# Unit No:1

# Introduction to Computer Networks and Internet

Marwadi University

Department of CE

Computer Networks
(3150710)

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# Syllabus

**Syllabus:**

| Sr. No. | Content | Total Hrs | % Weightage |
|---|---|---|---|
| 1 | **Introduction to computer networks and Internet:** Understanding of network and Internet, The network edge, The network core, Understanding of Delay, Loss and Throughput in the packet-switching network, protocols layers and their service model, History of the computer network | 08 | 15 |
| 2 | **Application Layer:** Principles of computer applications, Web and HTTP, E-mail, DNS, Socket programming with TCP and UDP | 09 | 17 |
| 3 | **Transport Layer:** Introduction and transport layer services, Multiplexing and Demultiplexing, Connectionless transport (UDP), Principles of reliable data transfer, Connection-oriented transport (TCP), Congestion control, TCP congestion control | 12 | 25 |
| 4 | **Network Layer:** Introduction to forwarding and routing, Network Service models, Virtual and Datagram networks, study of router, IP protocol and addressing in the Internet, Routing algorithms, Broadcast and Multicast routing | 13 | 25 |
| 5 | **The Link layer and Local area networks:** Introduction to link layer services, error-detection and correction techniques, Multiple access protocols, addressing, Ethernet, switches, VLAN | 10 | 18 |

# Course Outcome

**Course outcomes:** Students will be able to

| Sr. No. | CO statement | Marks % Weightage |
|---|---|---|
| 1 | **Explain** the basic terminologies used in networking and layered architecture of computer network. | 15 |
| 2 | **Comprehend** basic protocols of application layer and how they can be used to assist in network design and implementation. | 17 |
| 3 | **Describe and implement** the essential principles of a connectionless and connection-oriented protocols used for reliable data transfer, flow control and congestion control. | 25 |
| 4 | **Design** network architecture, assign IP addressing and **apply** various routing algorithms to find shortest paths for network-layer packet delivery. | 25 |
| 5 | **Illustrate** different link layer terminologies like error detection-correction, Multiple access protocol and Link layer addressing used in network. | 18 |

# Reference Books


- 1. Computer Networking- A Top-Down approach (6th edition), Kurose and Ross, Pearson
- 2. Computer Networks- A Top-Down approach, Behrouz Forouzan, McGraw Hill
- 3. Computer Networks (5th edition), Andrew Tanenbaum, Prentice Hall
- 4. Computer Networking and the Internet (5th edition),Fred Halsall, Addison Wesley
- 5. Data Communications and Networking (5th edition), Behrouz Forouzan, McGraw Hill
- 6. TCP/IP Protocol Suite (4th edition), Behrouz Forouzan, McGraw Hill

# Expectations

- Smiling Face 
- Interactive Session
- Participation
- Enjoy the joy of learning

# Methodology

- Why
  - Need to learn
- What
  - Definition, Meaning, is all about
- How
  - Performance, Implementation, Simulation, Development

# Topics

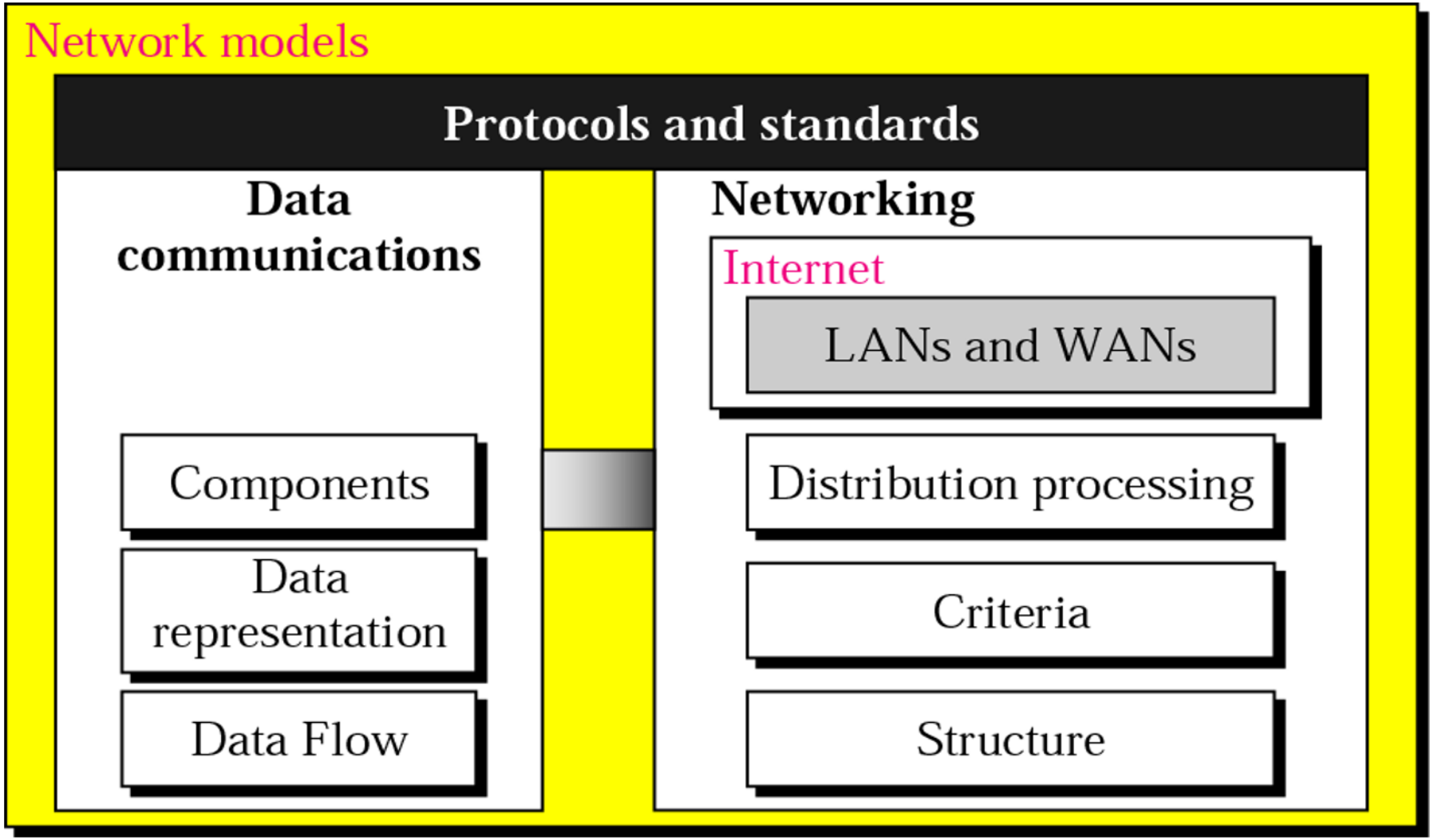
- Basic Understanding of Computer Network and Internet
- Transmission Media
- Switching Techniques
- Network Metrics
- Understanding of Delay, Loss and Throughput in the packet-switching network
- OSI Model
- TCP/IP Model.
- The network edge, The network Core
- History of the computer network

# How We Communicate ?

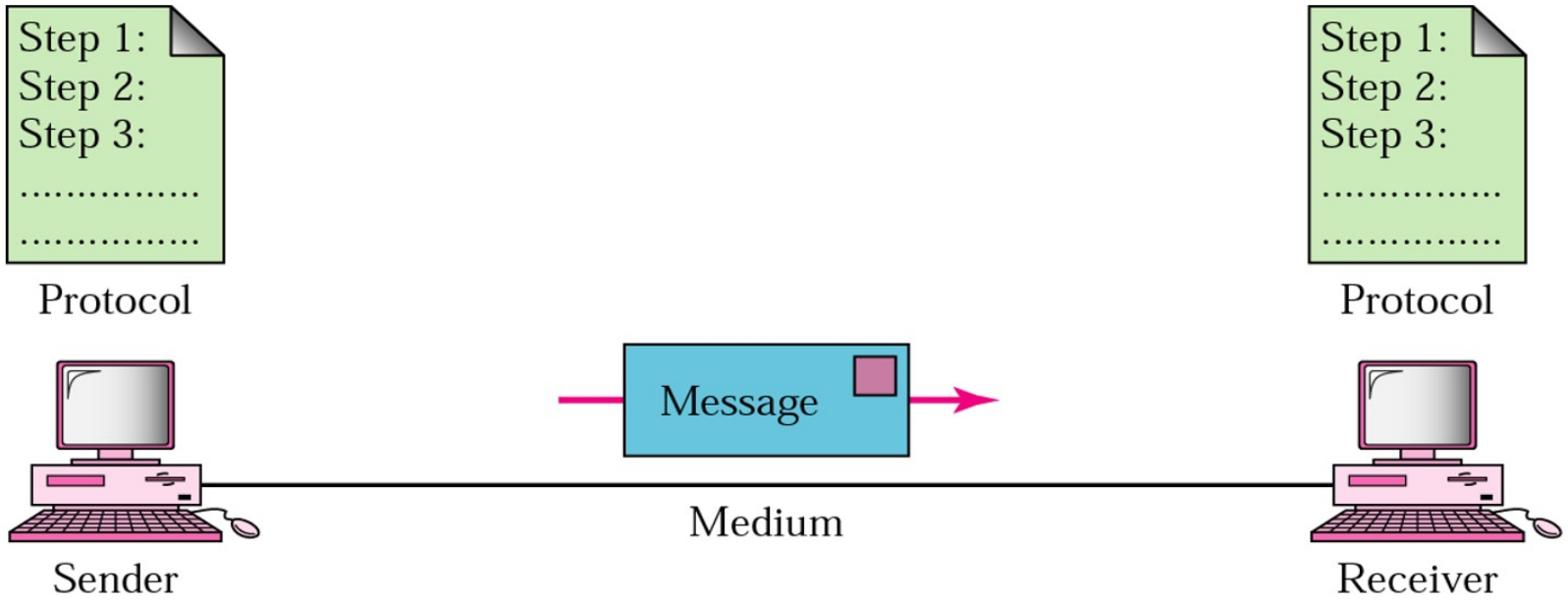
# DATA COMMUNIC--ATIONS

- *The term telecommunication means communication at a distance.*
- *The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.*
- *Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.*

# Network Model



# Similar Way, Computer, Component of Data Communication



# THE INTERNET

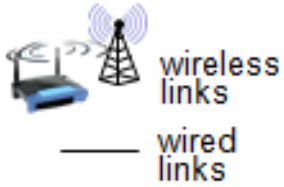
- *The Internet has revolutionized many aspects of our daily lives. It has affected the way we do business as well as the way we spend our leisure time.*

- *The Internet is a communication system that has brought a wealth of information to our fingertips and organized it for our use*

# What is the Internet?

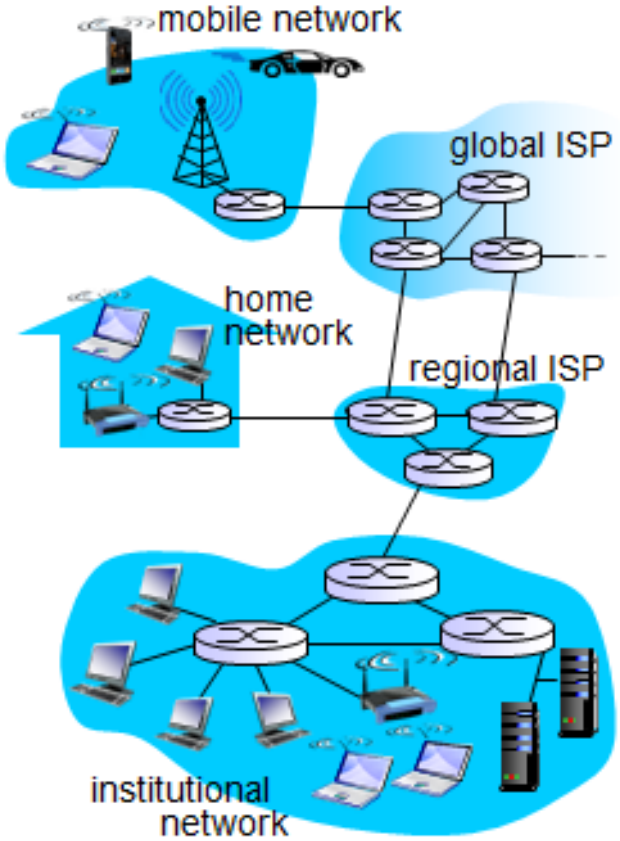
## What's the Internet: "nuts and bolts" view


- millions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*




- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

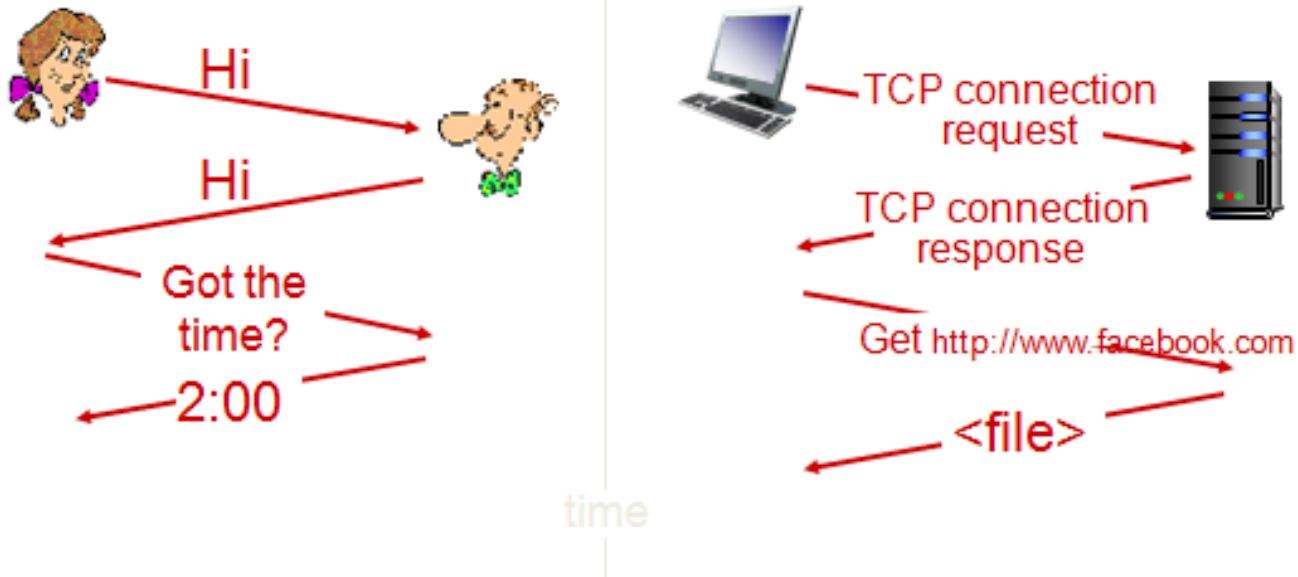

- *Packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



# Protocols

## Protocols

a human protocol and a computer network protocol:




*Protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt*

# Data Transmission Modes or Data flow

- **Data Transmission mode defines the direction of the flow of information between two communication devices. It is also called Data Communication or Directional Mode.**
- It specifies the direction of the flow of information from one place to another in a computer network.
- data transmission modes based on the direction of exchange, synchronization between the transmitter and receiver, and the number of bits sent simultaneously in a computer network.

# Data Transmission Modes or Data flow

The data transmission modes can be characterized in the following three types based on the direction of exchange of information:

1. Simplex
2. Half-Duplex
3. Full Duplex

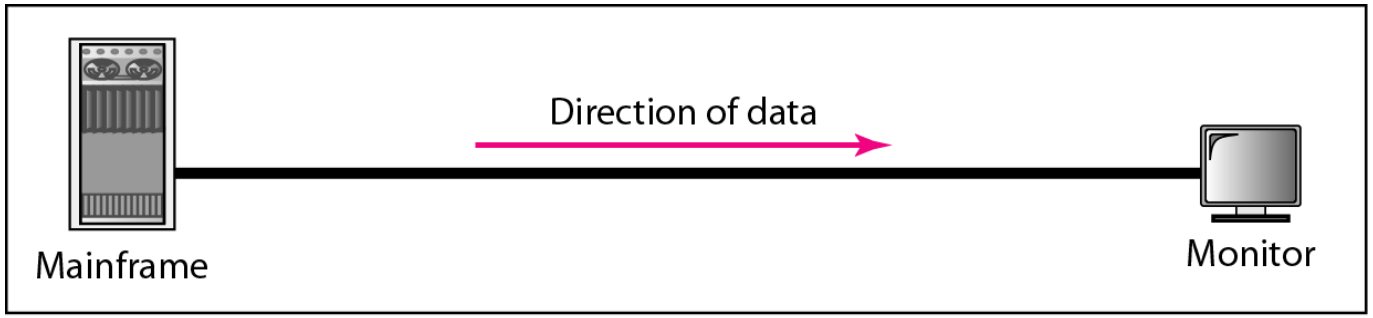
The data transmission modes can be characterized in the following two types based on the synchronization between the transmitter and the receiver:

1. Synchronous
2. Asynchronous

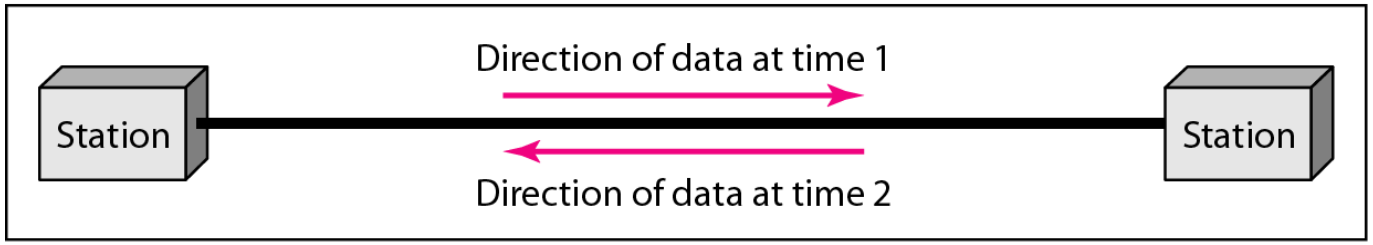
The data transmission modes can be characterized in the following two types based on the number of bits sent simultaneously in the network:

1. Serial (RS 232 protocol)
2. Parallel (IEEE 488 protocol)

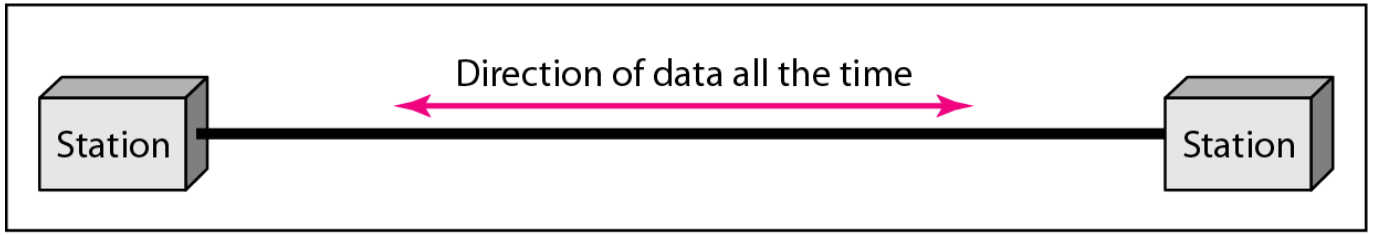
# Data Transmission Modes or Data flow




a. Simplex




b. Half-duplex

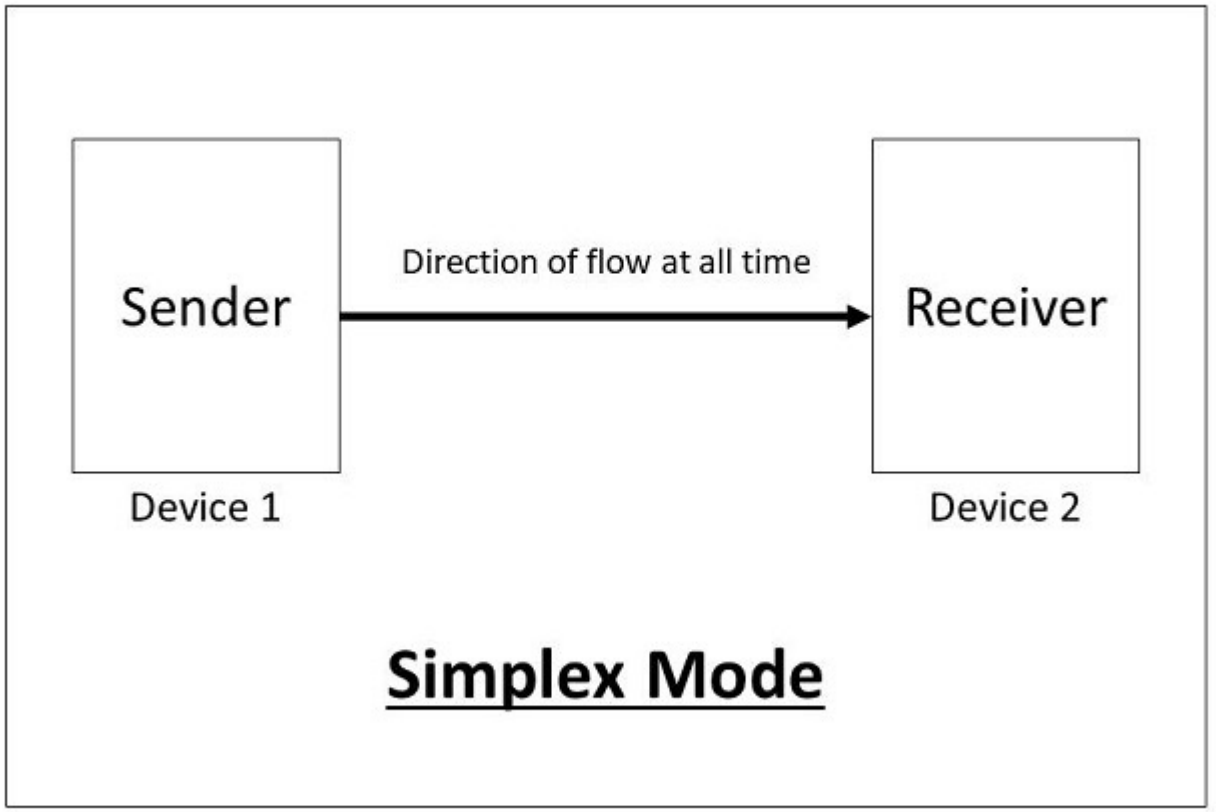



c. Full-duplex

# Simplex

- In simplex mode, the communication is unidirectional, as on a one-way street.
- Only one of the two devices on a link can transmit; the other can only receive.
- Keyboards and traditional monitors are examples of simplex devices. The keyboard can only introduce input; the monitor can only accept output.
- The simplex mode can use the entire capacity of the channel to send data in one direction.

# Simplex


Sender
Direction of flow at all time
Receiver
Device 1
Device 2
Simplex Mode

# Advantages and Disadvantages

- Following are the **advantages** of using a Simplex transmission mode:

- It utilizes the full capacity of the communication channel during data transmission.
- It has the least or no data traffic issues as data flows only in one direction.

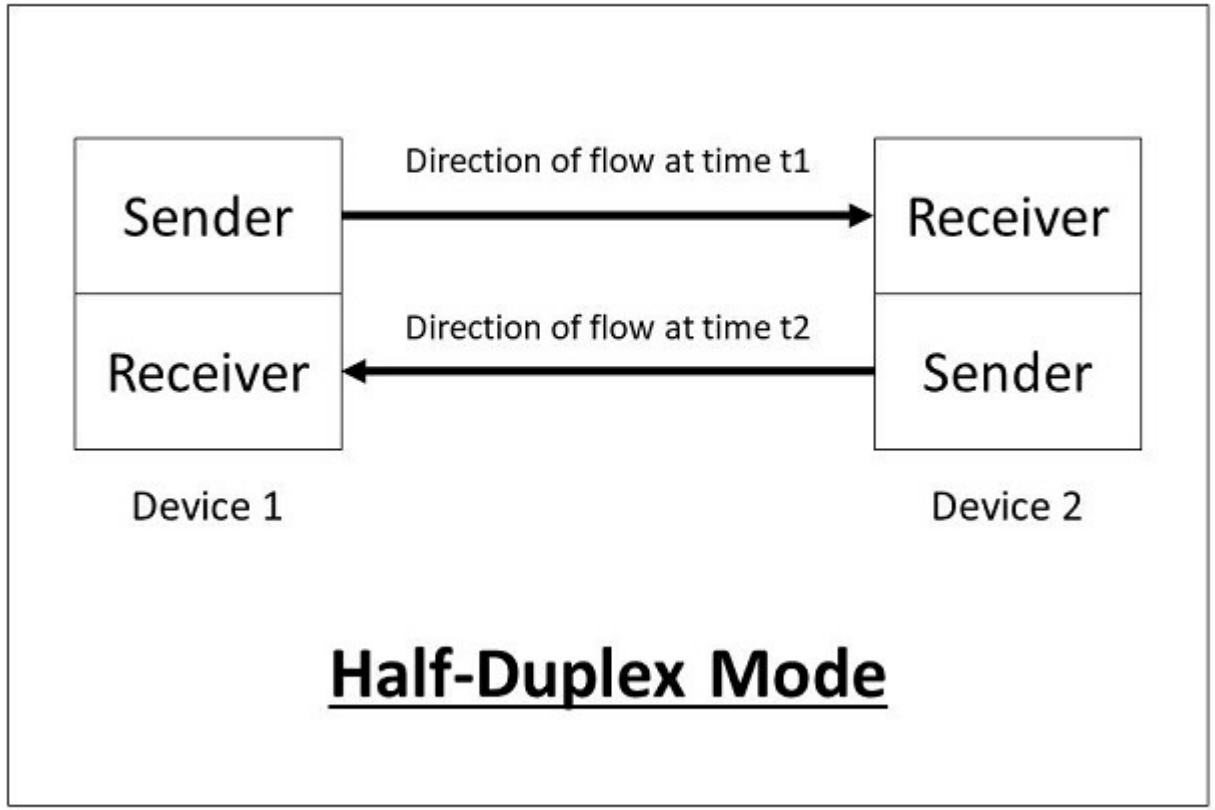
- Following are the **disadvantages** of using a Simplex transmission mode:

- It is unidirectional in nature having no inter-communication between devices.
- There is no mechanism for information to be transmitted back to the sender(No mechanism for acknowledgement).

# Half-Duplex

- In half-duplex mode, each station can both transmit and receive, but not at the same time.
- When one device is sending, the other can only receive, and vice versa.
- The half-duplex mode is like a one-lane road with traffic allowed in both directions.
- When cars are traveling in one direction, cars going the other way must wait.
- In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.
- Walkie-talkies are half-duplex system.

# Half Duplex


Sender
Direction of flow at time t1
Receiver
Receiver
Direction of flow at time t2
Sender
Device 1
Device 2
Half-Duplex Mode

# Advantages and Disadvantages

Following are the **advantages** of using a half-duplex transmission mode:

- It facilitates the optimum use of the communication channel.
- It provides two-way communication.

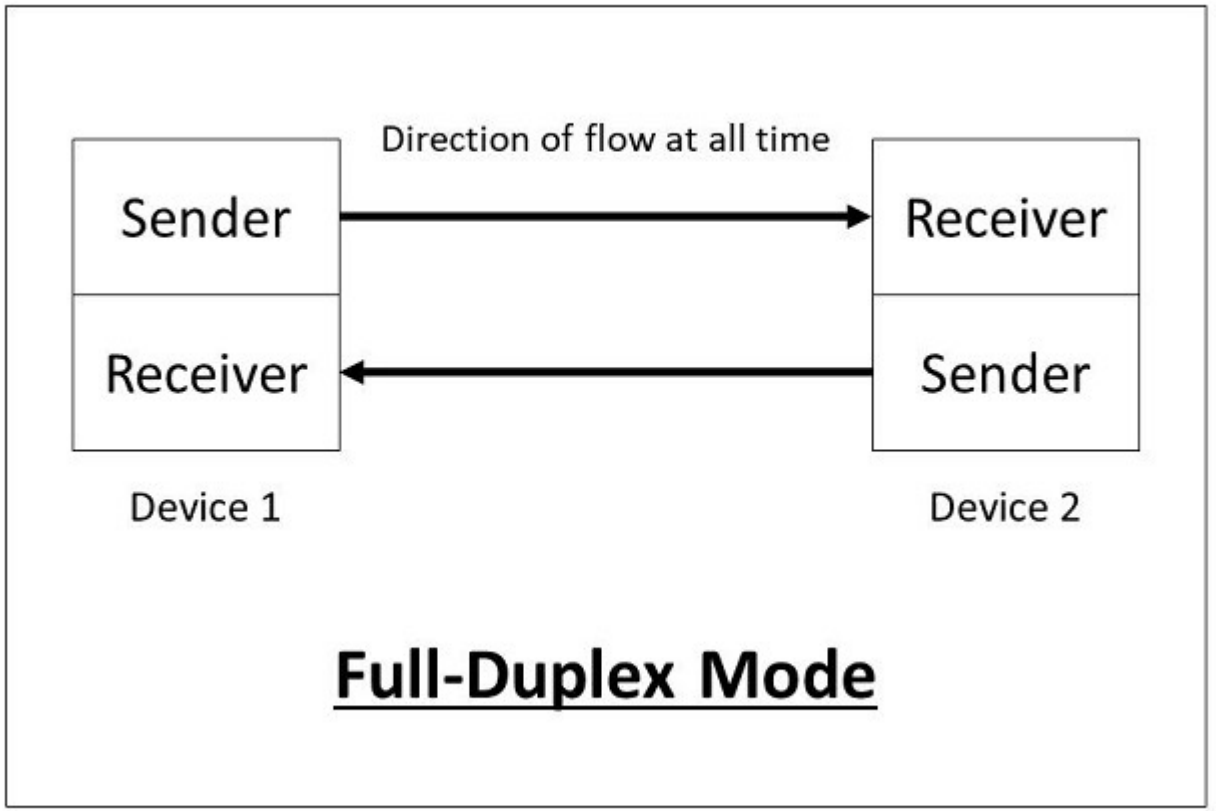
Following are the **disadvantages** of using a half-duplex transmission mode:

- The two-way communication can not be established simultaneously at the same time.
- Delay in transmission may occur as only one way communication can be possible at a time.

# Full-Duplex

- In full-duplex mode (also called duplex), both stations can transmit and receive simultaneously.
- The full-duplex mode is like a two-way street with traffic flowing in both directions at the same time.
- In full-duplex mode, signals going in one direction share the capacity of the link: with signals going in the other direction.
- This sharing can occur in two ways: Either the link must contain two physically separate transmission paths, one for sending and the other for receiving; or the capacity of the channel is divided between signals traveling in both directions.

# Full Duplex


Direction of flow at all time
Sender
Receiver
Receiver
Sender
Device 1
Device 2
Full-Duplex Mode

# Advantages and Disadvantages

**Following are the advantages of using a full-duplex transmission mode:**

- The two-way communication can be carried out simultaneously in both directions.
- It is the fastest mode of communication between devices.

**Following are the disadvantages of using a half-duplex transmission mode:**

- The capacity of the communication channel is divided into two parts. Also, no dedicated path exists for data transfer.
- It has improper channel bandwidth utilization as there exist two separate paths for two communicating devices.

# Data Representation

- Information today comes in different forms such as:

- Text
- Numbers
- Images
- Audio
- Video.

# Quiz

Which of the following 'pieces' of the Internet is a host (or end system)?

1. A modem
2. A router
3. An ISP
4. A Smartphone

# Network Metrics

- Metrics are a quantitative and qualitative way to verify a desired behaviour.
- For instance many operators like to measure their "uptime", a count of how often services are available for users.
- Network metrics are similar, and are related to desired outcomes.
- **Network capacity** can be described as "how much" traffic can cross a given link, segment, or aggregated path.
- **Network utilization** is a measurement of how much of the capacity is currently in use.

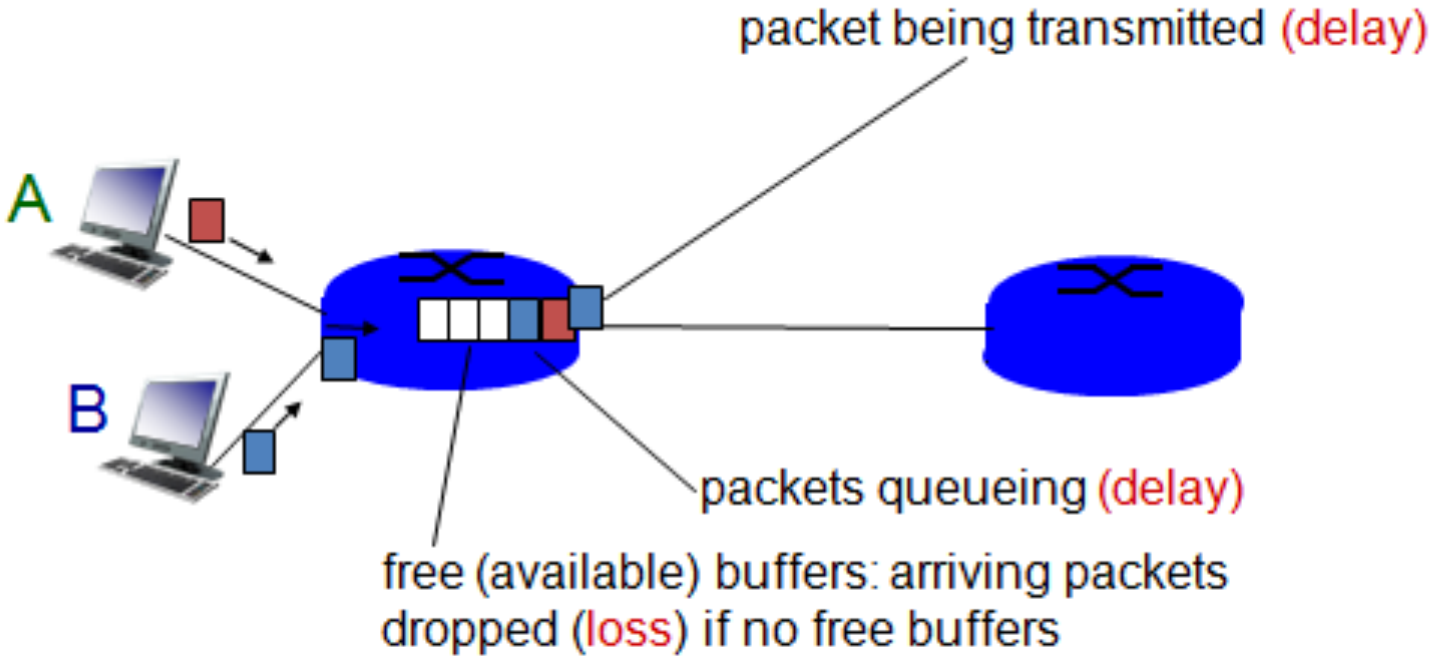
# Network Metrics

- Computer networks necessarily constrain **Throughput** (the amount of data per second that can be transferred) between end systems.
- Introduce delays between end systems and can actually lose packets.
- Delay
- Loss
- Throughput

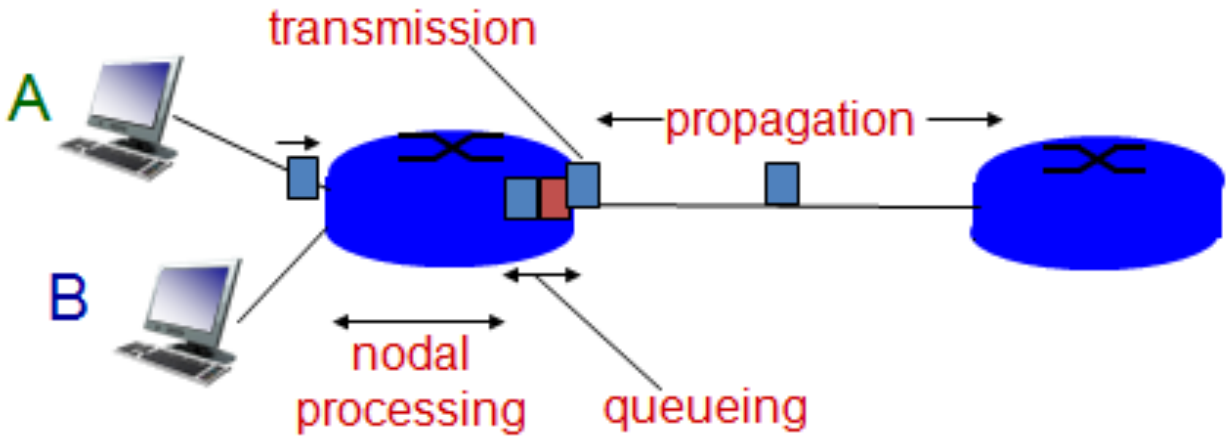
# How do loss and delay occur ?

