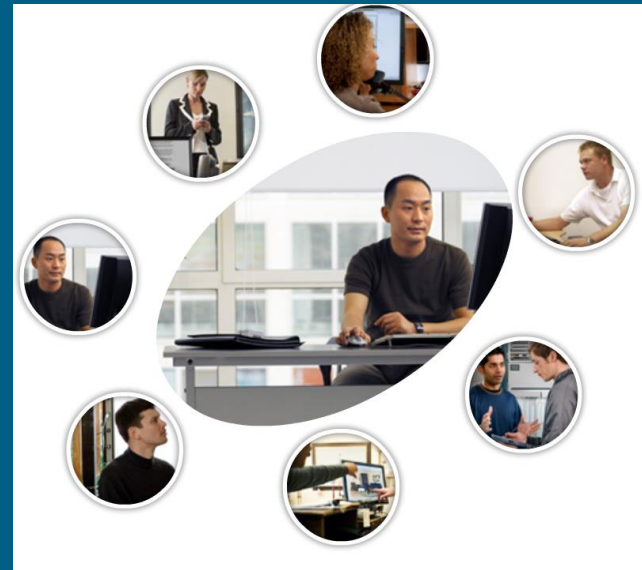




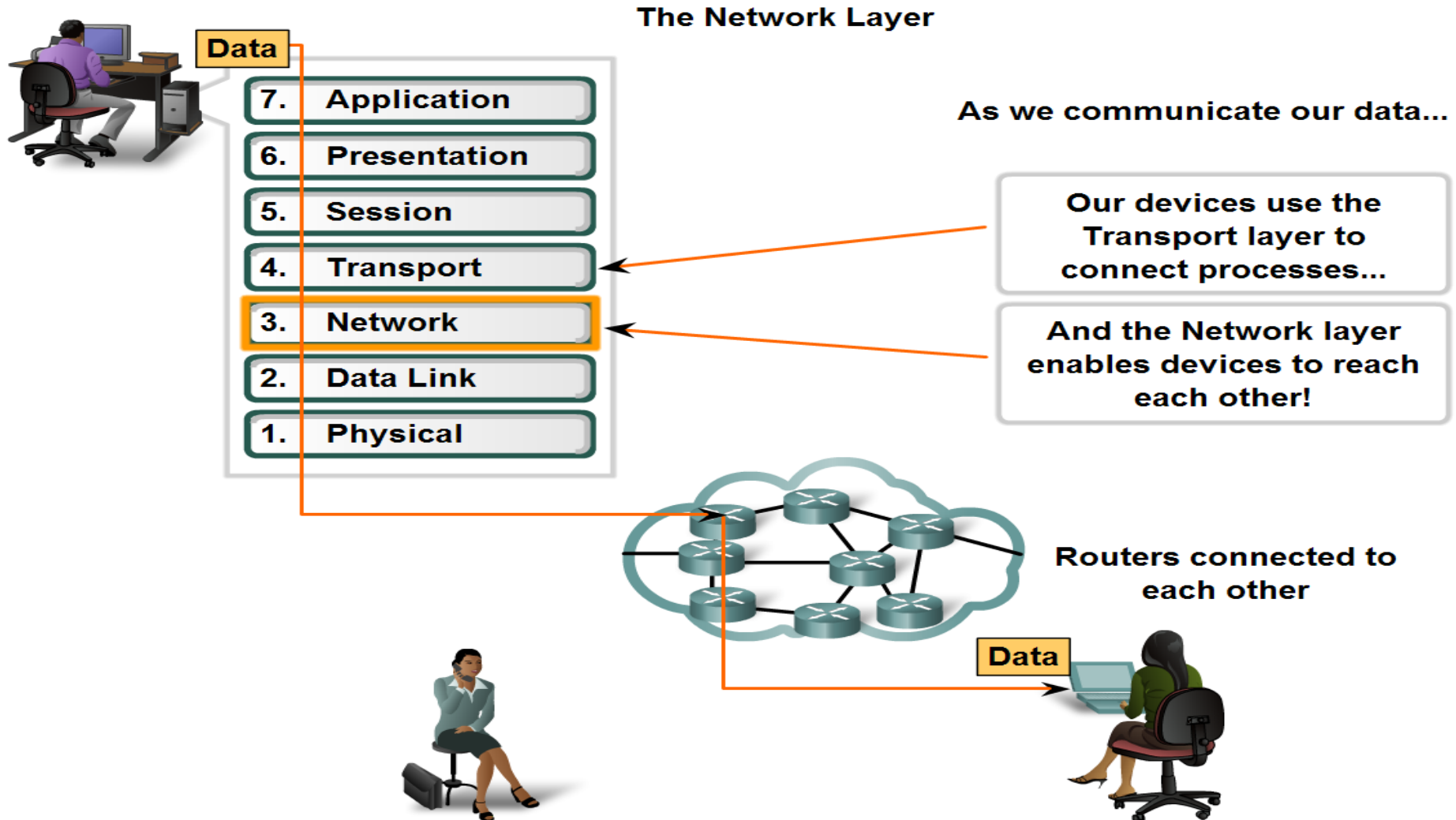
OSI Network Layer



Objectives

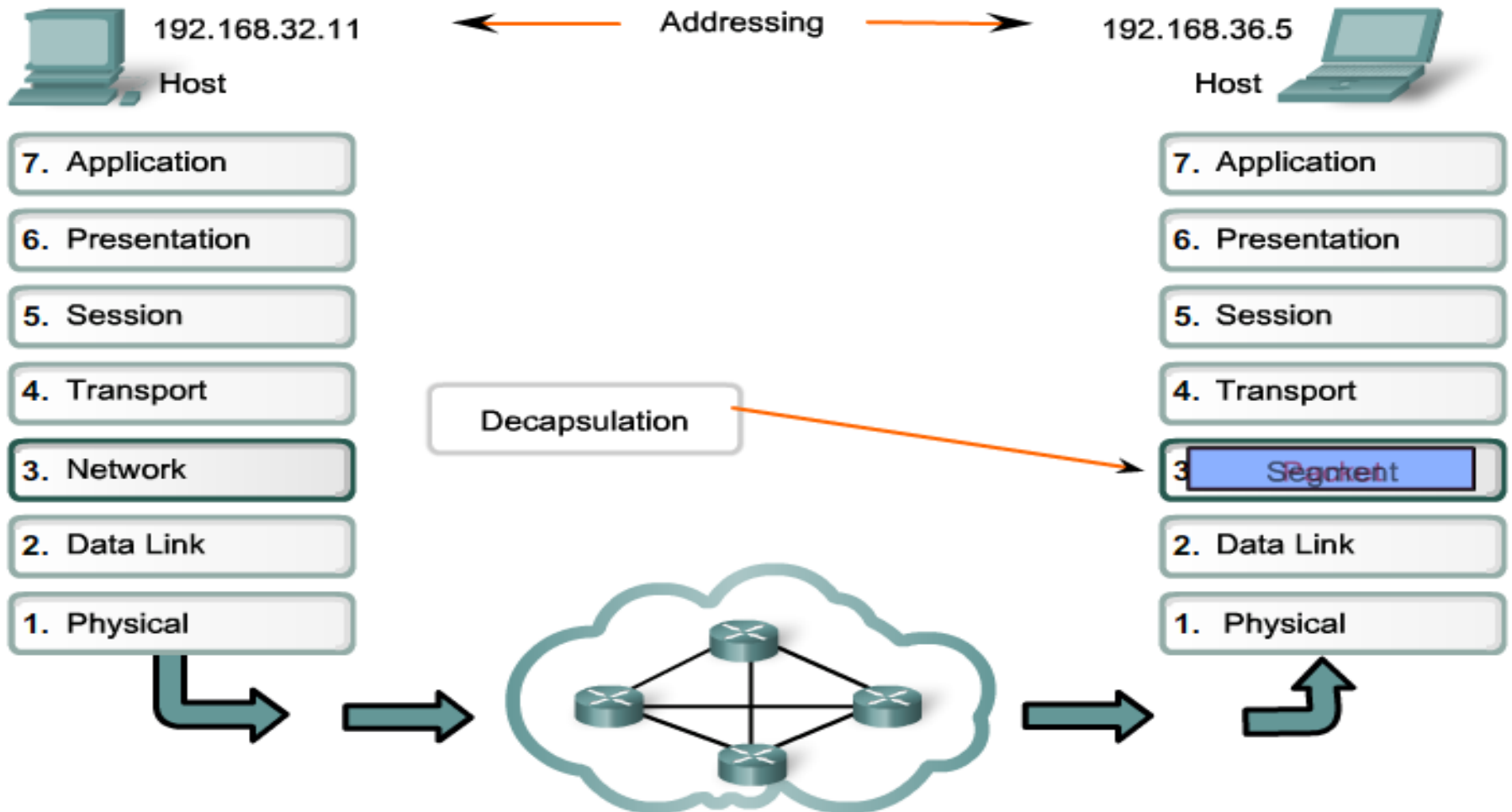
- Identify the role of the Network Layer, as it describes communication from one end device to another end device
- Examine the most common Network Layer protocol, Internet Protocol (IP), and its features for providing connectionless and best-effort service
- Understand the principles used to guide the division or grouping of devices into networks
- Understand the hierarchical addressing of devices and how this allows communication between networks
- Understand the fundamentals of routes, next hop addresses and packet forwarding to a destination network

Network Layer Protocols



Network Layer Protocols

Network layer protocols forward encapsulated Transport Layer PDUs between hosts



Network Layer Protocols

Network Layer Protocols

7. Application

6. Presentation

5. Session

4. Transport

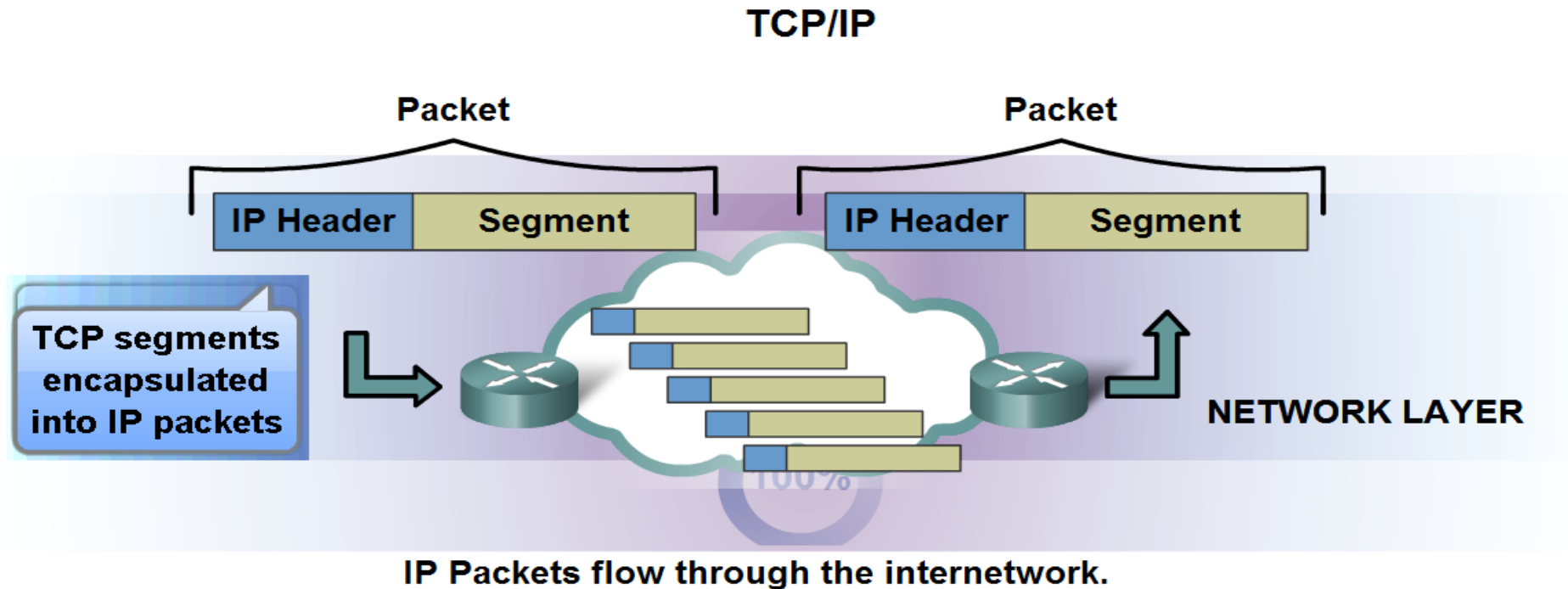
3. Network

2. Data Link

1. Physical

- Internet Protocol version 4 (IPv4)
- Internet Protocol version 6 (IPv6)
- Novell Internetwork Packet Exchange (IPX)
- AppleTalk
- Connectionless Network Service (CLNS/DECNet)

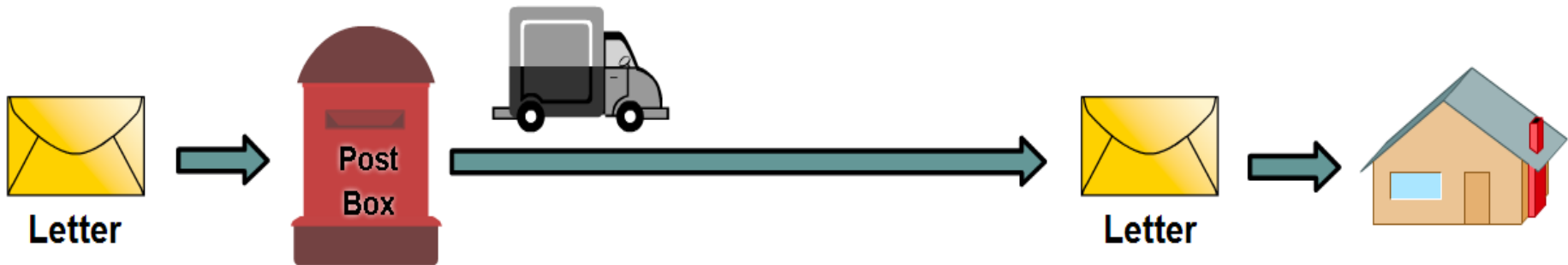
Network Layer Protocols and Internet Protocol (IP)



- **Connectionless** - No connection is established before sending data packets.
- **Best Effort (unreliable)** - No overhead is used to guarantee packet delivery.
- **Media Independent** - Operates independently of the medium carrying the data.

Network Layer Protocols and Internet Protocol (IP)

Connectionless Communication



A **letter** is sent.

