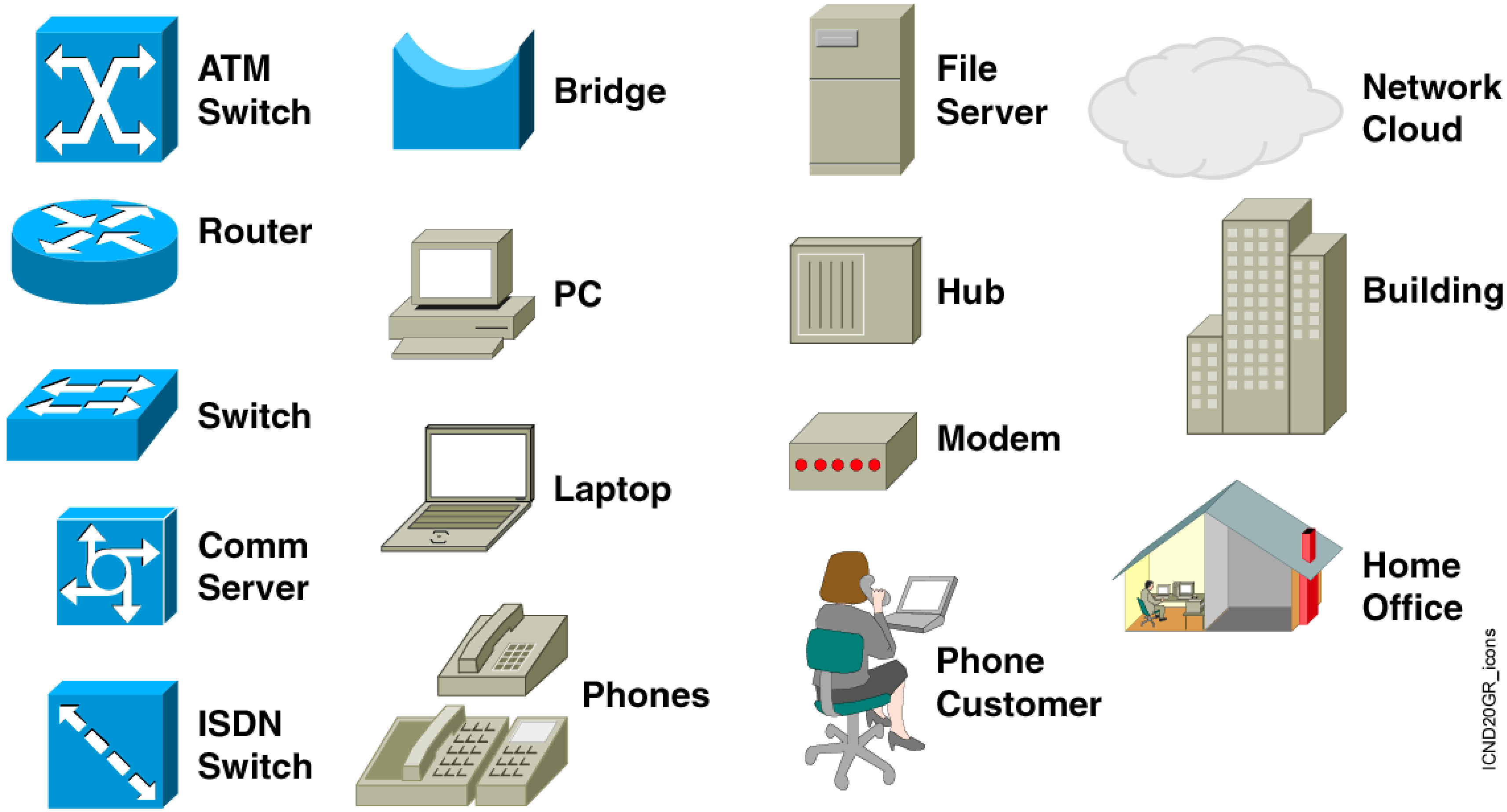
Cisco Icons and Symbols



ATM Switch

Router

Switch

Comm Server

ISDN Switch

Bridge

PC

Laptop

Phones

File Server

Hub

Modem

Phone Customer

Network Cloud

Building

Home Office

Data Networks

Sharing data through the use of floppy disks is not an efficient or cost-effective manner.

Businesses needed a solution that would successfully address the following three problems:

- How to avoid duplication of equipment and resources
- How to communicate efficiently
- How to set up and manage a network

Businesses realized that networking technology could increase productivity while saving money.

Networking Devices

Equipment that connects directly to a network segment is referred to as a device.

These devices are broken up into two classifications.

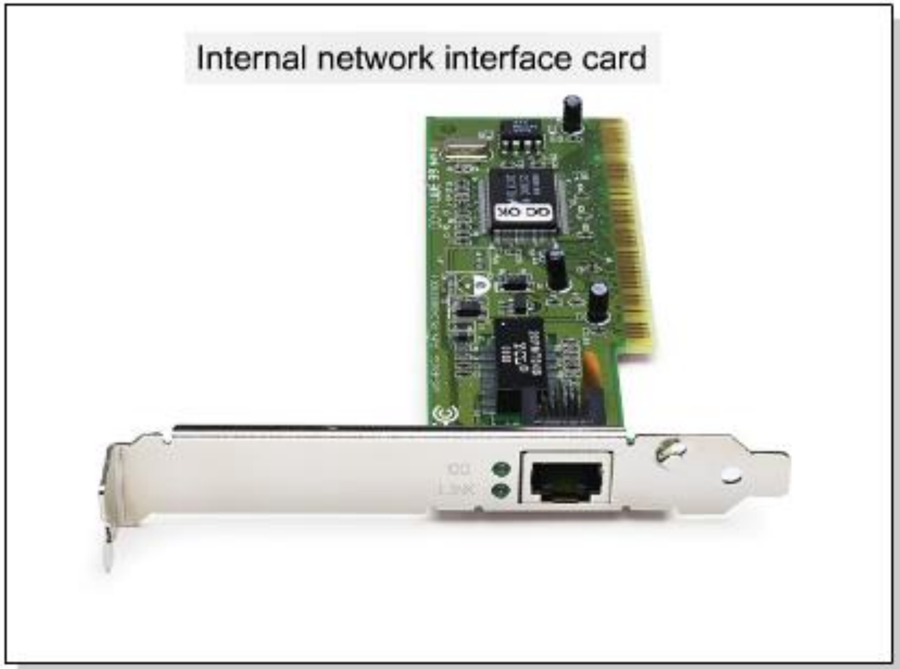
- ☐ End-user devices
- ☐ Network devices

End-user devices include computers, printers, scanners, and other devices that provide services directly to the user.

Network devices include all the devices that connect the end-user devices together to allow them to communicate.

Network Interface Card

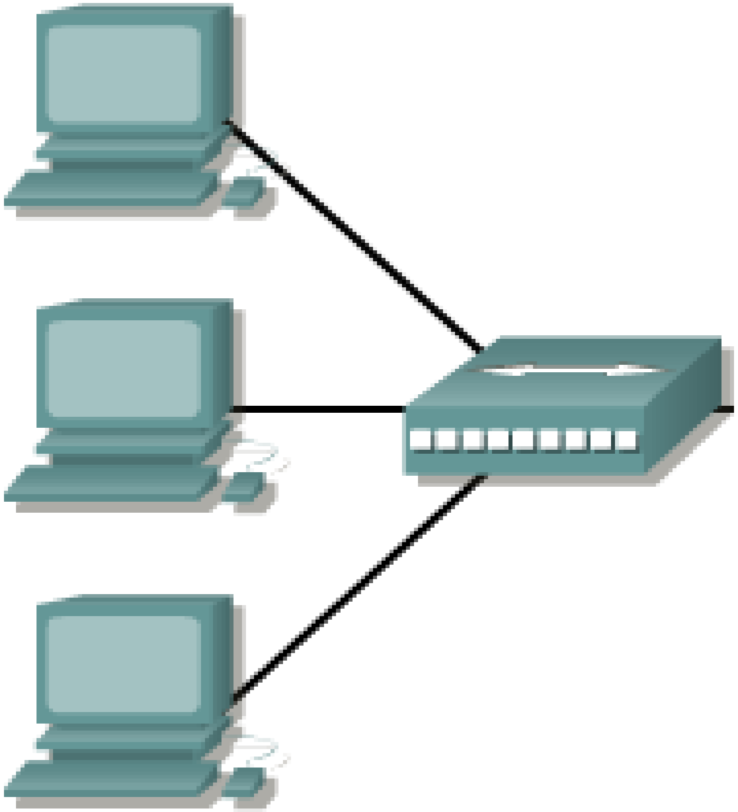
A network interface card (NIC) is a printed circuit board that provides network communication capabilities to and from a personal computer. Also called a LAN adapter.



Internal network interface card

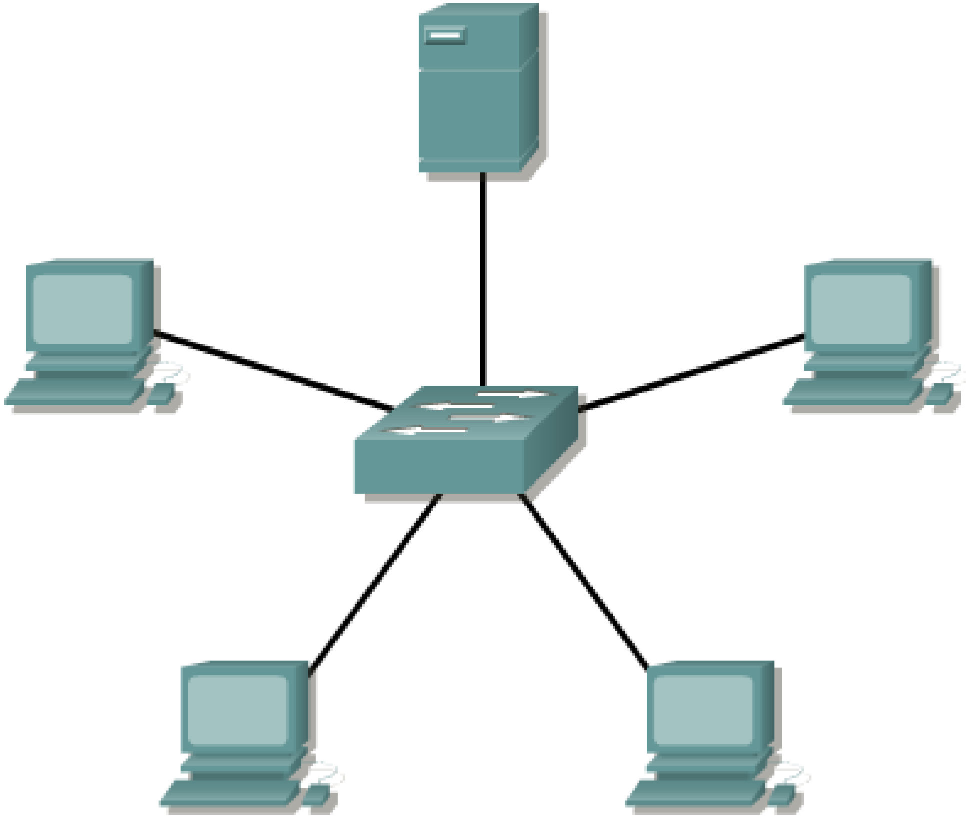
Hub

Connects a group of Hosts



Switch

Switches add more intelligence to data transfer management.



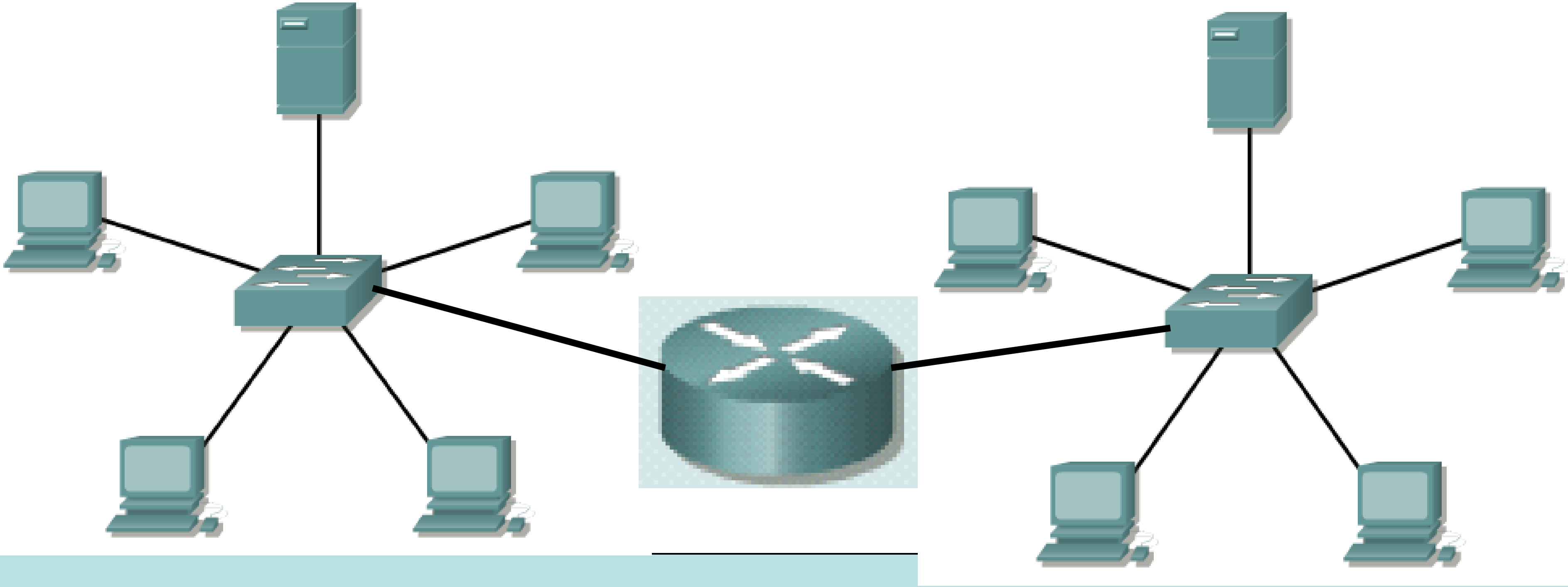
Router

❑Routers are used to connect networks together

❑Route packets of data from one network to another

❑Cisco became the de facto standard of routers because of their high-quality router products

❑Routers, by default, break up a *broadcast domain*



Network Topologies

Network topology defines the structure of the network.

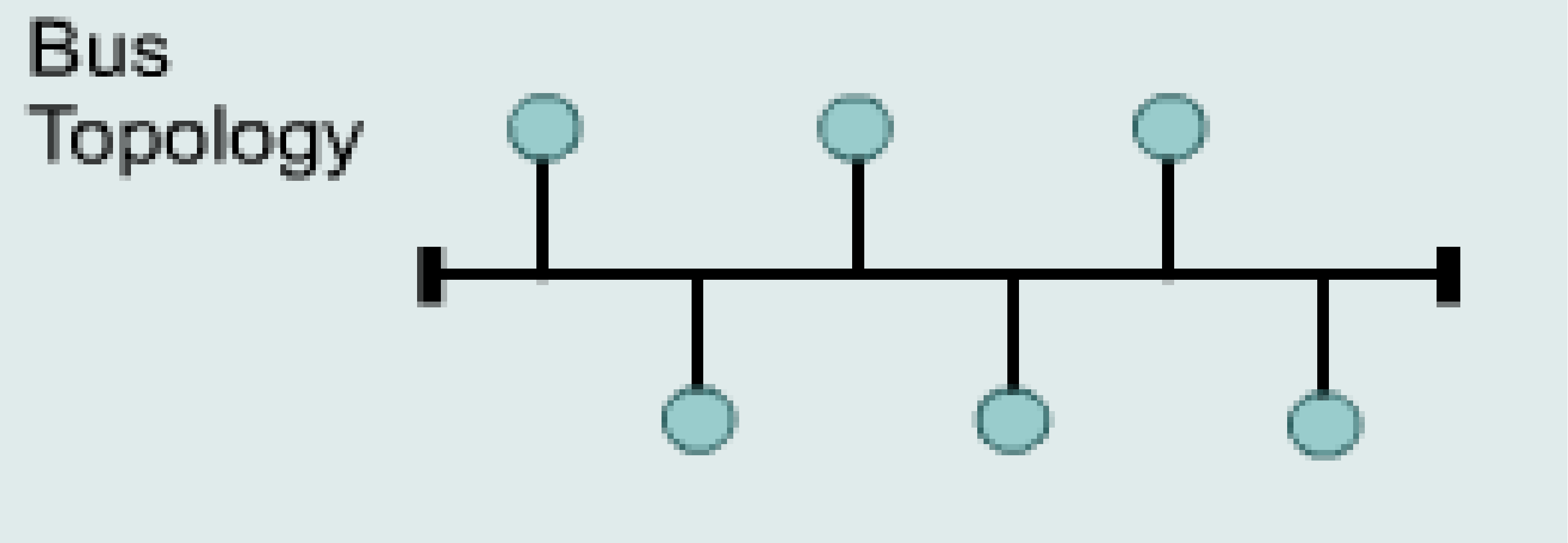
One part of the topology definition is the physical topology, which is the actual layout of the wire or media.

The other part is the logical topology,which defines how the media is accessed by the hosts for sending data.

Bus Topology

- ❑A bus topology uses a single backbone cable that is terminated at both ends.

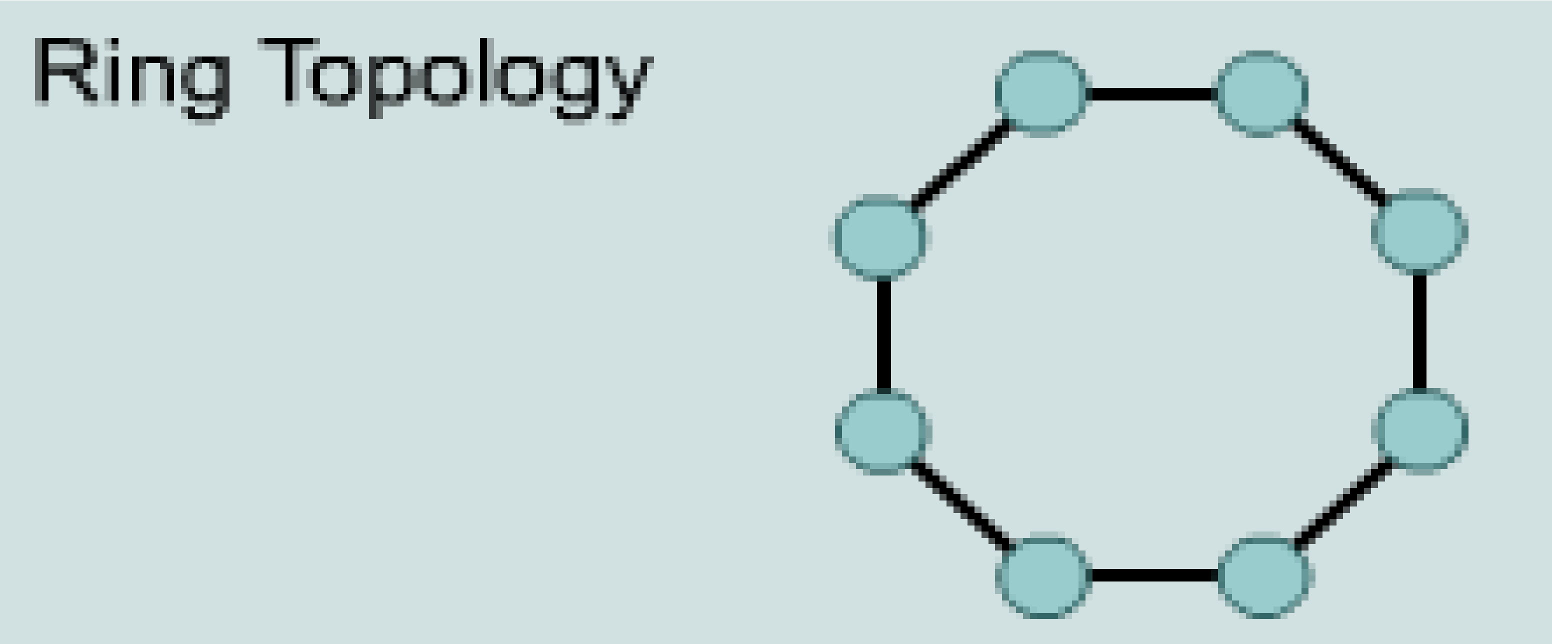
- ❑All the hosts connect directly to this backbone.



Ring Topology

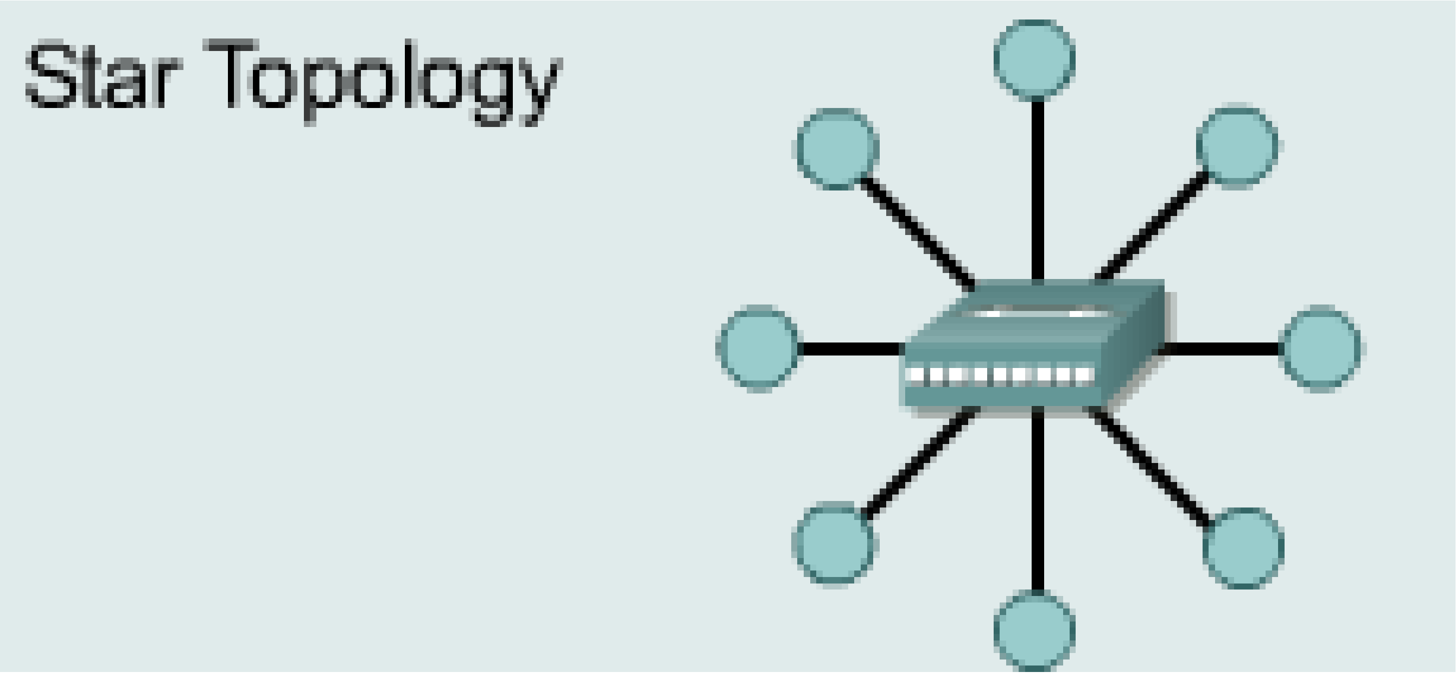
- ❑A ring topology connects one host to the next and the last host to the first.

- ❑This creates a physical ring of cable.



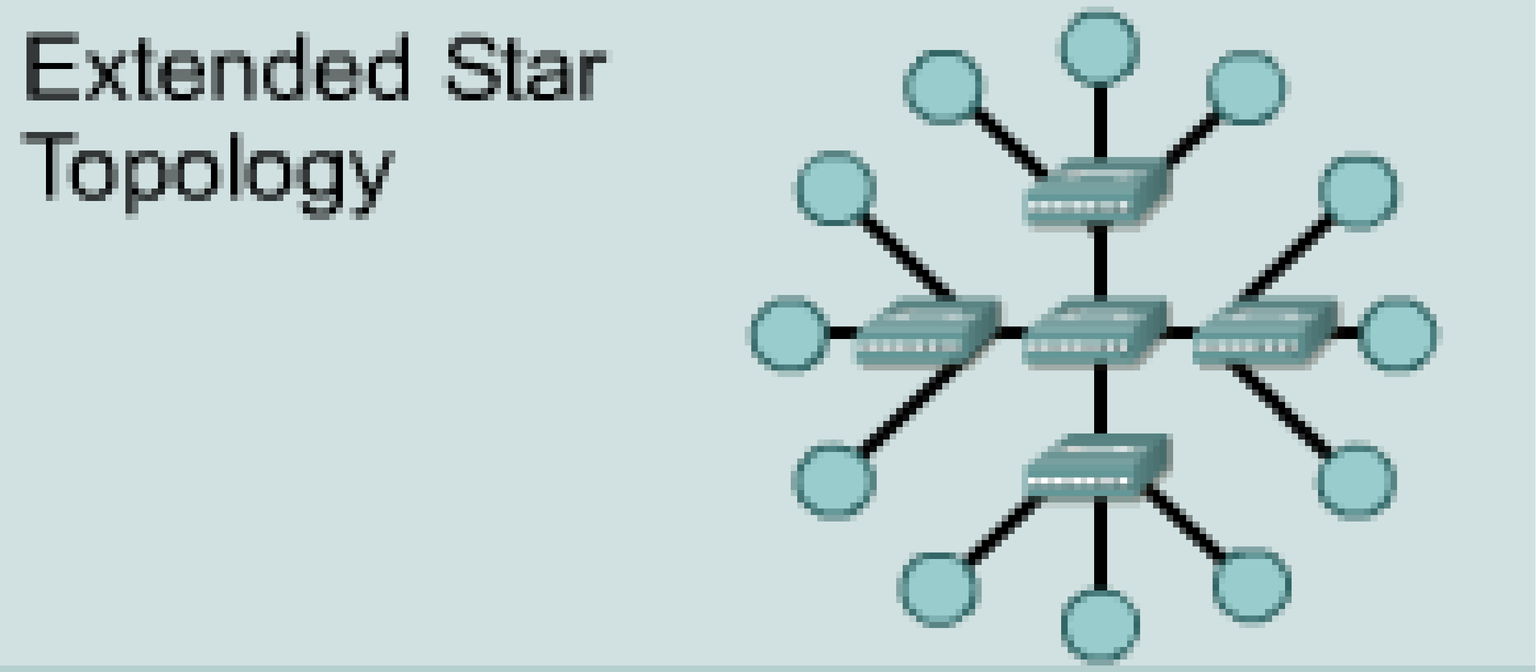
Star Topology

- A star topology connects all cables to a central point of concentration.



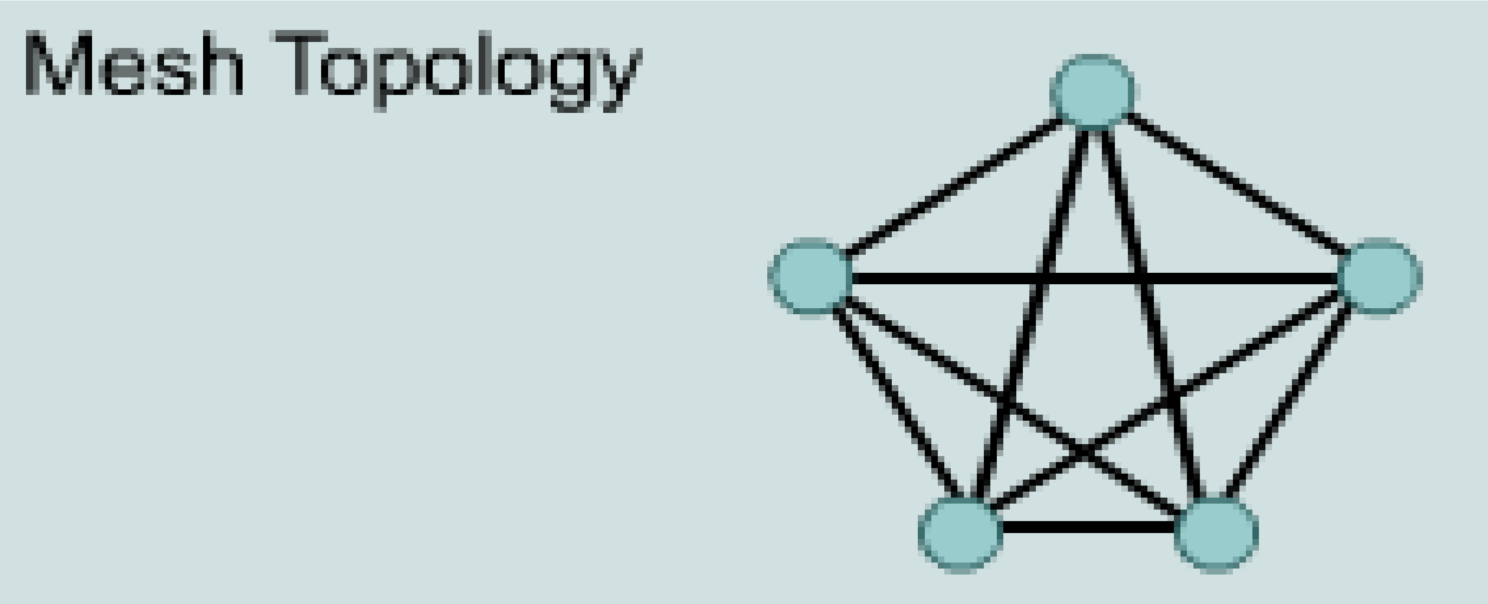
Extended Star Topology

❑An extended star topology links individual stars together by connecting the hubs and/or switches.This topology can extend the scope and coverage of the network.

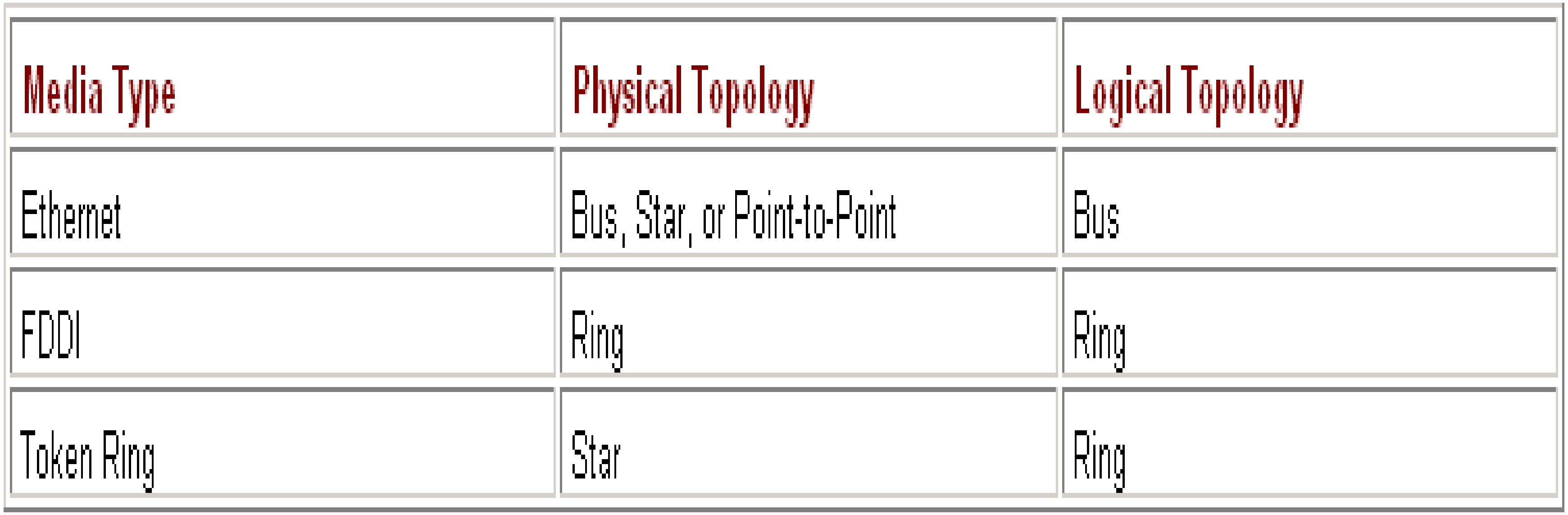


Mesh Topology

- A mesh topology is implemented to provide as much protection as possible from interruption of service.
- Each host has its own connections to all other hosts.
- Although the Internet has multiple paths to any one location, it does not adopt the full mesh topology.



Physical and Logical Topology



Media Type	Physical Topology	Logical Topology
Ethernet	Bus, Star, or Point-to-Point	Bus
FDDI	Ring	Ring
Token Ring	Star	Ring

LANs, MANs, & WANs

- One early solution was the creation of local-area network (LAN) standards which provided an open set of guidelines for creating network hardware and software, making equipment from different companies compatible.

- What was needed was a way for information to move efficiently and quickly, not only within a company, but also from one business to another.

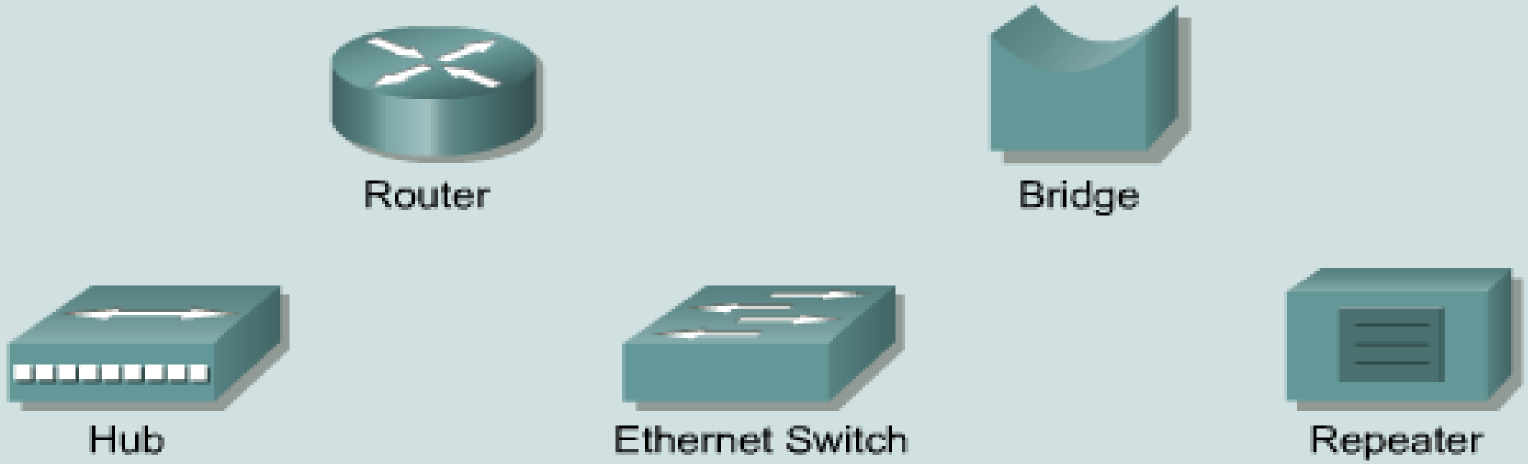
- The solution was the creation of metropolitan-area networks (MANs) and wide-area networks (WANs).

LANs

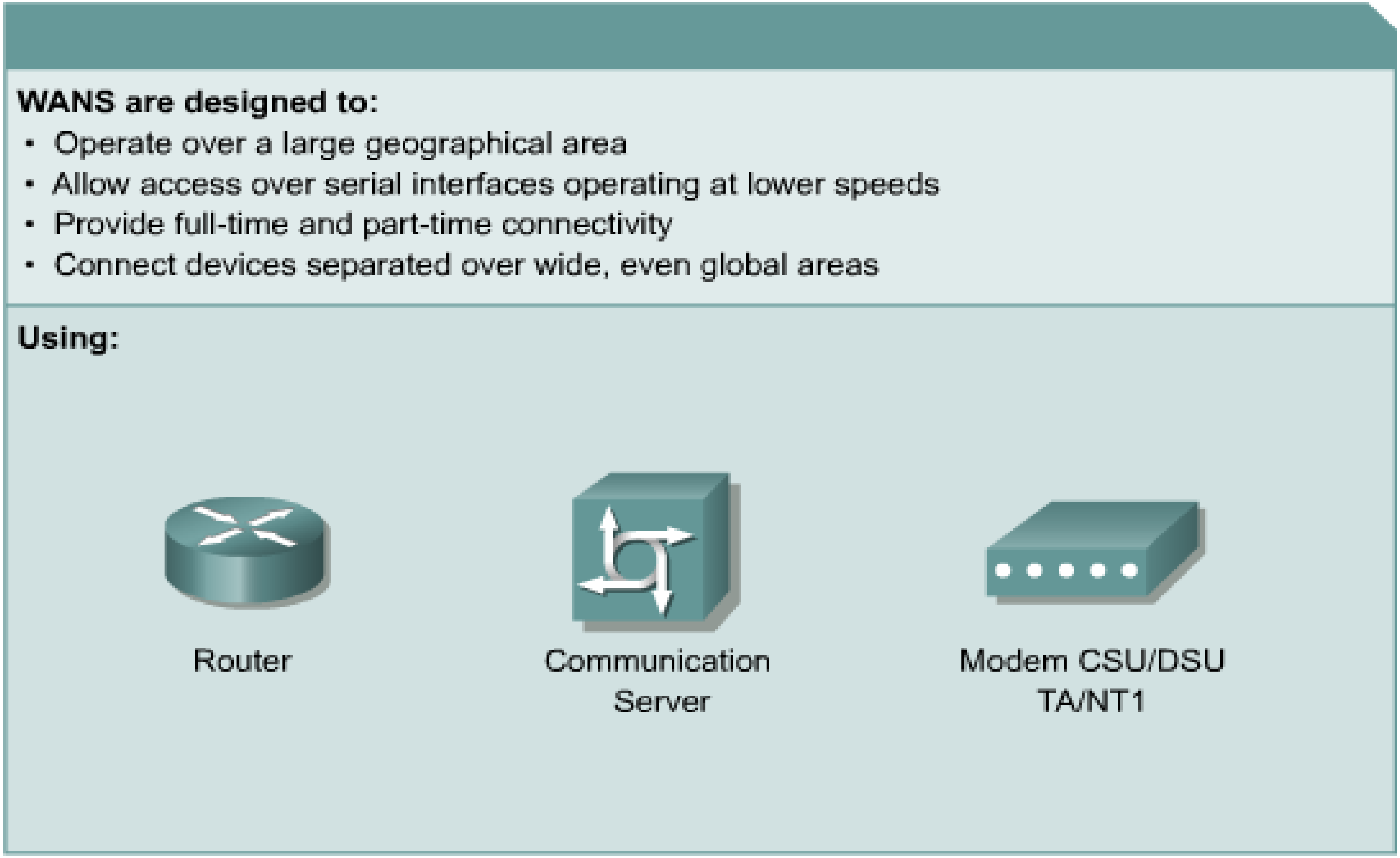
LANS are designed to:

- Operate within a limited geographic area
- Allow multi-access to high-bandwidth media
- Control the network privately under local administration
- Provide full-time connectivity to local services
- Connect physically adjacent devices

Using:



WANs



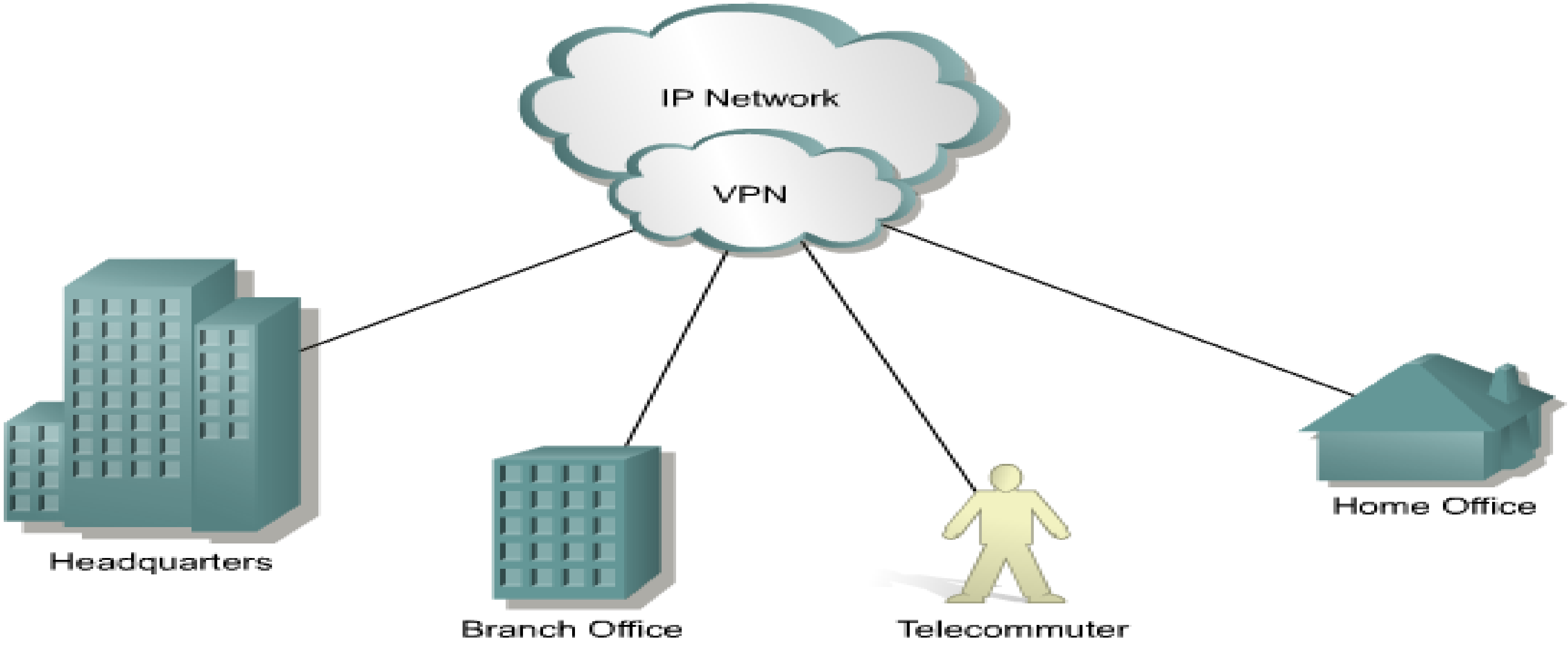
WANS are designed to:

- Operate over a large geographical area
- Allow access over serial interfaces operating at lower speeds
- Provide full-time and part-time connectivity
- Connect devices separated over wide, even global areas

Using:

Virtual Private Network

A VPN is a private network that is constructed within a public network infrastructure such as the global Internet. Using VPN, a telecommuter can access the network of the company headquarters through the Internet by building a secure tunnel between the telecommuter's PC and a VPN router in the headquarters.