## Packets *queue* in router buffers

- packet arrival rate to link (temporarily) exceeds output link capacity
- packets queue, wait for turn



# Sources of Packet Delay




$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

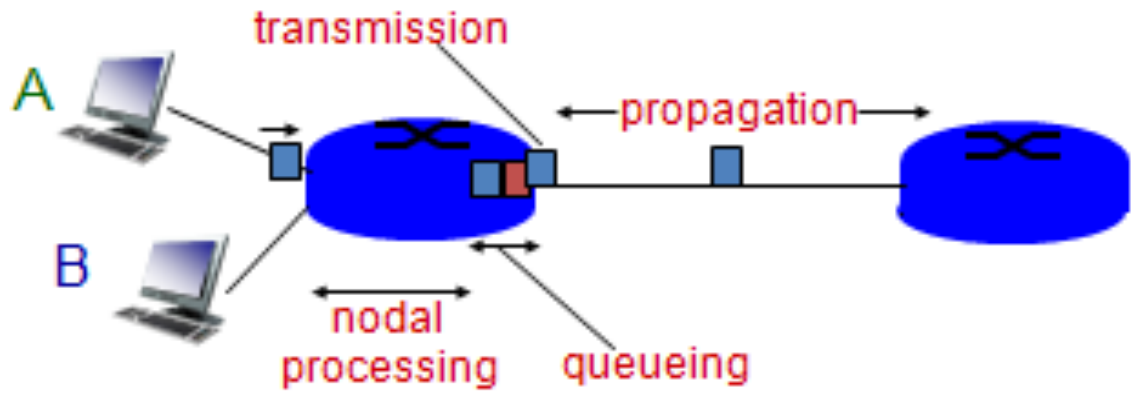
## $d_{proc}$: nodal processing

- check bit errors
- determine output link
- typically < msec

## $d_{queue}$: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

# Sources of Packet Delay




$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

$d_{trans}$: transmission delay:

- $L$: packet length (bits)
- $R$: link *bandwidth (bps)*
- $d_{trans} = L/R$

$d_{prop}$: propagation delay:

- $d$: length of physical link
- $s$: propagation speed in medium ($\sim 2 \times 10^8$ m/sec)
- $d_{prop} = d/s$

# Quiz

- How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed $2.5 * 10^8$ m/s, and transmission rate 2 Mbps?

# Answer

- 10msec;  d/s;

# Step-by-step-solution

**Step 1** of 5

Consider the given data:

Length of the packet $= 1000 \text{bytes}$

$= 1000 \times 8 \text{ bits}$

$= 8000 \text{ bits}$

Distance of the link $= 2500 \text{ km}$

$= 2500 \times 1000 \text{ m}$

$= 2500000 \text{ m}$

Propagation speed $= 2.5 \times 10^8 \text{m/s}$

Transmission rate $= 2\text{Mbps}$

Calculate the time taken by a packet to propagate by using propagation time formula.

$$\text{Propagation time} = \frac{\text{Distance of the link}}{\text{Propagation speed}}$$

$$= \frac{2500000\ \text{m}}{2.5 \times 10^8\ \text{m/sec}}$$

$$= \frac{2500000\ \text{sec}}{250000000}$$

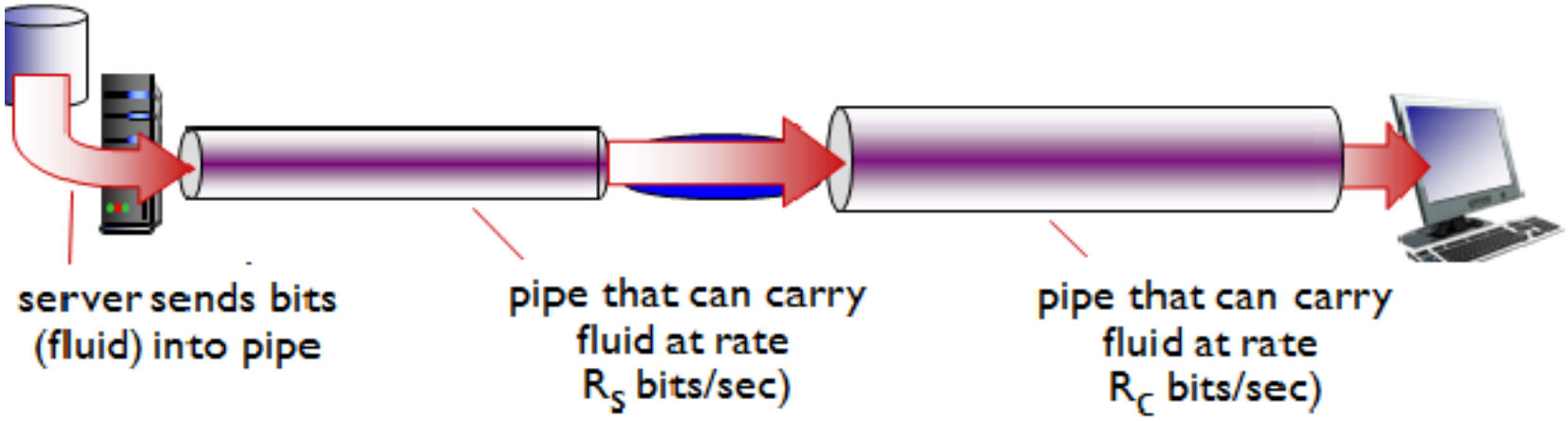
$$= 0.01\ \text{sec}$$

$$= 10\ \text{msec}$$

Therefore, the time taken for a packet of length 1,000 bytes to propagate over a link of distance 2,500 km with propagation speed of 2.5 x $10^8$ and transmission rate of 2 Mbps is $\boxed{10\ \text{msec}}$ .

# Throughput

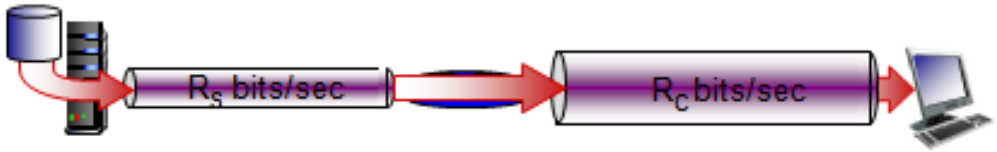
- Throughput: rate (bits/time unit) at which bits transferred between sender/receiver
  - instantaneous: rate at given point in time
  - average: rate over longer period of time



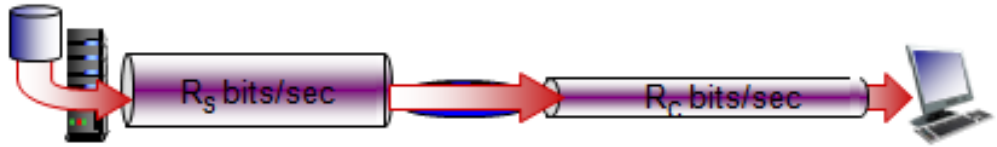
# Throughput

## Throughput

- $R_s < R_c$ What is average end-end throughput?




- $R_s > R_c$ What is average end-end throughput?




*bottleneck link*

link on end-end path that constrains end-end throughput

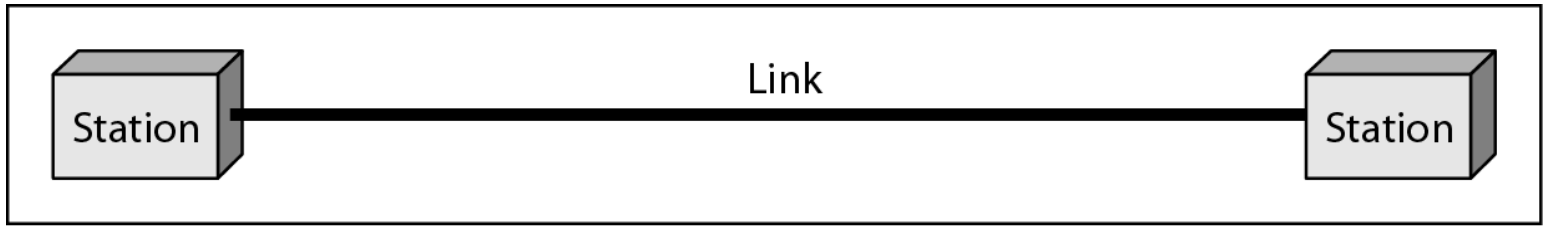
- The number of messages transferred successfully per unit of time is referred to as throughput. Throughput value depends upon many factors such as hardware capabilities, available signal-to-noise ratio, available bandwidth, etc.

- The maximal throughput of a computer network may be greater than the throughput achieved regularly. When various protocol costs are considered, the use rate of the transmitted data can be quite smaller than the maximum throughput achievable.

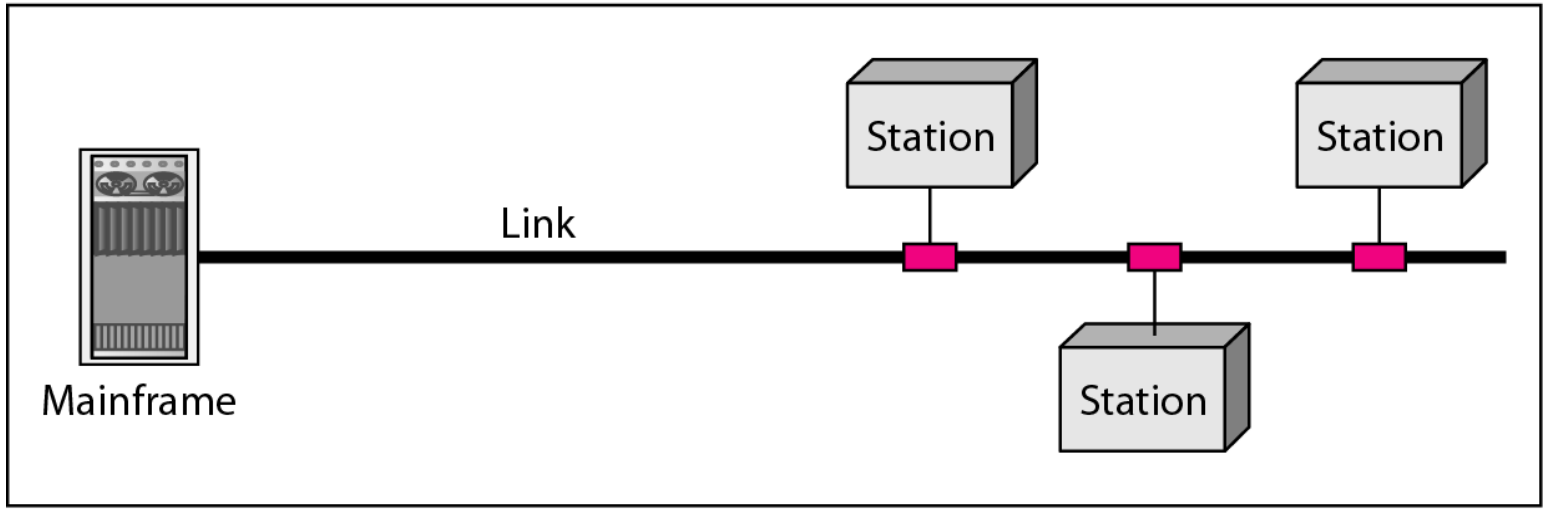
# NETWORKS

- A network is a set of devices (often referred to as nodes) connected by communication links.
- A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network.

# Types of connections: point-to-point and multipoint



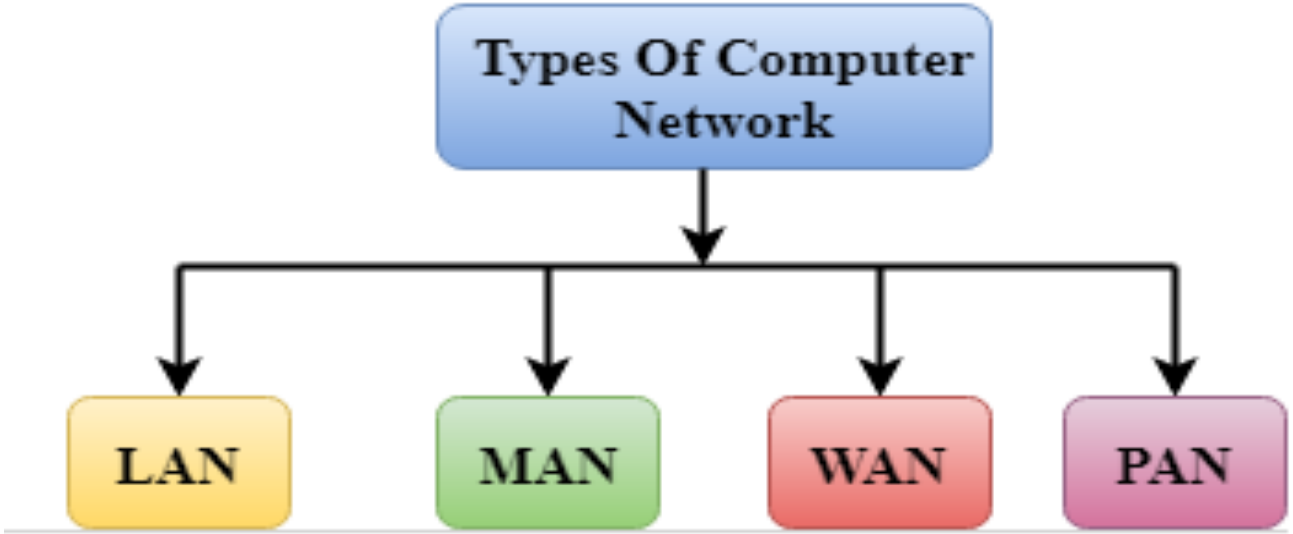

a. Point-to-point




b. Multipoint

# Types of Computer Network

A computer network can be categorized by their size.



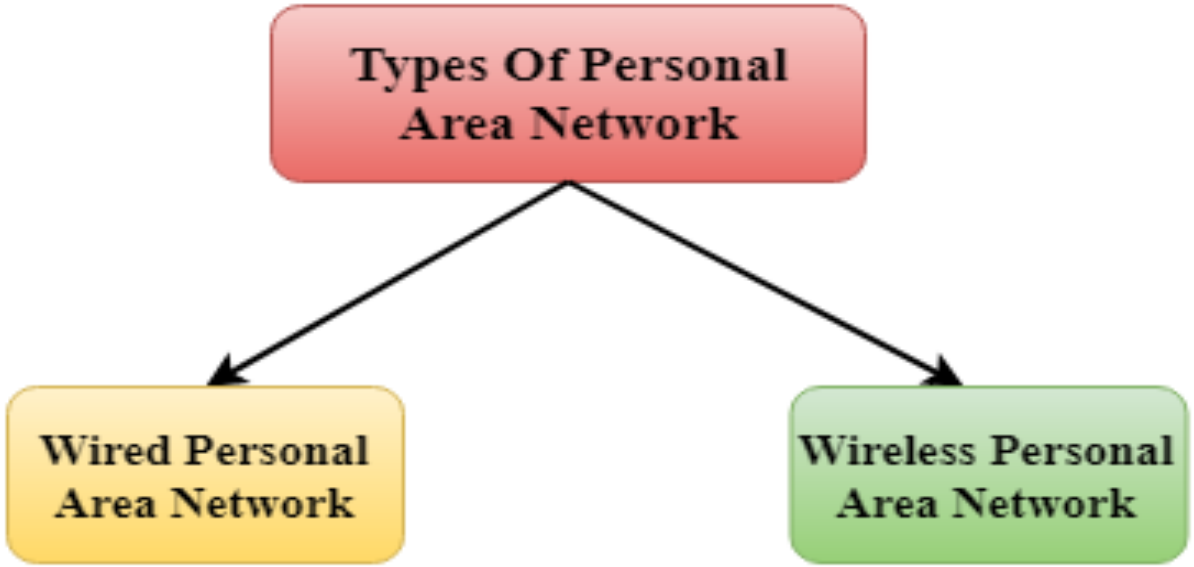
# LAN (LOCAL AREA NETWORK)

- Small Area network such as building, office
- Connecting two or more personal computers
- Less costly
- Data transfer is extremely faster
- Provides high security

# PAN (Personal Area Network )

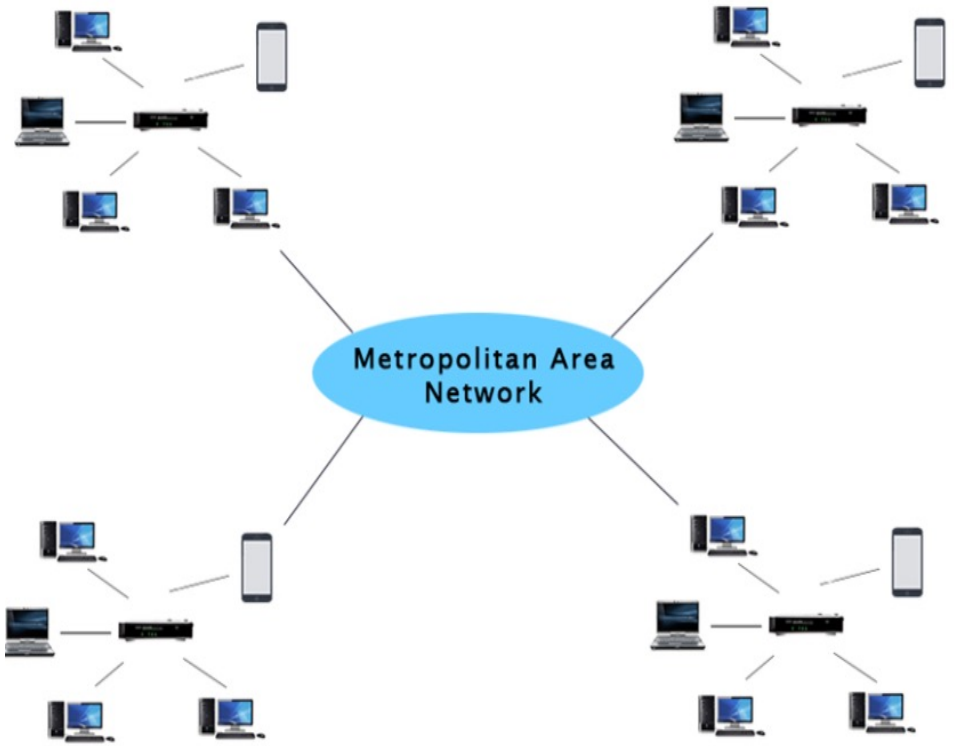
- Network arranged within an individual person.
- covers an area of 30 feet.
- Personal computer devices that are used to develop the personal area network are the laptop, mobile phones, media player and play stations.

# Types of Personal Area Network



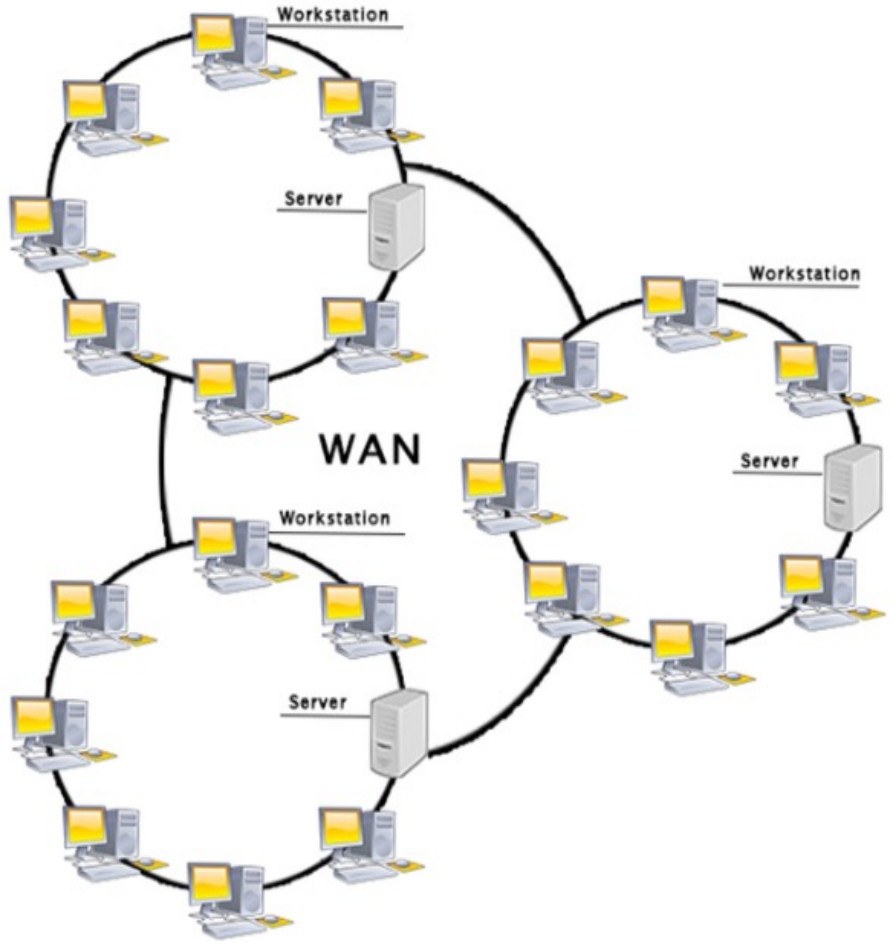
# MAN (Metropolitan Area Network)

- Covers a larger geographic area by interconnecting a different LAN to form a larger network.
- Government agencies use MAN.
- It has a higher range than Local Area Network(LAN).



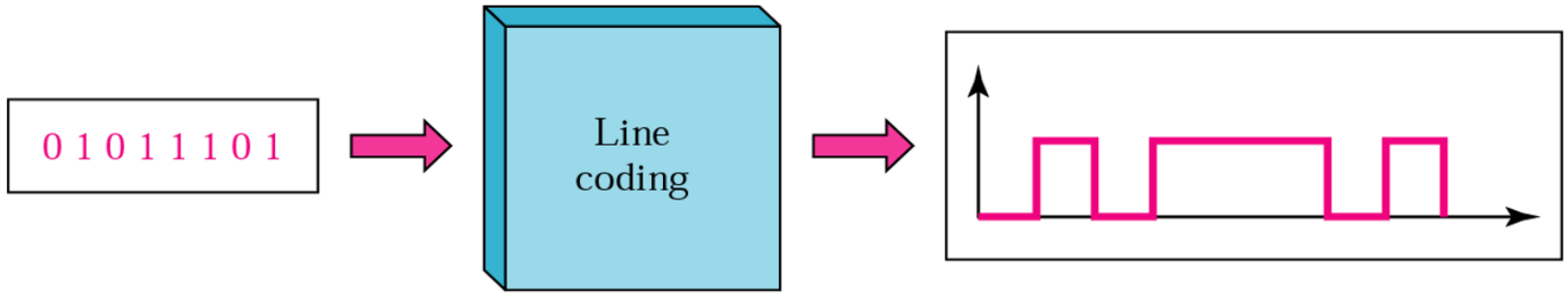
# WAN (Wide Area Network)

- Extends over a large geographical area such as states or countries.
- Quite bigger network than the LAN.
- Used in the field of Business, government, and education.



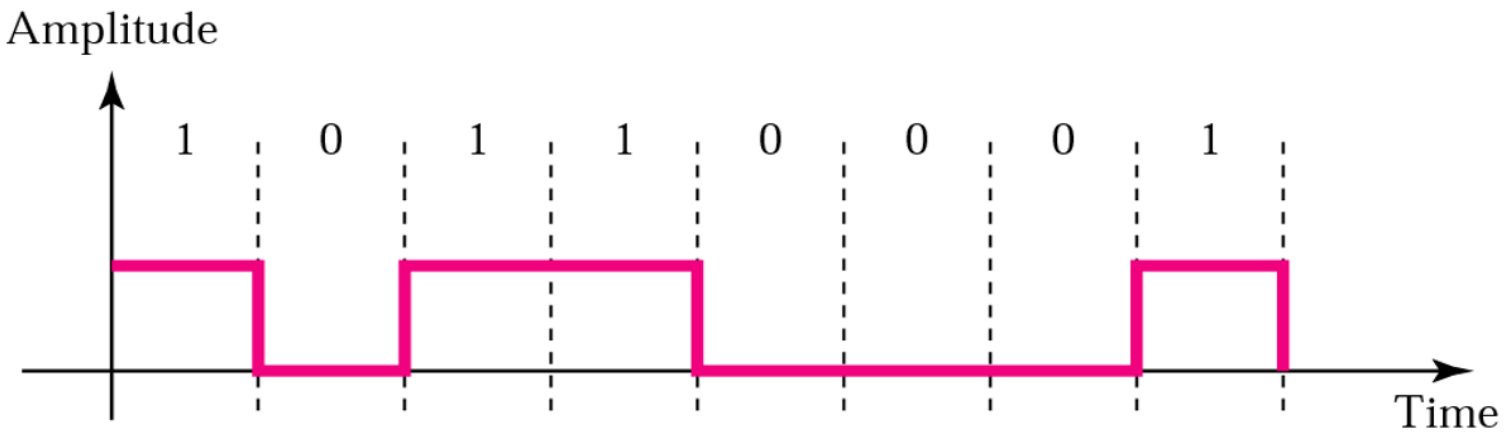
# Digital Transmission

## Line Coding

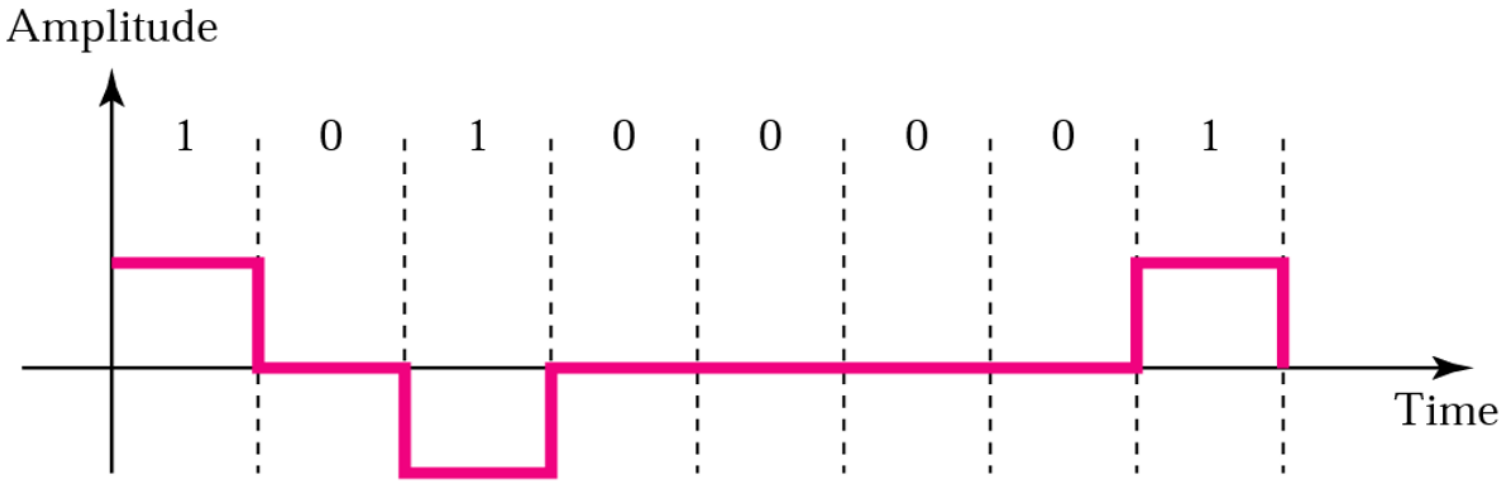


# Digital Transmission

## Signal Level Vs Data Level




a. Two signal levels, two data levels




b. Three signal levels, three data levels

# Numerical

A signal has two data levels with a pulse duration of 1 ms. We calculate the pulse rate and bit rate as follows:

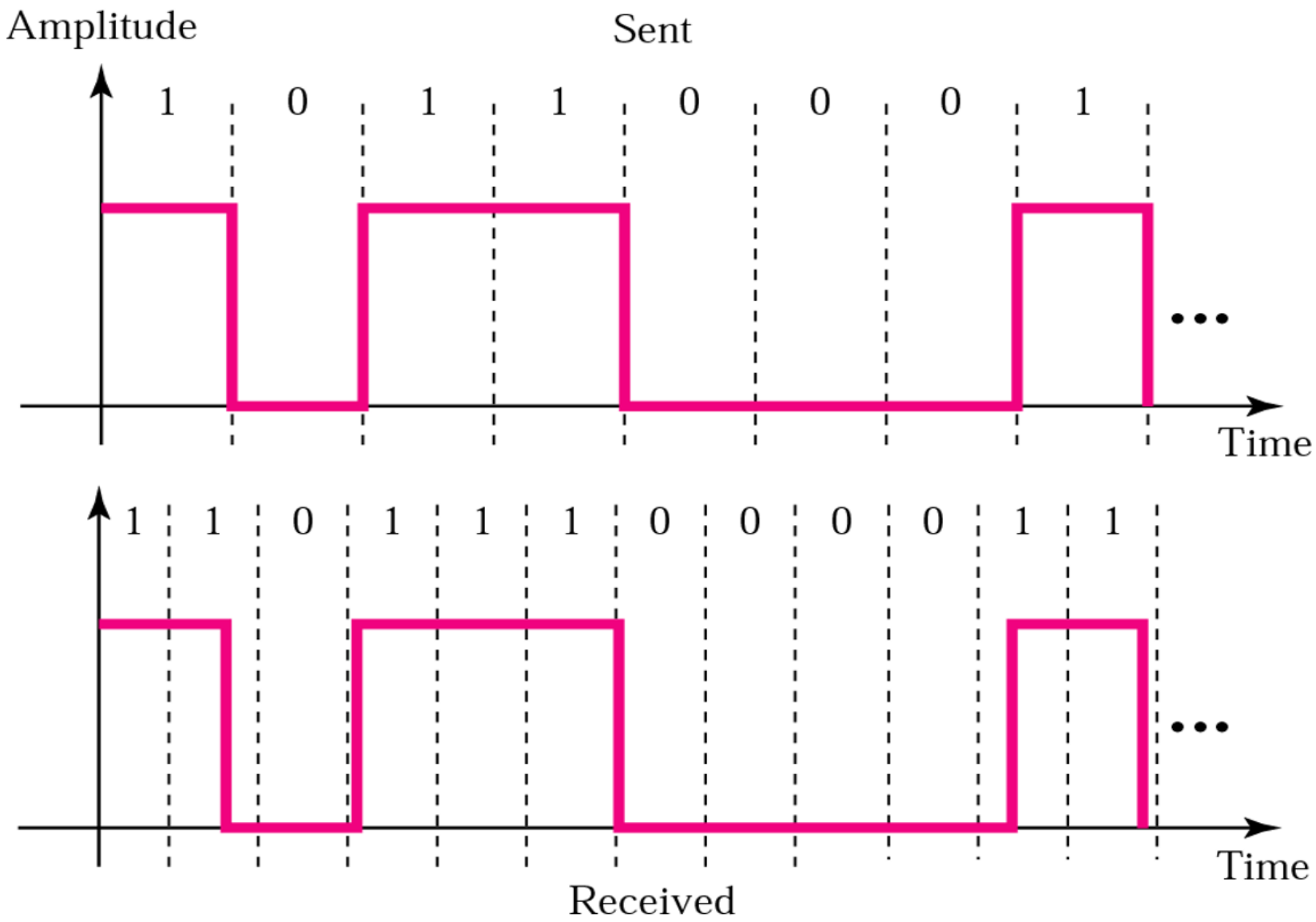
Pulse Rate = $1/10^{-3} = 1000$ pulses/s

Bit Rate = Pulse Rate x $\log_2 L = 1000 \times \log_2 2 = 1000$ bps

A signal has four data levels with a pulse duration of 1 ms. We calculate the pulse rate and bit rate as follows:

?????????

# Lack of Synchronization



# Numerical

In a digital transmission, the receiver clock is 0.1 percent faster than the sender clock. How many extra bits per second does the receiver receive if the data rate is 1 Kbps? How many if the data rate is 1 Mbps?