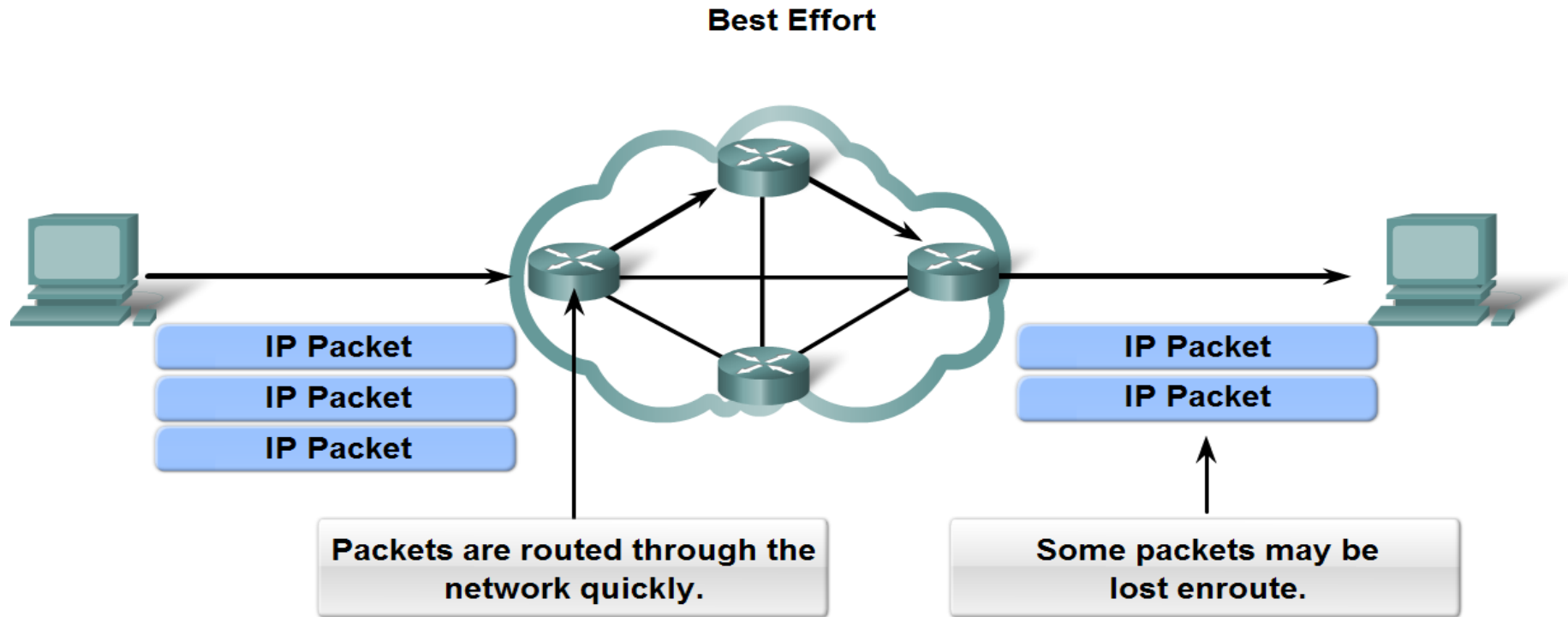
The sender doesn't know:

- 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

Network Layer Protocols and Internet Protocol (IP)

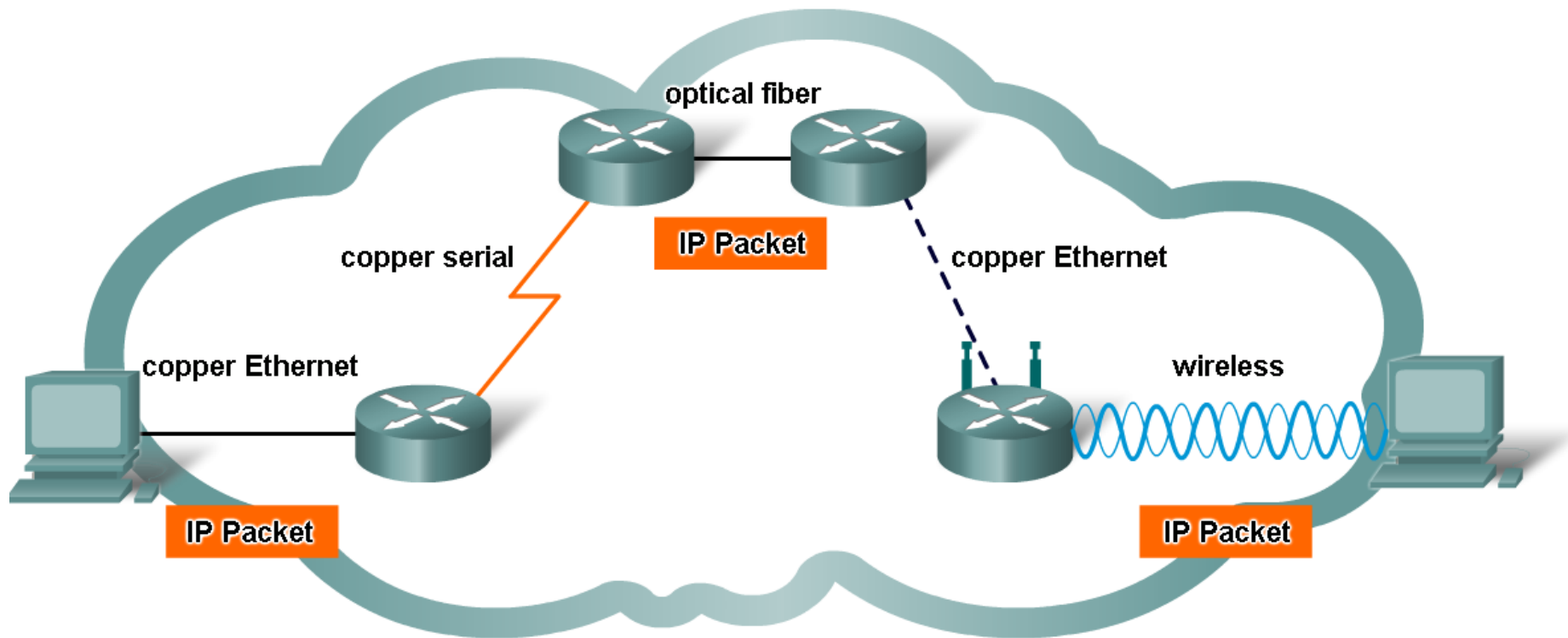


As an unreliable Network layer protocol, IP does not guarantee that all sent packets will be received.

Other protocols manage the process of tracking packets and ensuring their delivery.

Network Layer Protocols and Internet Protocol (IP)

Media Independence



IP packets can travel over different media.

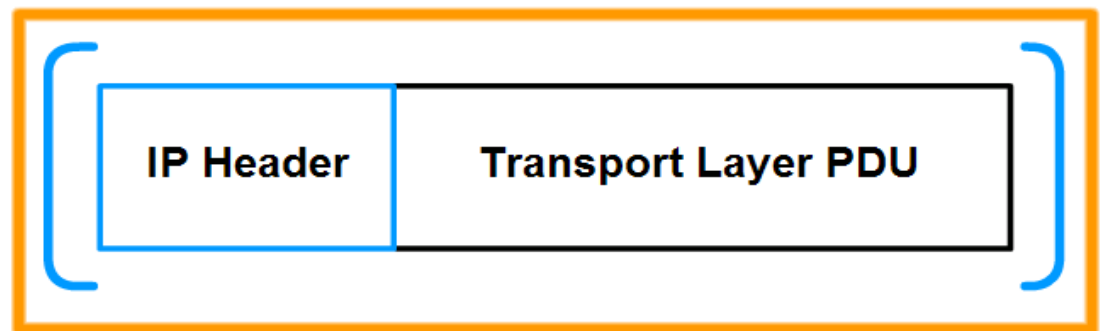
Network Layer Protocols and Internet Protocol (IP)

Generating IP Packets

Transport Layer Encapsulation



Network Layer Encapsulation

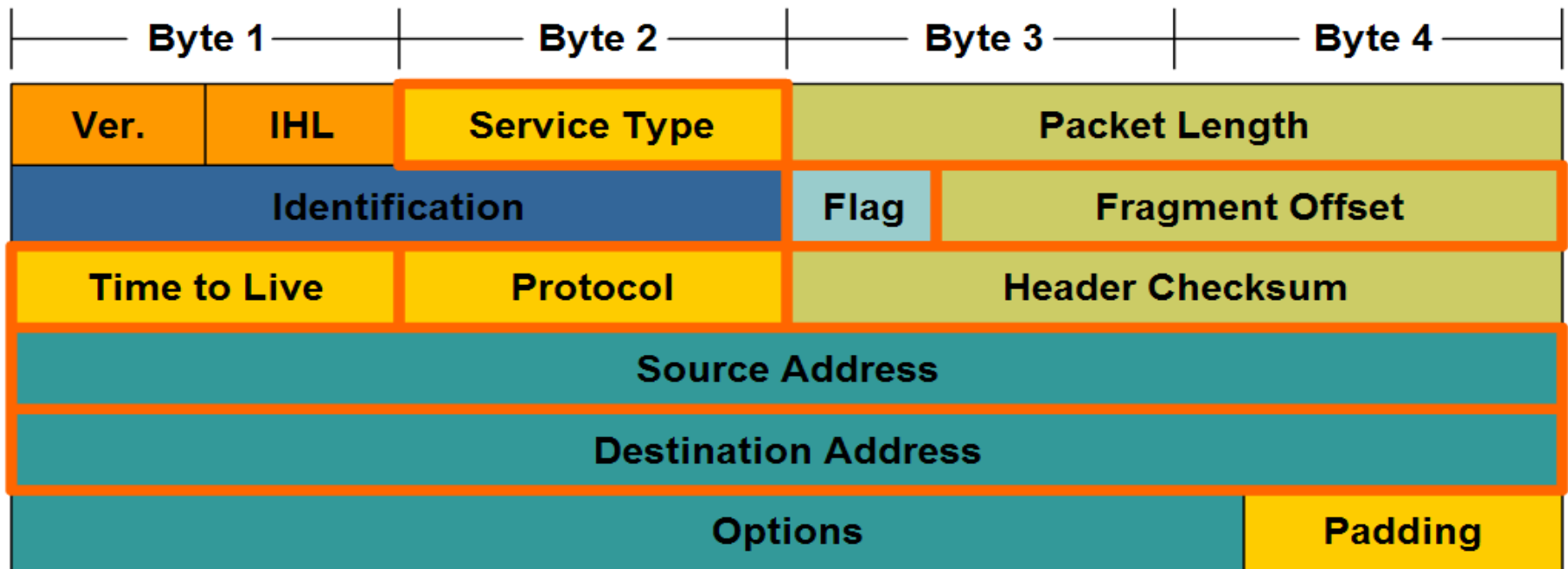


IP Packet

In **TCP/IP based networks**, the Network layer PDU is the **IP packet**.

Network Layer Protocols and Internet Protocol (IP)

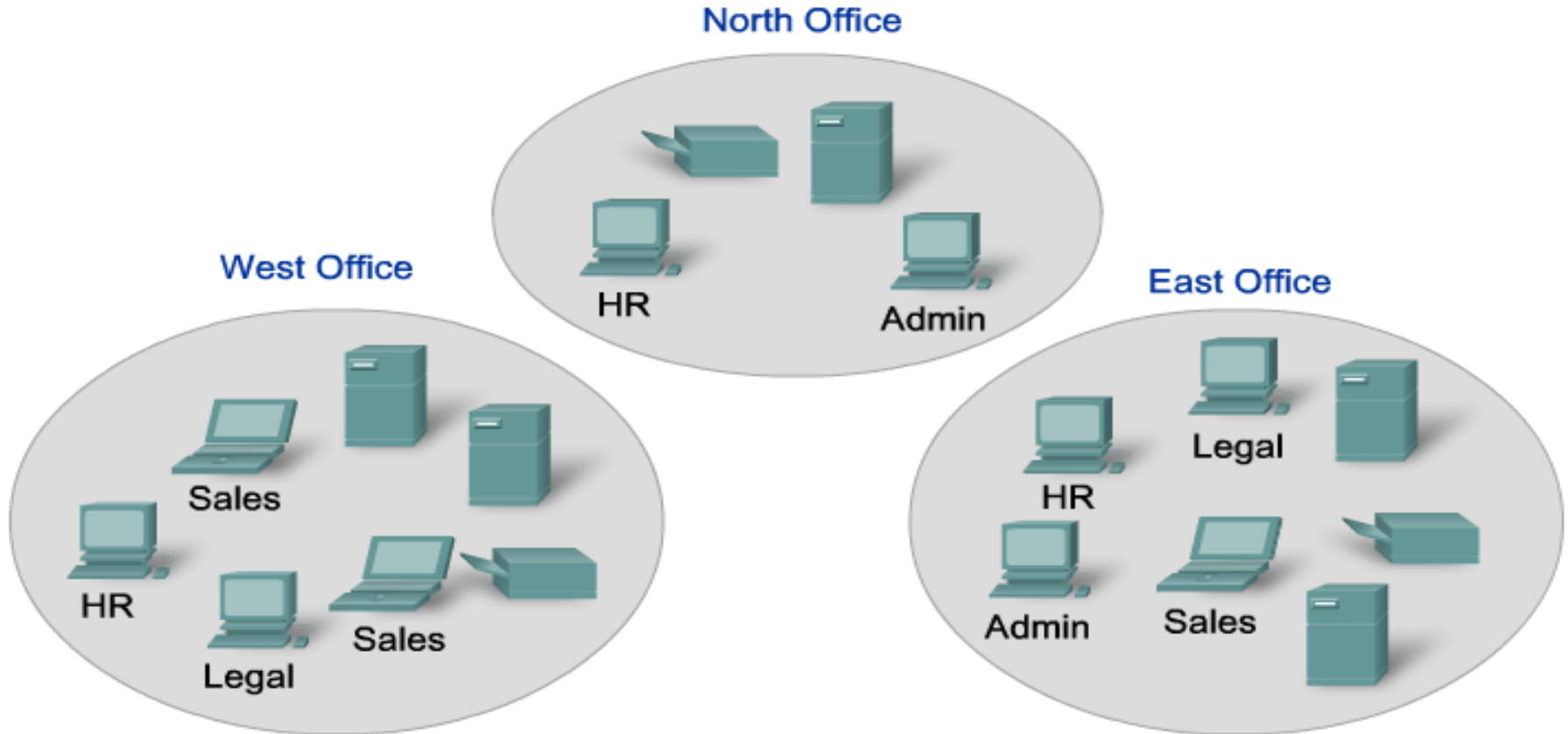
IPv4 Packet Header Fields



Traffic Types

- Unicast Vs Multicast Vs Broadcast
 - Unicast:- One source , One destination
 - Multicast:- One source , Many destination
 - Broadcast:-One source , All destinations
- Routers never forward the Broadcast traffic

Grouping Devices into Networks and Hierarchical Addressing

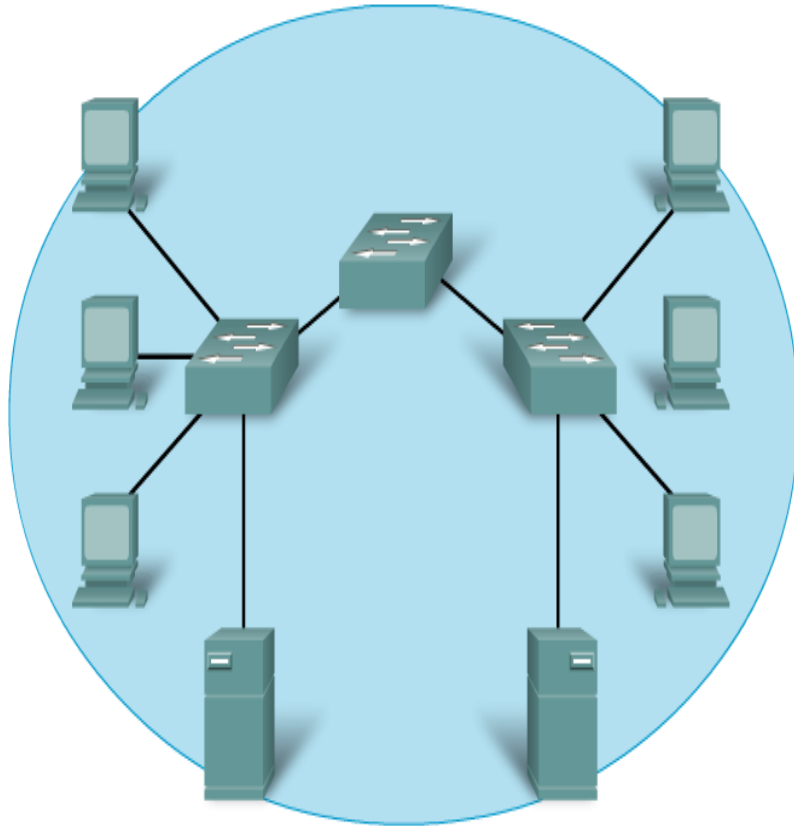


The simple fact of wiring together the physical network can make geographic location a logical place to start when segmenting a network.