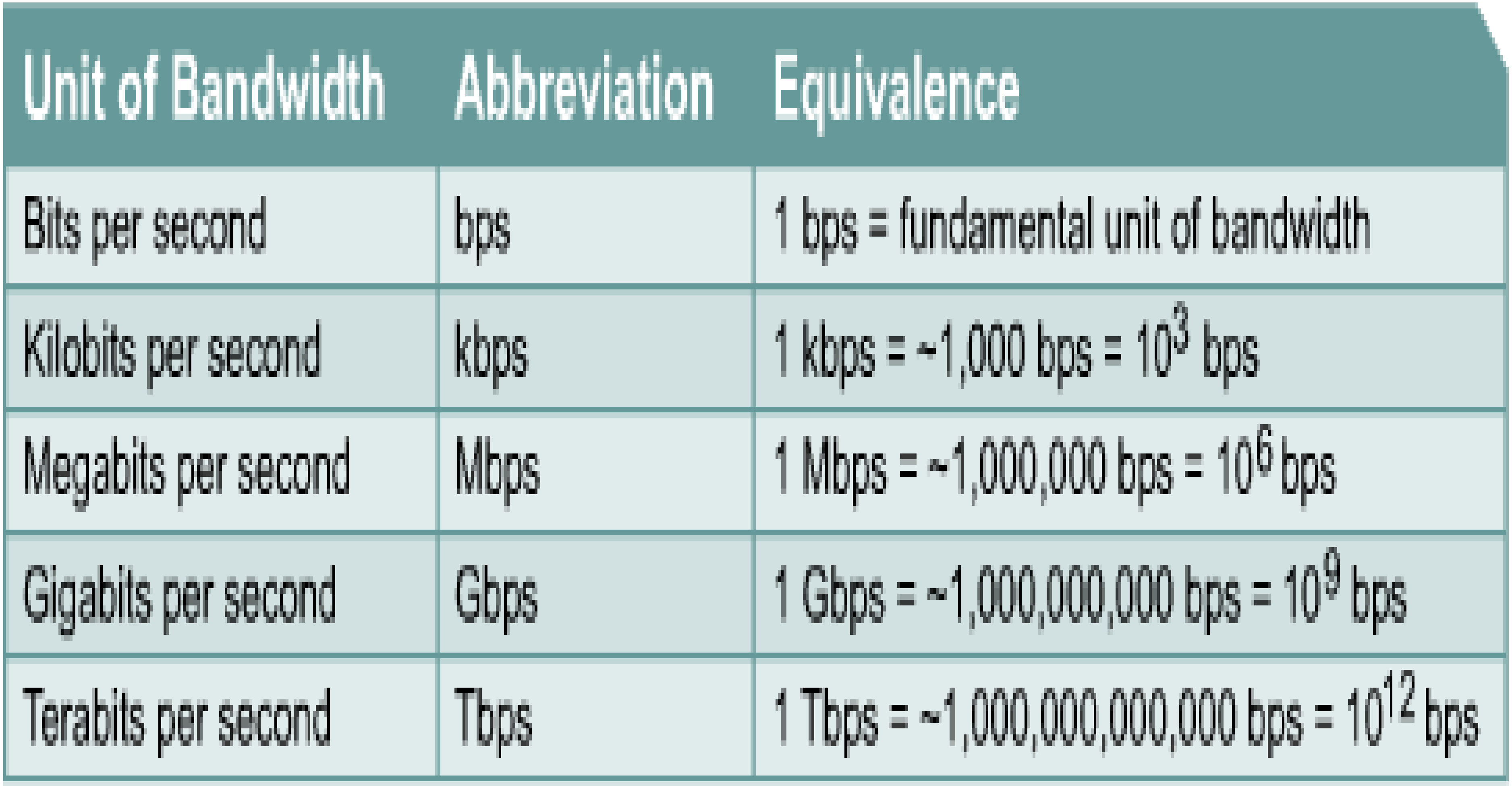
Bandwidth

Why bandwidth is important:

- Bandwidth is limited by physics and technology
- Bandwidth is not free
- Bandwidth requirements are growing at a rapid rate
- Bandwidth is critical to network performance

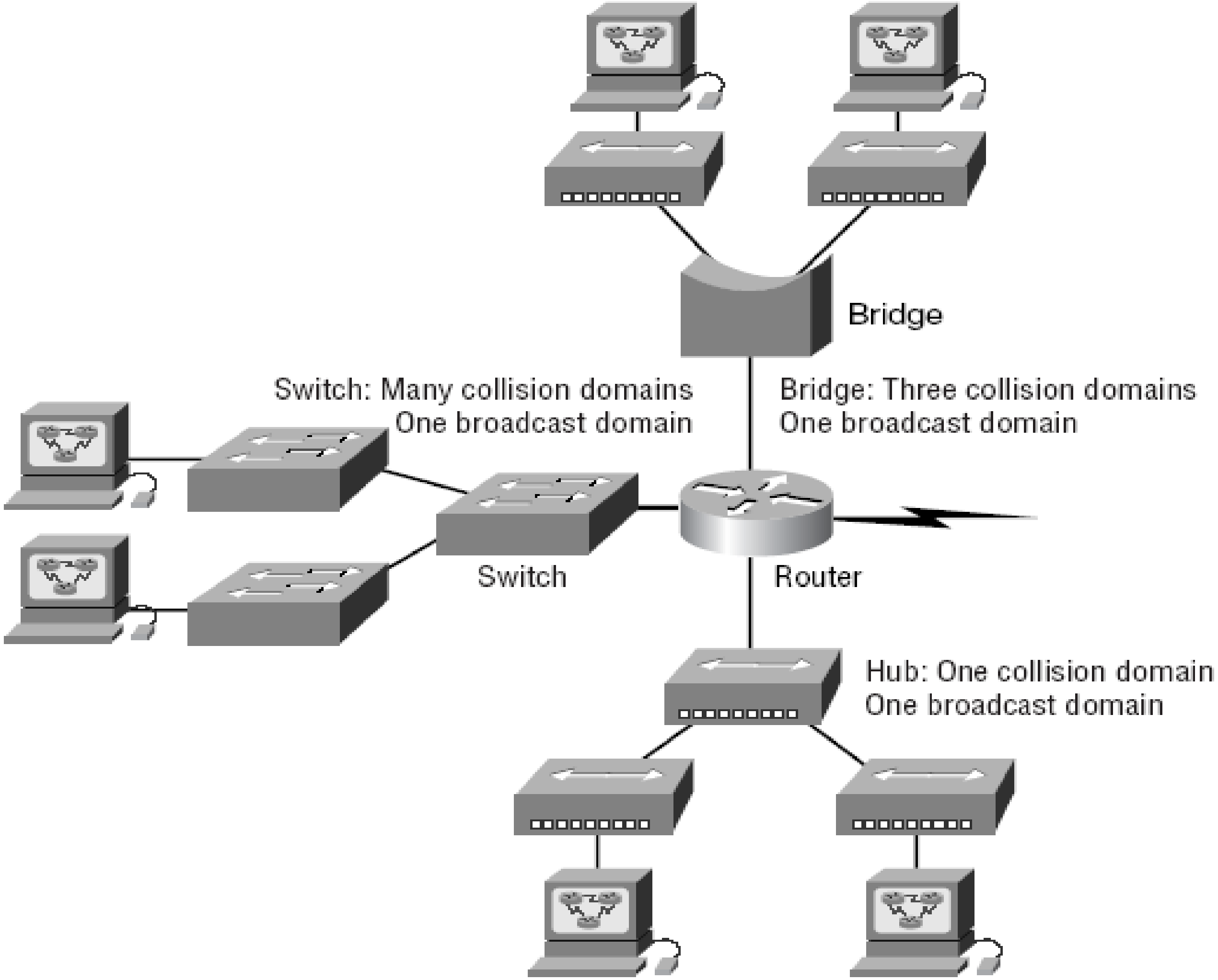
Bandwidth is like the number of lanes on a highway.

Measuring Bandwidth

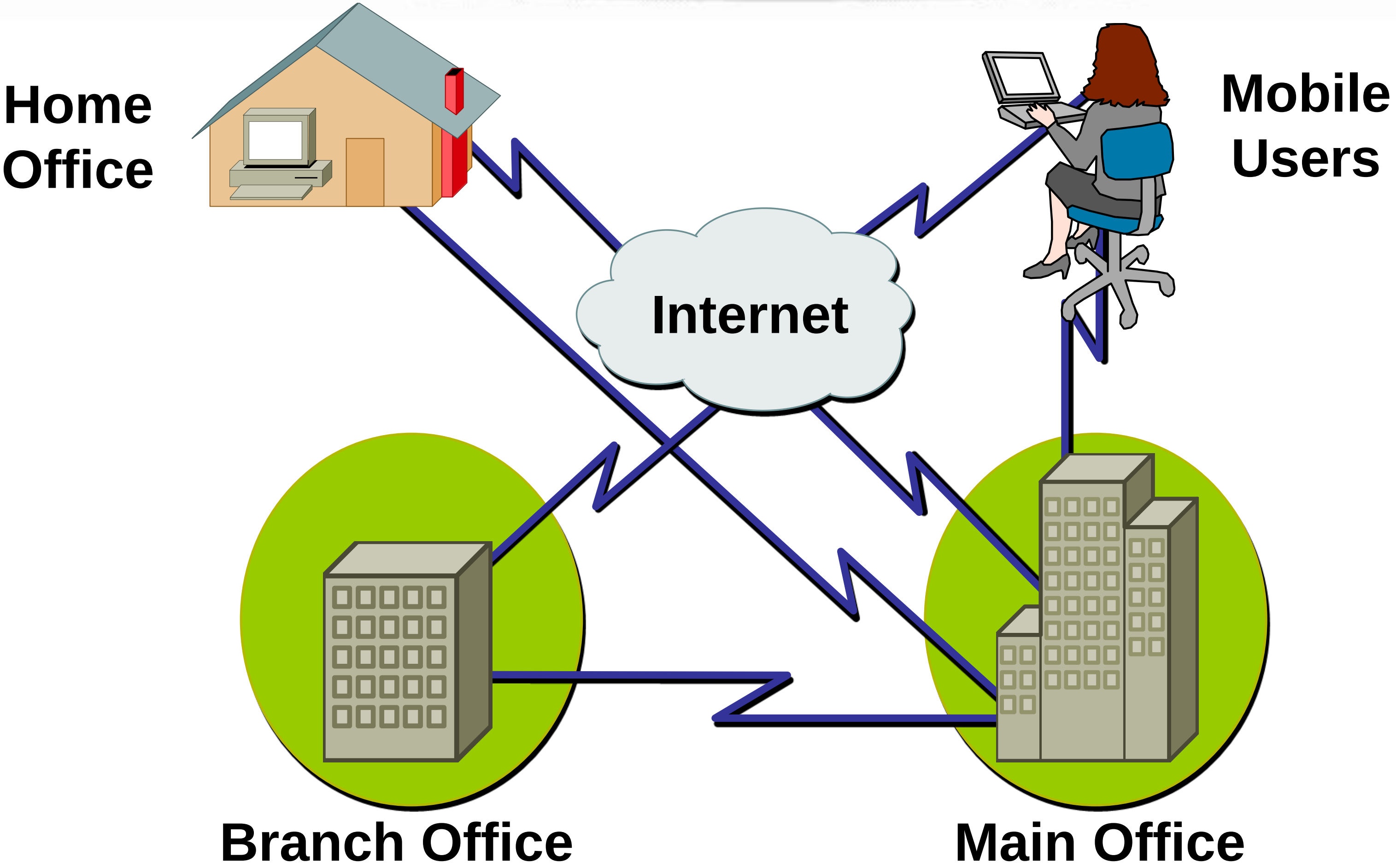


Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	bps	1 bps = fundamental unit of bandwidth
Kilobits per second	kbps	1 kbps = ~1,000 bps = 10^3 bps
Megabits per second	Mbps	1 Mbps = ~1,000,000 bps = 10^6 bps
Gigabits per second	Gbps	1 Gbps = ~1,000,000,000 bps = 10^9 bps
Terabits per second	Tbps	1 Tbps = ~1,000,000,000,000 bps = 10^{12} bps

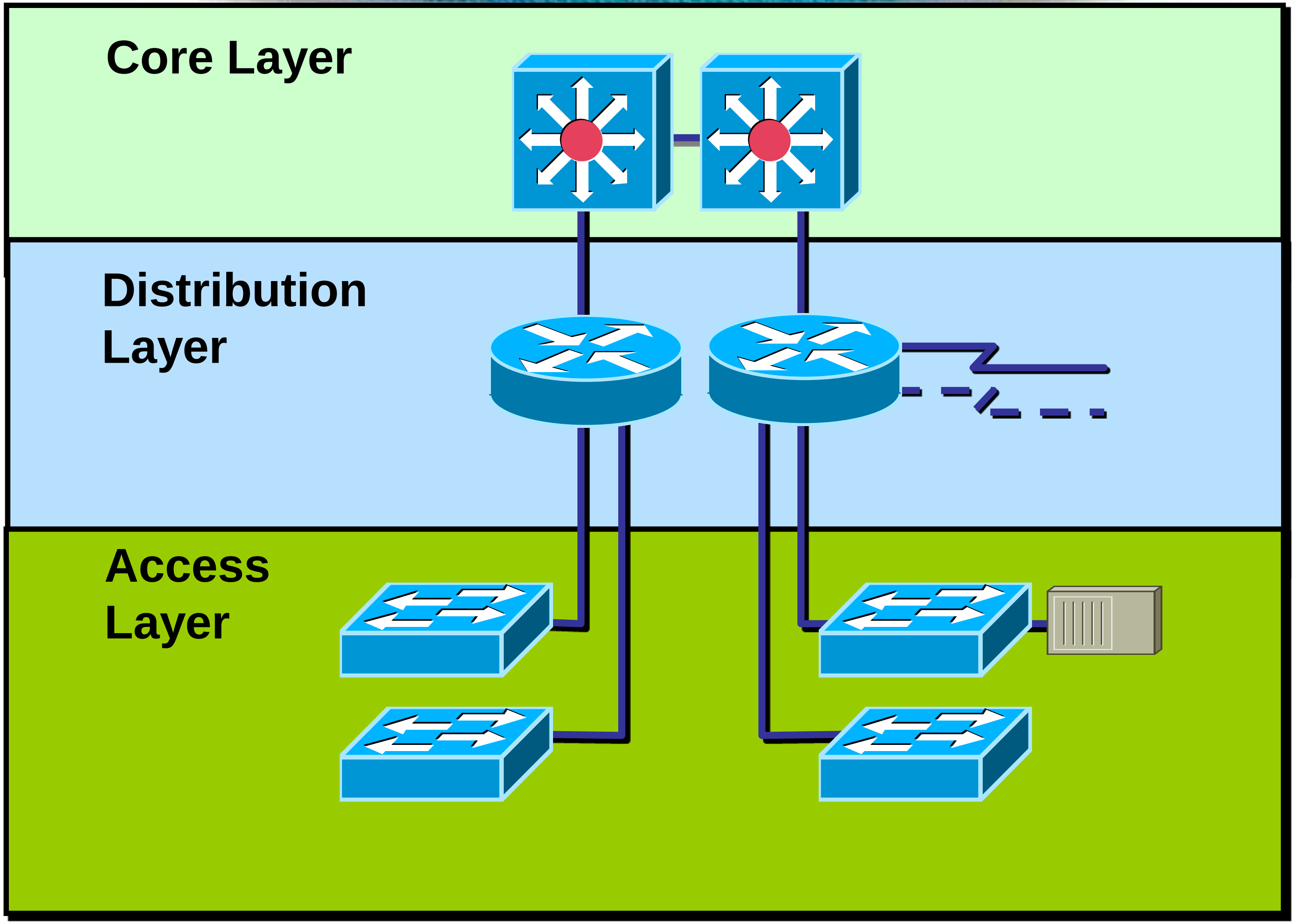
Internetworking Devices



What Are The Components Of A Network ?



Network Structure & Hierarchy



Core Layer

Distribution Layer

Access Layer

Institute of Electrical and Electronics Engineers (IEEE) 802 Standards

- ❑ IEEE 802.1: Standards related to network management.
- ❑ IEEE 802.2: General standard for the data link layer in the OSI Reference Model. The IEEE divides this layer into two sublayers -- the logical link control (LLC) layer and the media access control (MAC) layer.
- ❑ IEEE 802.3: Defines the MAC layer for bus networks that use CSMA/CD. This is the basis of the Ethernet standard.
- ❑ IEEE 802.4: Defines the MAC layer for bus networks that use a token-passing mechanism (token bus networks).
- ❑ IEEE 802.5: Defines the MAC layer for token-ring networks.
- ❑ IEEE 802.6: Standard for Metropolitan Area Networks (MANs)

The OSI Model

Why do we need the OSI Model?

❑To address the problem of networks increasing in size and in number, the International Organization for Standardization (ISO) researched many network schemes and recognized that there was a need to create a network model

❑This would help network builders implement networks that could communicate and work together

❑ISO therefore, released the OSI reference model in 1984.

Don’t Get Confused.

ISO - International Organization for Standardization

OSI - Open System Interconnection

IOS - Internetwork Operating System

To avoid confusion, some people say “International Standard Organization.”

The OSI Reference Model

7 Application

6 Presentation

5 Session

4 Transport

3 Network

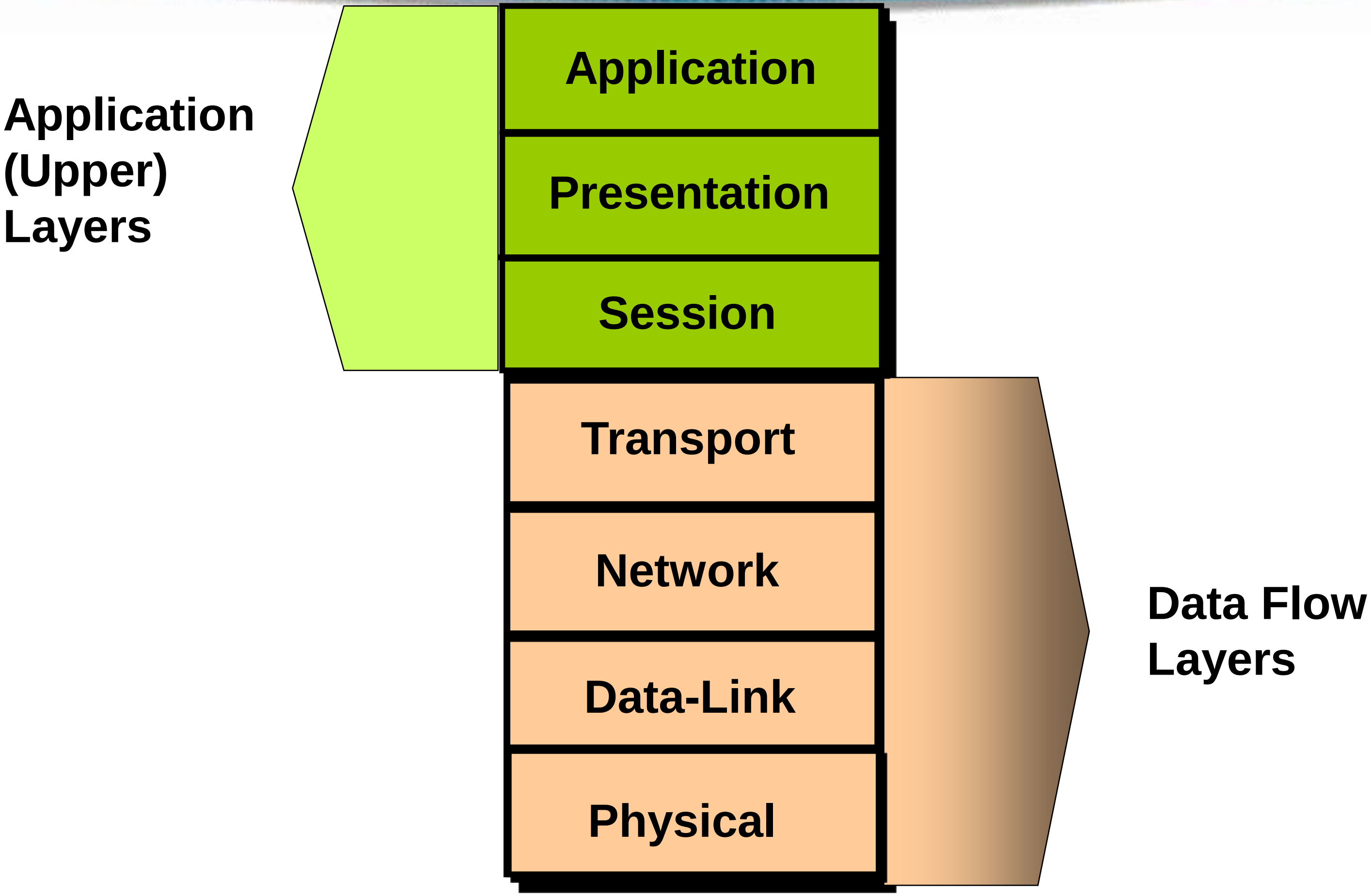
2 Data Link

1 Physical

The OSI Model will be used throughout your entire networking career!

Memorize it!

OSI Model



Application
(Upper)
Layers

Application

Presentation

Session

Transport

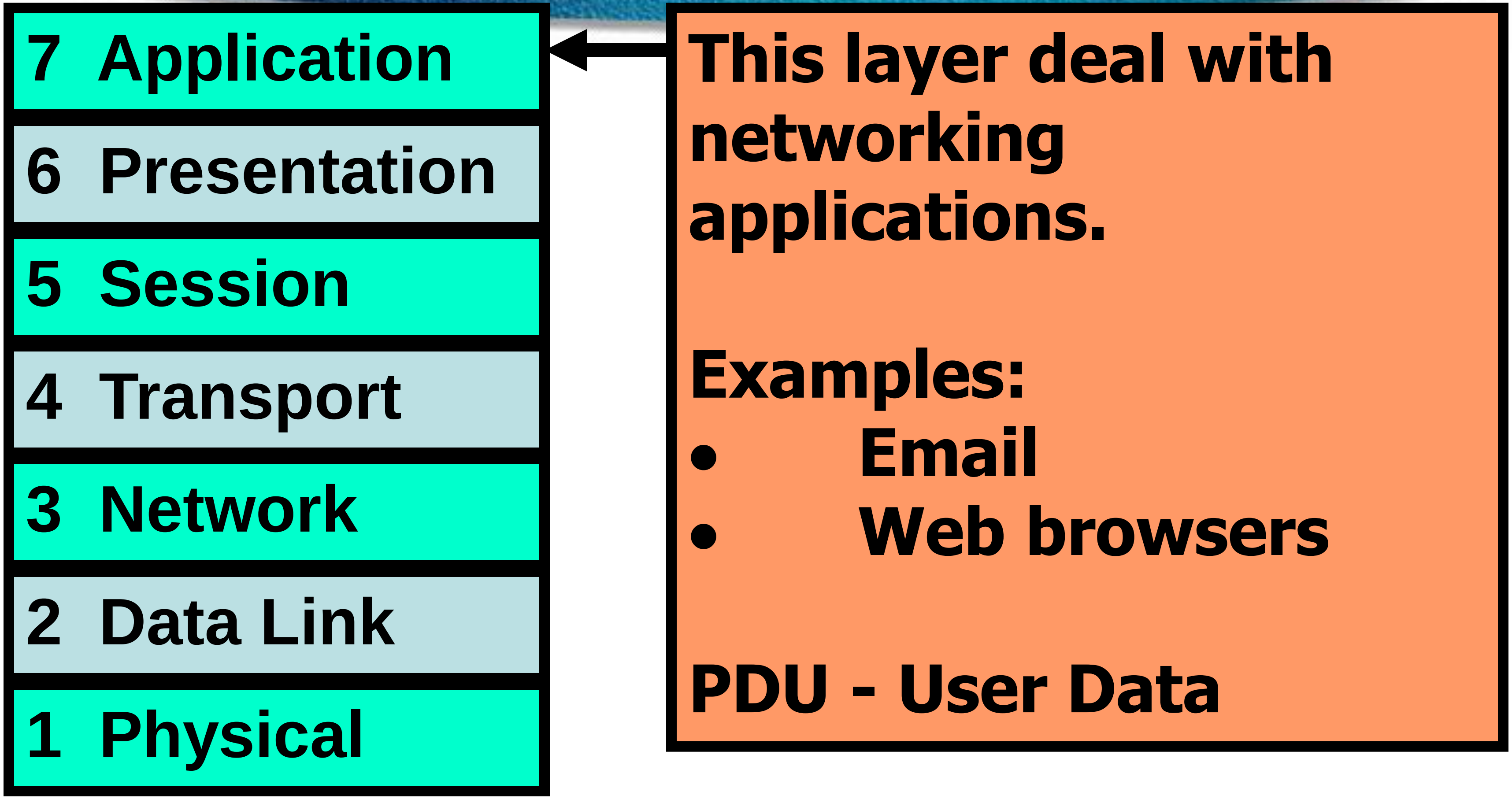
Network

Data-Link

Physical

Data Flow
Layers

Layer 7 - The Application Layer



7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

1 Physical

This layer deal with networking applications.

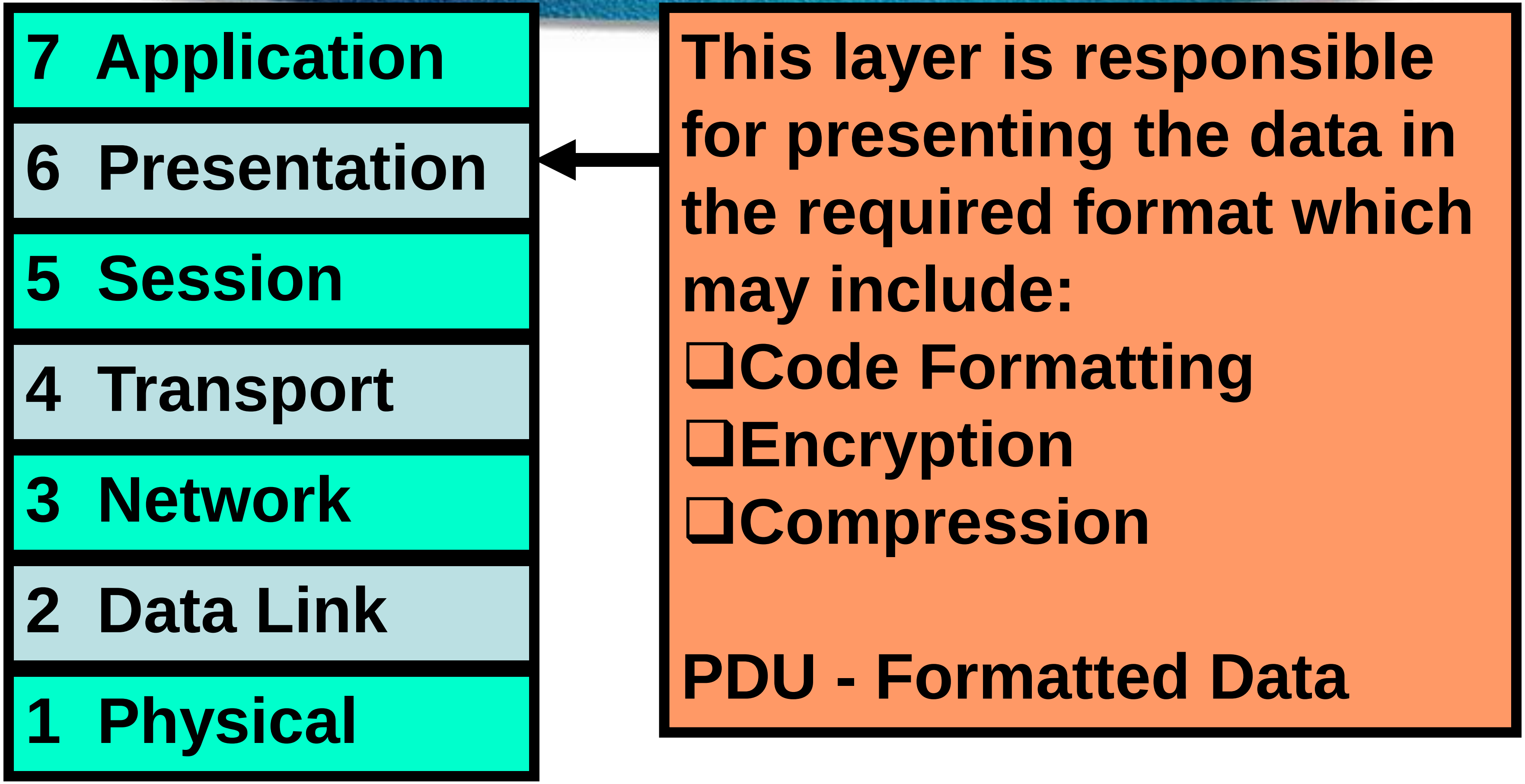
Examples:

- Email
- Web browsers

PDU - User Data

Each of the layers have Protocol Data Unit (PDU)

Layer 6 - The Presentation Layer



7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

1 Physical

This layer is responsible for presenting the data in the required format which may include:

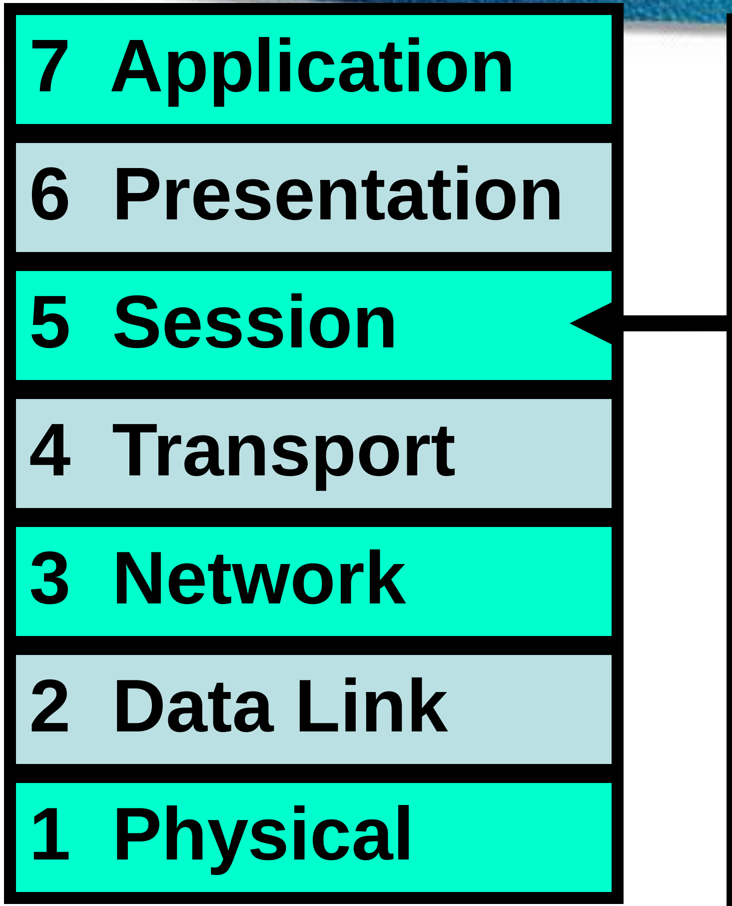
☐Code Formatting

☐Encryption

☐Compression

PDU - Formatted Data

Layer 5 - The Session Layer



- This layer establishes, manages, and terminates sessions between two communicating hosts.
- Creates Virtual Circuit
- Coordinates communication between systems
- Organize their communication by offering three different modes
  - Simplex
  - Half Duplex
  - Full Duplex

Example:

- **Client Software**
  (Used for logging in)

PDU - Formatted Data

Half Duplex

- It uses only one wire pair with a digital signal running in both directions on the wire.

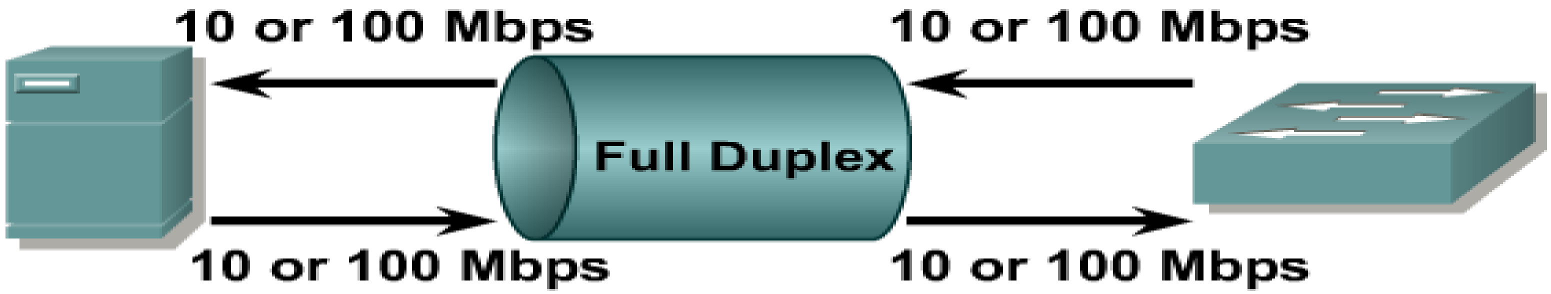
- It also uses the CSMA/CD protocol to help prevent collisions and to permit retransmitting if a collision does occur.

- If a hub is attached to a switch, it must operate in half-duplex mode because the end stations must be able to detect collisions.

- Half-duplex Ethernet—typically 10BaseT—is only about 30 to 40 percent efficient because a large 10BaseT network will usually only give you 3 to 4Mbps—at most.

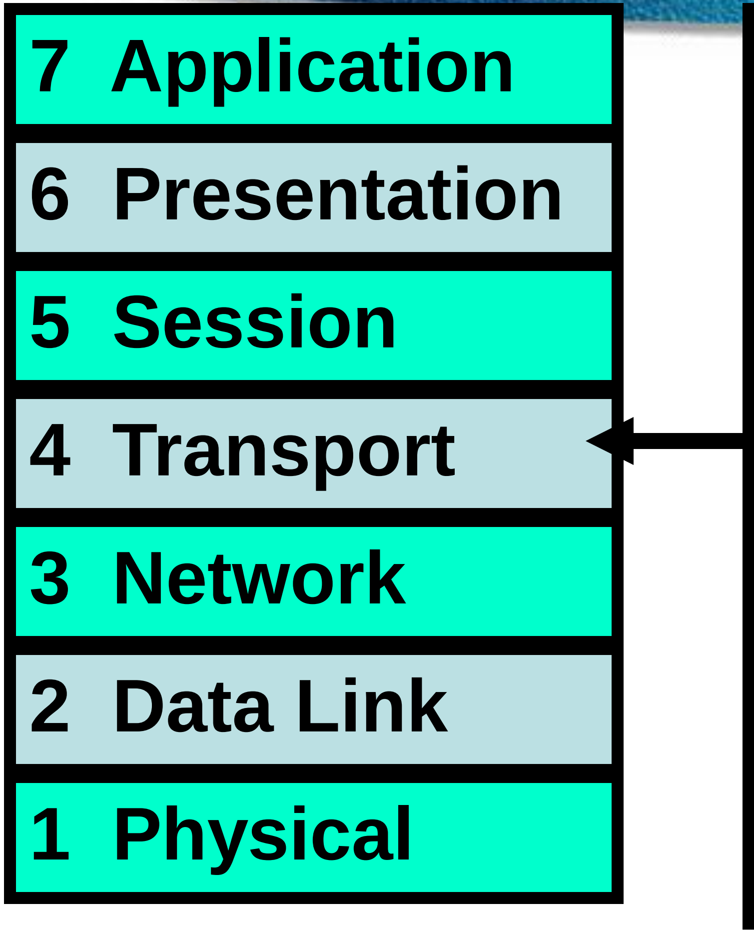
Full Duplex

In a network that uses twisted-pair cabling, one pair is used to carry the transmitted signal from one node to the other node. A separate pair is used for the return or received signal. It is possible for signals to pass through both pairs simultaneously. The capability of communication in both directions at once is known as full duplex.



- Doubles bandwidth between nodes
- Collision-free transmission
- Two 10- or 100- Mbps data paths

Layer 4 - The Transport Layer



7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

1 Physical

- This layer breaks up the data from the sending host and then reassembles it in the receiver.

- It also is used to insure reliable data transport across the network.
- Can be reliable or unreliable
- Sequencing
- Acknowledgment
- Retransmission
- Flow Control

PDU - Segments

Layer 3 - The Network Layer

7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

1 Physical

- Sometimes referred to as the “Cisco Layer”.
- End to End Delivery
- Provide logical addressing that routers use for path determination
- Segments are encapsulated
- Internetwork Communication
- Packet forwarding
- Packet Filtering
- Makes “Best Path Determination”
- Fragmentation

PDU – Packets – IP/IPX

Layer 2 - The Data Link Layer

7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical

- Performs Physical Addressing
- This layer provides reliable transit of data across a physical link.
- Combines bits into bytes and bytes into frames
- Access to media using MAC address
- Error detection, not correction
- LLC and MAC
- Logical Link Control performs Link establishment
- MAC Performs Access method

PDU - Frames

Preamble	**DMAC**	**SMAC**	**Data length**	**DATA**	**FCS**

Layer 1 - The Physical Layer

7 Application

6 Presentation

5 Session

4 Transport

3 Network

2 Data Link

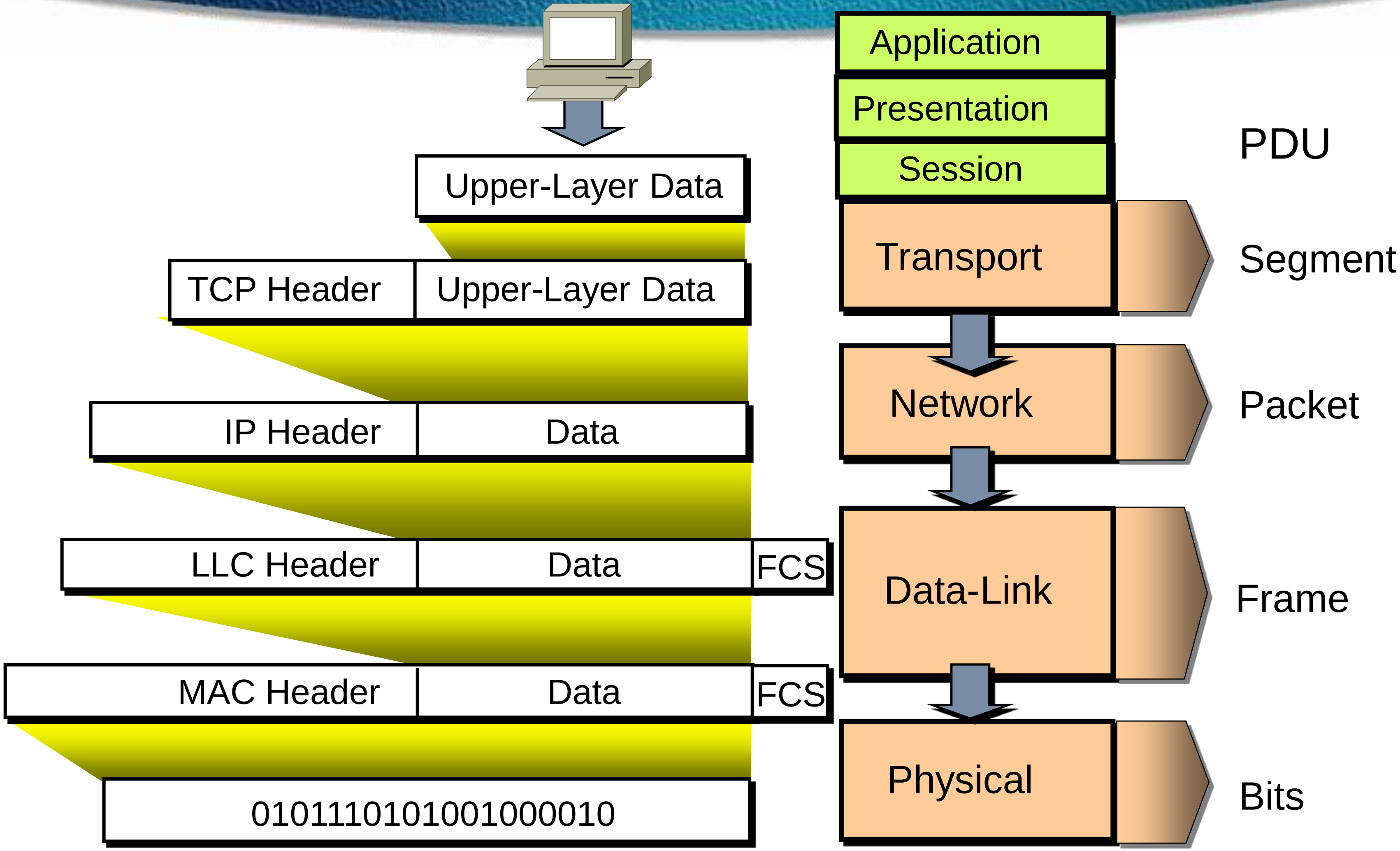
1 Physical

- This is the physical media through which the data, represented as electronic signals, is sent from the source host to the destination host.