***Solution***

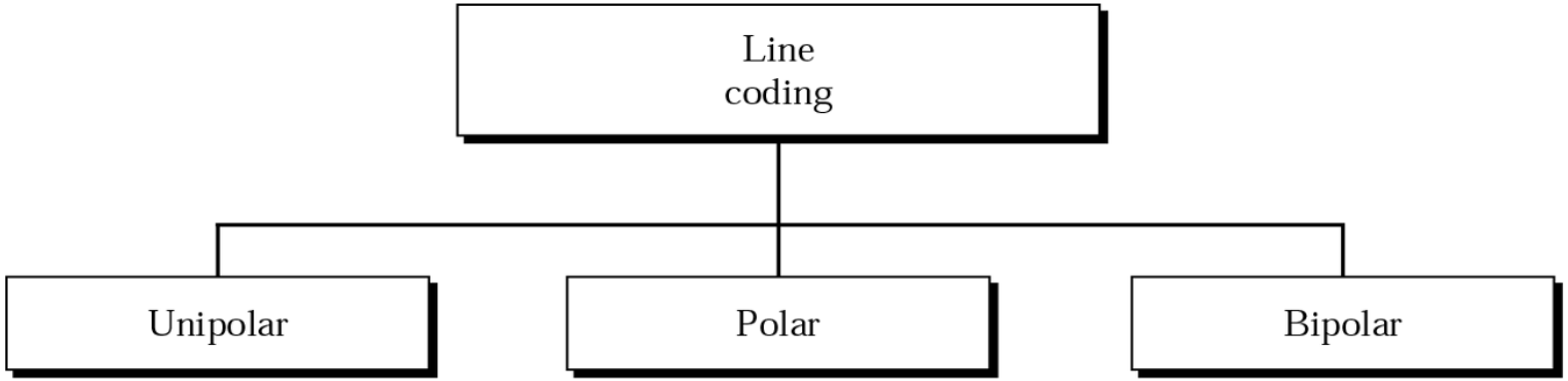
At 1 Kbps:

1000 bits sent ➔1001 bits received➔1 extra bps

At 1 Mbps:

1,000,000 bits sent ➔1,001,000 bits received➔1000 extra bps

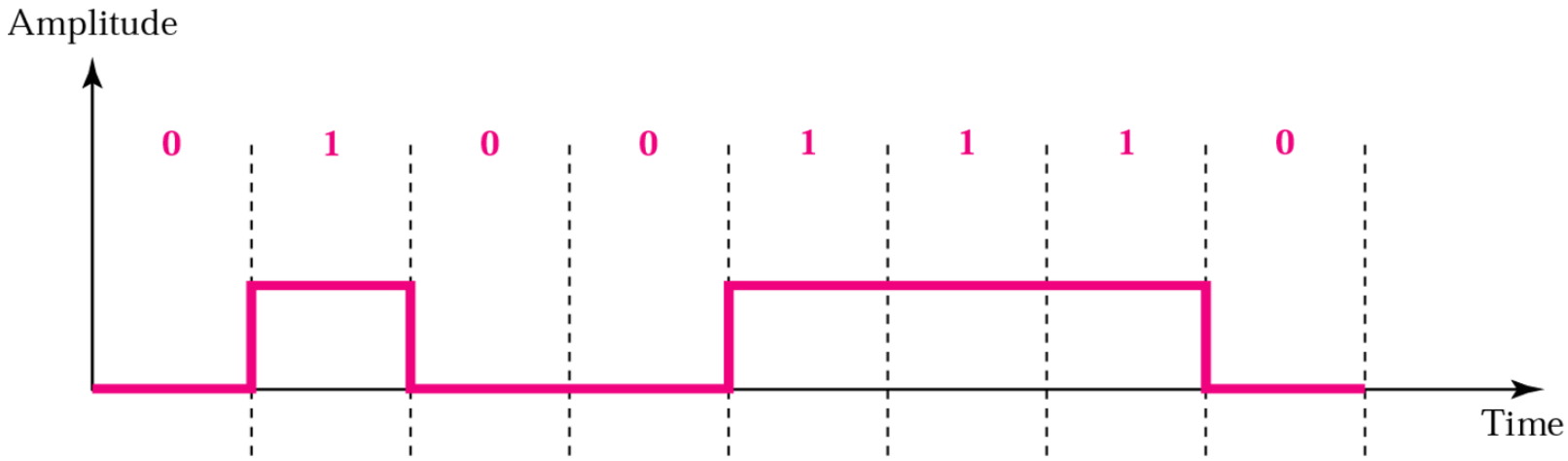
# Line Coding Scheme



# Unipolar

**Note:**

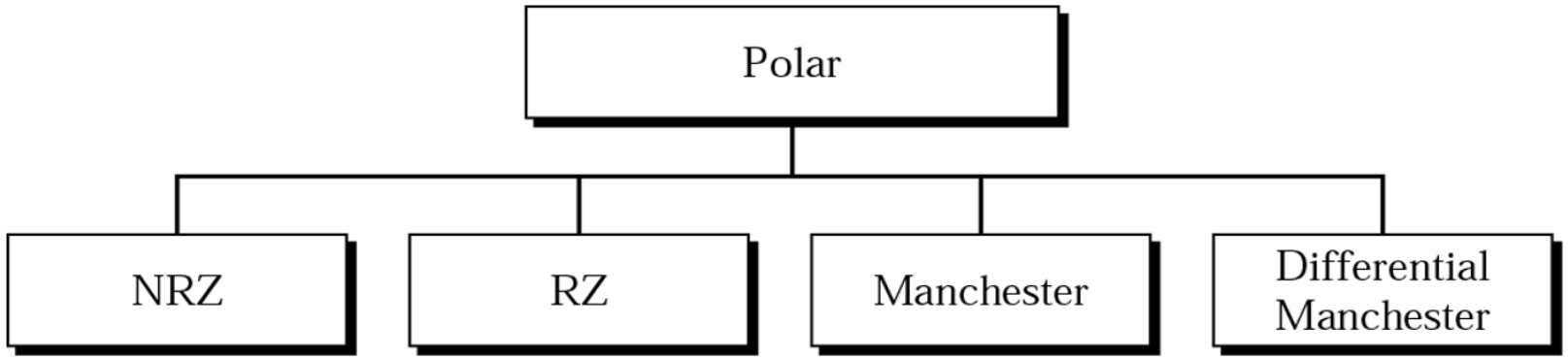
***Unipolar encoding uses only one voltage level.***



# Polar Encoding

**Note:**

***Polar encoding uses two voltage levels (positive and negative).***

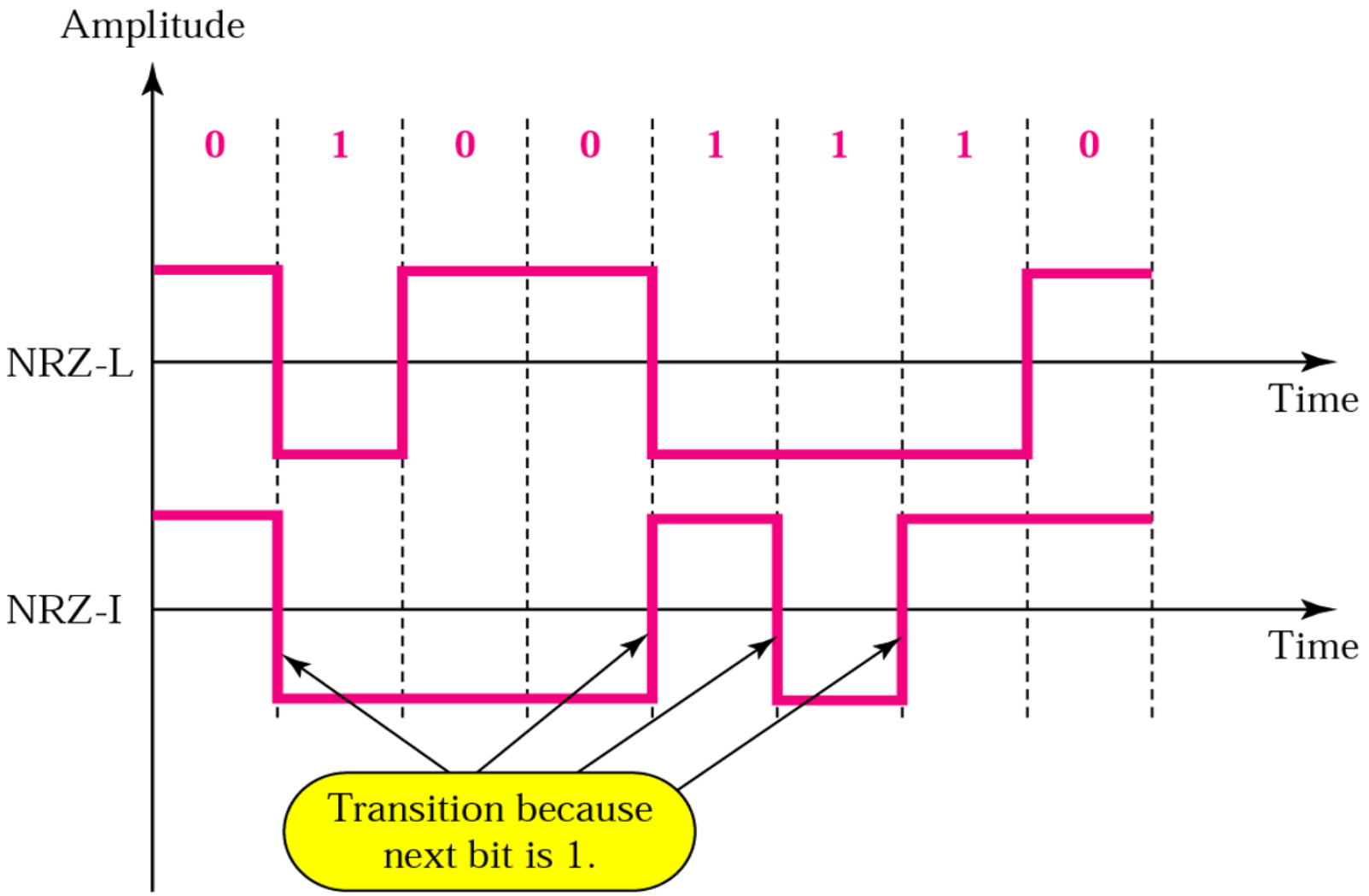


# NRZ-L, NRZ-I

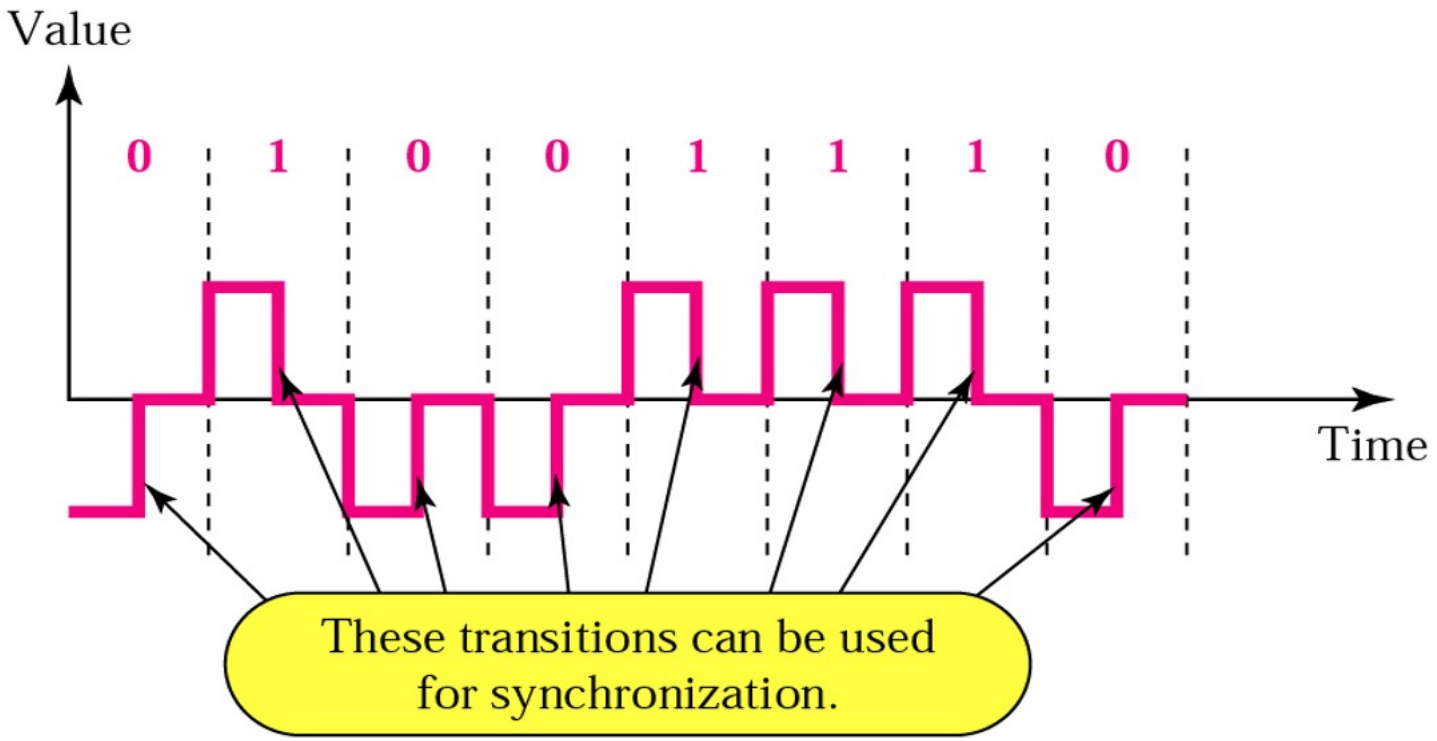

***In NRZ-L the level of the signal is dependent upon the state of the bit.***


***In NRZ-I the signal is inverted if a 1 is encountered.***

# NRZ-L, NRZ-I


Amplitude
0 1 0 0 1 1 1 0
NRZ-L
Time
NRZ-I
Time
Transition because next bit is 1.

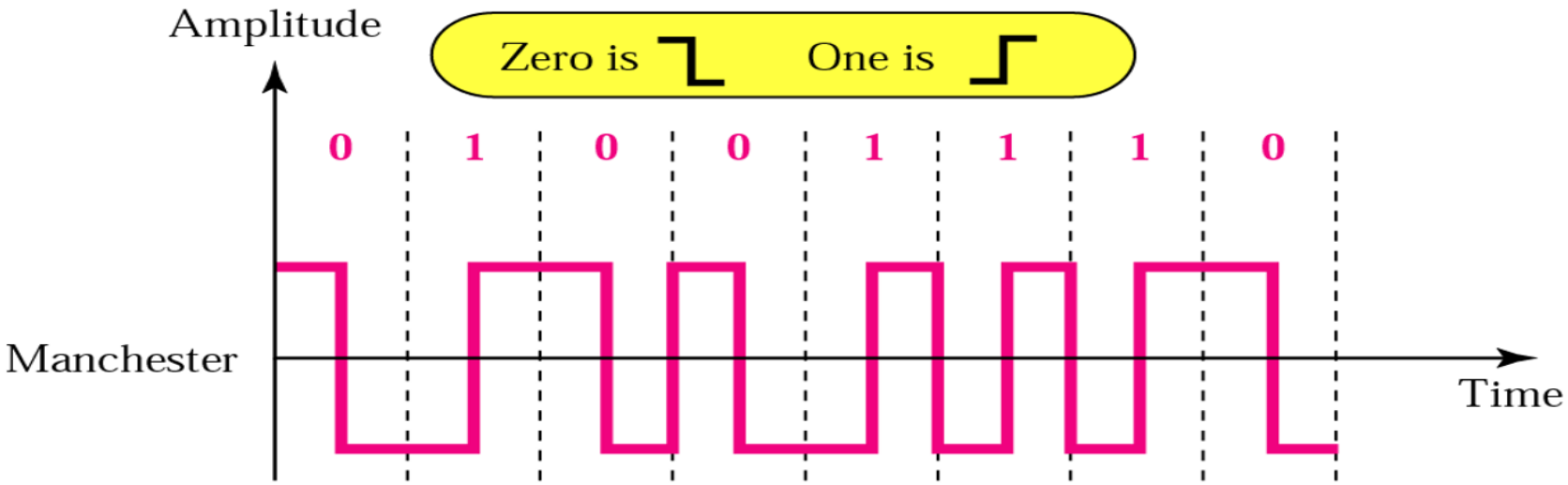
# RZ Encoding


Value
0
1
0
0
1
1
1
0
Time
These transitions can be used for synchronization.

# Manchester Encoding

**Note:**

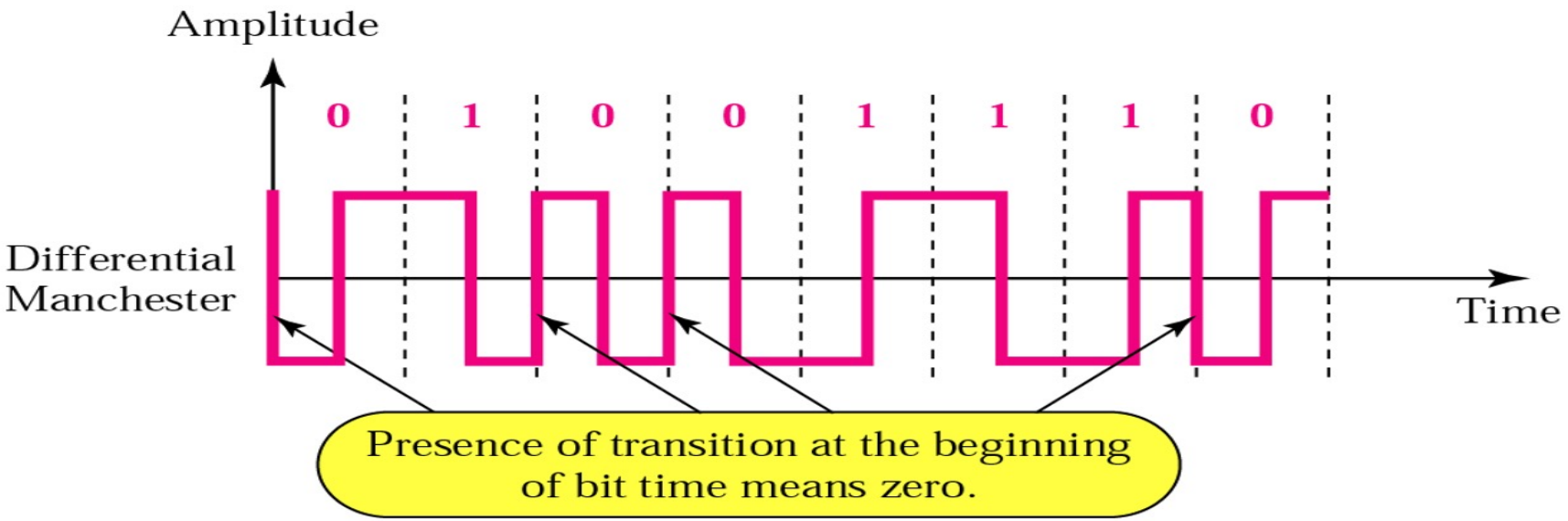
***In Manchester encoding, the transition at the middle of the bit is used for both synchronization and bit representation.***



# Differential Manchester Encoding

**Note:**

***In differential Manchester encoding, the transition at the middle of the bit is used only for synchronization. The bit representation is defined by the inversion or noninversion at the beginning of the bit.***



# Numerical

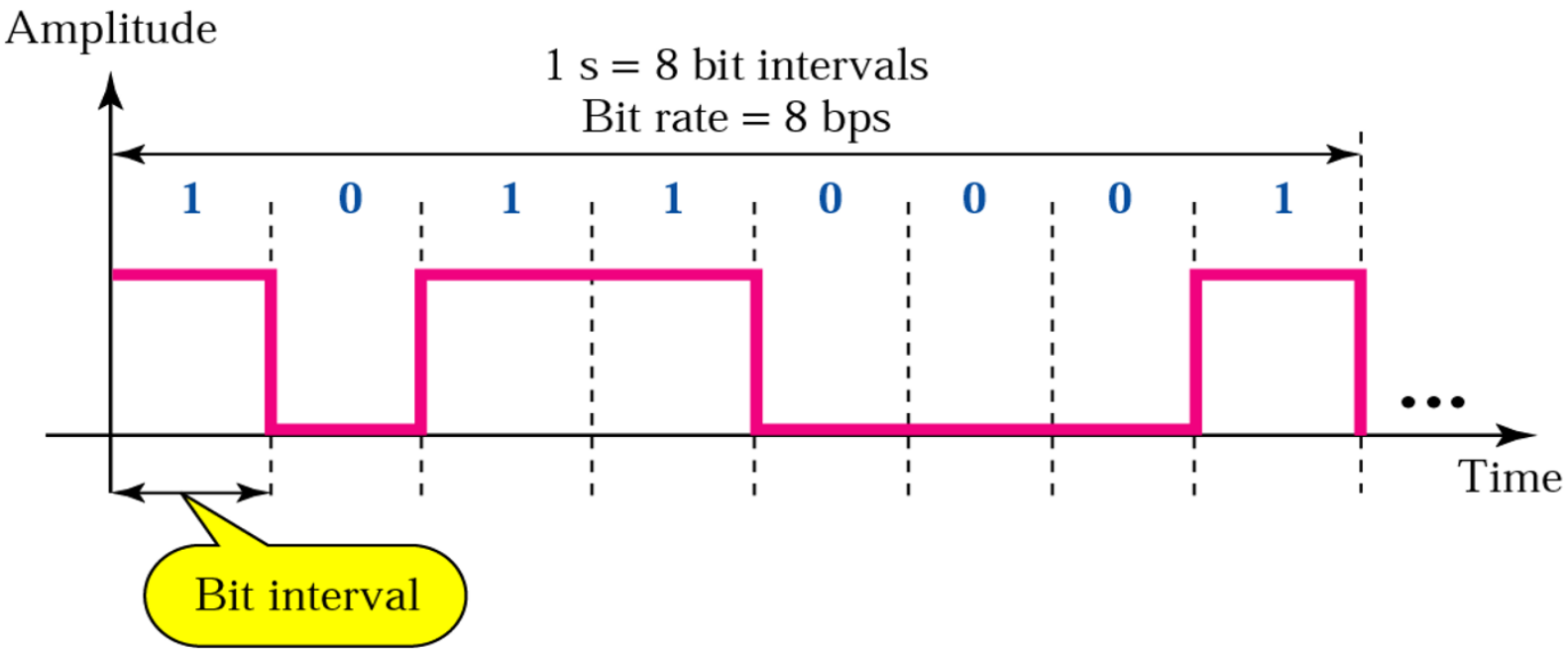
A digital signal has a bit rate of 2000 bps. What is the duration of each bit (bit interval)

**Solution**

The bit interval is the inverse of the bit rate.

Bit interval = 1/ 2000 s = 0.000500 s
= 0.000500 x $10^6$ μs = 500 μs

# Bit Rate and Bit Interval



# Numerical

Consider a noiseless channel with a bandwidth of 3000 Hz transmitting a signal with two signal levels. The maximum bit rate can be calculated as

$$\text{Bit Rate} = 2 \times 3000 \times \log_2 2 = 6000 \text{ bps}$$

Consider the same noiseless channel, transmitting a signal with four signal levels (for each level, we send two bits). The maximum bit rate can be calculated as:

$$\text{Bit Rate} = 2 \text{ x } 3000 \text{ x } \log_2 4 = 12{,}000 \text{ bps}$$

# Numerical

Consider an extremely noisy channel in which the value of the signal-to-noise ratio is almost zero. In other words, the noise is so strong that the signal is faint. For this channel the capacity is calculated as

$$C = B \log_2 (1 + SNR) = B \log_2 (1 + 0)$$

$$= B \log_2 (1) = B \times 0 = 0$$

We can calculate the theoretical highest bit rate of a regular telephone line. A telephone line normally has a bandwidth of 3000 Hz (300 Hz to 3300 Hz). The signal-to-noise ratio is usually 3162. For this channel the capacity is calculated as

$$C = B \log_2 (1 + SNR) = 3000 \log_2 (1 + 3162)$$
$$= 3000 \log_2 (3163)$$
$$C = 3000 \times 11.62 = 34{,}860 \text{ bps}$$

## Numerical

We have a channel with a 1 MHz bandwidth. The SNR for this channel is 63; what is the appropriate bit rate and signal level?

**Solution**

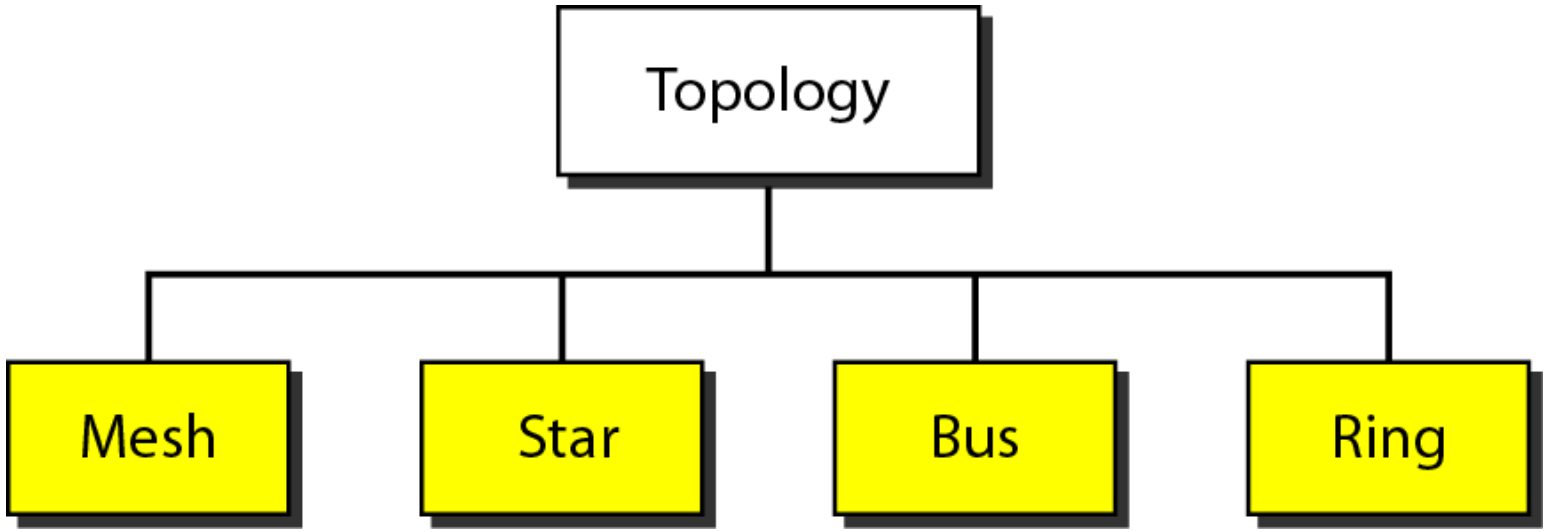
**First, we use the Shannon formula to find our upper limit.**

$$C = B \log_2 (1 + SNR) = 10^6 \log_2 (1 + 63) = 10^6 \log_2 (64) = 6 \text{ Mbps}$$

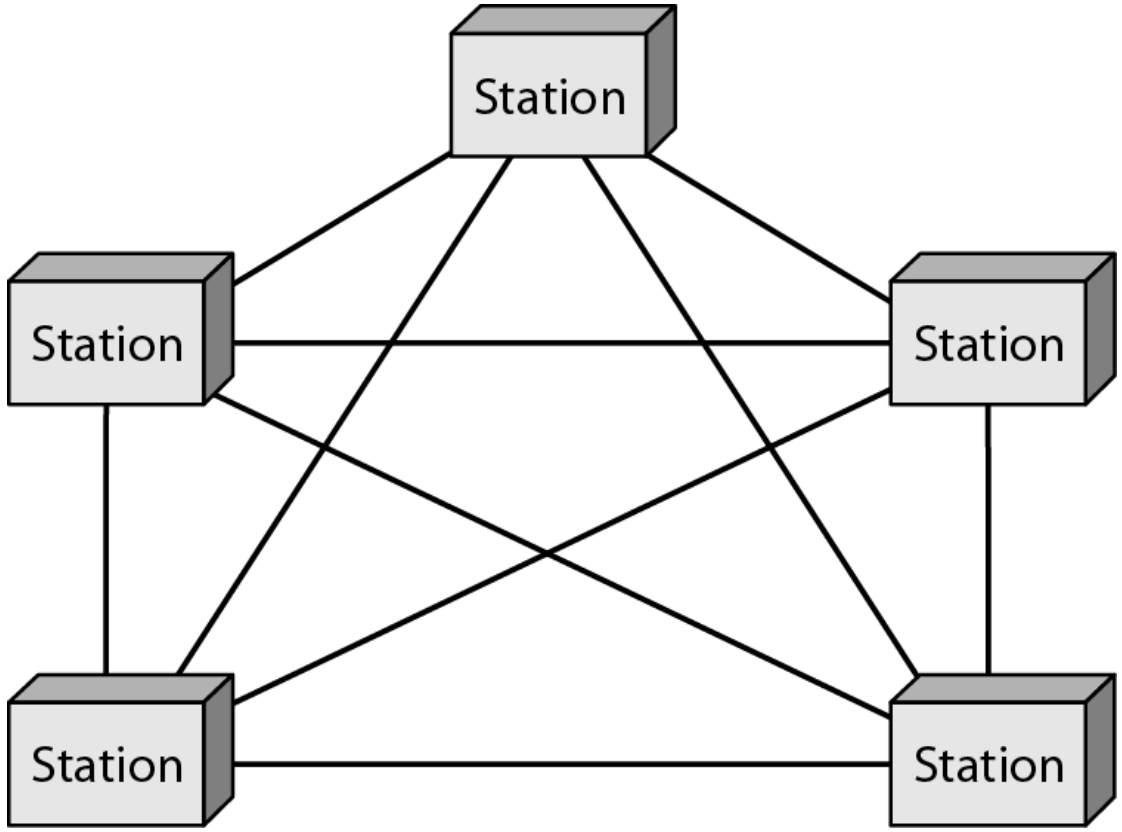
Then we use the Nyquist formula to find the number of signal levels.

$$4 \text{ Mbps} = 2 \times 1 \text{ MHz} \times \log_2 L \rightarrow L = 4$$

# Categories of Topology



# A fully connected mesh topology (five devices)




- Every device has a dedicated point to point link to every other device.
- Node 1 must connected to (n-1) nodes.
- Need n(n-1)/2 physical links……No. of wires.

# A fully connected mesh topology (five devices)

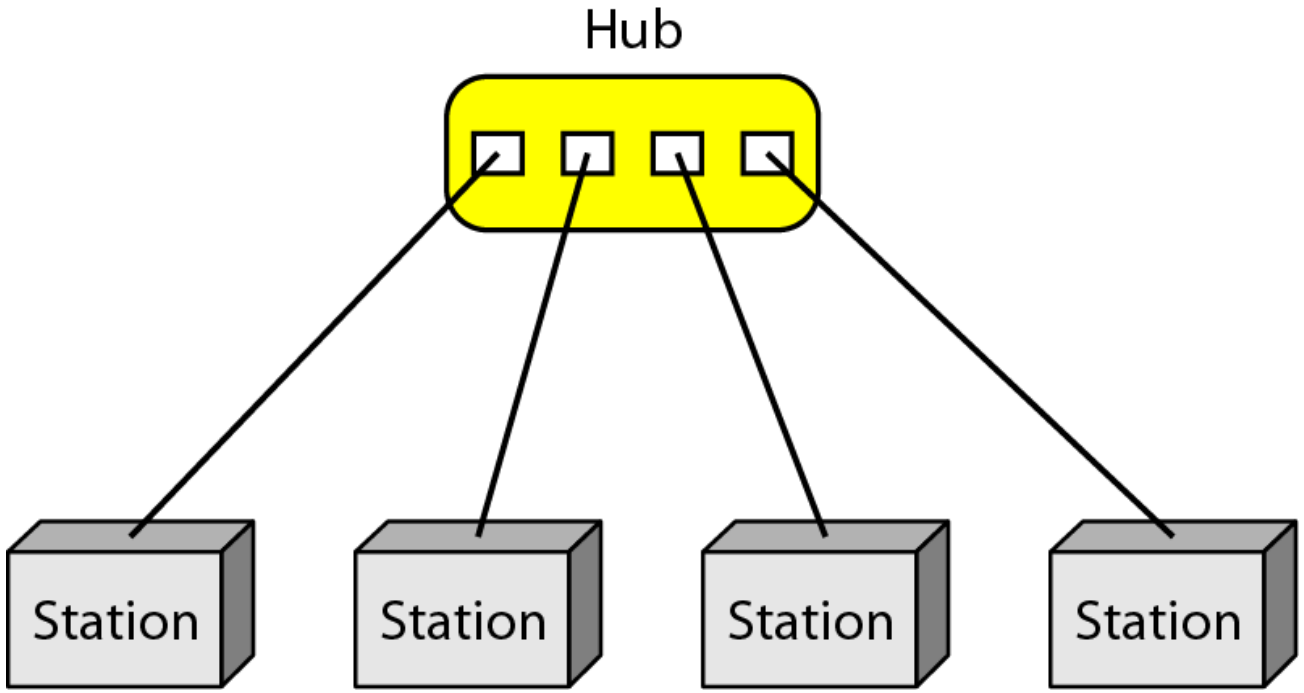
Advantages

- Eliminating the traffic problem.
- Robust
- Privacy and Security
- Fault Identification and Isolation easy

Disadvantage

- More Space
- More Wire
- Installation and Reconfiguration tough
- Expensive

# A star topology connecting four stations




- Every device has a dedicated point to point link to the Hub (Central Controller) .
- Works in LANs

# A star topology connecting four stations

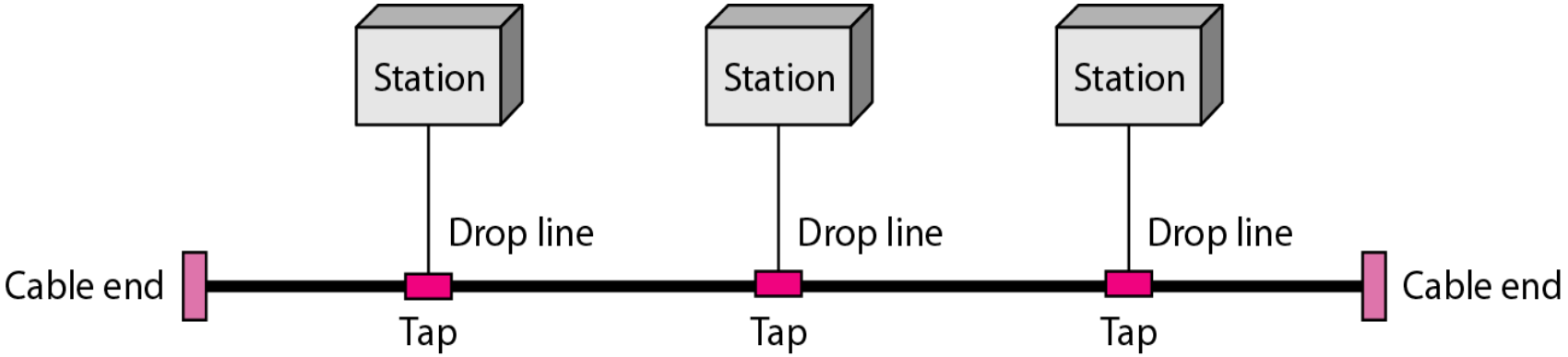
Advantages

- Less expensive than Mesh Topology.
- Installation and Reconfiguration Easy
- Robust
- Less cable than Mesh Topology.
- Fault Identification and Isolation easy

Disadvantage

- Hub is damage, then work is stop.

# A bus topology connecting three stations




- Use Multipoint Connection.
- Use long cable acts as a backbone.
- Ethernet LANs use this topology.