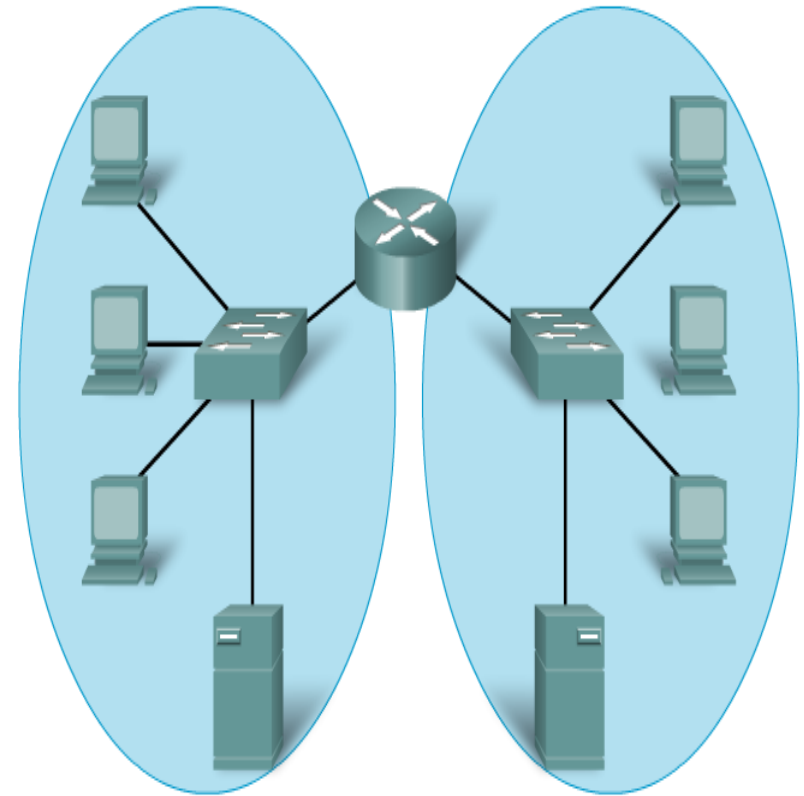
Segmentation of networks

- Purpose of network segmentation are:-
 - Increase Network performance
 - Increase Network Security
 - Increase Network Management

Increase Network performance

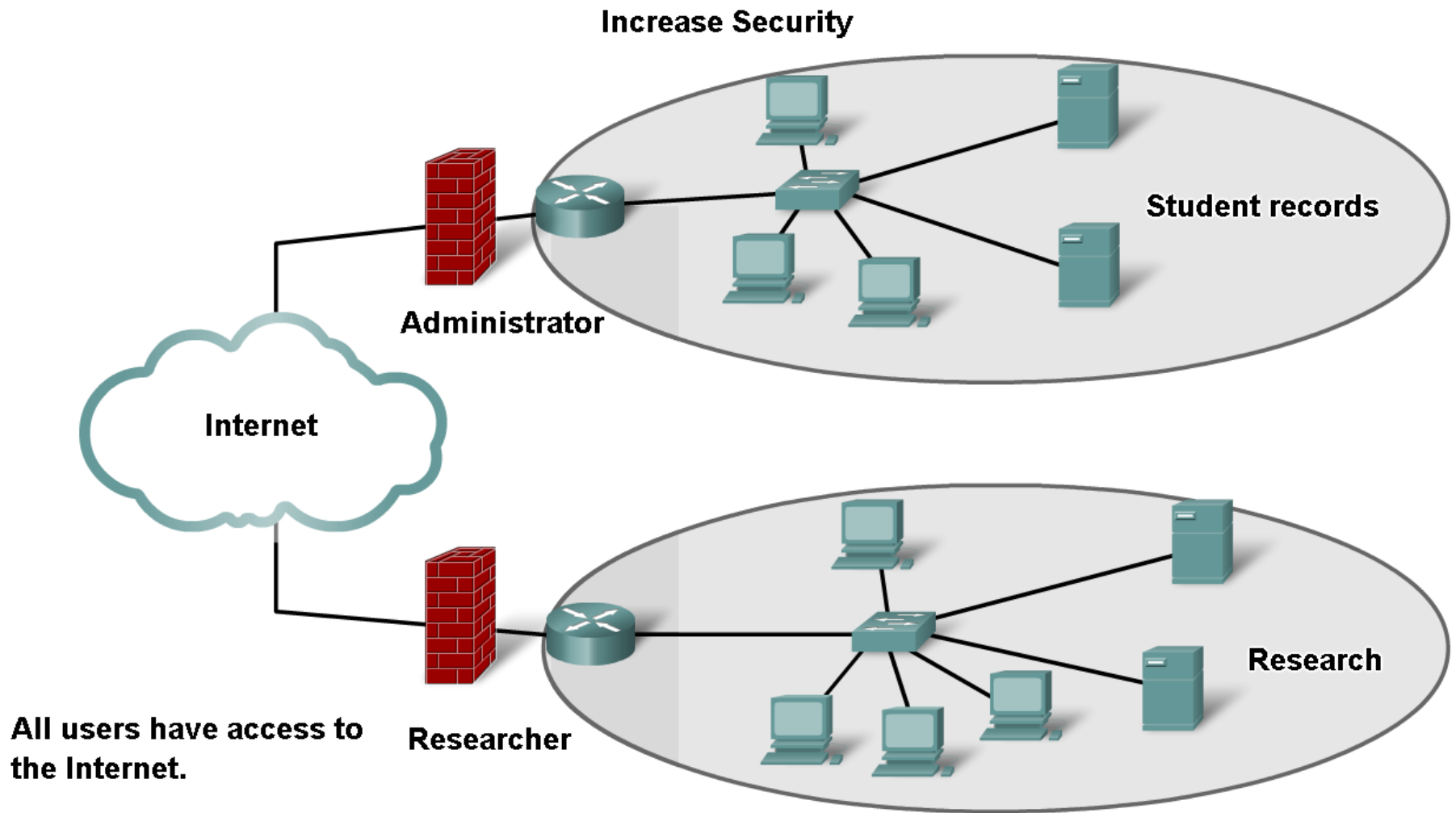


All devices in this network are connected in one broadcast domain when the switch is set to the factory default settings. Since switches forward broadcasts by default, broadcasts are processed by all devices in this network.

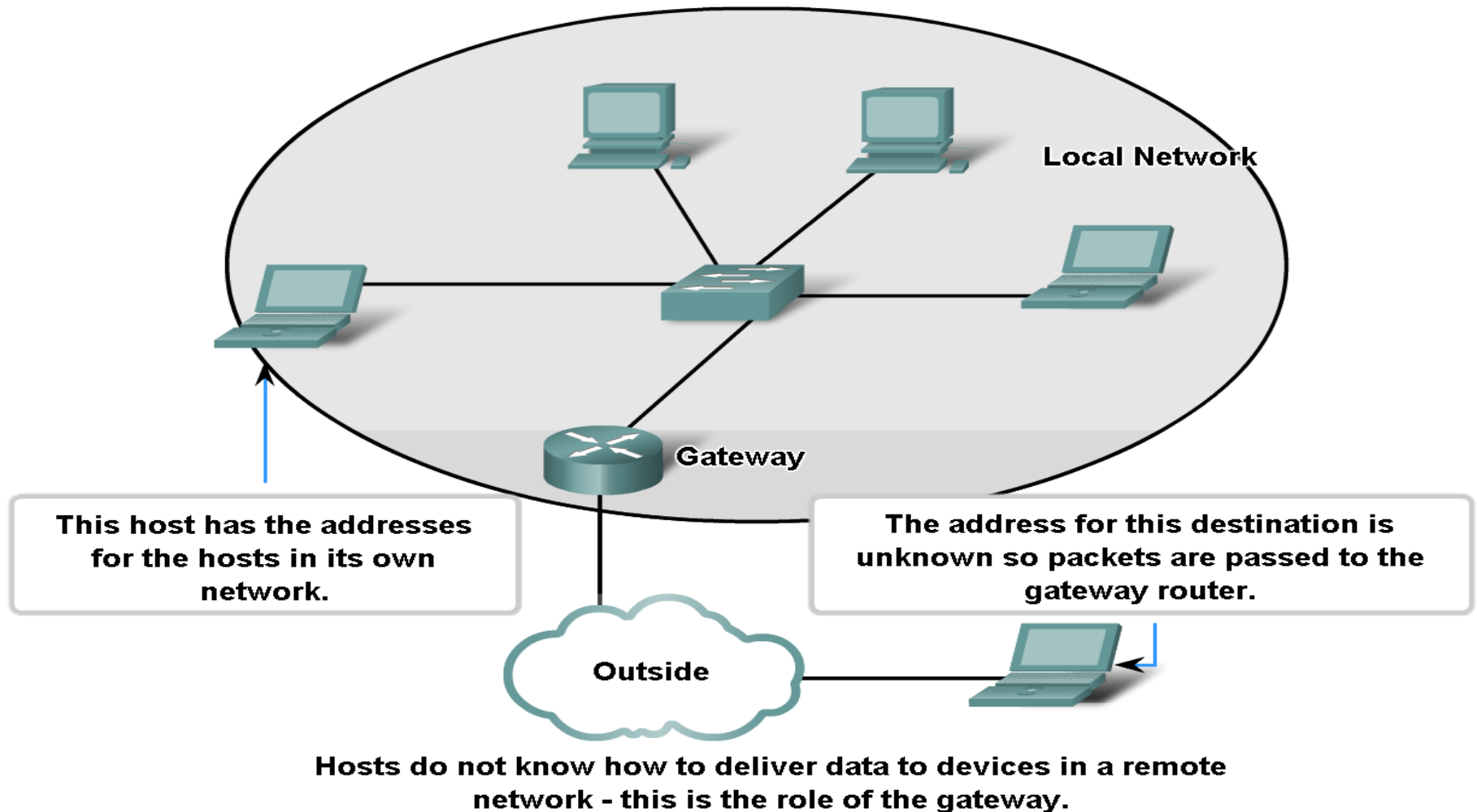


Replacing the middle switch with a router creates 2 IP subnets, hence, 2 distinct broadcast domains. All devices are connected but local broadcasts are contained.

Increase Network Security



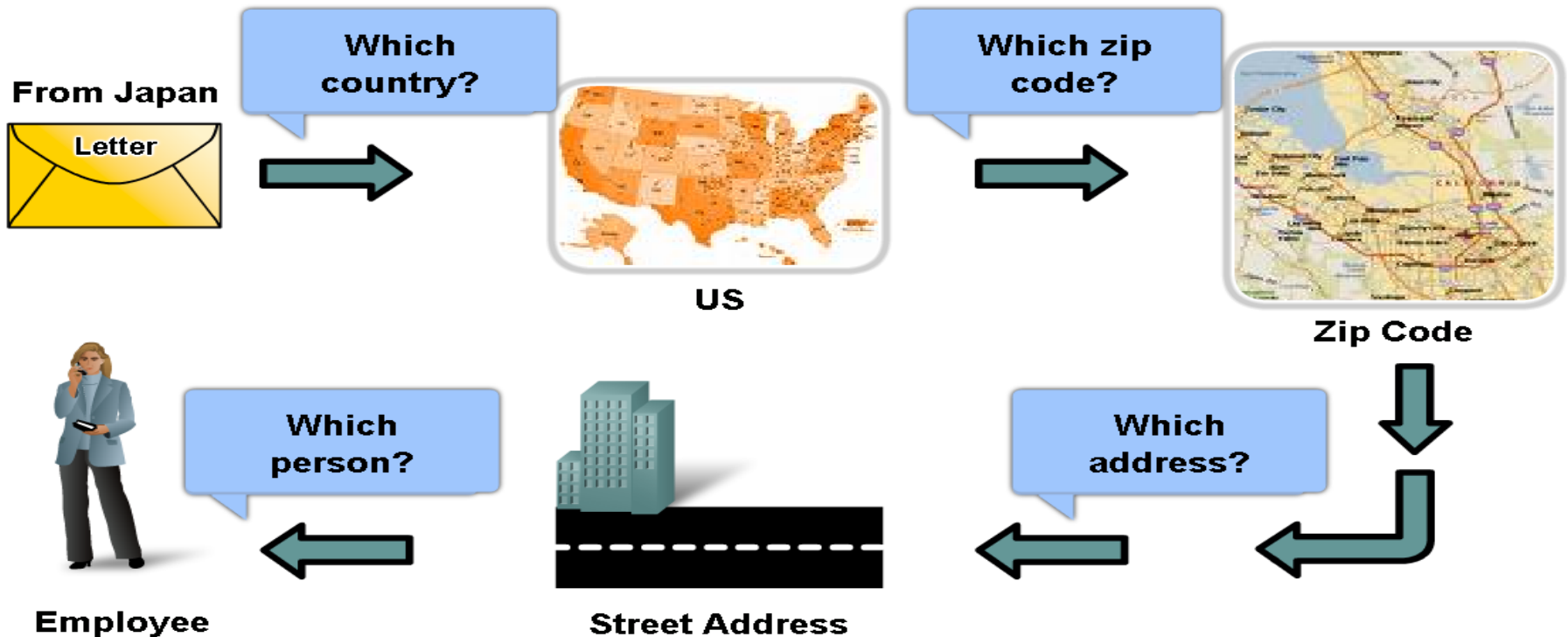
Increase Network manageability



Grouping Devices into Networks and Hierarchical Addressing

Hierarchical Addressing

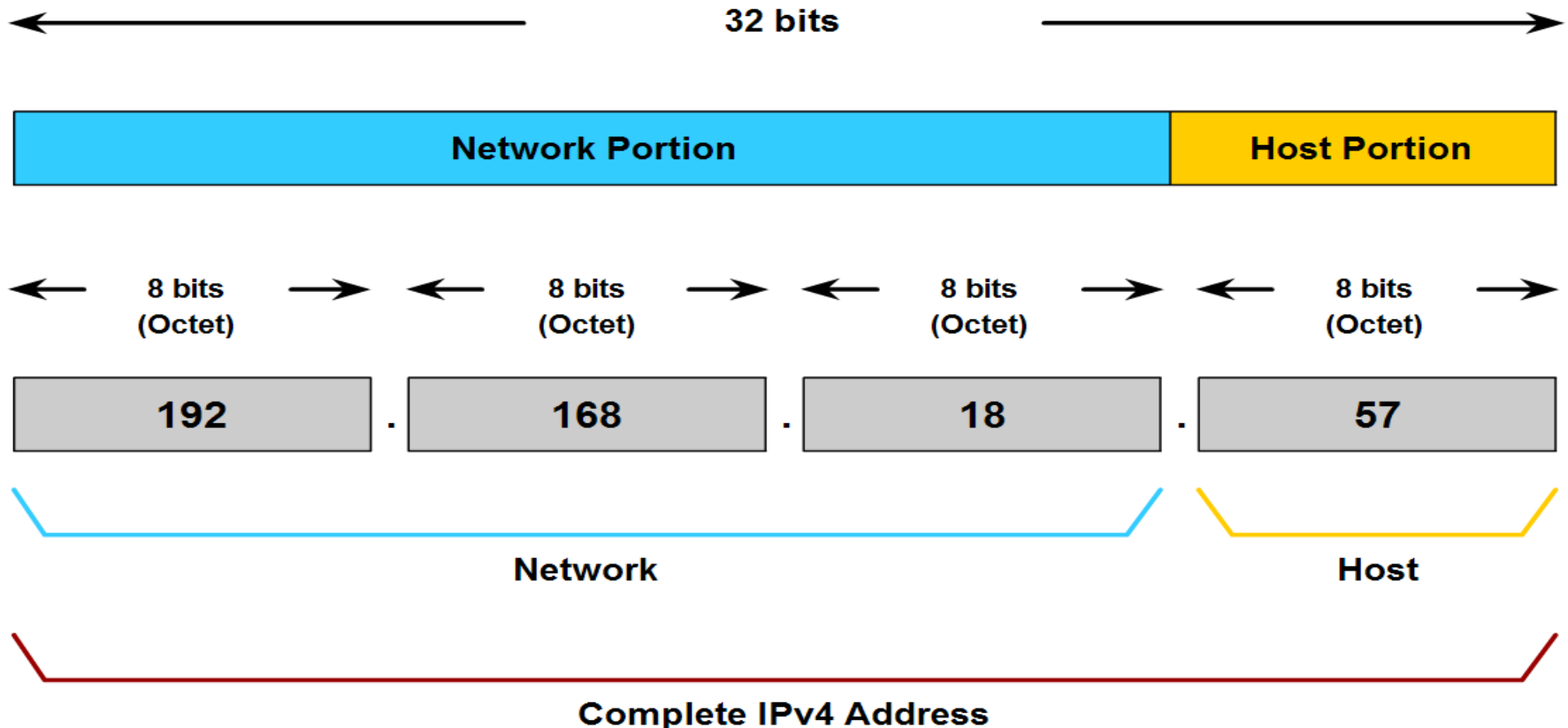
TO: Jane Doe 170 West Tasman Drive, San Jose, CA 95134, USA



At each step of delivery, the post office need only examine the next hierarchical level.