- Move bits between devices
- Encoding

PDU - Bits

Data Encapsulation



Upper-Layer Data

TCP Header | Upper-Layer Data

IP Header | Data

LLC Header | Data | FCS

MAC Header | Data | FCS

0101110101001000010

Application

Presentation

Session

Transport

Network

Data-Link

Physical

PDU

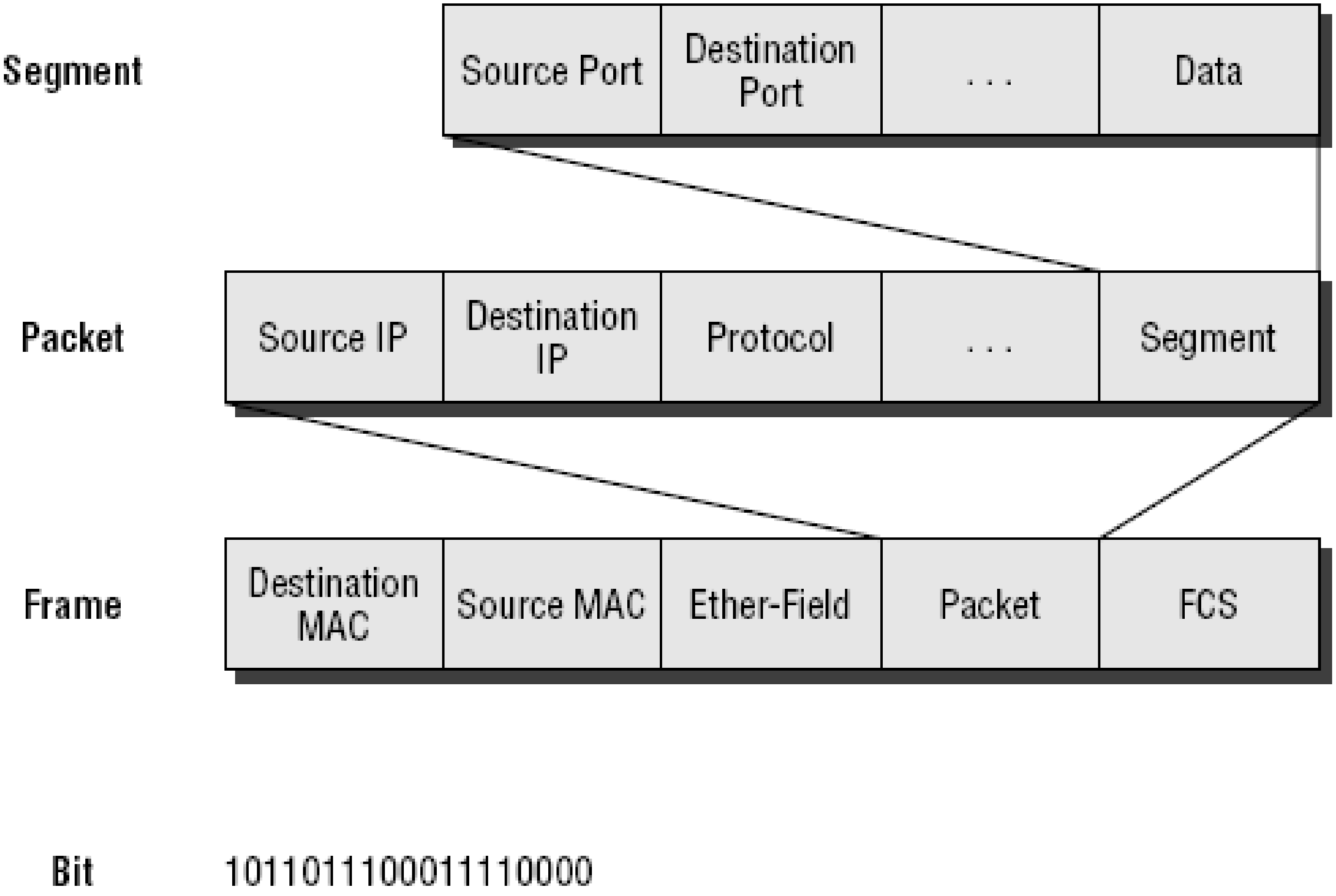
Segment

Packet

Frame

Bits

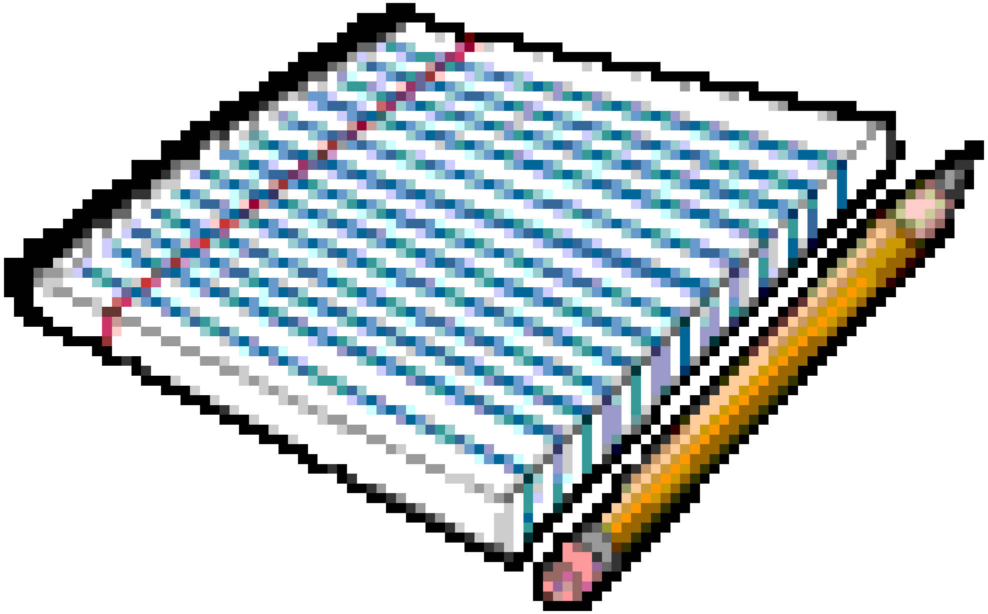
Data Encapsulation



OSI Model Analogy
Application Layer - Source Host

After riding your new bicycle a few times in Hyderabad, you decide that you want to give it to a friend who lives in DADAR, Mumbai.

OSI Model Analogy
Presentation Layer - Source Host

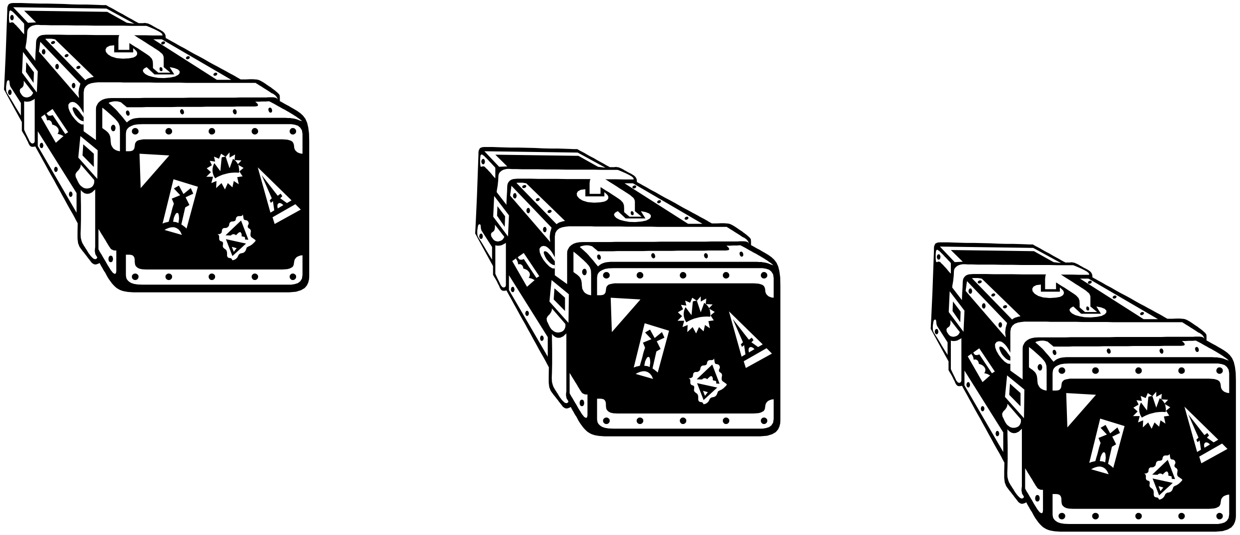


Make sure you have the proper directions to disassemble and reassemble the bicycle.

OSI Model Analogy
Session Layer - Source Host

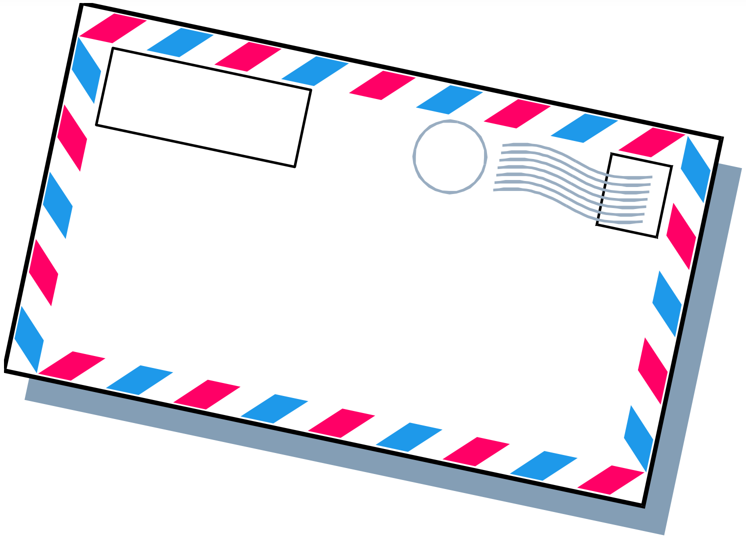
Call your friend and make sure you have his correct address.

OSI Model Analogy
Transport Layer - Source Host



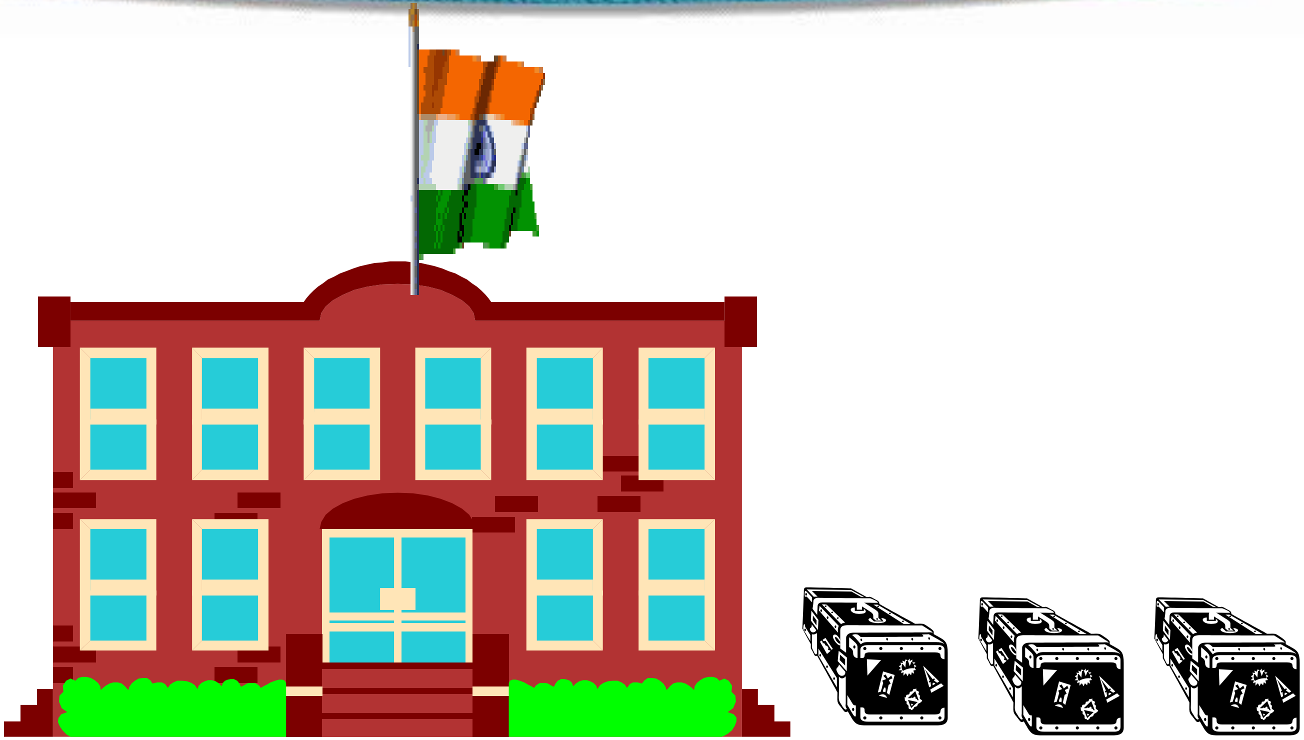
Disassemble the bicycle and put different pieces in different boxes. The boxes are labeled
 “1 of 3”, “2 of 3”, and “3 of 3”.

OSI Model Analogy
Network Layer - Source Host



Put your friend's complete mailing address (and yours) on each box.Since the packages are too big for your mailbox (and since you don’t have enough stamps) you determine that you need to go to the post office.

OSI Model Analogy
Data Link Layer – Source Host

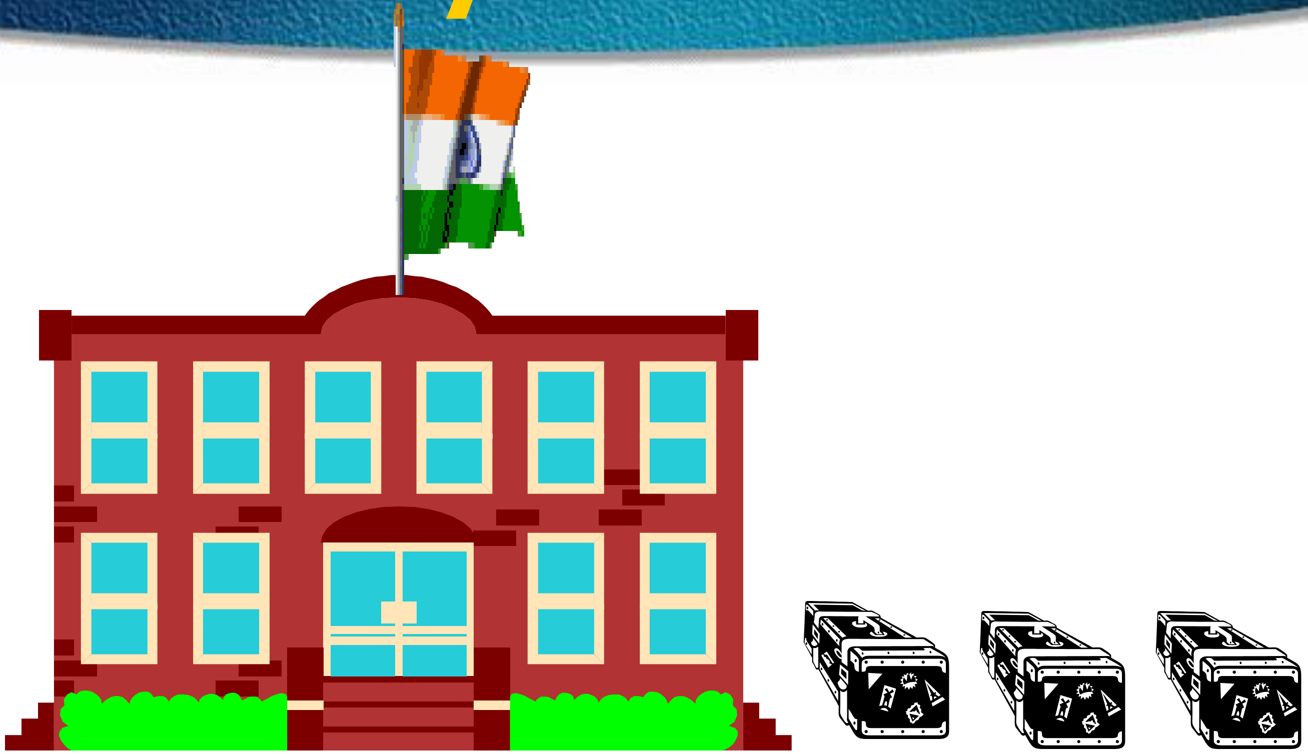


Hyderabad post office takes possession of the boxes.

OSI Model Analogy
Physical Layer - Media

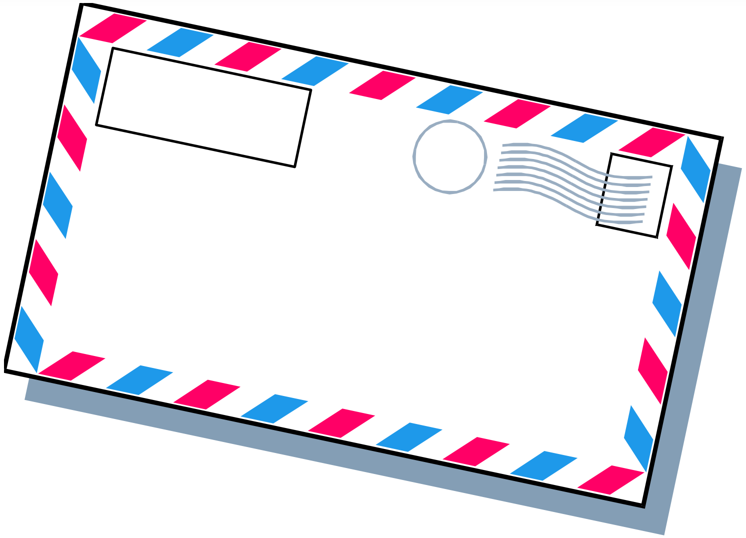
The boxes are flown from Hyderabad to Mumbai.

OSI Model Analogy
Data Link Layer - Destination



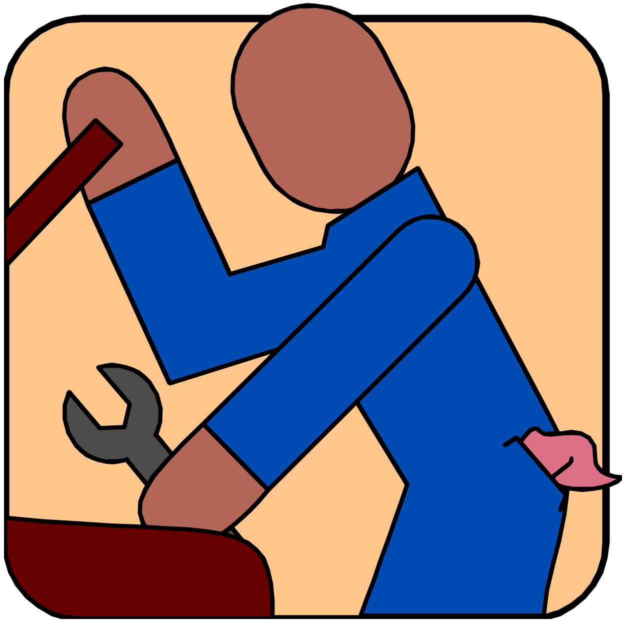
Dadar post office receives your boxes.

OSI Model Analogy
Network Layer - Destination



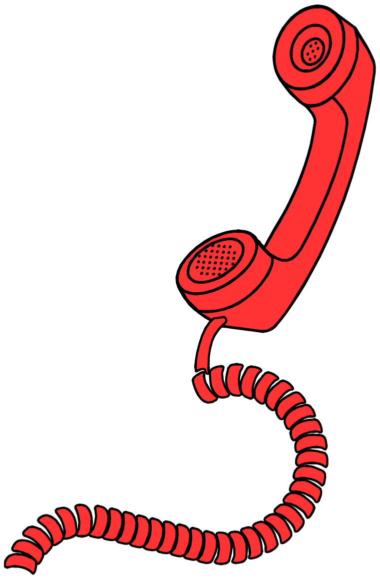
Upon examining the destination address, Dadar post office determines that your boxes should be delivered to your written home address.

OSI Model Analogy
Transport Layer - Destination



Your friend calls you and tells you he got all 3 boxes and he is having another friend named BOB reassemble the bicycle.

OSI Model Analogy
Session Layer - Destination



Your friend hangs up because he is done talking to you.

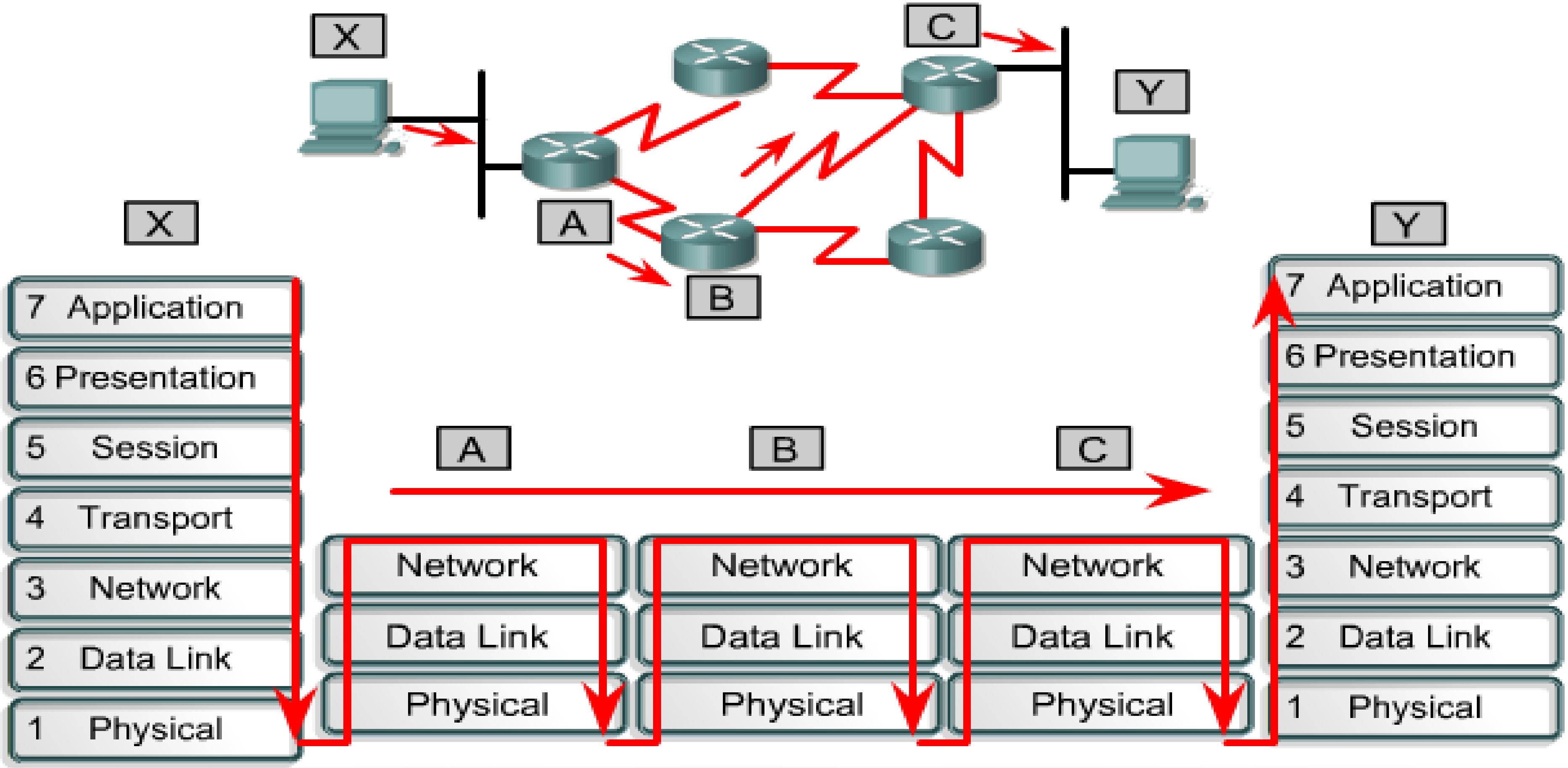
OSI Model Analogy
Presentation Layer - Destination

BOB is finished and "presents" the bicycle to your friend. Another way to say it is that your friend is finally getting him "present".

OSI Model Analogy Application Layer - Destination

Your friend enjoys riding his new bicycle in Dadar.

Data Flow Through a Network

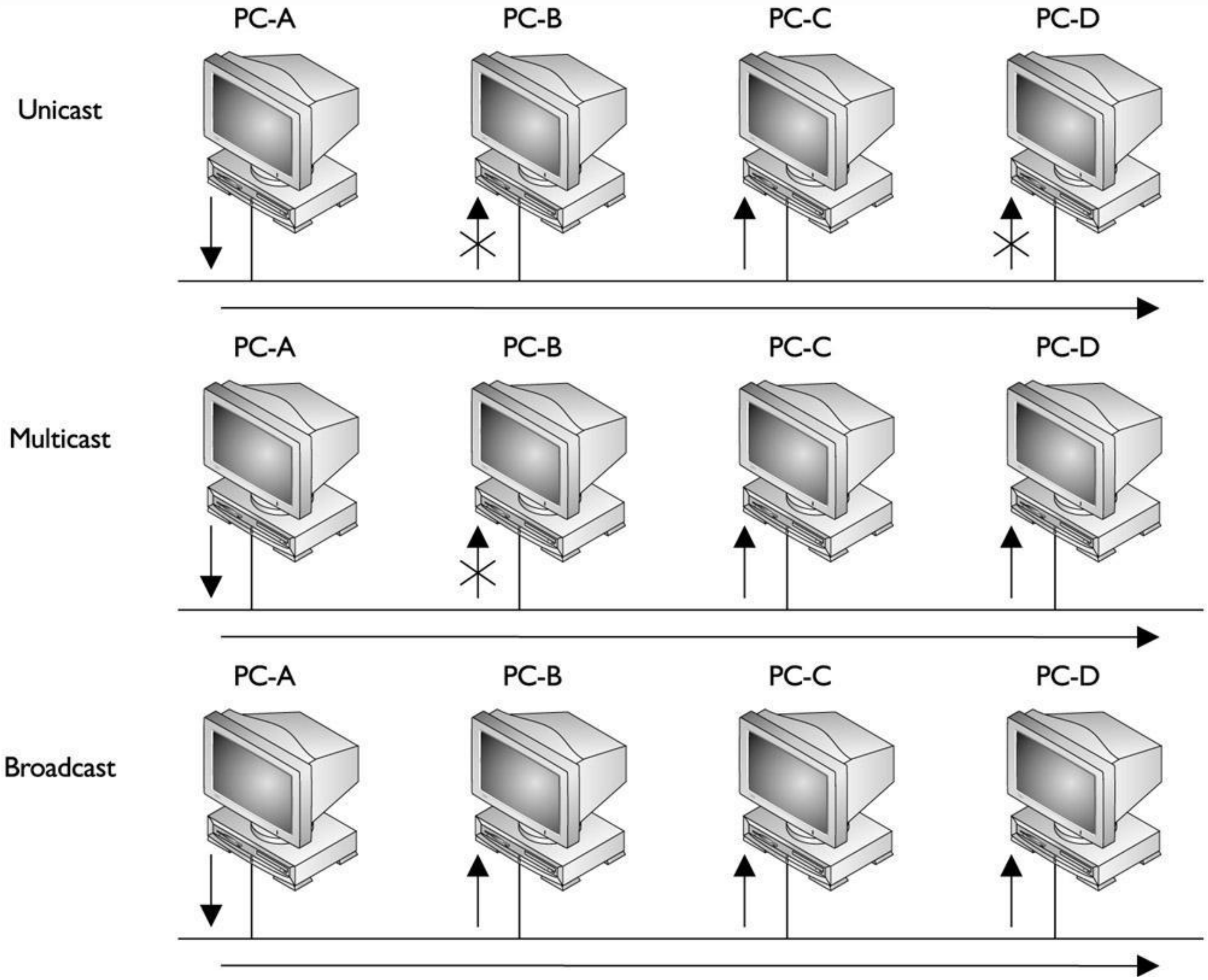


Data flow in a network focuses on layers one, two and three of the OSI model. This is after being transmitted by the sending host and before arriving at the receiving host.

Type of Transmission

- Unicast
- Multicast
- Broadcast

Type of Transmission



Broadcast Domain

- A group of devices receiving broadcast frames initiating from any device within the group

- Routers do not forward broadcast frames, broadcast domains are not forwarded from one broadcast to another.

Collision

- The effect of two nodes sending transmissions simultaneously in Ethernet. When they meet on the physical media, the frames from each node collide and are damaged.

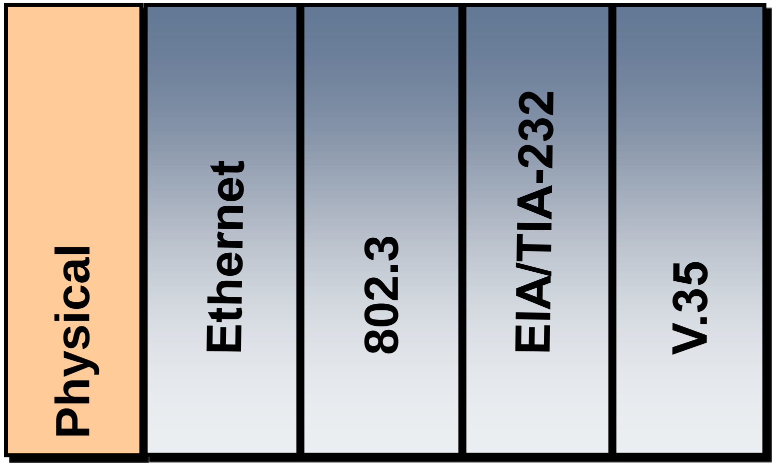
Collision Domain

- The network area in Ethernet over which frames that have collided will be detected.
- Collisions are propagated by hubs and repeaters
- Collisions are **Not** propagated by switches, routers, or bridges

Physical Layer

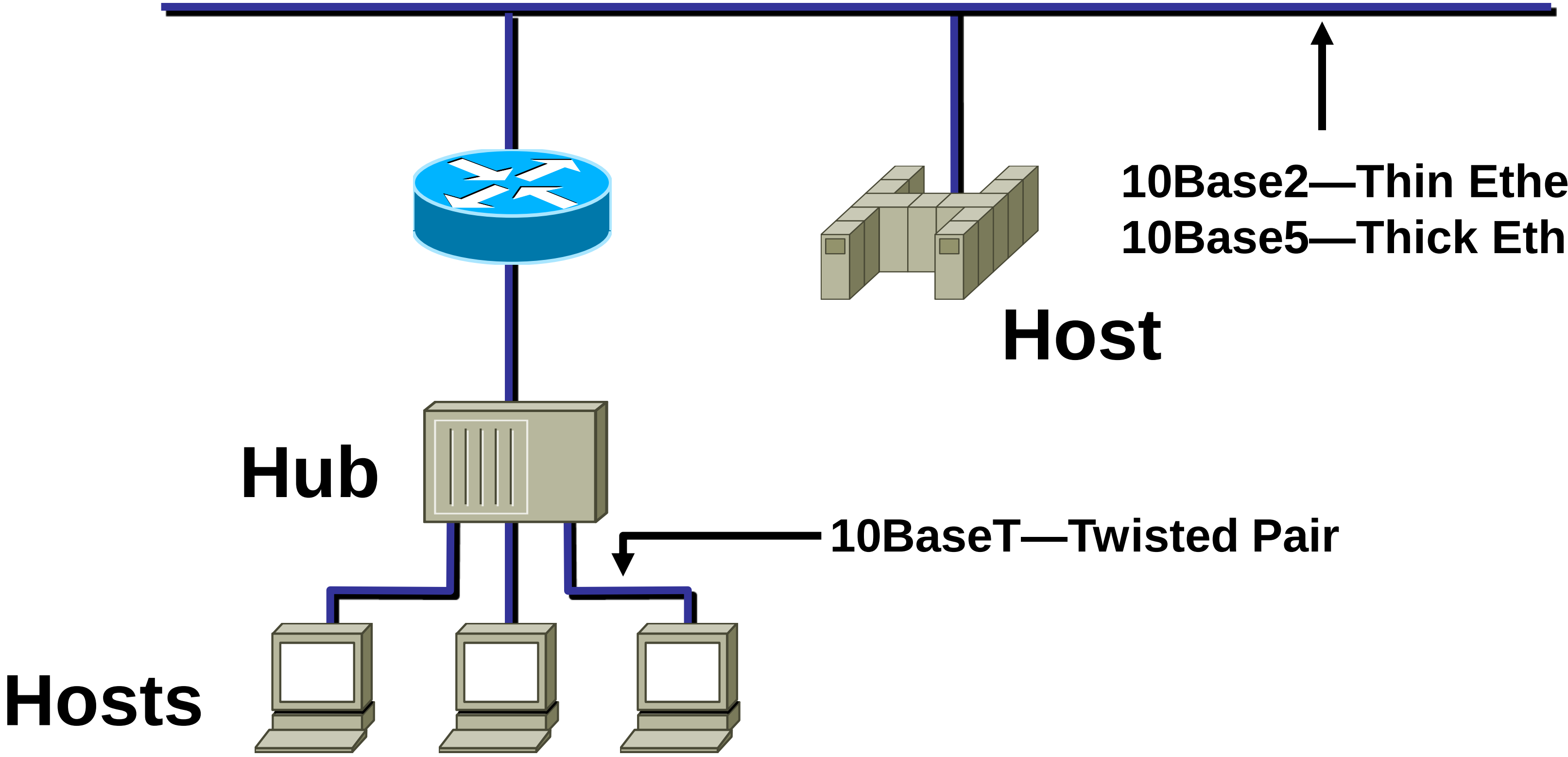
Defines

- **Media type**
- **Connector type**
- **Signaling type**

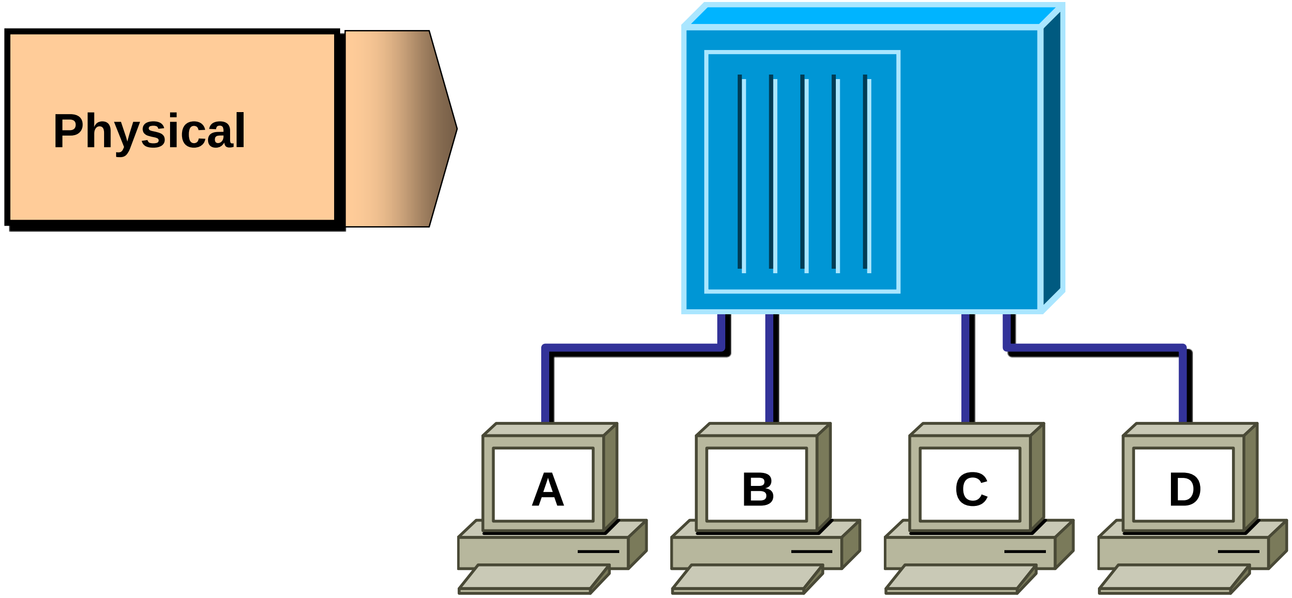


802.3 is responsible for LANs based on the carrier sense multiple access collision detect (CSMA/CD) access methodology. Ethernet is an example of a CSMA/CD network.

Physical Layer: Ethernet/802.3



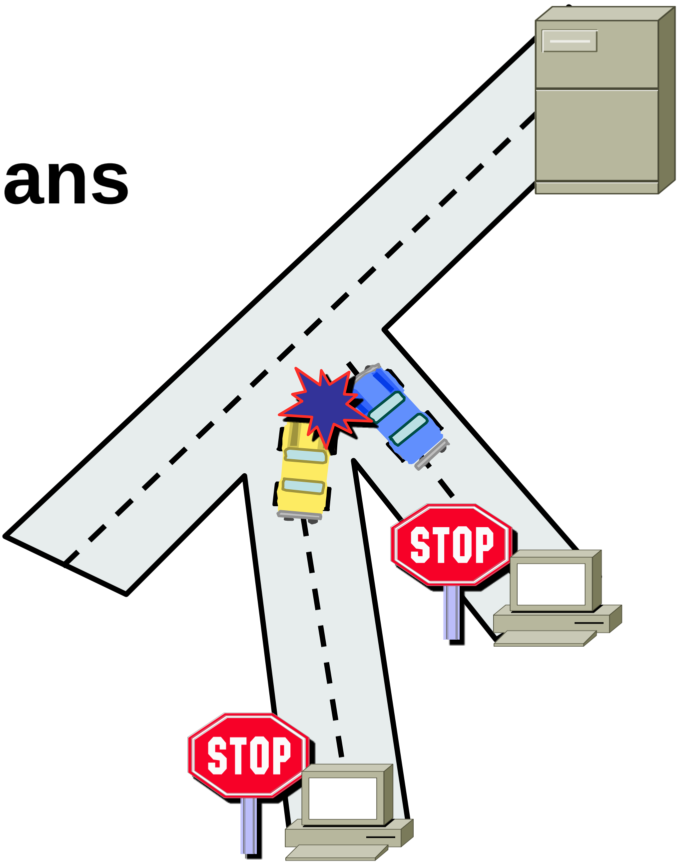
Device Used At Layer 1



- All devices are in the same collision domain.
- All devices are in the same broadcast domain.
- Devices share the same bandwidth.

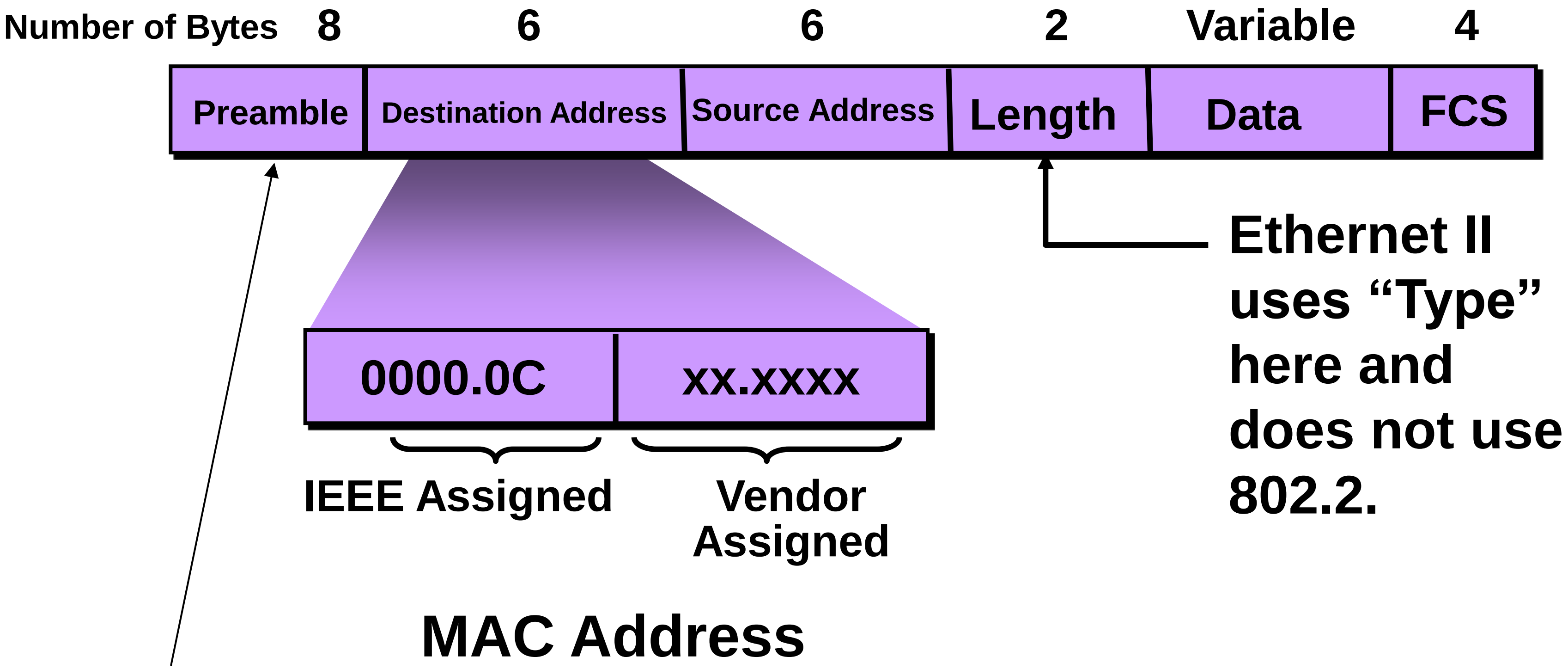
Hubs & Collision Domains

- More end stations means more collisions.
- CSMA/CD is used.



