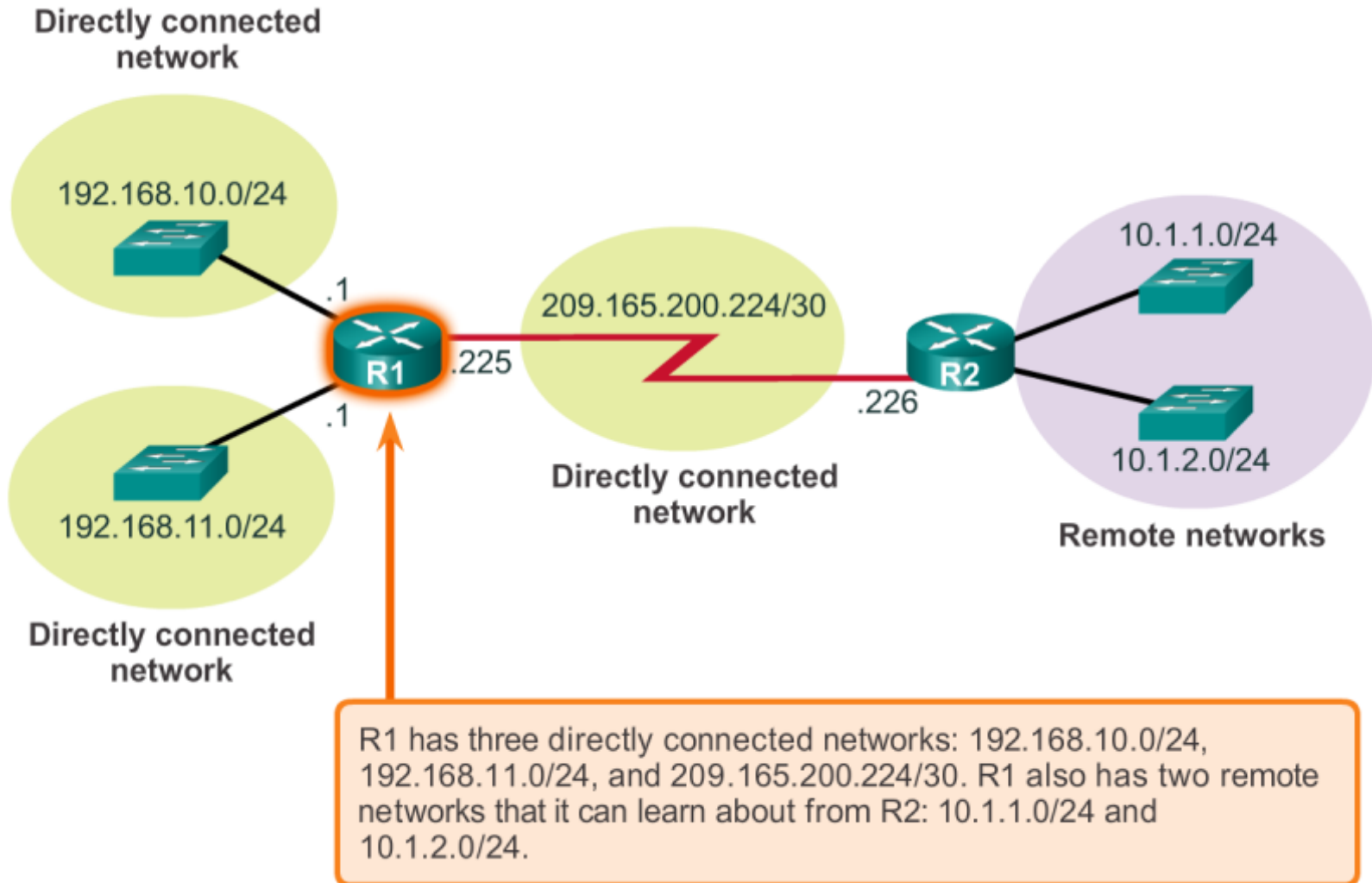






## Router Routing Tables

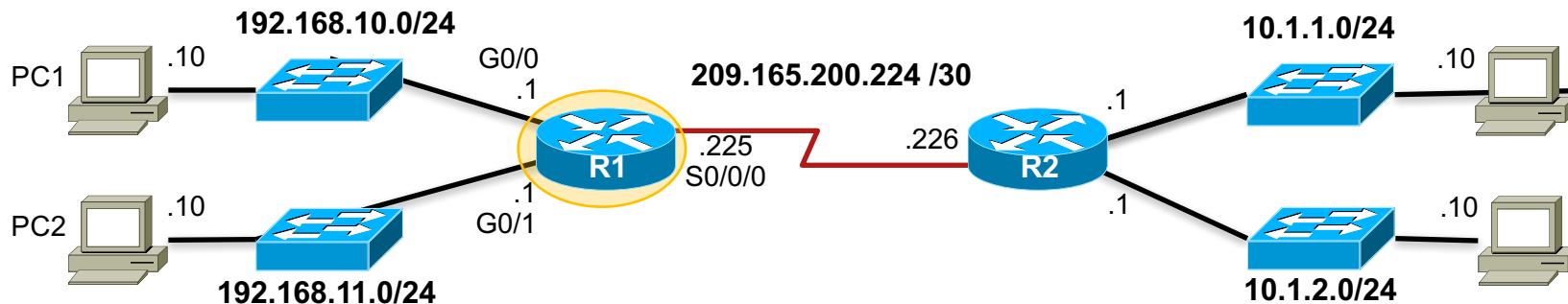
# Router Packet Forwarding Decision





# Router Routing Tables

## IPv4 Router Routing Table



R1#show ip route

Codes: L - local, C - connected, S - static, 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

```

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#