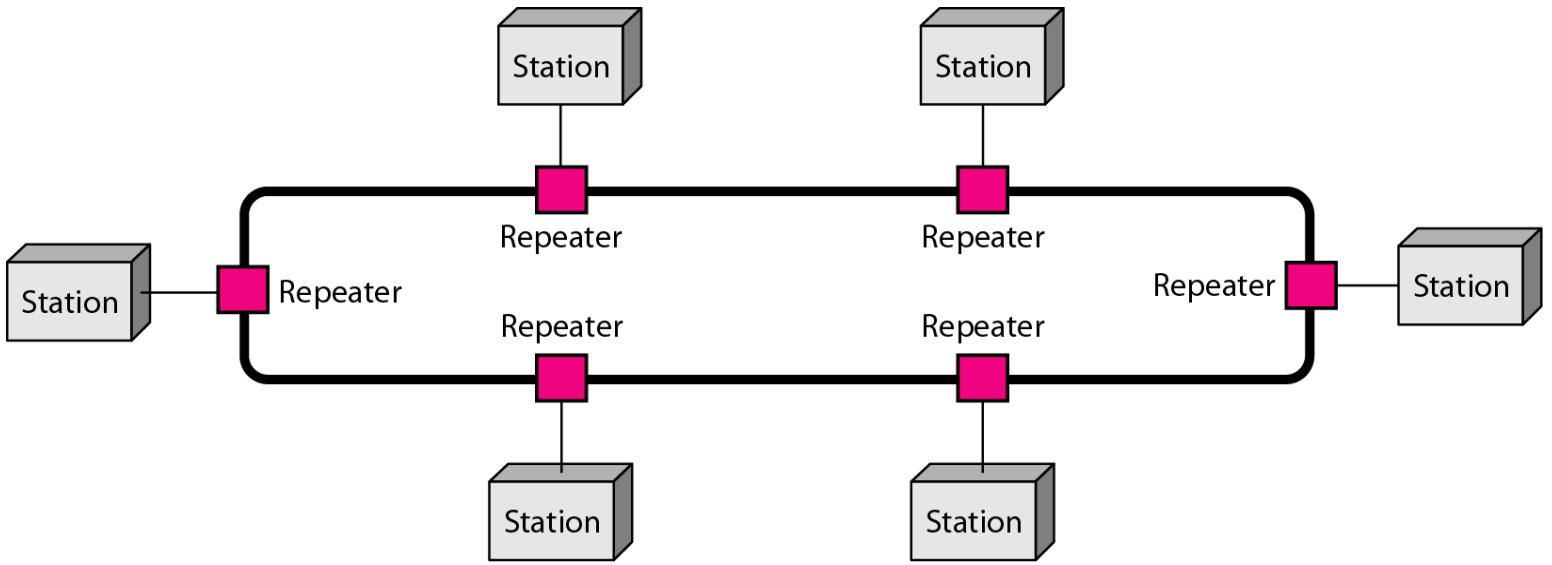
Advantages

- Easy Installation.
- Use less cable compare than Mesh and Star.
- No Redundance Issue.

Disadvantage

- Difficult to add or delete the devices
- Installation and Reconfiguration difficult

# A ring topology connecting six stations




- Each device has dedicated point to point link to other next and previous devices.

# A ring topology connecting six stations

Advantages

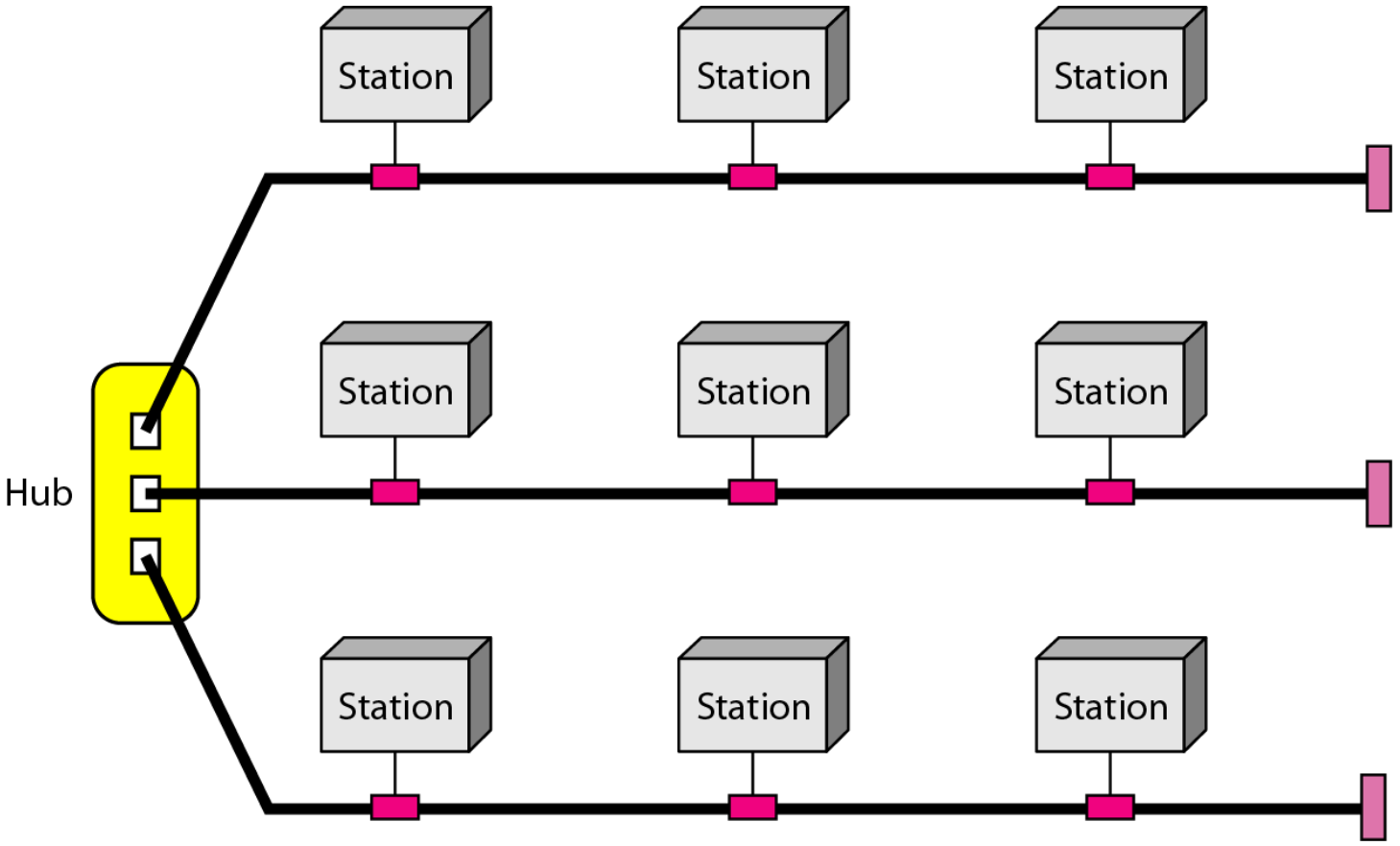
- Easy Installation and reconfiguration.
- Addition and deletion of device easy. (Two Connection needs)
- Fault Isolation is simplified.

Disadvantage

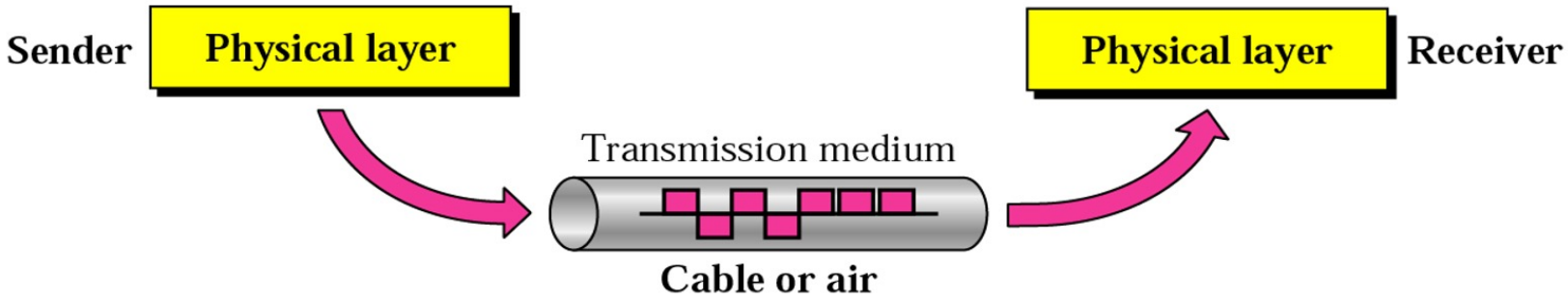
- Unidirectional traffic is main problem
- If connection is cut, then processing stop. (No Robust)

# Hybrid Topology

*A hybrid topology: a star backbone with three bus networks*

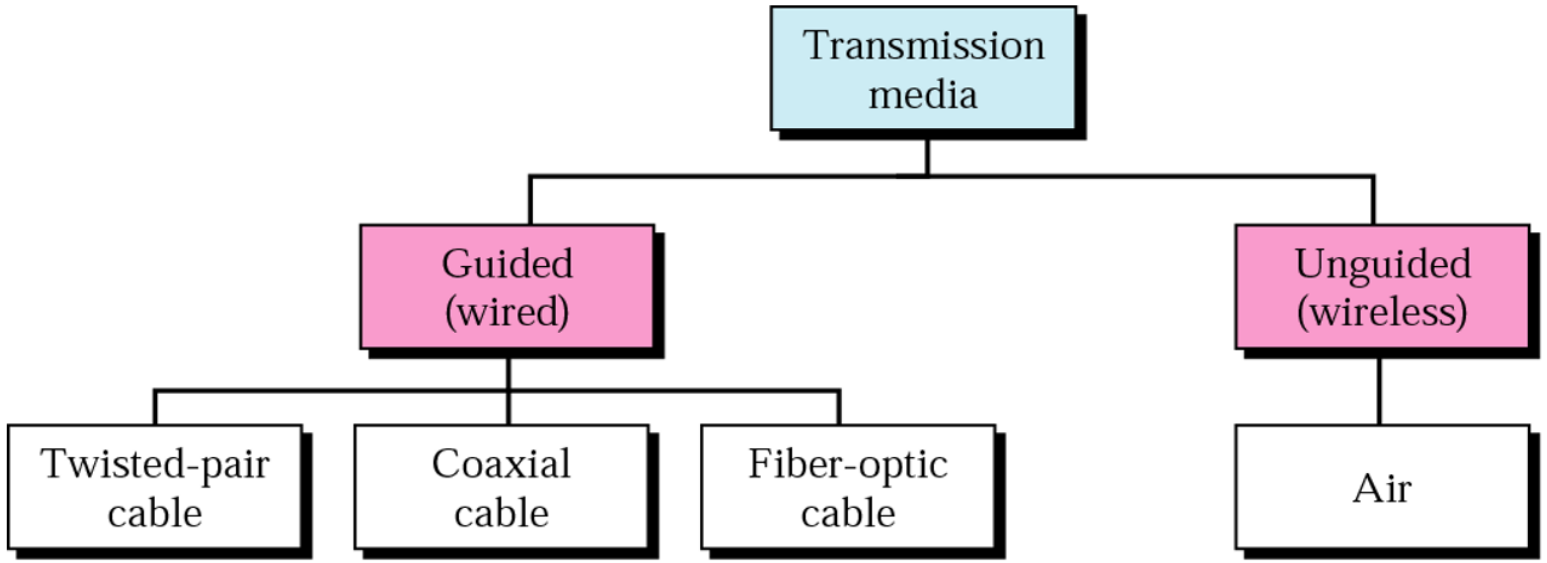


# Transmission Media




Transmission media means share the information from one place to other via some medium (Wire or Wireless).

# Classification Of Transmission Media

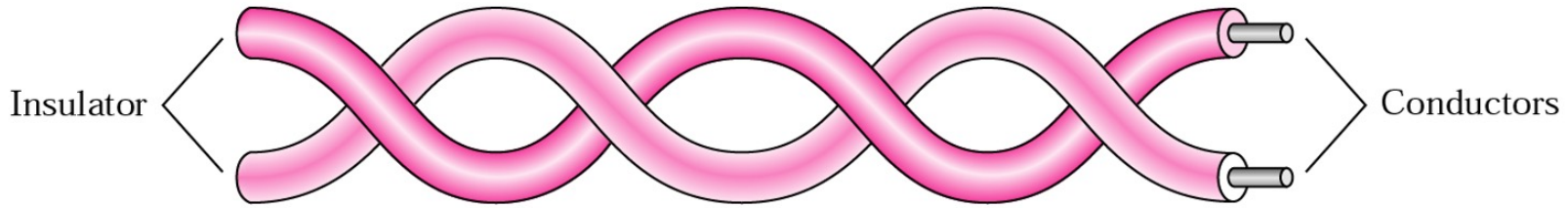


# Guided Media Twisted Pair Cable

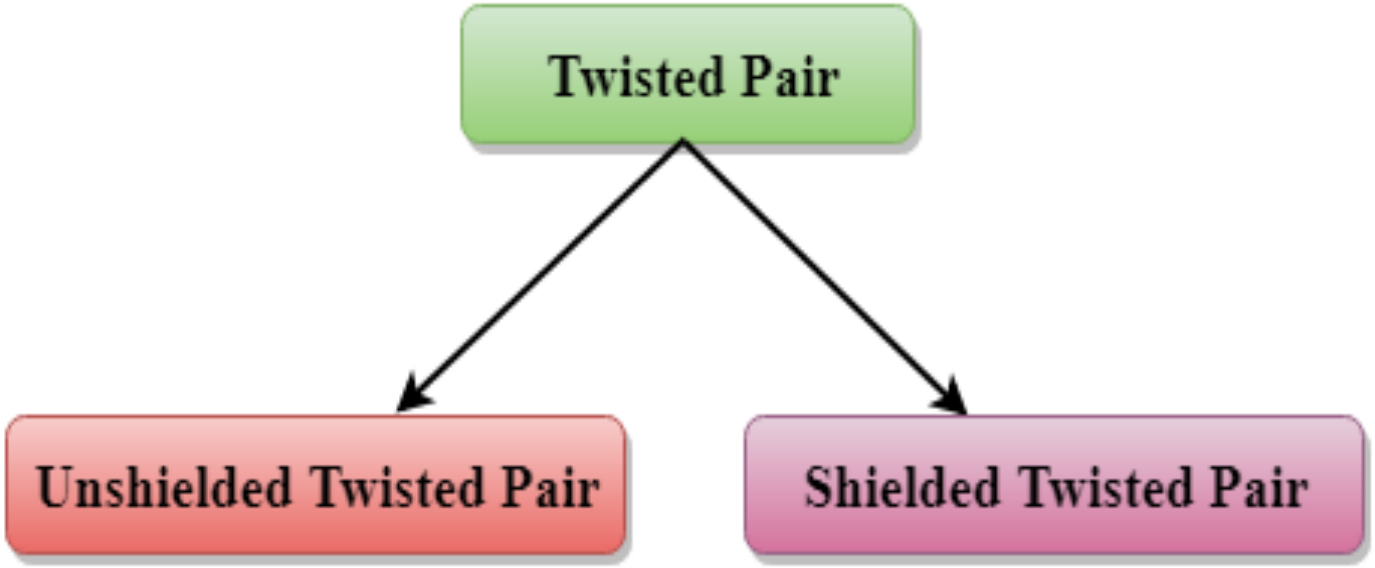
- It is defined as the physical medium through which the signals are transmitted. It is also known as Bounded media.

**Twisted Pair:**

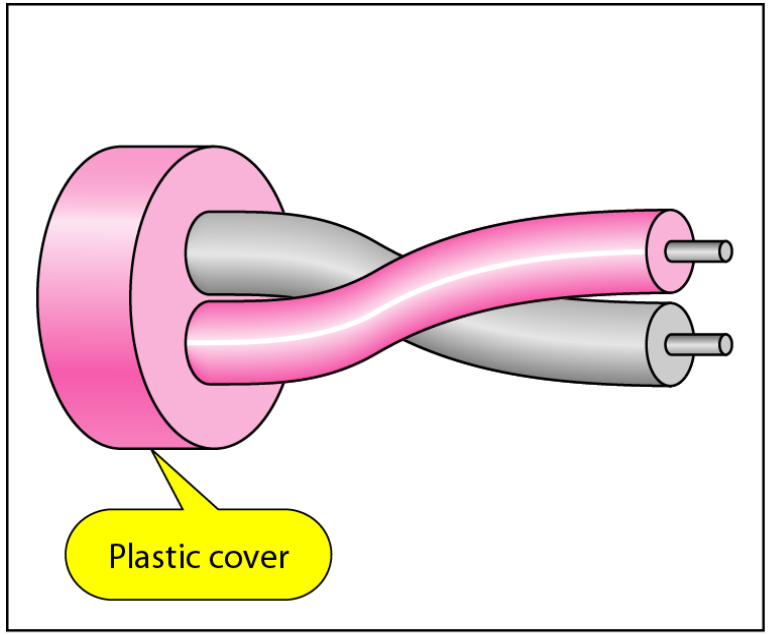
- Twisted pair is a physical media made up of a pair of cables twisted with each other.
- A twisted pair cable is cheap as compared to other transmission media.
- The frequency range for twisted pair cable is from 100Hz to 5MHz.
- Reduce the noise.



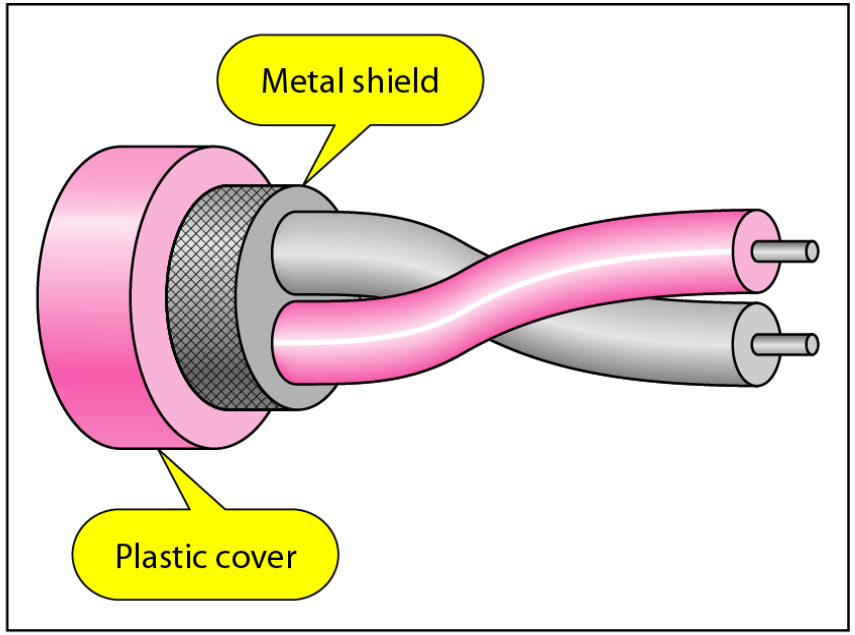
# Types of Twisted pair



# Difference between UTP and STP.




a. UTP




b. STP

# Unshielded Twisted Pair

**Advantages**

- It is cheap.
- Installation of the unshielded twisted pair is easy.
- It can be used for high-speed LAN.

**Disadvantage:**

- This cable can only be used for shorter distances because of attenuation.

# Shielded Twisted Pair

**Advantages**

- An installation of STP is easy.
- It is shielded that provides the higher data transmission rate.

**Disadvantages**

- It is more expensive as compared to UTP and coaxial cable.
- It has a higher attenuation rate.

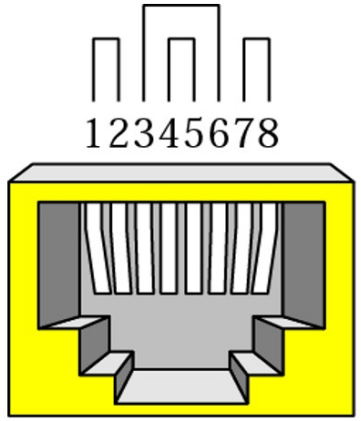
# Unshielded Twisted Pair

*Table 7.1 Categories of unshielded twisted-pair cables*

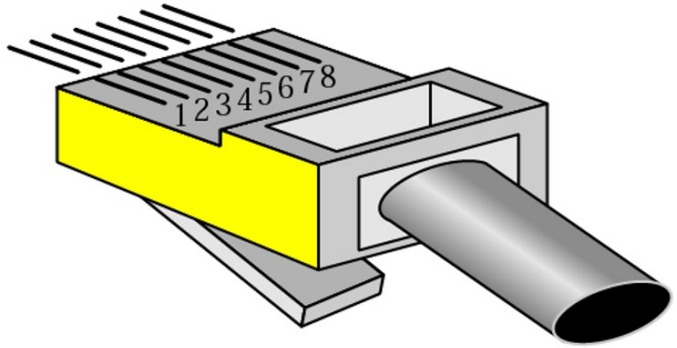
| Category | Bandwidth | Data Rate | Digital/Analog | Use |
|---|---|---|---|---|
| 1 | very low | < 100 kbps | Analog | Telephone |
| 2 | < 2 MHz | 2 Mbps | Analog/digital | T-1 lines |
| 3 | 16 MHz | 10 Mbps | Digital | LANs |
| 4 | 20 MHz | 20 Mbps | Digital | LANs |
| 5 | 100 MHz | 100 Mbps | Digital | LANs |
| 6 (draft) | 200 MHz | 200 Mbps | Digital | LANs |
| 7 (draft) | 600 MHz | 600 Mbps | Digital | LANs |

# Unshielded Twisted Pair

# Connectors and Performance

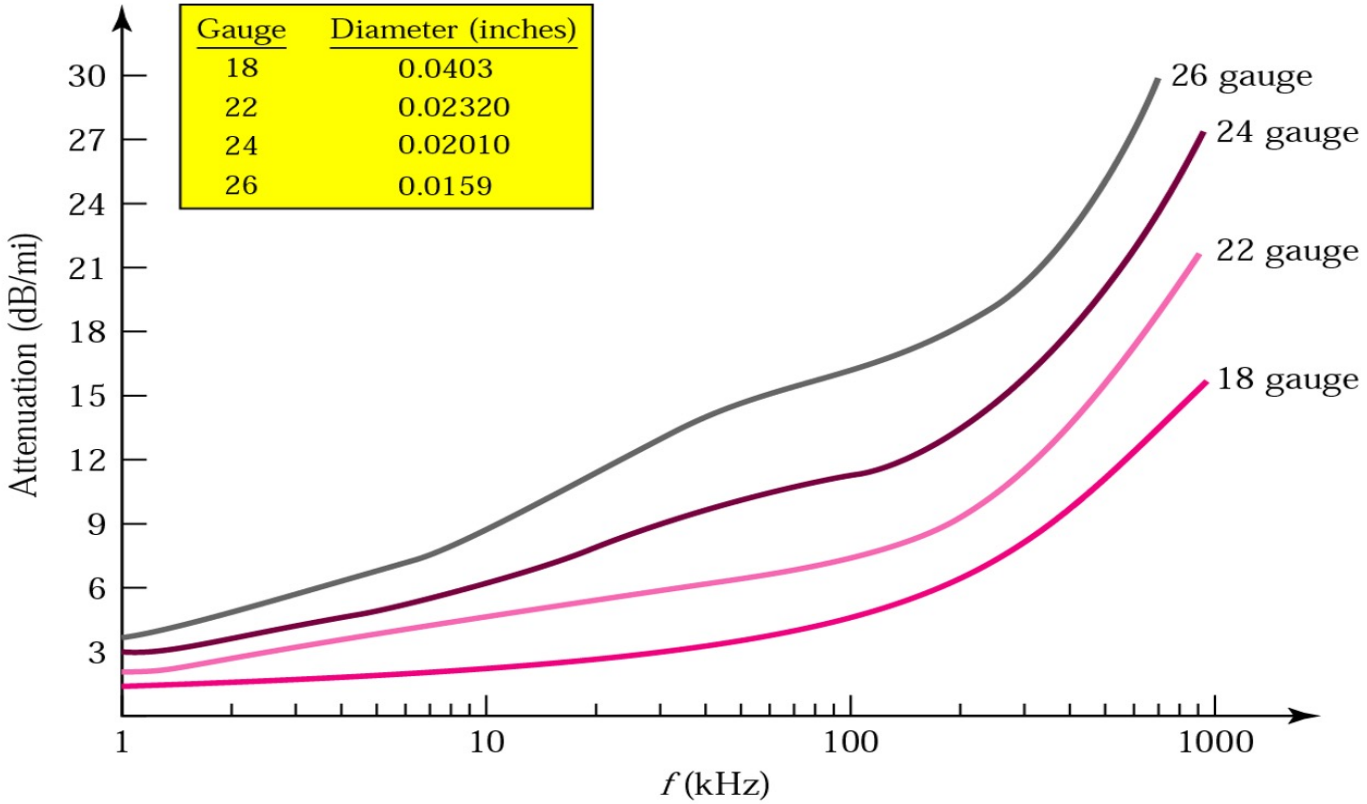



RJ-45 Female




RJ-45 Male

| Gauge | Diameter (inches) |
|---|---|
| 18 | 0.0403 |
| 22 | 0.02320 |
| 24 | 0.02010 |
| 26 | 0.0159 |



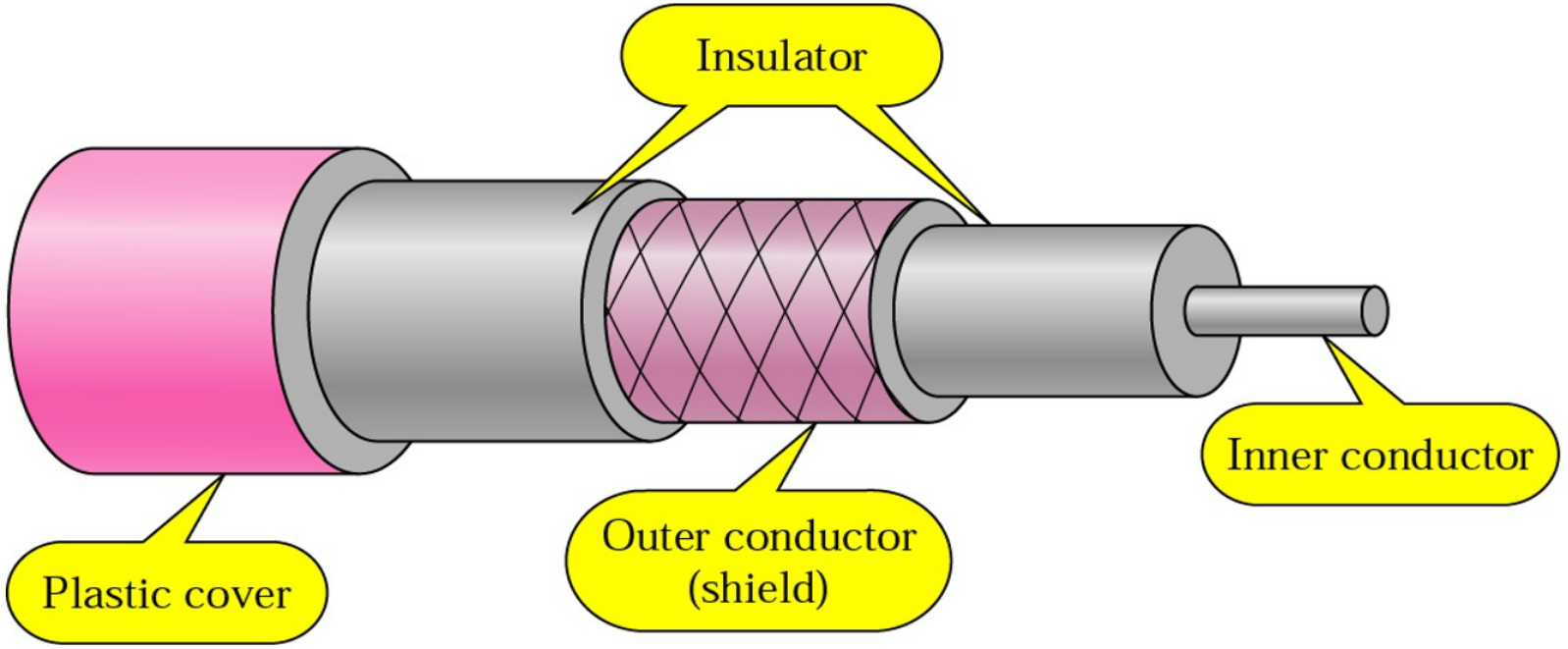

RJ--- Registered Jack

# Coaxial Cable

- Coaxial cable is very commonly used in TV.
- Two conductors parallel to each other.
- High frequency as compared to Twisted pair cable (100KHz-500MHz).

# Coaxial Cable

- The inner conductor is made up of copper, and the outer conductor is made up of copper mesh. The middle core is made up of non-conductive cover.
- The middle core is responsible for the data transferring whereas the copper mesh prevents from the **EMI**(Electromagnetic interference).



# Coaxial Cable

**Advantages**

- The data can be transmitted at high speed.
- It has better shielding as compared to twisted pair cable.
- It provides higher bandwidth.

**Disadvantages**

- It is more expensive as compared to twisted pair cable.
- If any fault occurs in the cable causes the failure in the entire network.

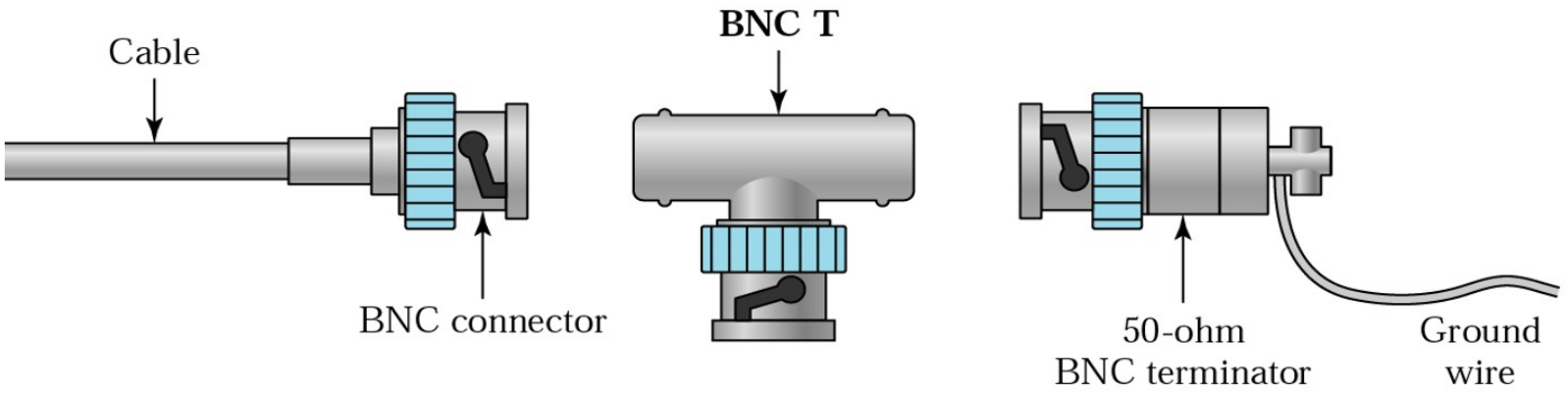
# Coaxial Cable

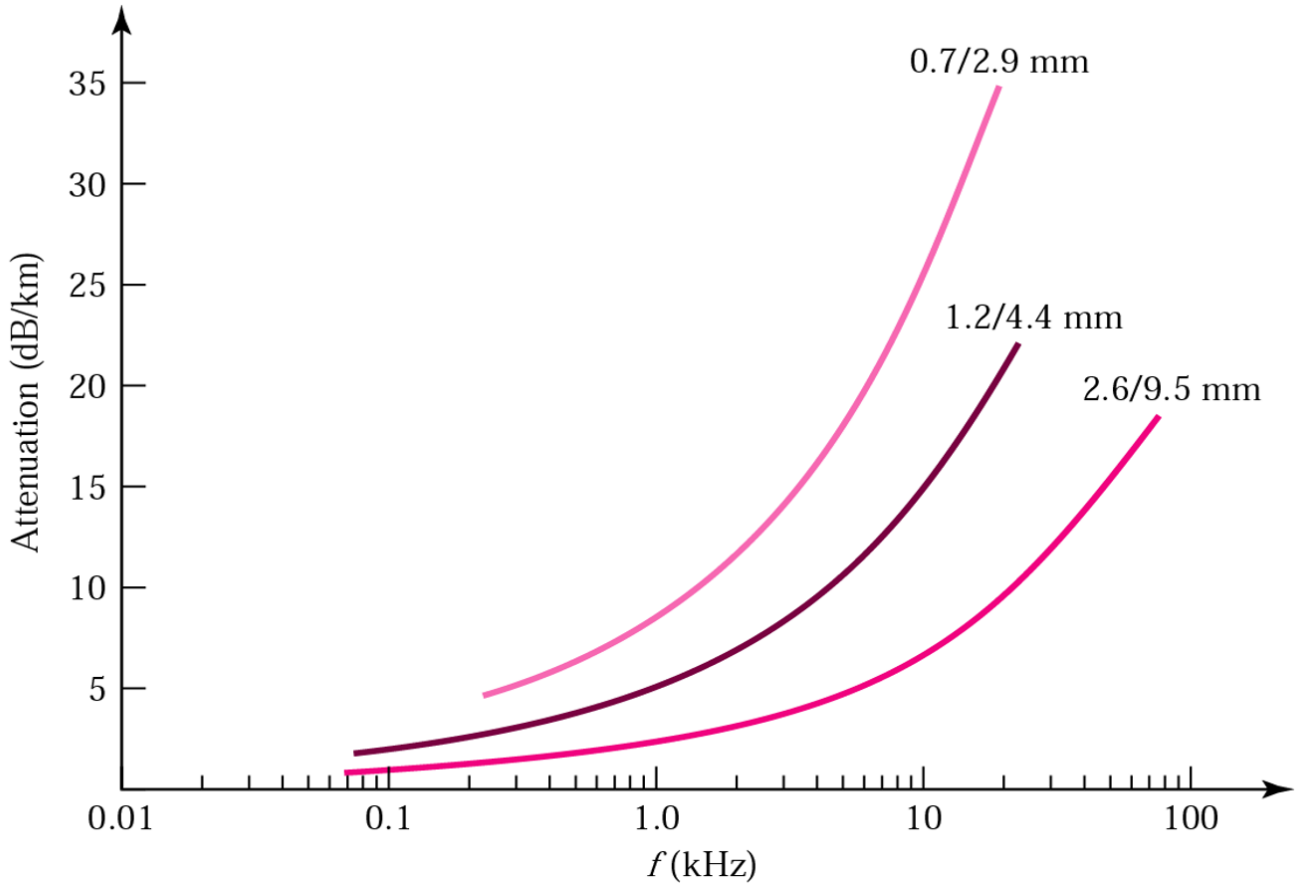
*Table 7.2 Categories of coaxial cables*

| Category | Impedance | Use |
|---|---|---|
| RG-59 | 75 Ω | Cable TV |
| RG-58 | 50 Ω | Thin Ethernet |
| RG-11 | 50 Ω | Thick Ethernet |

# Coaxial Cable

# Connectors and Performance

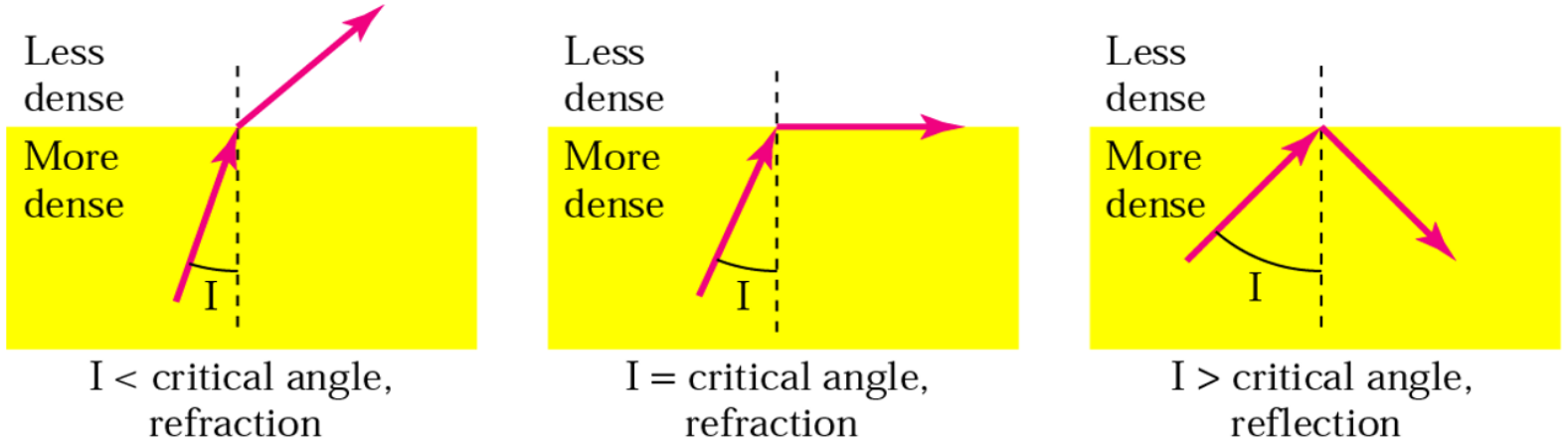


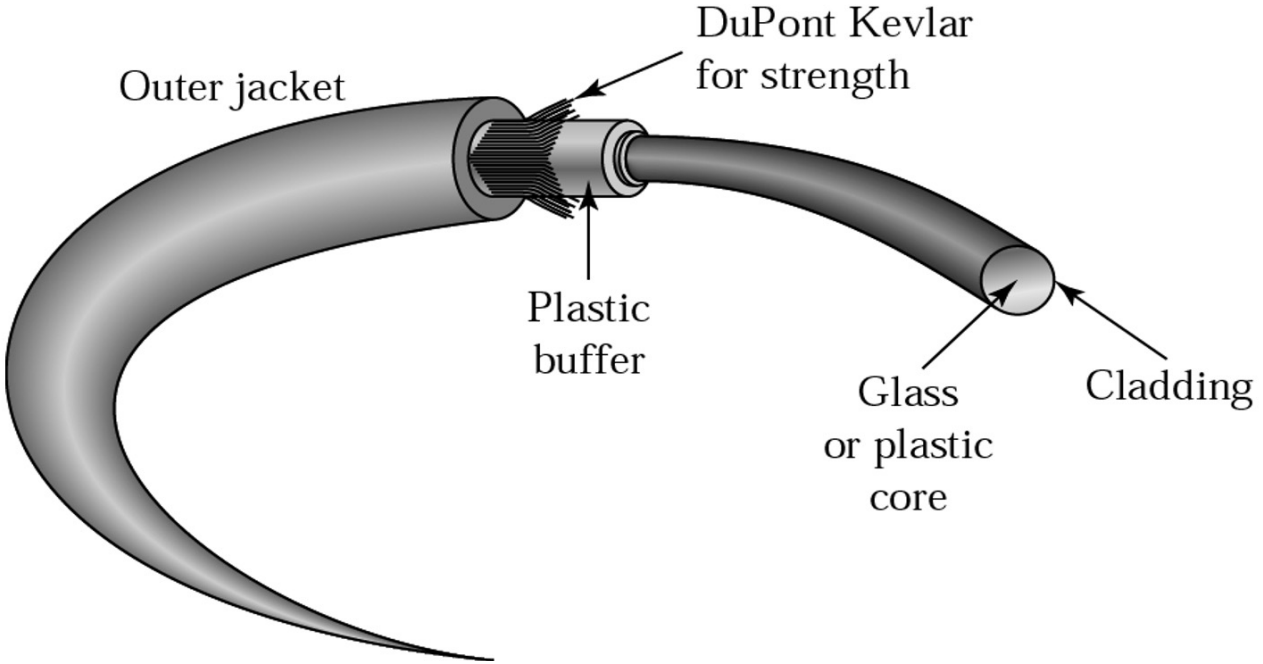

BNC----- Bayone-Neil-Concelman

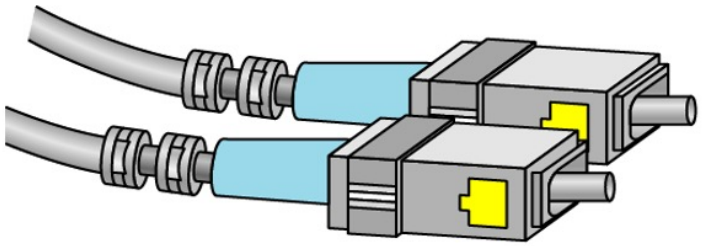
# Fibre Optic

- Fibre optic is a cable that holds the optical fibres coated in plastic that are used to send the data by pulses of light.
- The plastic coating protects the optical fibres from heat, cold, electromagnetic interference from other types of wiring.
- Fibre optics provide faster data transmission than copper wires.

