2- Physical Layer (06)

Compiled by- UBM

Note:

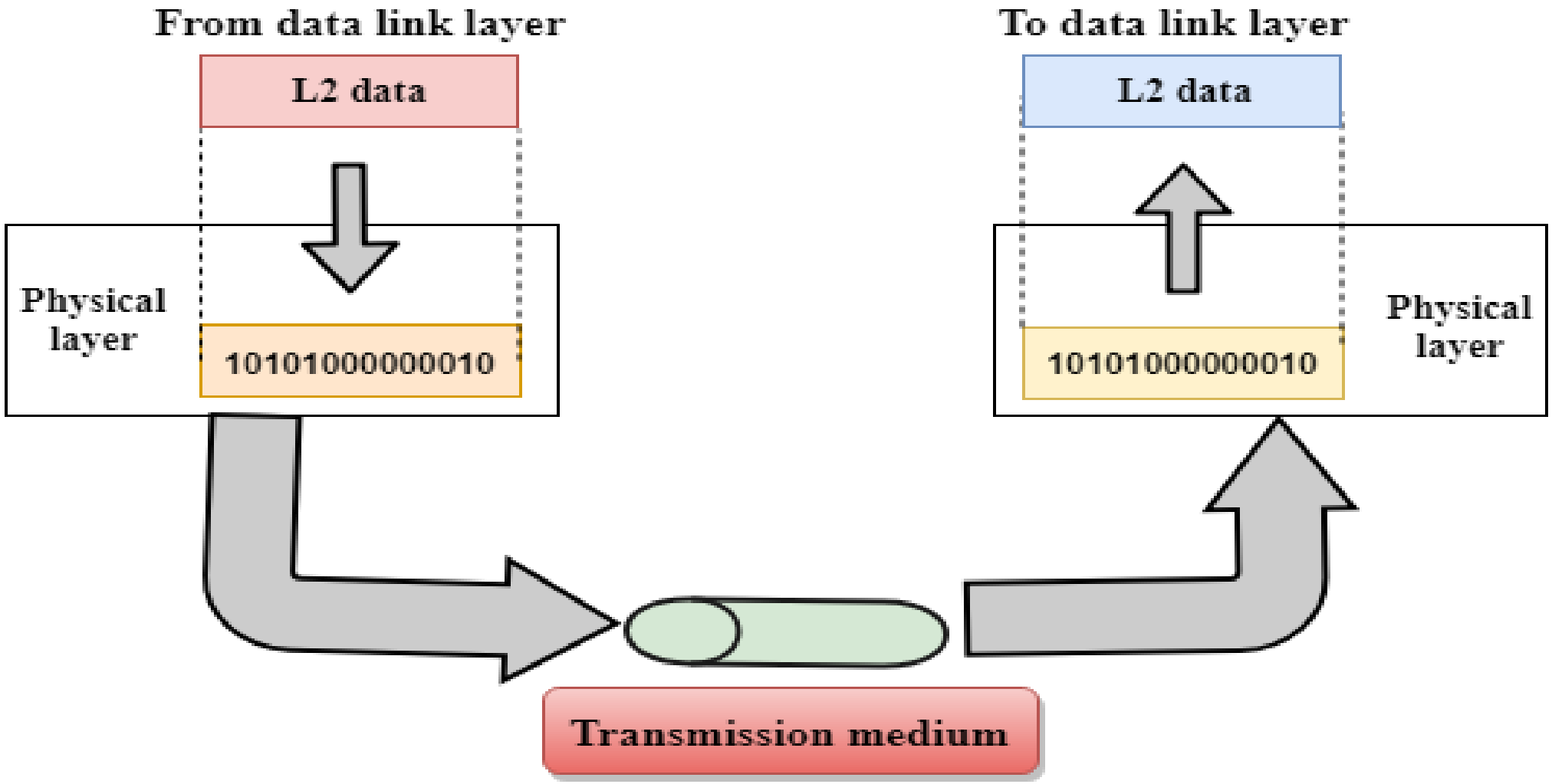
CN attendance will be floated in between the lecture, 5 minutes time will be given for the attendance form filling. So be present till the end.

2 Physical Layer (06)

2.1 Introduction to Communication System, digital Communication, Electromagnetic Spectrum.

2.2 Guided Transmission Media: Twisted pair, Coaxial, Fiber optics. Unguided media (Wireless Transmission): Radio Waves, Microwave, Bluetooth, Infrared, Circuit and Packet Switching.

Physical layer

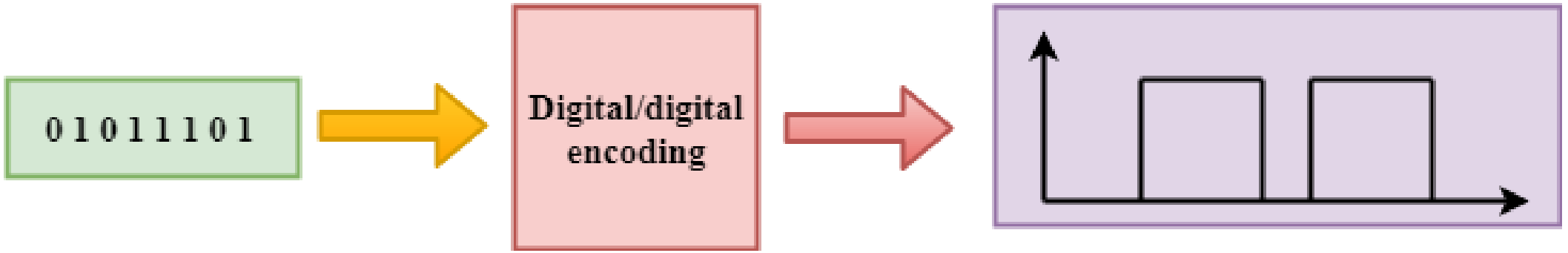


Functions of a Physical layer:

- **Line Configuration:** It **defines the way how two or more devices can be connected physically.**
- **Data Transmission:** It defines the transmission mode whether it is **simplex, half-duplex or full-duplex mode** between the two devices on the network.
- **Topology:** It defines the way how network devices are arranged.
- **Signals:** It determines the **type of the signal used** for transmitting the information.

Digital Transmission

- DIGITAL-TO-DIGITAL CONVERSION

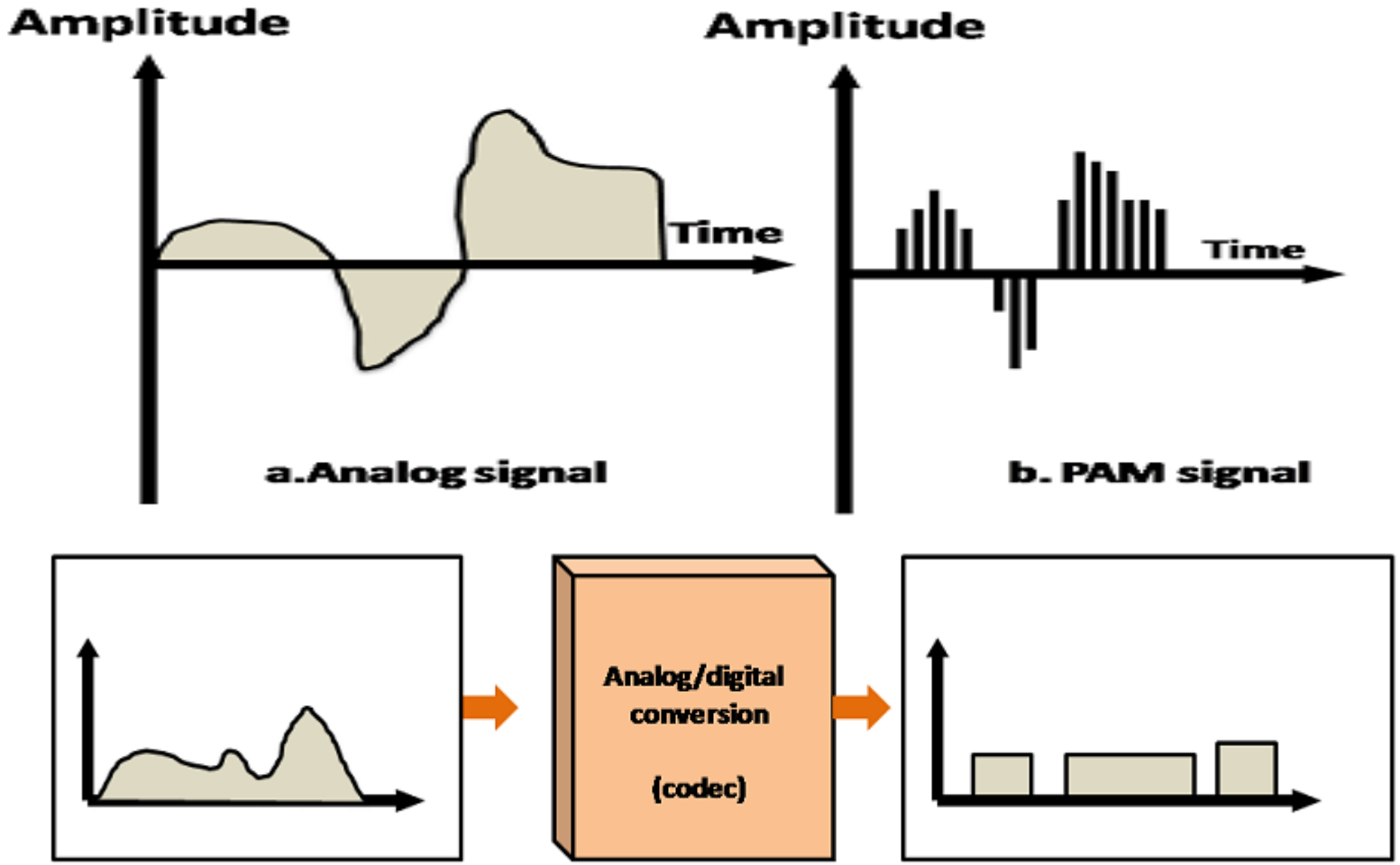


ANALOG-TO-DIGITAL CONVERSION

- Techniques for Analog-To-Digital Conversion : PAM
- PAM stands for **pulse amplitude modulation**.
- PAM is a technique **used in analog-to-digital conversion**.
- PAM technique **takes an analog signal, samples it, and generates a series of digital pulses.**
- PAM technique is not useful in data communication as it translates the original wave form into pulses, but these pulses are not digital.
- To make them digital, **PAM technique is modified to PCM technique**.

ANALOG-TO-DIGITAL CONVERSION

- PAM

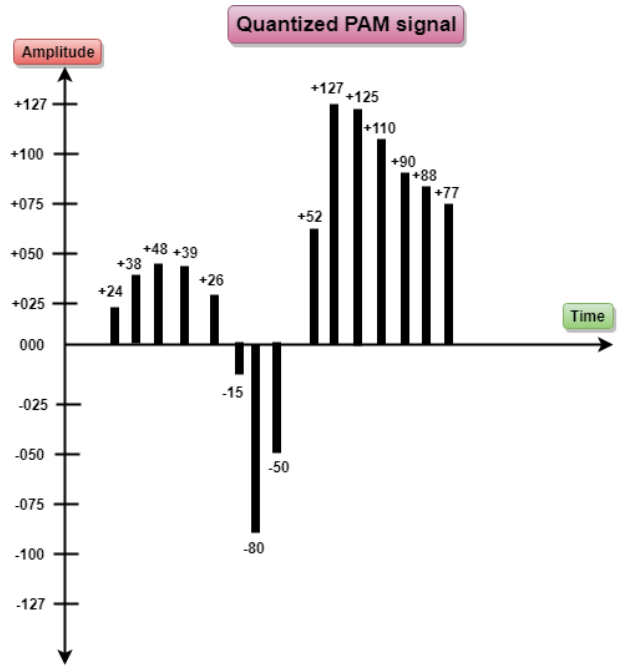


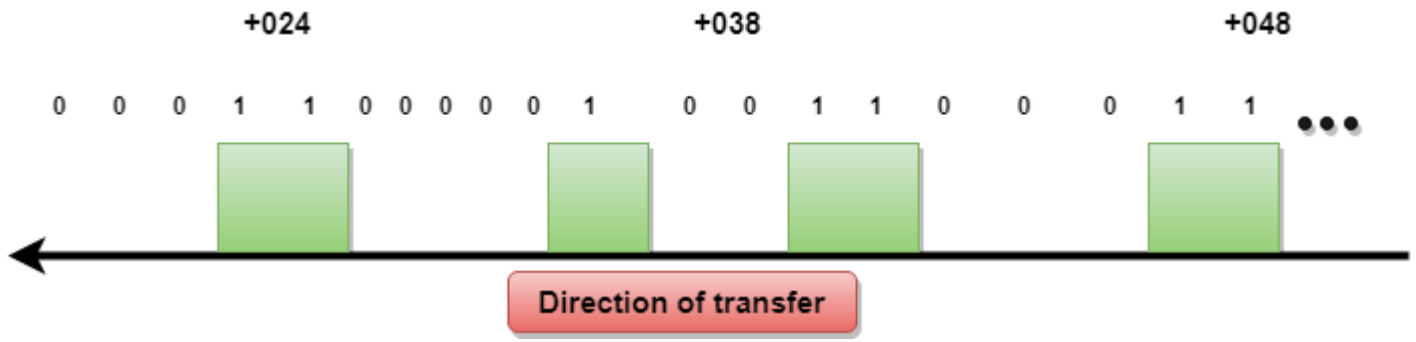
PCM - **Pulse Code Modulation**.