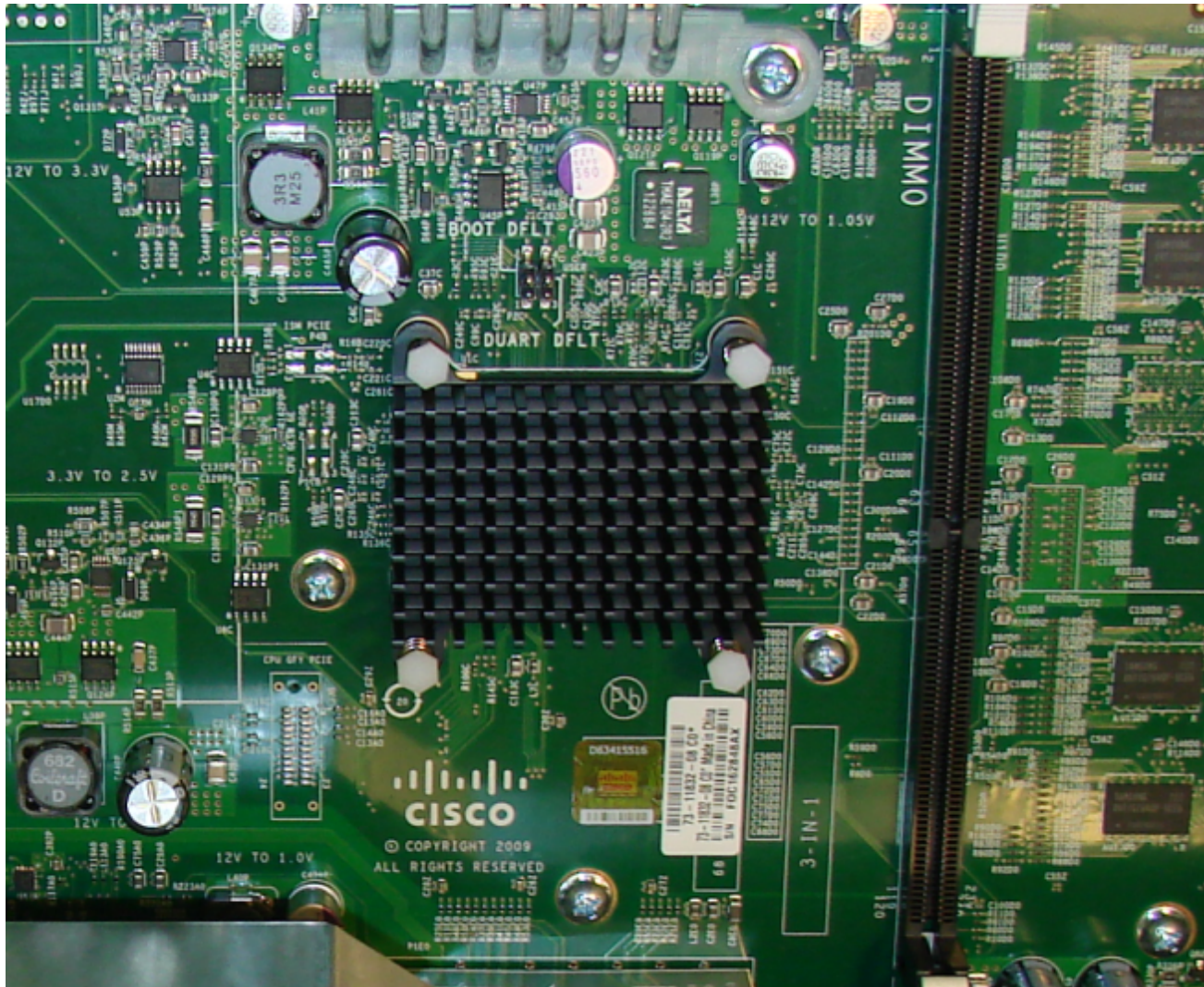


# Anatomy of a Router

## A Router is a Computer



# Router CPU and OS





# Anatomy of a Router

## Router Memory

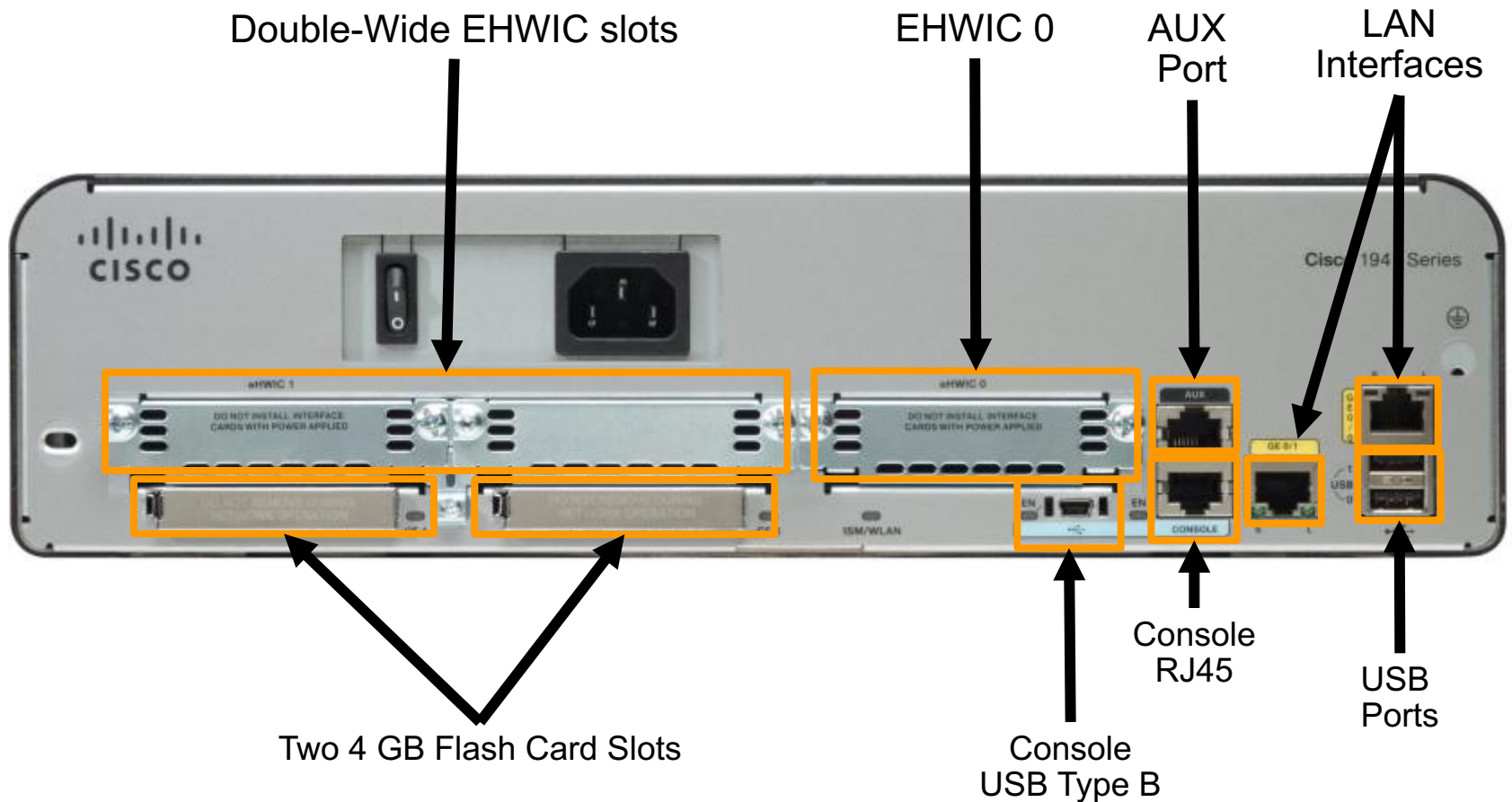
Memory	Volatile / Non-Volatile	Stores
<b>RAM</b>	Volatile	<ul style="list-style-type: none"> <li>• Running IOS</li> <li>• Running configuration file</li> <li>• IP routing and ARP tables</li> <li>• Packet buffer</li> </ul>