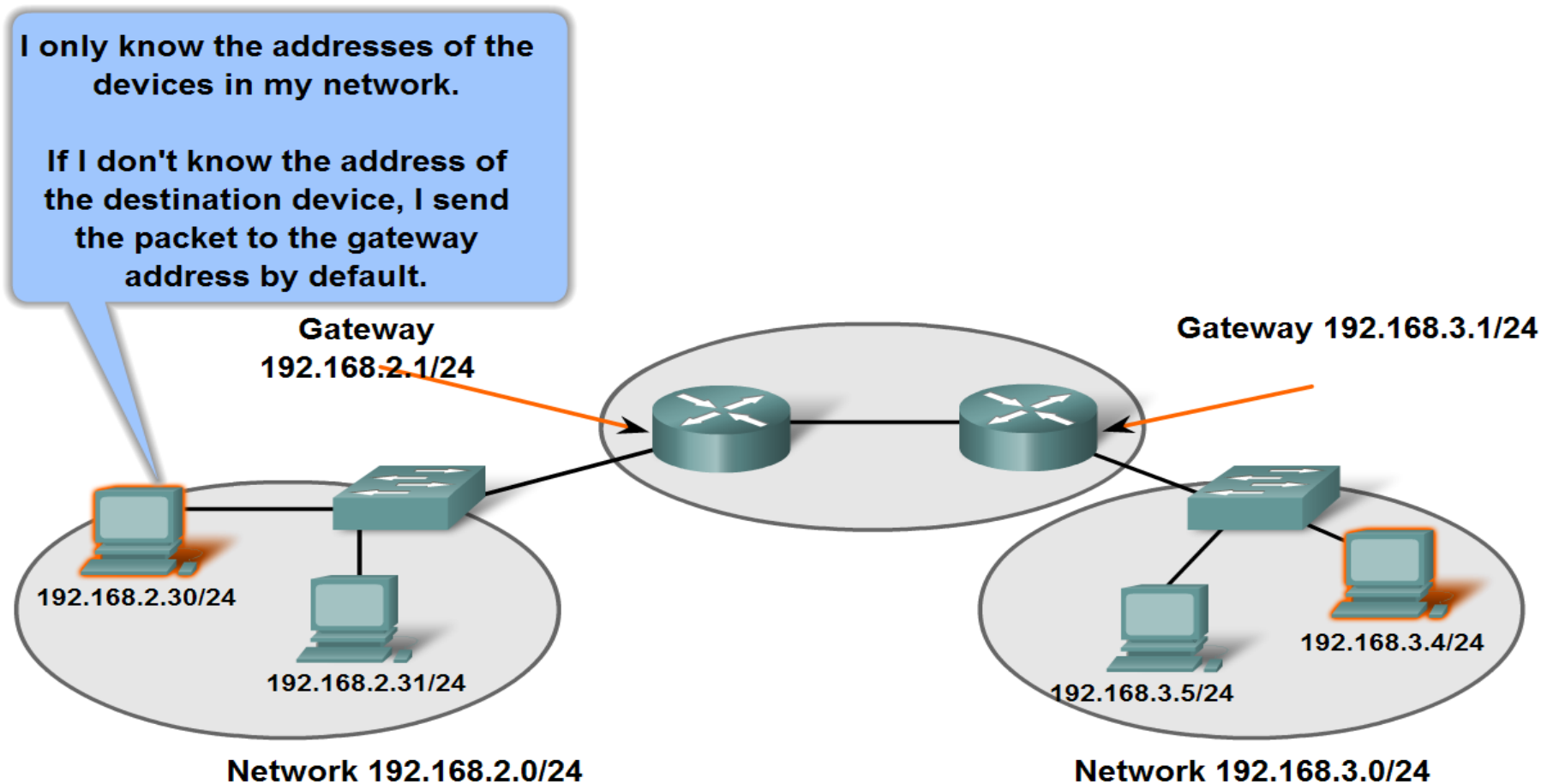
Grouping Devices into Networks and Hierarchical Addressing

Hierarchical IPv4 Address



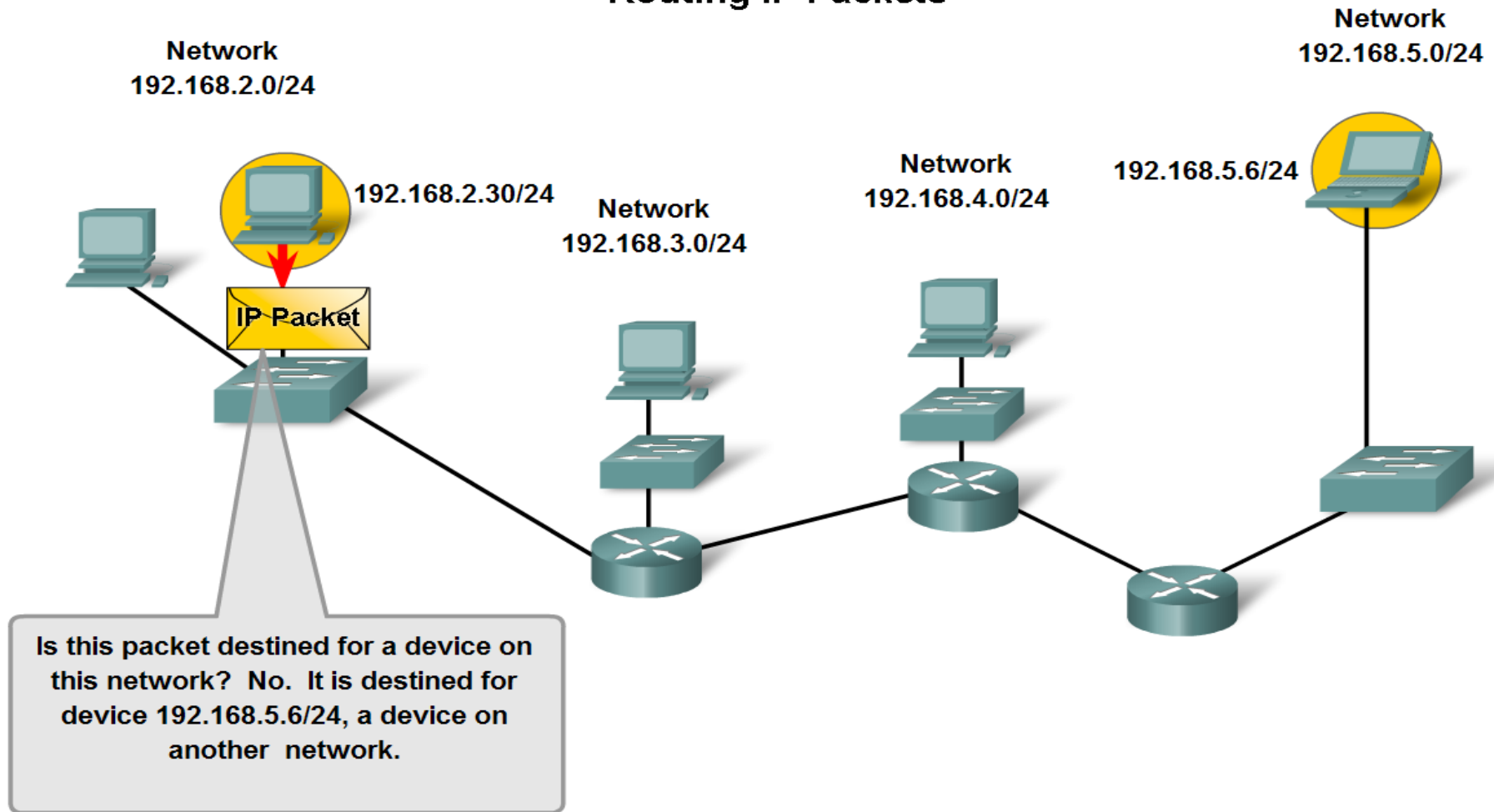
Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Gateways Enable Communications between Networks



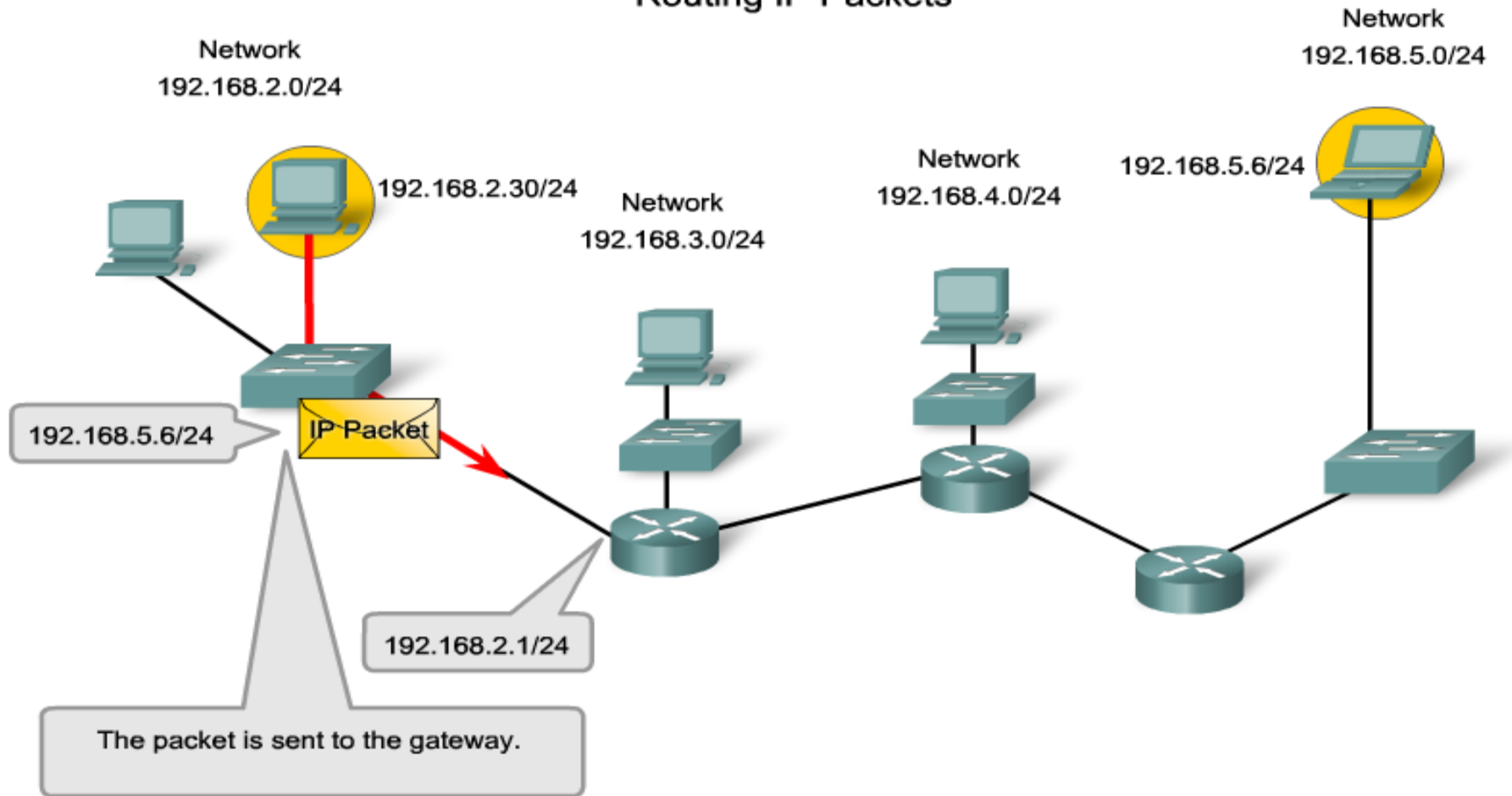
Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Routing IP Packets



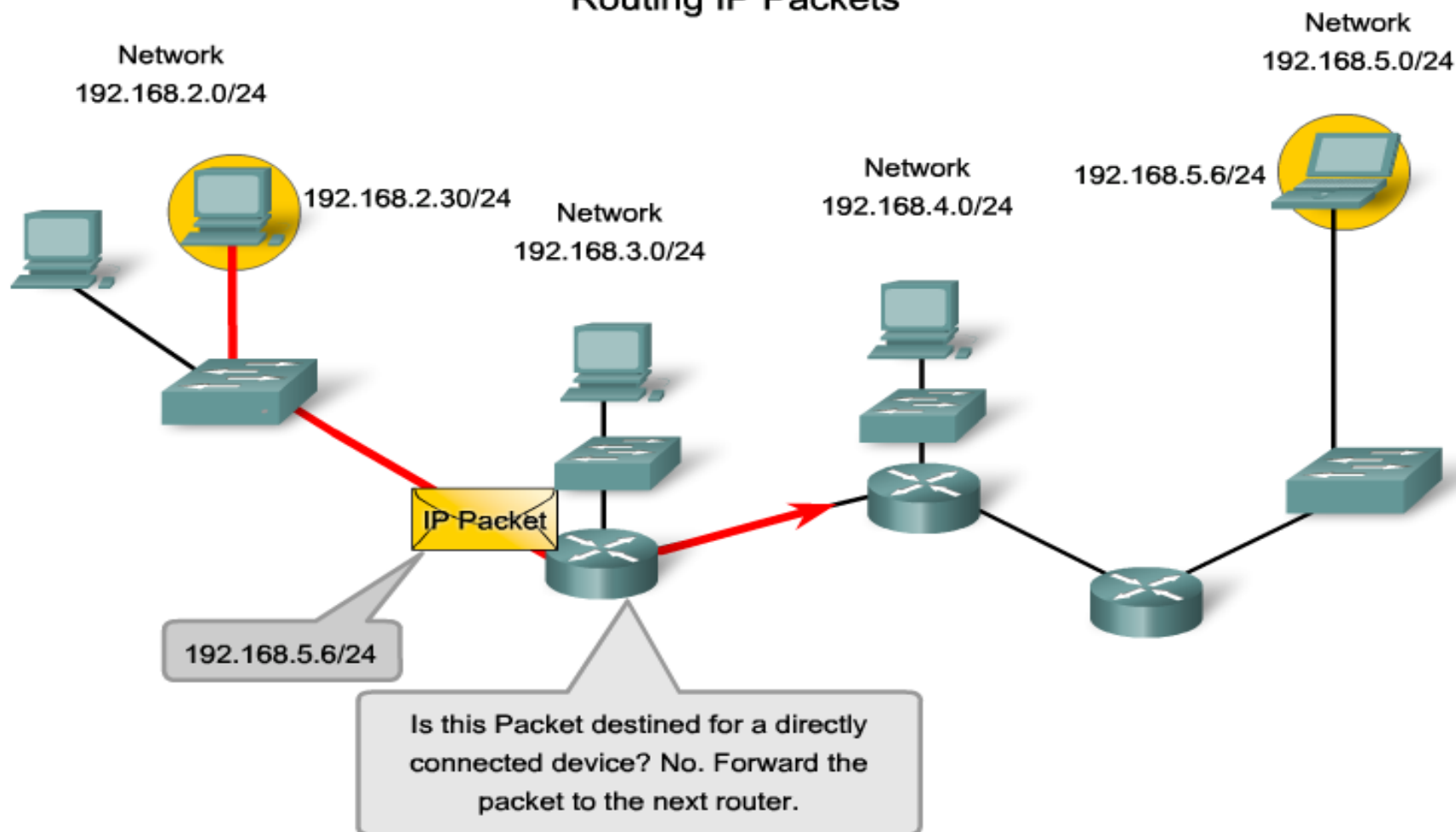
Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Routing IP Packets