Layer 2

MAC Layer—802.3



Number of Bytes	8	6	6	2	Variable	4
	Preamble	Destination Address	Source Address	Length	Data	FCS

0000.0C | xx.xxxx

IEEE Assigned

Vendor Assigned

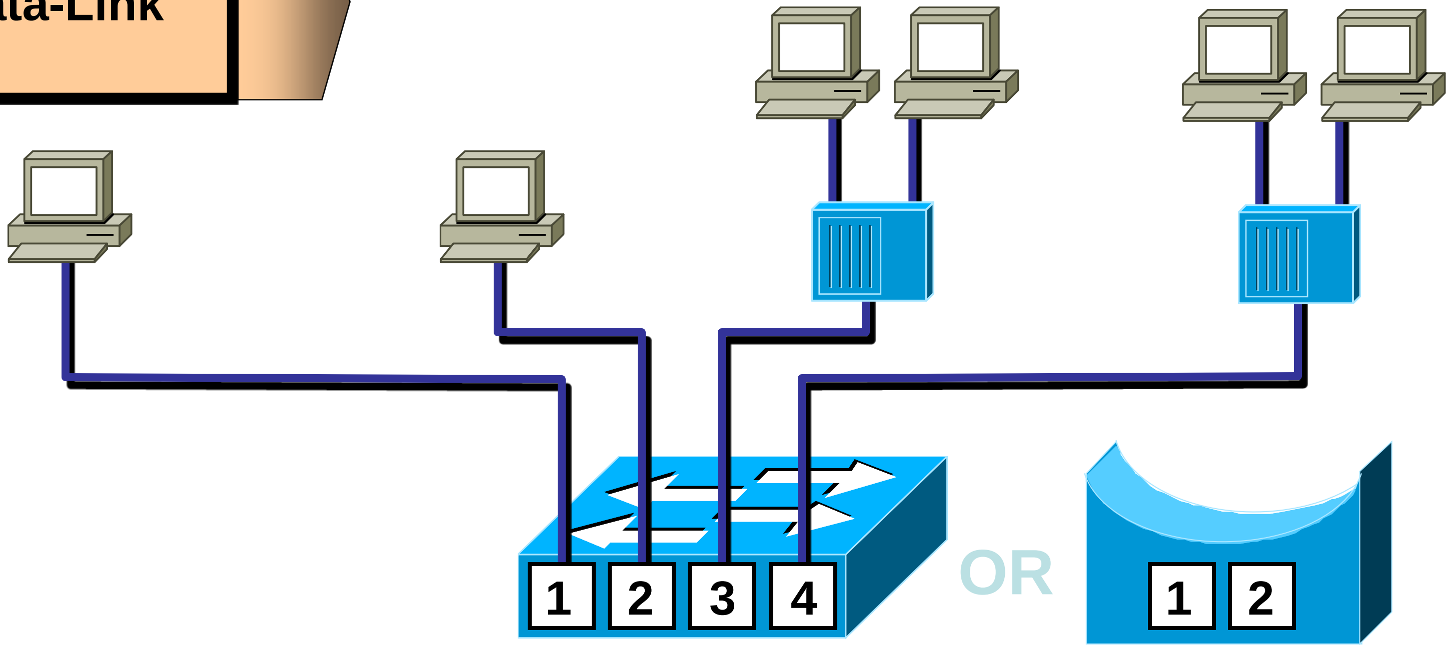
MAC Address

Ethernet II uses “Type” here and does not use 802.2.

synchronize senders and receivers

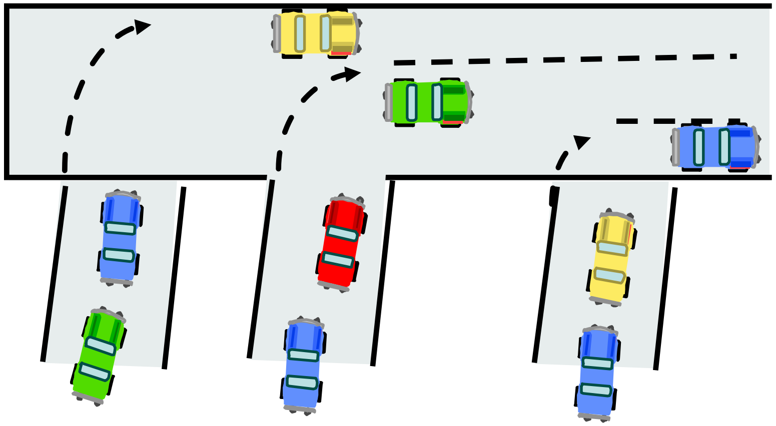
Devices On Layer 2 (Switches & Bridges)

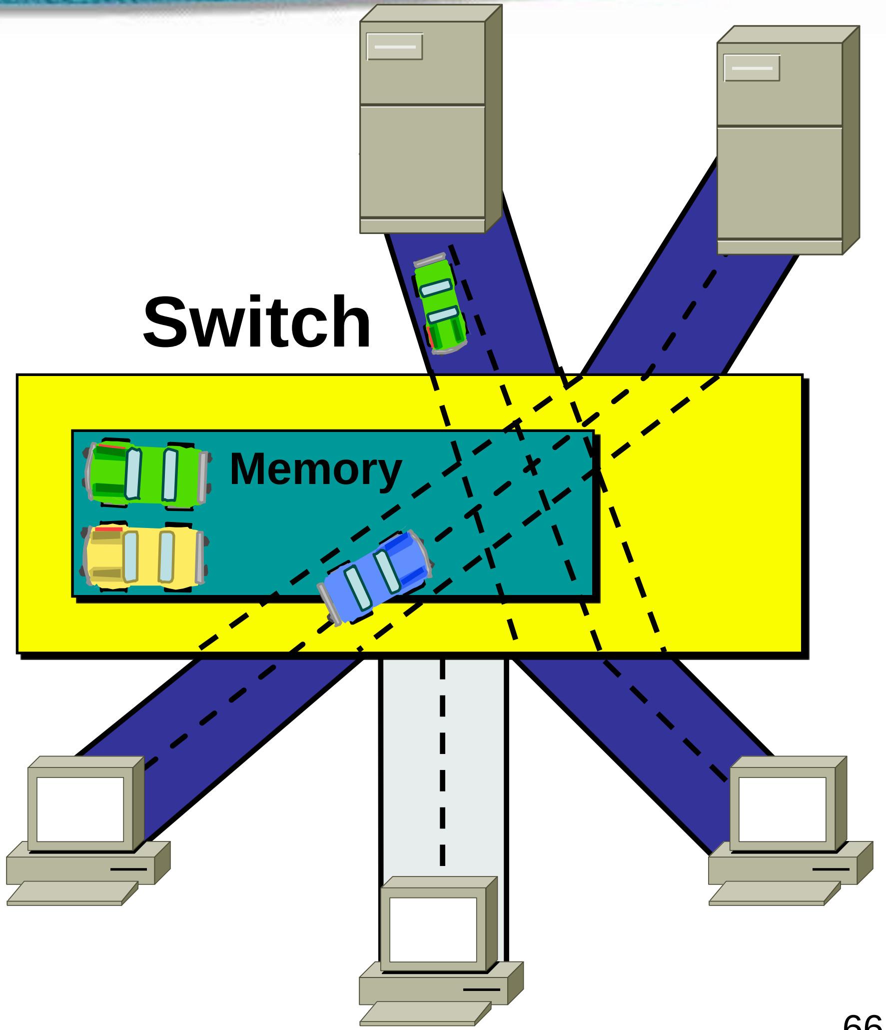
Data-Link



- **Each segment has its own collision domain.**
- **All segments are in the same broadcast domain.**

Switches

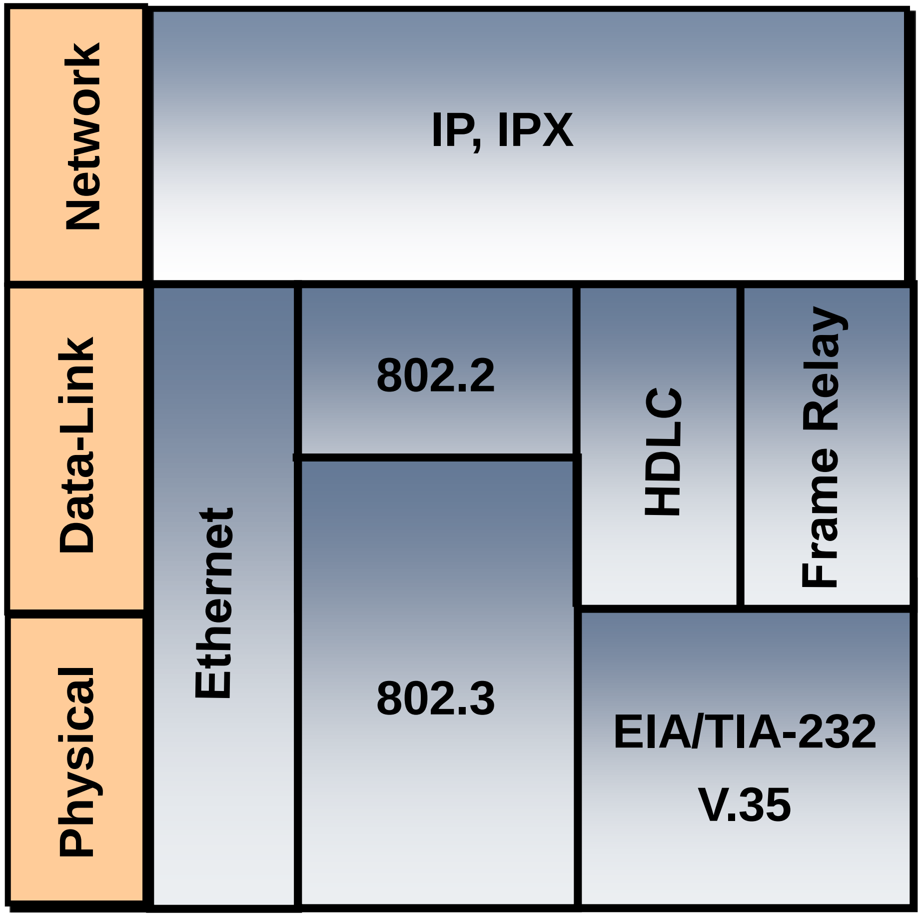




- **Each segment is its own collision domain.**
- **Broadcasts are forwarded to all segments.**

Layer 3 : Network Layer

- Defines logical source and destination addresses associated with a specific protocol
- Defines paths through network



Network

Data-Link

Physical

IP, IPX

Ethernet

802.2

802.3

HDLC

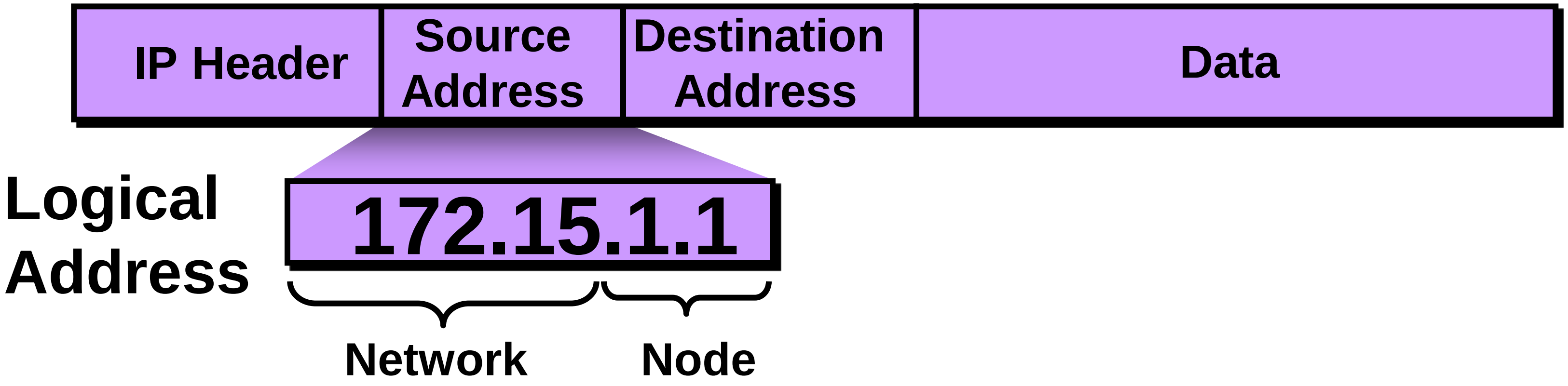
Frame Relay

EIA/TIA-232

V.35

Layer 3 : (cont.)

Network Layer End-Station Packet



IP Header | Source Address | Destination Address | Data

Logical Address

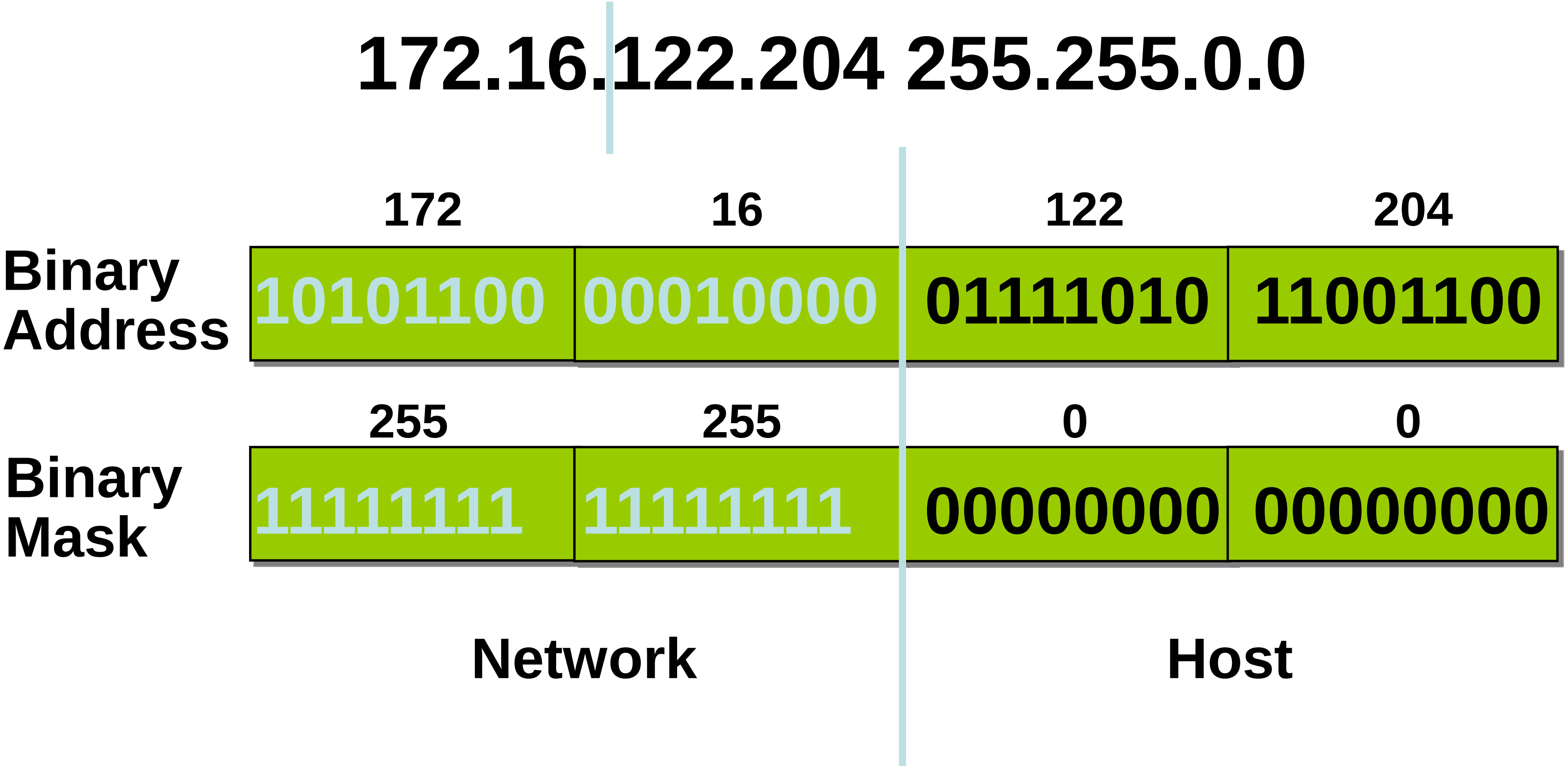
172.15.1.1

Network **Node**

❑Route determination occurs at this layer, so a packet must include a source and destination address.

❑Network-layer addresses have two components: a network component for internetwork routing, and a node number for a device-specific address. The example in the figure is an example of an IP packet and address.

Layer 3 (cont.)

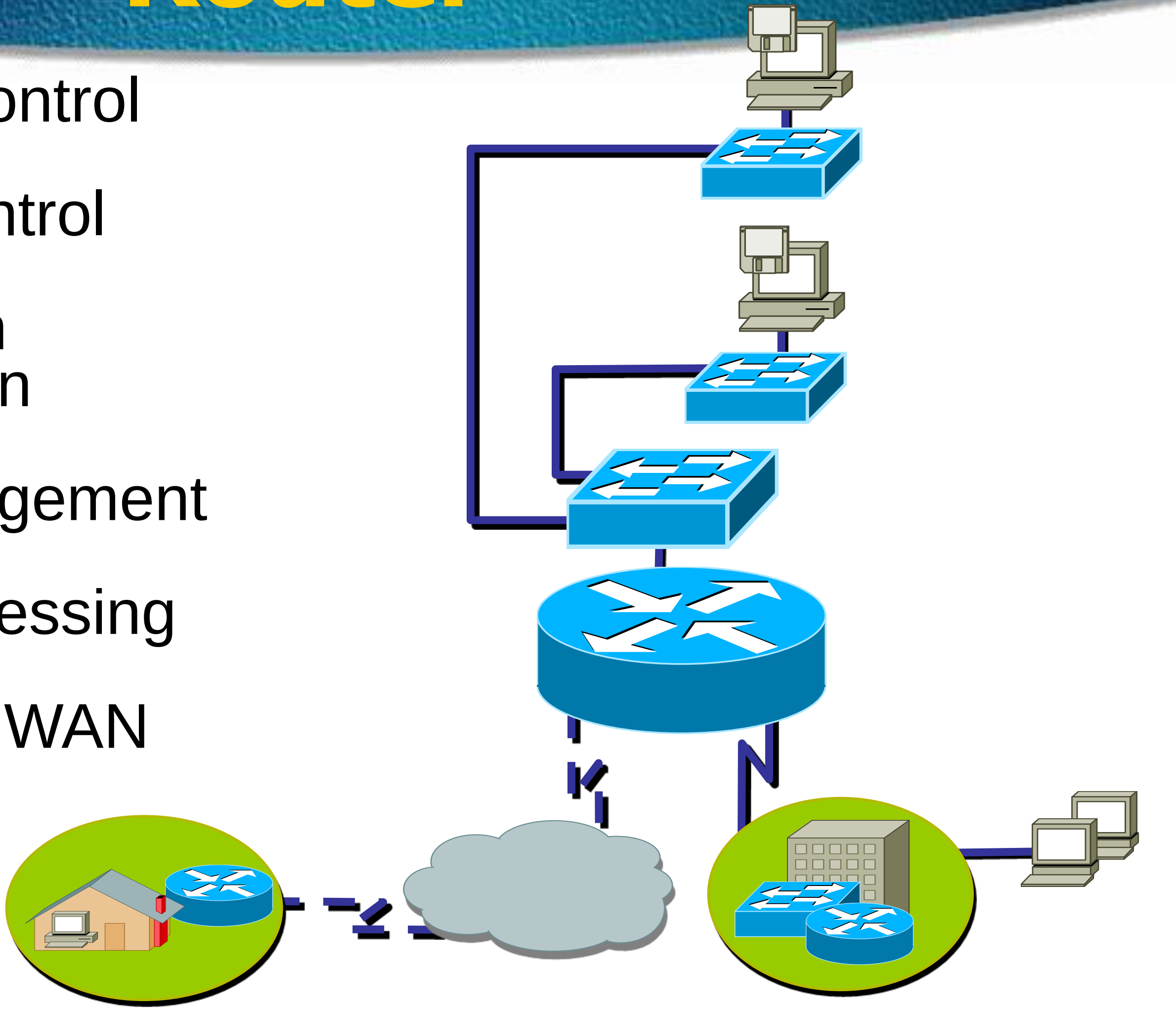


	Address	Mask
	172.16.122.204	255.255.0.0

	172	16	122	204
Binary Address	10101100	00010000	01111010	11001100
	255	255	0	0
Binary Mask	11111111	11111111	00000000	00000000
	Network		Host	

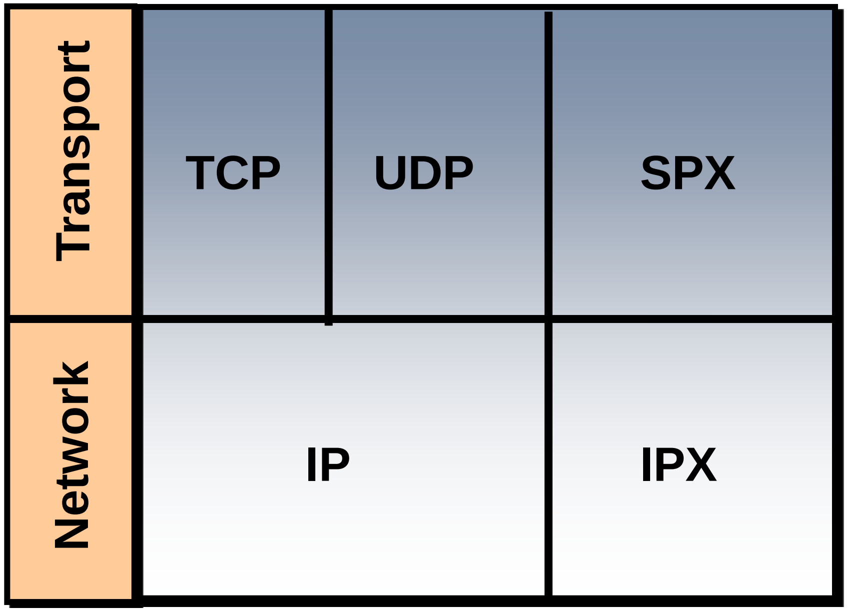
Device On Layer 3 Router

- Broadcast control
- Multicast control
- Optimal path determination
- Traffic management
- Logical addressing
- Connects to WAN services



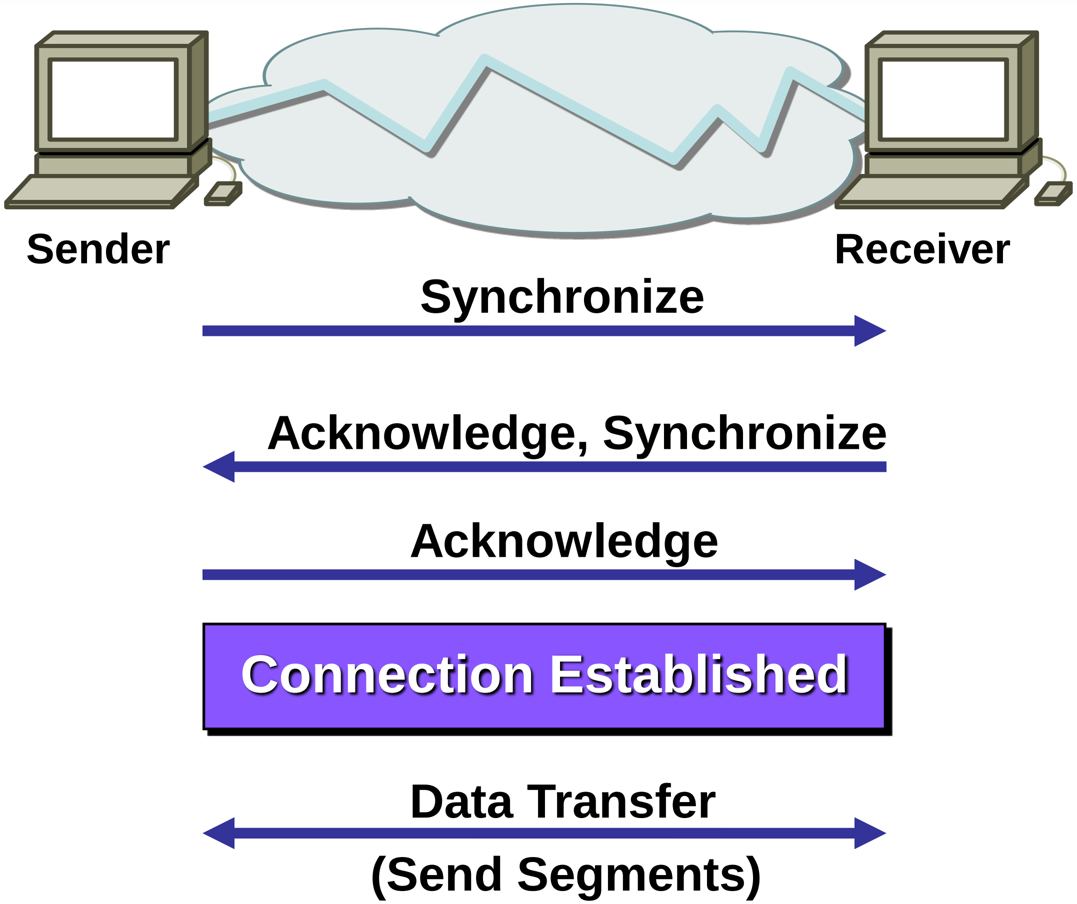
Layer 4 : Transport Layer

- Distinguishes between upper-layer applications
- Establishes end-to-end connectivity between applications
- Defines flow control
- Provides reliable or unreliable services for data transfer



Transport	TCP	UDP	SPX
Network	IP		IPX

Reliable Service



Sender

Receiver

Synchronize

Acknowledge, Synchronize

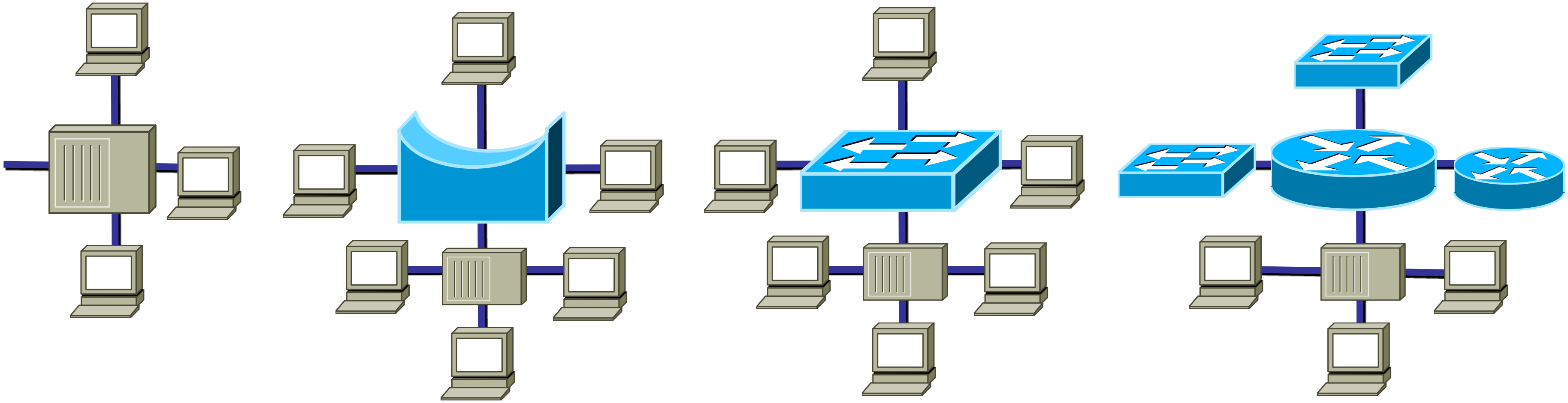
Acknowledge

Connection Established

Data Transfer

(Send Segments)

How They Operate



	Hub	Bridge	Switch	Router
Collision Domains:	1	4	4	4
Broadcast Domains:	1	1	1	4

TCP/IP MODEL

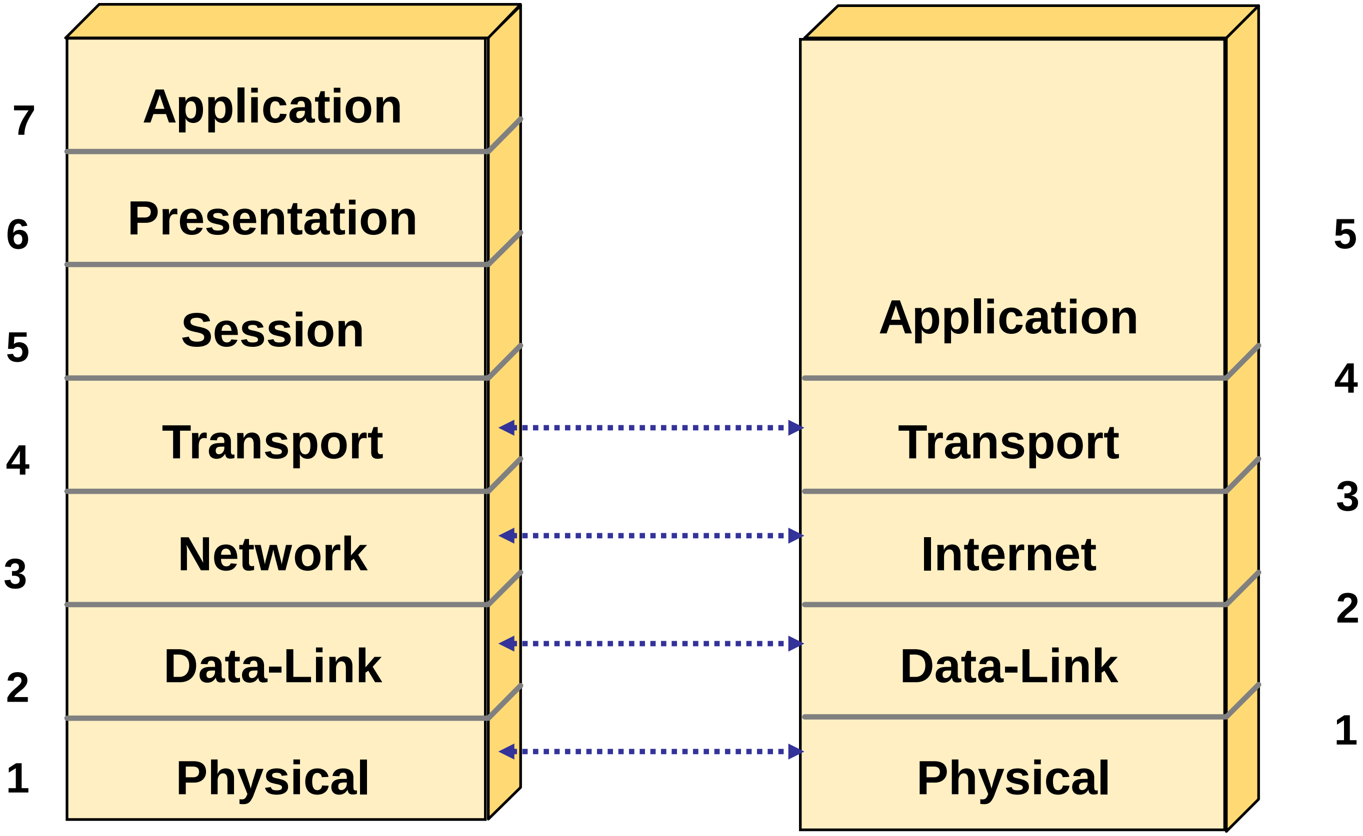
Why Another Model?

Although the OSI reference model is universally recognized, the historical and technical open standard of the Internet is Transmission Control Protocol / Internet Protocol (TCP/IP).

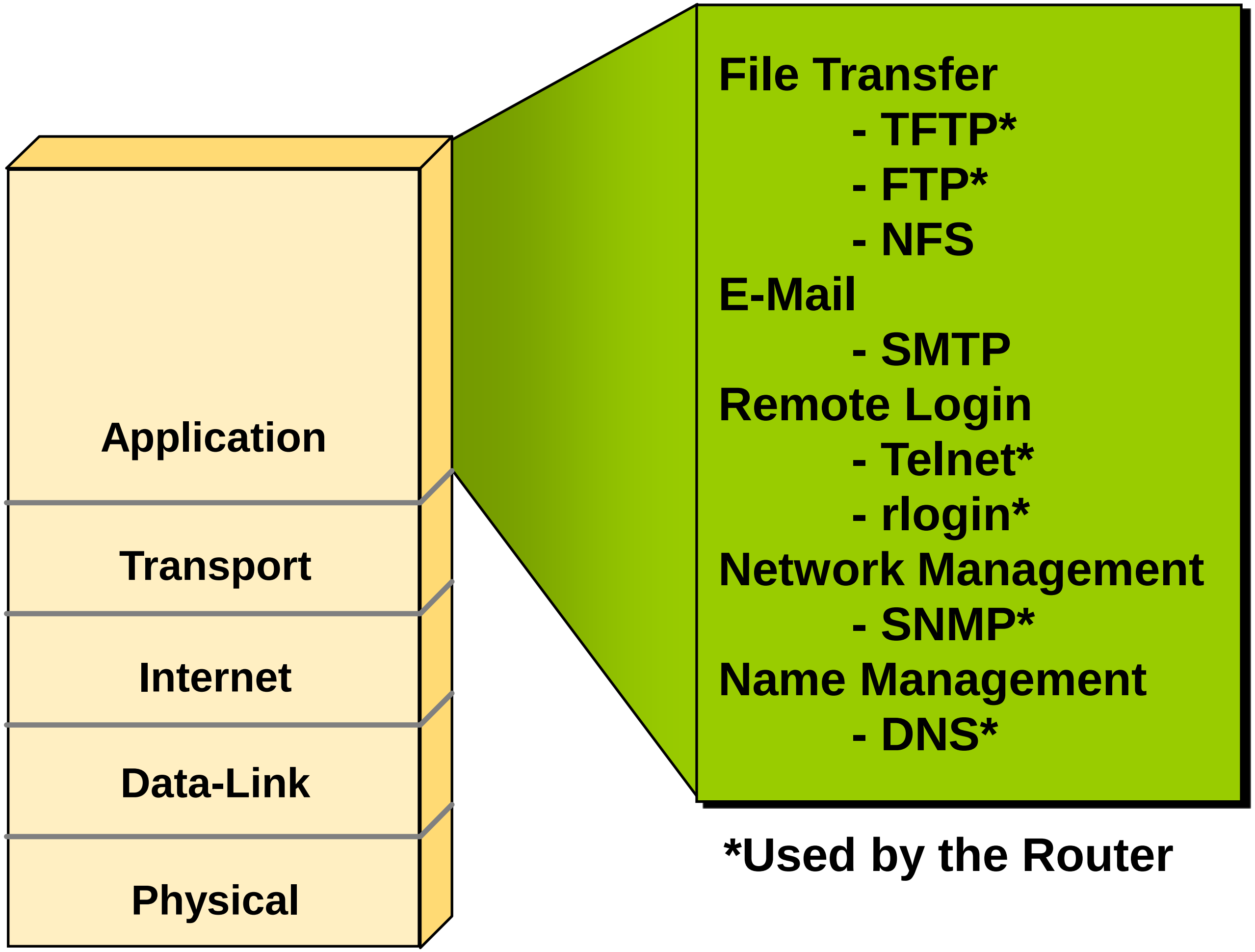
The TCP/IP reference model and the TCP/IP protocol stack make data communication possible between any two computers, anywhere in the world, at nearly the speed of light.

The U.S. Department of Defense (DoD) created the TCP/IP reference model because it wanted a network that could survive any conditions, even a nuclear war.

TCP/IP Protocol Stack



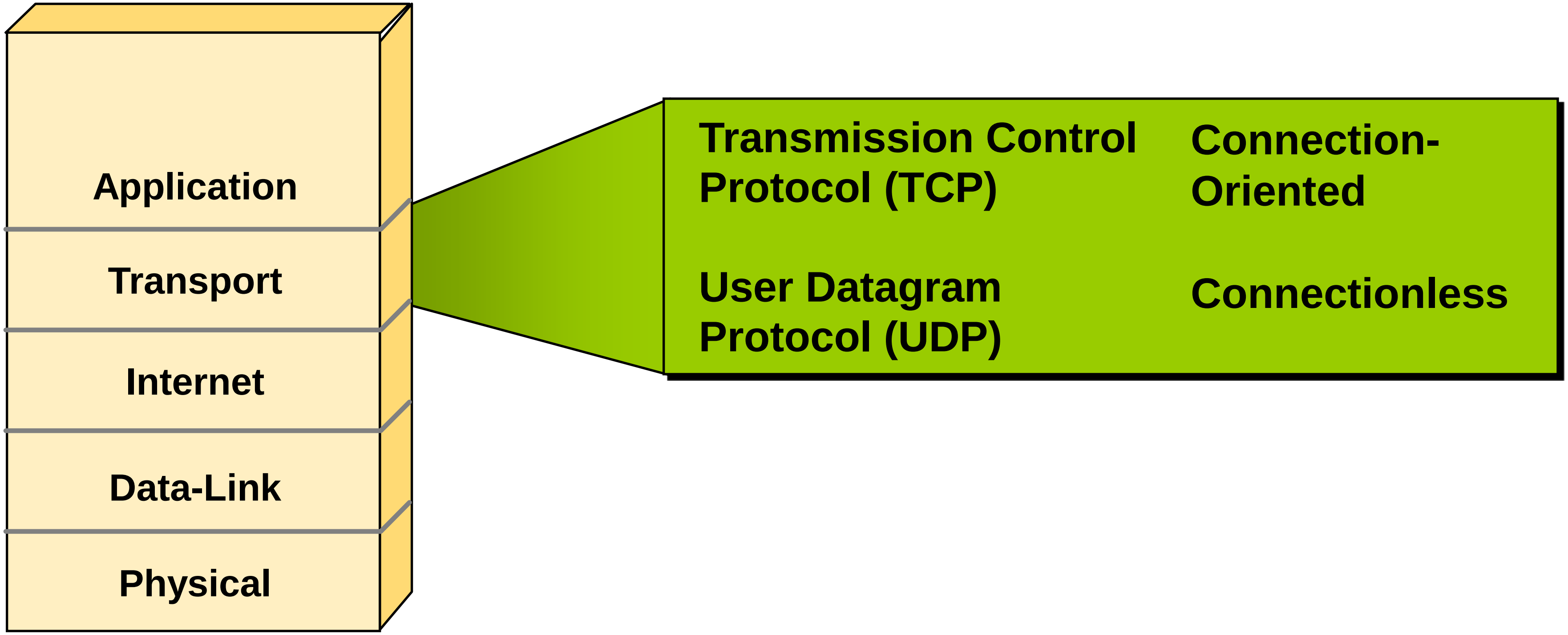
Application Layer Overview



- File Transfer
  - TFTP*
  - FTP*
  - NFS
- E-Mail
  - SMTP
- Remote Login
  - Telnet*
  - rlogin*
- Network Management
  - SNMP*
- Name Management
  - DNS*

*Used by the Router

Transport Layer Overview



Application

Transport

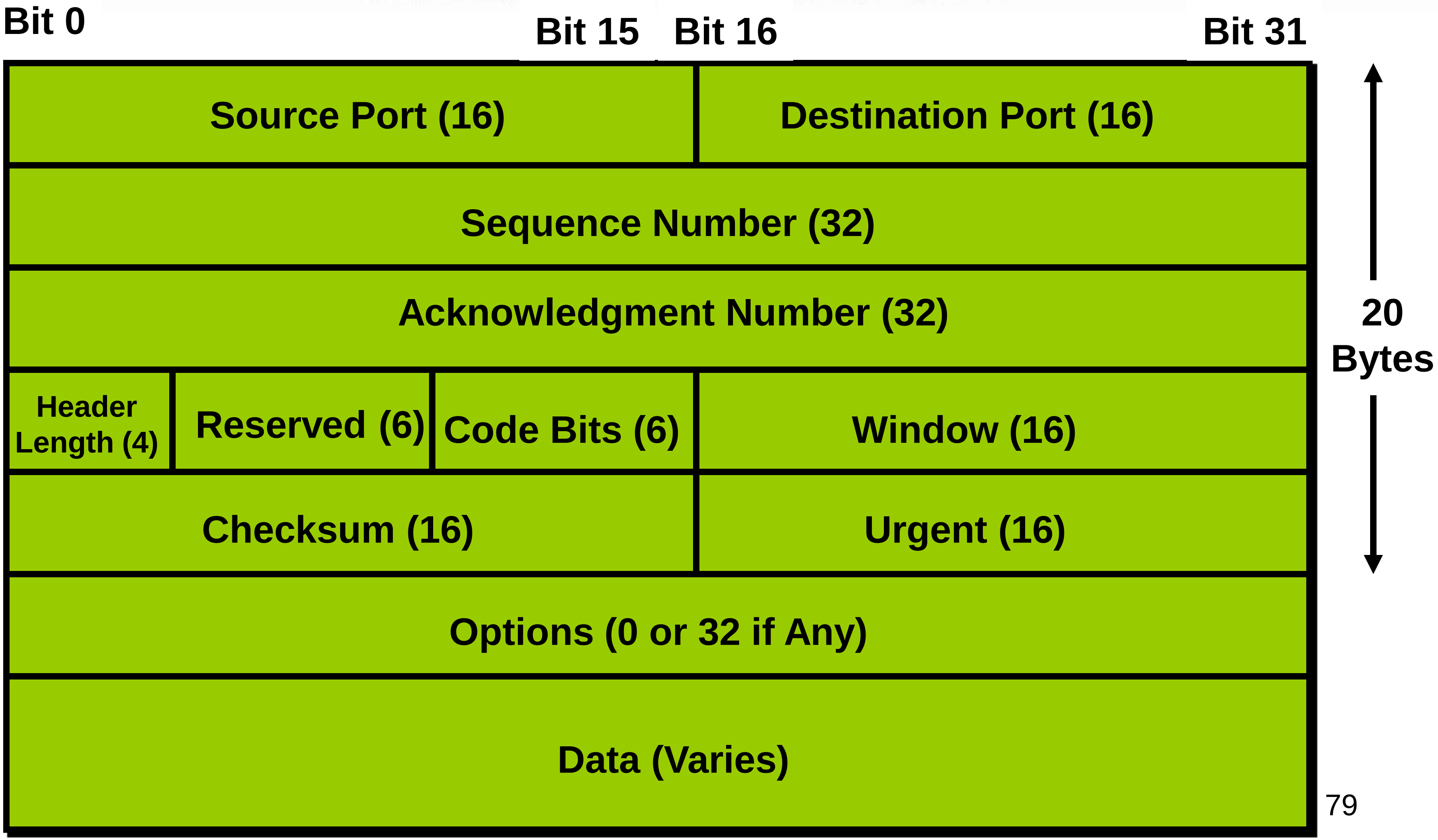
Internet

Data-Link

Physical

Transmission Control Protocol (TCP)	Connection-Oriented
User Datagram Protocol (UDP)	Connectionless