<b>ROM</b>	Non-Volatile	<ul style="list-style-type: none"> <li>• Bootup instructions</li> <li>• Basic diagnostic software</li> <li>• Limited IOS</li> </ul>
<b>NVRAM</b>	Non-Volatile	<ul style="list-style-type: none"> <li>• Startup configuration file</li> </ul>
<b>Flash</b>	Non-Volatile	<ul style="list-style-type: none"> <li>• IOS</li> <li>• Other system files</li> </ul>





# Anatomy of a Router

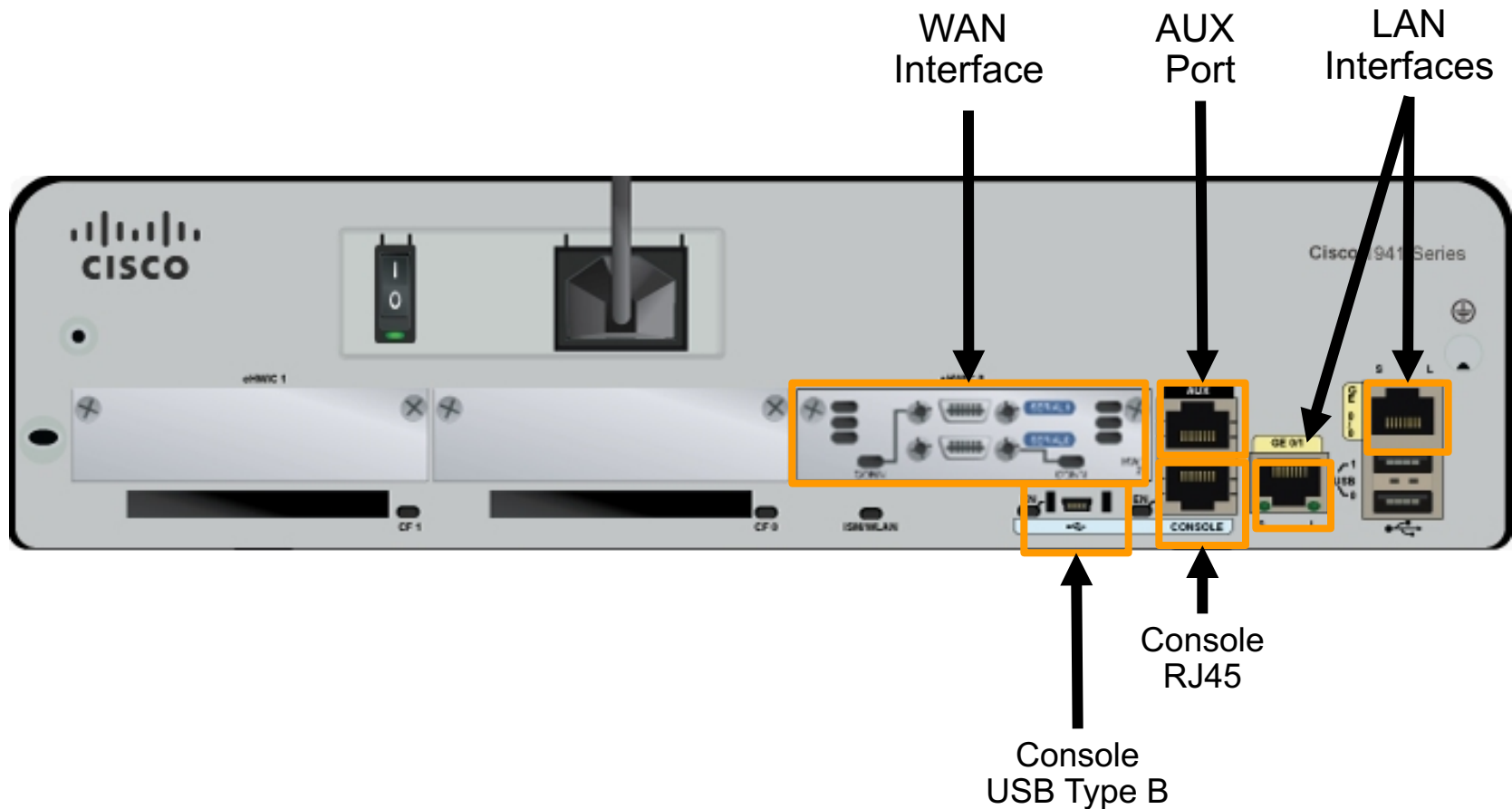
## Router Backplane





# Anatomy of a Router

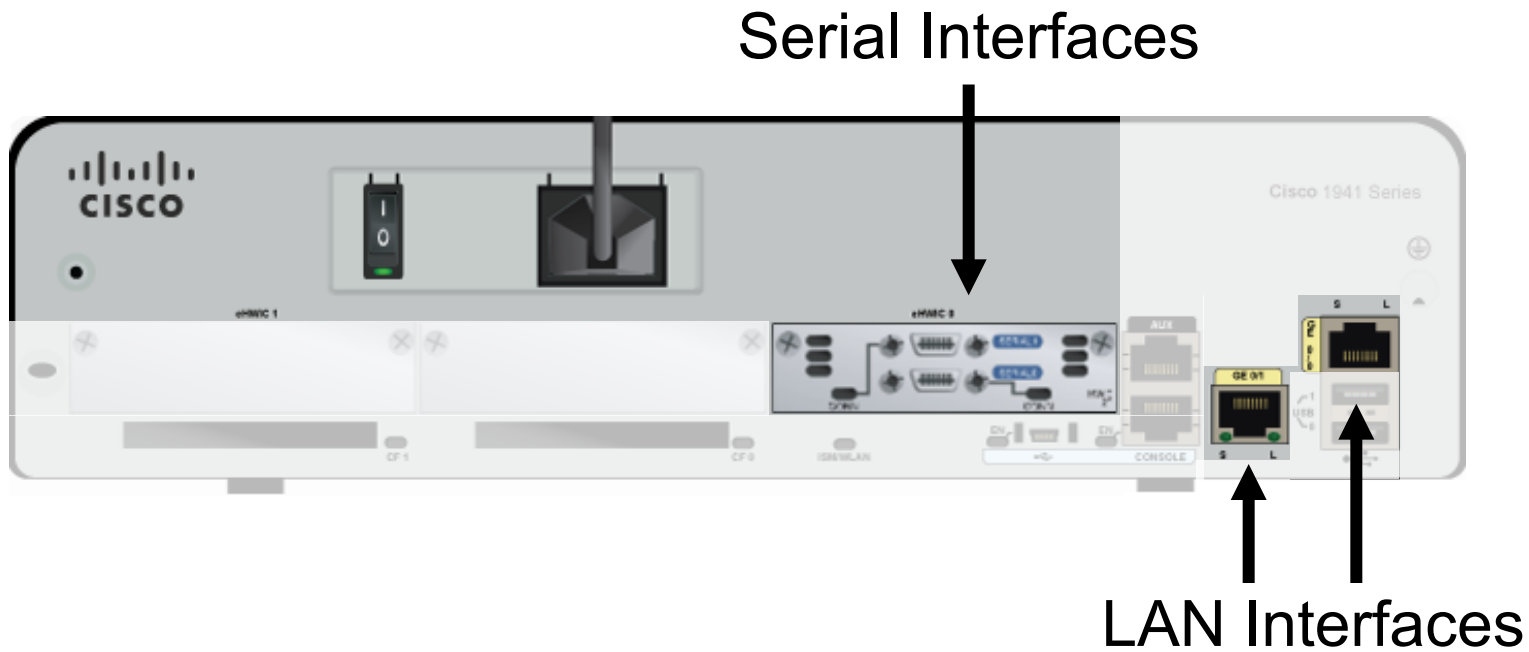
## Connecting to a Router





# Anatomy of a Router

## LAN and WAN Interfaces







## Router Boot-up

# Cisco IOS

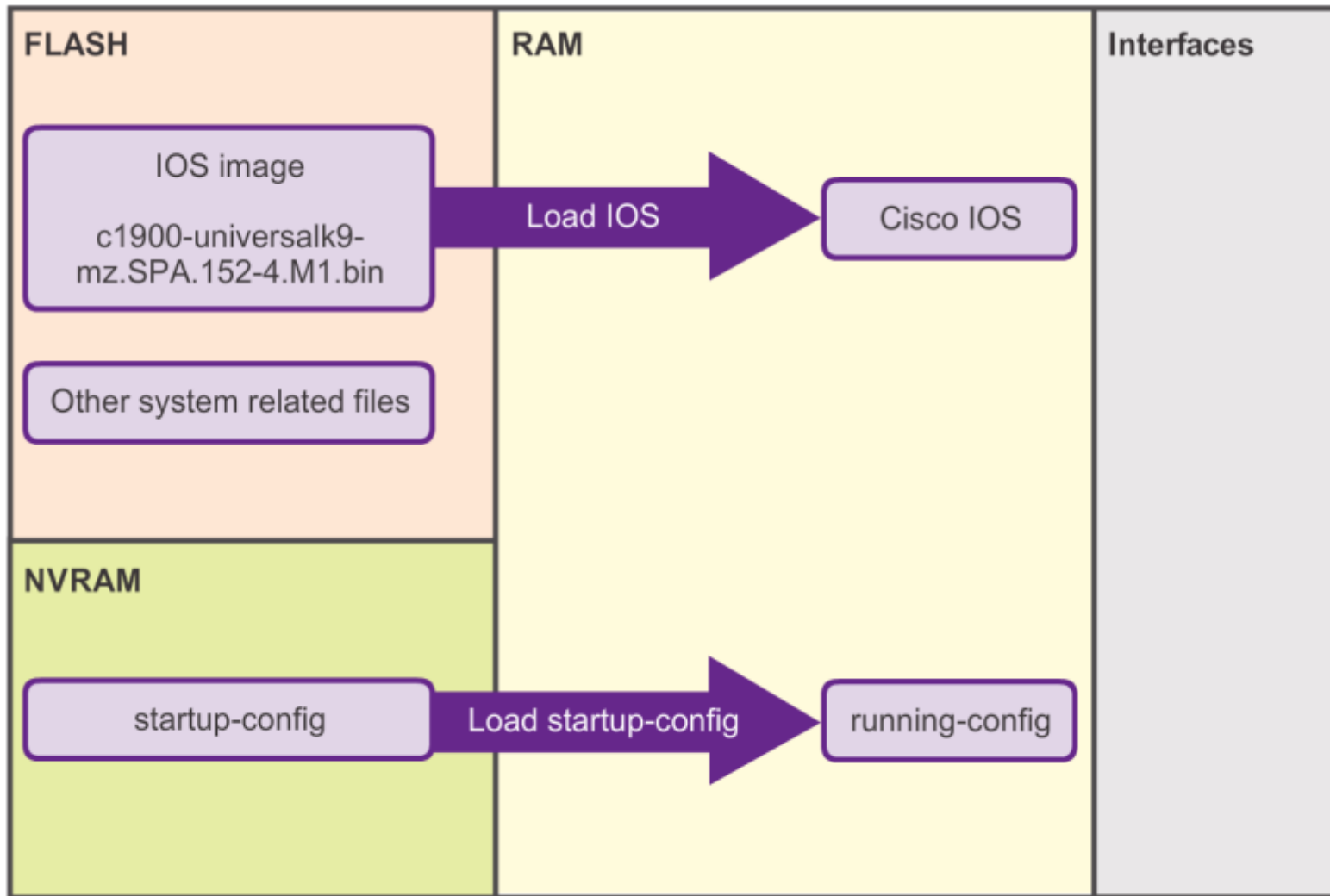