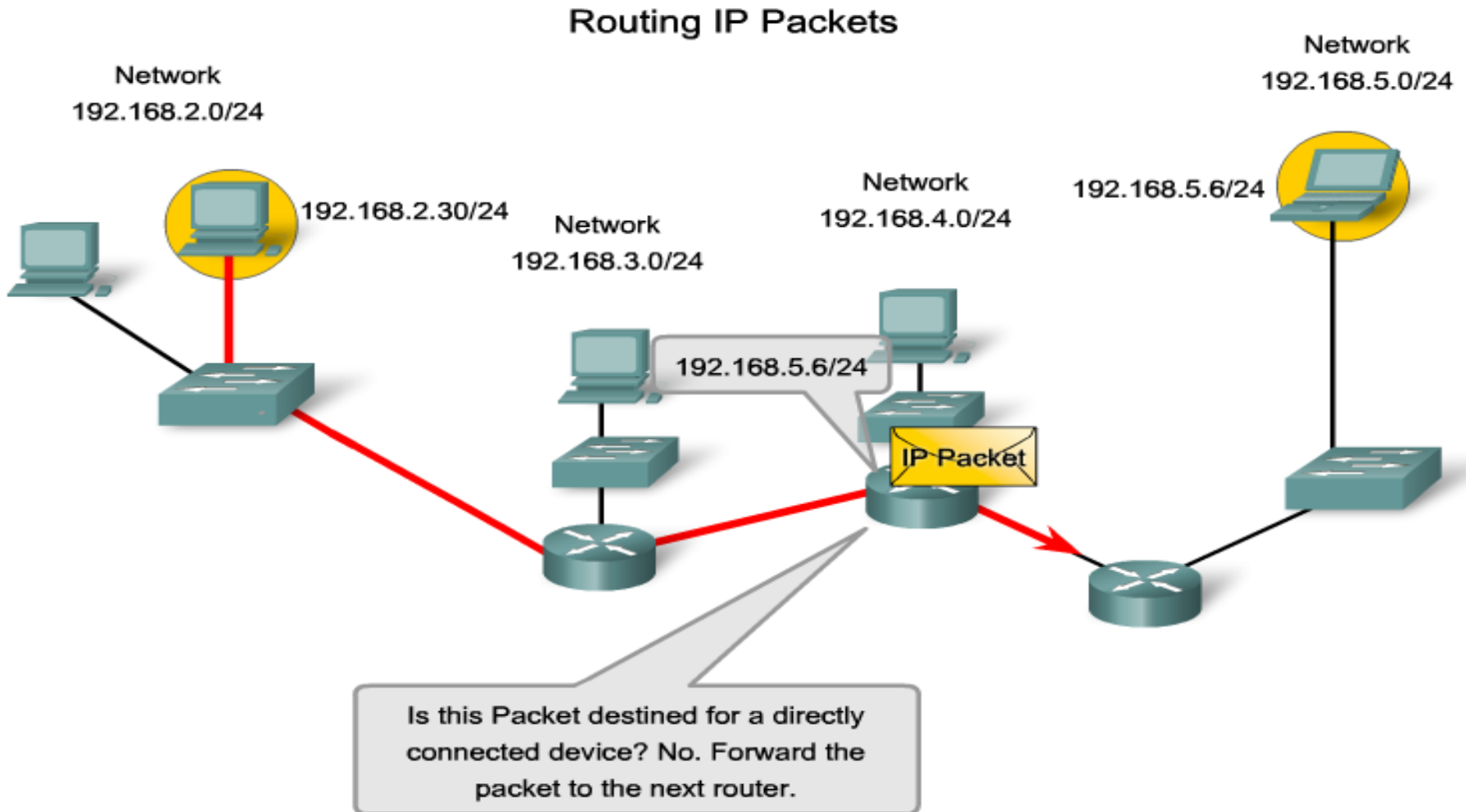


Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Routing IP Packets

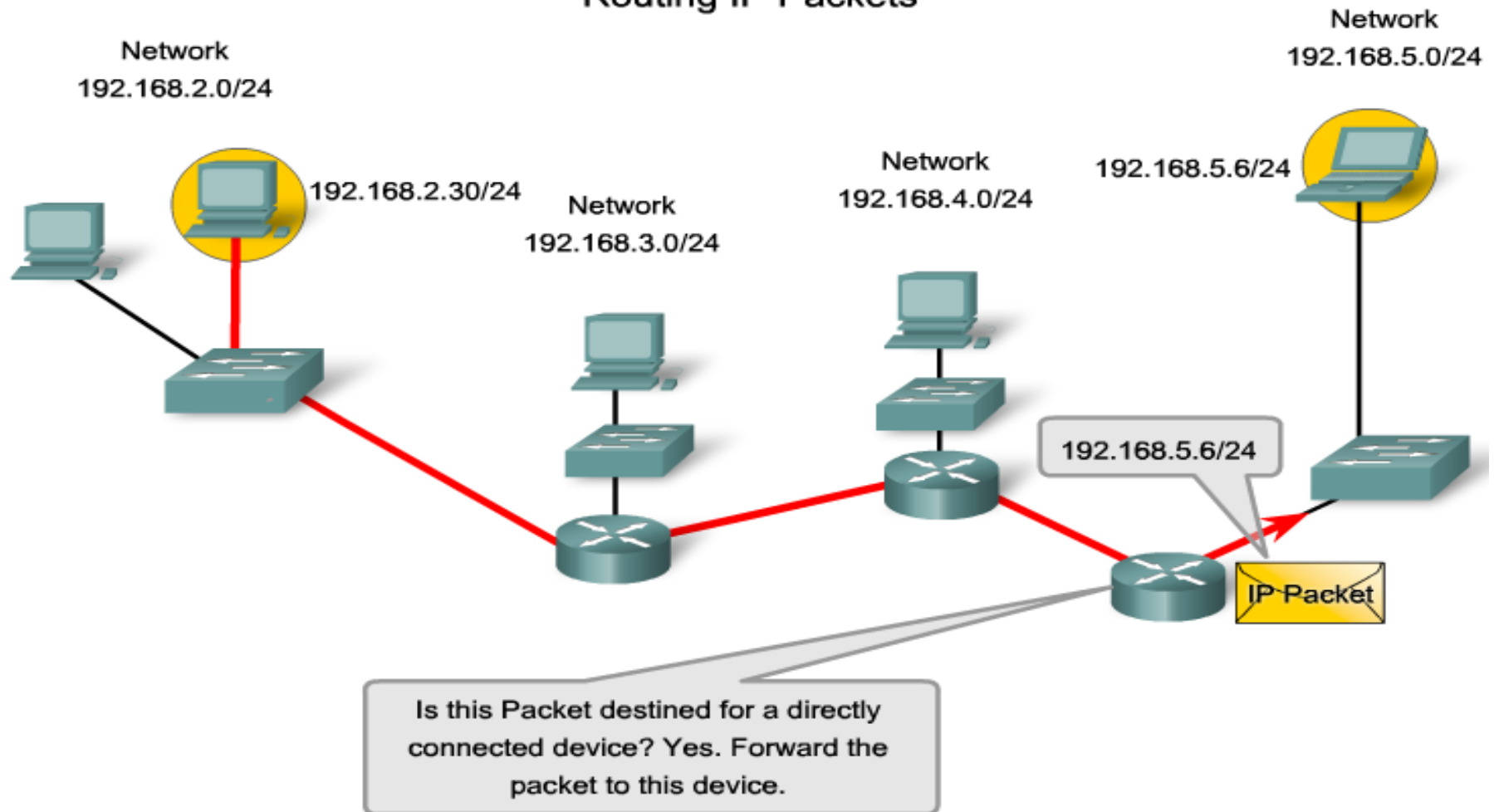


Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

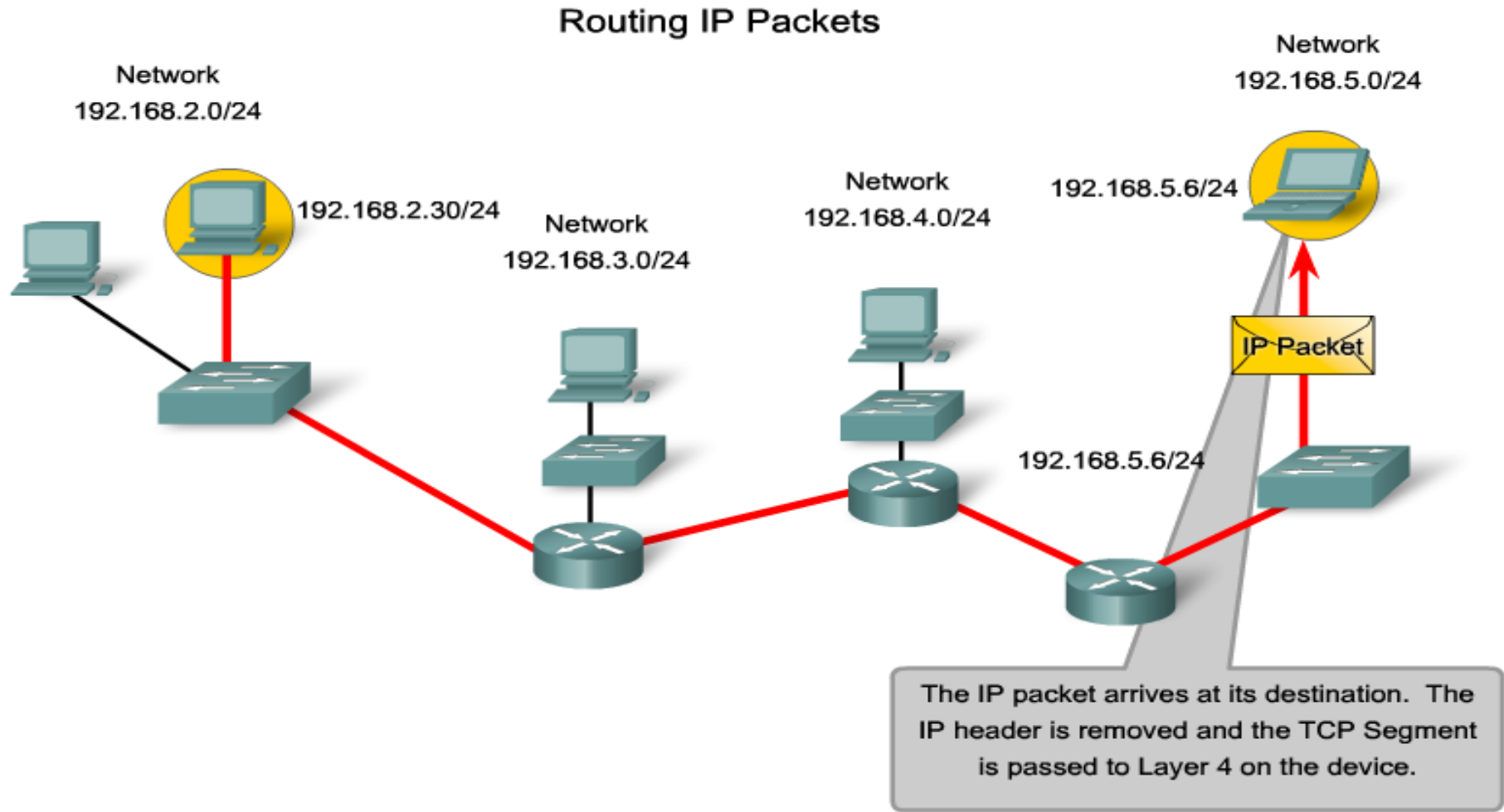


Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Routing IP Packets



Fundamentals of Routes, Next Hop Addresses and Packet Forwarding



Configuring the IP address & default gateway

The diagram illustrates a network topology where three computers are connected to a central switch, which is in turn connected to a router. The computers are configured with the following IP addresses and gateway addresses:

- Computer 1: IP Address 192.168.1.2/24, Gateway Address 192.168.1.254/24
- Computer 2: IP Address 192.168.1.3/24, Gateway Address 192.168.1.254/24
- Computer 3: IP Address 192.168.1.1/24, Gateway Address 192.168.1.254/24

The router is configured with the IP address 192.168.1.254/24. The screenshot of the Windows Internet Protocol (TCP/IP) Properties dialog box shows the configuration for the first computer:

- General** tab is selected.
- ☐ Obtain an IP address automatically is unselected.
- ☒ Use the following IP address: is selected.
- IP address: 192.168.1.2
- Subnet mask: 255.255.255.0
- Default gateway: 192.168.1.254
- ☐ Obtain DNS server address automatically is selected.
- Use the following DNS server addresses: Preferred DNS server and Alternate DNS server fields are empty.
- Advanced... button is visible.
- OK and Cancel buttons are at the bottom.

The gateway is configured in Windows using Internet Protocol (TCP/IP) Properties.

Configuring the IP address & default gateway

Confirming the Gateway Settings

```
C:\>ipconfig

Windows IP Configuration

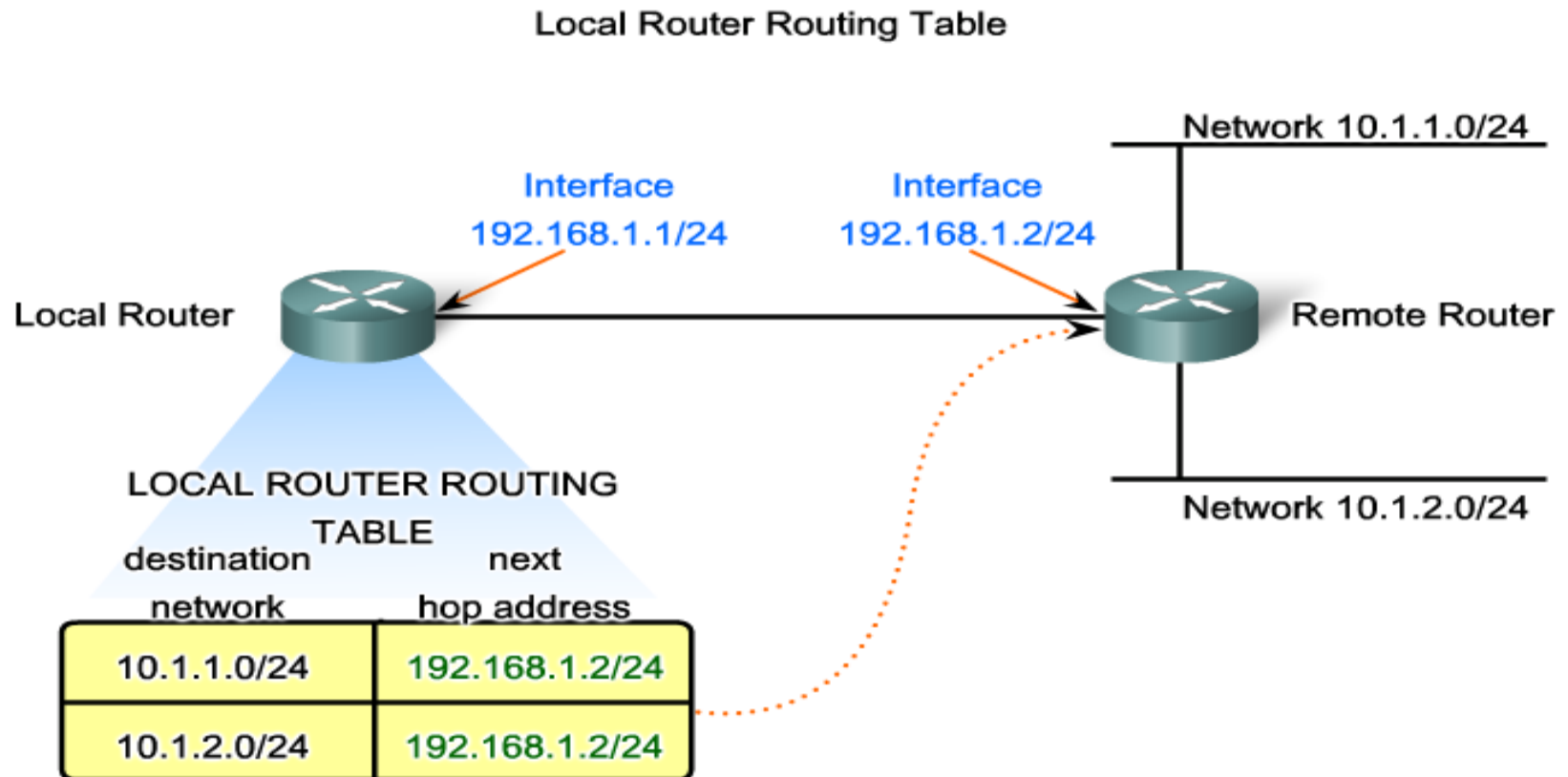
Ethernet adapter Local Area Connection:

    Connection-specific DNS Suffix  . : 
    ① IP Address. . . . . : 192.168.1.2
    ② Subnet Mask . . . . . : 255.255.255.0
    ③ Default Gateway . . . . . : 192.168.1.254
```