TCP Segment Format



Bit 0

Bit 15

Bit 16

Bit 31

Source Port (16)

Destination Port (16)

Sequence Number (32)

Acknowledgment Number (32)

Header Length (4)

Reserved (6)

Code Bits (6)

Window (16)

Checksum (16)

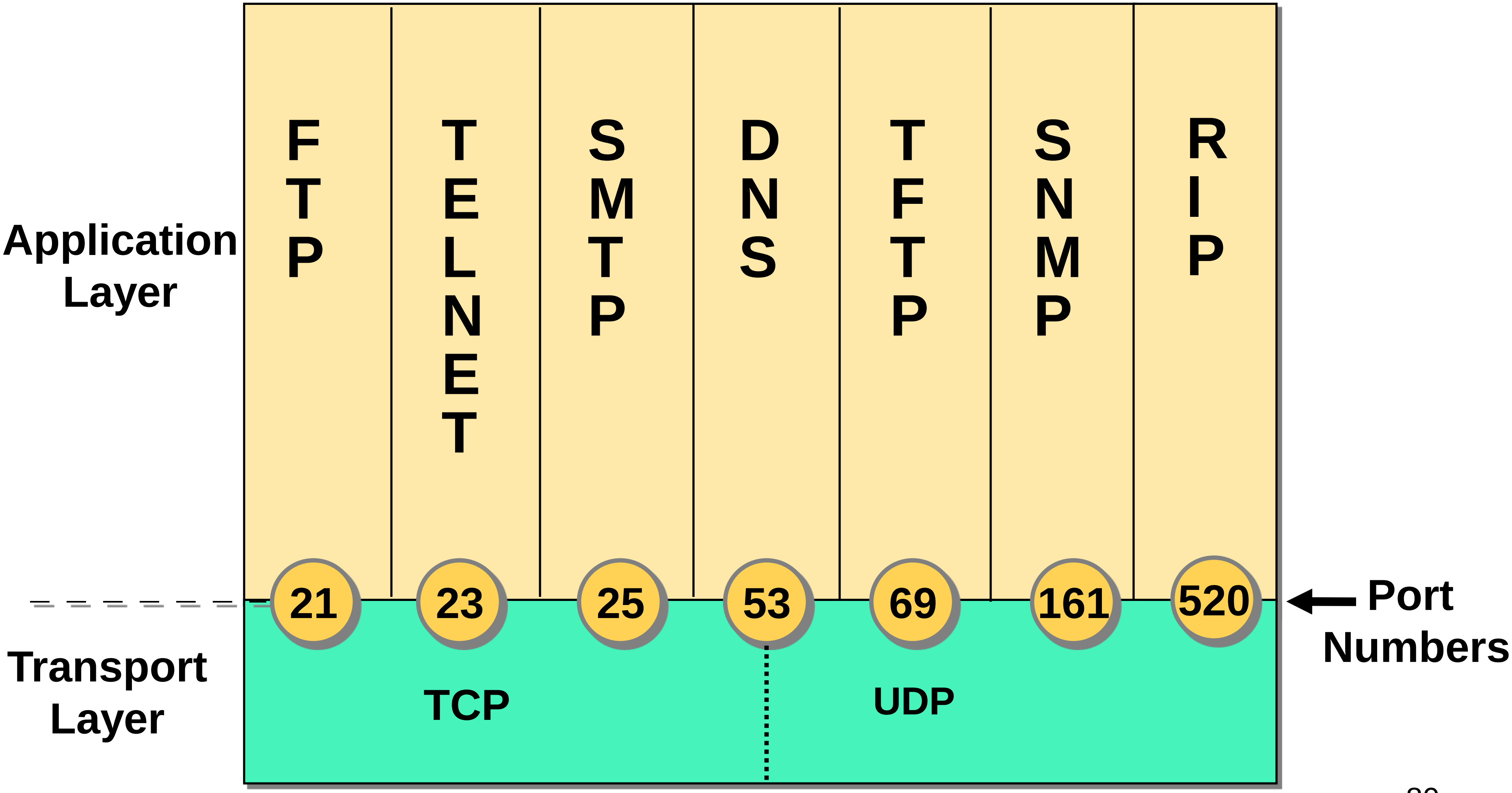
Urgent (16)

Options (0 or 32 if Any)

Data (Varies)

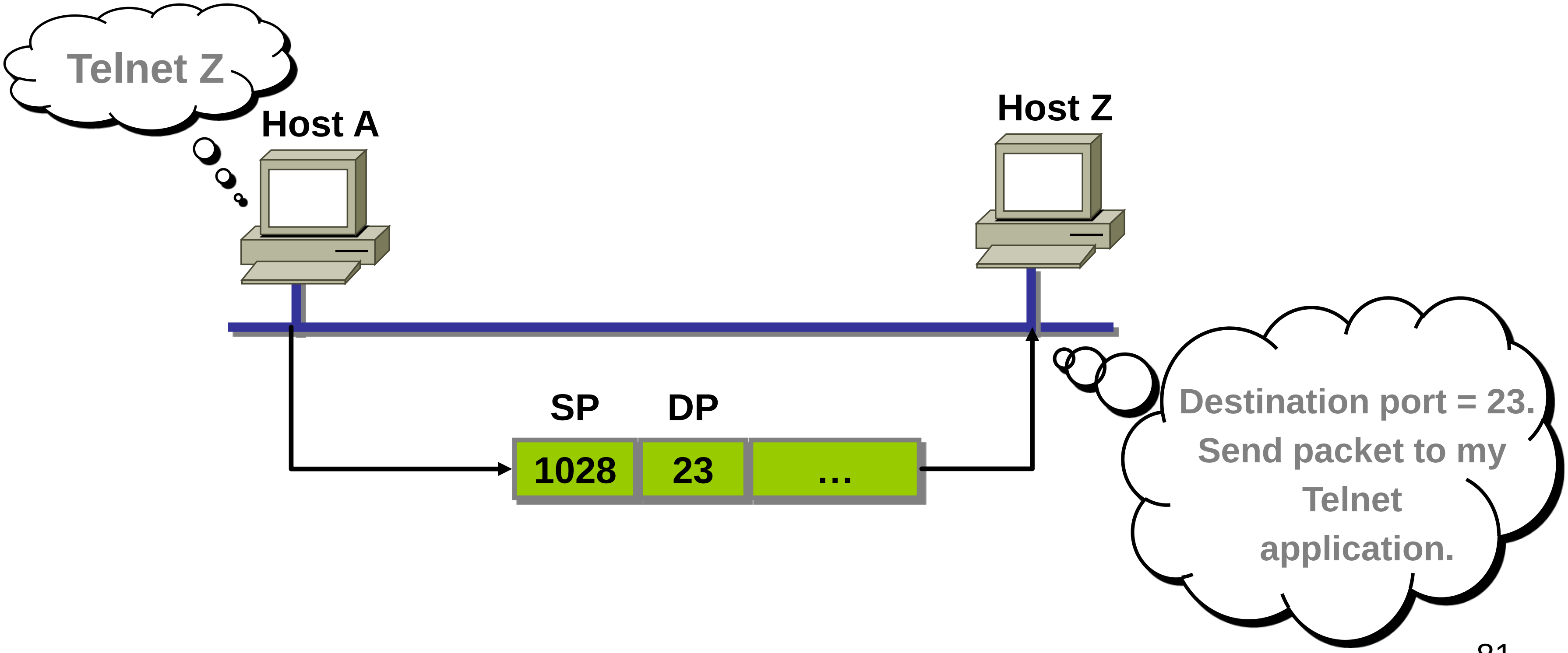
20 Bytes

Port Numbers



TCP Port Numbers

Source Port	Destination Port	…



Telnet Z

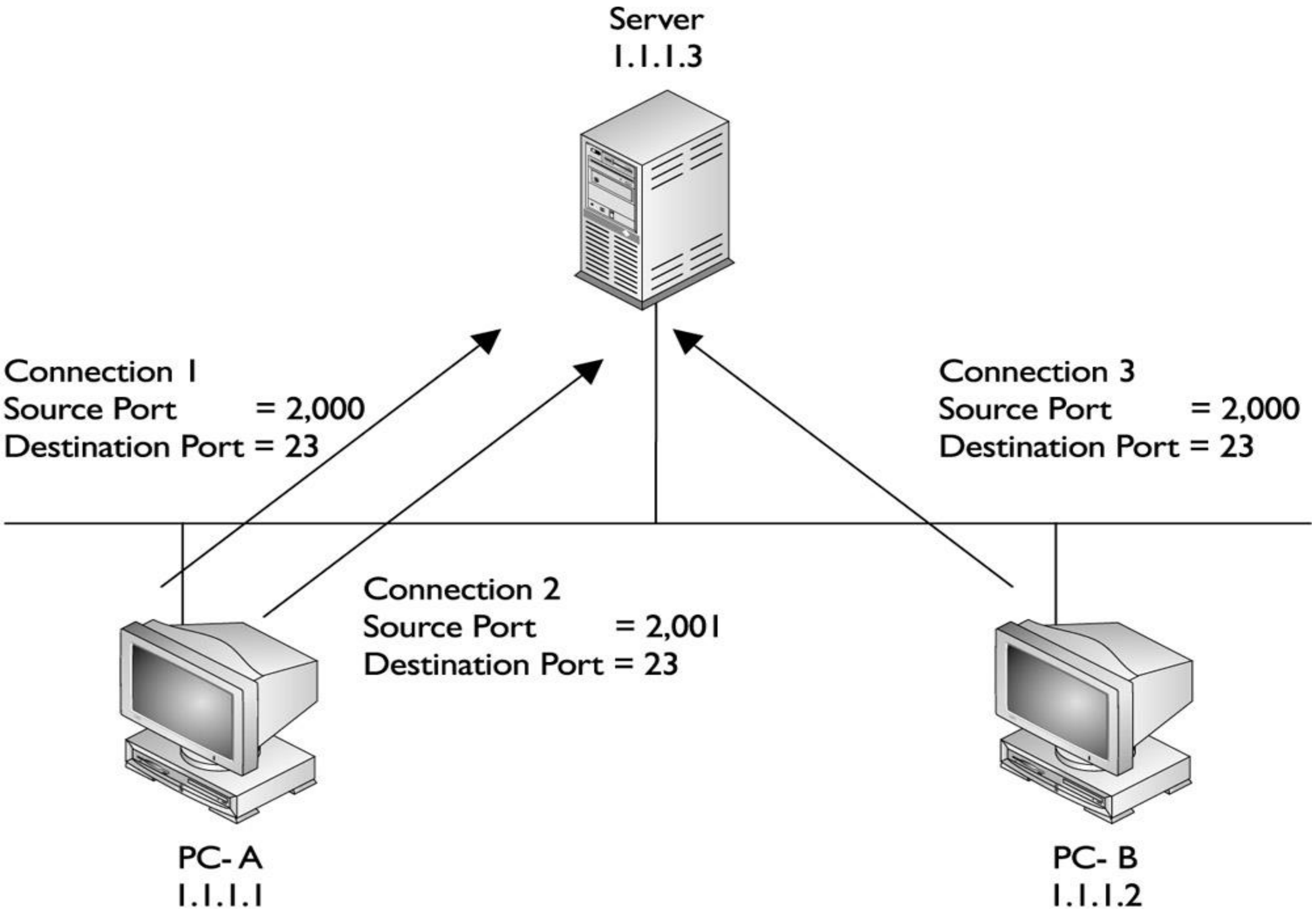
Host A

Host Z

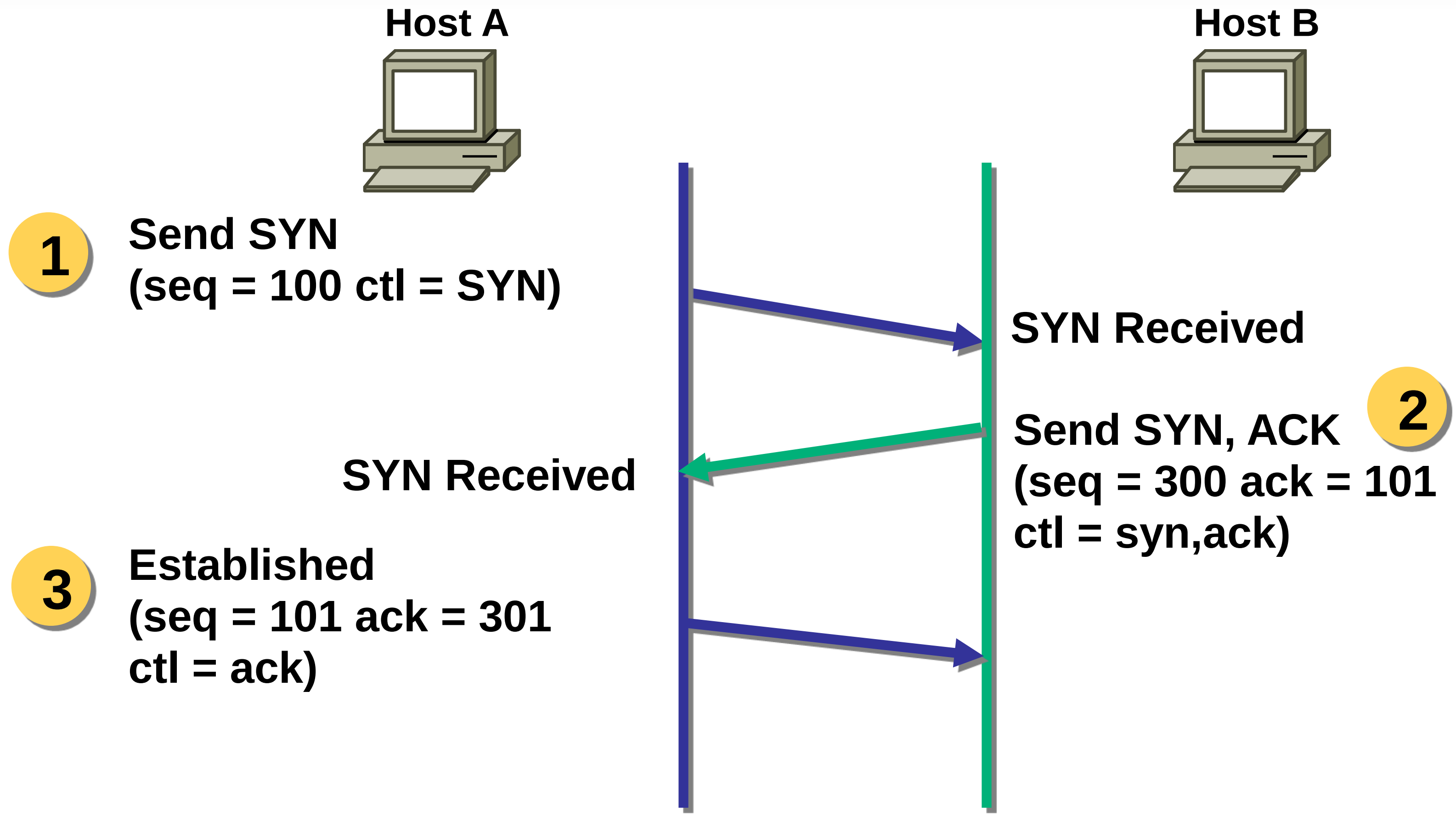
SP	DP	
1028	23	…

Destination port = 23. Send packet to my Telnet application.

TCP Port Numbers



TCP Three-Way Handshake/Open Connection



Host A

Host B

1 **Send SYN**
(seq = 100 ctl = SYN)

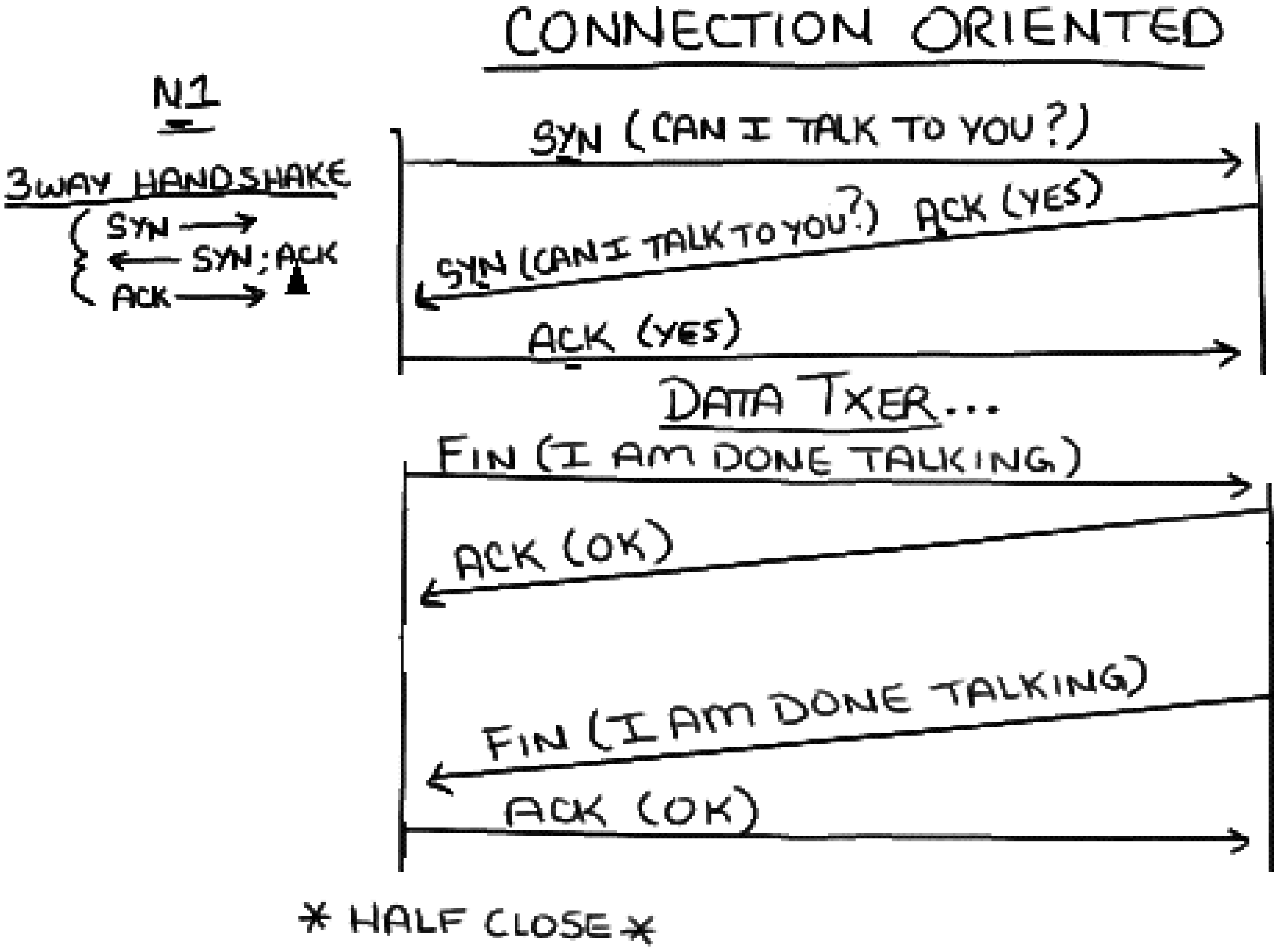
SYN Received

2 **Send SYN, ACK**
(seq = 300 ack = 101
ctl = syn,ack)

SYN Received

3 **Established**
(seq = 101 ack = 301
ctl = ack)

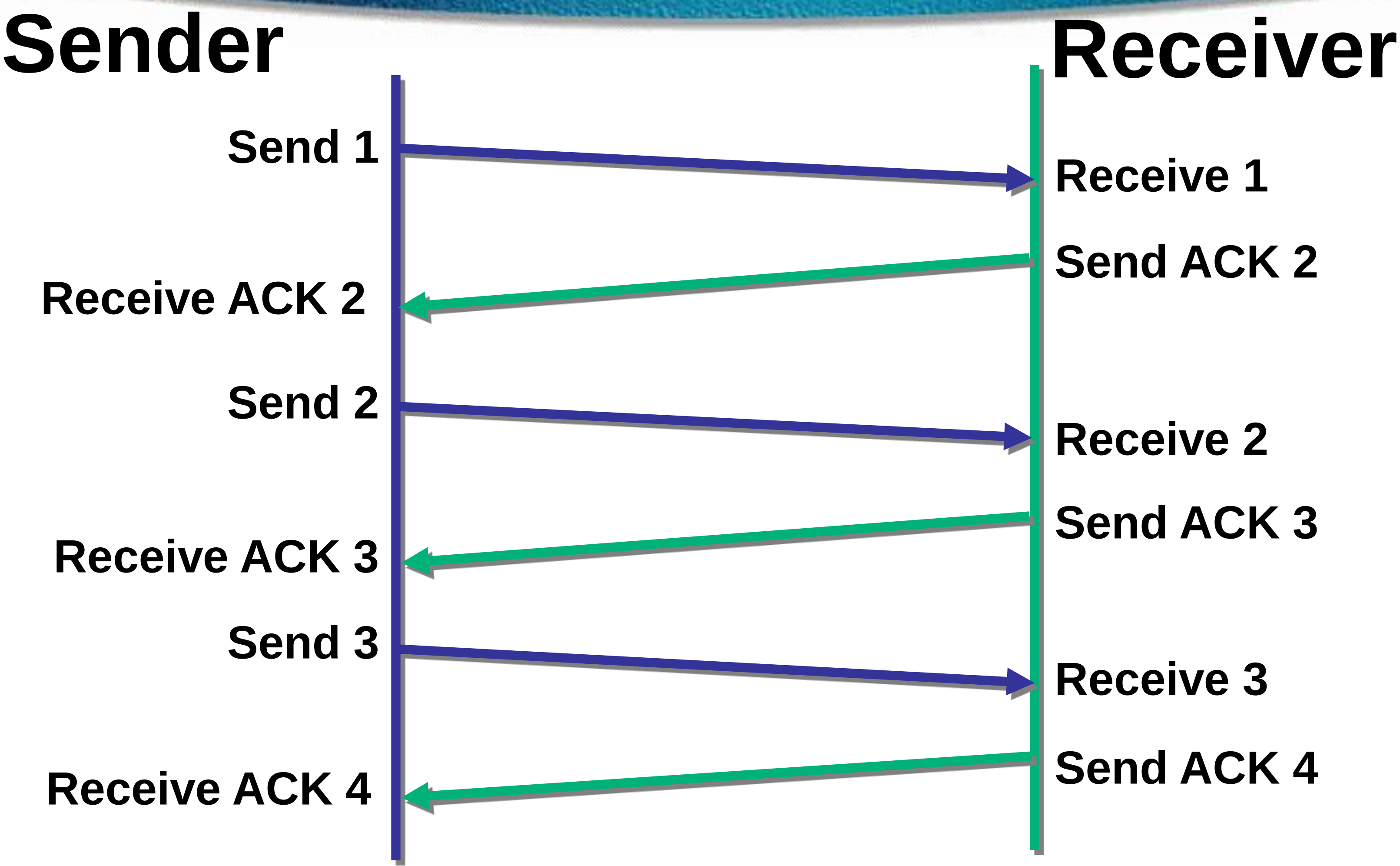
Opening & Closing Connection



Windowing

- Windowing in networking means the quantity of data segments which is measured in bytes that a machine can transmit/send on the network without receiving an acknowledgement

TCP Simple Acknowledgment



Sender

Receiver

Send 1

Receive 1

Send ACK 2

Receive ACK 2

Send 2

Receive 2

Send ACK 3

Receive ACK 3

Send 3

Receive 3

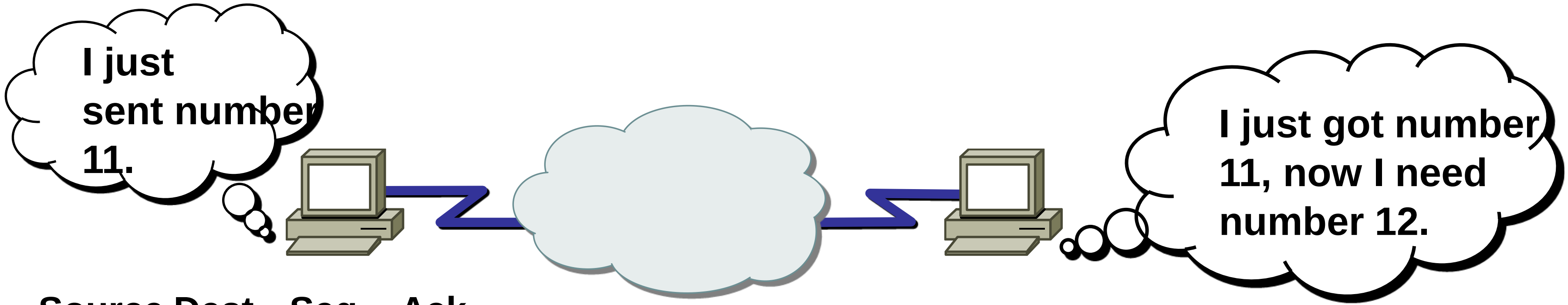
Send ACK 4

Receive ACK 4

- Window Size = 1

TCP Sequence and Acknowledgment Numbers

Source Port	Destination Port	Sequence	Acknowledgment	…



I just sent number 11.

I just got number 11, now I need number 12.

Source	Dest.	Seq.	Ack.
1028	23	10	100

→

Source	Dest.	Seq.	Ack.
23	1028	100	11

←

Source	Dest.	Seq.	Ack.
1028	23	11	101

→

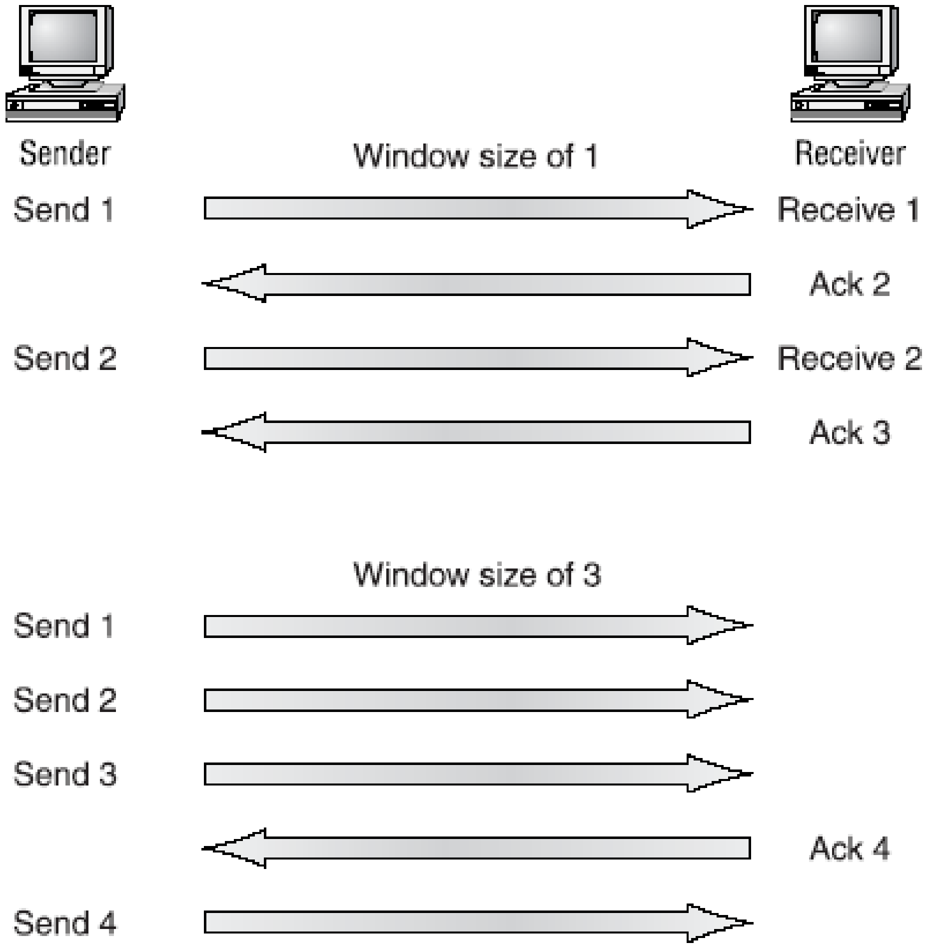
Source	Dest.	Seq.	Ack.
23	1028	101	12

←

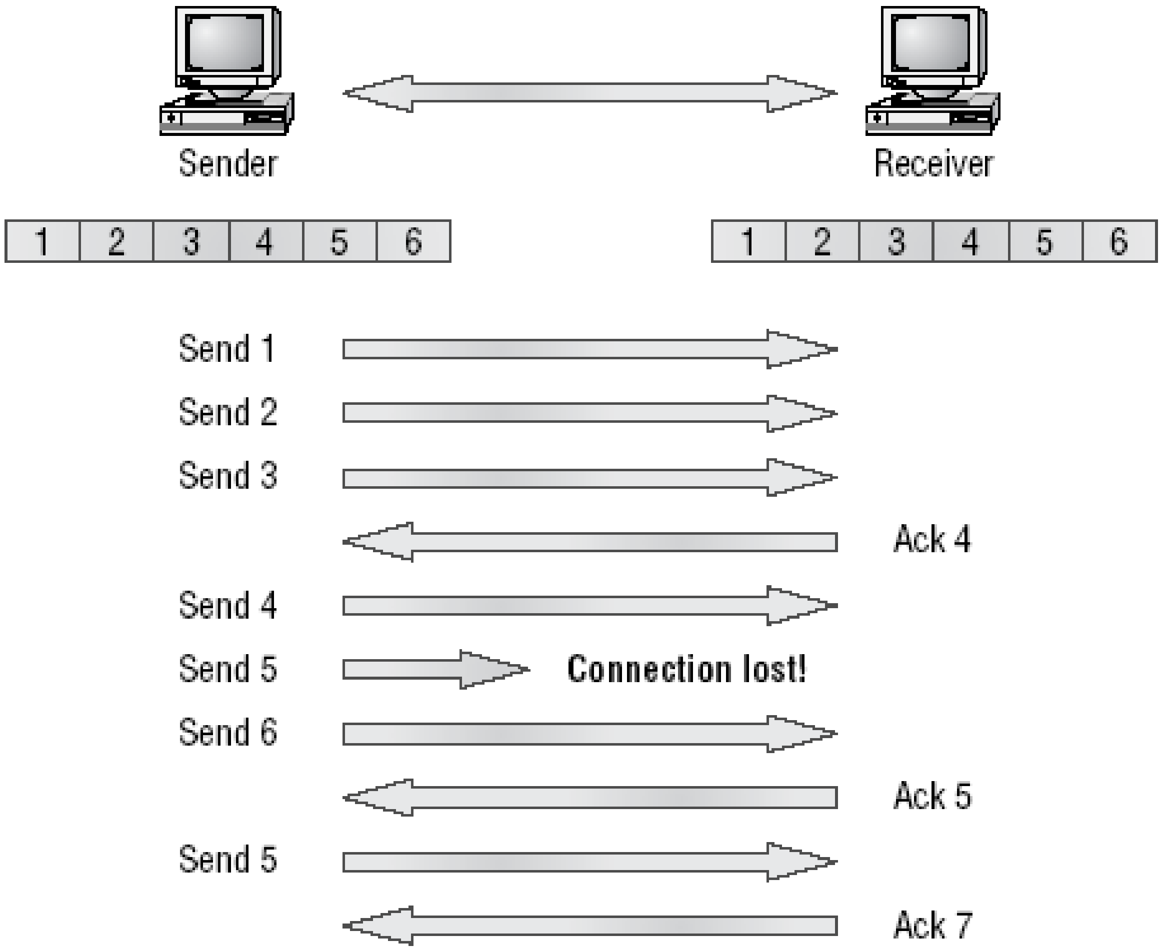
Windowing

- There are two window sizes—one set to 1 and one set to 3.
- When you've configured a window size of 1, the sending machine waits for an acknowledgment for each data segment it transmits before transmitting another
- If you've configured a window size of 3, it's allowed to transmit three data segments before an acknowledgment is received.

Windowing


Sender
Receiver
Window size of 1
Send 1
Receive 1
Ack 2
Send 2
Receive 2
Ack 3
Window size of 3
Send 1
Send 2
Send 3
Ack 4
Send 4

Transport Layer Reliable Delivery



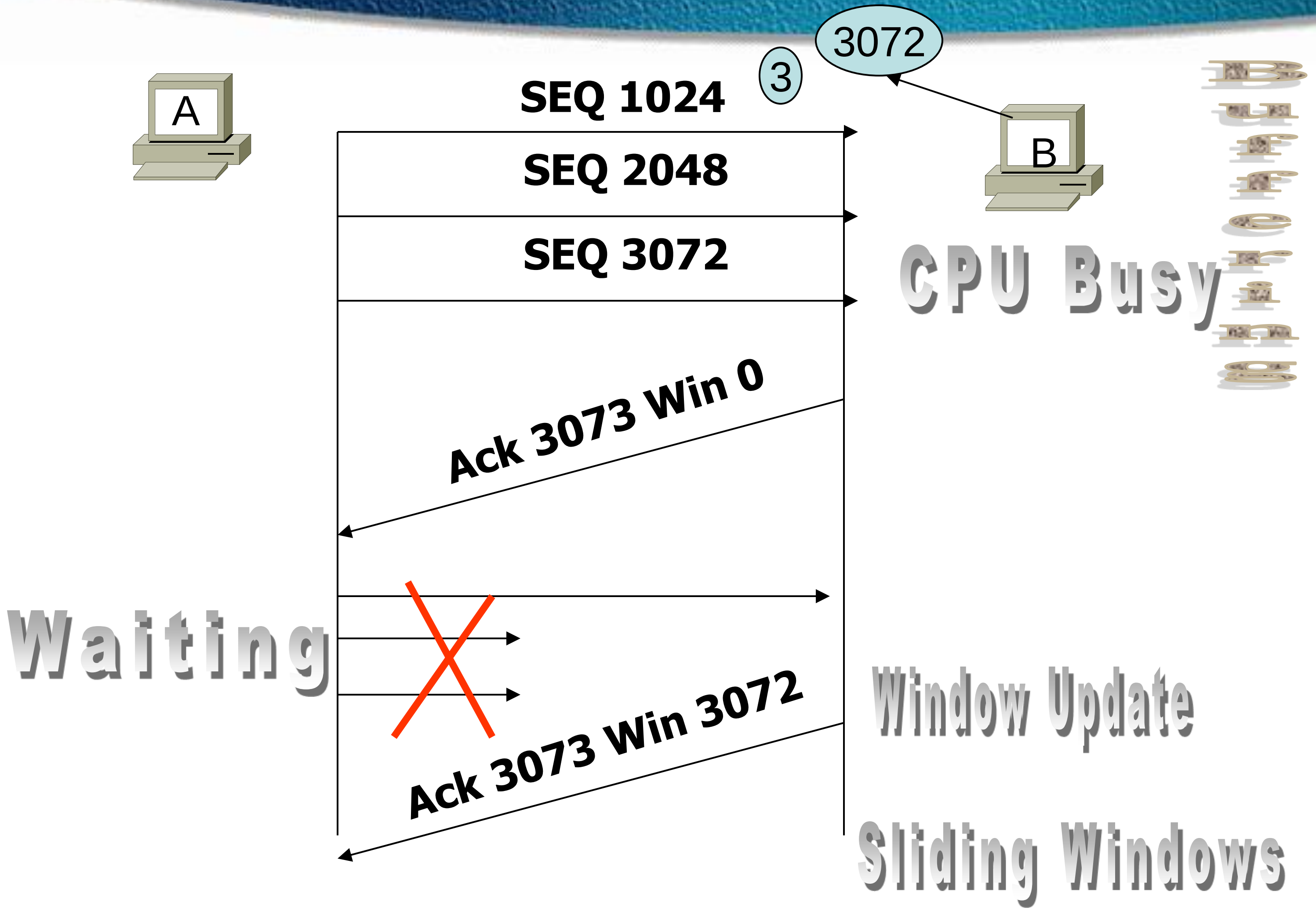
Flow Control

- Another function of the transport layer is to provide optional flow control.

- Flow control is used to ensure that networking devices don’t send too much information to the destination, overflowing its receiving buffer space, and causing it to drop the sent information

- The purpose of flow control is to ensure the destination doesn't get overrun by too much information sent by the source

Flow Control



A

B

3072

3

SEQ 1024

SEQ 2048

SEQ 3072

CPU Busy

Buffering

Ack 3073 Win 0

Waiting

Window Update

Ack 3073 Win 3072

Sliding Windows

User Datagram Protocol (UDP)

User Datagram Protocol (UDP) is the connectionless transport protocol in the TCP/IP protocol stack.

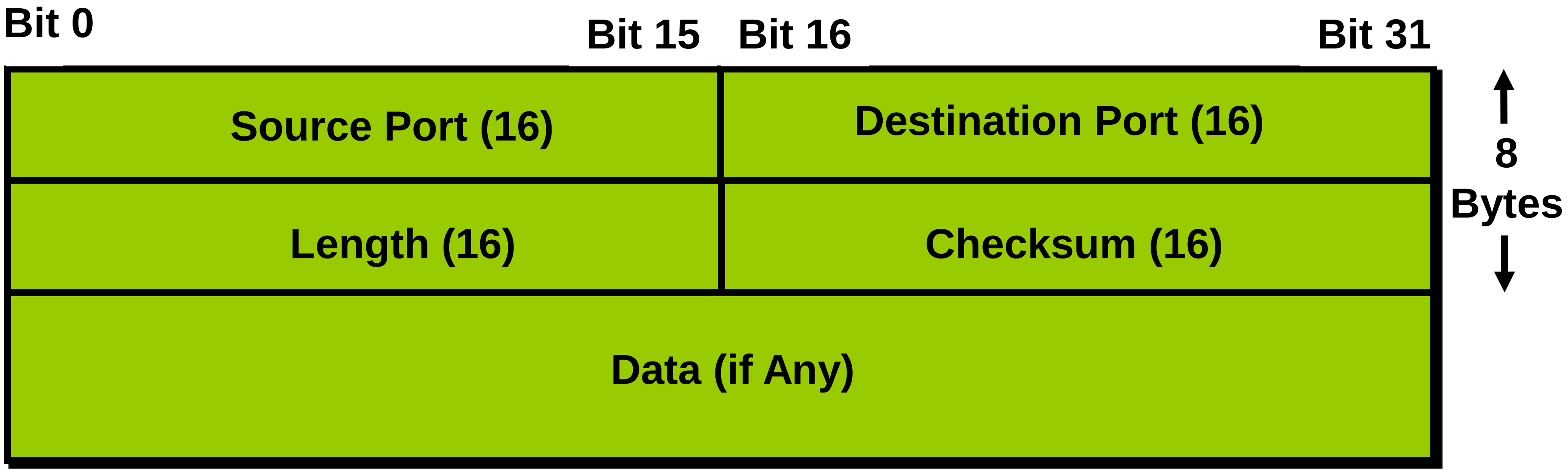
UDP is a simple protocol that exchanges datagrams, without acknowledgments or guaranteed delivery. Error processing and retransmission must be handled by higher layer protocols.

UDP is designed for applications that do not need to put sequences of segments together.