The Cisco IOS operational details vary on different internetworking devices, depending on the device's purpose and feature set. However, Cisco IOS for routers provides the following:

- Addressing
- Interfaces
- Routing
- Security
- QoS
- Resources Management



# Router Boot-up

## Bootset Files

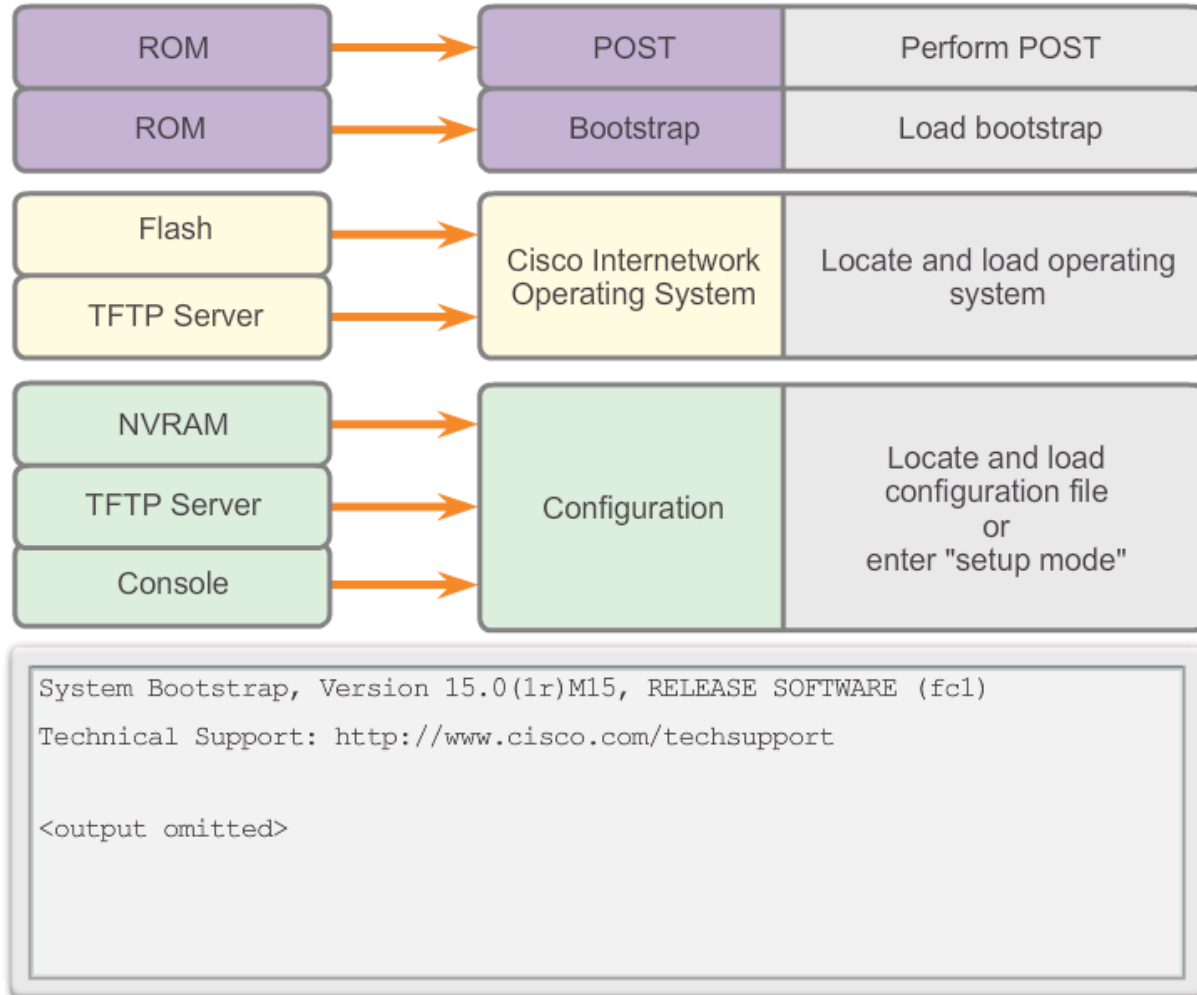




## Router Boot-up

# Router Bootup Process

### How a Router Boots Up





## 6.4 Configuring a Cisco Router

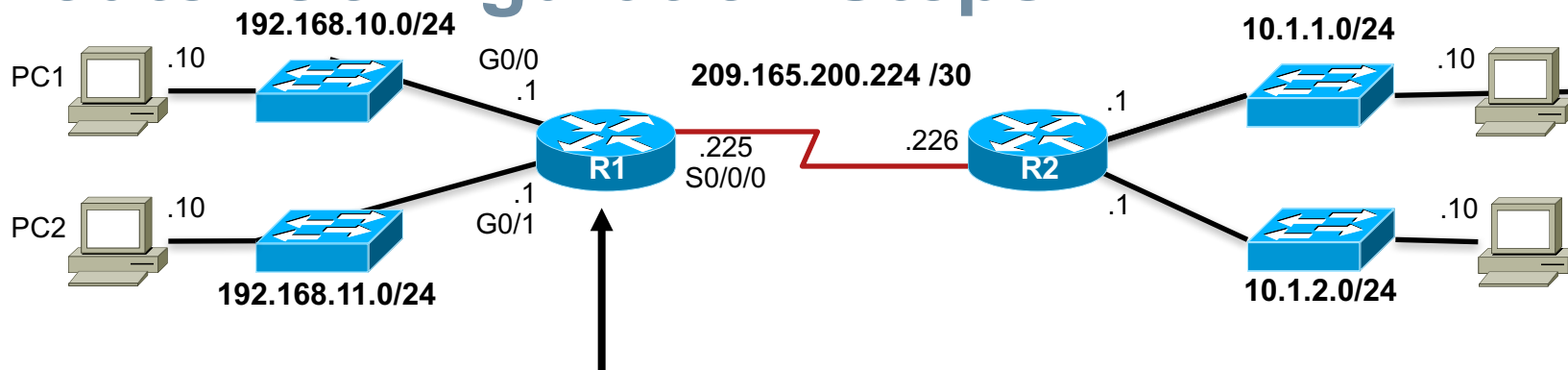


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# Configure Initial Settings

## Router Configuration Steps



```
Router> enable
Router# configure terminal
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# hostname R1
R1(config)#
```

OR

```
Router> en
Router# conf t
Enter configuration commands, one per line.
End with CNTL/Z.