Default gateway address for this host computer

Sample ipconfig output showing default gateway address

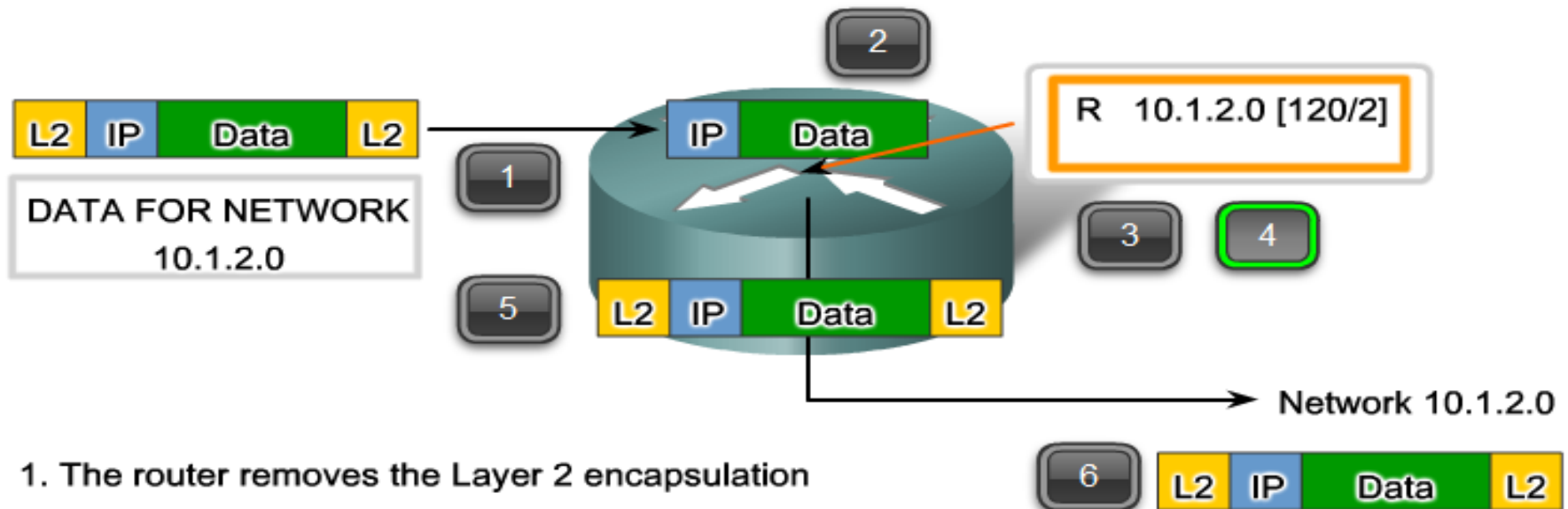
Fundamentals of Routes, Next Hop Addresses and Packet Forwarding



The next hop for both networks 10.1.1.0/24 and 10.1.2.0/24 from Local Router is 192.168.1.2/24

Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Route Entry Exists

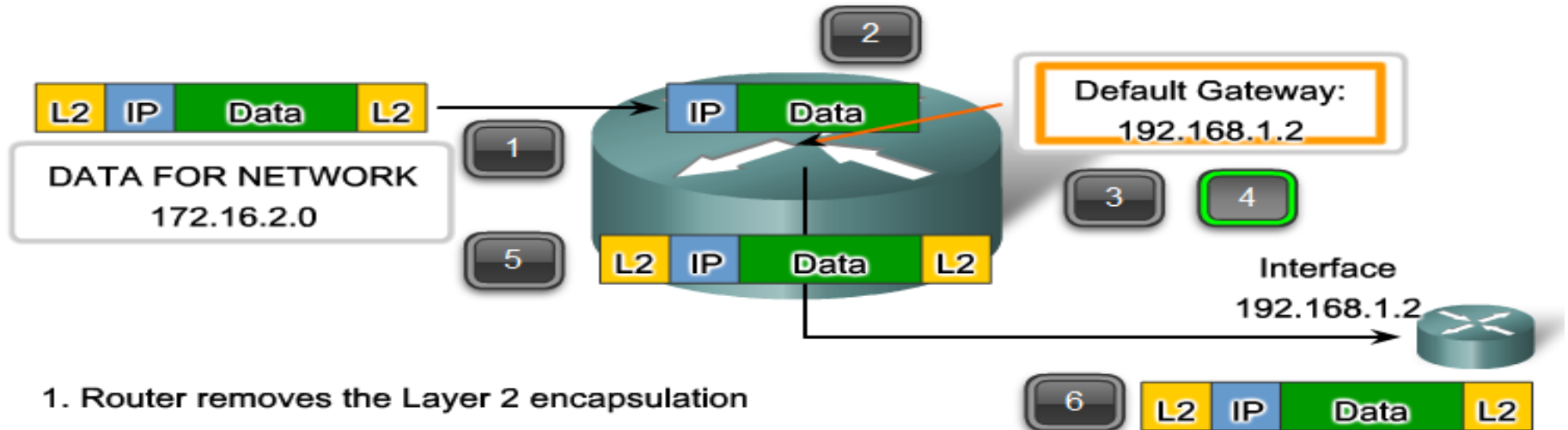


1. The router removes the Layer 2 encapsulation
2. Router extracts the destination IP address
3. Router checks the routing table for a match
4. Network 10.1.2.0 is found in the routing table
5. Router re-encapsulates the packet
6. Packet is sent to Network 10.1.2.0

Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

No Route Entry But Default Route Exists

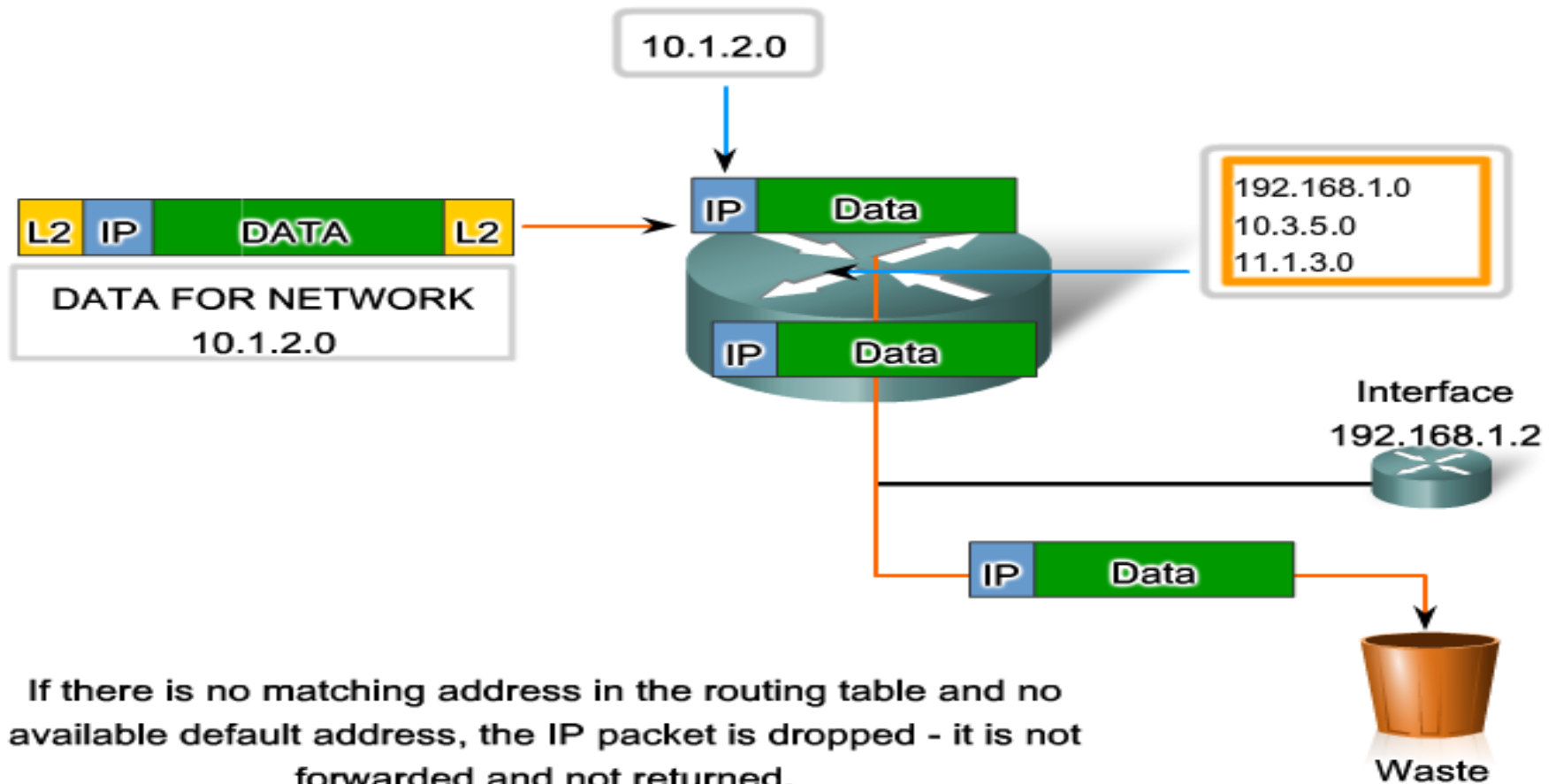
Roll over to see the steps the router takes.



1. Router removes the Layer 2 encapsulation
2. Router extracts IP Address
3. Router checks the routing table for a match
4. Network 172.16.2.0 not in the routing table but default route to 192.168.1.2 exists
5. Router re-encapsulates the packet
6. Packet is sent to Interface 192.168.1.2

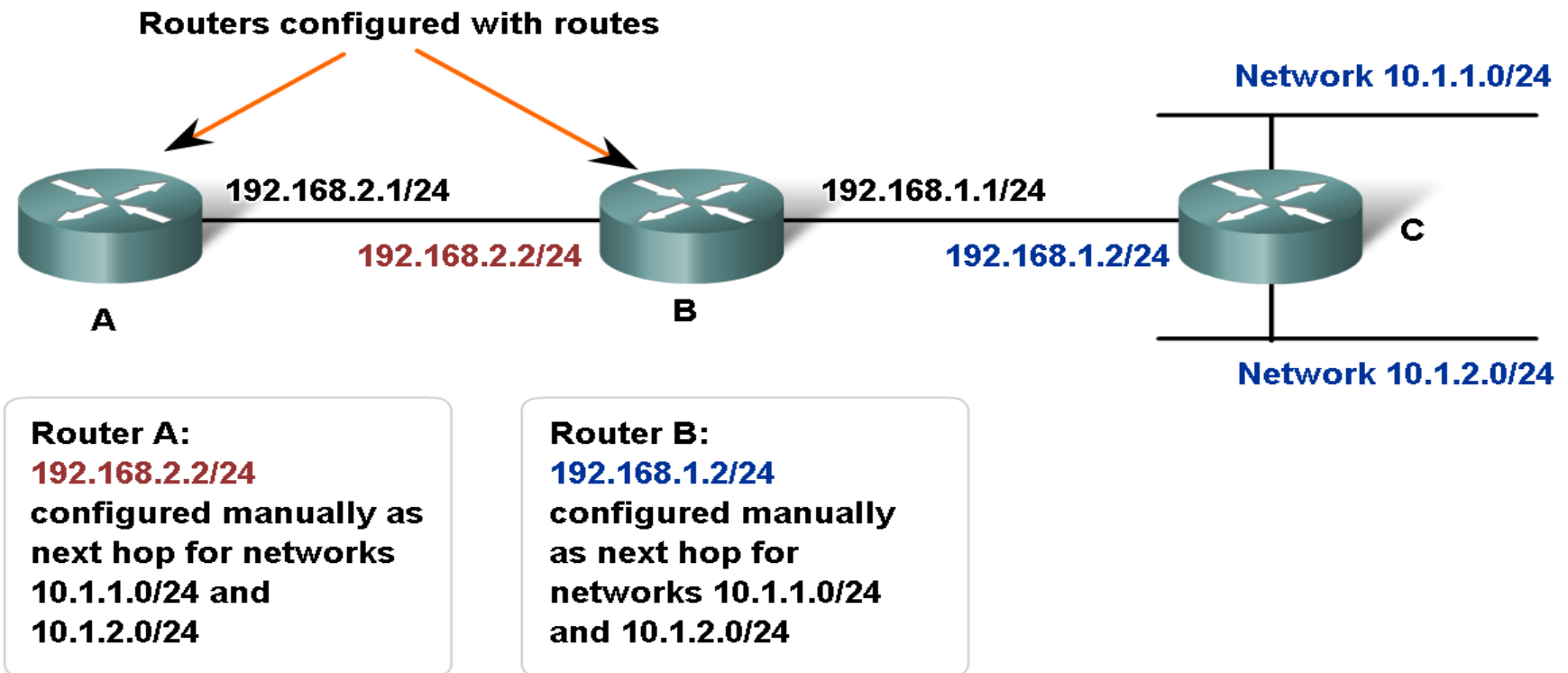
Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

No Route Entry and No Default Route

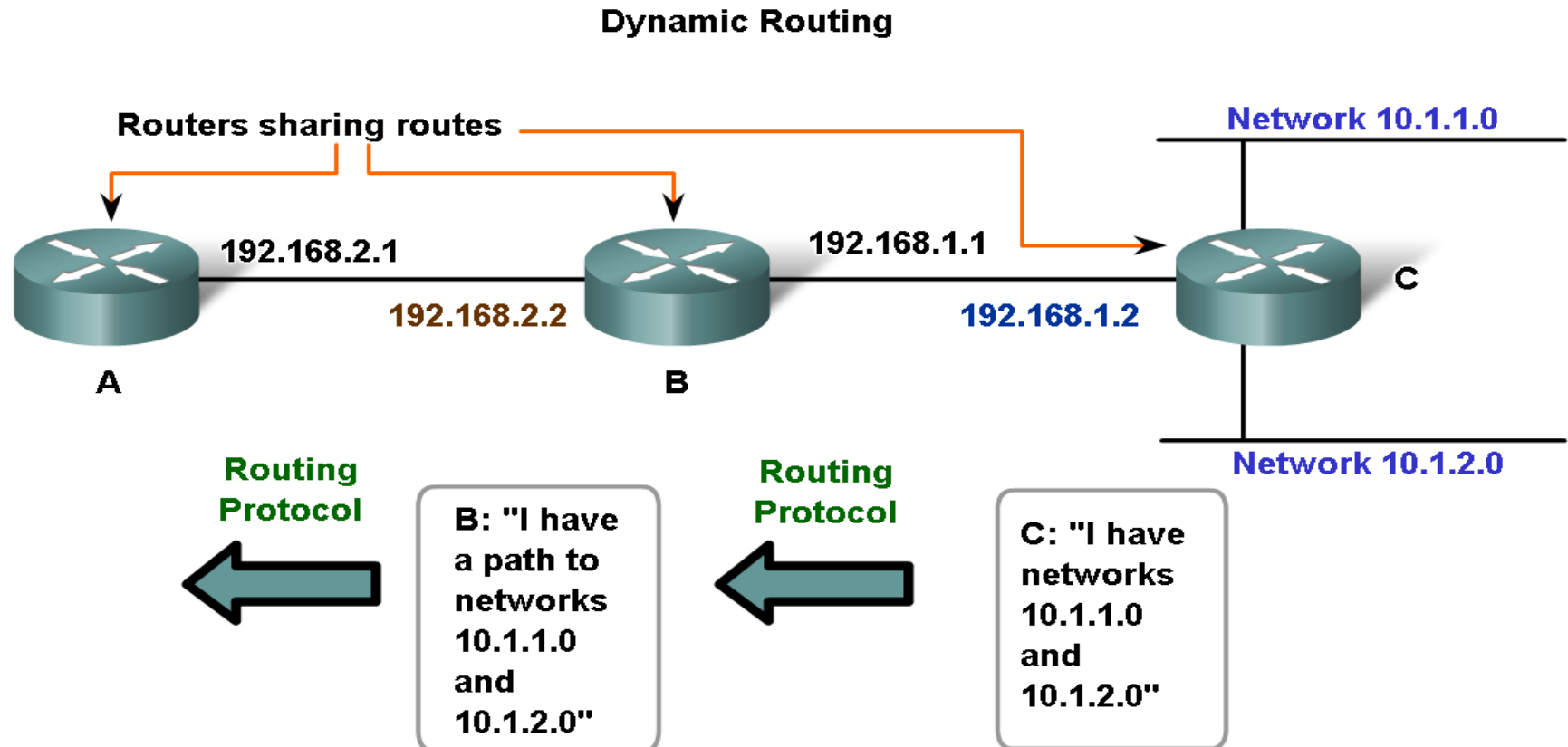


Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

Static Routing



Fundamentals of Routes, Next Hop Addresses and Packet Forwarding

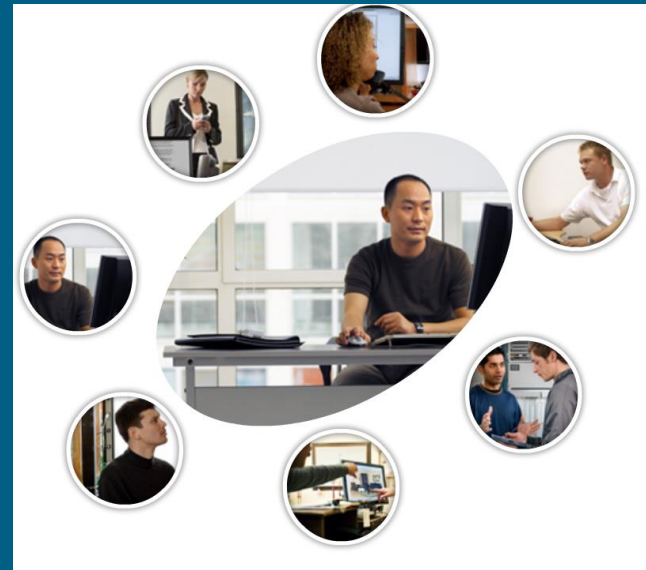


**Router B learns about Router C's networks dynamically.
Router B's next hop to 10.1.1.0 and 10.1.2.0 is **192.168.1.2** (Router C).
Router A learns about Router C's networks dynamically from Router B.
Router A's next hop to 10.1.1.0 and 10.1.2.0 is **192.168.2.2** (Router B).**