The protocols that use UDP include:

- TFTP (Trivial File Transfer Protocol)
- SNMP (Simple Network Management Protocol)
- DHCP (Dynamic Host Control Protocol)
- DNS (Domain Name System)

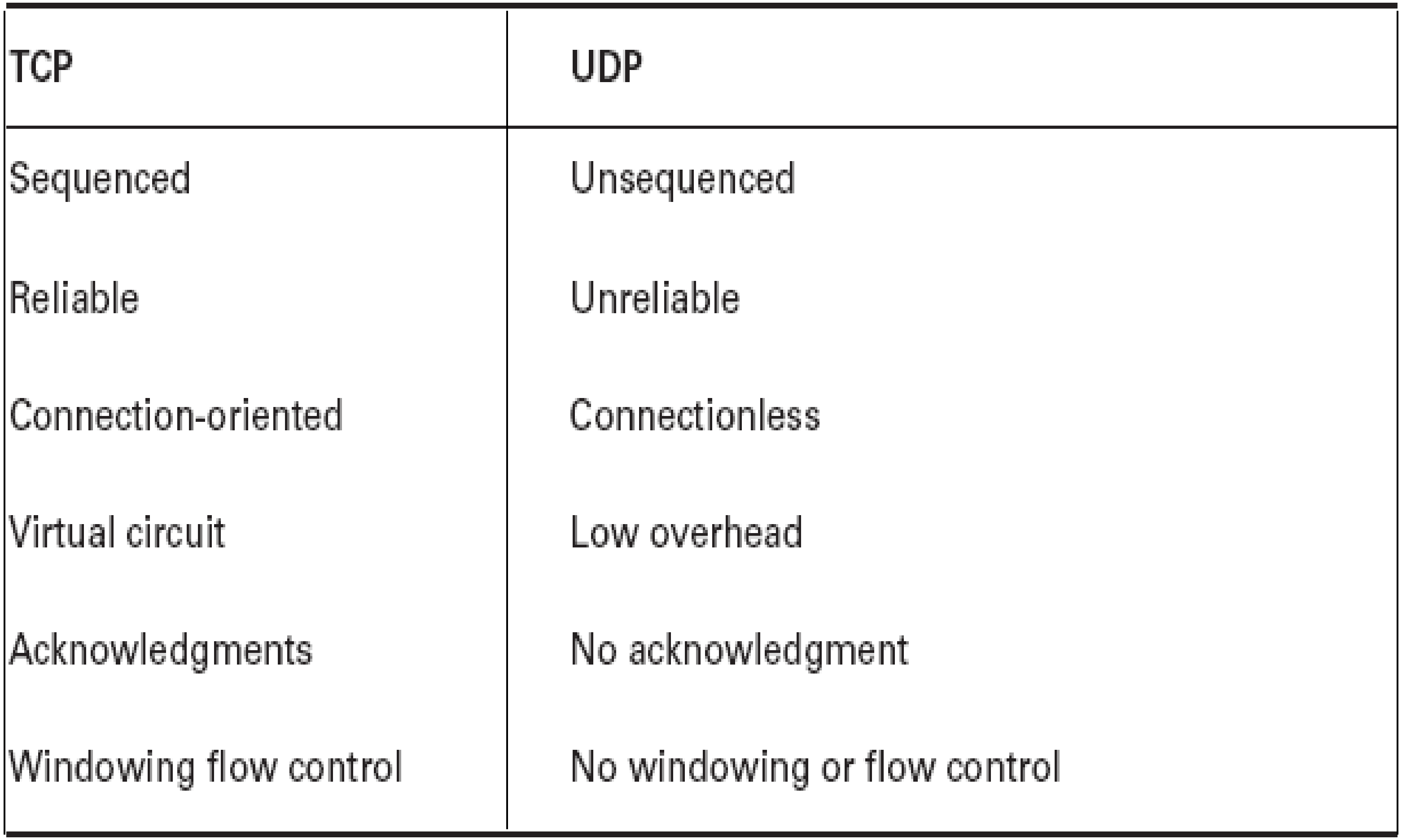
UDP Segment Format



Source Port (16)	Destination Port (16)
Length (16)	Checksum (16)
Data (if Any)	

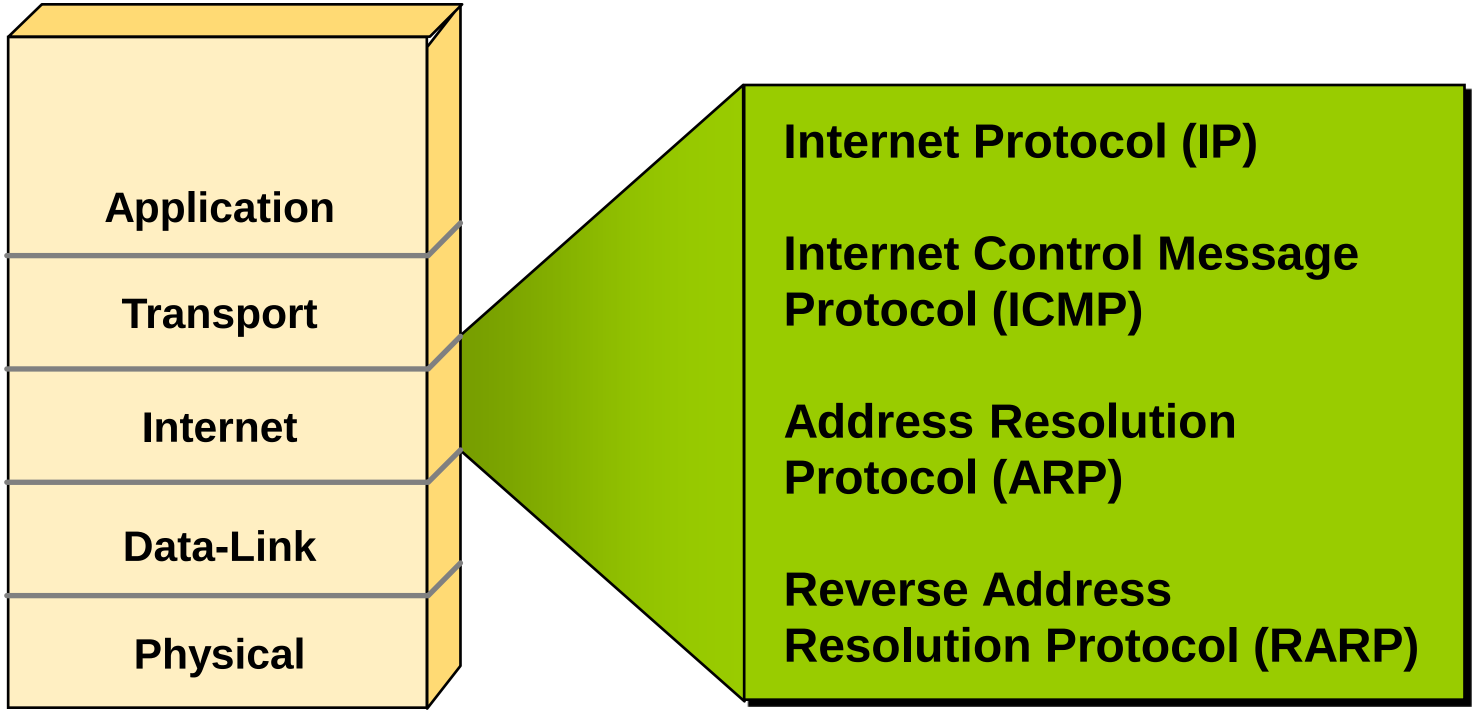
- No sequence or acknowledgment fields

TCP vs UDP



TCP	UDP
Sequenced	Unsequenced
Reliable	Unreliable
Connection-oriented	Connectionless
Virtual circuit	Low overhead
Acknowledgments	No acknowledgment
Windowing flow control	No windowing or flow control

Internet Layer Overview



Application

Transport

Internet

Data-Link

Physical

Internet Protocol (IP)

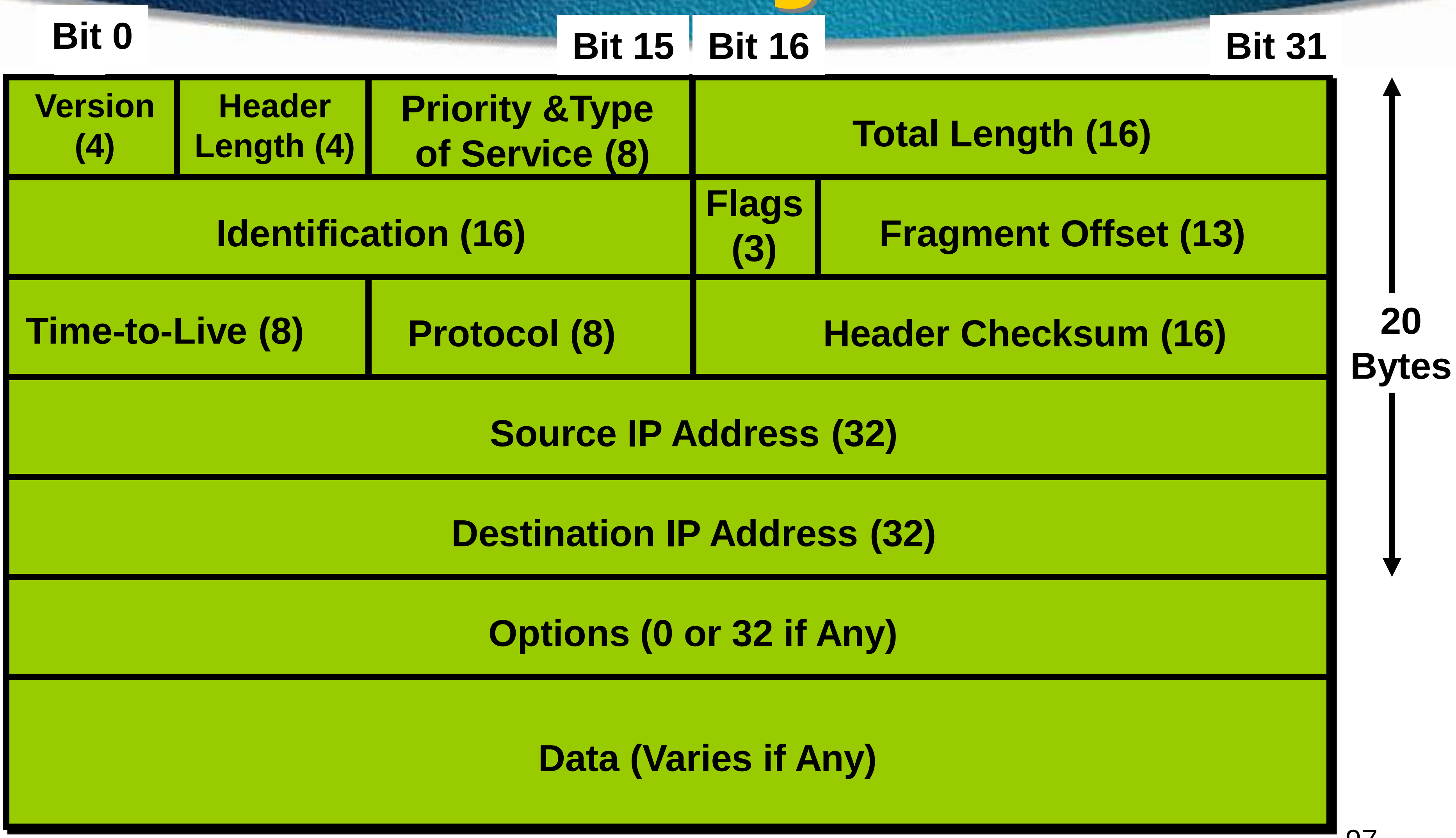
Internet Control Message Protocol (ICMP)

Address Resolution Protocol (ARP)

Reverse Address Resolution Protocol (RARP)

- In the OSI reference model, the network layer corresponds to the TCP/IP Internet layer.

IP Datagram



Bit 0

Bit 15

Bit 16

Bit 31

Version (4)

Header Length (4)

Priority &Type of Service (8)

Total Length (16)

Identification (16)

Flags (3)

Fragment Offset (13)

Time-to-Live (8)

Protocol (8)

Header Checksum (16)

Source IP Address (32)

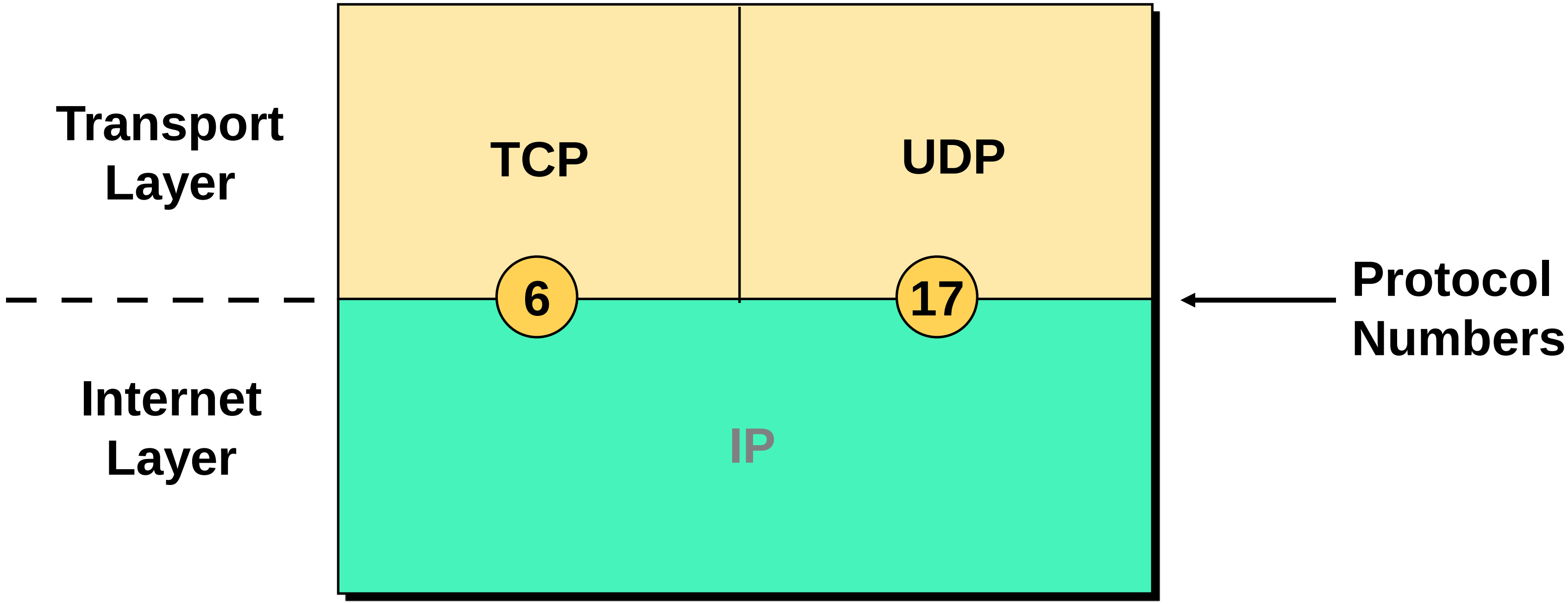
Destination IP Address (32)

Options (0 or 32 if Any)

Data (Varies if Any)

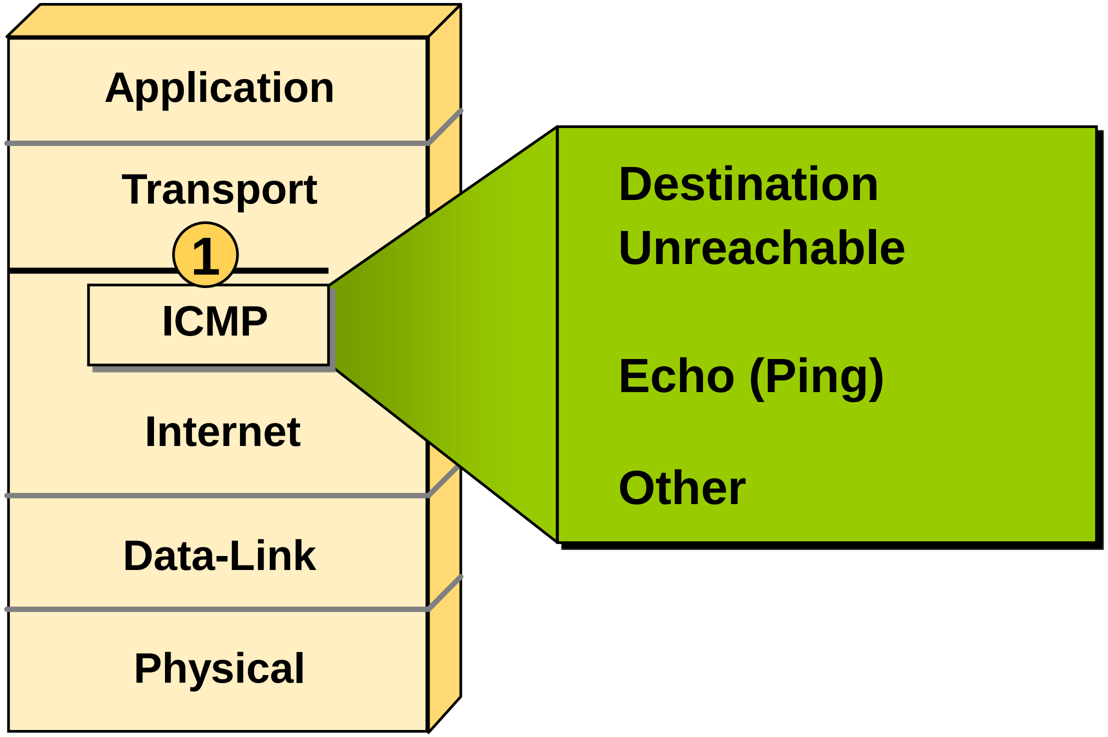
20 Bytes

Protocol Field



- Determines destination upper-layer protocol

Internet Control Message Protocol

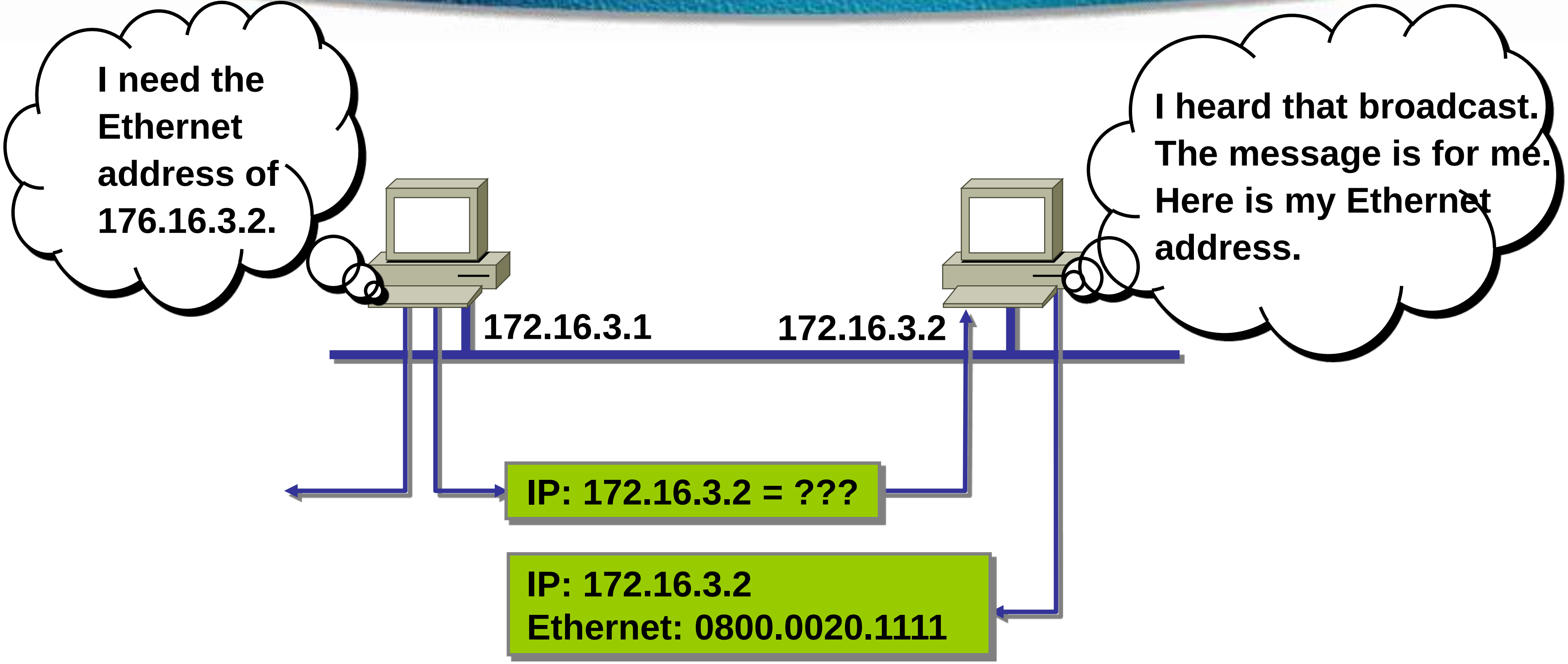


Destination Unreachable

Echo (Ping)

Other

Address Resolution Protocol



I need the Ethernet address of 176.16.3.2.

I heard that broadcast. The message is for me. Here is my Ethernet address.

172.16.3.1

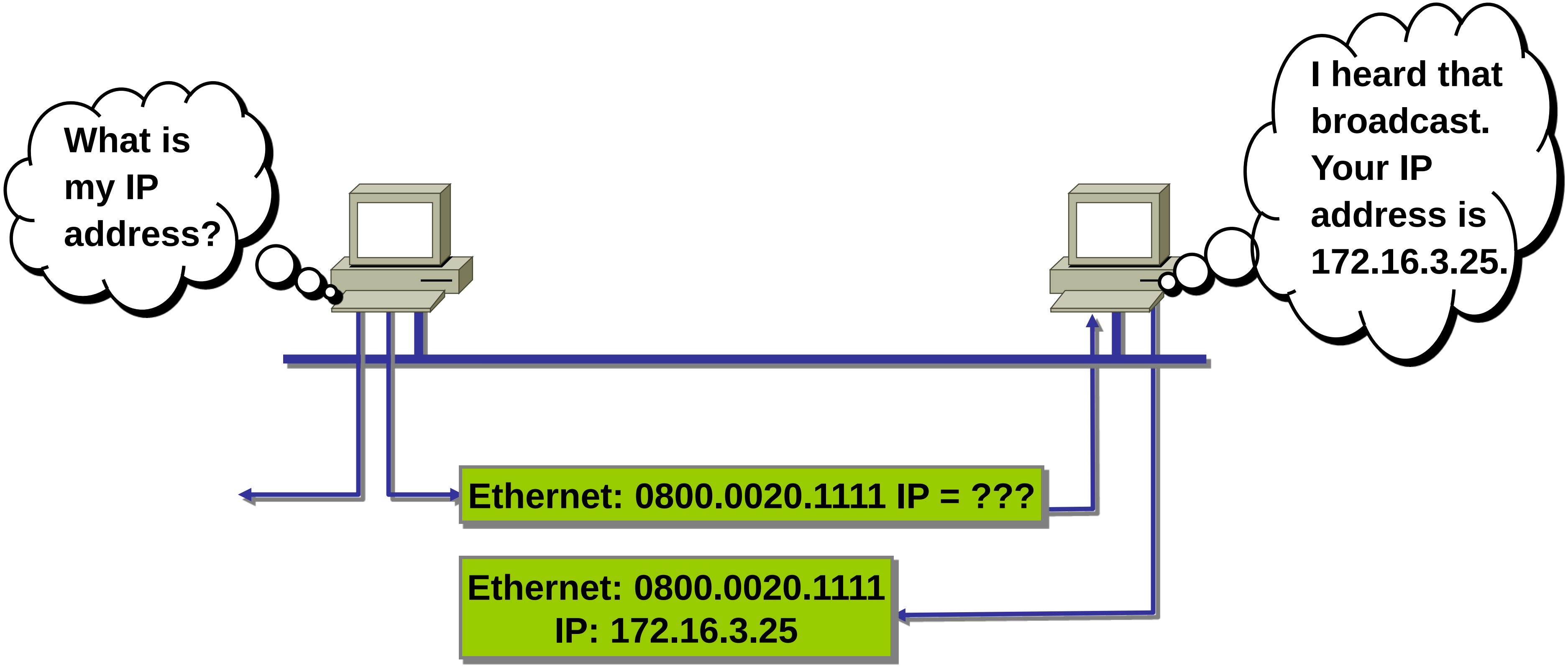
172.16.3.2

IP: 172.16.3.2 = ???

IP: 172.16.3.2
Ethernet: 0800.0020.1111

- Map IP → MAC
- Local ARP

Reverse ARP



- Map MAC → IP

The Networking Media

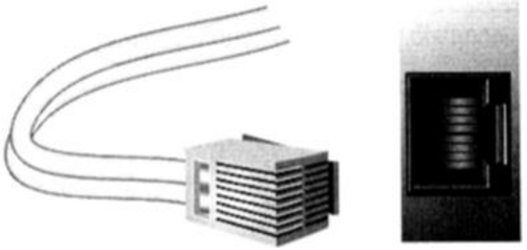
Origin of Ethernet

- ❑Found by Xerox Palo Alto Research Center (PARC) in 1975
- ❑Original designed as a 2.94 Mbps system to connect 100 computers on a 1 km cable
- ❑Later, Xerox, Intel and DEC drew up a standard support 10 Mbps – Ethernet II
- ❑Basis for the IEEE's 802.3 specification
- ❑Most widely used LAN technology in the world

10 Mbps IEEE Standards - 10BaseT

- 10BaseT ⇒ 10 Mbps, baseband, over Twisted-pair cable
- Running Ethernet over twisted-pair wiring as specified by IEEE 802.3
- Configure in a star pattern
- Twisting the wires reduces EMI
- Fiber Optic has no EMI

Unshielded twisted-pair



RJ-45 Plug and Socket

Twisted Pair Cables

- Unshielded Twisted Pair Cable (UTP)
    - most popular
    - maximum length 100 m
    - prone to noise

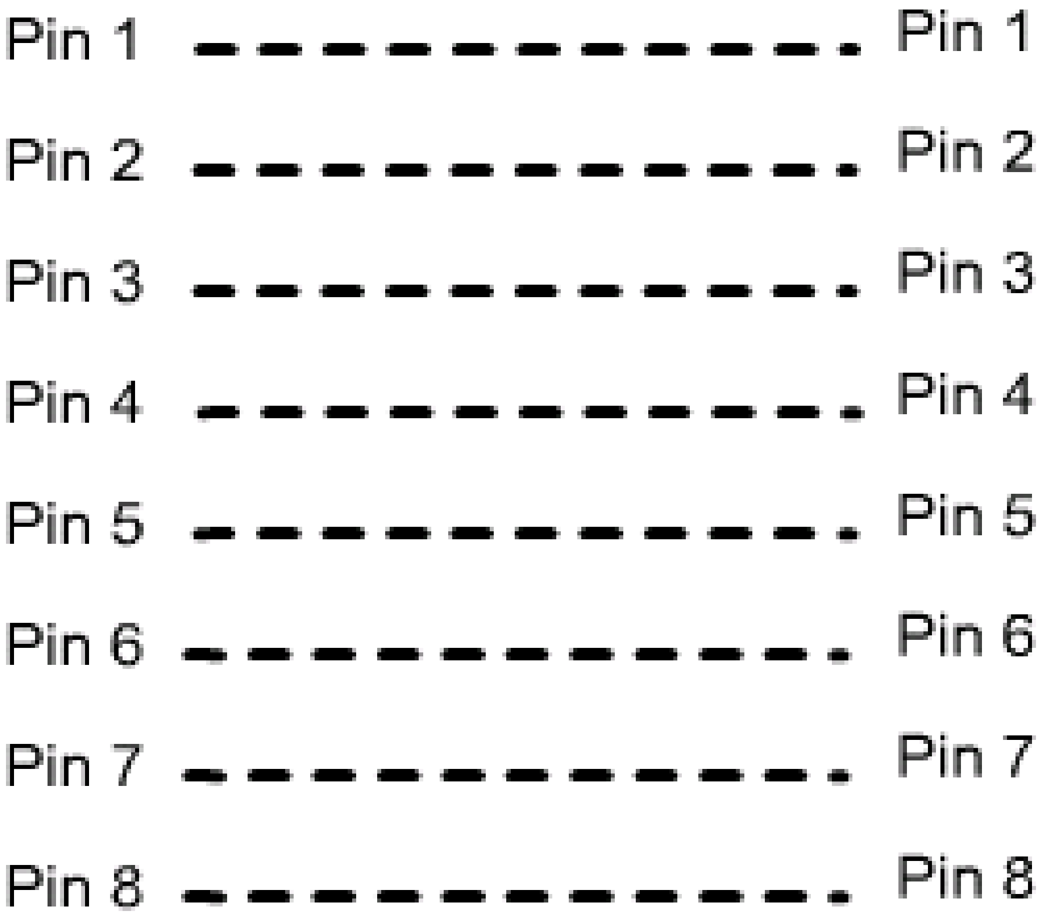
Category 1	Voice transmission of traditional telephone
Category 2	For data up to 4 Mbps, 4 pairs full-duplex
Category 3	For data up to 10 Mbps, 4 pairs full-duplex
Category 4	For data up to 16 Mbps, 4 pairs full-duplex
Category 5	For data up to 100 Mbps, 4 pairs full-duplex
Category 6	For data up to 1000 Mbps, 4 pairs full-duplex

Baseband VS Broadband

- Baseband Transmission
  - Entire channel is used to transmit a single digital signal
  - Complete bandwidth of the cable is used by a single signal
  - The transmission distance is shorter
  - The electrical interference is lower
- Broadband Transmission
  - Use analog signaling and a range of frequencies
  - Continuous signals flow in the form of waves
  - Support multiple analog transmission (channels)

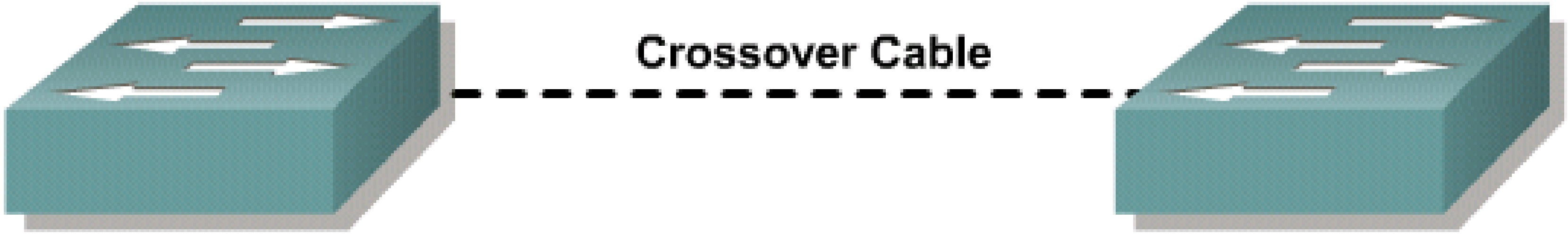
Straight-through cable

Straight-through cable pinout

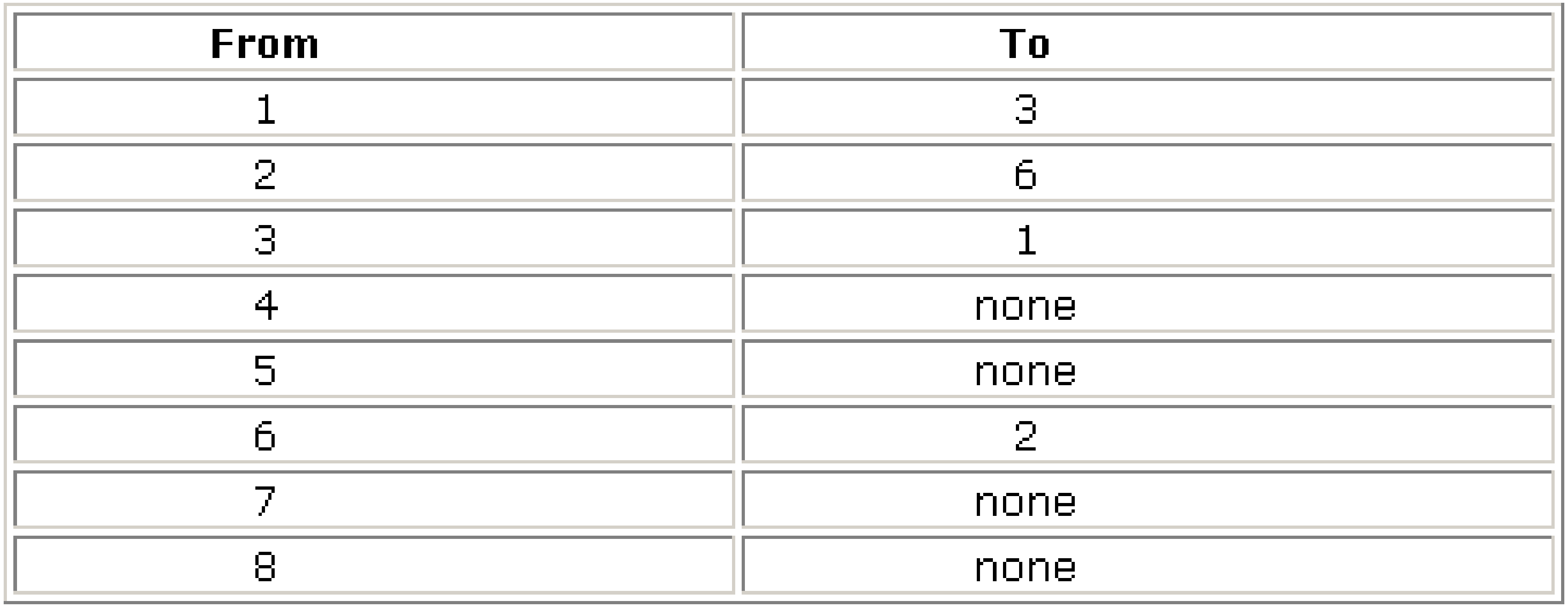


Pin 1	Pin 1
Pin 2	Pin 2
Pin 3	Pin 3
Pin 4	Pin 4
Pin 5	Pin 5
Pin 6	Pin 6
Pin 7	Pin 7
Pin 8	Pin 8

Crossover cable

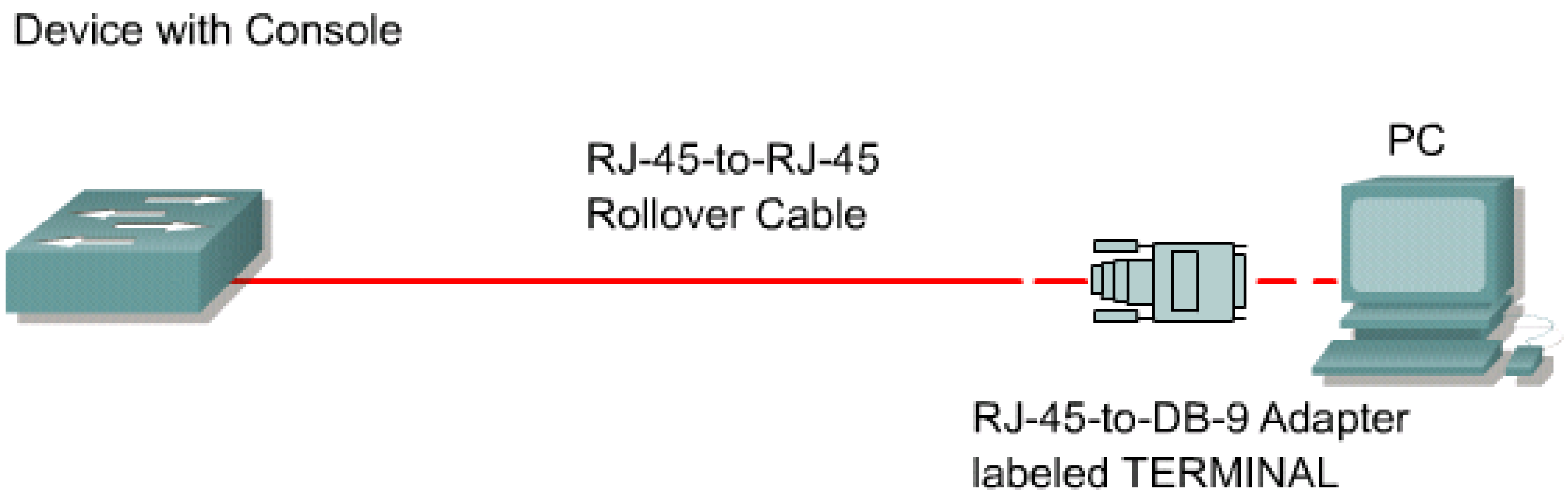


Crossover cable



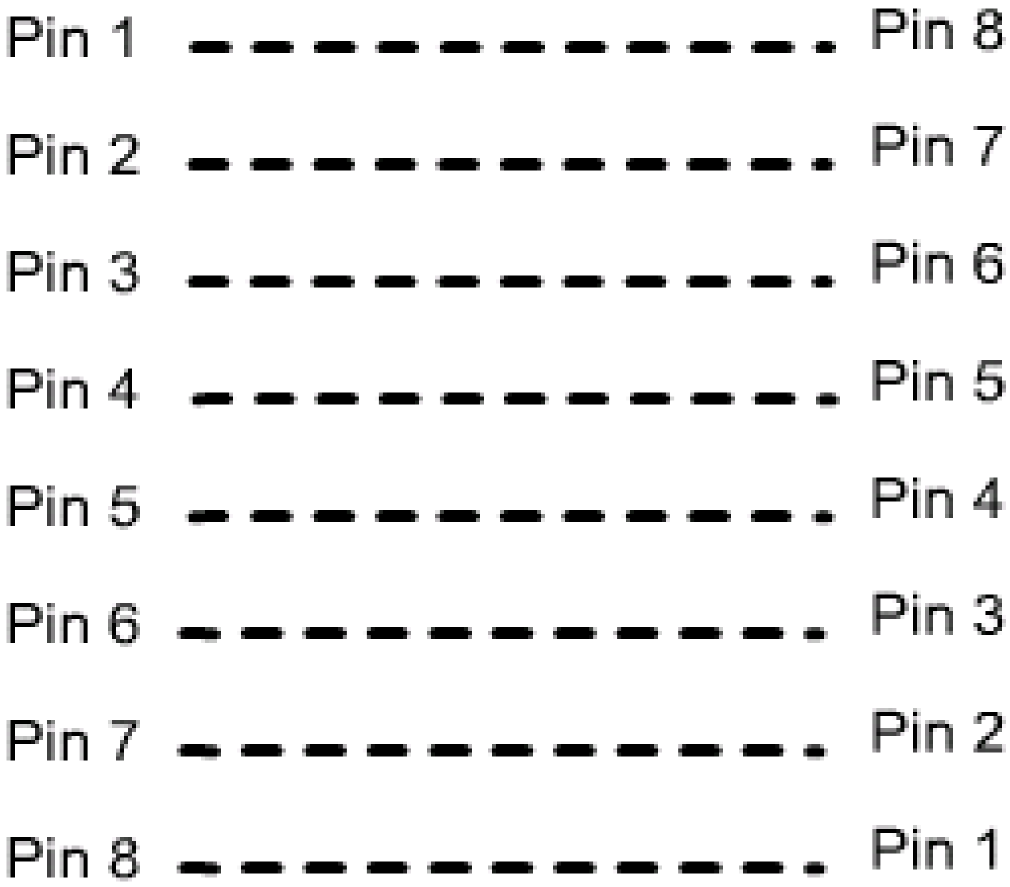
From	To
1	3
2	6
3	1
4	none
5	none
6	2
7	none
8	none

Rollover cable



- PCs require an RJ-45 to DB-9 or RJ-45 to DB-25 adapter.
- COM port settings are 9600 bps, 8 data bits, no parity, 1 stop bit, no flow control.
- This provides out-of-band console access.
- AUX switch port may be used for a modem-connected console.

Rollover cable pinout



Pin 1	Pin 8
Pin 2	Pin 7
Pin 3	Pin 6
Pin 4	Pin 5
Pin 5	Pin 4
Pin 6	Pin 3
Pin 7	Pin 2
Pin 8	Pin 1

Straight-Thru or Crossover

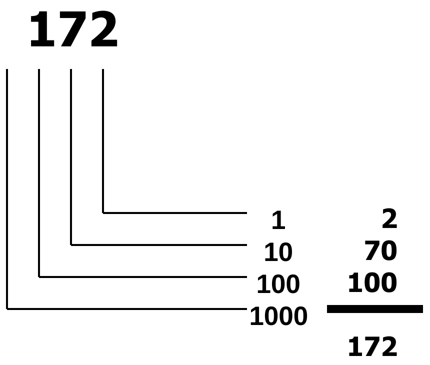
- Use straight-through cables for the following cabling:
  - Switch to router
  - Switch to PC or server
  - Hub to PC or server

- Use crossover cables for the following cabling:
  - Switch to switch
  - Switch to hub
  - Hub to hub
  - Router to router
  - PC to PC
  - Router to PC

TCP/IP Math

Decimal to Binary

172 – Base 10

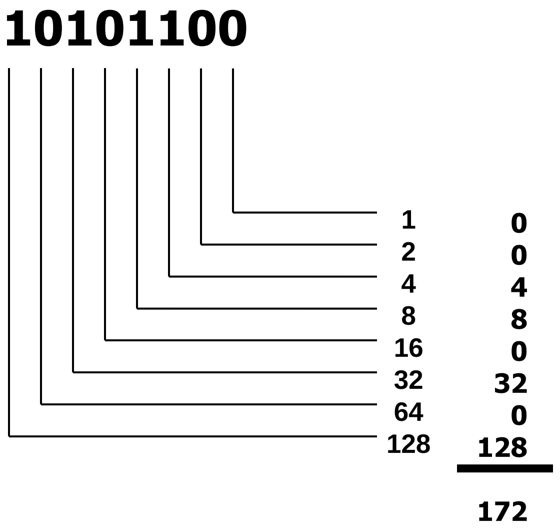


172

1	2
10	70
100	100
1000	
	172

$10^0 = 1$
$10^1 = 10$
$10^2 = 100$
$10^3 = 1000$

10101100– Base 2



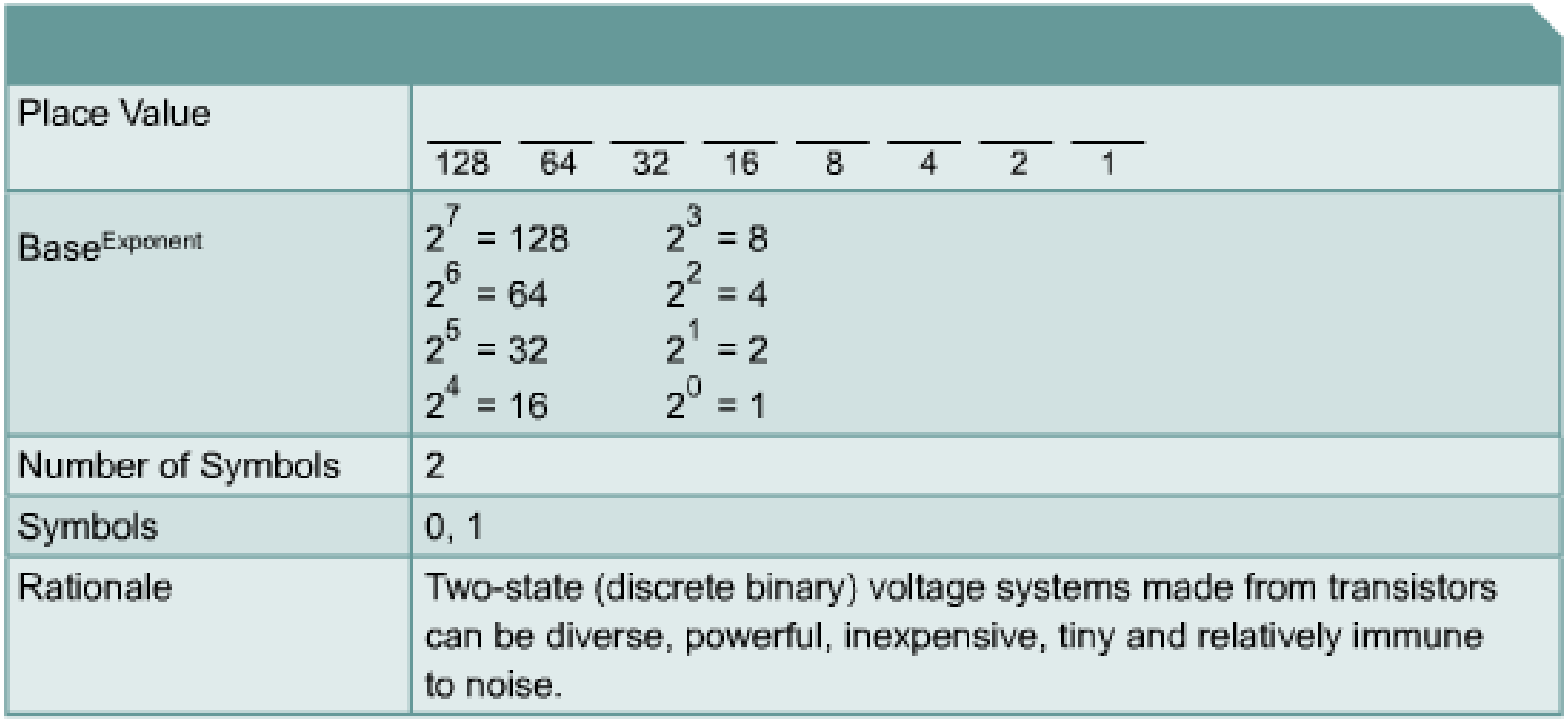
10101100

1	0
2	0
4	4
8	8
16	0
32	32
64	0
128	128
	172

$2^0 = 1$
$2^1 = 2$
$2^2 = 4$
$2^3 = 8$
$2^4 = 16$
$2^5 = 32$
$2^6 = 64$
$2^7 = 128$

Base 2 Number System

$$10110_2 = (1 \text{ x } 2^4 = 16) + (0 \text{ x } 2^3 = 0) + (1 \text{ x } 2^2 = 4) + (1 \text{ x } 2^1 = 2) + (0 \text{ x } 2^0 = 0) = 22$$



Place Value	___ 128 ___ 64 ___ 32 ___ 16 ___ 8 ___ 4 ___ 2 ___ 1
Base$^{\text{Exponent}}$	$2^7 = 128$ $2^6 = 64$ $2^5 = 32$ $2^4 = 16$ $2^3 = 8$ $2^2 = 4$ $2^1 = 2$ $2^0 = 1$
Number of Symbols	2
Symbols	0, 1
Rationale	Two-state (discrete binary) voltage systems made from transistors can be diverse, powerful, inexpensive, tiny and relatively immune to noise.