Router(config)# ho R1
R2(config)#
```

```
R1(config)# enable secret class
R1(config)#
R1(config)# line console 0
R1(config-line)# password cisco
R1(config-line)# login
R1(config-line)# exit
R1(config)#
R1(config)# line vty 0 4
R1(config-line)# password cisco
R1(config-line)# login
R1(config-line)# exit
R1(config)#
R1(config)# service password-encryption
R1(config)#
```

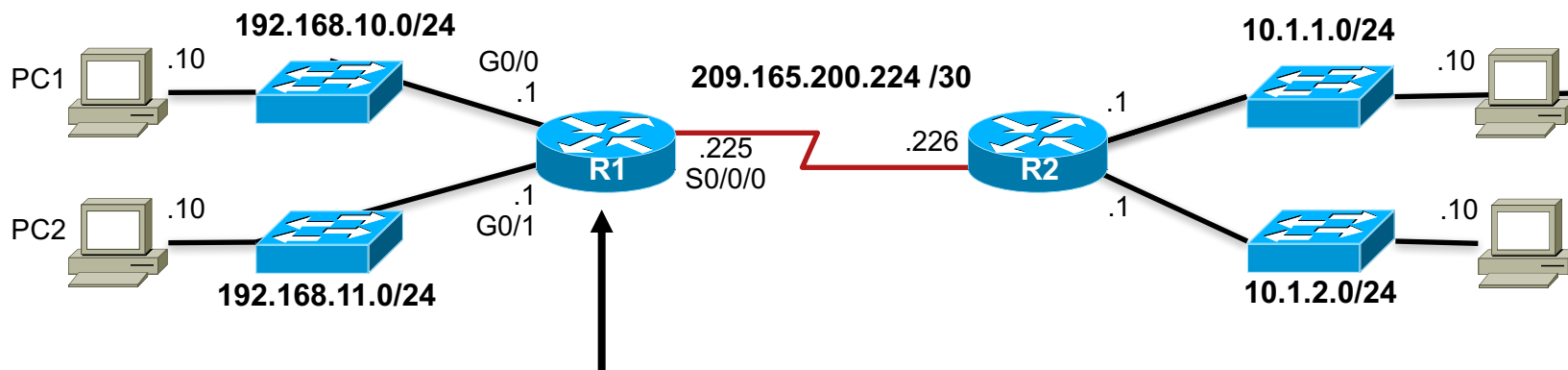
```
R1(config)# banner motd #
Enter TEXT message. End with the character '#'.
*****
WARNING: Unauthorized access is prohibited!
*****
#
R1(config)#
```

```
R1# copy running-config startup-config
Destination filename [startup-config]?
Building configuration...
[OK]
R1#
```



# Configure Interfaces

## Configure LAN Interfaces

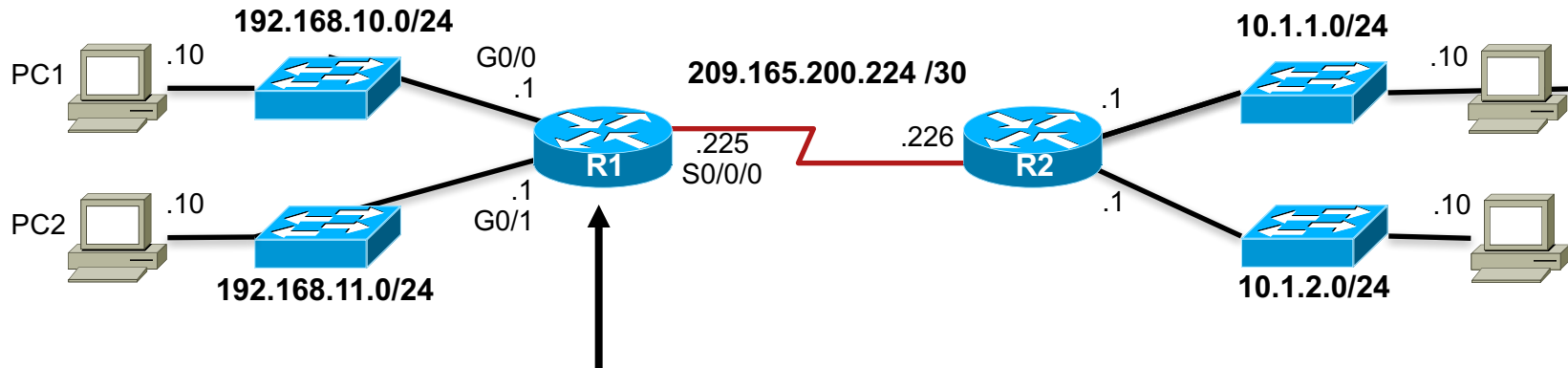


```
R1# conf t
Enter configuration commands, one per line. End with CNTL/Z.