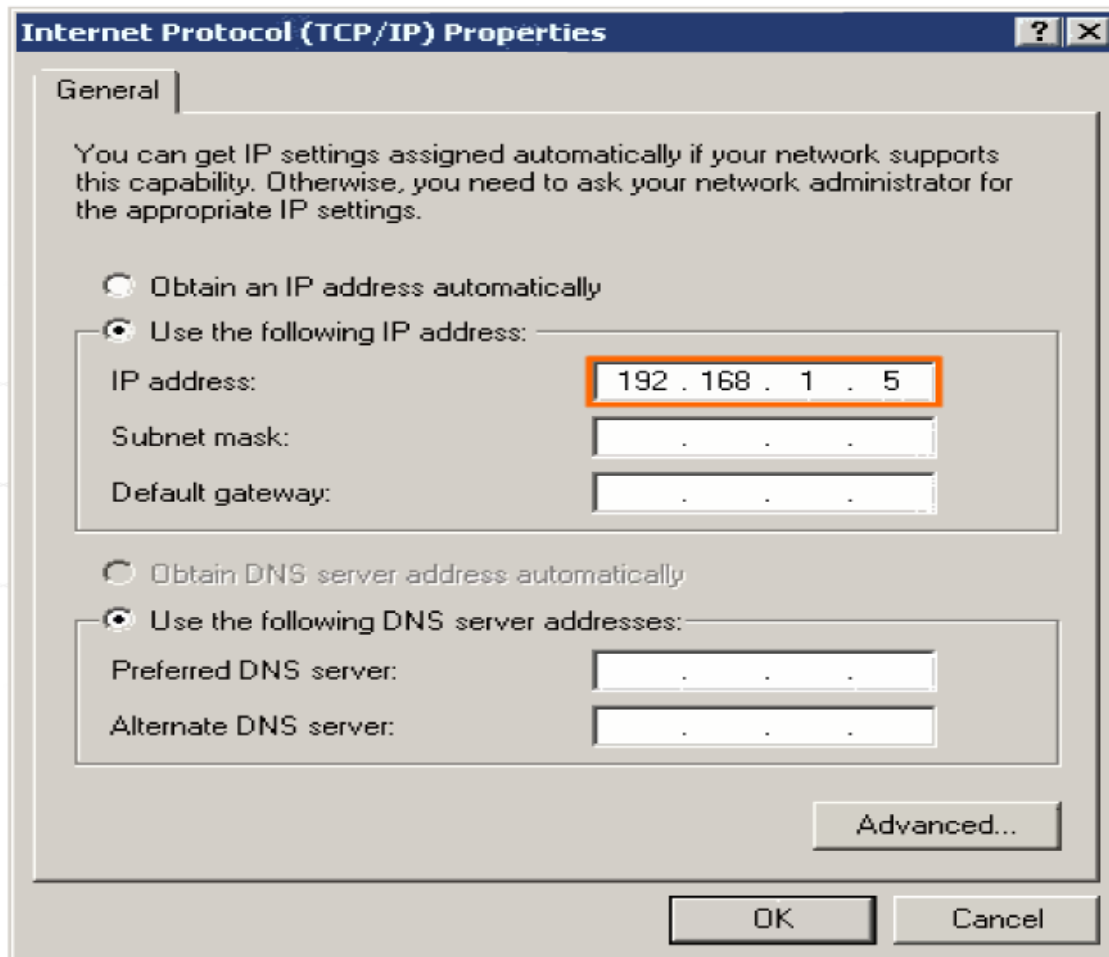
Addressing the Network – IPv4



Objectives

- Explain the structure IP addressing and demonstrate the ability to convert between 8-bit binary and decimal numbers.
- Given an IPv4 address, classify by type and describe how it is used in the network
- Explain how addresses are assigned to networks by ISPs and within networks by administrators
- Determine the network portion of the host address and explain the role of the subnet mask in dividing networks.
- Given IPv4 addressing information and design criteria, calculate the appropriate addressing components.
- Use common testing utilities to verify and test network connectivity and operational status of the IP protocol stack on a host.

IP Addressing Structure



Internet Protocol (TCP/IP) Properties

General

You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.

☐ Obtain an IP address automatically

☒ Use the following IP address:

IP address: 192 . 168 . 1 . 5

Subnet mask: . . .

Default gateway: . . .

☐ Obtain DNS server address automatically

☒ Use the following DNS server addresses:

Preferred DNS server: . . .

Alternate DNS server: . . .

Advanced...

OK Cancel

I see you have assigned me an IP address
**11000000.1010
1000.00000001.
00000101**
Now other hosts can find me!



IP version 4 (IPv4) is the current form of addressing used on the Internet.

IP Addressing Structure

IPv4 Addresses

192	.	168	.	10	.	1
11000000		11000000		11000000		11000000

**The computer using this IP address is on network
192.168.10.0.**

Binary & Decimal Numbering System

Binary To Decimal Conversion

Exponent	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0							
Position	128	64	32	16	8	4	2	1							
Bits	1	1	1	1	0	1	0	1							
	1 BYTE / 1 Octet														
Add these numbers together	128	+	64	+	32	+	16	+	0	+	4	+	0	+	1
Decimal	245														

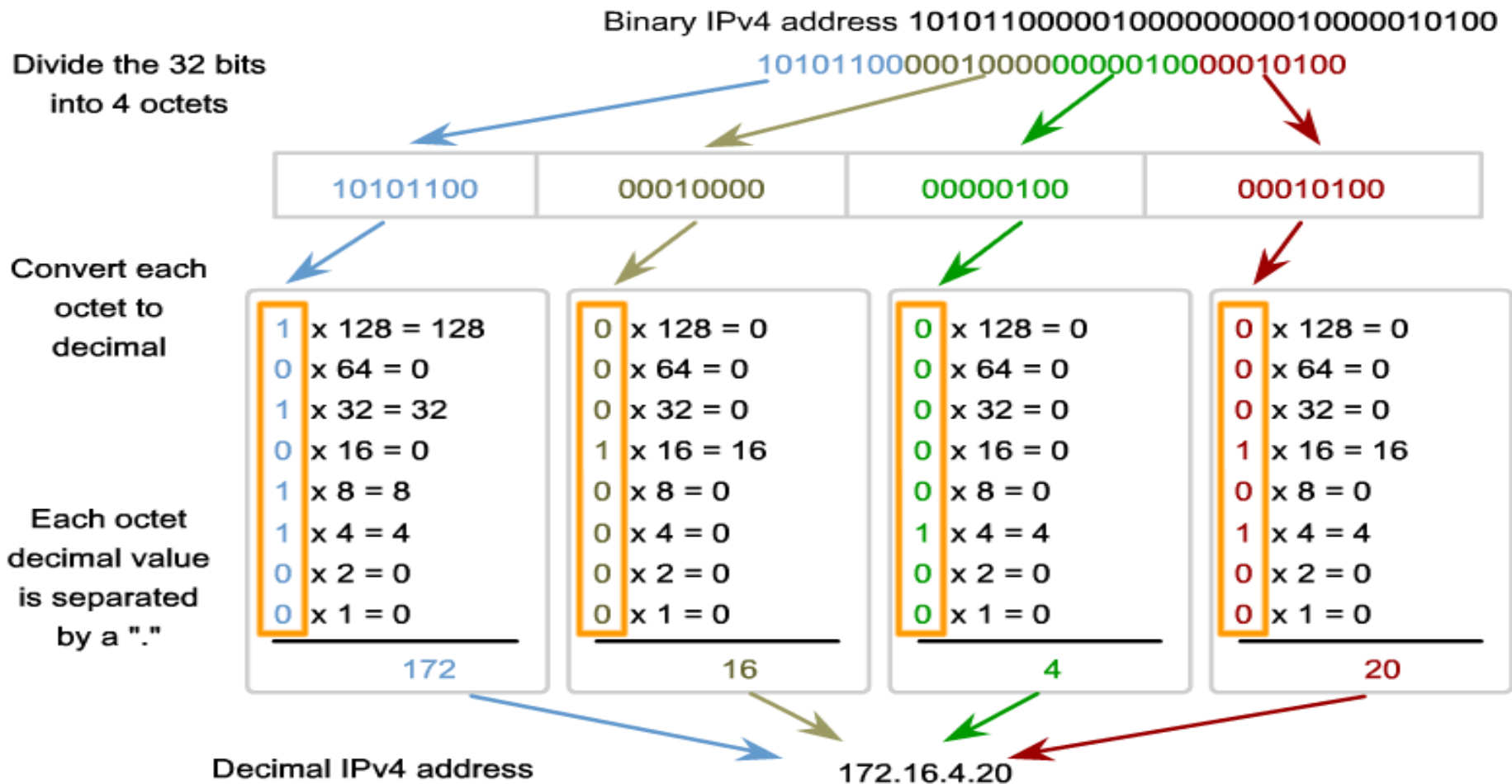
A 1 in this position means 64 is added to the total.

A 0 in any position means that 0 is added to the total.