- PCM technique is used **to modify the pulses created by PAM to form a digital signal.**
- To achieve this, PCM quantizes PAM pulses. **Quantization is a process of assigning integral values in a specific range to sampled instances**.
- PCM is made of four separate processes:
  - PAM,
  - quantization,
  - binary encoding,
  - and digital-to-digital encoding.

ANALOG-TO-DIGITAL CONVERSION

- PCM





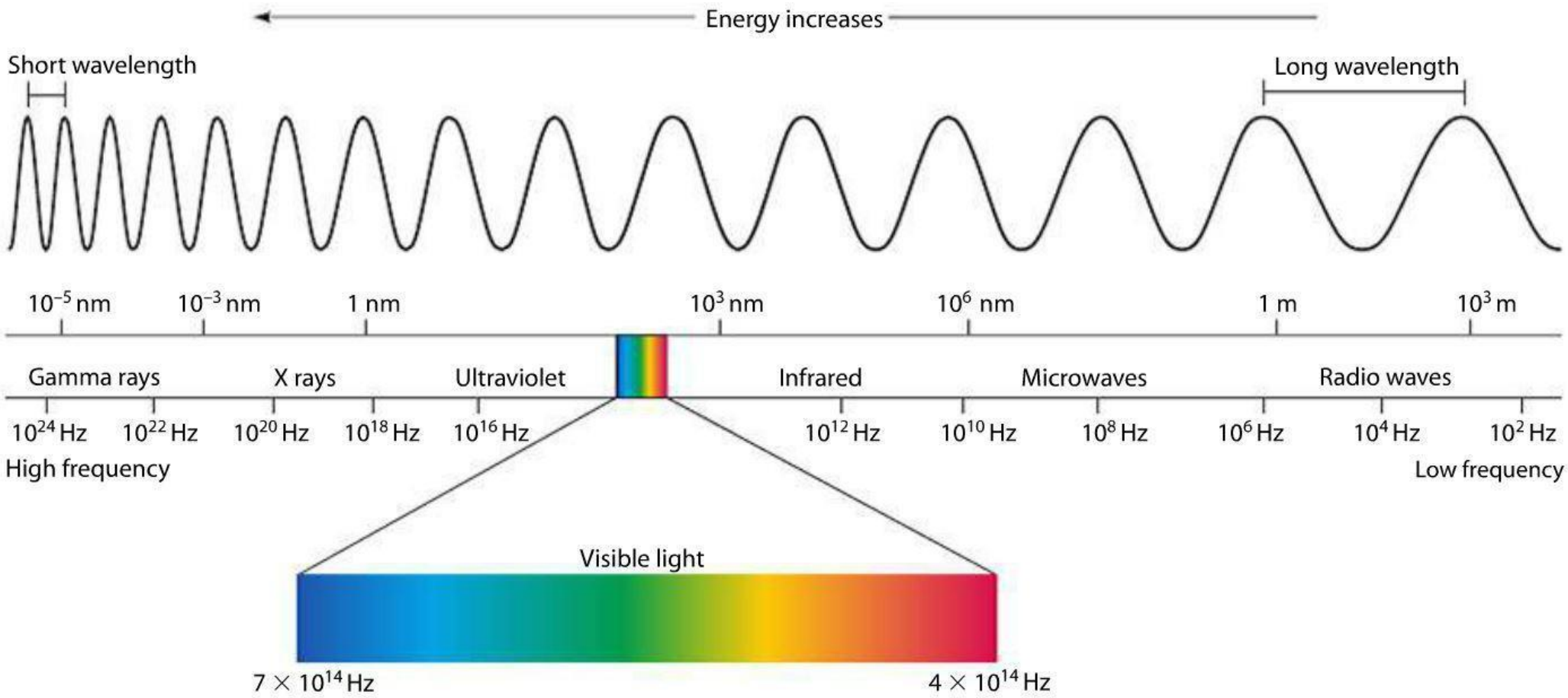
Electromagnetic spectrum

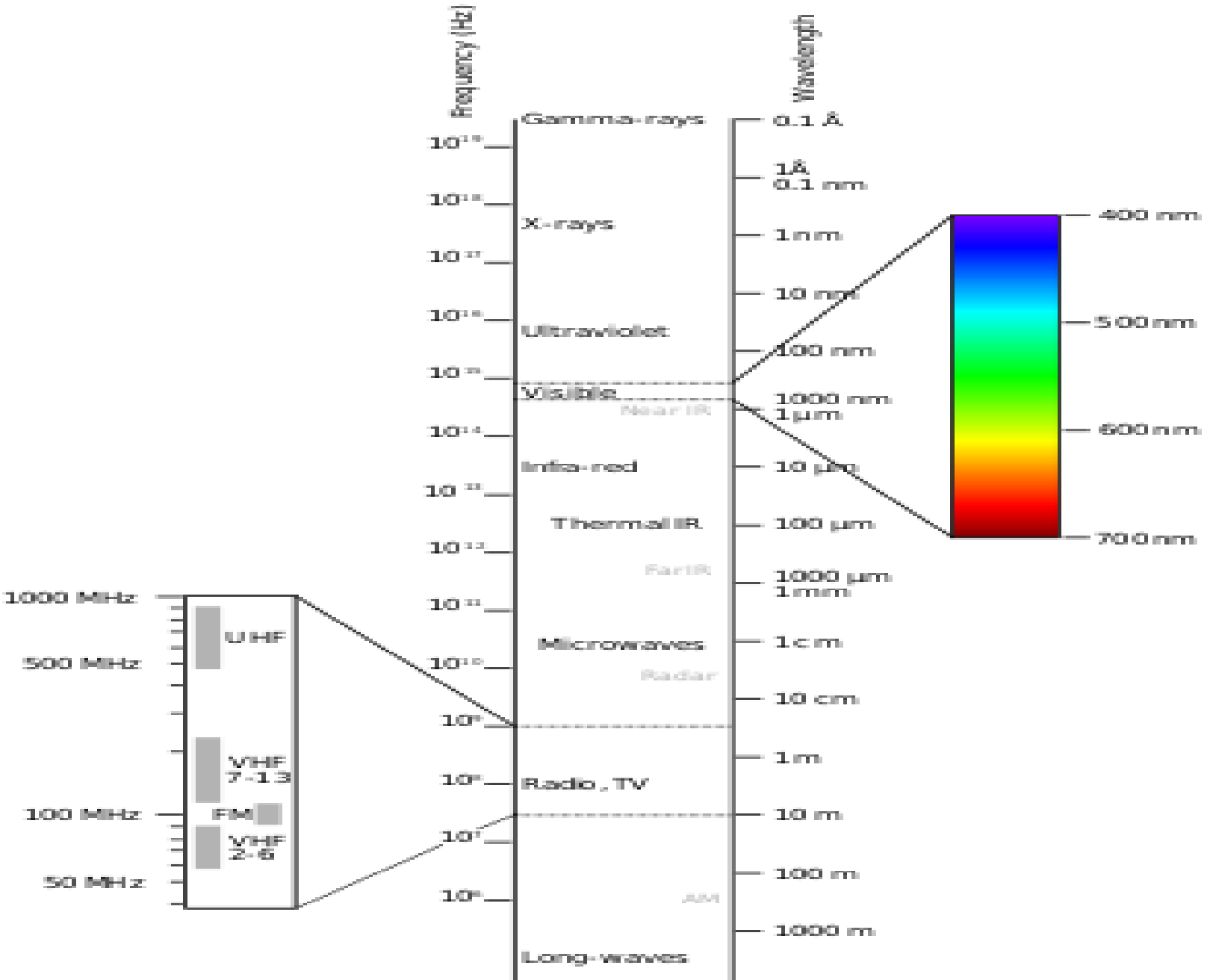
- The **electromagnetic spectrum** is the range of frequencies (the **spectrum**) of **electromagnetic** radiation and their respective wavelengths and photon energies.

Electro magnetic spectrum

- The types of electromagnetic radiation are broadly classified into the following classes (regions, bands or types):
- **Gamma radiation**
- **X-ray radiation**
- **Ultraviolet radiation**
- **Visible radiation**
- **Infrared radiation**
- **Terahertz radiation**
- **Microwave radiation**
- **Radio waves**

Electro magnetic spectrum




Frequency (Hz)
Wavelength
Gamma-rays
X-rays
Ultraviolet
Visible
Near IR
Infra-red
Thermal IR
Far IR
Microwaves
Radar
Radio , TV
AM
Long-waves
0.1 Å
1Å
0.1 nm
1 nm
10 nm
100 nm
1000 nm
1 µm
10 µm
100 µm
1000 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1000 m
400 nm
500 nm
600 nm
700 nm
1000 MHz
500 MHz
100 MHz
50 MHz
UHF
VHF 7-13
FM
VHF 2-6

Uses of Electromagnetic Waves

Introduction

- Wavelength of the Electro Magnetic spectrum continually changes
  - high frequency = short wavelength
  - high frequency = high energy
  - high energy = more dangerous

Uses of Electro Magnetic Waves

- **Radio Waves (communications)**
- TV and FM radio (short wavelength)
- Direct line of sight with transmitter (do not diffract)
- Medium wavelength – travel further because they reflect from layers in the atmosphere

Uses of Electro Magnetic Waves

- **<u>Satellite signals (Microwaves)</u>**
- **Frequency of microwaves pass easily through atmosphere and clouds**
- **<u>Cooking (Microwaves)</u>**
- **Microwaves are absorbed by water molecules.**
- These **water molecules become heated > heat food**
- **Dangers**: microwaves **are absorbed by living tissue Internal heating will damage or kill cells**

Uses of Electro Magnetic Waves

- **<u>Infrared Radiation (remote controls, toasters)</u>**
- **Any object that radiates heat radiates Infrared Radiation**
- **Infrared Radiation is absorbed by all materials** and causes heating
- It is **used for night vision and security cameras** as Infrared Radiation is visible in daytime or night-time
- Police use it to catch criminals, army use it to detect enemy
- **Dangers**: **damage to cells** (burns)

Uses of Electro Magnetic Waves

- **<u>Ultraviolet</u>**
- **Dangers**: over-exposure to **UVA and B damages surface cells and eyes and can cause cancer.**
  - **Sun exposure for the skin is best restricted to before 11am** and after **3pm in the UK in summer months.**
- **Benefits:**
  - **UVC is germicidal,** destroying bacteria, viruses and moulds in the air, in water and on surfaces.
  - **UV synthesises vitamin D in skin**, controls the endocrine system and is a painkiller.
  - **Used in state of the art air-handling units, personal air purifiers and swimming pool technology and Water Purifier.**
  - **Used to detect forged bank notes:** they fluoresce in UV light; real bank notes don’t.
  - **Used to identify items outside visible spectrum areas,** known as 'black lighting'.

Uses of Electro Magnetic Waves

- **X-rays**
- X-rays detect bone breaks
- X-rays pass through flesh but not dense material like bones
- **Dangers**: **X-rays damage cells and cause cancers.** Radiographer precautions include wearing lead aprons and standing behind a lead screen to minimise exposure
- **Gamma Rays**
- **Gamma Rays cause and treat cancers**
- In **high doses, gamma can kill normal cells and cause cancers**
- Gamma can be **used to kill mutated cells** though too.

What is Transmission media?

- Transmission media is a **communication channel that carries the information from the sender to the receiver.** Data is transmitted through the electromagnetic signals.
- The **main functionality is to carry the information through a physical path** between transmitter and receiver in data communication.
- In a **copper-based network, the bits in the form of electrical signals**.
- In a **fibre based network, the bits in the form of light pulses**.

Two Types of Transmission media

- **wired media :** In wired media, **medium characteristics are more important whereas,**
- **wireless media**. : in wireless media, **signal characteristics are more important.**
- **Properties of transmission media**
  - **bandwidth,**
  - **delay,**
  - **cost and**
  - **ease of installation and maintenance**.