R1(config)#
R1(config)# interface gigabitethernet 0/0
R1(config-if)# ip address 192.168.10.1 255.255.255.0
R1(config-if)# description Link to LAN-10
R1(config-if)# no shutdown
%LINK-5-CHANGED: Interface GigabitEthernet0/0, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/0,
changed state to up
R1(config-if)# exit
R1(config)#
R1(config)# int g0/1
R1(config-if)# ip add 192.168.11.1 255.255.255.0
R1(config-if)# des Link to LAN-11
R1(config-if)# no shut
%LINK-5-CHANGED: Interface GigabitEthernet0/1, changed state to up
%LINEPROTO-5-UPDOWN: Line protocol on Interface GigabitEthernet0/1,
changed state to up
R1(config-if)# exit
R1(config)#
```



# Configure Interfaces

## Verify Interface Configuration



```
R1# show ip interface brief
Interface                IP-Address      OK? Method Status      Protocol
GigabitEthernet0/0       192.168.10.1    YES manual  up          up
GigabitEthernet0/1       192.168.11.1    YES manual  up          up
Serial0/0/0               209.165.200.225 YES manual  up          up
Serial0/0/1               unassigned      YES NVRAM   administratively down down
Vlan1                     unassigned      YES NVRAM   administratively down down
R1#
R1# ping 209.165.200.226

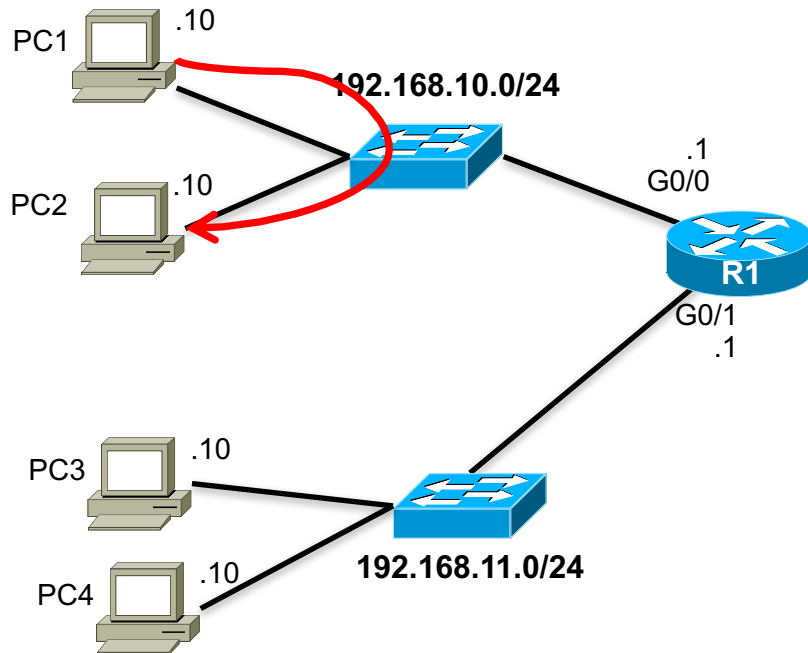
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 209.165.200.226, timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/9 ms
R1#
```



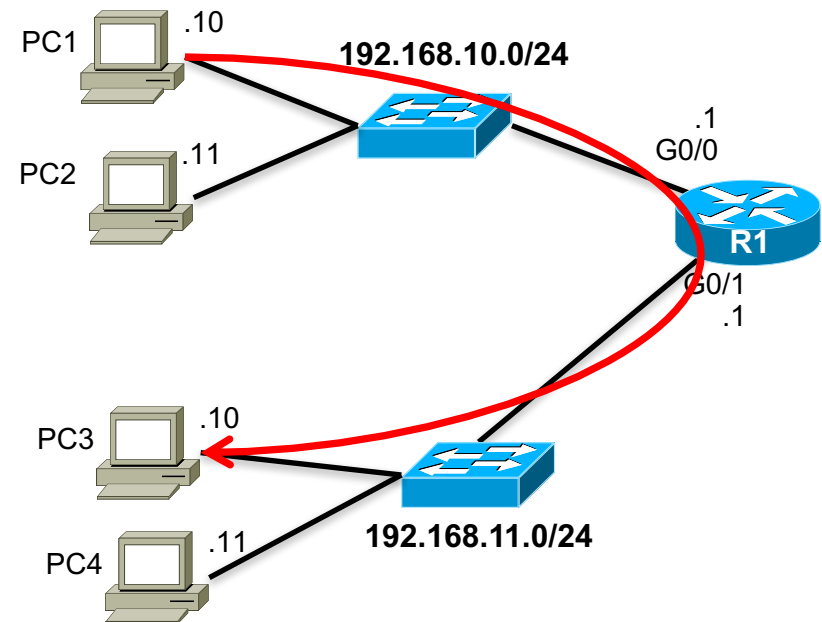
## Configuring the Default Gateway

# Default Gateway on a Host

Default Gateway  
not needed



Default Gateway  
needed



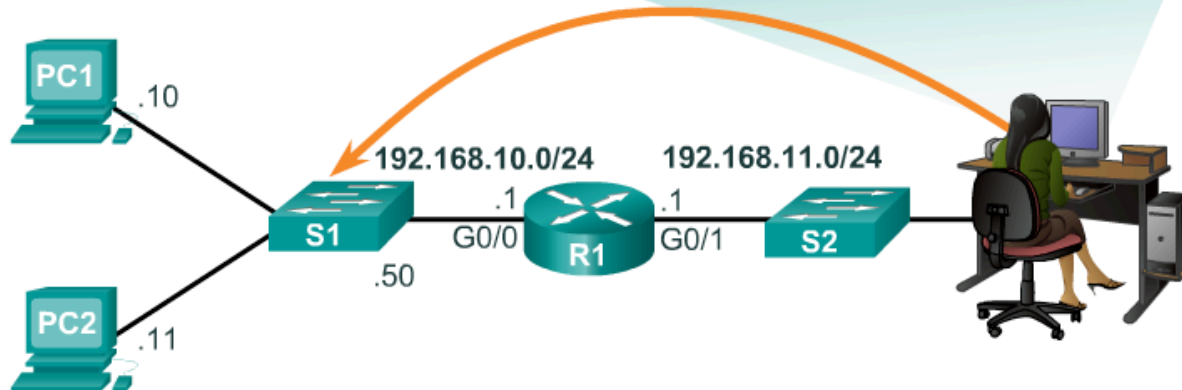




# Configuring the Default Gateway

## Default Gateway on a Switch

```
S1# show running-config
Building configuration...
!
<output omitted>
service password-encryption
!
hostname S1
!
Interface Vlan1
ip address 192.168.10.50
!
ip default-gateway 192.168.10.1
<output omitted>
```



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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