Converting Decimal to Binary

Convert 201_{10} to binary:

201 / 2 = 100 remainder **1**

100 / 2 = 50 remainder **0**

50 / 2 = 25 remainder **0**

25 / 2 = 12 remainder **1**

12 / 2 = 6 remainder **0**

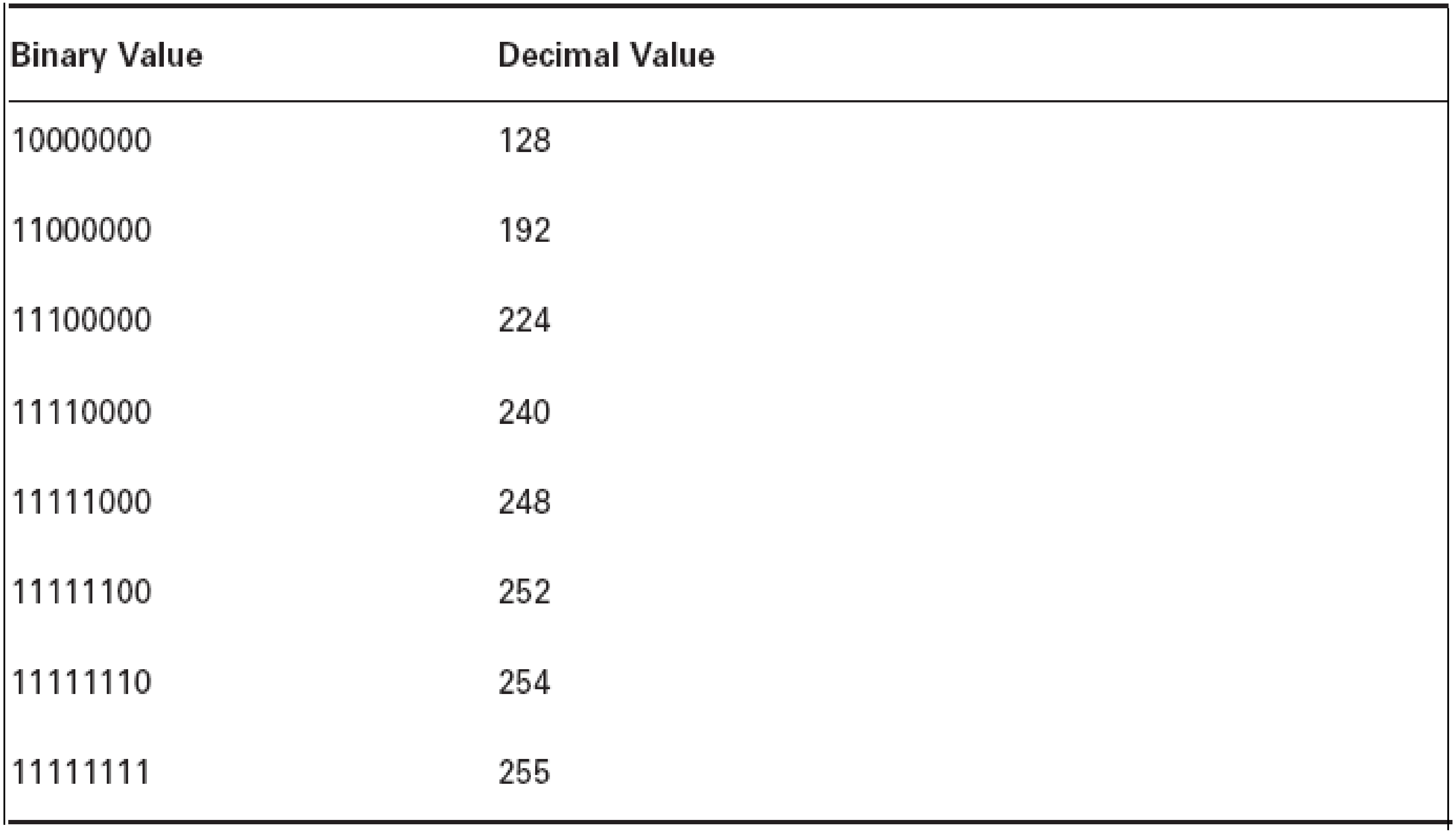
6 / 2 = 3 remainder **0**

3 / 2 = 1 remainder **1**

1 / 2 = 0 remainder **1**

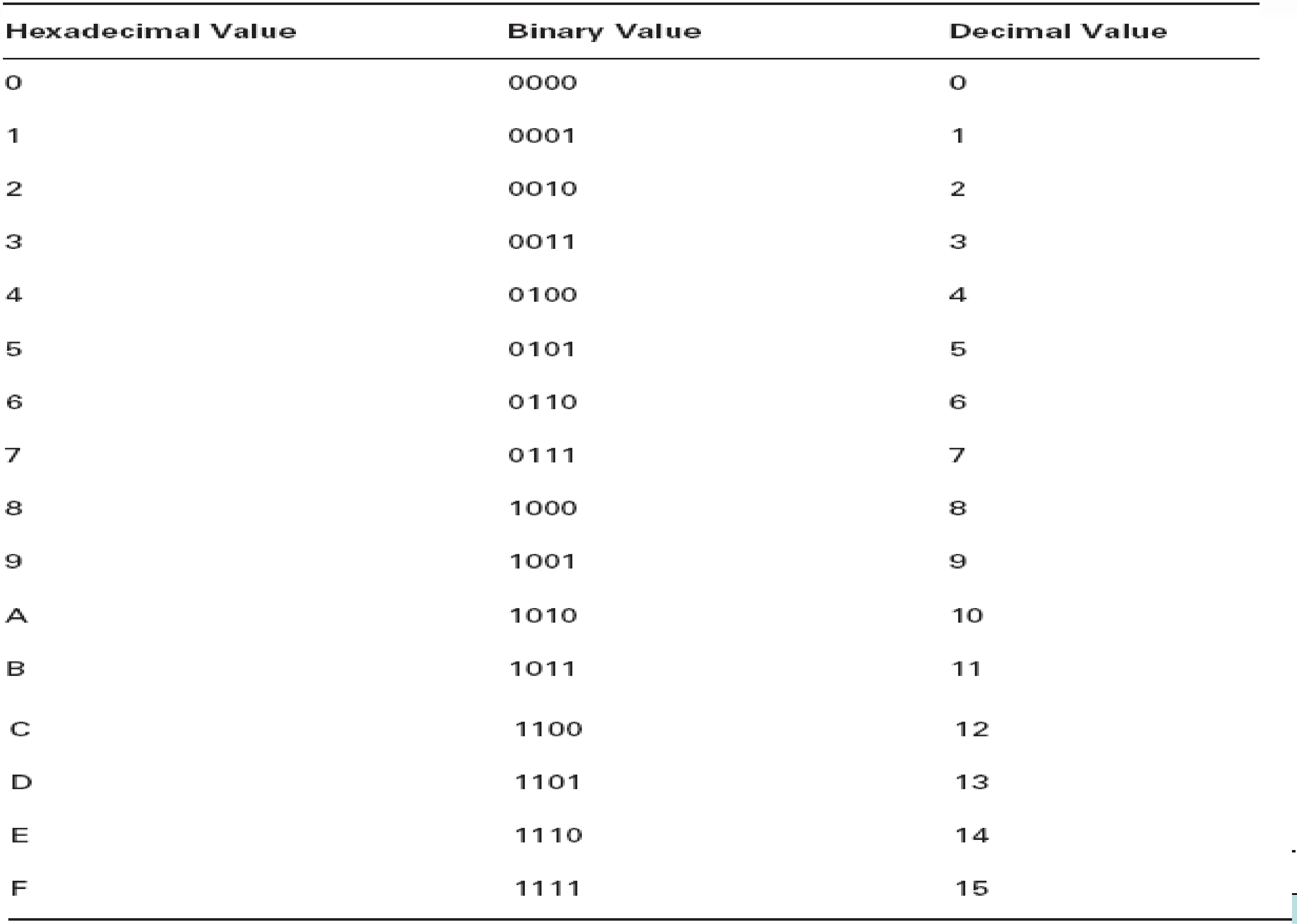
When the quotient is 0, take all the remainders in reverse order for your answer: **$201_{10} = 11001001_2$**

Binary to Decimal Chart



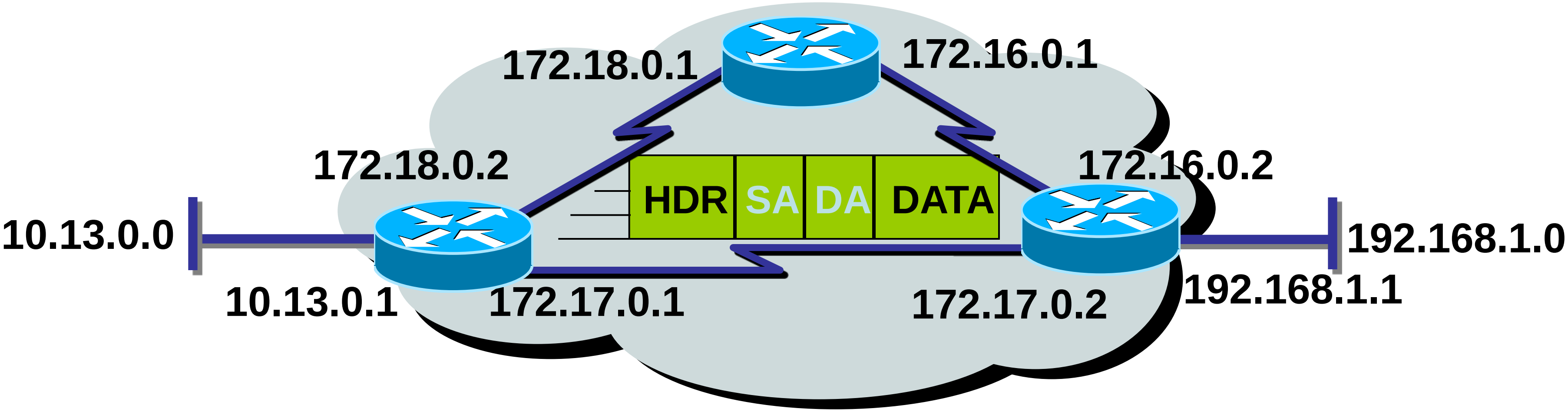
Binary Value	Decimal Value
10000000	128
11000000	192
11100000	224
11110000	240
11111000	248
11111100	252
11111110	254
11111111	255

Hex to Binary to Decimal Chart



Hexadecimal Value	Binary Value	Decimal Value
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
A	1010	10
B	1011	11
C	1100	12
D	1101	13
E	1110	14
F	1111	15

Introduction to TCP/IP Addresses



- Unique addressing allows communication between end stations.
- Path choice is based on destination address.

IP Addressing

32 Bits

Dotted Decimal	Network		Host	
Maximum	255	255	255	255
	1 8	9 16	17 24	25 32
Binary	11111111	11111111	11111111	11111111
	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1	128 64 32 16 8 4 2 1
Example Decimal	172	16	122	204
Example Binary	10101100	00010000	01111010	11001100

IP Address Classes

	8 Bits	8 Bits	8 Bits	8 Bits
•Class A:	Network	**Host**	**Host**	**Host**
•Class B:	Network	Network	**Host**	**Host**
•Class C:	Network	Network	Network	**Host**

•Class D: Multicast

•Class E: Research

IP Address Classes

Bits:	1 8	9 16	17 24	25 32
Class A:	0NNNNNNN	Host	Host	Host

Range (1-126)

Bits:	1 8	9 16	17 24	25 32
Class B:	10NNNNNN	Network	Host	Host

Range (128-191)

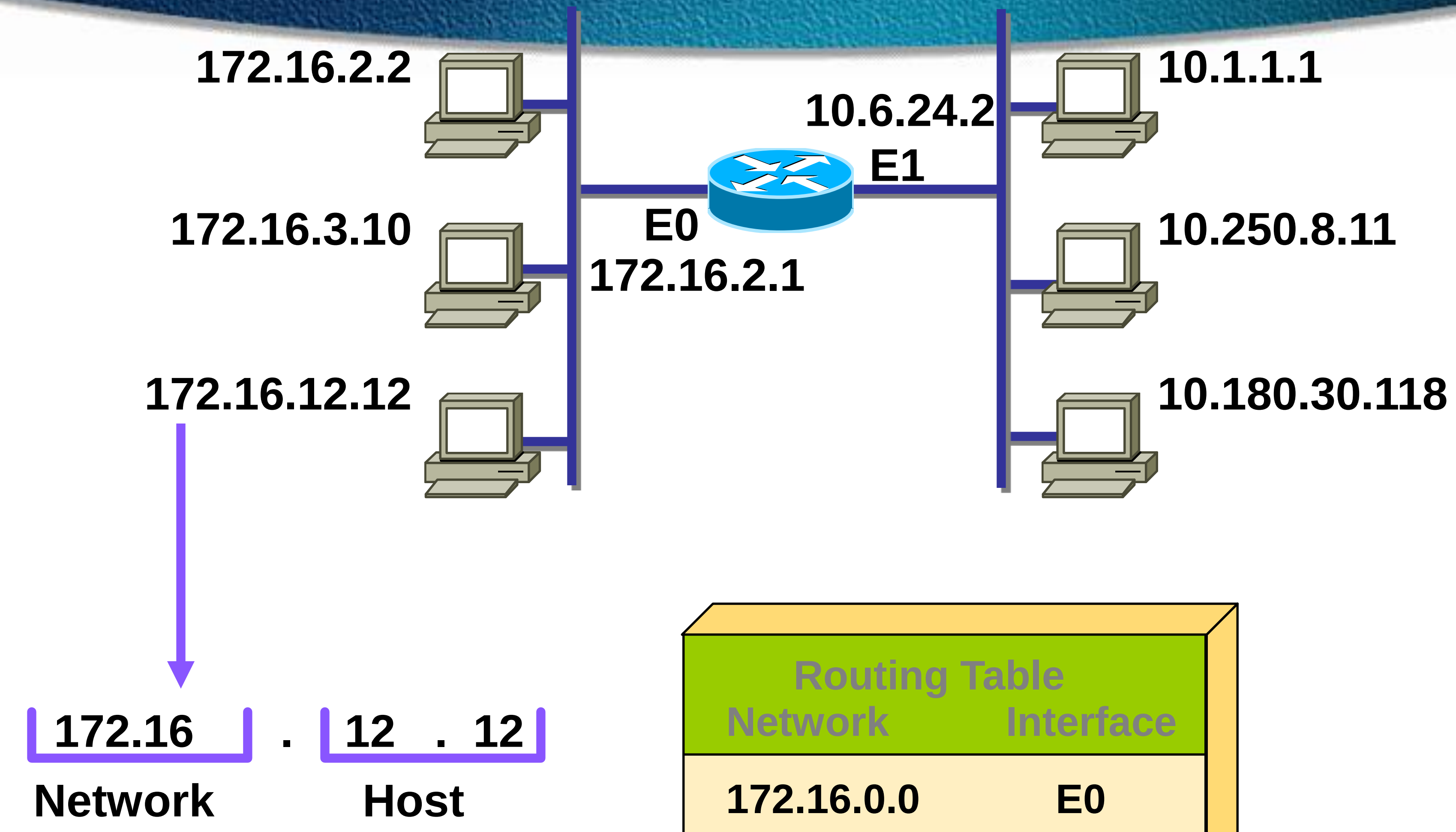
Bits:	1 8	9 16	17 24	25 32
Class C:	110NNNNN	Network	Network	Host

Range (192-223)

Bits:	1 8	9 16	17 24	25 32
Class D:	1110MMMM	Multicast Group	Multicast Group	Multicast Group

Range (224-239)

Host Addresses



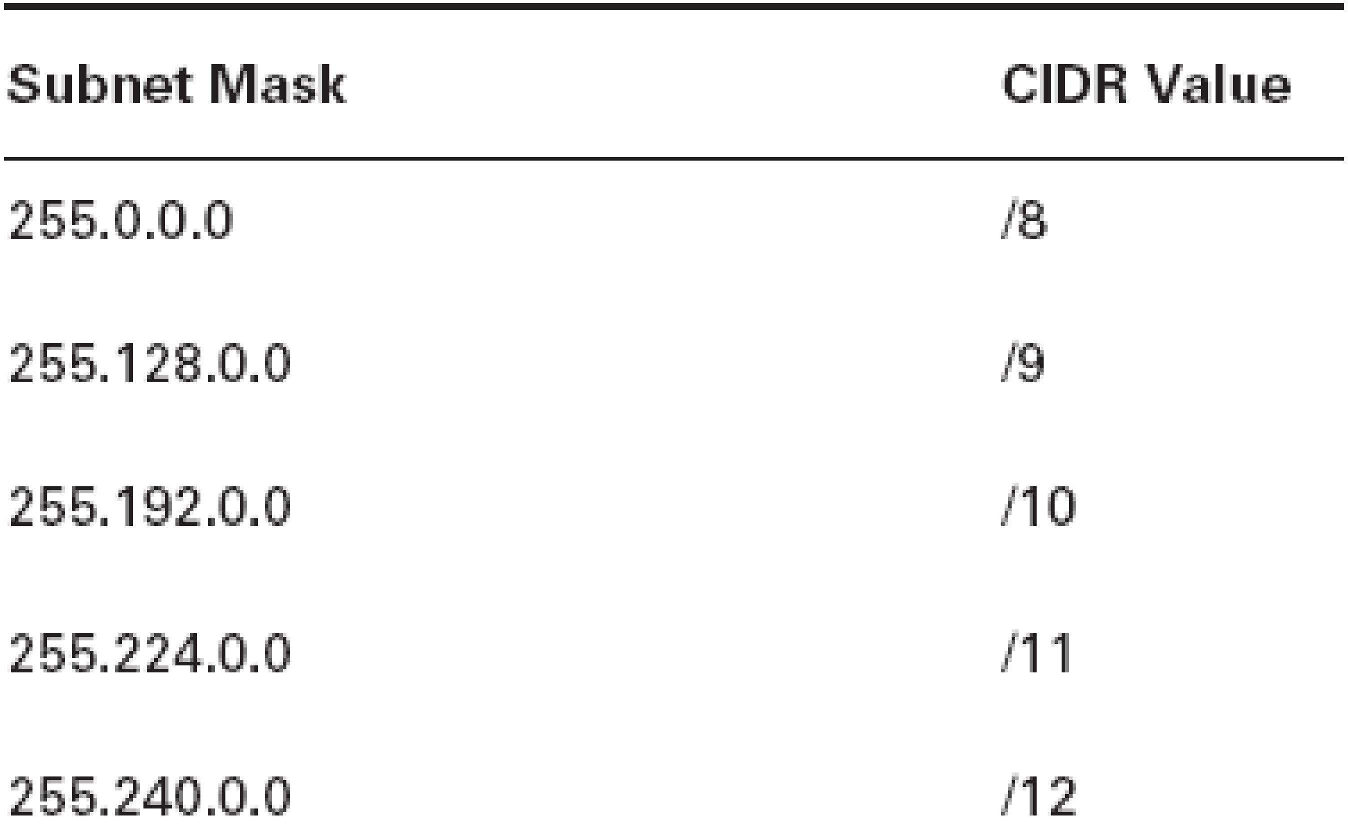
Routing Table

Network	Interface
172.16.0.0	E0
10.0.0.0	E1

Classless Inter-Domain Routing (CIDR)

- Basically the method that ISPs (Internet Service Providers) use to allocate an amount of addresses to a company, a home
- Ex : 192.168.10.32/28
- The slash notation (/) means how many bits are turned on (1s)

CIDR Values



Subnet Mask	CIDR Value
255.0.0.0	/8
255.128.0.0	/9
255.192.0.0	/10
255.224.0.0	/11
255.240.0.0	/12

Determining Available Host Addresses

Network Host

172		16	0	0

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 N

10101100 00010000

00000000	00000000	1
00000000	00000001	2
00000000	00000011	3
⋮	⋮	⋮
11111111	11111101	65534
11111111	11111110	65535
11111111	11111111	65536

$$2^N - 2 = 2^{16} - 2 = 65534$$

$$\begin{array}{r} 65536 \\ -\quad 2 \\ \hline 65534 \end{array}$$

IP Address Classes Exercise

Address	Class	Network	Host
10.2.1.1			
128.63.2.100			
201.222.5.64			
192.6.141.2			
130.113.64.16			
256.241.201.10			

IP Address Classes Exercise Answers

Address	Class	Network	Host
10.2.1.1	A	10.0.0.0	0.2.1.1
128.63.2.100	B	128.63.0.0	0.0.2.100
201.222.5.64	C	201.222.5.0	0.0.0.64
192.6.141.2	C	192.6.141.0	0.0.0.2
130.113.64.16	B	130.113.0.0	0.0.64.16
256.241.201.10	Nonexistent		

Subnetting

- Subnetting is logically dividing the network by extending the 1’s used in SNM
- Advantage
  - Can divide network in smaller parts
  - Restrict Broadcast traffic
  - Security
  - Simplified Administration

Formula

- Number of subnets – 2^x-2

  Where X = number of bits borrowed

- Number of Hosts – 2^y-2

  Where y = number of 0's

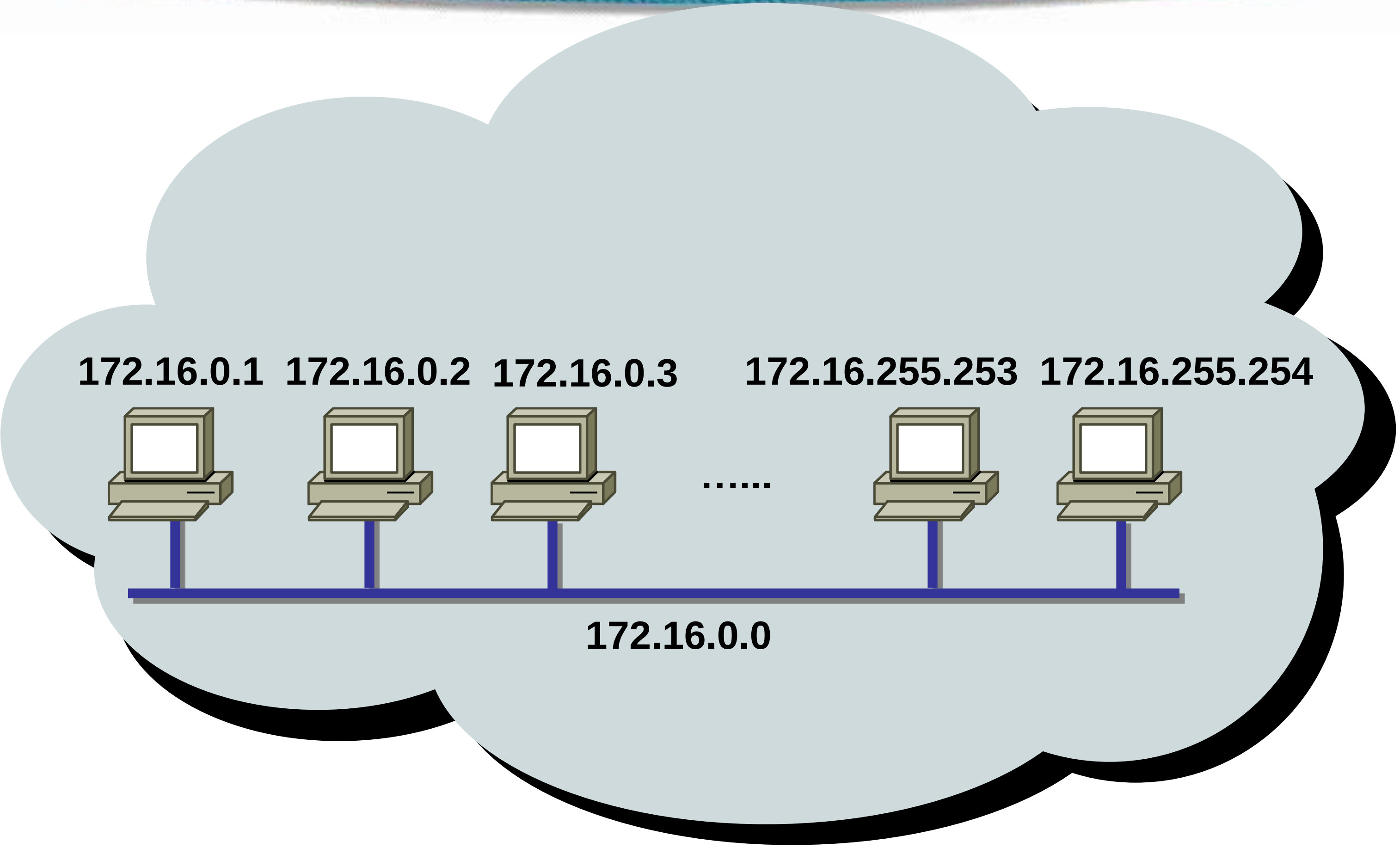
- Block Size = Total number of Address

  Block Size = 256-Mask

Subnetting

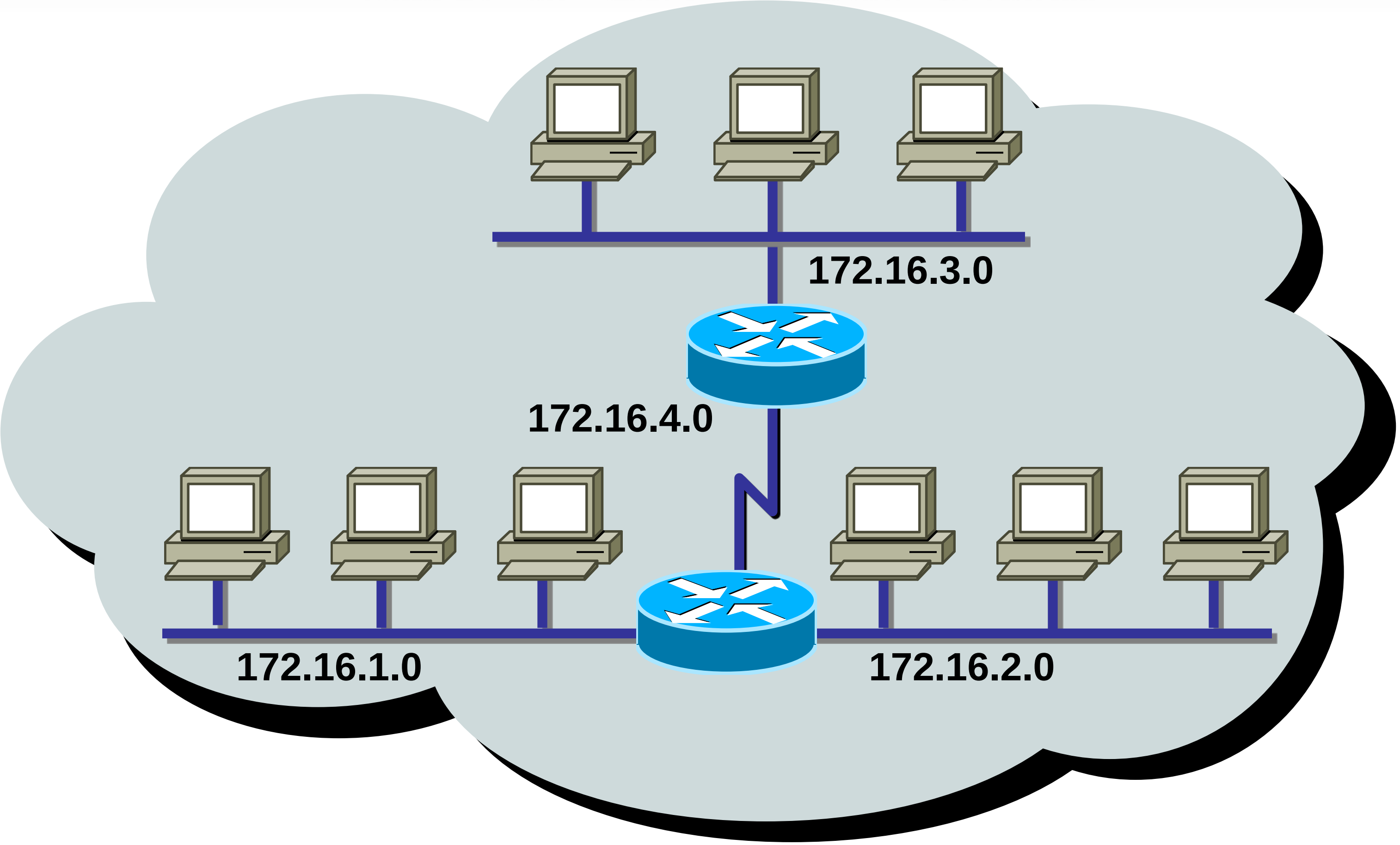
- ☐ Classful IP Addressing SNM are a set of 255's and 0's.
- ☐ In Binary it's contiguous 1's and 0's.
- ☐ SNM cannot be any value as it won't follow the rule of contiguous 1's and 0's.
- ☐ Possible subnet mask values
  - **0**
  - **128**
  - **192**
  - **224**
  - **240**
  - **248**
  - **252**
  - **254**
  - **255**

Addressing Without Subnets



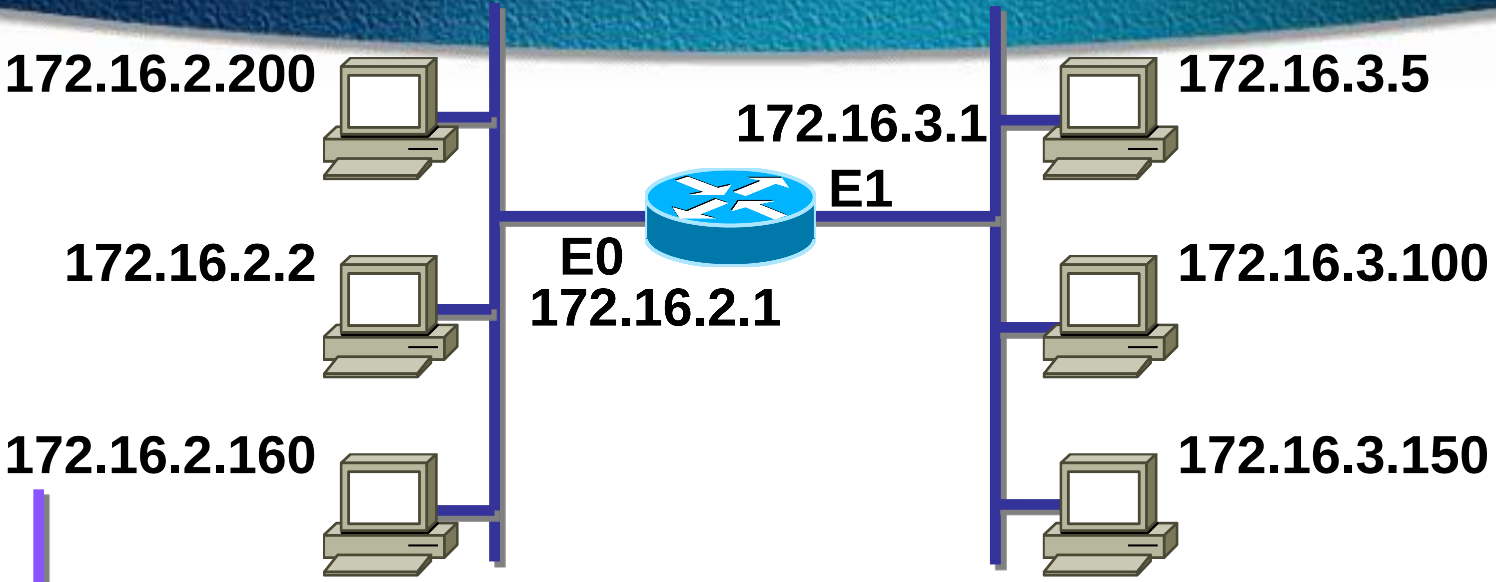
- Network 172.16.0.0

Addressing with Subnets



- Network 172.16.0.0

Subnet Addressing

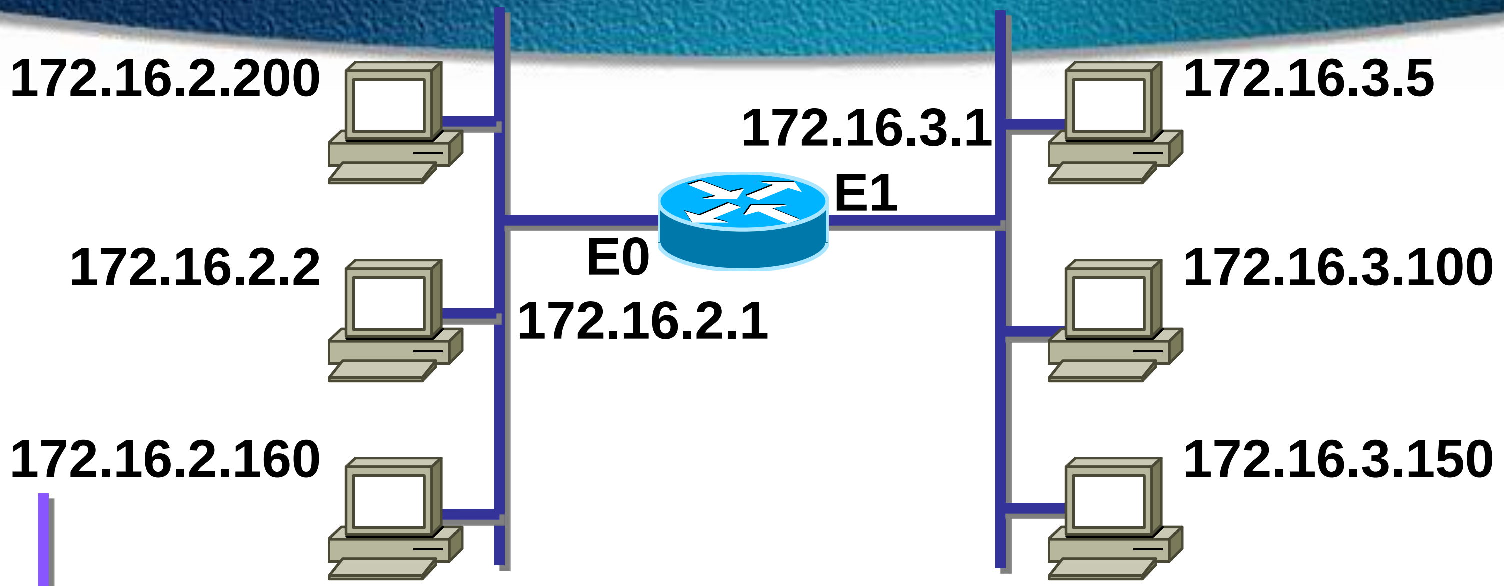


172.16 . 2 . 160

Network **Host**

New Routing Table	
Network	Interface
172.16.0.0	E0
172.16.0.0	E1

Subnet Addressing



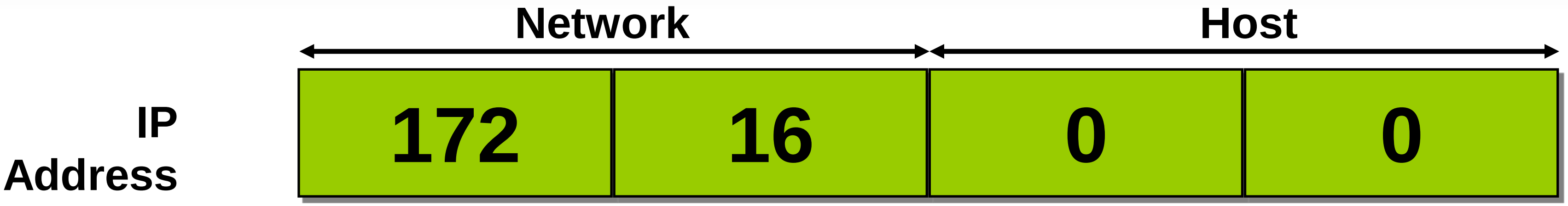
172.16 . **2** . **160**

Network **Subnet** **Host**

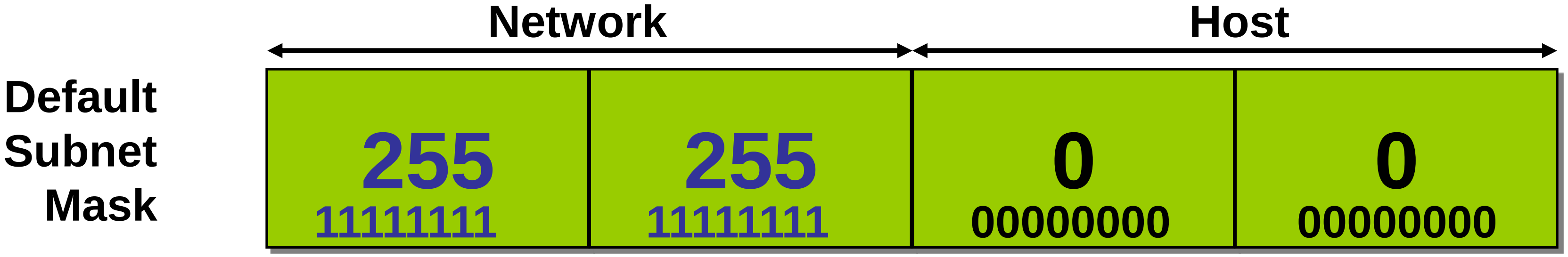
New Routing Table

Network	Interface
172.16.2.0	E0
172.16.3.0	E1

Subnet Mask

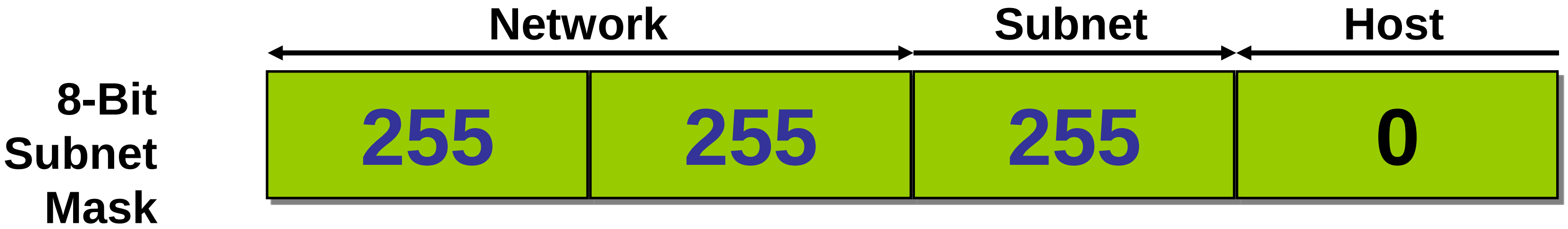


IP Address	172	16	0	0



Default Subnet Mask	255 11111111	255 11111111	0 00000000	0 00000000

- **Also written as "/16," where 16 represents the number of 1s in the mask**



8-Bit Subnet Mask	255	255	255	0

- **Also written as "/24," where 24 represents the number of 1s in the mask**

Decimal Equivalents of Bit Patterns

128	64	32	16	8	4	2	1		
0	0	0	0	0	0	0	0	=	0
1	0	0	0	0	0	0	0	=	128
1	1	0	0	0	0	0	0	=	192
1	1	1	0	0	0	0	0	=	224
1	1	1	1	0	0	0	0	=	240
1	1	1	1	1	0	0	0	=	248
1	1	1	1	1	1	0	0	=	252
1	1	1	1	1	1	1	0	=	254
1	1	1	1	1	1	1	1	=	255

Subnet Mask Without Subnets

	Network		Host	
172.16.2.160	10101100	00010000	00000010	10100000
255.255.0.0	11111111	11111111	00000000	00000000
	10101100	00010000	00000000	00000000
Network Number	172	16	0	0

- Subnets not in use—the default

Subnet Mask with Subnets

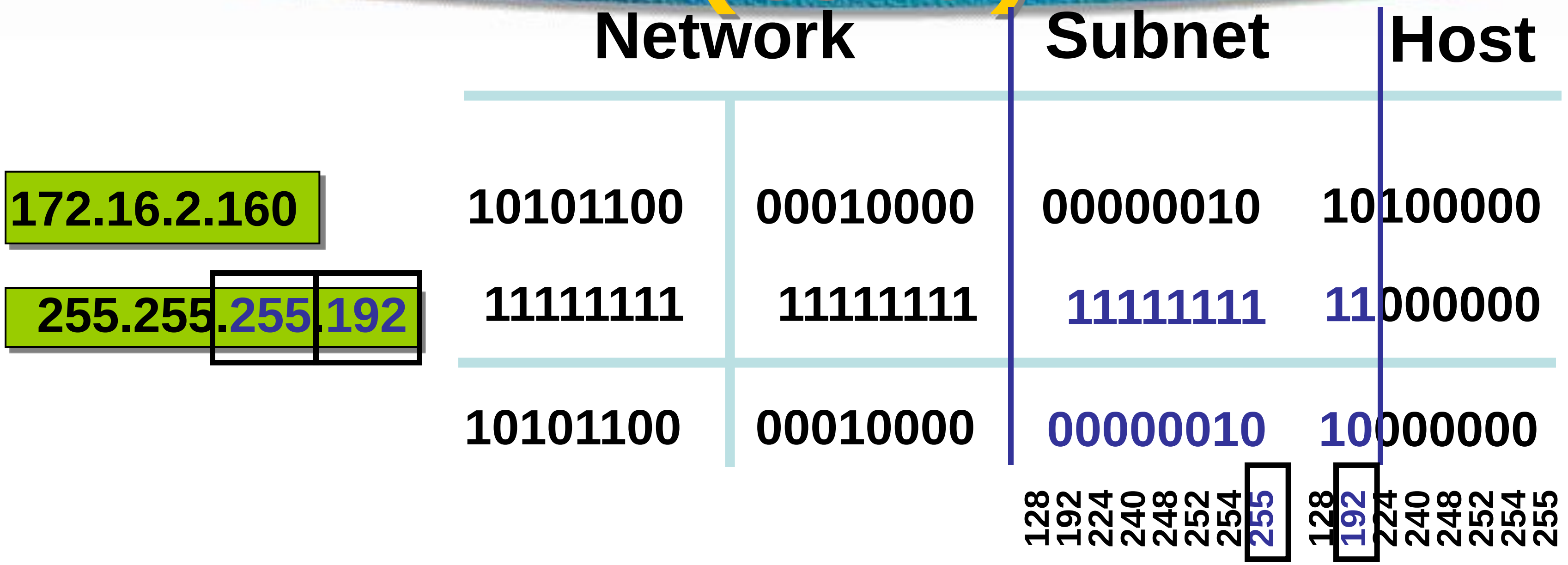
	Network		Subnet	Host
172.16.2.160	10101100	00010000	00000010	10100000
255.255.255.0	11111111	11111111	11111111	00000000
	10101100	00010000	00000010	00000000
			128 192 224 240 248 252 254 255	

Network Number

172	16	2	0

- Network number extended by eight bits

Subnet Mask with Subnets (cont.)