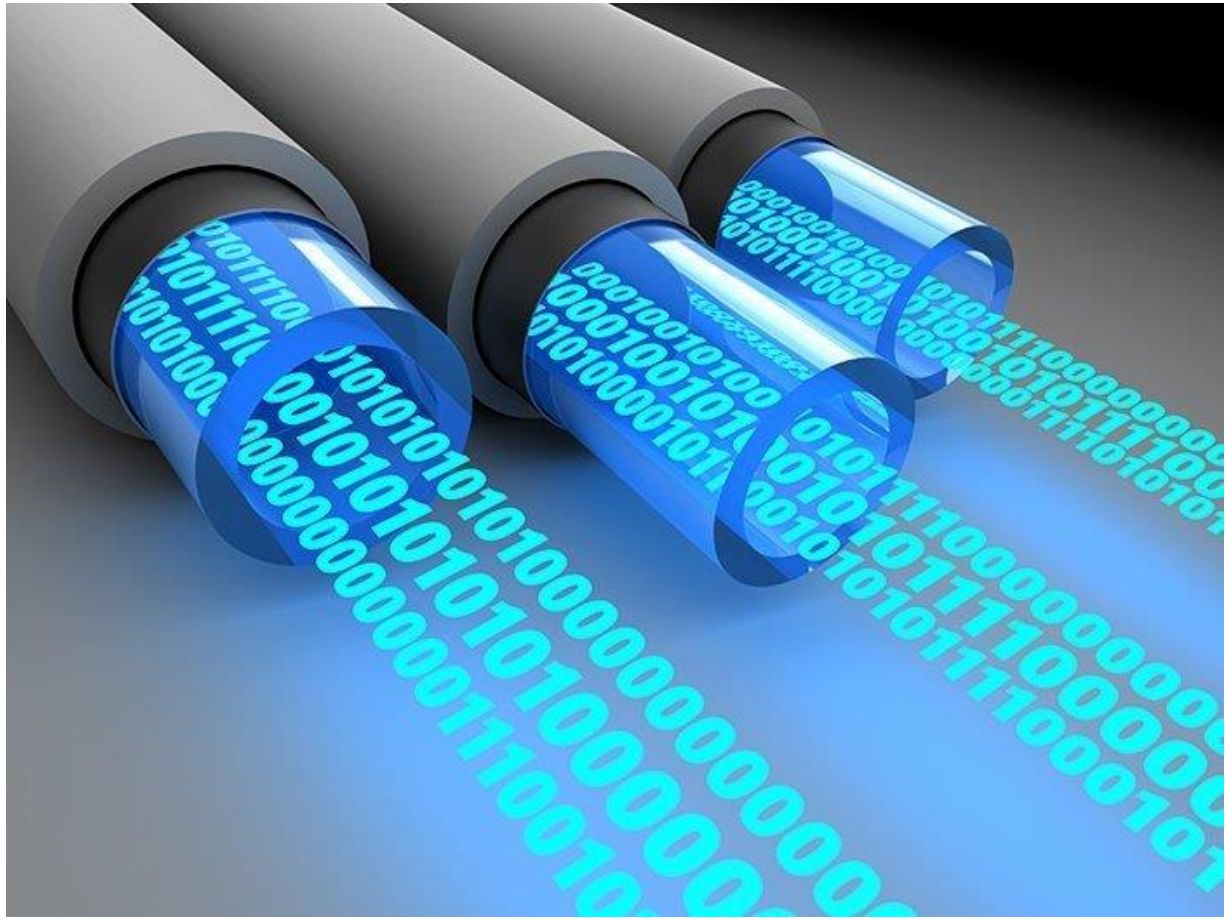
Bandwidth

- **Bandwidth: Bandwidth is the capacity of a wired or wireless network** communications link to transmit the maximum amount of data from one point to another over a computer network in a given amount of time -- usually one second. Synonymous with capacity, bandwidth describes the **data transfer rate.**
- Bandwidth is **not a measure of network speed** -- a common misconception.
- Bandwidth can be compared to the amount of water that can flow through a water pipe.

Bandwidth

- While **bandwidth is traditionally expressed in bitsper second** (bps, Mbps, Gbps),.
- Bandwidth connections can be symmetrical, which means the data capacity is the same in both directions to upload or download data, or
- asymmetrical, which means download and upload capacity are not equal. In asymmetrical connections, upload capacity is typically smaller than download capacity.

Bandwidth



Propagation Delay

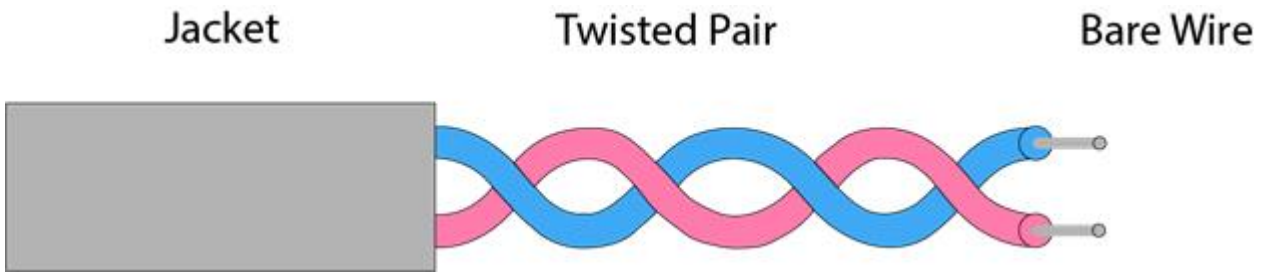
- In computer networks, **propagation delay is the amount of time it takes for the head of the signal to travel from the sender to the receiver.**
- It can be **computed as the ratio between the link length and the propagation speed** over the specific medium.
- **Transmission Delay = Data size / bandwidth = (L/B) second.**

Guided Media

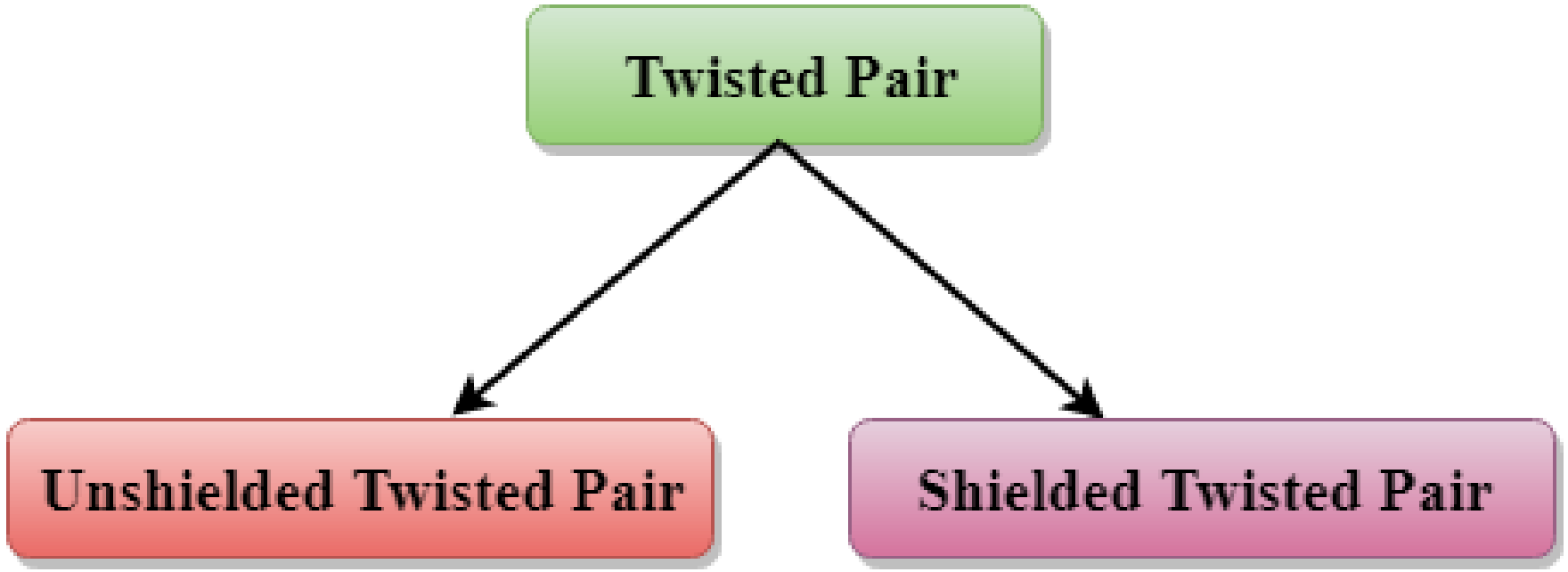
- It is defined as the physical medium through which the signals are transmitted. It **is also known as Bounded media.**
- Types Of Guided media:
  1. **Twisted pair**
  2. **Coaxial Cable**
  3. **Fibre Optic**

Twisted pair:

- is a physical media
- made up of a **pair of cables twisted with each other**.
- is cheap as compared to other transmission media.
- Installation is easy,
- is a lightweight cable.
- The **frequency range for from 0 to 3.5KHz**.



Types of Twisted pair:



Unshielded Twisted Pair(UTP):

- An unshielded twisted pair is widely used in telecommunication.
- Commonly used types of UTP cabling are as follows:
- **Category 1—Used for telephone communications**. Not suitable for transmitting data.
- **Category 2**—Capable of transmitting data at **speeds up to 4** Mbps.
- **Category 3—Used in 10BASE-T networks.** Can transmit data at **speeds up to 10 Mbps**.
- **Category 4—Used in Token Ring networks**. Can transmit **data at speeds up to 16 Mbps**.
- **Category 5**—Can transmit data at **speeds up to 100 Mbps**.
- **Category 5e** —Used in networks running at **speeds up to 1000 Mbps** (1 gigabit per second [Gbps]).
- **Category 6**—Typically, Category 6 cable consists of **four pairs of 24 American Wire Gauge (AWG) copper wires.** Category 6 cable is currently the fastest standard for UTP

What is 10BASE-T

- 10BASE-T, one of several physical media specified in the IEEE 802.3 standard for Ethernet local area networks (LANs), is ordinary telephone twisted pair wire. 10BASE-T supports Ethernet's 10 Mbps transmission speed. In addition to 10BASE-T, 10 megabit Ethernet can be implemented with these media types:
- The **"BASE" refers to baseband signalling, which means that only Ethernet signals are carried on the medium**.
- The **"T" represents twisted-pair; the "F" represents fiber optic cable**; and the "2", "5", and "36" refer to the coaxial cable segment length (the 185 meter length has been rounded up to "2" for 200).

What is 10BASE-T

- 10BASE-2 (Thin wire coaxial cable with a maximum segment length of 185 meters)
- 10BASE-5 (Thick wire coaxial cable with a maximum segment length of 500 meters)
- 10BASE-F (optical fiber cable)
- 10BASE-36 (broadband coaxial cable carrying multiple baseband channels for a maximum length of 3,600 meters)

Unshielded Twisted Pair:

- **Advantages Of Unshielded Twisted Pair:**
  - It is cheap.
  - Installation 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 (STP)

- A shielded twisted pair is a cable that **contains the mesh surrounding the wire** that allows the **higher transmission rate**.
- **Characteristics Of Shielded Twisted Pair:**
  - The cost is **not very high and not very low**.
  - An **installation of STP is easy.**
  - It has higher capacity as compared to unshielded twisted pair cable.
  - It has a higher attenuation.
  - 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**.