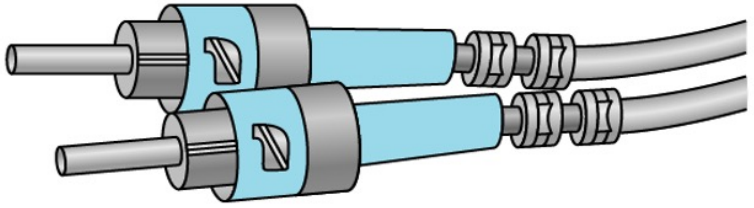


# Fibre Optic Connectors

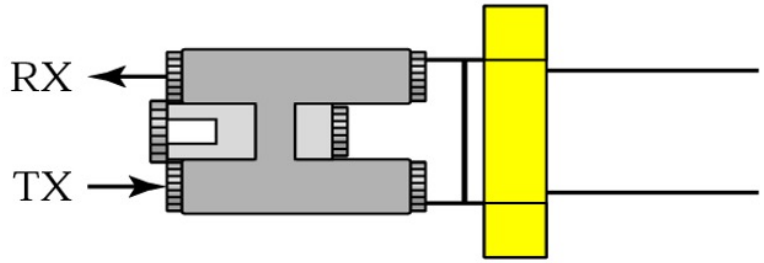


SC connector



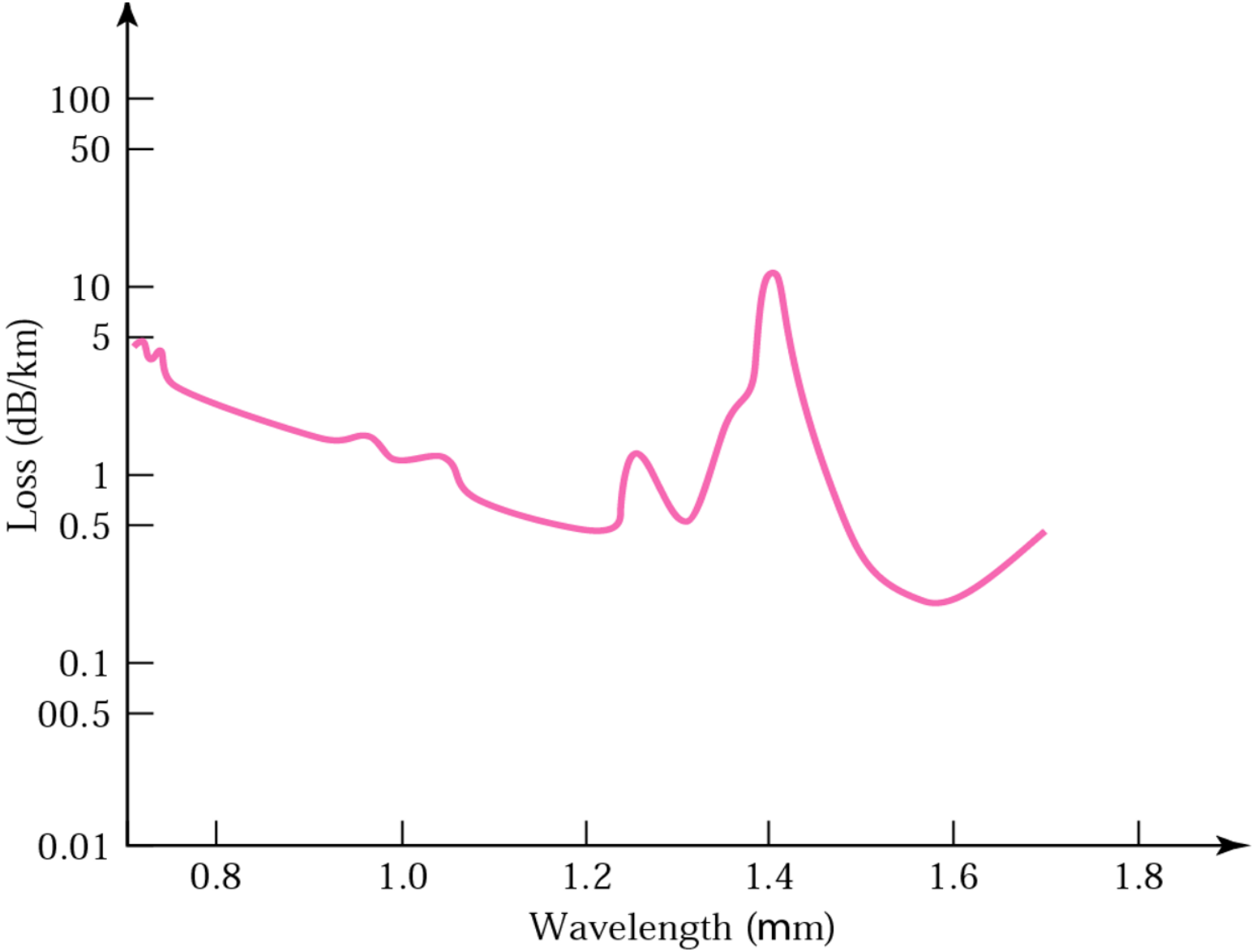
ST connector




MT-RJ connector

SC—Subscriber Channel, ST– Straight Tip

# Fibre Optic Performance

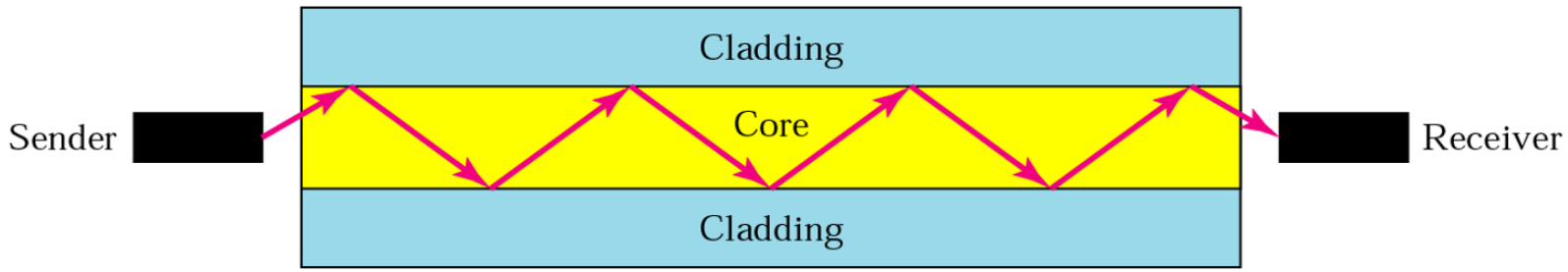


# Basic elements of Fibre optic cable

- **Basic Elements of Fibre optic cable:**

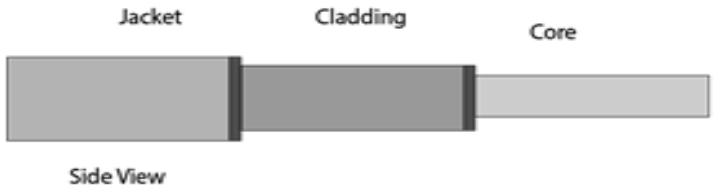
1. **Core**
2. **Cladding**
3. **Jacket**

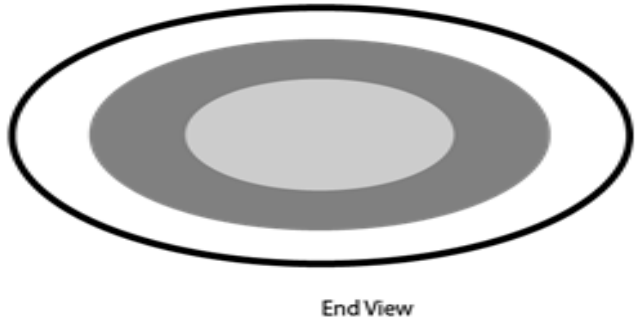
- **Core:** The optical fibre consists of a narrow strand of glass or plastic known as a core. A core is a light transmission area of the fibre. The more the area of the core, the more-light will be transmitted into the fibre.



# Fibre Optics

- **Cladding:** The concentric layer of glass is known as cladding. The main functionality of the cladding is to provide the lower refractive index at the core interface as to cause the reflection within the core so that the light waves are transmitted through the fibre.
- **Jacket:** The protective coating consisting of plastic is known as a jacket. The main purpose of a jacket is to preserve the fibre strength, absorb shock and extra fibre protection.

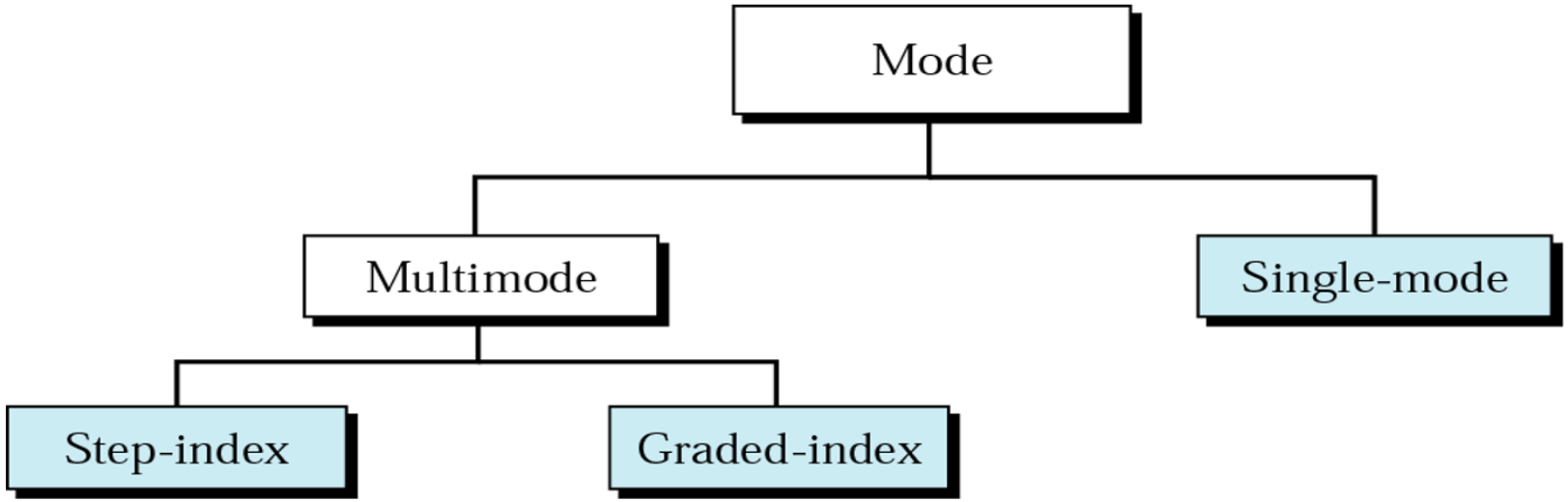


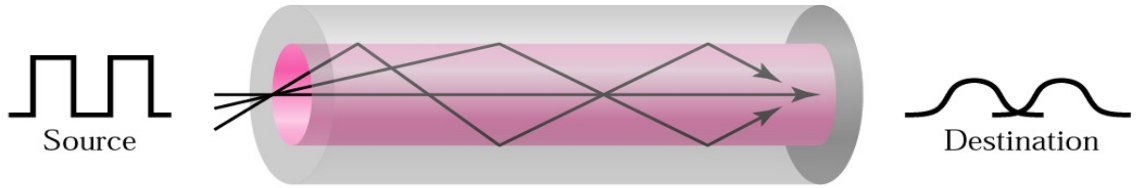



# Advantages of fibre optic cable over copper

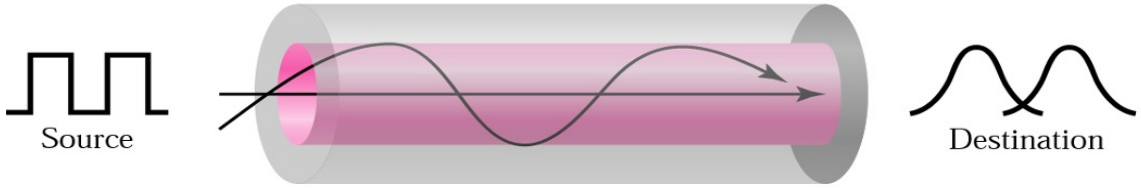
- Greater Bandwidth
- Faster speed
- Longer distances
- Better reliability
- Thinner and Sturdier

# Propagation Modes

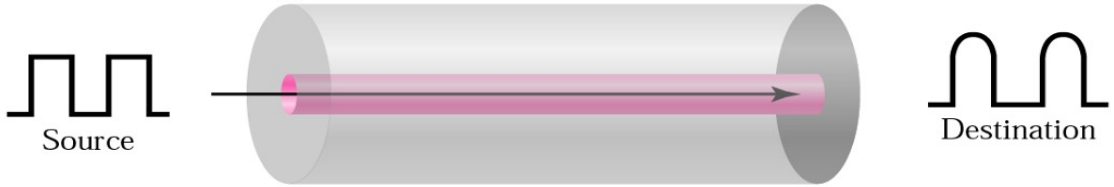



a. Multimode, step-index



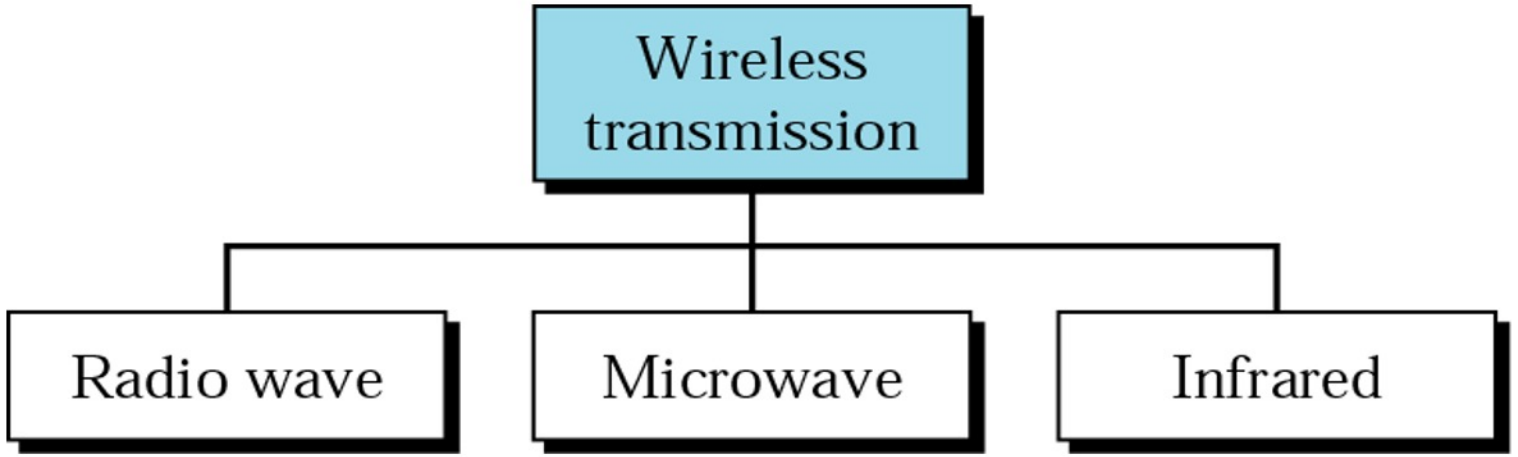

b. Multimode, graded-index



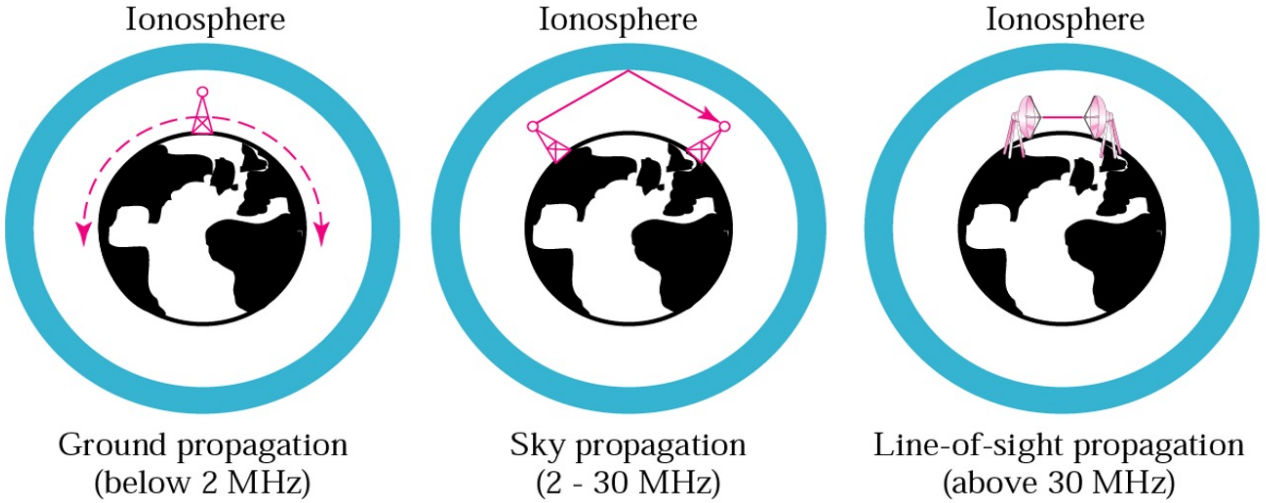

c. Single-mode

# Unguided Transmission

- An unguided transmission transmits the electromagnetic waves without using any physical medium. Therefore, it is also known as **wireless transmission**.
- In unguided media, air is the media through which the electromagnetic energy can flow easily.
- Unguided transmission is broadly classified into three categories:



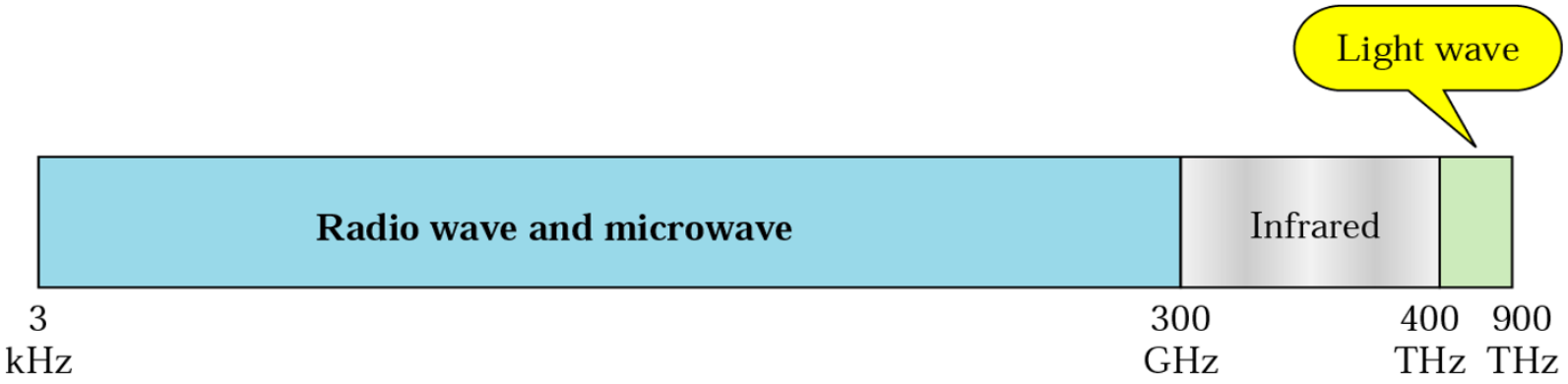
# Propagation Methods




| Band | Range | Propagation | Application |
|---|---|---|---|
| VLF | 3–30 KHz | Ground | Long-range radio navigation |
| LF | 30–300 KHz | Ground | Radio beacons and navigational locators |
| MF | 300 KHz–3 MHz | Sky | AM radio |
| HF | 3–30 MHz | Sky | Citizens band (CB), ship/aircraft communication |
| VHF | 30–300 MHz | Sky and line-of-sight | VHF TV, FM radio |
| UHF | 300 MHz–3 GHz | Line-of-sight | UHF TV, cellular phones, paging, satellite |
| SHF | 3–30 GHz | Line-of-sight | Satellite communication |
| EHF | 30–300 GHz | Line-of-sight | Long-range radio navigation |

# Radio waves

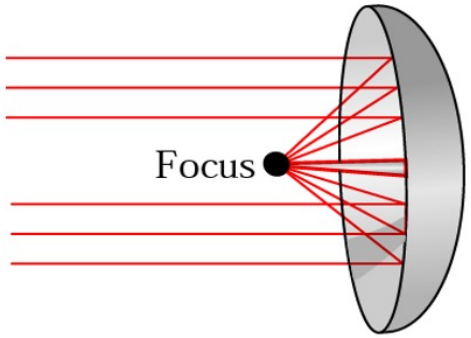
- Radio waves are the electromagnetic waves that are transmitted in all the directions of free space.
- Radio waves are omnidirectional, i.e., the signals are propagated in all the directions.
- In the case of radio waves, the sending and receiving antenna are not aligned, i.e., the wave sent by the sending antenna can be received by any receiving antenna.
- An example of the radio wave is **FM radio**.



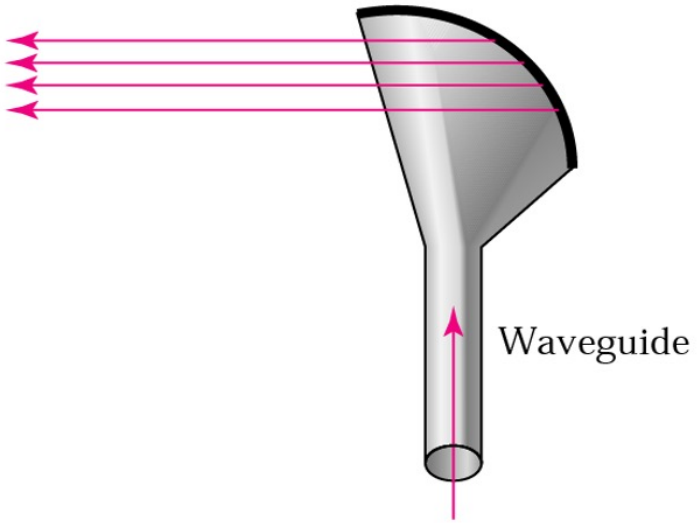
# Radio waves

**Note:**

***Radio waves are used for multicast communications, such as radio and television, and paging systems.***




a. Dish antenna




b. Horn antenna

# Application and Advantage

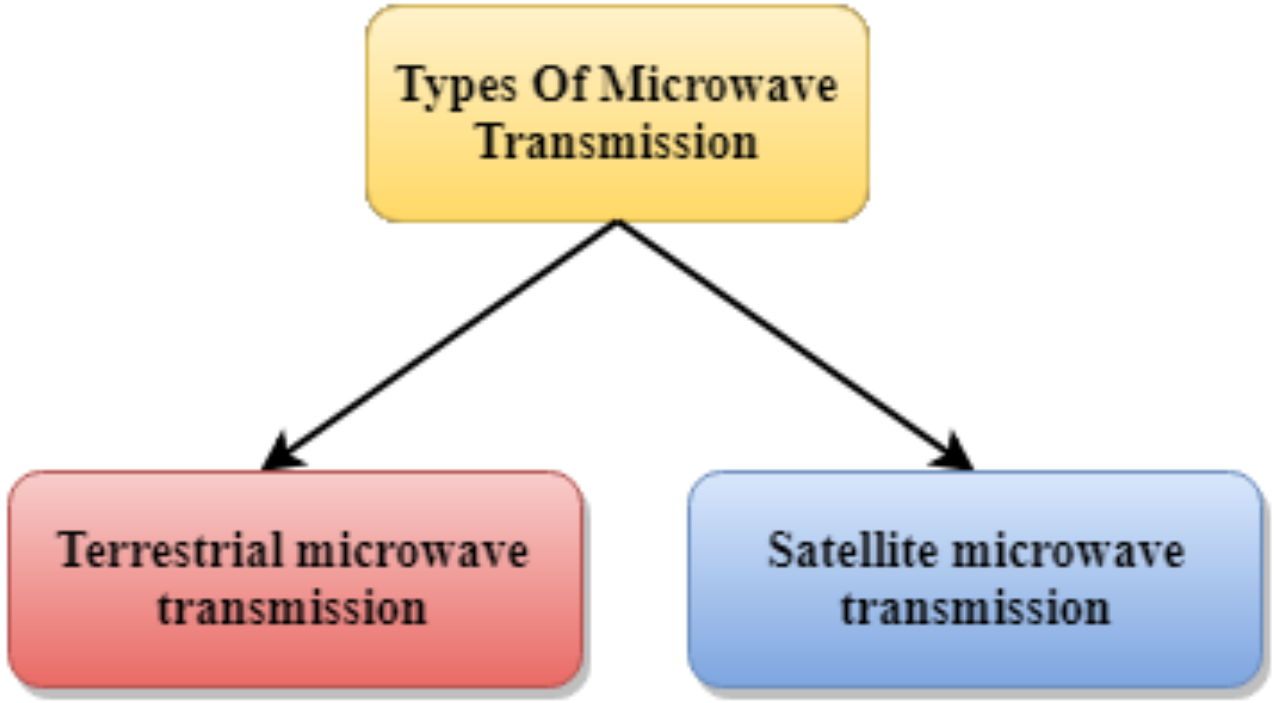
- A Radio wave is useful for multicasting when there is one sender and many receivers.
- An FM radio, television, cordless phones are examples of a radio wave.
- Radio transmission is mainly used for wide area networks and mobile cellular phones.
- Radio waves cover a large area, and they can penetrate the walls.
- Radio transmission provides a higher transmission rate.

# Microwaves

**Note:**

***Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.***

# Microwaves


Types Of Microwave Transmission
Terrestrial microwave transmission
Satellite microwave transmission

# Terrestrial Microwave Transmission

- Terrestrial Microwave transmission is a technology that transmits the focused beam of a radio signal from one ground-based microwave transmission antenna to another.
- Microwaves are the electromagnetic waves having the frequency in the range from 1GHz to 1000 GHz.
- Microwaves are unidirectional as the sending and receiving antenna is to be aligned, i.e., the waves sent by the sending antenna are narrowly focussed.

# Advantages and disadvantages

## Advantages

- Microwave transmission is cheaper than using cables.
- It is free from land acquisition as it does not require any land for the installation of cables.
- Microwave transmission provides an easy communication in terrains as the installation of cable in terrain is quite a difficult task.
- Communication over oceans can be achieved by using microwave transmission.

## Disadvantages

- Eavesdropping
- Out of phase signal
- Susceptible to weather condition
- Bandwidth limited

# Satellite Microwave Communication

- A satellite is a physical object that revolves around the earth at a known height.
- Satellite communication is more reliable nowadays as it offers more flexibility than cable and fibre optic systems.
- We can communicate with any point on the globe by using satellite communication.

**How Does Satellite work?**

- The satellite accepts the signal that is transmitted from the earth station, and it amplifies the signal. The amplified signal is retransmitted to another earth station.

# Advantages Of Satellite Microwave Communication

- The coverage area of a satellite microwave is more than the terrestrial microwave.
- It is easy to install.
- It is used in a wide variety of applications such as weather forecasting, radio/TV signal broadcasting, mobile communication, etc.

# Disadvantages Of Satellite Microwave Communication

- Satellite designing and development requires more time and higher cost.
- The Satellite needs to be monitored and controlled on regular periods so that it remains in orbit.
- The life of the satellite is about 12-15 years. Due to this reason, another launch of the satellite has to be planned before it becomes non-functional.

# Infrared

**Note:**

***Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.***

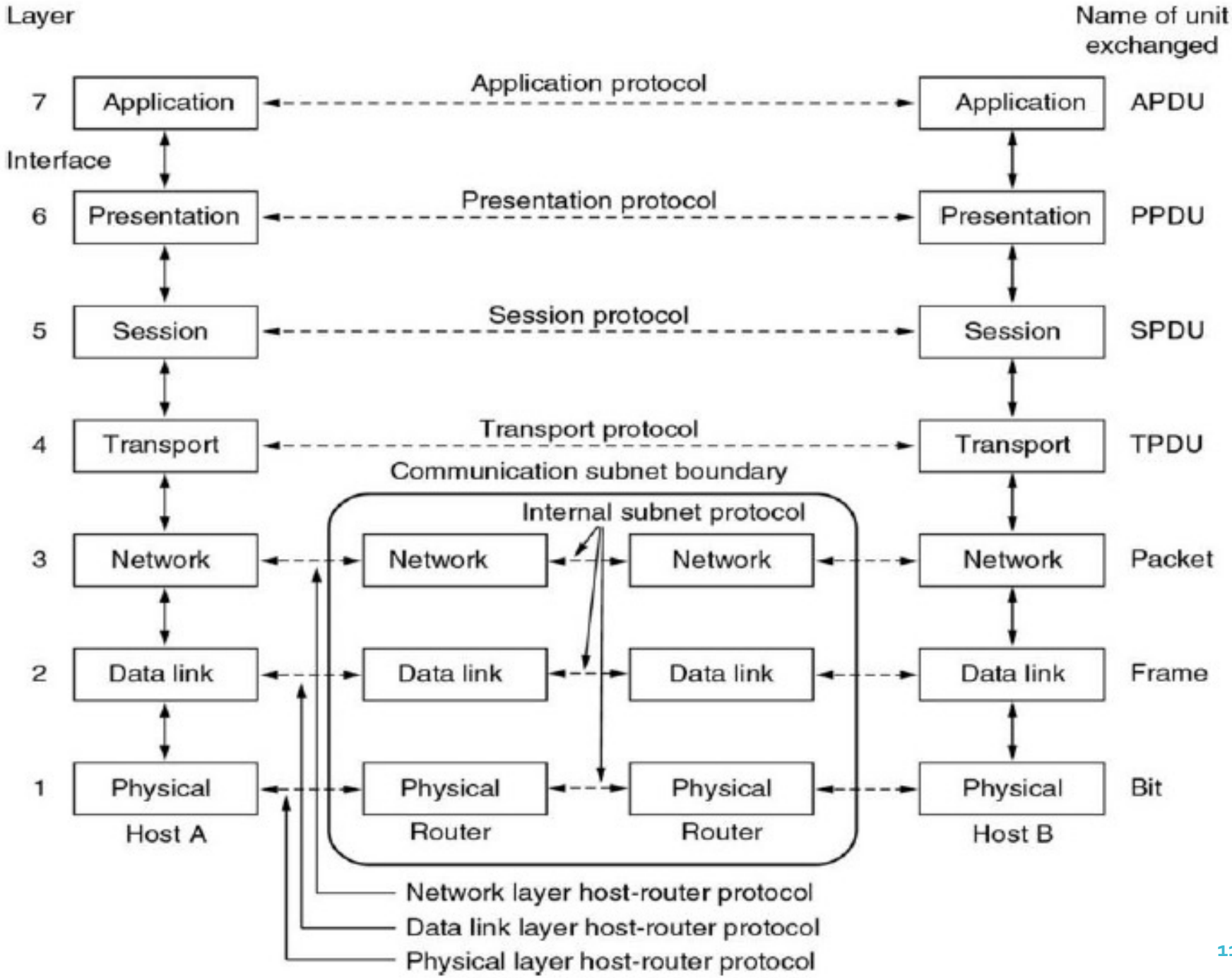
# Infrared

- An infrared transmission is a wireless technology used for communication over short ranges.
- The frequency of the infrared in the range from 300 GHz to 400 THz.
- It is used for short-range communication such as data transfer between two cell phones, TV remote operation, data transfer between a computer and cell phone resides in the same closed area.