11110101 in Binary = Decimal Number 245

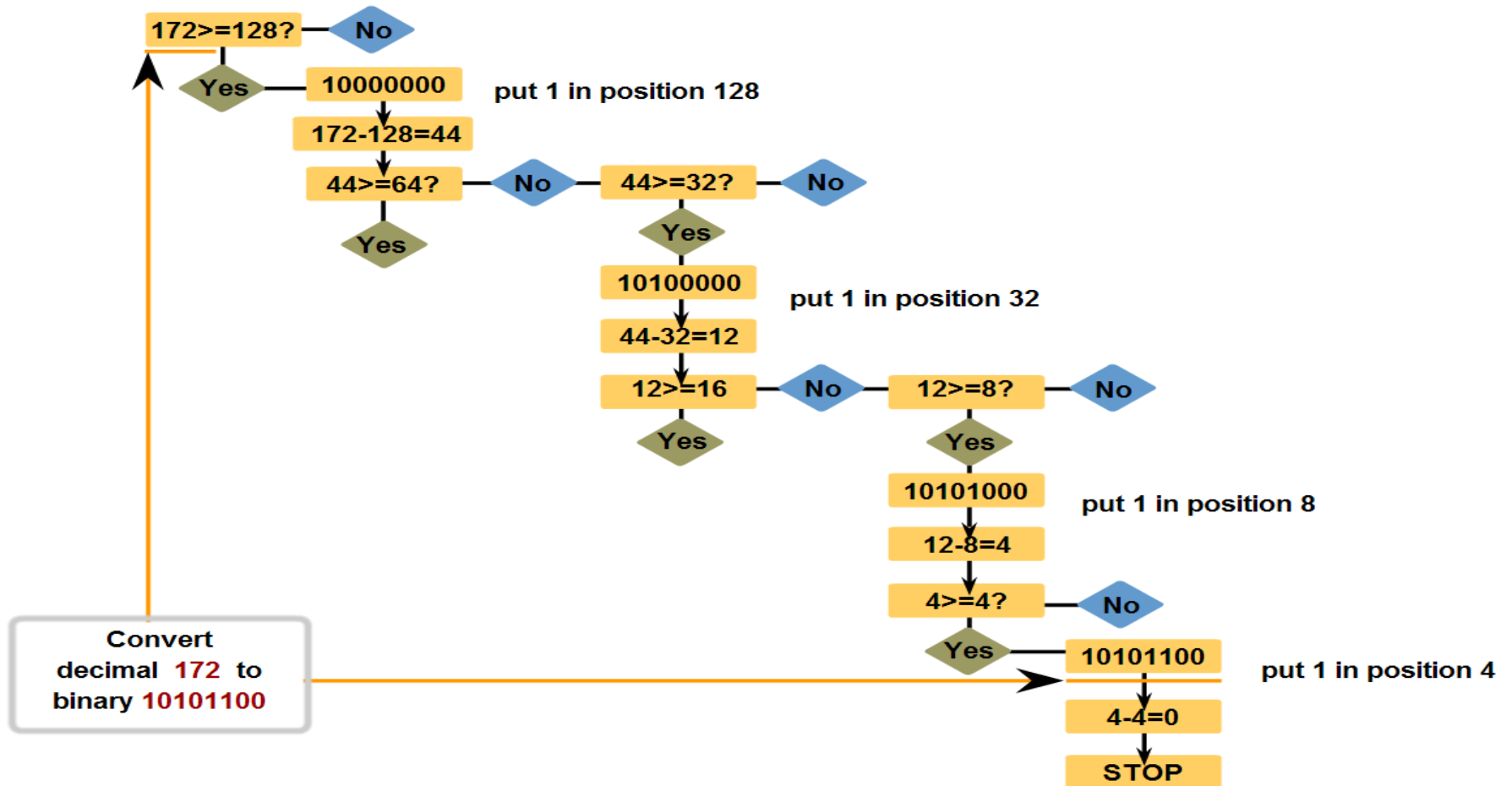
Binary & Decimal Numbering System

Converting an IPv4 from Binary to Dotted Decimal Notation

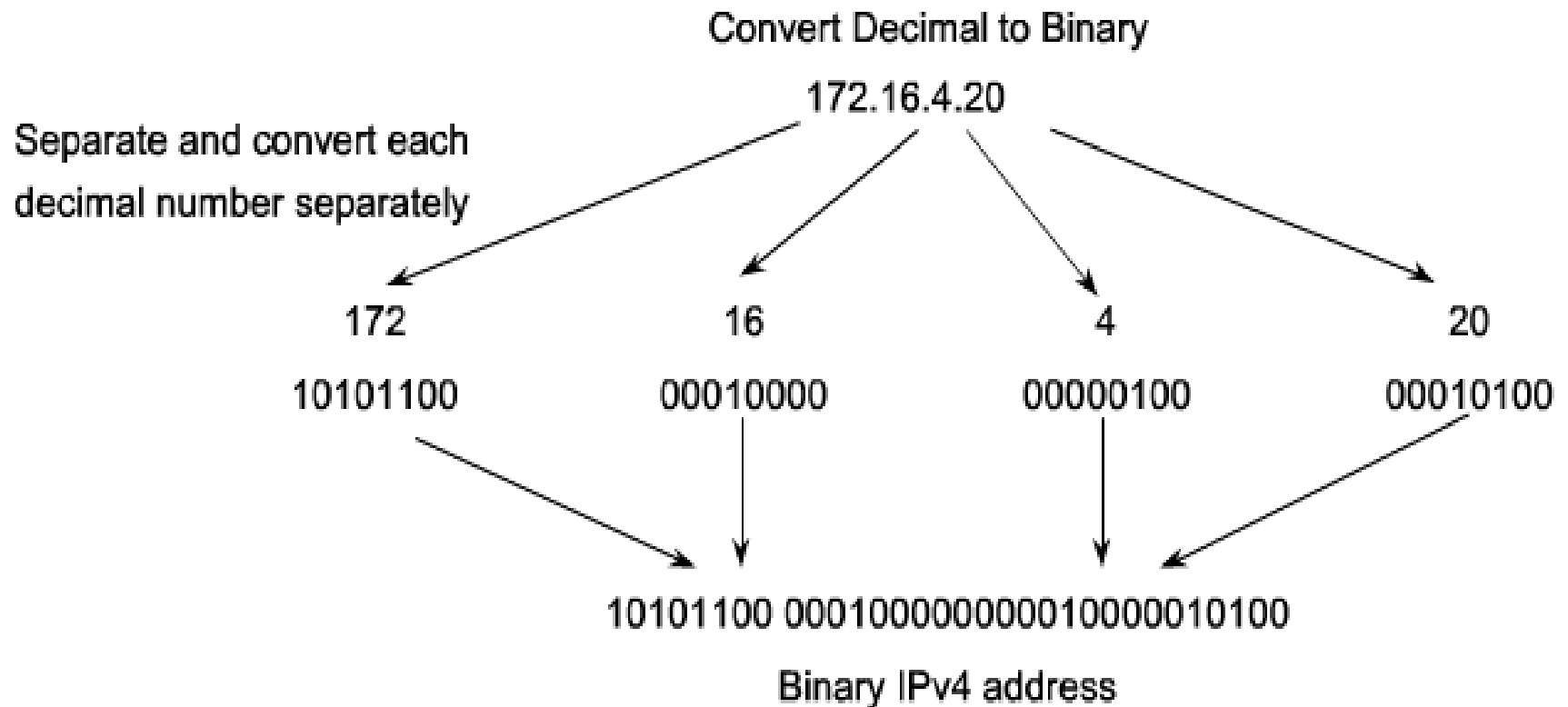


Binary & Decimal Numbering System

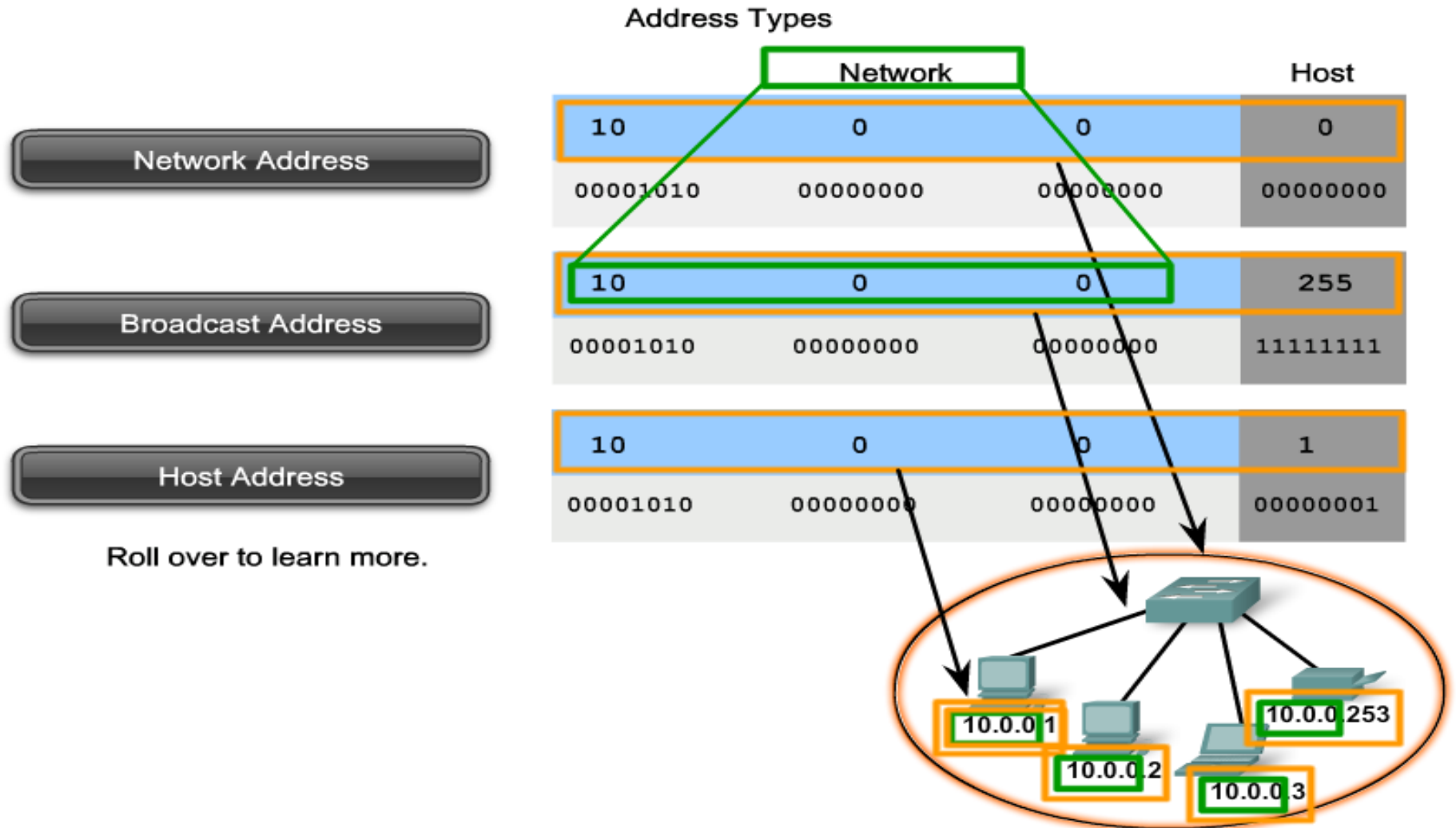
Decimal to Binary Conversion Steps



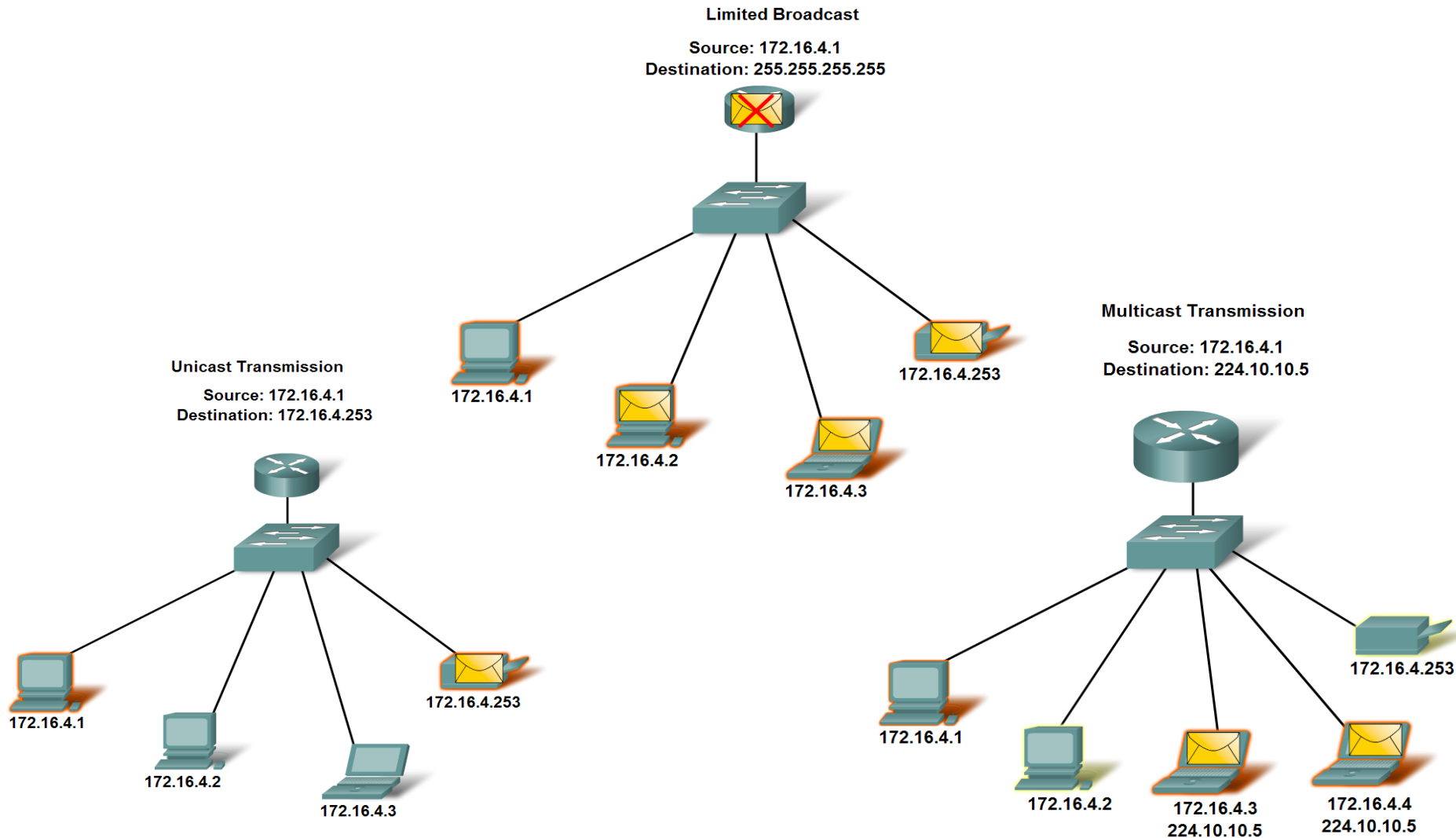
Binary & Decimal Numbering System



Classify and Define IPv4 Addresses



Classify and Define IPv4 Addresses



IP address Classes

IP Address Classes

Address Class	1st octet range (decimal)	1st octet bits (green bits do not change)	Network(N) and Host(H) parts of address	Default subnet mask (decimal and binary)	Number of possible networks and hosts per network
A	1-127**	00000000-01111111	N.H.H.H	255.0.0.0	128 nets (2^7) 16,777,214 hosts per net ($2^{24}-2$)
B	128-191	10000000-10111111	N.N.H.H	255.255.0.0	16,384 nets (2^{14}) 65,534 hosts per net ($2^{16}-2$)
C	192-223	11000000-11011111	N.N.N.H	255.255.255.0	2,097,150 nets (2^{21}) 254 hosts per net (2^8-2)
D	224-239	11100000-11101111	NA (multicast)		
E	240-255	11110000-11111111	NA (experimental)		

** All zeros (0) and all ones (1) are invalid hosts addresses.

Subnet mask

Applying the Subnet Mask

A device with address 192.0.0.1 belongs to network 192.0.0.0

	High order bits Prefix /16				Low order bits			
	192	.	0	.	0	.	1	
Host Address	11000000	00000000	00000000	00000001				
Subnet Mask	255	255	0	0				
	11111111	11111111	00000000	00000000				
Network Address	11000000	00000000	00000000	00000000				
Network	192	.	0	.	0	.	0	

Private Addresses

- These private IP addresses are for intra-network use only and can not be routed across the Internet.
- These private addresses are
 - Class A → 10.0.0.0/8 to 10.255.255.255/8
 - Class B → 172.16.0.0/16 to 172.31.255.255/16
 - Class C → 192.168.0.0/24 to 192.168.255.255/24

Private IP Addresses

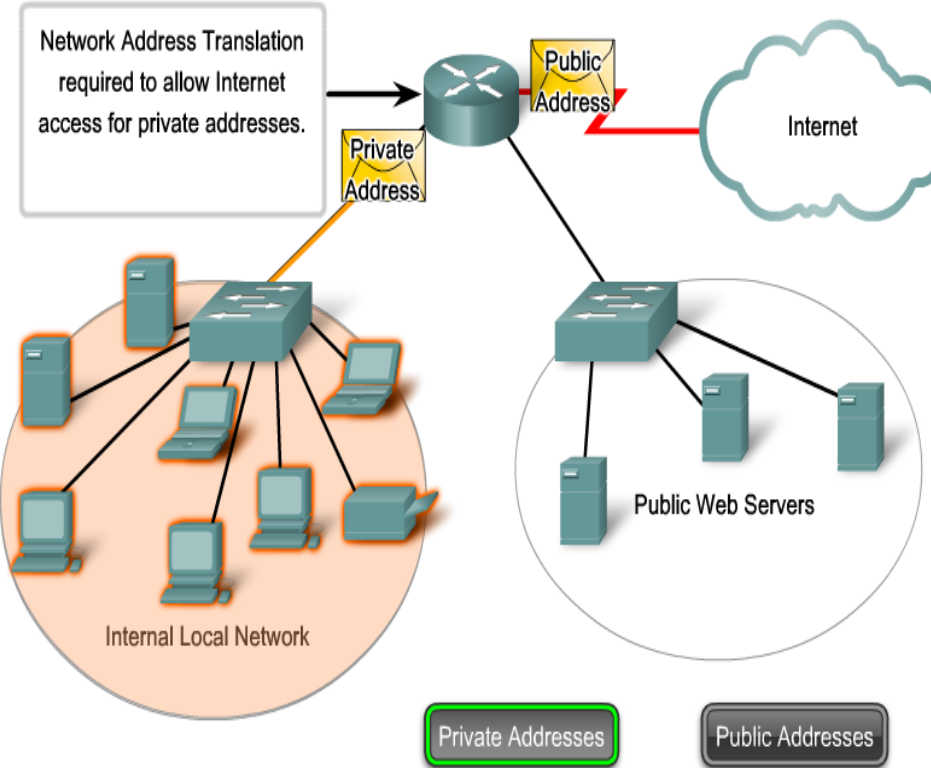
Private IP addresses are another solution to the problem of the impending exhaustion of public IP addresses. As mentioned, public networks require hosts to have unique IP addresses.

However, private networks that are not connected to the Internet may use any host addresses, as long as each host within the private network is unique.

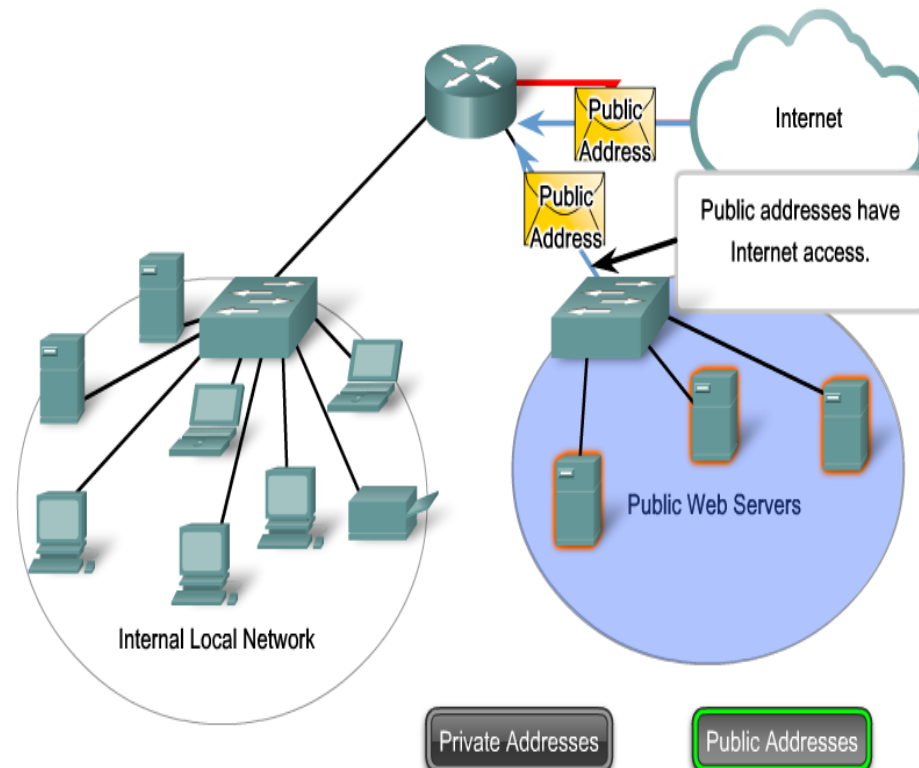
Class	RFC 1918 internal address range
A	10.0.0.0 to 10.255.255.255
B	172.16.0.0 to 172.31.255.255
C	192.168.0.0 to 192.168.255.255

Private IP Addresses

IPv4 Address Planning and Assignment
Public and Private Addresses



IPv4 Address Planning and Assignment
Public and Private Addresses



Classify and Define IPv4 Addresses

Private Addresses used in Networks without NAT