	Network		Subnet	Host
172.16.2.160	10101100	00010000	00000010	10100000
255.255.255.192	11111111	11111111	11111111	11000000
	10101100	00010000	00000010	10000000

Network Number

172	16	2	128

- Network number extended by ten bits

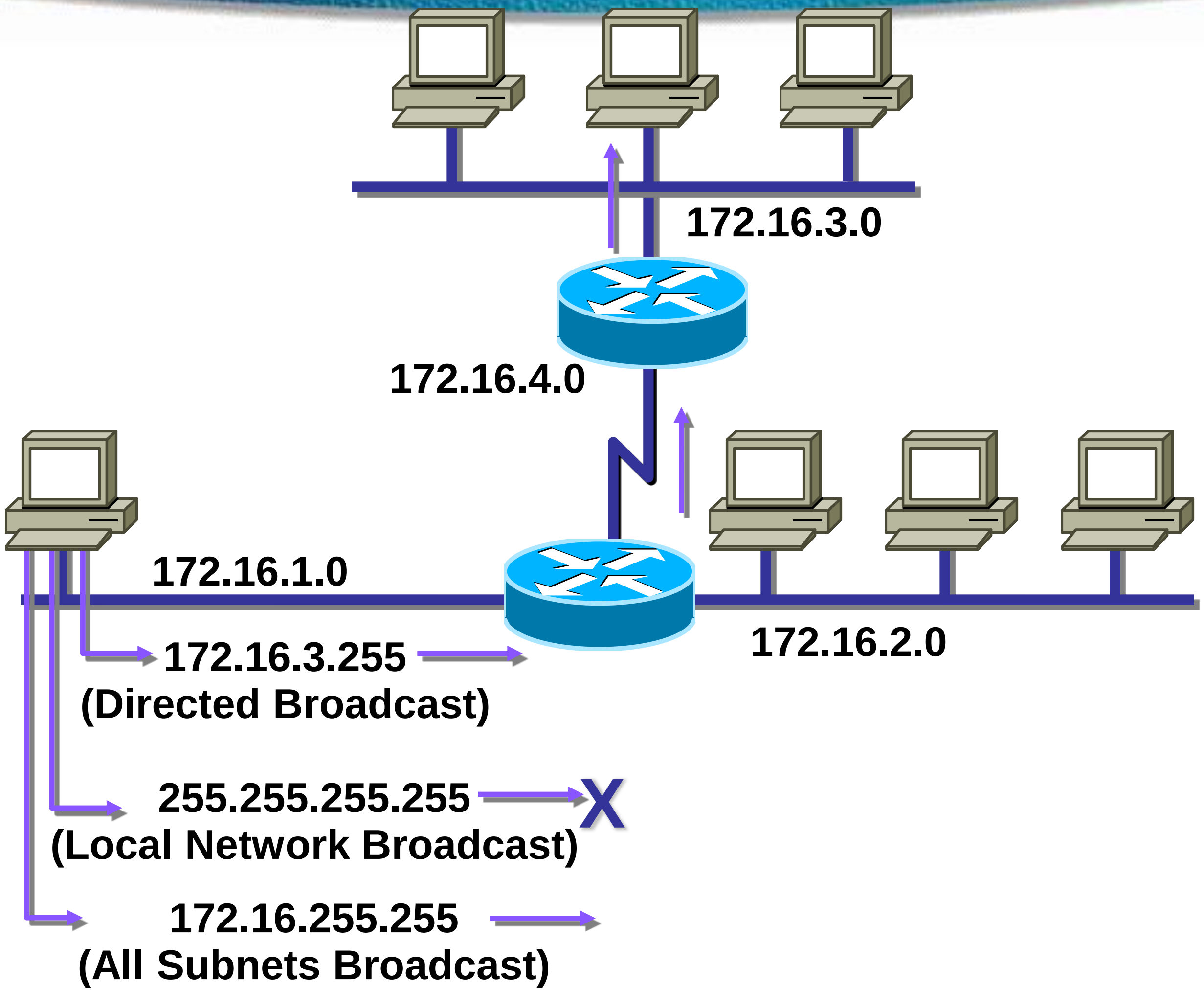
Subnet Mask Exercise

Address	Subnet Mask	Class	Subnet
172.16.2.10	255.255.255.0		
10.6.24.20	255.255.240.0		
10.30.36.12	255.255.255.0		

Subnet Mask Exercise Answers

Address	Subnet Mask	Class	Subnet
172.16.2.10	255.255.255.0	B	172.16.2.0
10.6.24.20	255.255.240.0	A	10.6.16.0
10.30.36.12	255.255.255.0	A	10.30.36.0

Broadcast Addresses



172.16.3.0

172.16.4.0

172.16.1.0

172.16.2.0

172.16.3.255
(Directed Broadcast)

255.255.255.255 X
(Local Network Broadcast)

172.16.255.255
(All Subnets Broadcast)

Addressing Summary Example

	172	16	2	160	
				③	
172.16.2.160	10101100	00010000	00000010	10100000	Host ①
255.255.255.192	11111111	11111111	11111111	11000000	Mask ②
⑨ ⑧					
172.16.2.128	10101100	00010000	00000010	10000000	Subnet ④
172.16.2.191	10101100	00010000	00000010	10111111	Broadcast ⑤
172.16.2.129	10101100	00010000	00000010	10000001	First ⑥
172.16.2.190	10101100	00010000	00000010	10111110	Last ⑦

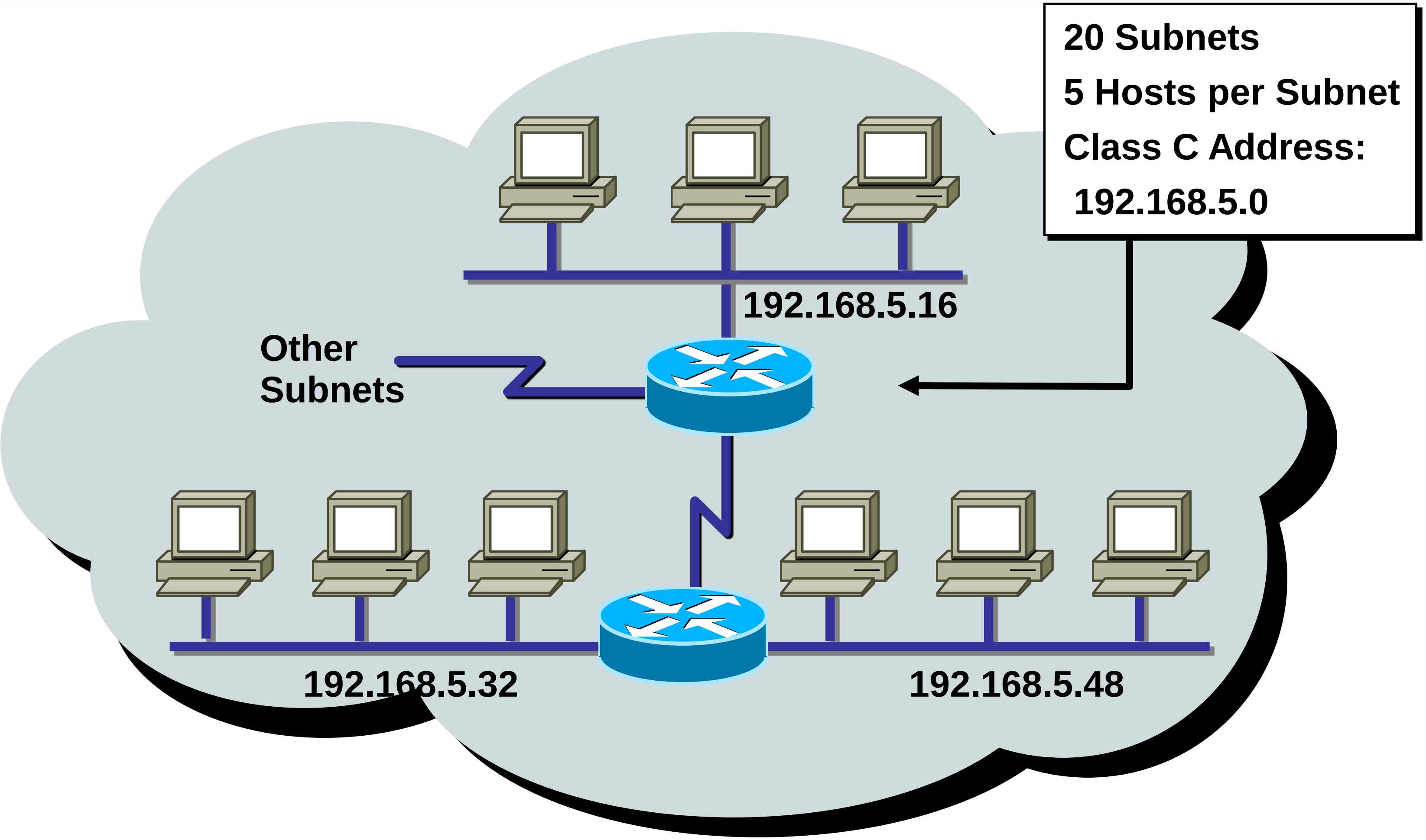
Class B Subnet Example

IP Host Address: 172.16.2.121
Subnet Mask: 255.255.255.0

	Network	Network	Subnet	Host
172.16.2.121:	**10101100**	**00010000**	**00000010**	**01111001**
255.255.255.0:	**11111111**	**11111111**	**11111111**	**00000000**
Subnet:	**10101100**	**00010000**	**00000010**	**00000000**
Broadcast:	**10101100**	**00010000**	**00000010**	**11111111**

- Subnet Address = 172.16.2.0
- Host Addresses = 172.16.2.1–172.16.2.254
- Broadcast Address = 172.16.2.255
- Eight Bits of Subnetting

Subnet Planning



20 Subnets

5 Hosts per Subnet

Class C Address:

192.168.5.0

Class C Subnet Planning Example

IP Host Address: 192.168.5.121
Subnet Mask: 255.255.255.248

	Network	Network	Network	Subnet	Host
192.168.5.121:	**11000000**	**10101000**	**00000101**	**01111**	**001**
255.255.255.248:	**11111111**	**11111111**	**11111111**	**11111**	**000**
Subnet:	**11000000**	**10101000**	**00000101**	**01111**	**000**
Broadcast:	**11000000**	**10101000**	**00000101**	**01111**	**111**

- Subnet Address = 192.168.5.120
- Host Addresses = 192.168.5.121–192.168.5.126
- Broadcast Address = 192.168.5.127
- Five Bits of Subnetting

Exercise

- **192.168.10.0**
- **/27**

? – SNM

? – Block Size

?- Subnets

Exercise

- **/27**

? – SNM – 224

? – Block Size = 256-224 = 32

?- Subnets

Subnets	10.0	10.32	10.64
FHID	10.1	10.33	
LHID	10.30	10.62	
Broadcast	10.31	10.63	

Exercise

- **192.168.10.0**
- **/30**

? – SNM

? – Block Size

?- Subnets

Exercise

- **/30**

? – SNM – 252

? – Block Size = 256-252 = 4

?- Subnets

Subnets	10.0	10.4	10.8
FHID	10.1	10.5	
LHID	10.2	10.6	
Broadcast	10.3	10.7	

Exercise

	Mask	**Subnets**	**Host**
/26	?	?	?
/27	?	?	?
/28	?	?	?
/29	?	?	?
/30	?	?	?

Exercise

	Mask	Subnets	Host
/26	192	4	62
/27	224	8	30
/28	240	16	14
/29	248	32	6
/30	252	64	2

Exam Question

- Find Subnet and Broadcast address
  - 192.168.0.100/27

Exercise

- 192.168.10.54 /29
- Mask ?
- Subnet ?
- Broadcast ?

Exercise

- 192.168.10.130 /28
- Mask ?
- Subnet ?
- Broadcast ?

Exercise

☐192.168.10.193 /30

☐Mask ?

☐Subnet ?

☐Broadcast ?

Exercise

- 192.168.1.100 /26
- Mask ?
- Subnet ?
- Broadcast ?

Exercise

- ☐192.168.20.158 /27
- ☐Mask ?
- ☐Subnet ?
- ☐Broadcast ?

Class B

172.16.0.0 /19

Subnets ?

Hosts ?

Block Size ?

Class B

172.16.0.0 /19
Subnets 2^3 -2 = 6
Hosts 2^{13} -2 = 8190
Block Size 256-224 = 32

Subnets	0.0	32.0	64.0	96.0
FHID	0.1	32.1	64.1	96.1
LHID	31.254	63.254	95.254	127.254
Broadcast	31.255	63.255	95.255	127.255

Class B

172.16.0.0 /27

Subnets ?

Hosts ?

Block Size ?

Class B

172.16.0.0 /27

Subnets 2^{11} -2 = 2046

Hosts 2^{5} -2 = 30

Block Size 256-224 = 32

Subnets	0.0	0.32	0.64	0.96
FHID	0.1	0.33	0.65	0.97
LHID	0.30	0.62	0.94	0.126
Broadcast	0.31	0.63	0.95	0.127

Class B

172.16.0.0 /23

Subnets ?

Hosts ?

Block Size ?

Class B

172.16.0.0 /23
Subnets 2^7 -2 = 126
Hosts 2^9 -2 = 510
Block Size 256-254 = 2

Subnets	0.0	2.0	4.0	6.0
FHID	0.1	2.1	4.1	6.1
LHID	1.254	3.254	5.254	7.254
Broadcast	1.255	3.255	5.255	7.255

Class B

172.16.0.0 /24

Subnets ?

Hosts ?

Block Size ?

Class B

172.16.0.0 /24

Subnets 2^8 -2 = 254

Hosts 2^8 -2 = 254

Block Size 256-255 = 1

Subnets	0.0	1.0	2.0	3.0
FHID	0.1	1.1	2.1	3.1
LHID	0.254	1.254	2.254	3.254
Broadcast	0.255	1.255	2.255	3.255

Class B

172.16.0.0 /25

Subnets ?

Hosts ?

Block Size ?

Class B

172.16.0.0 /25
Subnets 2^9 -2 = 510
Hosts 2^7 -2 = 126
Block Size 256-128 = 128

Subnets	0.0	0.128	1.0	1.128	2.0	2.128
FHID	0.1	0.129	1.1	1.129	2.1	2.129
LHID	0.126	0.254	1.126	1.254	2.126	2.254
Broadcast	0.127	0.255	1.127	1.255	2.127	2.255

Find out Subnet and Broadcast Address

- 172.16.85.30/29

Find out Subnet and Broadcast Address

- 172.30.101.62/23

Find out Subnet and Broadcast Address

- 172.20.210.80/24

Exercise

- Find out the mask which gives 100 subnets for class B

Exercise

- Find out the Mask which gives 100 hosts for Class B

Class A

10.0.0.0 /10

Subnets ?

Hosts ?

Block Size ?

Class A

10.0.0.0 /10
Subnets 2^2 -2 = 2
Hosts 2^{22} -2 = 4194302
Block Size 256-192 = 64

Subnets	10.0	10.64	10.128	10.192
FHID	10.0.0.1	10.64.0.1	10.128.0.1	10.192.0.1
LHID	10.63.255.254	10.127.255.254	10.191.255.254	10.254.255.254
Broadcast	10.63.255.255	10.127.255.255	10.191.255.255	10.254.255.255

Class A

10.0.0.0 /18

Subnets ?

Hosts ?

Block Size ?

Class A

10.0.0.0 /18
Subnets 2^{10} -2 = 1022
Hosts 2^{14} -2 = 16382
Block Size 256-192 = 64

Subnets	10.0.0.0	10.0.64.0	10.0.128.0	10.0.192.0
FHID	10.0.0.1	10.0.64.1	10.0.128.1	10.0.192.1
LHID	10.0.63.254	10.0.127.254	10.0.191.254	10.0.254.254
Broadcast	10.0.63.255	10.0.127.255	10.0.191.255	10.0.254.255

Broadcast Addresses Exercise

Address	Subnet Mask	Class	Subnet	Broadcast
201.222.10.60	255.255.255.248			
15.16.193.6	255.255.248.0			
128.16.32.13	255.255.255.252			
153.50.6.27	255.255.255.128			

Broadcast Addresses Exercise Answers

Address	Subnet Mask	Class	Subnet	Broadcast
201.222.10.60	**255.255.255.248**	**C**	**201.222.10.56**	**201.222.10.63**
15.16.193.6	**255.255.248.0**	**A**	**15.16.192.0**	**15.16.199.255**
128.16.32.13	**255.255.255.252**	**B**	128.16.32.12	128.16.32.15
153.50.6.27	**255.255.255.128**	**B**	153.50.6.0	153.50.6.127

VLSM

- VLSM is a method of designating a different subnet mask for the same network number on different subnets

- Can use a long mask on networks with few hosts and a shorter mask on subnets with many hosts

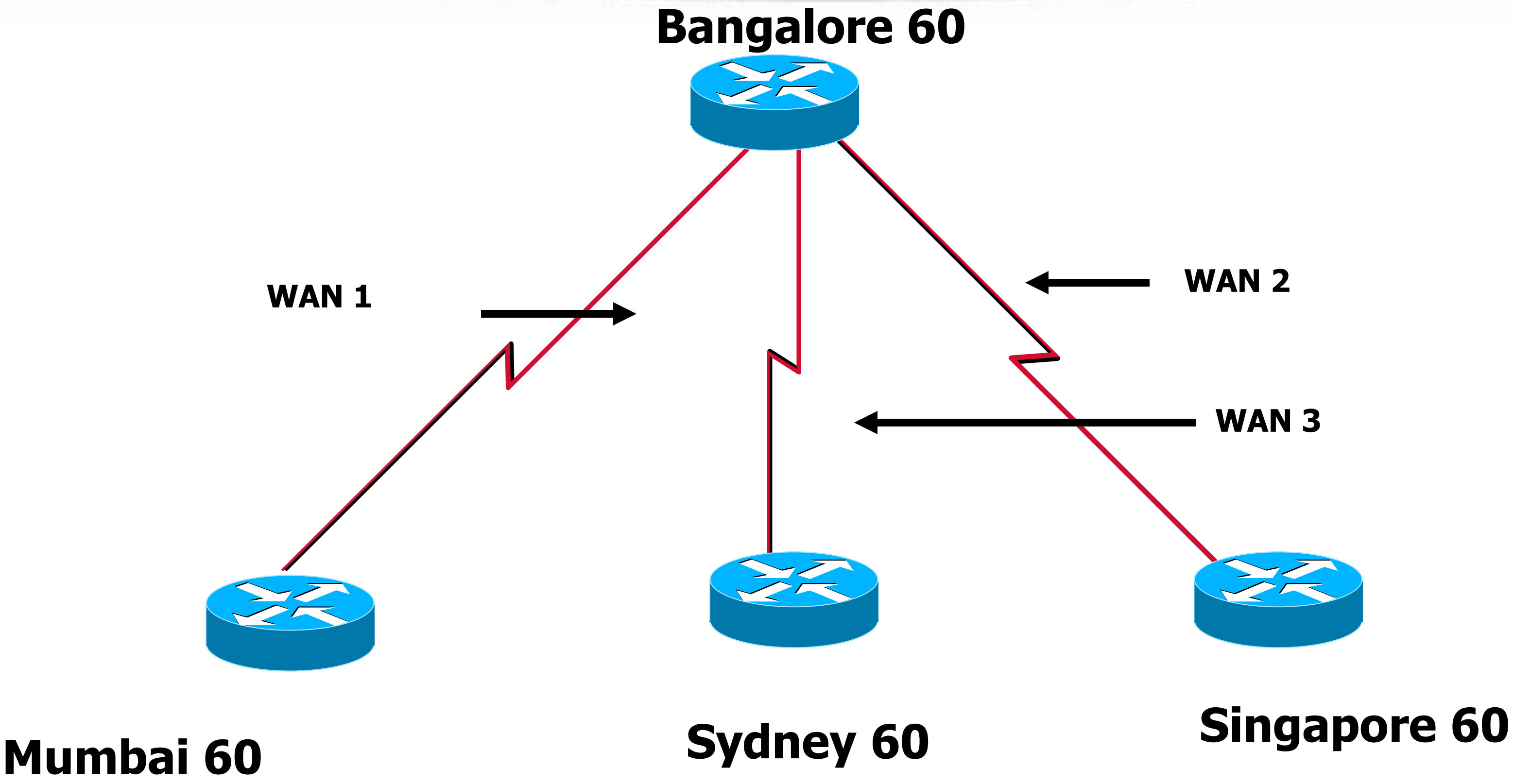
- With VLSMs we can have different subnet masks for different subnets.

Variable Length Subnetting

- VLSM allows us to use one class C address to design a networking scheme to meet the following requirements:

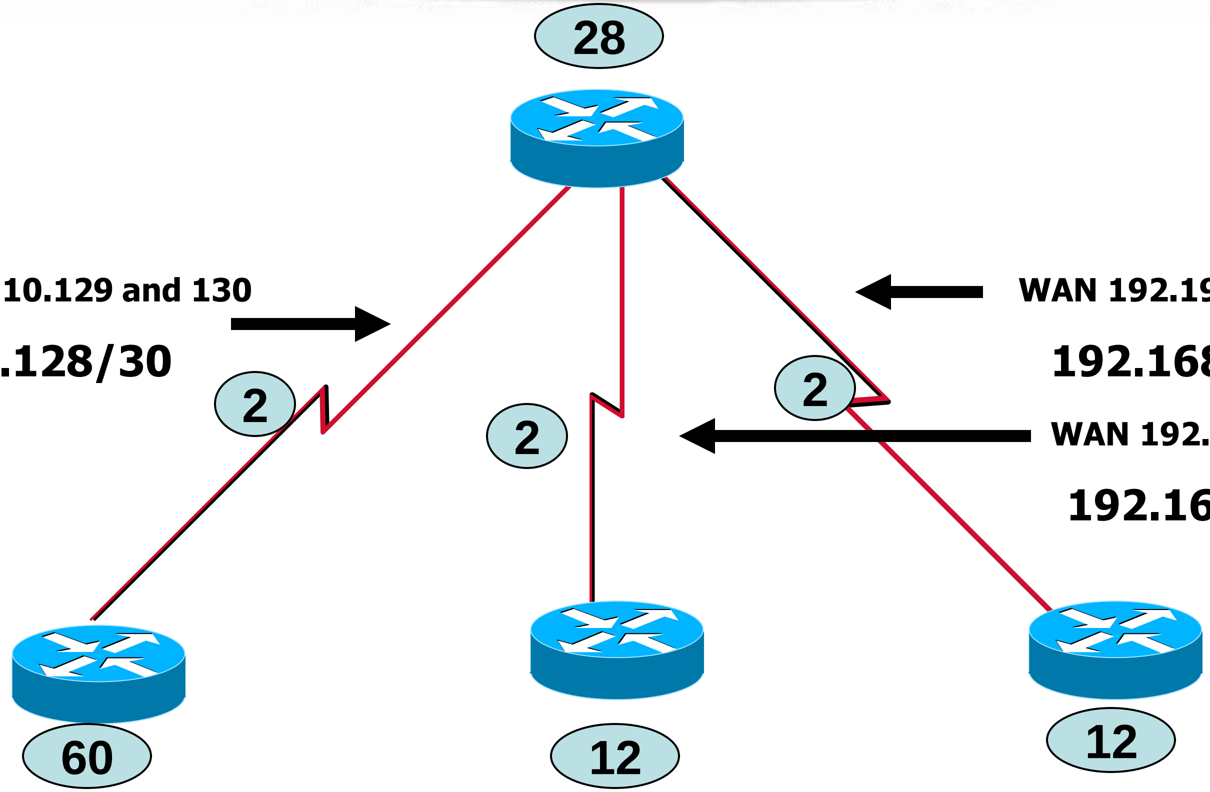
Bangalore	60 Hosts
Mumbai	28 Hosts
Sydney	12 Hosts
Singapore	12 Hosts
WAN 1	2 Hosts
WAN 2	2 Hosts
WAN 3	2 Hosts

Networking Requirements



- ❑In the example above, a /26 was used to provide the 60 addresses for Bangalore and the other LANs. There are no addresses left for WAN links

Networking Scheme



Mumbai 192.168.10.64/27

WAN 192.168.10.129 and 130

192.168.10.128/30

WAN 192.198.10.133 and 134

192.168.10.132/30

WAN 192.198.10.137 and 138

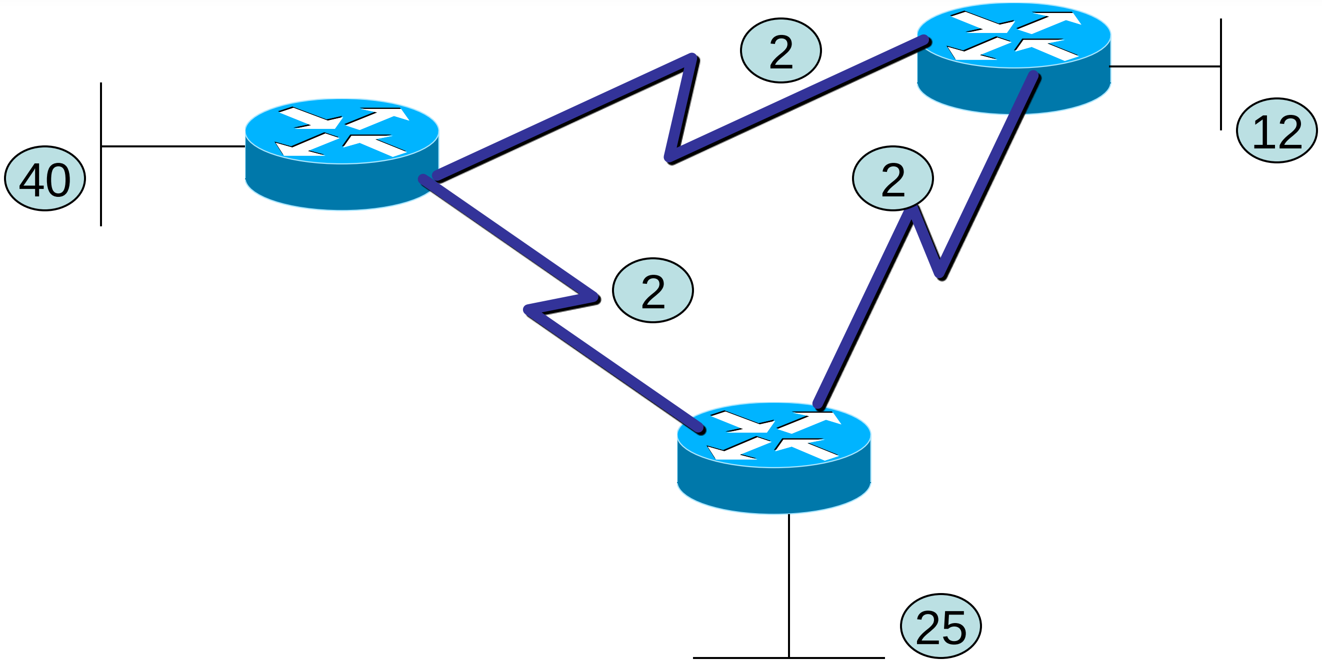
192.168.10.136/30

Bangalore
192.168.10.0/26

Sydney 192.168.10.96/28

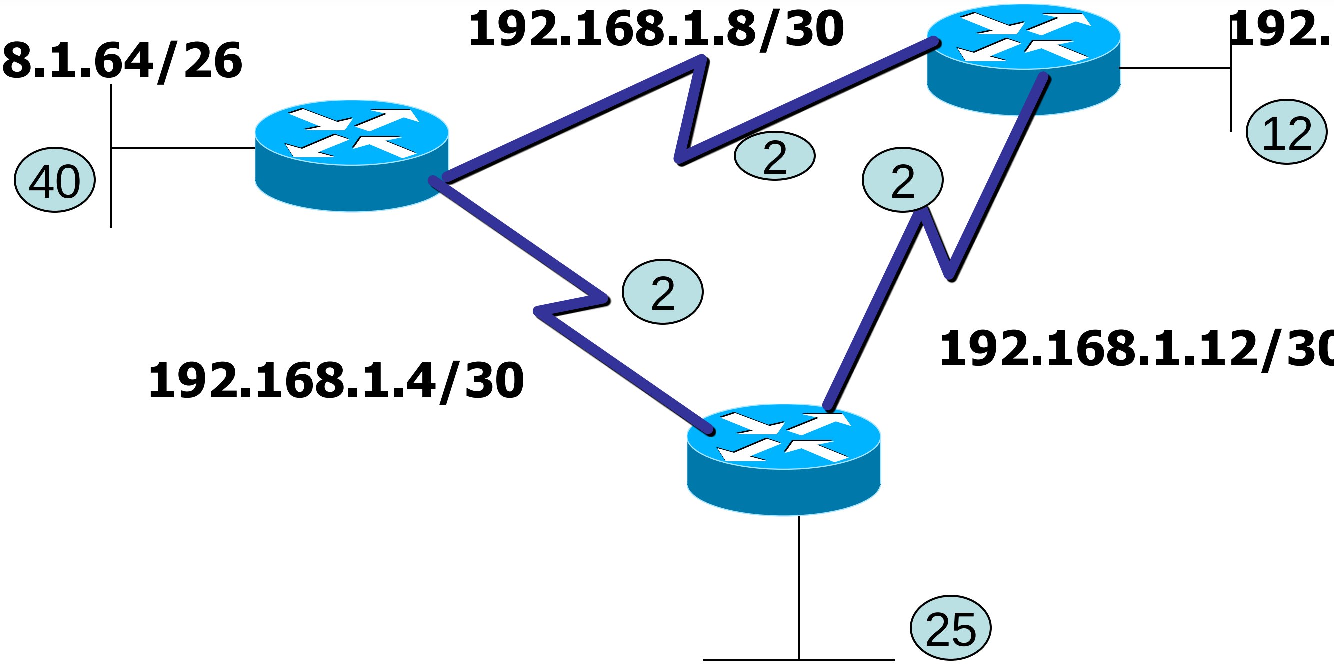
Singapore 192.168.10.112/28

VLSM Exercise



192.168.1.0

VLSM Exercise



192.168.1.64/26

192.168.1.8/30

192.168.1.16/28

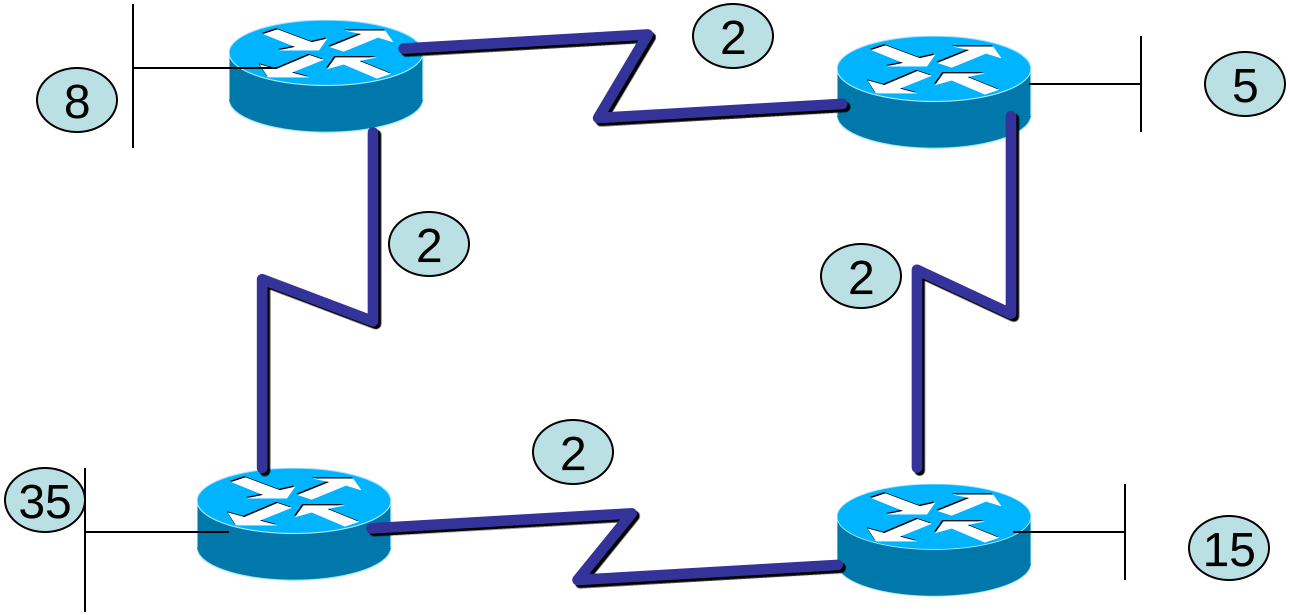
192.168.1.12/30

192.168.1.4/30

192.168.1.32/27

192.168.1.0

VLSM Exercise

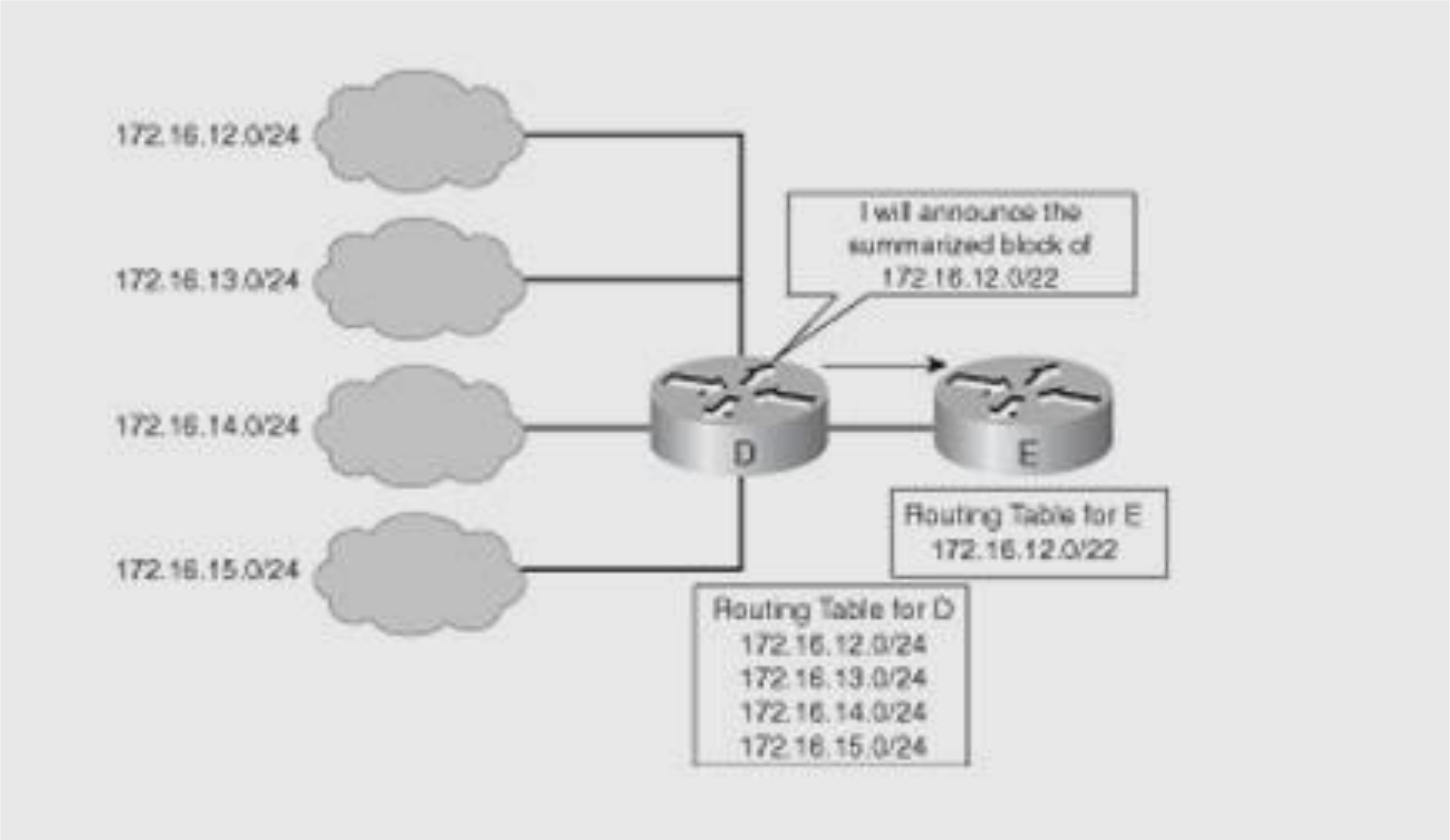


192.168.1.0

Summarization

- Summarization, also called route aggregation, allows routing protocols to advertise many networks as one address.
- The purpose of this is to reduce the size of routing tables on routers to save memory
- Route summarization (also called route aggregation or supernetting) can reduce the number of routes that a router must maintain
- Route summarization is possible only when a proper addressing plan is in place
- Route summarization is most effective within a subnetted environment when the network addresses are in contiguous blocks

Summarization



Supernetting

	Network	Network	Network	Subnet
			16 8 4 2 1	
172.16.12.0	11000000	10101000	**00001100**	00000000
172.16.13.0	11000000	10101000	**00001101**	00000000
172.16.14.0	11000000	10101000	**00001110**	00000000
172.16.15.0	11000000	10101000	**00001111**	00000000
255.255.255.0	11111111	11111111	**11111111**	00000000

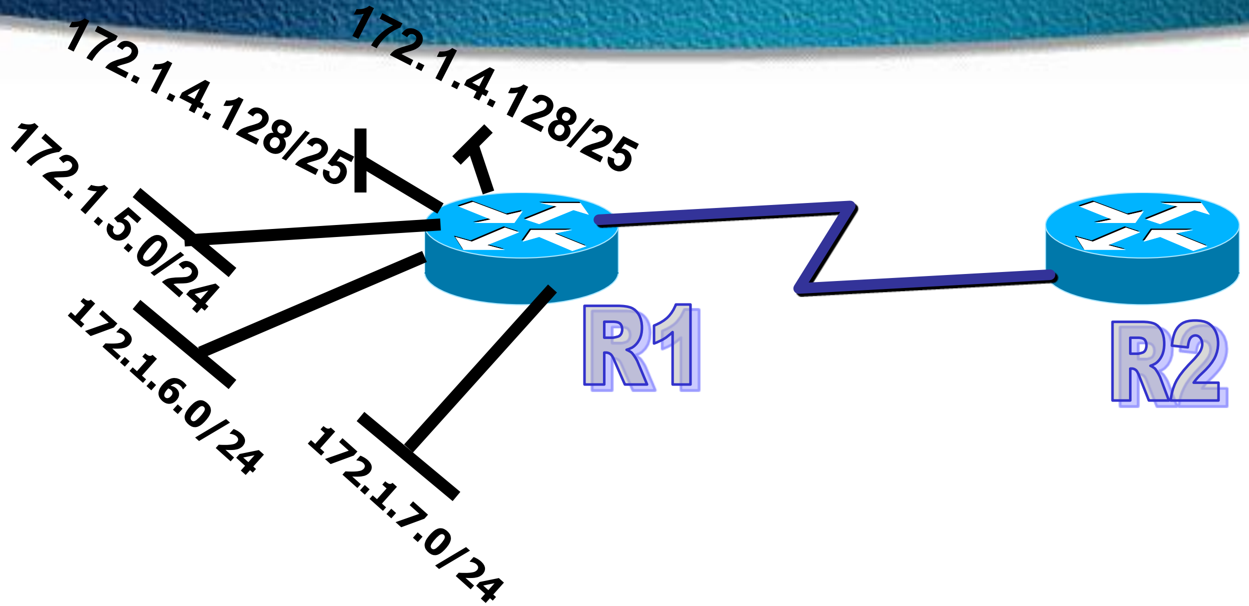
Supernetting

	Network	Network	Network	Subnet
			16 8 4 2 1	
172.16.12.0	11000000	10101000	00001100	00000000
172.16.13.0	11000000	10101000	00001101	00000000
172.16.14.0	11000000	10101000	00001110	00000000
172.16.15.0	11000000	10101000	00001111	00000000
255.255.252.0	11111111	11111111	11111100	00000000

172.16.12.0/24
172.16.13.0/24
172.16.14.0/24
172.16.15.0/24

172.16.12.0/22

Supernetting Question



- ☐ **What is the most efficient summarization that TK1 can use to advertise its networks to TK2?**

A. 172.1.4.0/24172.1.5.0/24172.1.6.0/24172.1.7.0/24
B. 172.1.0.0/22
C. 172.1.4.0/25172.1.4.128/25172.1.5.0/24172.1.6.0/24172.1.7.0/24
D. 172.1.0.0/21
E. 172.1.4.0/22