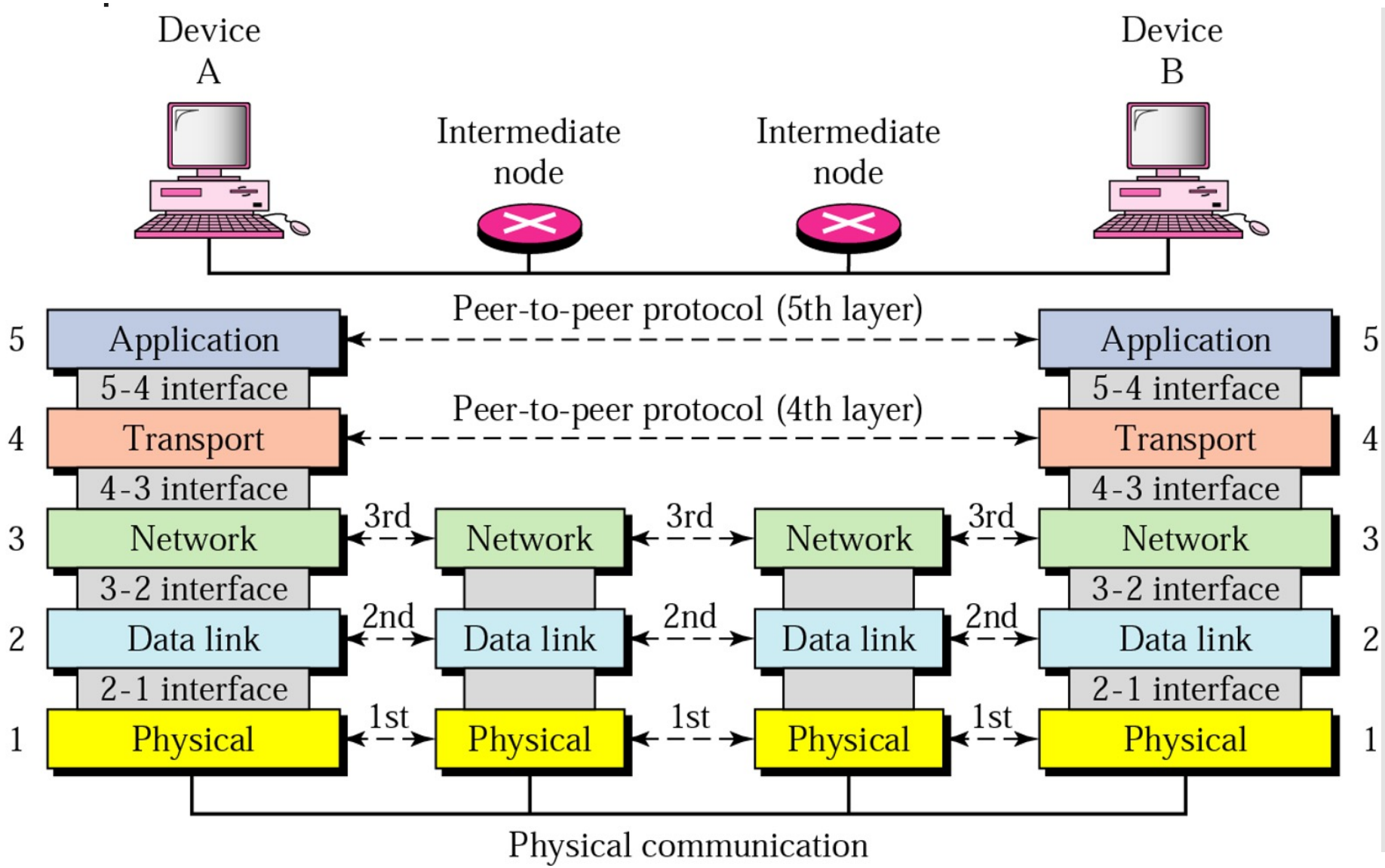
# Characteristics Of Infrared

- It supports high bandwidth, and hence the data rate will be very high.
- Infrared waves cannot penetrate the walls. Therefore, the infrared communication in one room cannot be interrupted by the nearby rooms.
- An infrared communication provides better security with minimum interference.
- Infrared communication is unreliable outside the building because the sun rays will interfere with the infrared waves.

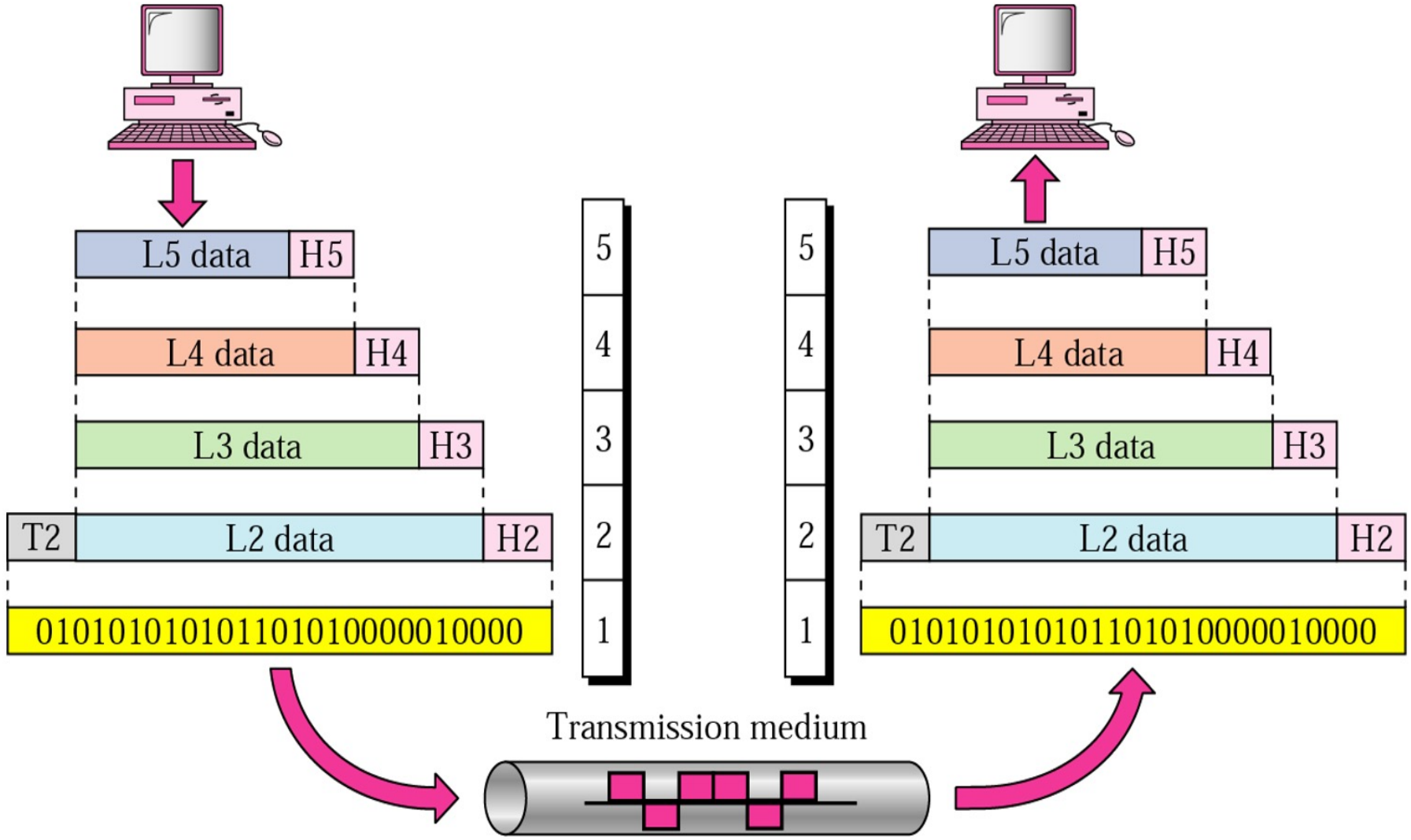
# ISO/OSI Reference Model



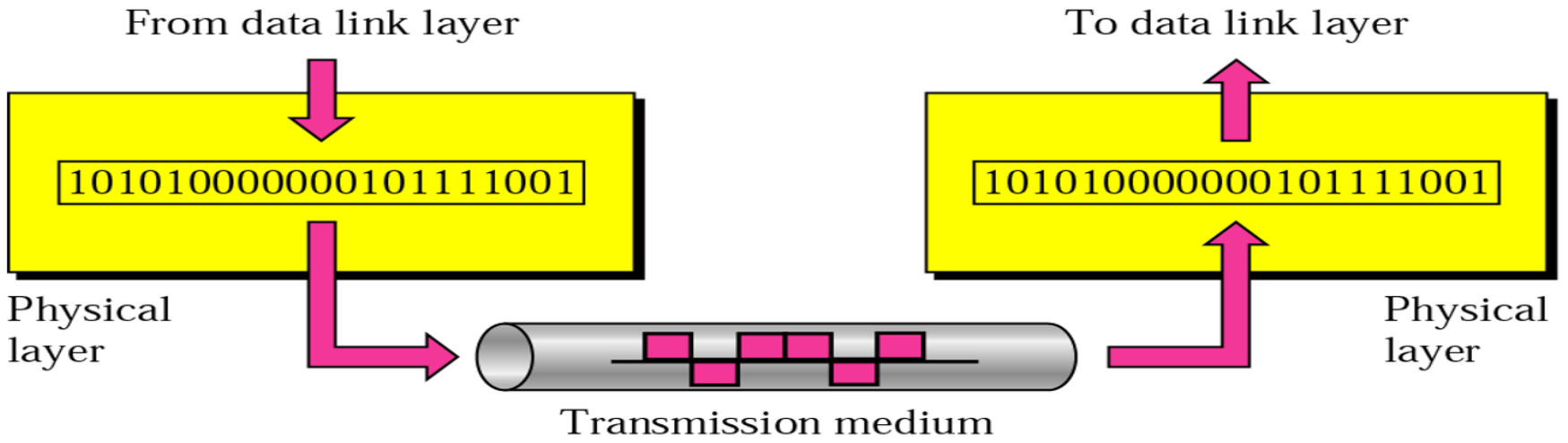
# Internet Model, TCP/IP Model



# Internet Model, TCP/IP Model



# Physical Layer




**Note:**

***The physical layer is responsible for transmitting individual bits from one node to the next.***

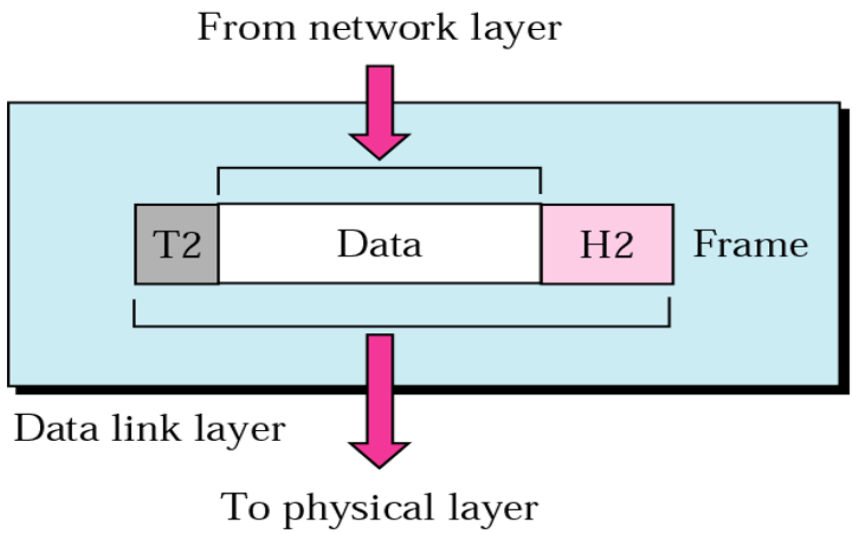
# Physical Layer

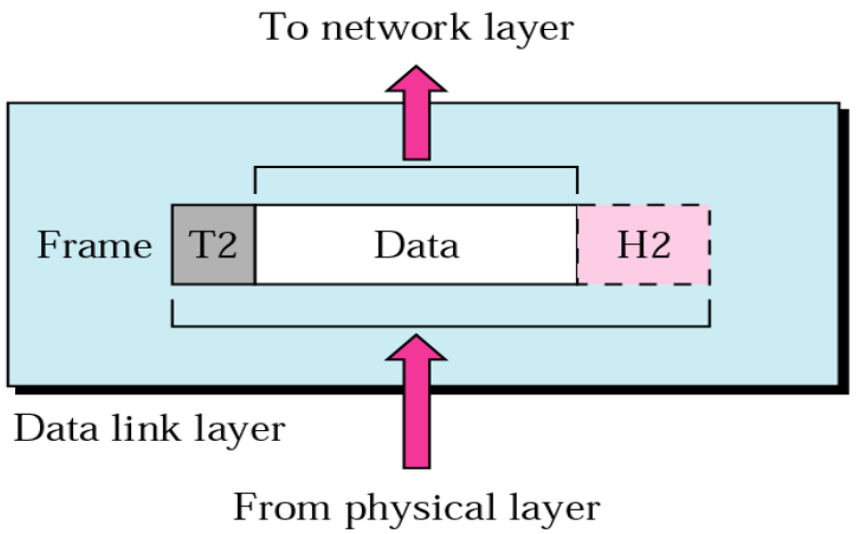
# Functions

1. Representation of bits
2. Data Rate
3. Synchronization of bits
4. Line Configuration
5. Transmission Mode
6. Physical Topology
7. Physical Characteristics of Interfaces and Medium

- Number of pins and functions of each pin of the network connector (Mechanical)
- Signal Level, Data rate (Electrical)
- Whether simultaneous transmission in both directions
- Establishing and breaking of connection
- Deals with physical transmission.

# Data Link Layer





***The data link layer is responsible for transmitting frames from one node to the next.***

# Data Link Layer

## Functions

1. **Framing:** Group the physical layer bit stream into units called frames. Note that frames are nothing more than ``packets'' or ``messages''. By convention, we shall use the term ``**frames**'' when discussing DLL packets.
2. Sender calculates the checksum and sends checksum together with data. The checksum allows the receiver to determine when a frame has been damaged in transit or received correctly. This is called **error detection and correction**.

# Data Link Layer

## Functions

3. Error control protocol returns a positive or negative acknowledgment to the sender. A positive acknowledgment indicates the frame was received without errors, while a negative acknowledgment indicates the opposite.

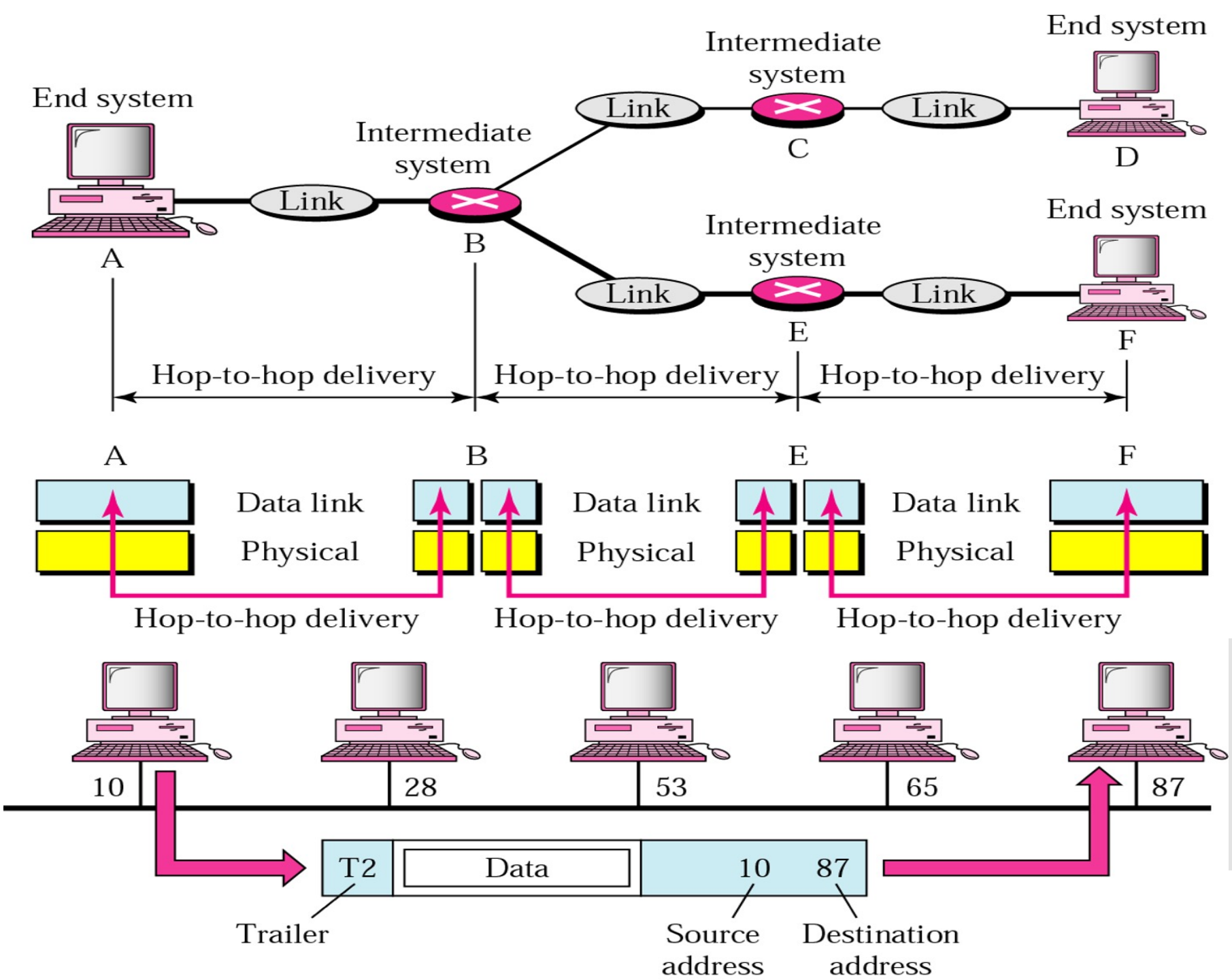
4. **Flow control** prevents a fast sender from overwhelming a slower receiver. For example, a supercomputer can easily generate data faster than a PC can consume it.

5. **Access Control**

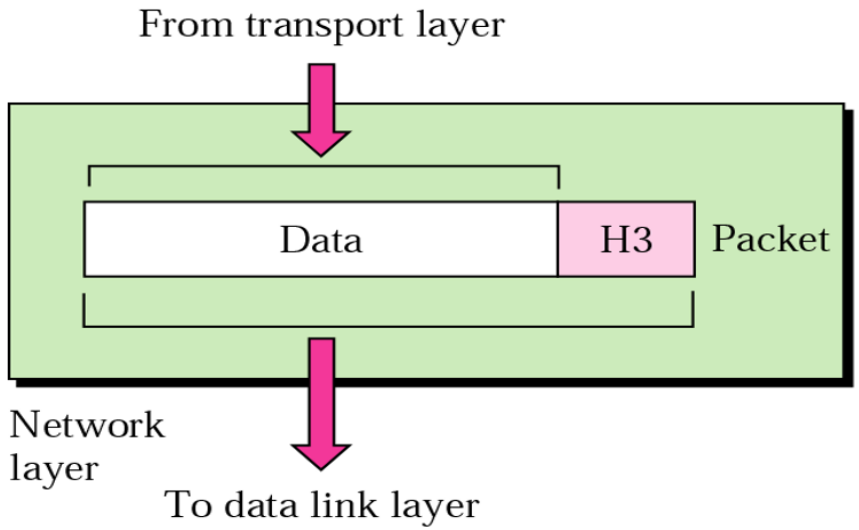
6. **Physical Addressing (MAC Address)**

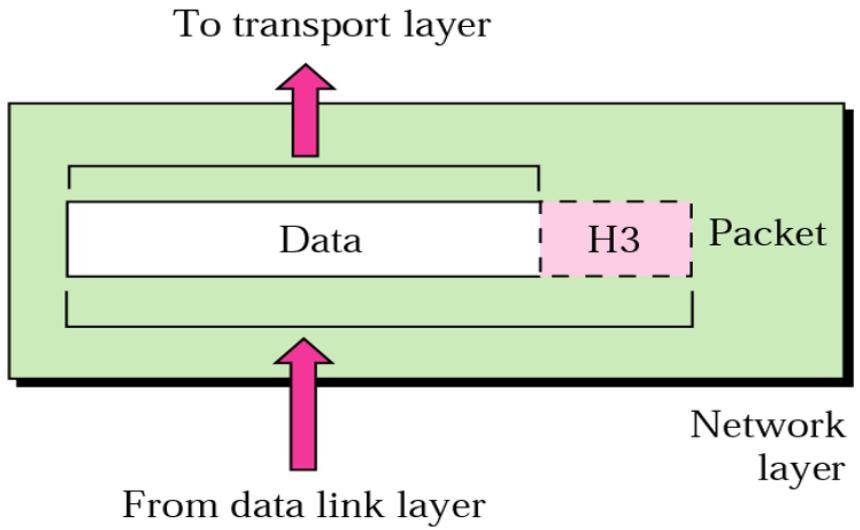
# Data Link Layer

# Node to Node Delivery



# Network Layer





***The network layer is responsible for the delivery of packets from the original source to the final destination.***

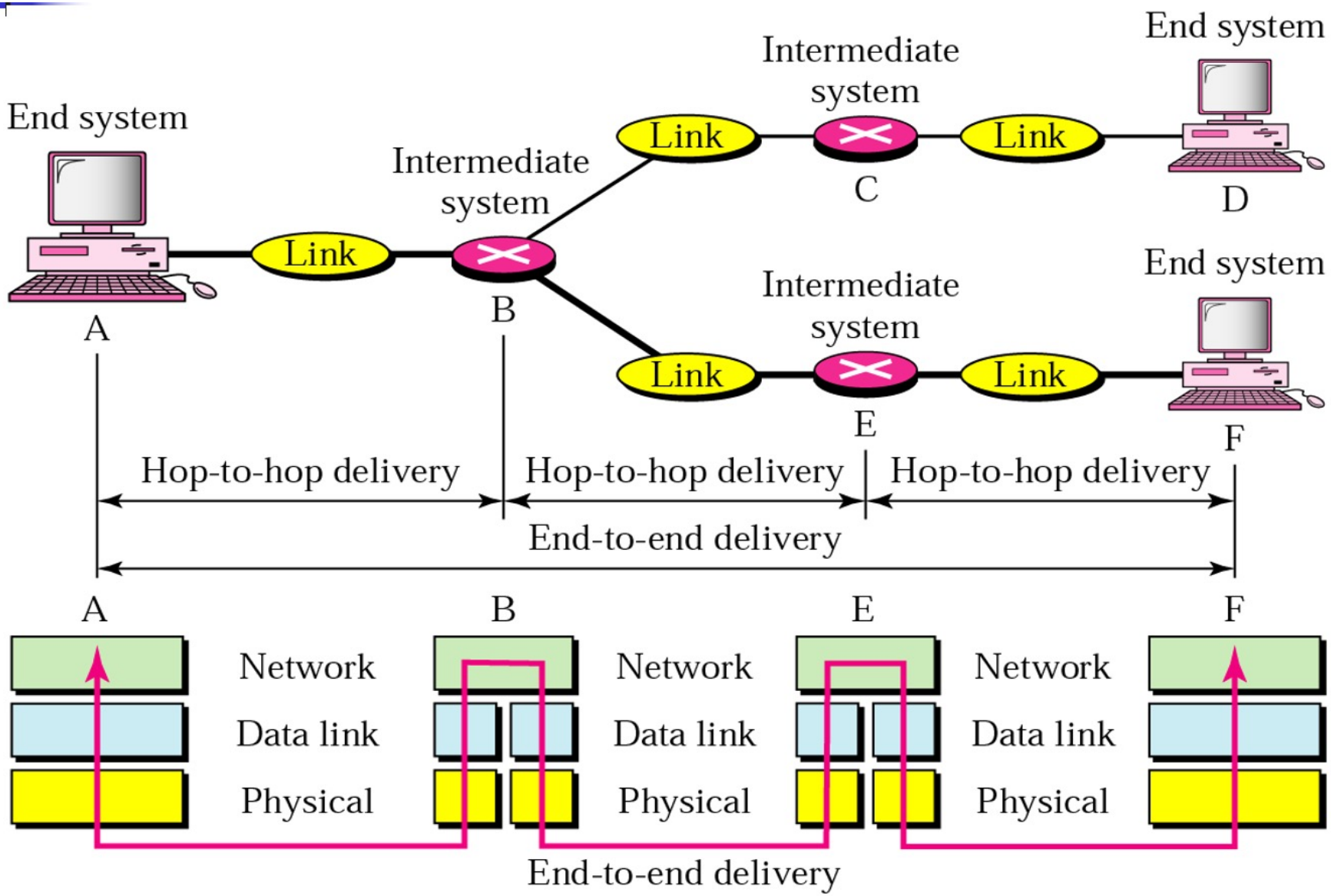
# Network Layer

## Functions

1. Interface between the host and the network (the network layer is typically the boundary between the host and subnet)
2. Routing
3. Logical Addressing-----IP Addressing
3. Congestion and deadlock
4. Internetworking (A path may traverse different network technologies (e.g., Ethernet, point-to-point links, etc.)

# Network Layer

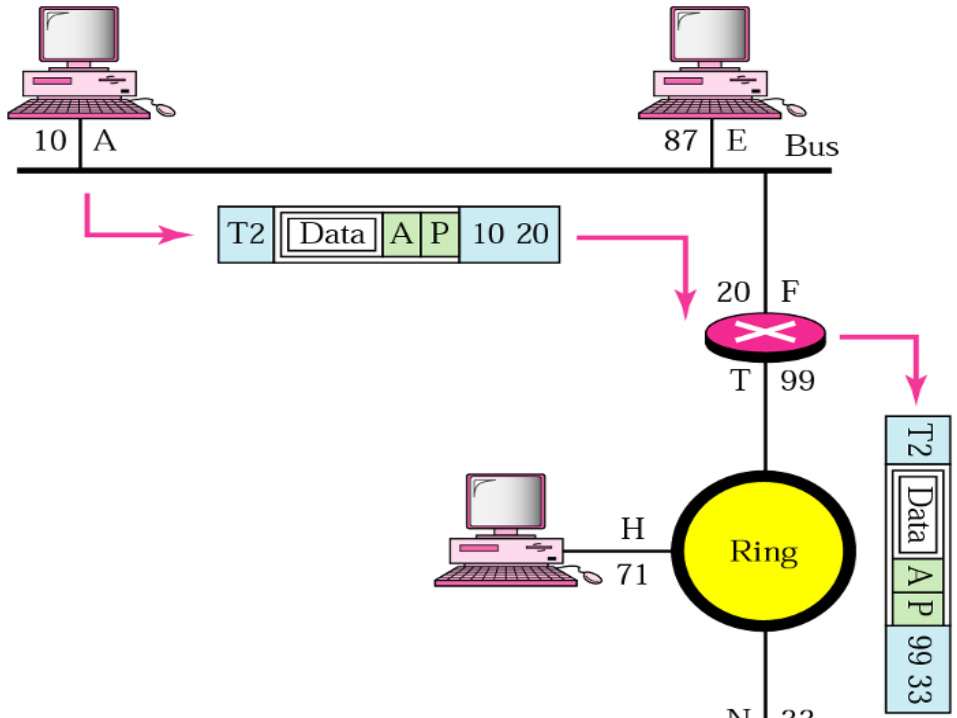
## Source to Destination Delivery



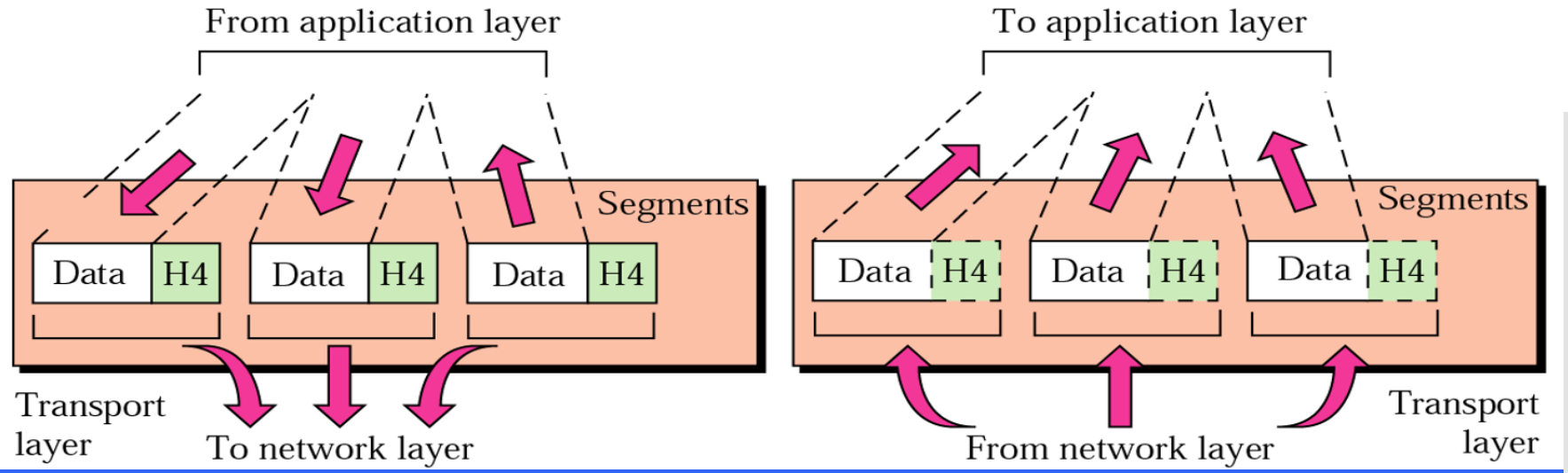
# Network Layer

## Example

In Figure 2.11 we want to send data from a node with network address A and physical address 10, located on one LAN, to a node with a network address P and physical address 95, located on another LAN. Because the two devices are located on different networks, we cannot use physical addresses only; the physical addresses only have local jurisdiction. What we need here are universal addresses that can pass through the LAN boundaries. The network (logical) addresses have this characteristic.