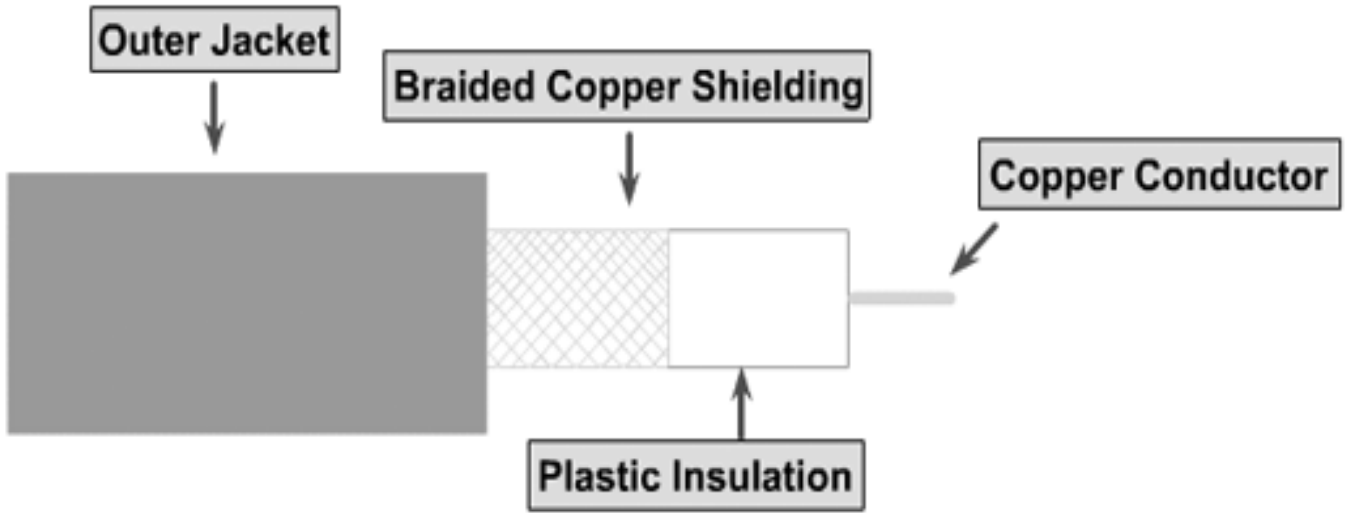
UTP Vs STP

- The speed of both types of cable is usually **satisfactory for local-area distances.**
- These are the least-expensive media for data communication. **UTP is less expensive than STP.**

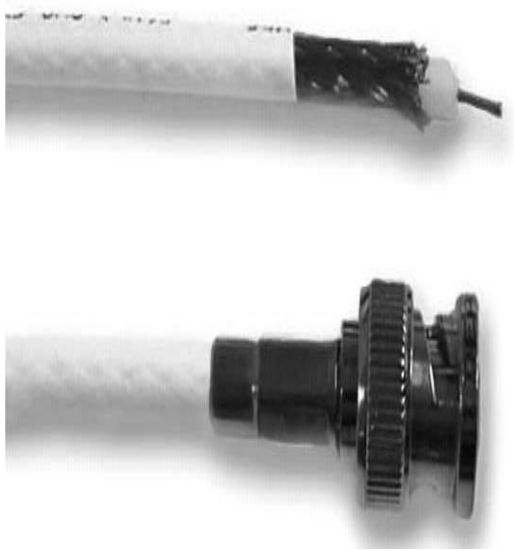
Coaxial Cable

- It is **very commonly used transmission media, for example, TV wire is usually a coaxial cable.**
- It contains **two conductors parallel to each other**.
- It has a **higher frequency as compared to Twisted pair cable**.
- The inner conductor **cable is made up of copper**, and the outer conductor is made up of **copper mesh** these are separated by non-conductive.
- The inner (middle) **core is responsible for the data transferring** whereas the **copper mesh prevents from the EMI(Electromagnetic interference)**.

Coaxial Cable



Coaxial Cable



BNC Connector

Coaxial cable is of two types:

1. **Baseband transmission:** It is defined as the process of transmitting a single signal at high speed.
2. **Broadband transmission:** It is defined as the process of transmitting multiple signals simultaneously.

- **Advantages Of Coaxial cable:**
  - The data can be transmitted **at high speed**.
  - It **has better shielding** as compared to twisted pair cable.
  - It **provides higher bandwidth.**
- **Disadvantages Of Coaxial cable:**
  - It is **more expensive** as compared to twisted pair cable.
  - If **any fault occurs in the cable causes the failure in the entire network**.

Features of coaxial cables:

- Speed and throughput—**10 to 100 Mbps**
- Average cost per node—**Inexpensive**
- Media and connector size—**Medium**
- Maximum cable length—**500 m** (medium)

Know more about these

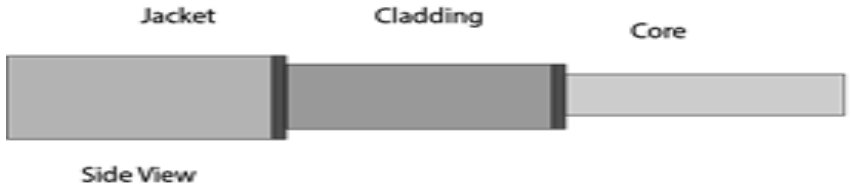
- Plenum Cable?
- Types of Coaxial Cable?

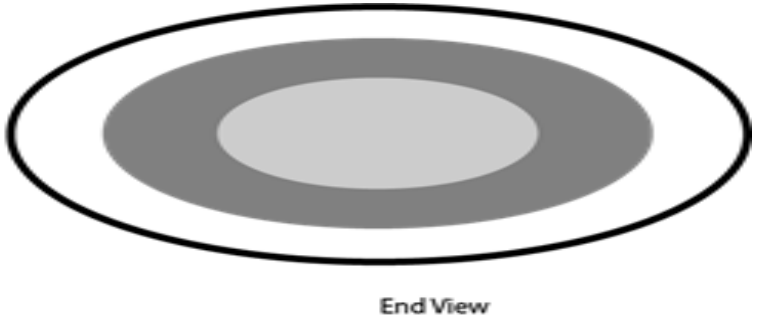
Fibre Optic

- 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**.

Basic elements of Fibre optic cable:

- **Core:** The **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.
- **Cladding:** The **concentric layer of glass is known as cladding**. The main functionality 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 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:

- **Greater Bandwidth:** provides more bandwidth and carries more data as compared to copper cable.
- **Faster speed:** carries the data in the form of light which makes it to carry the signals at a higher speed.
- **Longer distances:** carries the data to a longer distance (0 to 1000Kms).
- **Better reliability:** is immune to any temperature changes.
- **Thinner and Sturdier:** is thinner and lighter in weight so it can withstand more pull pressure than copper cable.

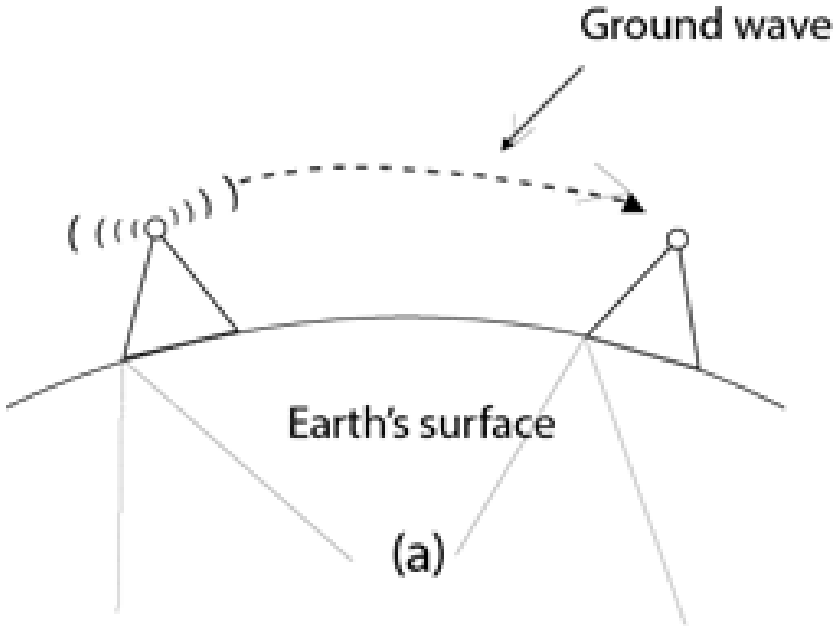
Un Guided Transmission (**wireless transmission**)

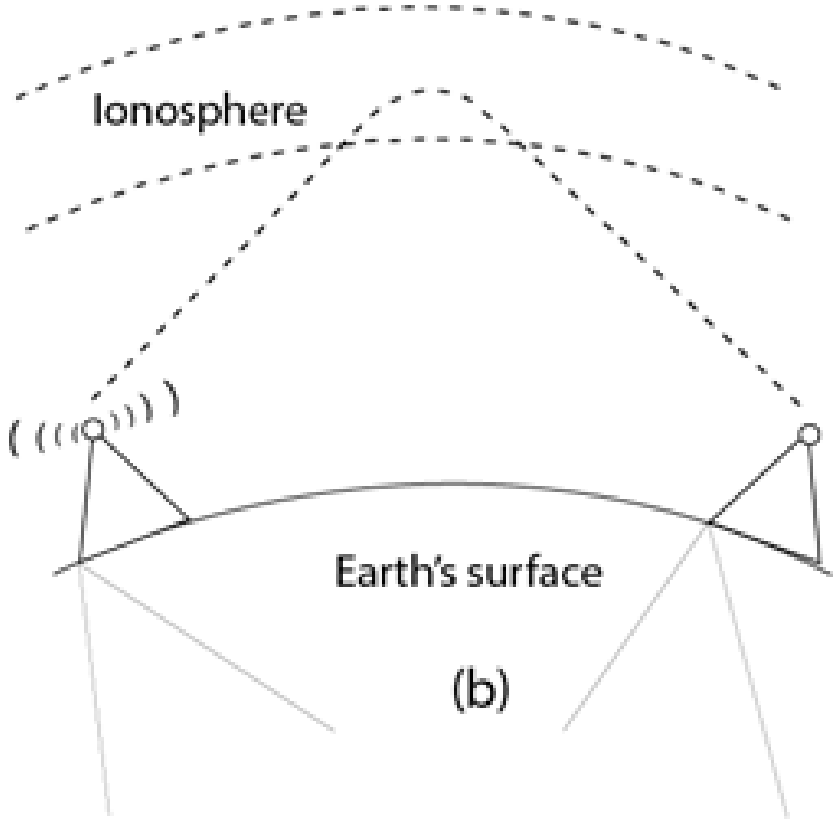
- It transmits the electromagnetic waves without using any physical medium. Therefore it is also known as **wireless transmission**.
- **Space is the media through which the electromagnetic energy can flow easily.**
- Categories:
  1. Radio waves
  2. Microwaves
  3. Infrared

Radio waves

- Radio waves are the electromagnetic waves that are **transmitted in all the directions of free space.**
- Are omnidirectional, i.e., the signals are propagated in all the directions.
- **Radio waves** have frequencies as high as **300 gigahertz (GHz) to as low as 30 hertz (Hz)**. At 300 GHz, the corresponding **wavelength is 1 mm, and at 30 Hz is 10,000 km.**
- In the case of radio waves, the **sending and receiving antenna are not aligned.**
- An example of the radio wave is **FM radio**.

Radio Wave

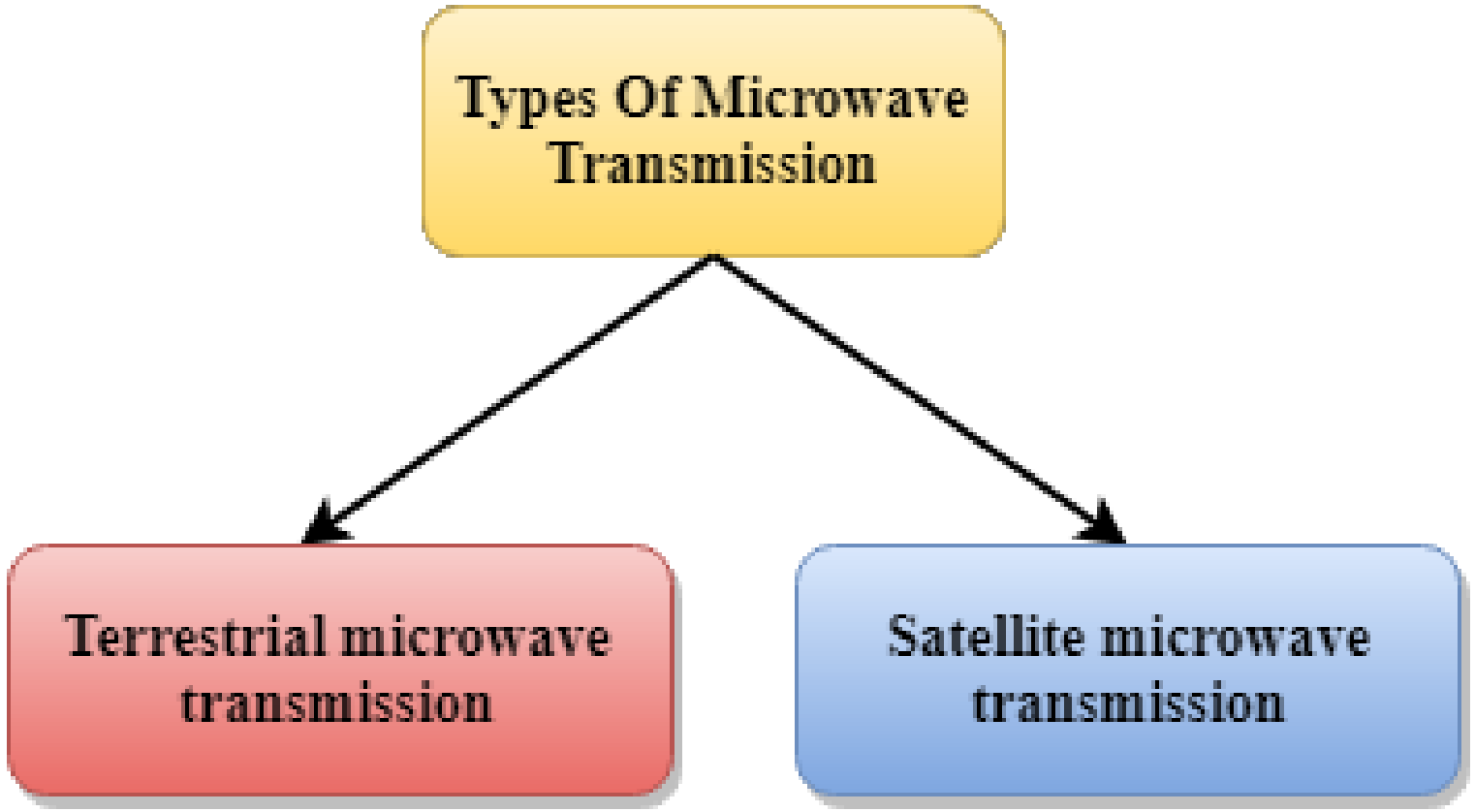




Radio Wave

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

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.**
- frequency in the range from **1GHz to 1000 GHz**.
- **unidirectional as the sending and receiving antenna is to be aligned,** i.e., the waves sent by the sending antenna are narrowly focussed.
- **antennas are mounted on the towers to send a beam** to another antenna which is few kms away.
- **It works on the line of sight transmission,** i.e., the antennas mounted on the towers are the direct sight of each other.