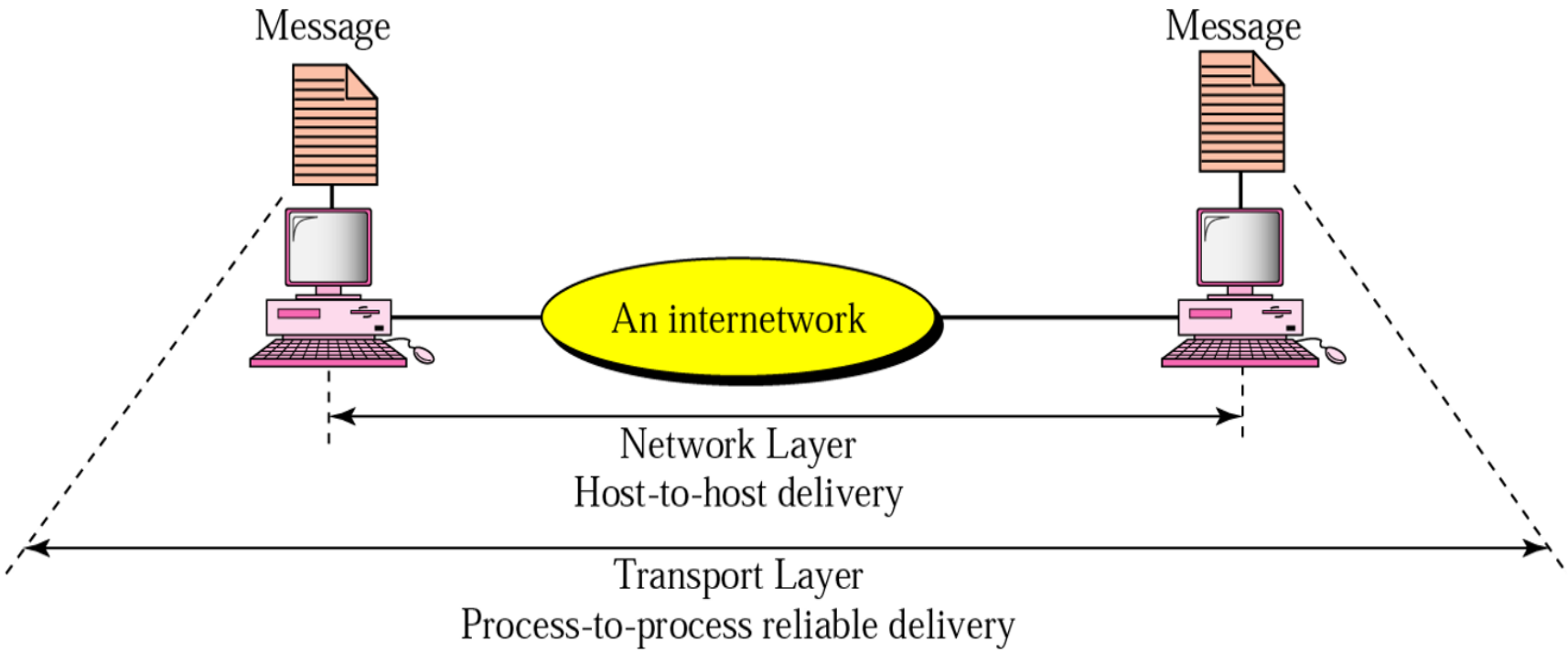
# Transport Layer





***The transport layer is responsible for delivery of a message from one process to another.***

# Transport Layer

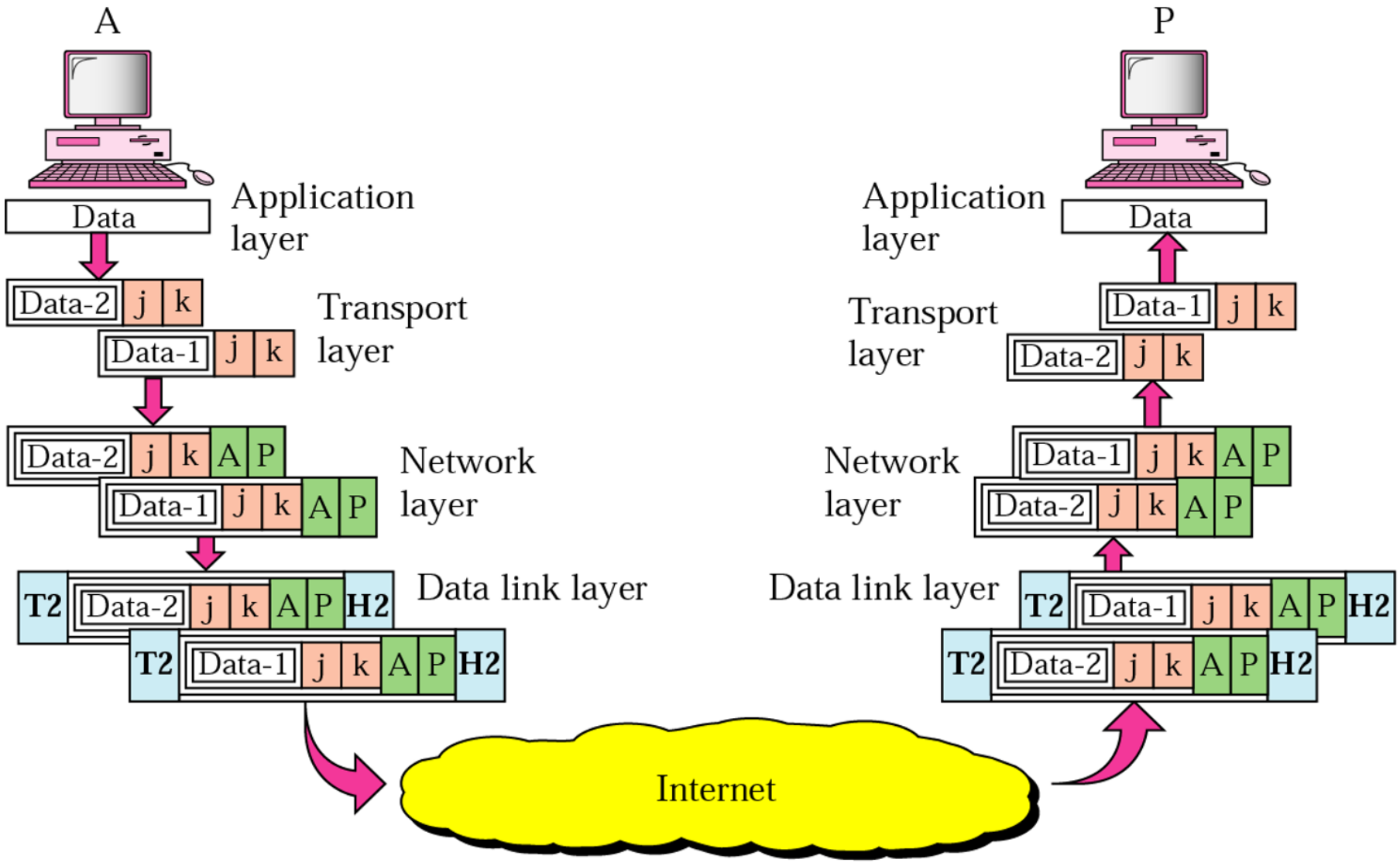


# Transport Layer

## Functions

- The transport level provides end-to-end communication (Process to Process Delivery) between processes executing on different machines.
- **Segmentation**
- **Service Point Addressing**
- **Negotiation of Quality and Type of Services.**
- **Deal with congestion control**
- **Connection establishment and termination.**
- **Multiplexing – Demultiplexing.**
- **Error control**

# Transport Layer



# Session Layer

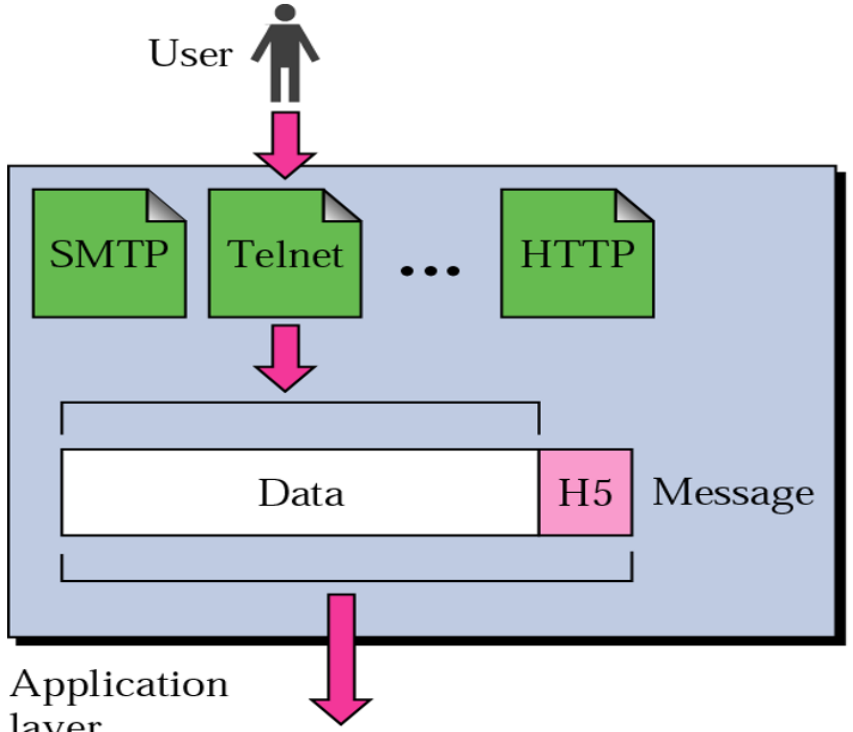
# Functions

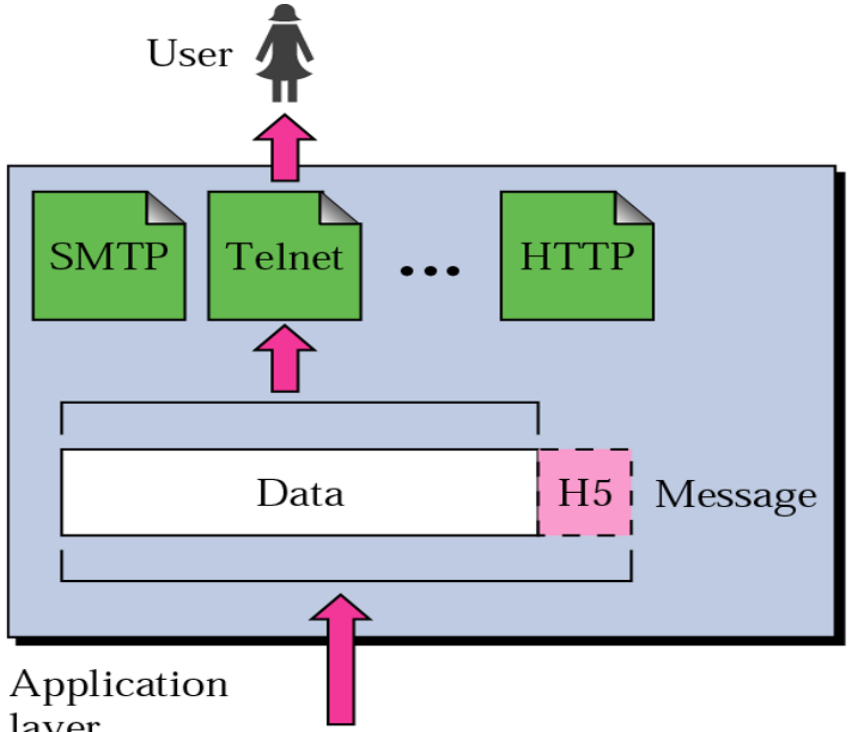
- This layer manages **Dialogue Control**. Session can allow traffic to go in both direction at the same time, or in only one direction at one time.
- **Token management**. For some protocols, it is required that both sides don't attempt same operation at the same time. To manage these activities, the session layer provides tokens that can be exchanged. Only one side that is holding token can perform the critical operation.
- **Synchronization/Check Pointing:** Session layer provides a way to insert checkpoints into data streams, so that after a crash, only the data transferred after the last checkpoint have to be repeated.

# Presentation Layer

- This layer is concerned with Syntax and Semantics of the information transmitted. Few of the services that Presentation layer provides are:
- Encoding data in a standard agreed upon way.
- It manages the abstract data structures and converts from representation used inside computer to network standard representation and back.
- Translation
- Encryption/ Decryption
- Composition
- Compression/ Decompression

# Application Layer





***The application layer is responsible for providing services to the user.***

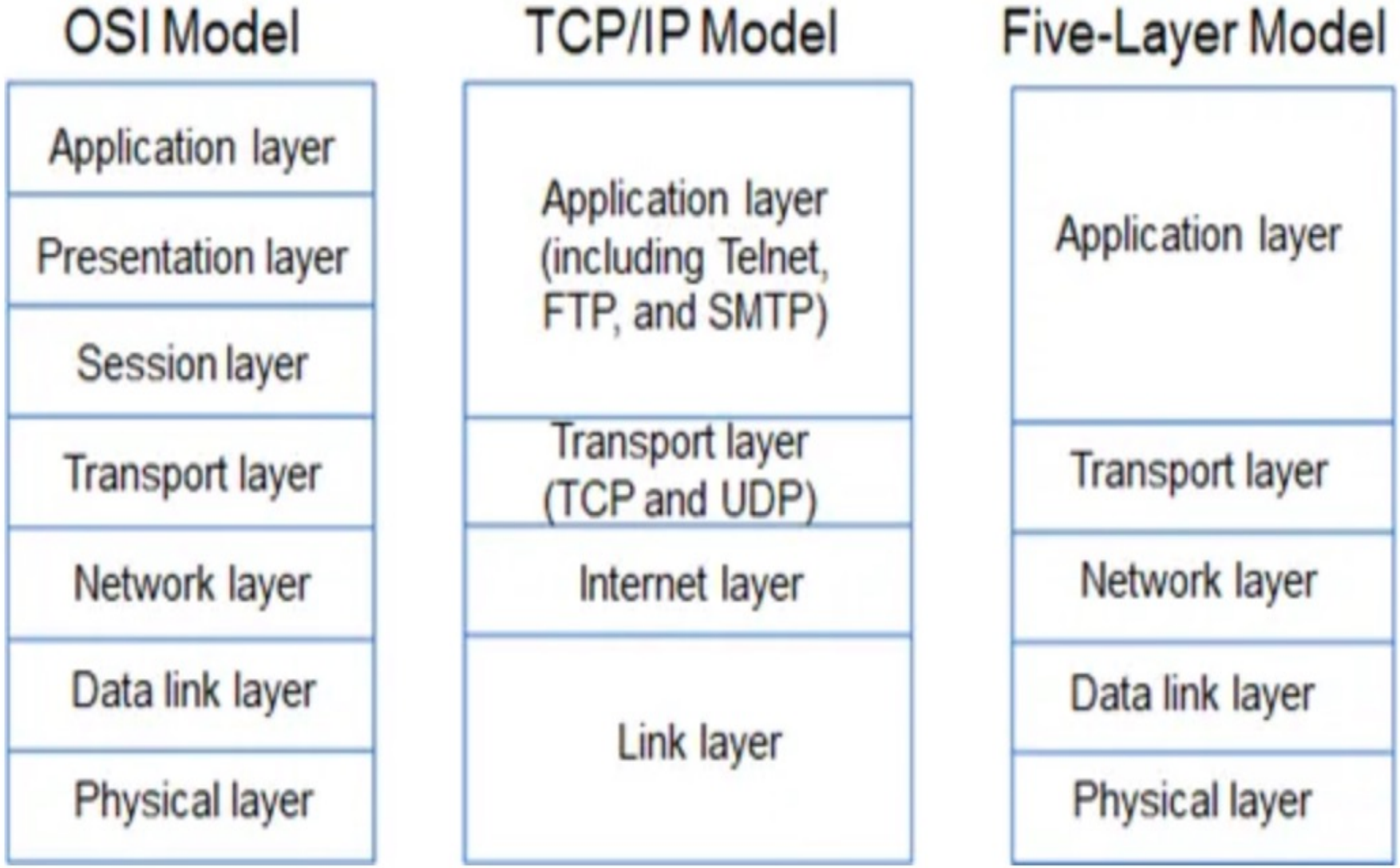
# Application Layer

## Functions

- **File transfer (FTP):** Connect to a remote machine and send or fetch an arbitrary file. FTP deals with authentication, listing a directory contents, ASCII or binary files, etc.
- **Remote login (telnet):** A remote terminal protocol that allows a user at one site to establish a TCP connection to another site, and then pass keystrokes from the local host to the remote host.
- **Mail (SMTP):** Allow a mail delivery agent on a local machine to connect to a mail delivery agent on a remote machine and deliver mail.
- **News (NNTP):** Allows communication between a news server and a news client.
- **Web (HTTP):** Base protocol for communication on the World Wide Web.

***MIME: Multi Purpose Internet Mail Extension***

# TCP/IP Reference Model



# Difference between OSI and TCP/IP Model

| FUNCTION | TCP/IP MODEL | OSI MODEL |
|---|---|---|
| Definition | TCP/IP stands for Transmission control protocol/ Internet protocol | OSI stands for Open systems Interconnection |
| Developed by | It is developed by DOD (Department of Defence) project agency. | OSI model is developed by ISO (International standard organization). |
| Technology/ Platform | It comprises of a set of standard protocols which lead to development of the Internet. It is a communication medium which provides connection between hosts. | It is an independent standard and generic protocol used as a communication gateway between network and end user. |
| Delivery of Packets | No guaranteed delivery of packets at transport layer. | Transport layer provides guaranteed delivery of packets. |
| Approach | Based on horizontal approach. | Based on vertical approach. |
| Application Layer | Session and presentation layers are not separate, both are included in application layer. | Session and presentation layers are separate |

# Difference between OSI and TCP/IP Model

## Continue..

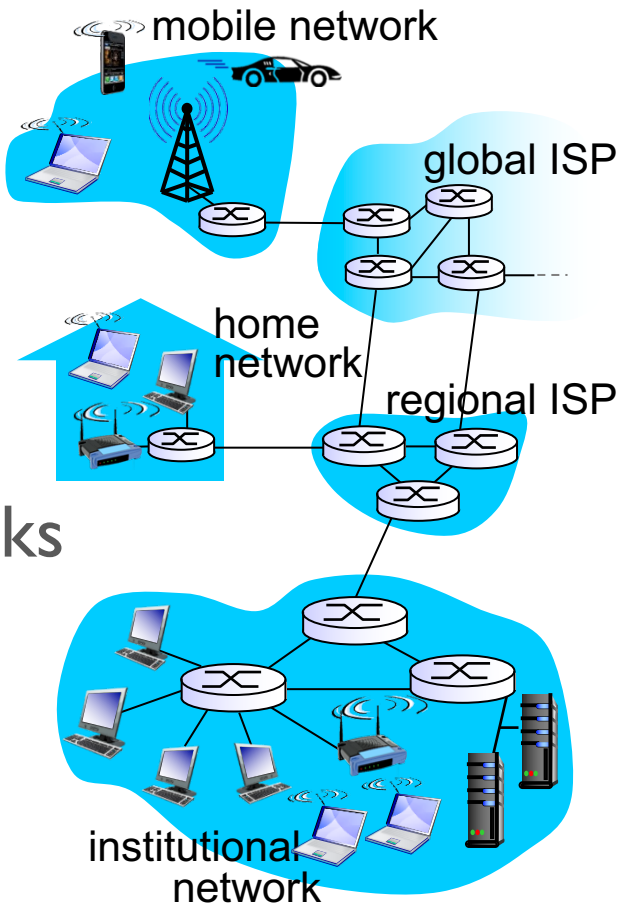
| FUNCTION | TCP/IP MODEL | OSI MODEL |
|---|---|---|
| Type of Model | Implemented model of OSI model. | It is a reference model on which various networks are built. |
| Network layer | Network layer provides only connectionless service. | Network layer provides connection oriented and connection less services (Both) |
| Replaceable/ Non-replaceable Protocols | Protocols can't be easily replaceable | In OSI model protocols are hidden and can be easily replaceable when technology changes occur |
| Number of Layers | Comprises of four layers | It comprises of seven layers |
| Protocol Dependent/Independent | Services, protocols, and interfaces are not properly segregated but are protocol dependent | Services, protocols and interfaces are defined and it is protocol independent |
| Usage | Widely used model | Limited usage of the model |
| Standardization of devices | Do not provide standardization of devices | Standardization of devices like router, switches, load balancers and other hardware devices |

# Network Edge

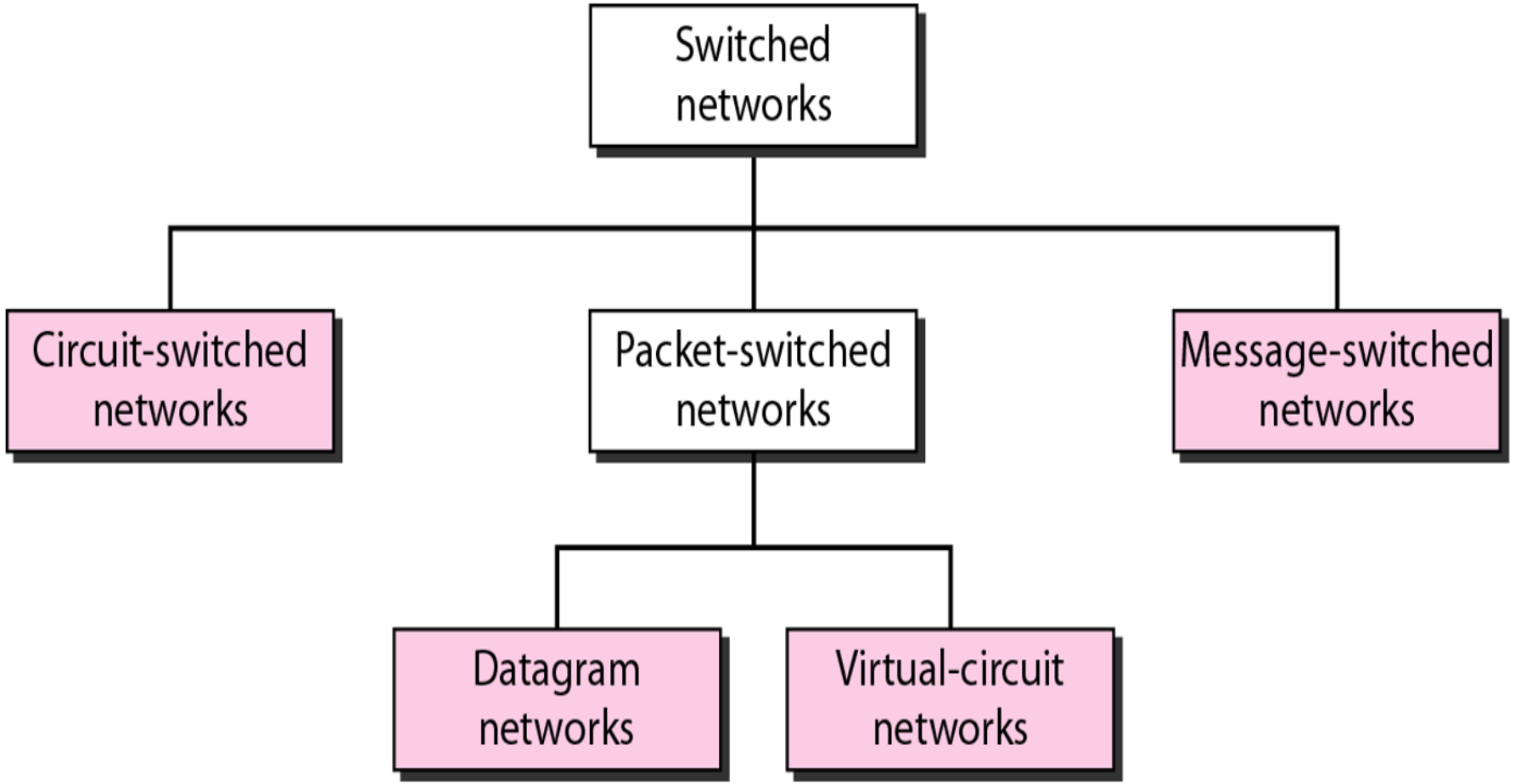
- An edge device is any piece of hardware that controls data flow at the boundary between two networks.
- Edge devices fulfil a variety of roles, depending on what type of device they are, but they essentially serve as network entry (or exit) points.
- Some common functions of edge devices are the **transmission, routing, processing, monitoring, filtering, translation and storage of data passing between networks.**
- Edge devices are used by **enterprises and service providers.**

# Closer Look of Network

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *access networks, physical media:*
- wired, wireless communication links



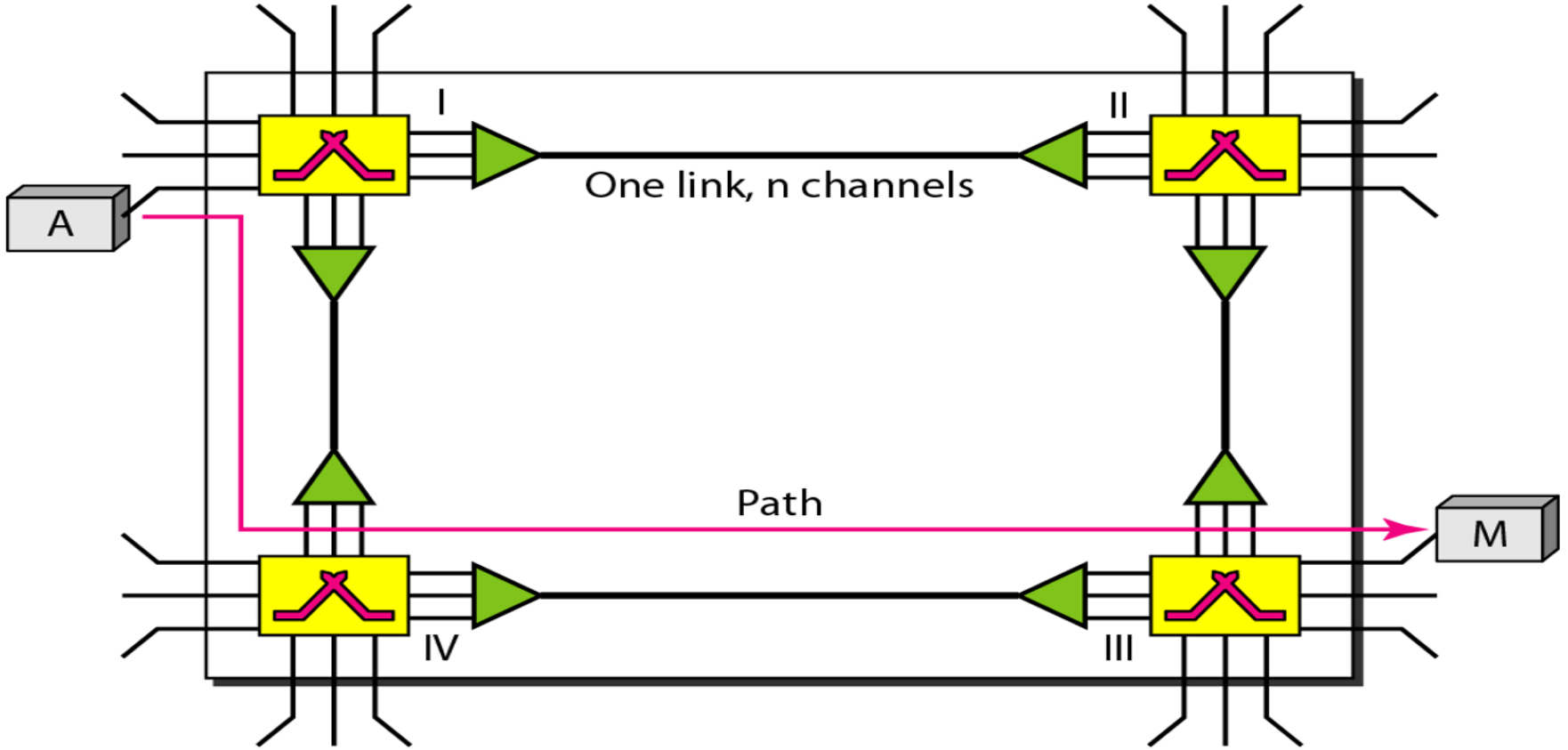
# Network Core



# Circuit-switching

**Note**

**A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into *n* channels.**



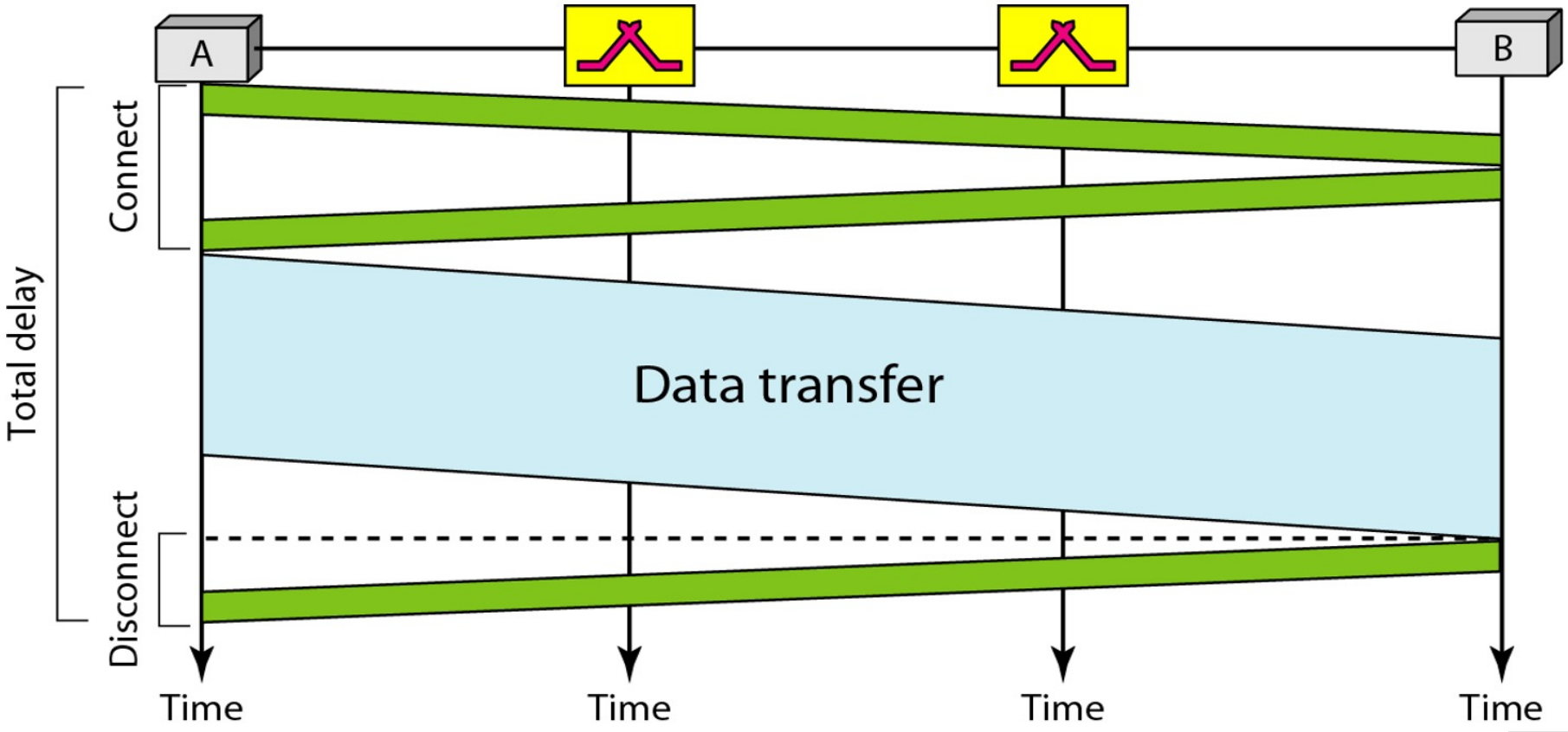
# Circuit-switching

***A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. However, each connection uses only one dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM.***

- In circuit switching network resources (bandwidth) is divided into pieces and bit delay is constant during a connection.
- The dedicated path/circuit established between sender and receiver provides a guaranteed data rate.
- Data can be transmitted without any delays once the circuit is established.
- **Telephone system network** is the one of example of Circuit switching.
- TDM (Time Division Multiplexing) and FDM (Frequency Division Multiplexing) are two methods of multiplexing multiple signals into a single carrier.

# Circuit-switching

## Delay




***Note***

**Switching at the physical layer in the traditional telephone network uses the circuit-switching approach.**

# Circuit-switching

# Advantages and Disadvantages

## Advantages

- It uses a fixed bandwidth.
- A dedicated communication channel increases the quality of communication.
- Data is transmitted with a fixed data rate.
- No waiting time at switches.
- Suitable for long continuous communication.

## Disadvantages

- A dedicated connection makes it impossible to transmit other data even if the channel is free.
- Resources are not utilized fully.
- The time required to establish the physical link between the two stations is too long.
- As a dedicated path has to be established for each connection, circuit switching is more expensive.
- Even if there is no transfer of data, the link is still maintained until it is terminated by users. By this channel remains ideal for a long time thereby making circuit switching inefficient.
- Dedicated channels require more bandwidth.

Note

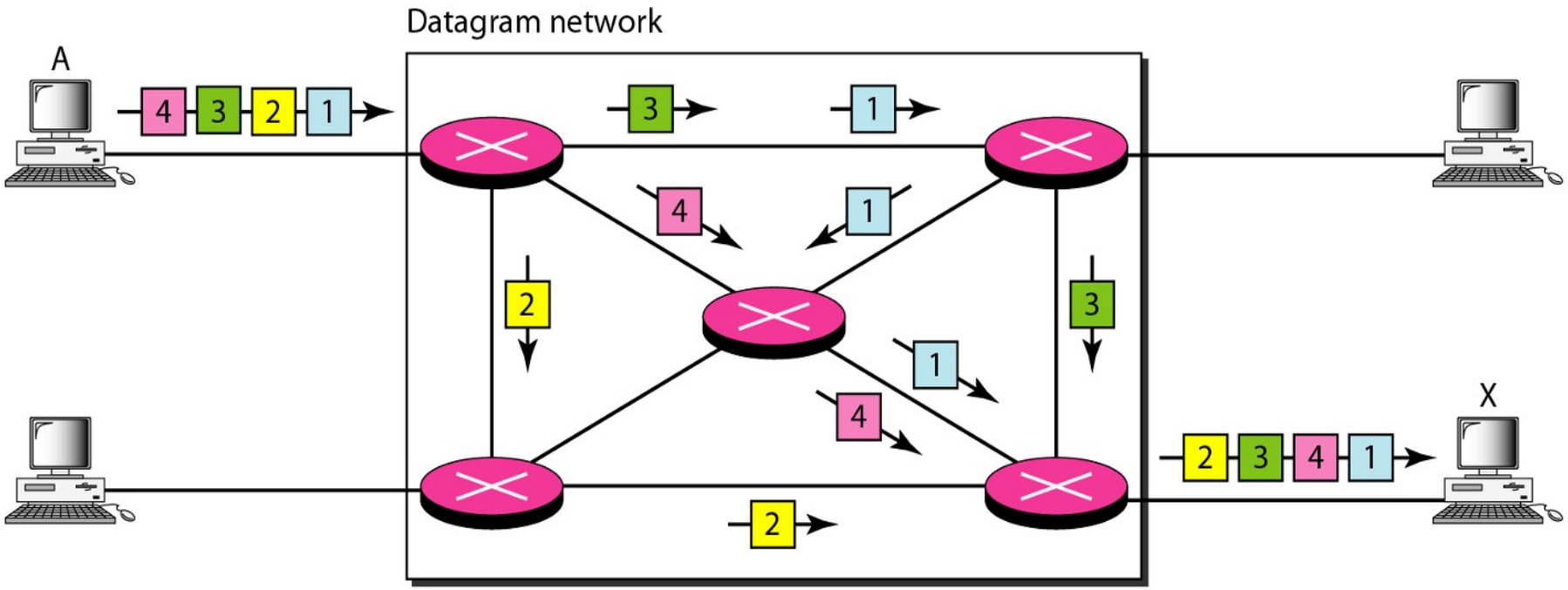
**In a packet-switched network, there is no resource reservation; resources are allocated on demand.**

# Packet Switching

- Packet switching is a method of transferring the data to a network in form of packets.
- In order to transfer the file fast and efficient manner over the network and minimize the transmission latency, the data is broken into small pieces of variable length, called Packet.
- At the destination, all these small-parts (packets) has to be reassembled, belonging to the same file.
- A packet composes of payload and various control information. No pre-setup or reservation of resources is needed.