Terrestrial Microwave Transmission

- **Characteristics of Terrestrial Microwave:**
- **Frequency range:** from 4-6 GHz to 21-23 GHz.
- **Bandwidth:** bandwidth from 1 to 10 Mbps.
- **Short distance:** It is inexpensive for short distance.
- **Long distance:** It is expensive as it requires a higher tower for a longer distance.
- **Attenuation:** Attenuation means loss of signal. It is affected by environmental conditions and antenna size.

Terrestrial Microwave Transmission

- **Advantages Of Microwave:**
  - **transmission is cheaper** than using cables.
  - it does **require small area** for the installation.
  - provides an **easy communication in terrains**.
  - Communication over oceans can be achieved by using microwave transmission.
- **Disadvantages of Microwave transmission:**
  - **Eavesdropping:** An eavesdropping creates insecure communication. Any malicious user can catch the signal in the air by using there own antenna.
  - **Out of phase signal:** A signal can be moved out of phase by using microwave transmission.
  - **Susceptible to weather condition:** is susceptible to weather condition.
  - **Bandwidth limited:** Allocation of bandwidth is limited.

Satellite Microwave Communication

- A satellite is a physical object that revolves around the earth at a known height.
- Satellite communication is more reliable one 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**.

Satellite Microwave Communication

- **Advantages Of Satellite Microwave Communication:**
  - The **coverage area more** than the terrestrial microwave.
  - The **transmission cost of the satellite is independent of the distance** from the centre of the coverage area.
  - It is **used in mobile and wireless communication** applications.
  - It is easy to install. Applications are : **weather forecasting, radio/TV signal broadcasting, mobile communication,** etc.

Satellite Microwave Communication

- **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 made.

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**.

Infrared

- **Characteristics Of Infrared:**
  - It **supports high bandwidth so more data at higher data rate**.
  - **Infrared waves cannot penetrate the walls.** Therefore, the infrared communication in one room cannot be interrupted by the nearby rooms this increases security.
  - **is unreliable outside the building because the sun rays will interfere with the infrared waves.**

Bluetooth

- Bluetooth **is a wireless technology** standard
- for **exchanging data between fixed and**
- **mobile devices over short distances using short-wavelength**
- **UHF radio waves in the industrial, scientific and medical radio bands**, from **2.400 to 2.485 GHz, and building personal area networks**.

Bluetooth

- **Frequency**: 2.45 GHz
- **Developed by**: Bluetooth Special Interest Group
- **Physical range**: Typically less than 10 m (33 ft), up to 100 m (330 ft); Bluetooth 5.0: 40–400 m (100–1,000 ft)
- **Compatible hardware**: Personal computers; Smartphones; Gaming consoles; Audio devices

Bluetooth

Ranges of Bluetooth devices by class			
Class	Max. permitted power		Typ. range[2] (m)
	(mW)	(dBm)	
1	100	20	~100
1.5 (BT 5 Vol 6 Part A Sect 3)	10	10	~20
2	2.5	4	~10
3	1	0	~1
4	0.5	−3	~0.5

1G: Voice Only

- Remember Analog phones back in the day? Cell phones began with 1G technology in the 1980s. **1G is the first generation of wireless cellular technology. 1G supports voice only calls**.
- 1G is Analog technology, and the **phones using it had poor battery life and voice quality, little security, and were prone to dropped calls**.
- The maximum speed of **1G technology is 2.4 Kbps.**

2G: SMS and MMS

- **2G started place in Finland in 1991 on GSM networks** and effectively took cell phones from analog to digital communications.
- The 2G telephone technology **introduced call and text encryption,** along with data services such **as SMS, picture messages, and MMS.**
- The maximum speed of **2G with General Packet Radio Service (GPRS) is 50 Kbps. The speed is 1 Mbps with Enhanced Data Rates for GSM** Evolution (EDGE).

2.5G and 2.75G: Data, Finally

- 2.5G and 2.75G were interim standards that bridged the gap to make data transmission — **slow data transmission — possible**.
- **2.5G introduced a new packet-switching technique**
- This led to **2.75G, which provided a theoretical threefold speed increase.** AT&T was the first GSM network to support 2.75G with EDGE in the U.S.
- **2.5G and 2.75G were not defined formally as wireless standards.** They served mostly as marketing tools to promote new cell phone features to the public.

3G: More Data, Video Calling, and Mobile Internet

- 3G networks in 1998 ushered in **faster data-transmission speeds,** such as for video calling and mobile internet access. **The term "mobile broadband" was first applied to 3G cellular technology.**
- Like 2G, **3G evolved into the much faster 3.5G and 3.75G** as more features were introduced to bring about 4G.
- The **maximum speed of 3G is estimated to be around 2 Mbps for non-moving devices and 384 Kbps in moving vehicles.**

4G: The Current Standard

- Released in 2008,
- **4G supports mobile web access, gaming services, HD mobile TV, video conferencing, 3D TV, and other features that demand high speeds**.
- The max speed when the **device is moving is 100 Mbps**. The **speed is 1 Gbps for low-mobility communication** such as when the caller is stationary or walking.

5G: Coming Soon

- 5G is a not-yet-implemented wireless technology that's intended to improve on 4G.
- 5G promises significantly faster data rates, higher connection density, much lower latency, and energy savings, among other improvements.
- The anticipated theoretical speed of 5G connections is up to **20 Gbps per second.**

Switching

- When a user accesses the internet or another computer network outside their immediate location, **messages are sent through the network of transmission media.**
- **This technique of transferring the information from one computer network to another network is known as switching.**
- **Switching is transparent to the user** and does not require any configuration in the home network.

Switch

- Switching in a computer network is **achieved by using switches**.
- A **switch is a small hardware device which is used to join multiple computers together** with one local area network (LAN).
- **Network switches operate at layer 2 (Data link layer) in the OSI model**.
- Switches are **used to forward the packets based on MAC addresses.**
- A Switch **is used to transfer the data only to the device that has been addressed**.
- It is **operated in full duplex mode.**
- **Packet collision is minimum** as it directly communicates between source and destination.
- **It does not broadcast the message** as it works with limited bandwidth.

Switching

- Why is Switching Concept required?
- Switching concept is developed because of the following reasons:
- **Bandwidth:** The switching techniques are used for the effective utilization of the bandwidth of a network.
- **Collision:** To overcome this problem, switching technology is implemented so that packets do not collide with each other.

Switching

- Advantages of Switching:
  - **increases the bandwidth** of the network.
  - It **reduces the workload on individual PCs**
  - It **increases the overall performance of the network** by reducing the traffic on the network.
  - There will be **less frame collision as switch creates the collision domain for each connection.**
- Disadvantages of Switching:
  - A **Switch is more expensive than network bridges**.
  - A **Switch cannot determine the network connectivity issues easily**.
  - **Proper designing and configuration of the switch are required** to handle multicast packets.

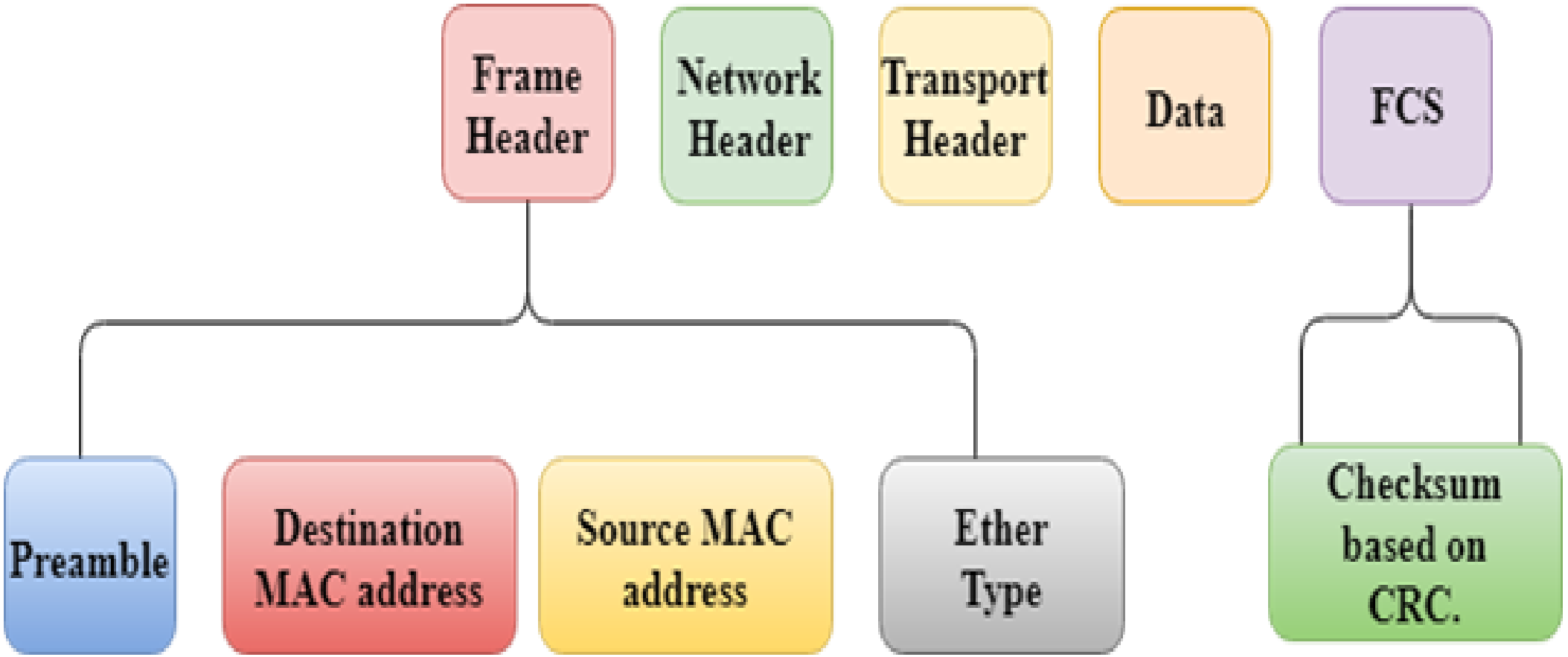
Switching Modes

- The layer 2 switches are **used for transmitting the data on the data link layer, and it also performs error checking on transmitted and received frames.**
- The layer 2 switches **forward the packets with the help of MAC address.**
- Different modes are used for forwarding the packets known as **Switching modes**.
- In **switching mode**, Different parts of a frame are recognized. The frame consists of several parts such as preamble, destination MAC address, source MAC address, user's data, FCS.

Frame

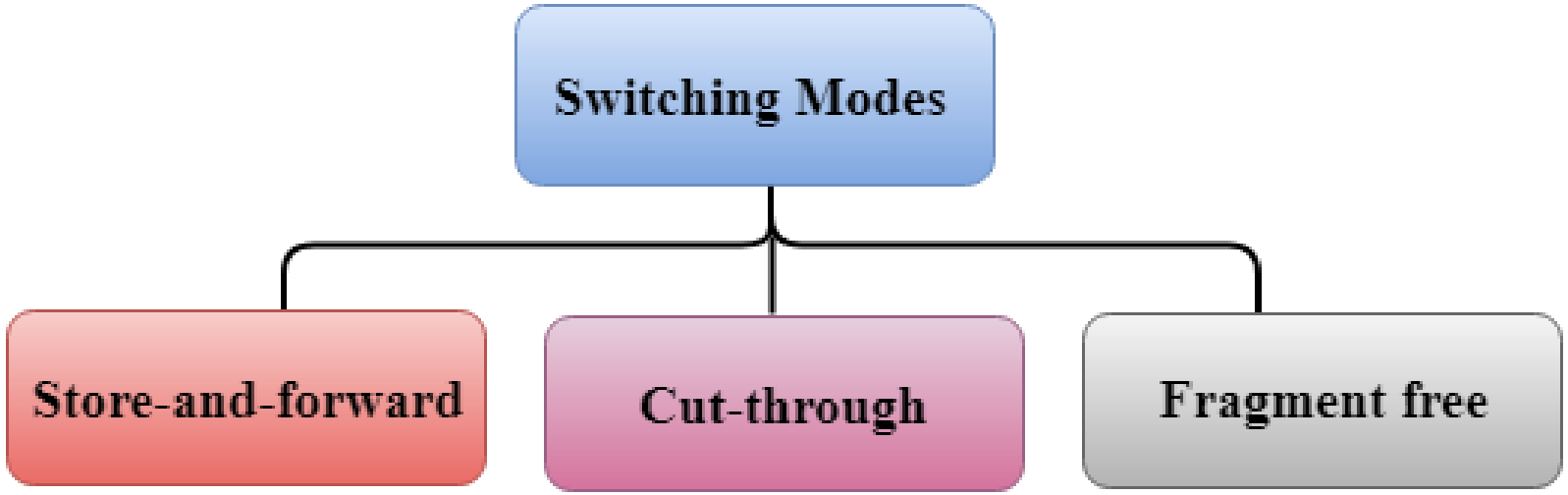
- A **frame** is a digital data transmission unit in computer **networking**.
- In packet switched systems, a **frame** is a simple container for a single **network** packet.