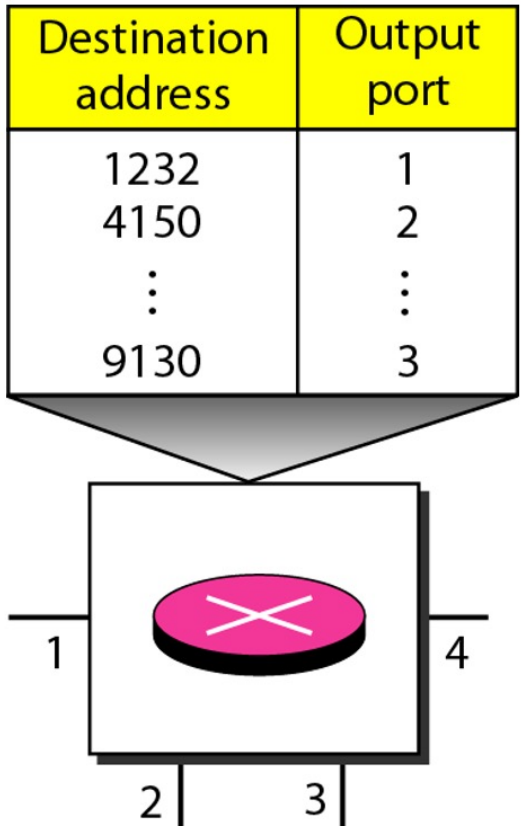
# Datagram Network

***In data communications, we need to send messages from one end system to another. If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size. The size of the packet is determined by the network and the governing protocol.***



# Datagram Network

# (Routing Table)




**Note**

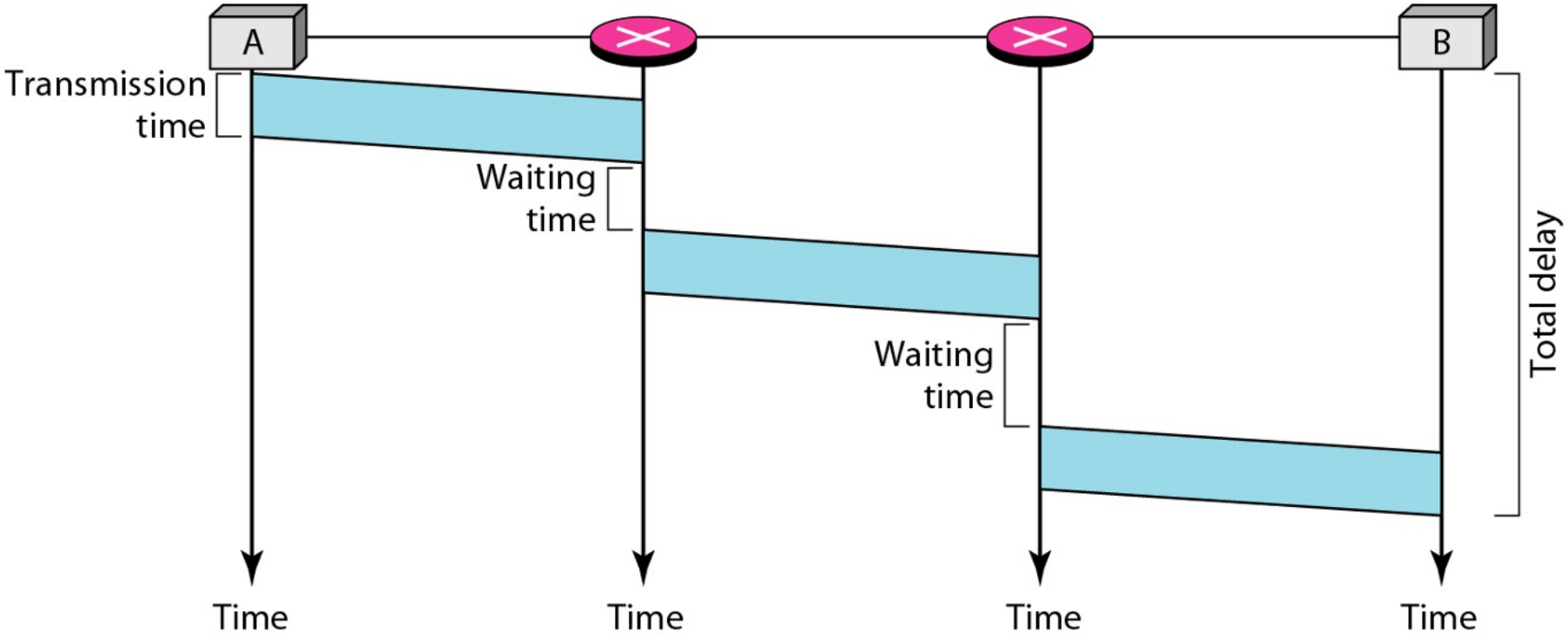
**A switch in a datagram network uses a routing table that is based on the destination address.**

**Note**

**The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.**

# Datagram Network

# (Delay)




***Note***

**Switching at the Internet is done by using the datagram approach to packet switching at the network layer.**

# Virtual Circuit Network

***A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.***

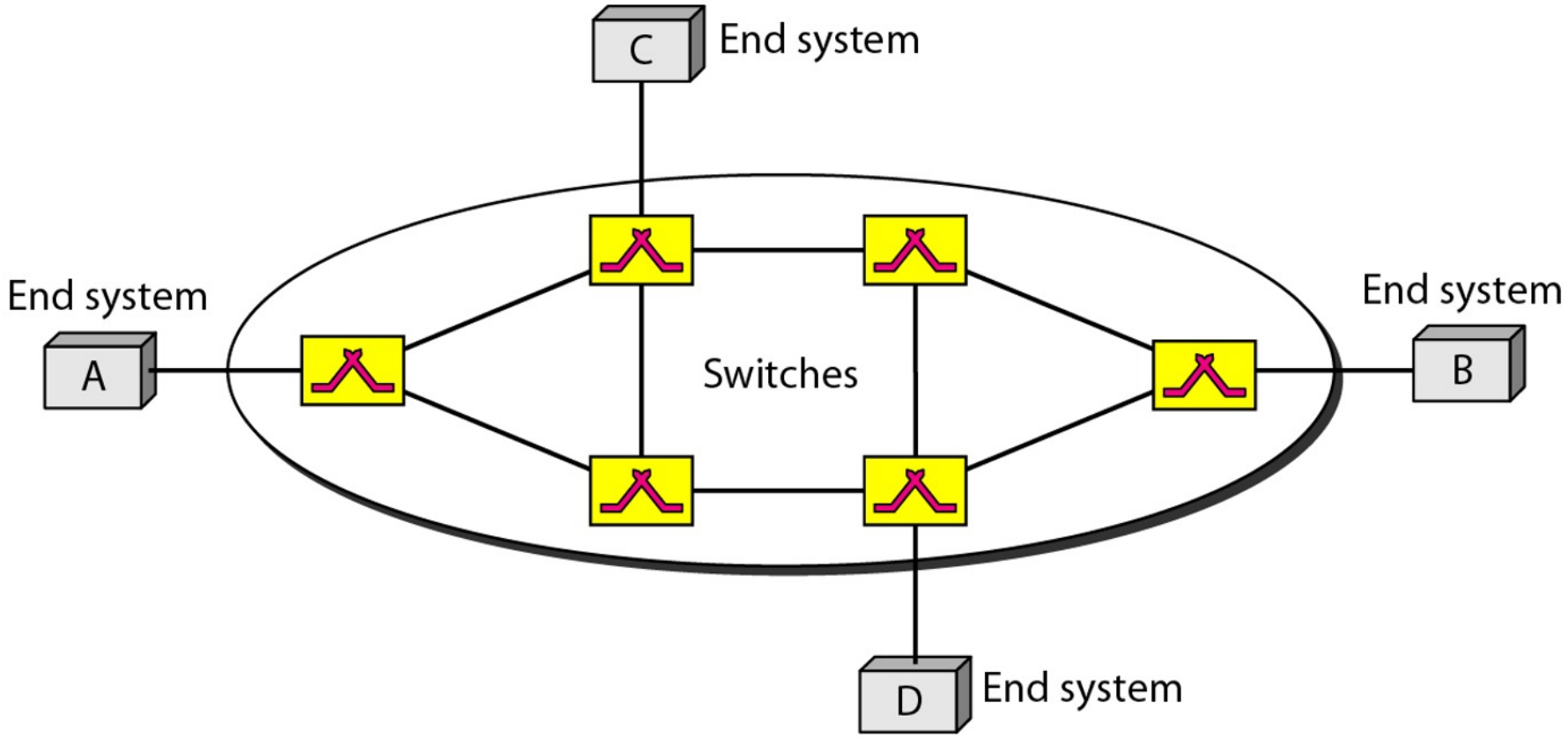


Figure: *Virtual-circuit identifier*

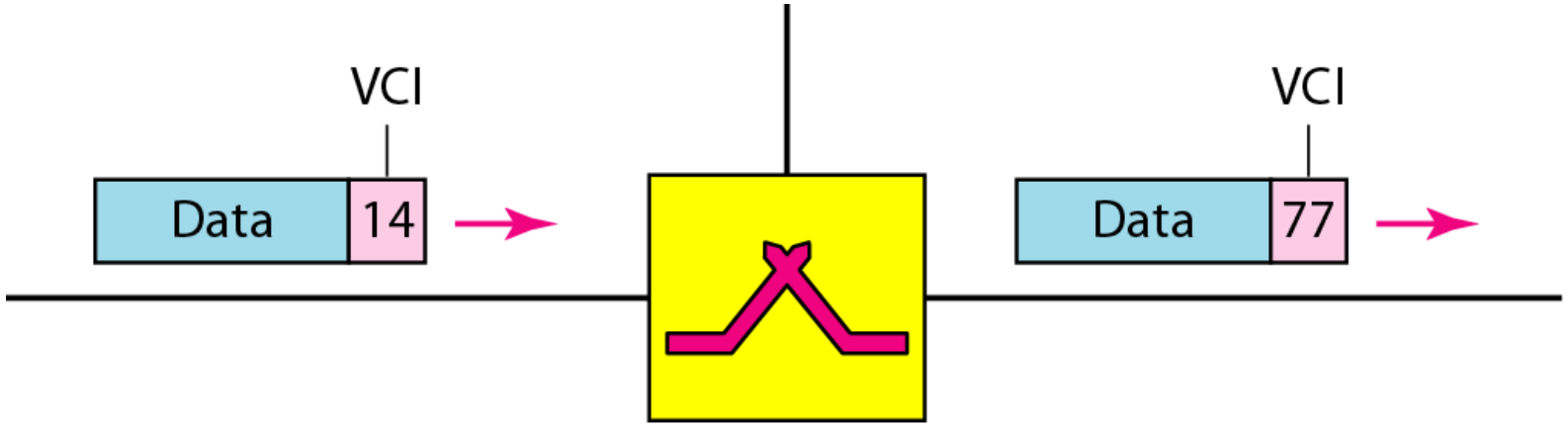


Figure: *Switch and tables in a virtual-circuit network*

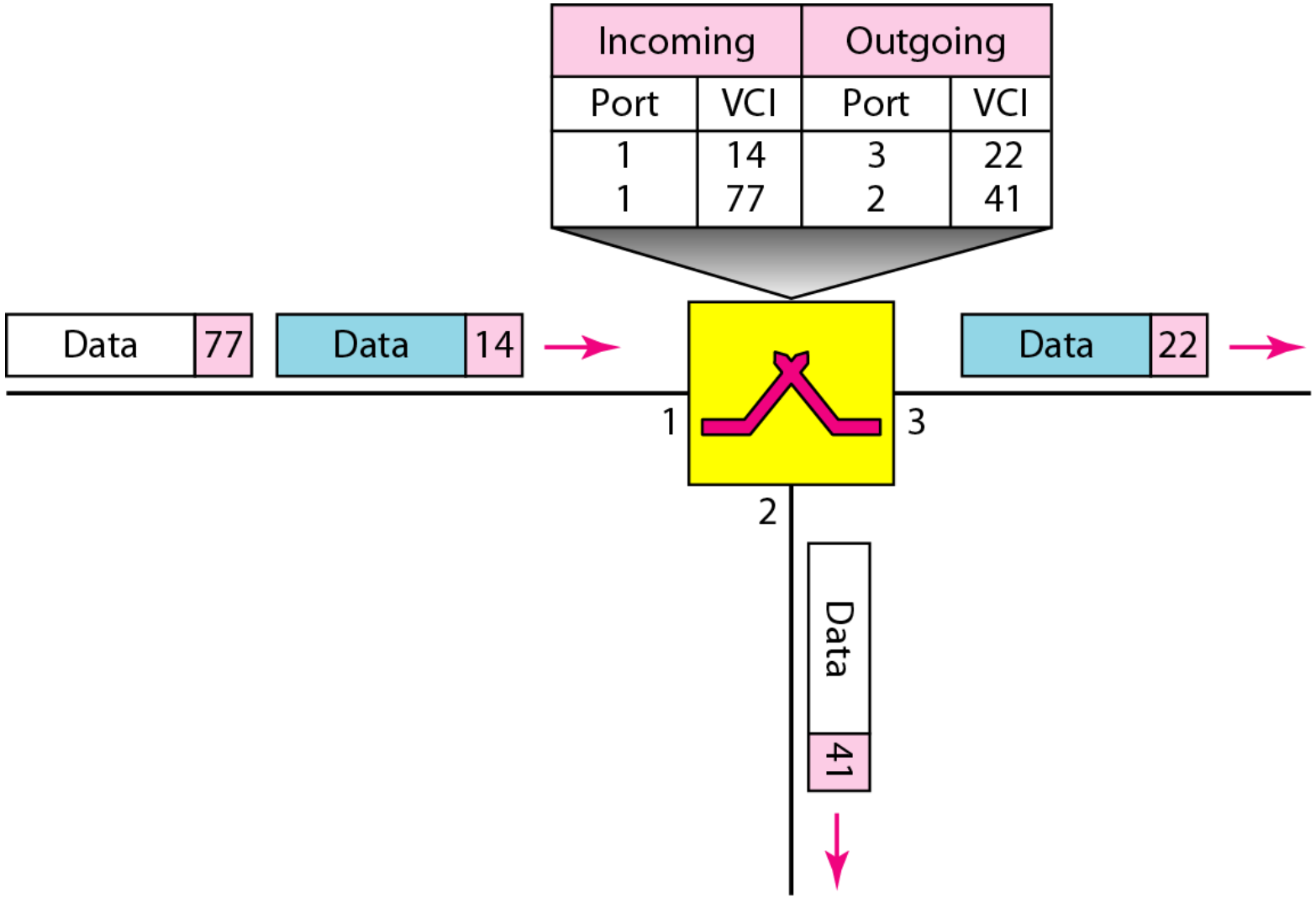


Figure: *Source-to-destination data transfer in a virtual-circuit network*

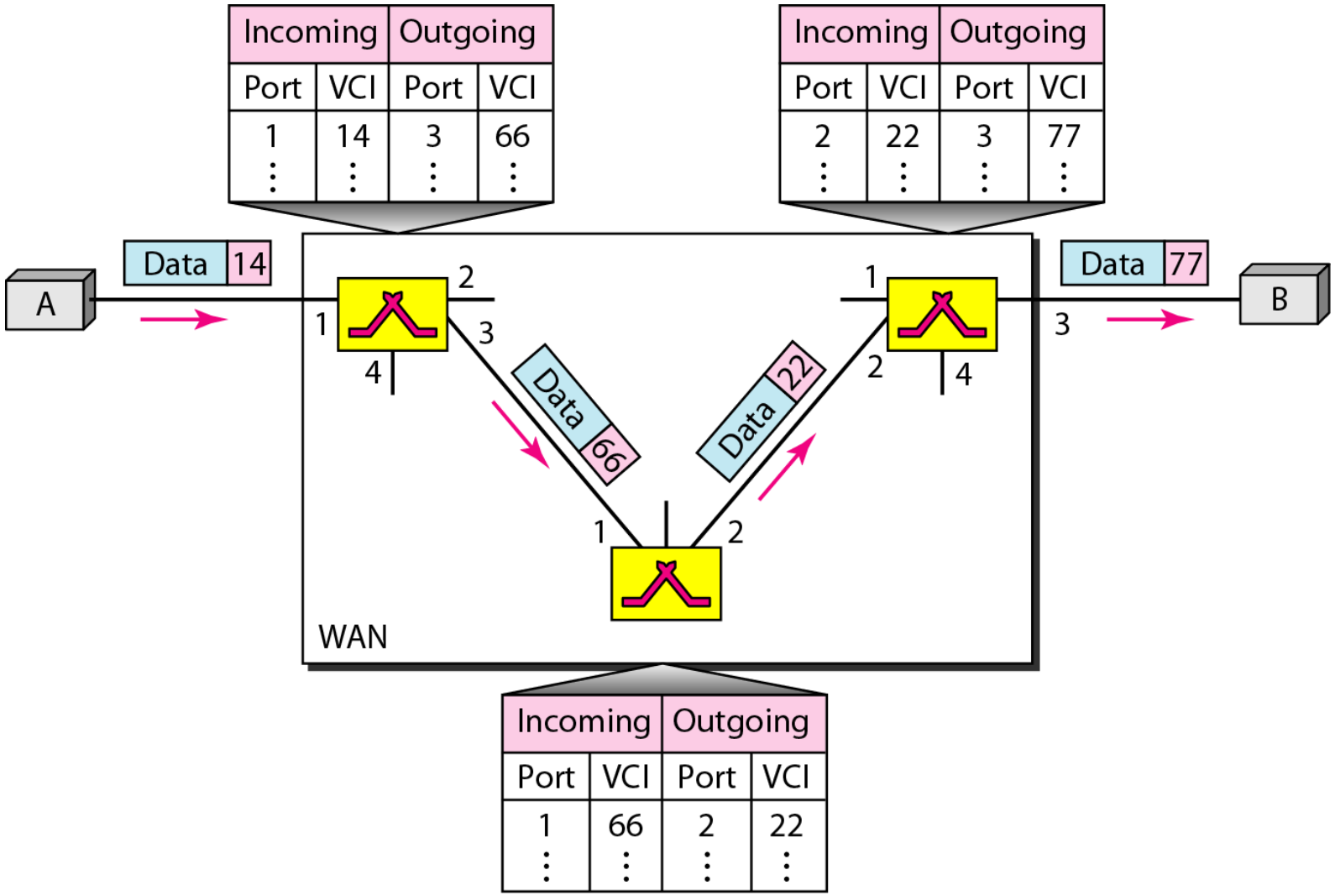


Figure: *Setup request in a virtual-circuit network*

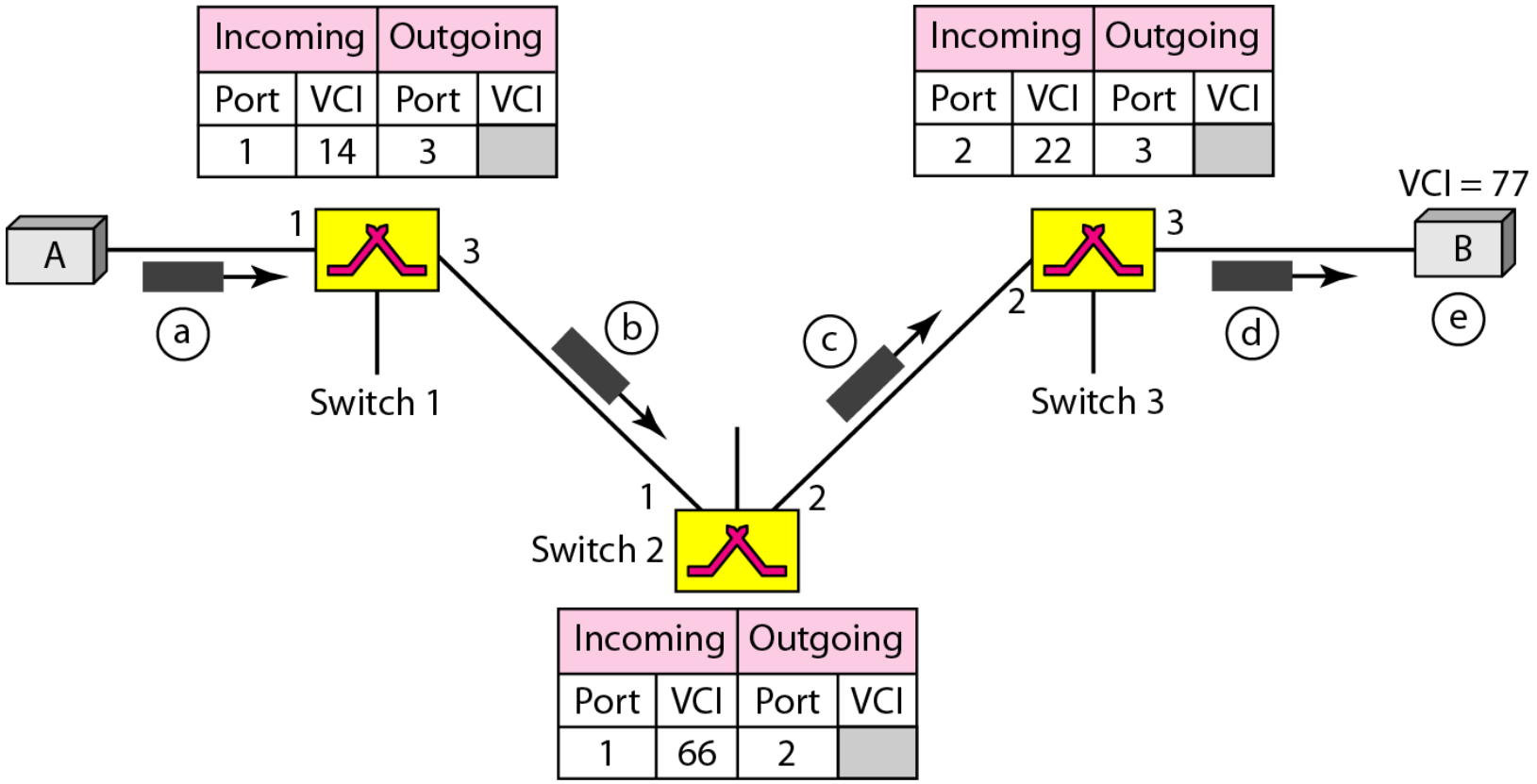
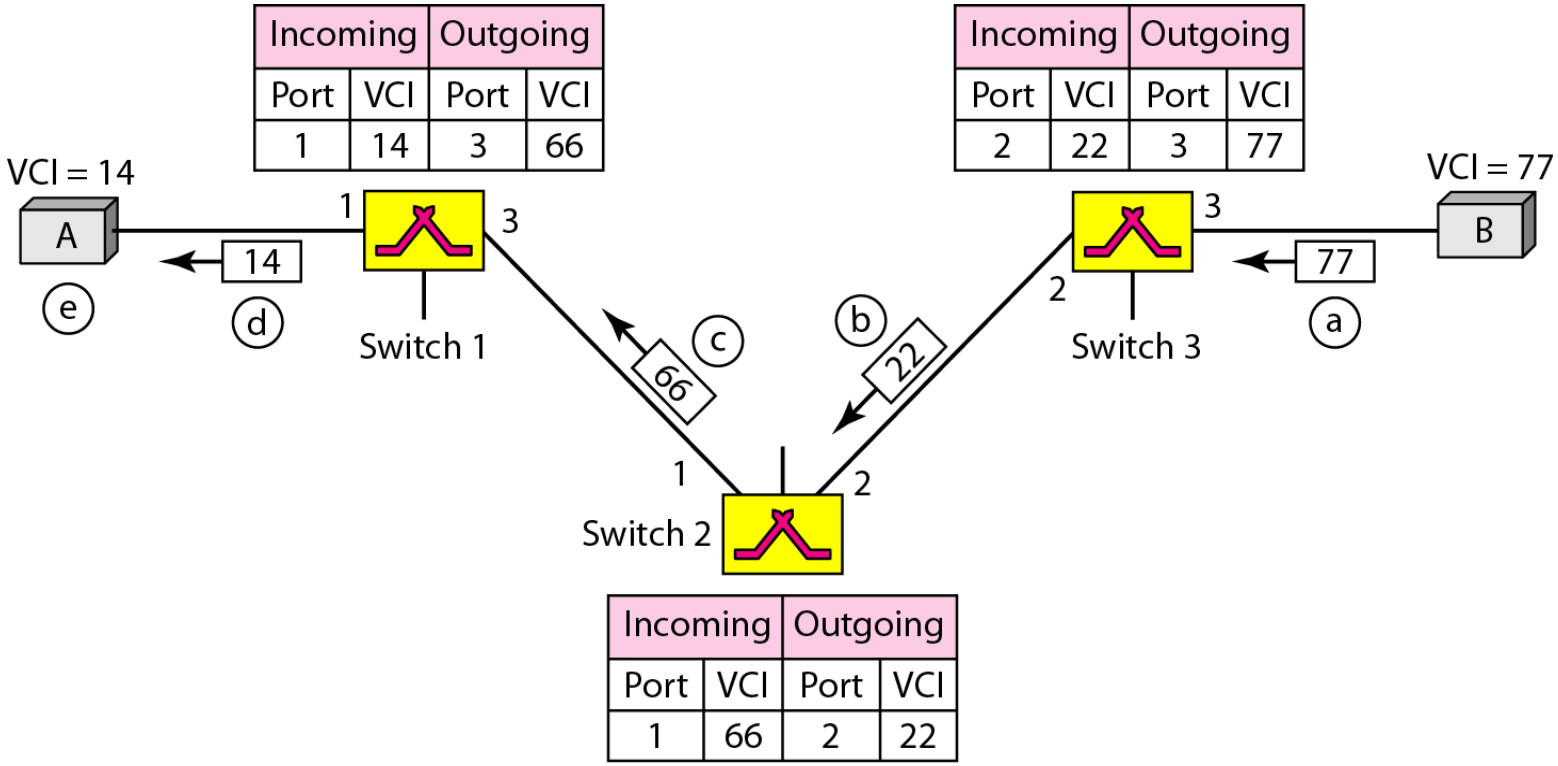


Figure: *Setup acknowledgment in a virtual-circuit network*




Note

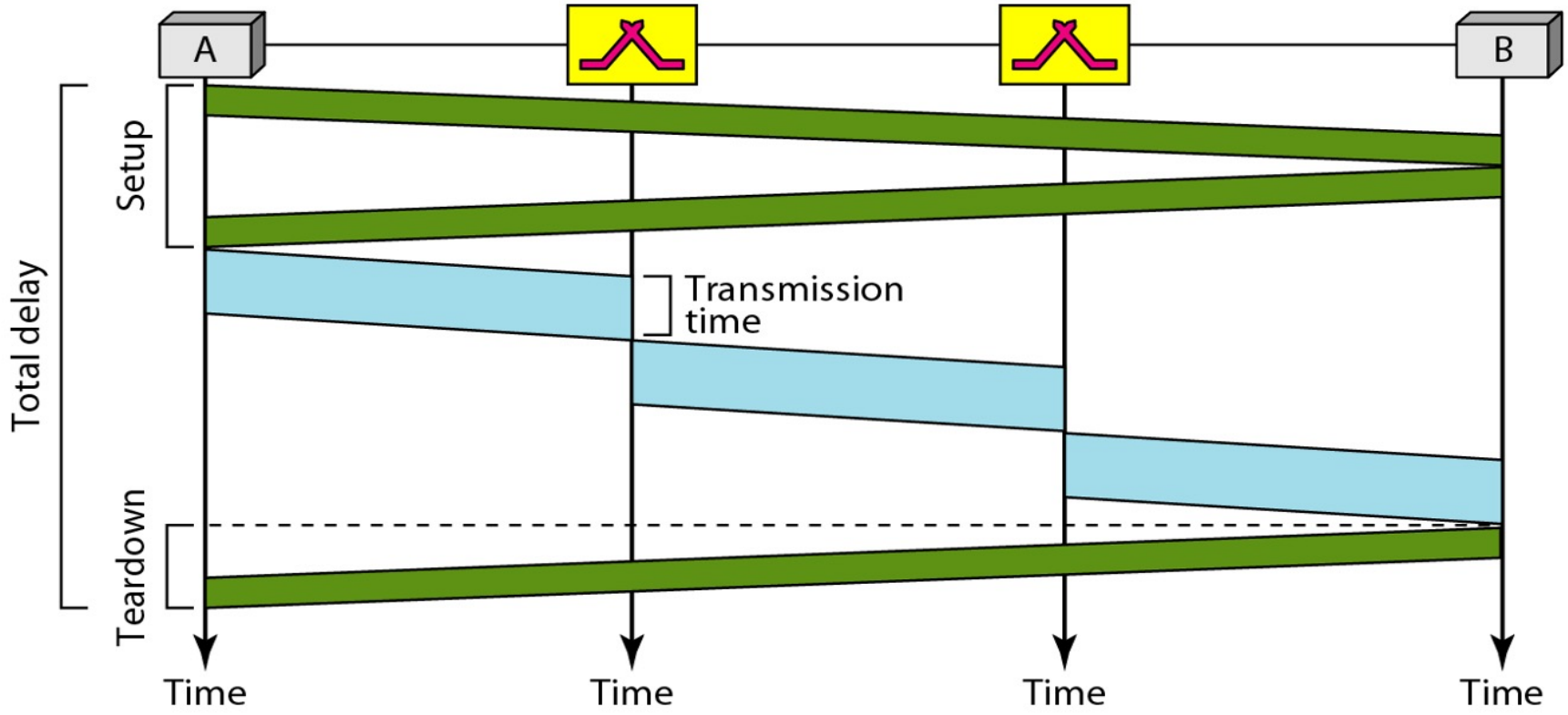
Switching at the data link layer in a switched WAN is normally implemented by using virtual-circuit techniques.

# Virtual Circuit Network

# (Delay)

Note

In virtual-circuit switching, all packets belonging to the same source and destination travel the same path;
but the packets may arrive at the destination with different delays if resource allocation is on demand.



# Packet Switching

# Advantages and Disadvantages

***Advantages:***

- Packet switching is cost effective, because switching devices do not need massive amount of secondary storage.
- Packet switching offers improved delay characteristics, because there are no long messages in the queue (maximum packet size is fixed).
- Packet can be rerouted if there is any problem, such as, busy or disabled links.
- The advantage of packet switching is that many network users can share the same channel at the same time.
- Packet switching can maximize link efficiency by making optimal use of link bandwidth.

***Disadvantages:***

- Protocols for packet switching are typically more complex.
- It can add some initial costs in implementation.
- If packet is lost, sender needs to retransmit the data.
- Another disadvantage is that packet-switched systems still can't deliver the same quality as dedicated circuits in applications requiring very little delay - like voice conversations or moving images.

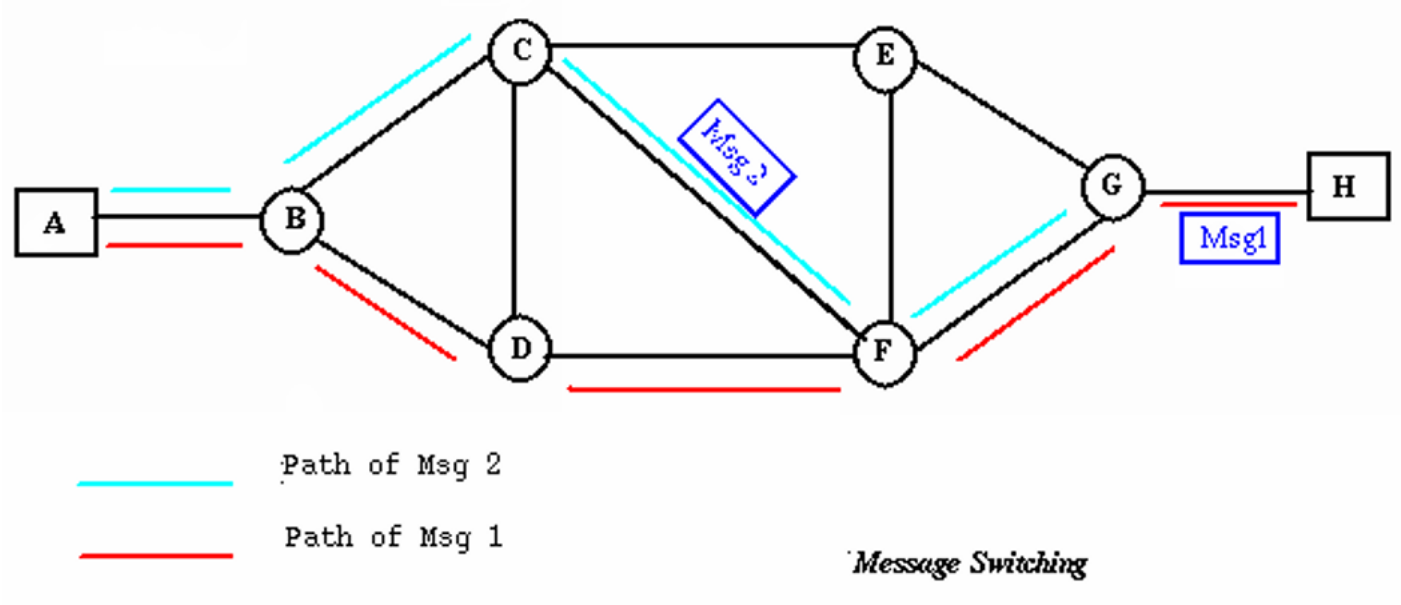
# Message Switching

# (Store and Forward Network)

- With message switching there is no need to establish a dedicated path between two stations.
- When a station sends a message, the destination address is appended to the message.
- The message is then transmitted through the network, in its entirety, from node to node.
- Each node receives the entire message, stores it in its entirety on disk, and then transmits the message to the next node.
- This type of network is called a **store-and-forward network**.

# Message Switching

# (Store and Forward Network)




A message-switching node is typically a general-purpose computer. The device needs sufficient secondary-storage capacity to store the incoming messages, which could be long. A time delay is introduced using this type of scheme due to store- and-forward time, plus the time required to find the next node in the transmission path.

# Message Switching

# Advantages and Disadvantages

***Advantages:***

- Channel efficiency can be greater compared to circuit-switched systems, because more devices are sharing the channel.
- Traffic congestion can be reduced, because messages may be temporarily stored in route.
- Message priorities can be established due to store-and-forward technique.
- Message broadcasting can be achieved with the use of broadcast address appended in the message.

***Disadvantages***

- Message switching is not compatible with interactive applications.
- Store-and-forward devices are expensive, because they must have large disks to hold potentially long messages.

# Connection-less versus Connection-oriented

| Criteria | Connection-Oriented | Connection-Less |
|---|---|---|
| **Connection** | Prior connection needs to be established. | No prior connection is established. |
| **Resource Allocation** | Resources need to be allocated. | No prior allocation of resource is required. |
| **Reliability** | It ensures reliable transfer of data. | Reliability is not guaranteed as it is a best effort service. |
| **Congestion** | Congestion is not at all possible. | Congestion can occur likely. |
| **Transfer mode** | It can be implemented either using Circuit Switching or VCs. | It is implemented using Packet Switching. |
| **Retransmission** | It is possible to retransmit the lost data bits. | It is not possible. |
| **Suitability** | It is suitable for long and steady communication. | It is suitable for bursty transmissions. |
| **Signaling** | Connection is established through process of signaling. | There is no concept of signaling. |
| **Packet travel** | In this packets travel to their destination node in a sequential manner. | In this packets reach the destination in a random manner. |
| **Delay** | There is more delay in transfer of information, but once connection established faster delivery. | There is no delay due absence of connection establishment phase. |

# History of Computer Networks

| S. No | Period | Method | History |
|---|---|---|---|
| 1 | Late 1950 | SAGE (Semi – Automatic Ground Environment) | It was used at U.S Military Radar system. |
| 2 | 1960 | SABRE(Semi Automatic Business Research Environment) | At Commercial Airline Reservation system online connected with two main frame computers. |
| | | Packet switching | **Packet switching** was developed by **Paul Baran** and **Donald Devices** to transfer the information between computers and network.<br>**NPL** network (**National Physical Laboratory** ) at united kingdom local area network (LAN) using line speed of 768kbit/s was implemented by Davies pioneered |
| 3 | 1963 | Intergalactic Computer network | Intergalactic Computer network was send by J.C.RLicklider to his office colleagues discussing about this concept, a computer network engaged to access communication with users of computers. |
| 4 | 1965 | Telephone switch | At first widely used Telephone switch was introduced by **Western Electric** which implemented true computer control. |
| 5 | 1966 | WAN (Wide Area Network ) | An experimental paper on WAN (Wide Area Network) has been published by Thomas Marill and Lawrence G.Roberts published in the area of time sharing. |

# History of Computer Networks

| | | | |
|---|---|---|---|
| 6 | 1969-1970 | ARPANET (Hierarchical routing after 1970's Internet today) | First In 1969, four nodes of ARPANET were connected between four universities namely the university of California at Los Angeles, at Santa Barbara, the Stanford Research Institute and the university of Utah using the 50 Kbit/s circuits.<br>Packet –switched networks was the theoretical work to model was performed by **Leonard Kleinrock** , ARPANET was which underpinned the development of it and his theoretical work on hierarchical routing in late 1970 s with his student Farouk Kamoun remains critical to the operation of the Internet today. |
| 7 | 1972 | X.25<br>TCP/IP | Using X.25 as commercial services were deployed then was using an infrastructure for expanding TCP/IP networks. |
| 8 | 1973 | Hosts | In1973, a French network named **CYCLADES** was the first for making **hosts** which is responsible for reliable delivery of data, later it became centralized service of network in itself. |
| 9 | 1973-1979 | Ethernet | A memo at Xerox PARC was written by Robert Metcalfe describing Ethernet in 1973, in an Aloha based networking system which was developed in 1960s by Norman Abramson and colleagues at the University of Hawaii.<br>At July 1976 the paper published "Ethernet: Distributed Packet Switching for Local Computer Networks" by Robert Metcalfe and David Boggs, then collaborated on many patents received in 1977 and 1978. Robert Metcalfe pursued making on open standard at 1979. |

# History of Computer Networks

| | | | |
|---|---|---|---|
| 10 | 1976 | ARCNET | ARCNET was created by John Murphy of Data point corporation in which token-passing network was used first to share the storage device in 1976. |
| 11 | 1995 | NEW FIBRE OPTIC CABLES | The speed capacity of transmission for Ethernet was slightly elevated from 10 Mbit/s to 100Mbit/sat 1995.After 19913, Ethernet supported transmission speed capacity towards gigabit. Frequently, highest speeds up to 100 Gbit/s were appended (still 2016). Ethernet has ability to grow easily (such as quick compatible to support new fiber optic cable speed) |