Parts of Frames

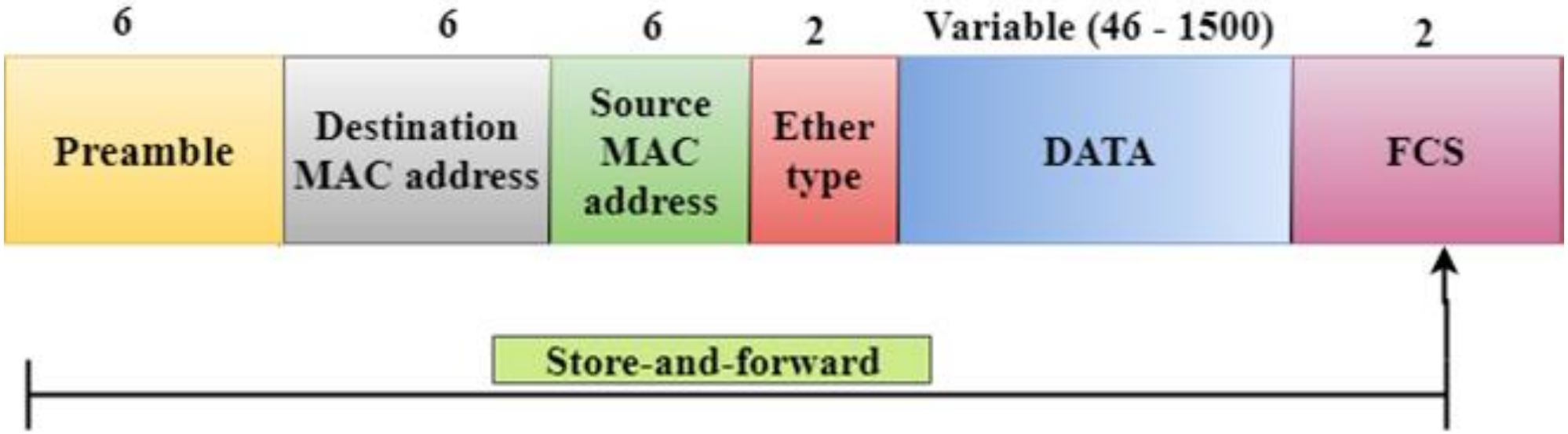


Switching Modes

- **There are three types of switching modes:**
  - Store-and-forward
  - Cut-through
  - Fragment-free



Store-and-forward



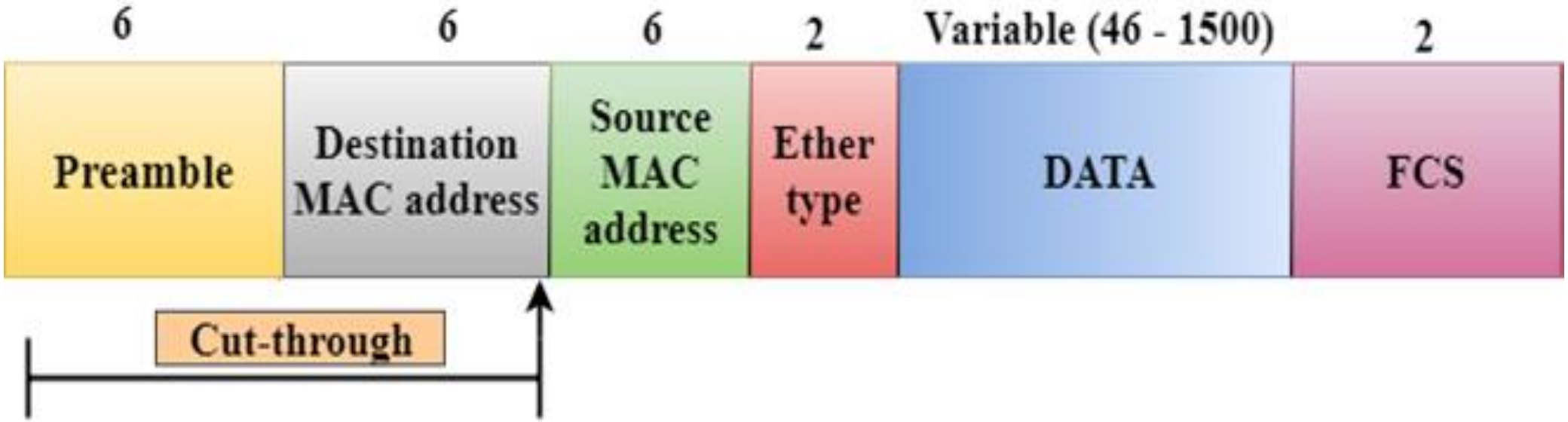
Store-and-forward

- Store-and-forward is a technique in which the **intermediate nodes store the received frame and then check for errors before forwarding the packets to the next node.**
- The layer 2 switch waits until the entire frame has received. **On receiving the entire frame, switch store the frame into the switch buffer memory.** This process is known as **storing the frame**.
- When the frame is stored, **then the frame is checked for the errors. If any error found, the message is discarded otherwise the message is forwarded to the next node.** This process is known as **forwarding the frame**.

Store-and-forward

- **CRC (Cyclic Redundancy Check) technique is implemented that uses a number of bits to check for the errors on the received frame.**
- The **store-and-forward technique ensures a high level of security as the destination network will not be affected by the corrupted frames**.
- **Store-and-forward switches are highly reliable** as it does not forward the collided frames.

Cut-through Switching



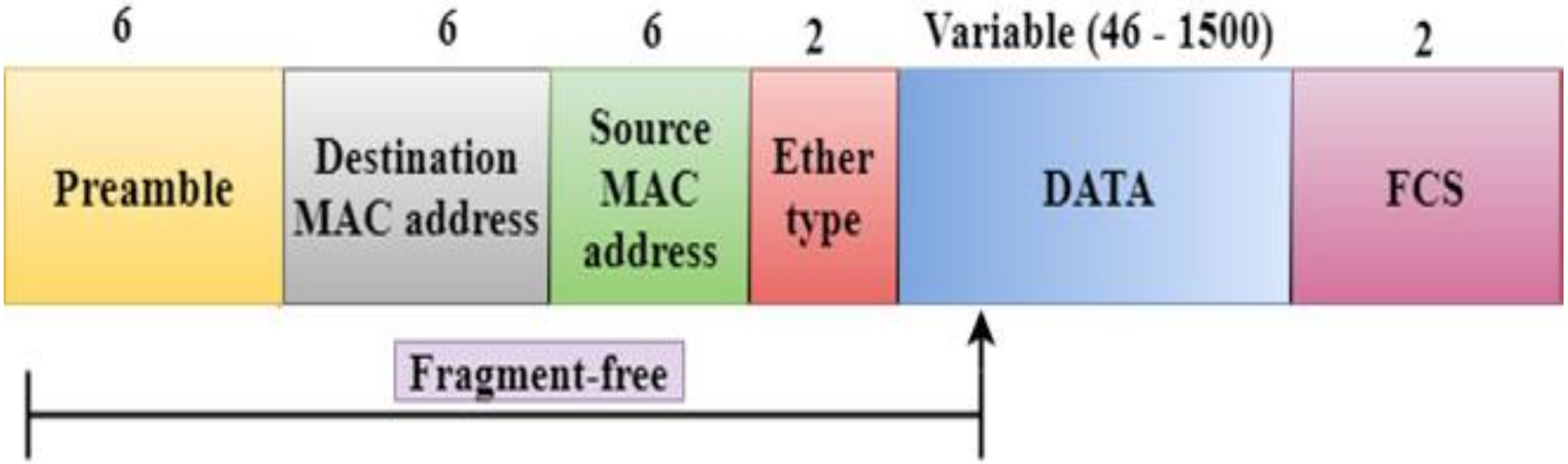
Cut-through Switching

- Cut-through switching is a technique in which the **switch forwards the packets after the destination address has been identified without waiting for the entire frame to be received.**
- Once the frame is received, **it checks the first six bytes of the frame following the preamble, the switch checks the destination in the switching table to determine the outgoing interface port, and forwards the frame to the destination.**
- It has **low latency** rate as the switch does not wait for the entire frame to be received before sending the packets to the destination.

Cut-through Switching

- It has no **error checking technique**. Therefore, the errors can be sent with or without errors to the receiver.
- A Cut-through switching technique has **low wait time** as it forwards the packets as soon as it identifies the destination MAC address.
- In this technique, collision is not detected, if frames have collided will also be forwarded.

Fragment-free Switching



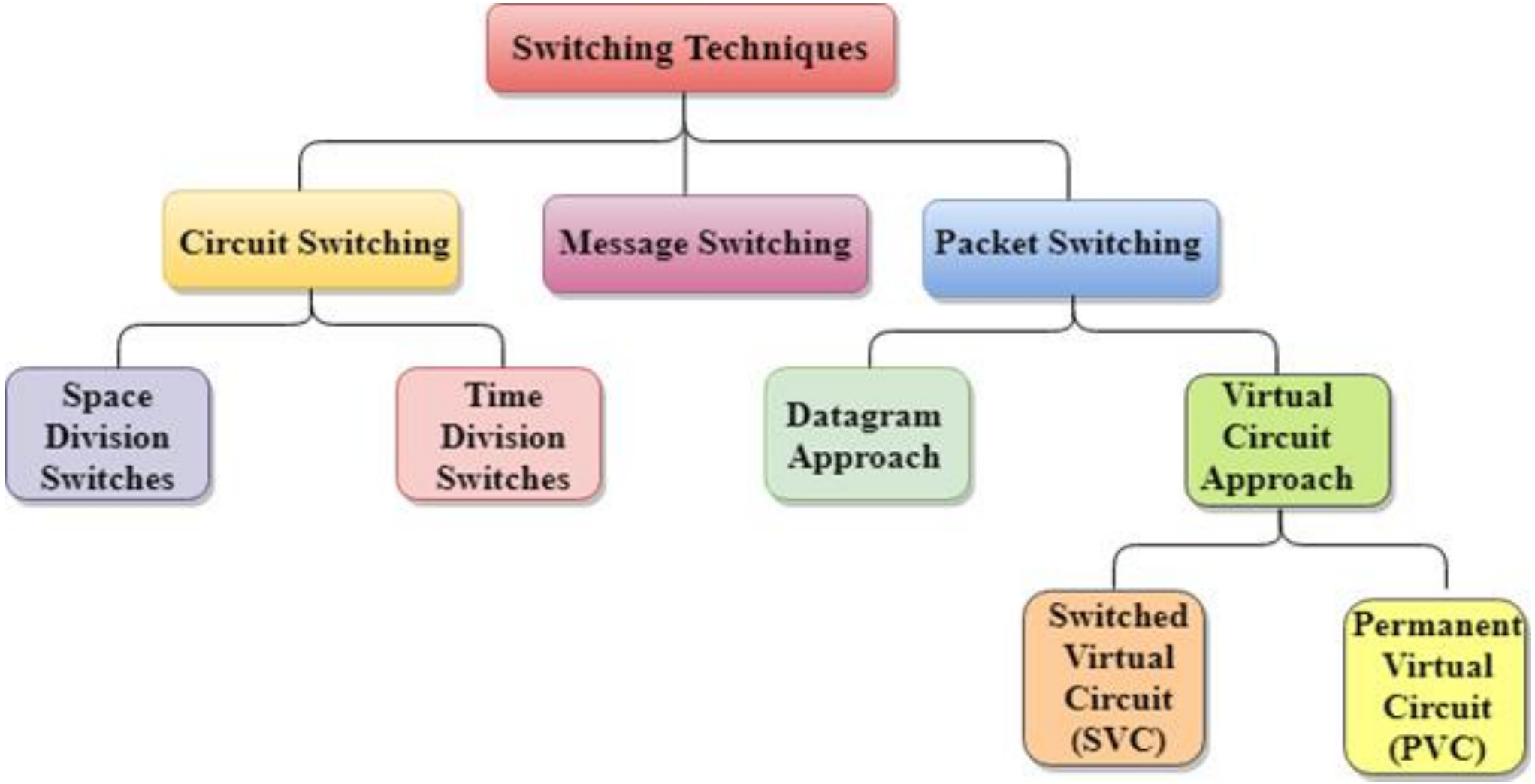
Fragment-free Switching

- A Fragment-free switching is an **advanced technique of the Cut-through Switching.**
- A Fragment-free switching is a **technique that reads at least 64 bytes of a frame before forwarding to the next node to provide the error-free transmission.**
- It combines the speed of **Cut-through Switching with the error checking functionality.**
- This technique checks the **64 bytes of the ethernet frame where addressing information is available.**
- A **collision is detected within 64 bytes of the frame, the frames which are collided will not be forwarded further**.

Switching techniques

- In large networks, there can be multiple paths from sender to receiver. **The switching technique will decide the best route for data transmission.**
- Switching technique **is used to connect the systems for making one-to-one communication.**
- **Classification Of Switching Techniques**
  1. **Circuit Switching**
  2. **Message Switching**
  3. **Packet Switching**

Classification Of Switching Techniques



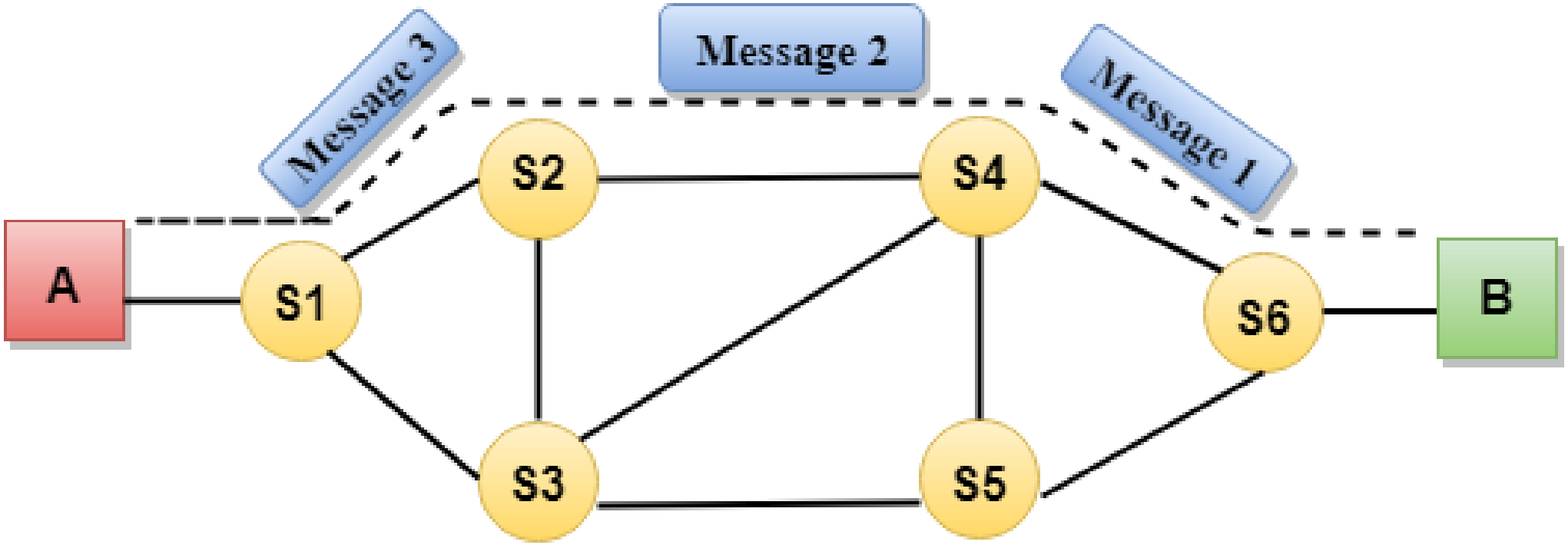
Circuit Switching

- It is a switching technique that establishes a **dedicated path between sender and receiver.**
- In this, **once the connection is established then the dedicated path will remain to exist until the connection is terminated.**
- It **operates in a similar way as the telephone works.**
- A **complete end-to-end path must exist before the communication takes place.**
- In case of circuit switching technique, when any user wants to send the data, voice, video, **a request signal is sent to the receiver then the receiver sends back the acknowledgment to ensure the availability of the dedicated path. After receiving the acknowledgment, dedicated path transfers the data.**

Circuit Switching

- **Communication through circuit switching has 3 phases:**
- Circuit establishment
- Data transfer
- Circuit Disconnect

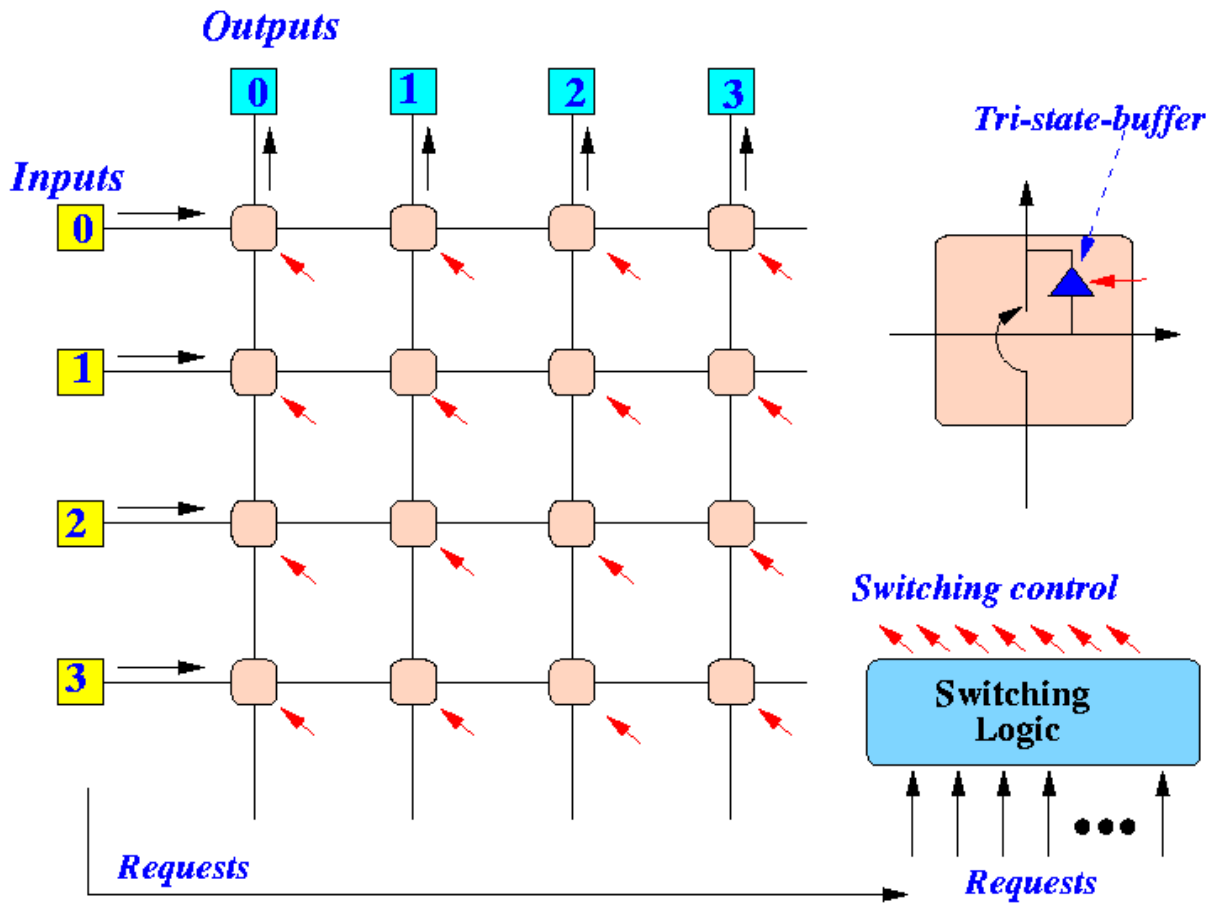
Circuit Switching



Circuit Switching

- **Space Division Switches:** is a circuit switching technology in which a **single transmission path is accomplished in a switch by using a physically separate set of cross points.**
- It can be achieved by using crossbar switch. A **crossbar switch is a metallic cross point or semiconductor gate that can be enabled or disabled by a control unit.**
- The Crossbar switch is made by using the semiconductor. For example, Xilinx crossbar switch using FPGAs.
- These are **high speed, high capacity, and non blocking switches**.

Crossbar Switch



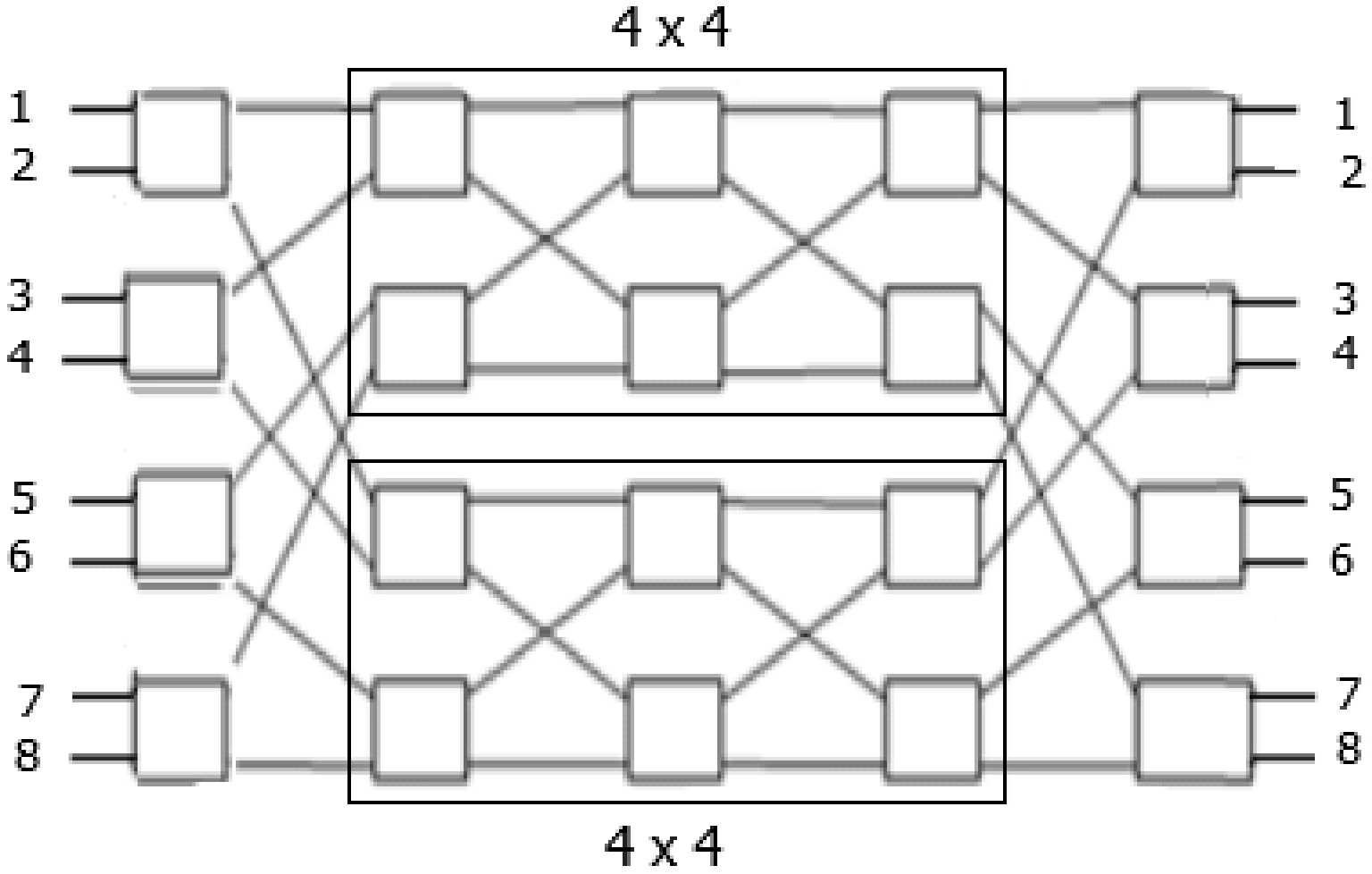
Circuit Switching

- **Space Division Switches can be categorized in two ways:**
  - **Crossbar Switch**
  - **Multistage Switch**
- **Crossbar Switch :** The Crossbar switch is a switch that has n input lines and n output lines. The crossbar switch has n^2 intersection points known as **cross points.**
- **Disadvantage of Crossbar switch:**
- The number of cross points increases as the number of stations is increased. Therefore, it becomes very expensive for a large switch. The solution to this is to use a multistage switch.

Circuit Switching

- **Multistage Switch : Multistage Switch is made by splitting the crossbar switch into the smaller units and then interconnecting them.**
- It **reduces the number of crosspoints**.
- If **one path fails, then there will be an availability of another path.**

Multistage Switch



Circuit Switching

- **Advantages Of Circuit Switching:**
- In the case of Circuit Switching technique, **the communication channel is dedicated.**
- It **has fixed bandwidth.**

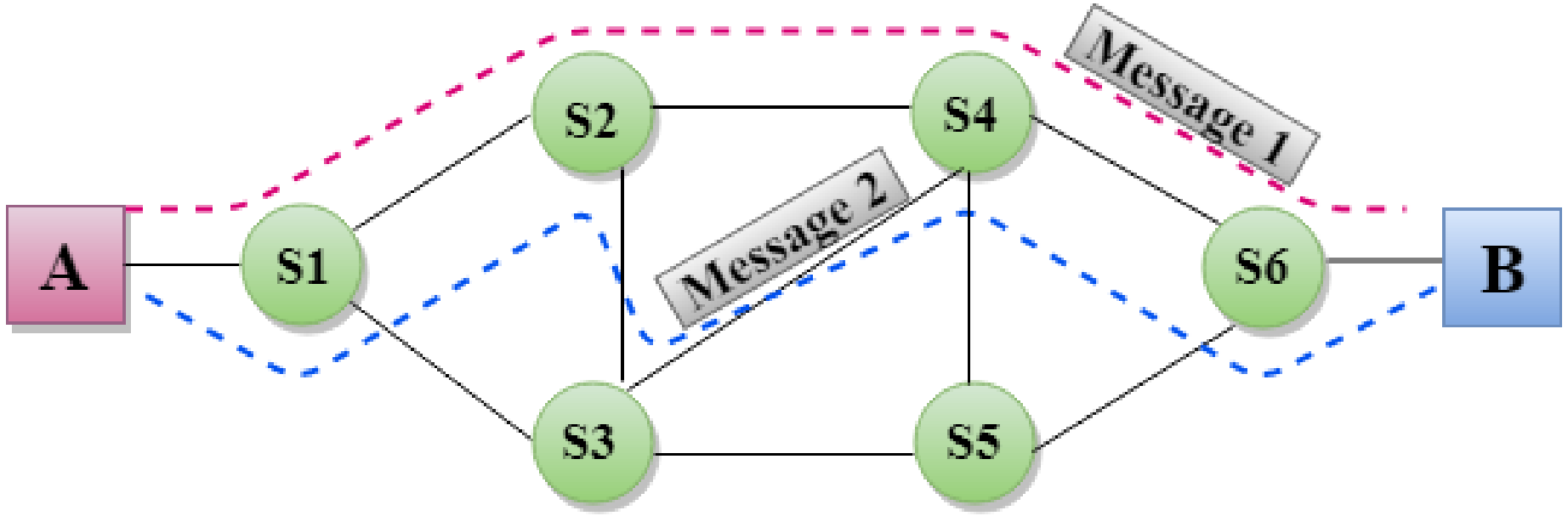
Circuit Switching

- **Disadvantages Of Circuit Switching:**
- Once the dedicated path is established, the only delay occurs in the speed of data transmission.
- **It takes a long time to establish a connection approx 10 seconds** during which no data can be transmitted.
- It is **more expensive** than other switching techniques as a dedicated path is required for each connection.
- It is **inefficient to use because once the path is established and no data is transferred, then the capacity of the path is wasted**.
- In this case, the connection is dedicated therefore **no other data can be transferred even if the channel is free.**

Message Switching

- **Message Switching : i**s a switching technique in which a **message is transferred as a complete unit and routed through intermediate nodes at which it is stored and forwarded.**
- In this there is **no establishment of a dedicated path between the sender and receiver.**
- The **destination address is appended to the message.** It **provides a dynamic routing as the message is routed through the intermediate nodes** based on the information available in the message.
- Message switches are programmed in such a way so that they can **provide the most efficient routes.**
- **Each and every node stores the entire message and then forward** it to the next node. This type of network is known as **store and forward network.**
- Message switching **treats each message as an independent entity.**

Message Switching



Message Switching

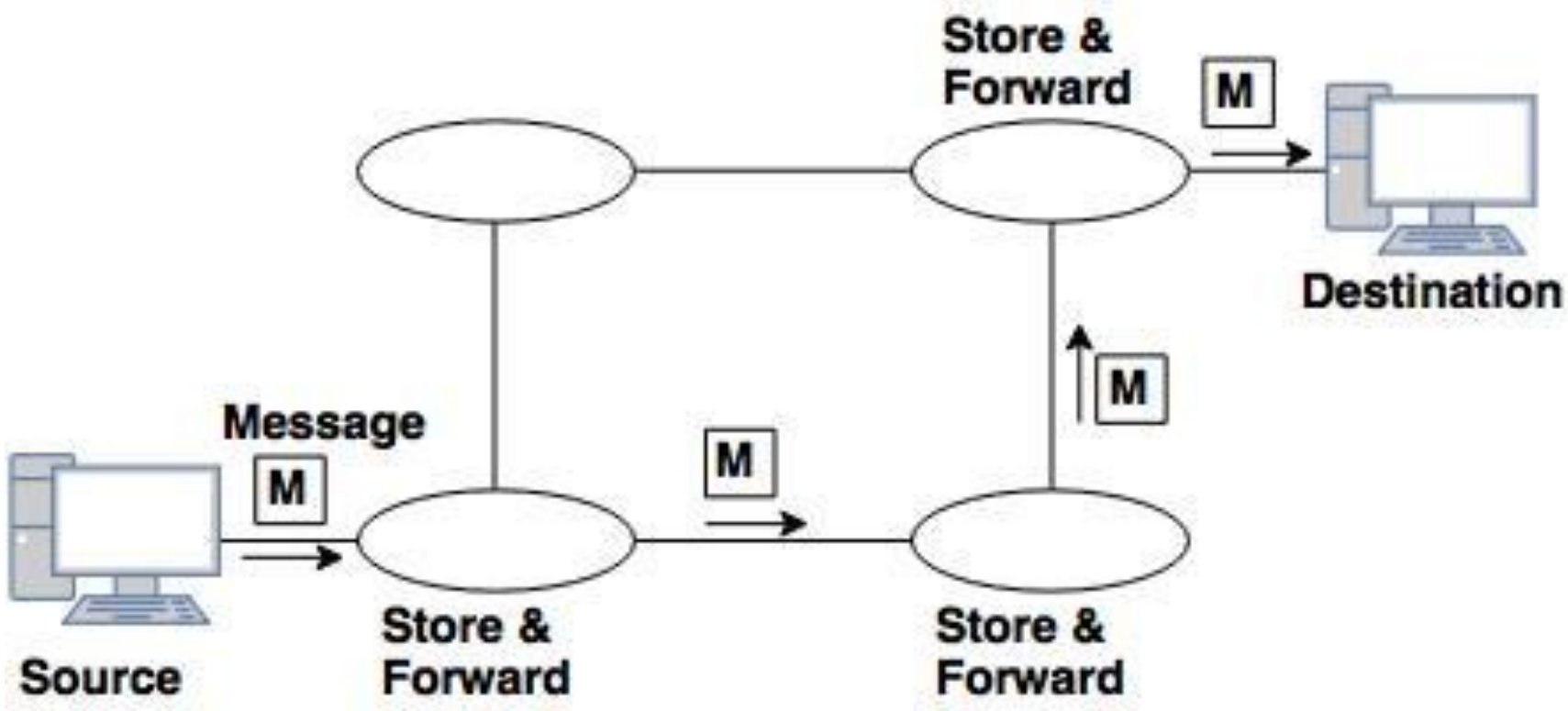


Fig: Message Switching

Message Switching

- **Advantages Of Message Switching**
- **Data channels are shared** among the communicating devices that improve the efficiency of using available bandwidth.
- **Traffic congestion can be reduced because the message is temporarily stored in the nodes**.
- **Message priority can be used to manage the network.**
- The **size of the message which is sent over the network can be varied.** Therefore, it supports the data of unlimited size.

Message Switching

- **Disadvantages Of Message Switching**
- The **message switches must be equipped with sufficient storage** to enable them to store the messages until the message is forwarded.
- The **Long delay can occur due to the storing and forwarding facility** provided by the message switching technique.

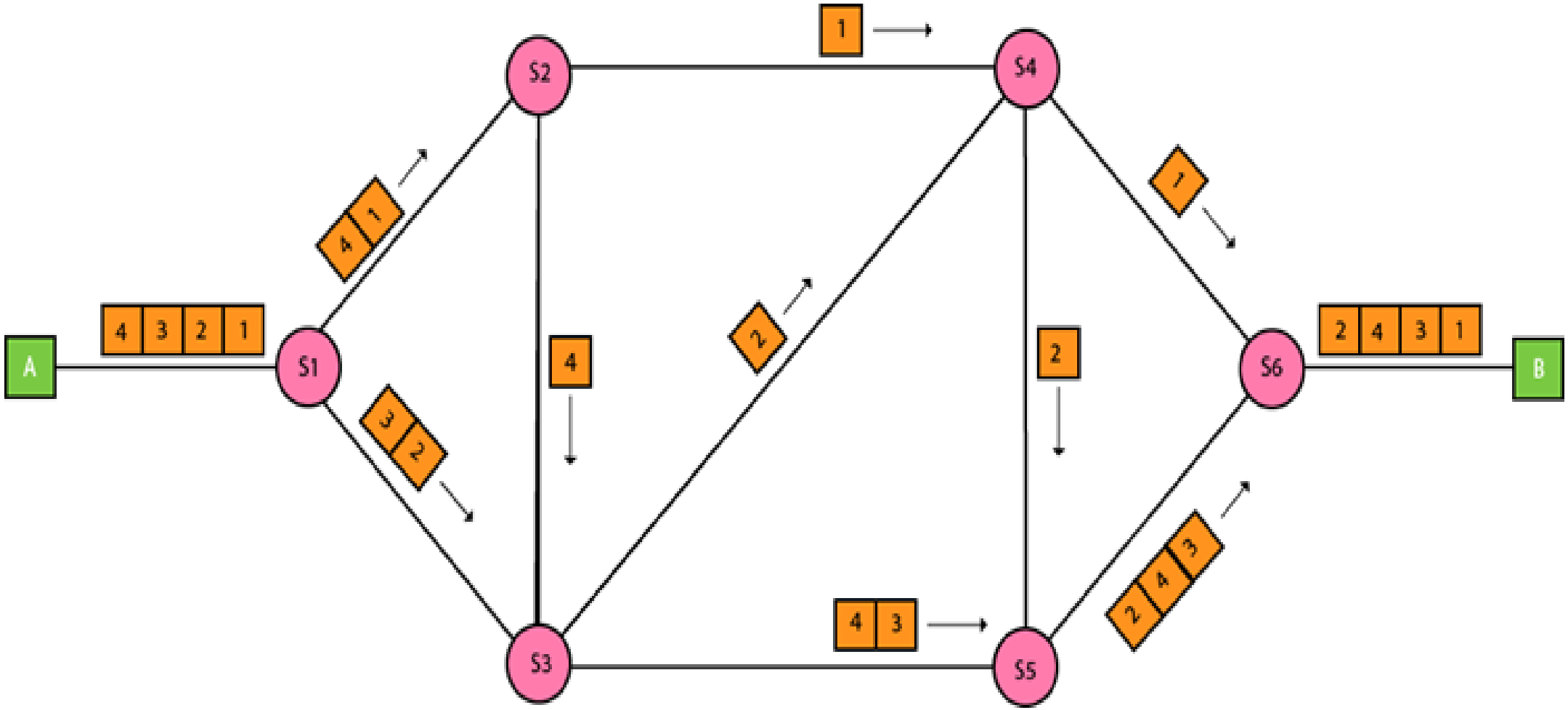
Packet Switching

- The packet switching : is a switching technique in which the **message is sent in one go, but it is divided into smaller pieces, and they are sent individually.**
- The message splits into smaller pieces known as packets and **packets are given a unique number to identify their order at the receiving end.**
- **Every packet contains some information in its headers such as source address, destination address and sequence number.**

Packet Switching

- **Packets will travel across the network, taking the shortest path** as possible.
- **All the packets are reassembled at the receiving end in correct order.**
- If any **packet is missing or corrupted, then the message will be sent to resend the message.**
- If the **correct order of the packets is reached, then the acknowledgment message will be sent.**

Packet Switching



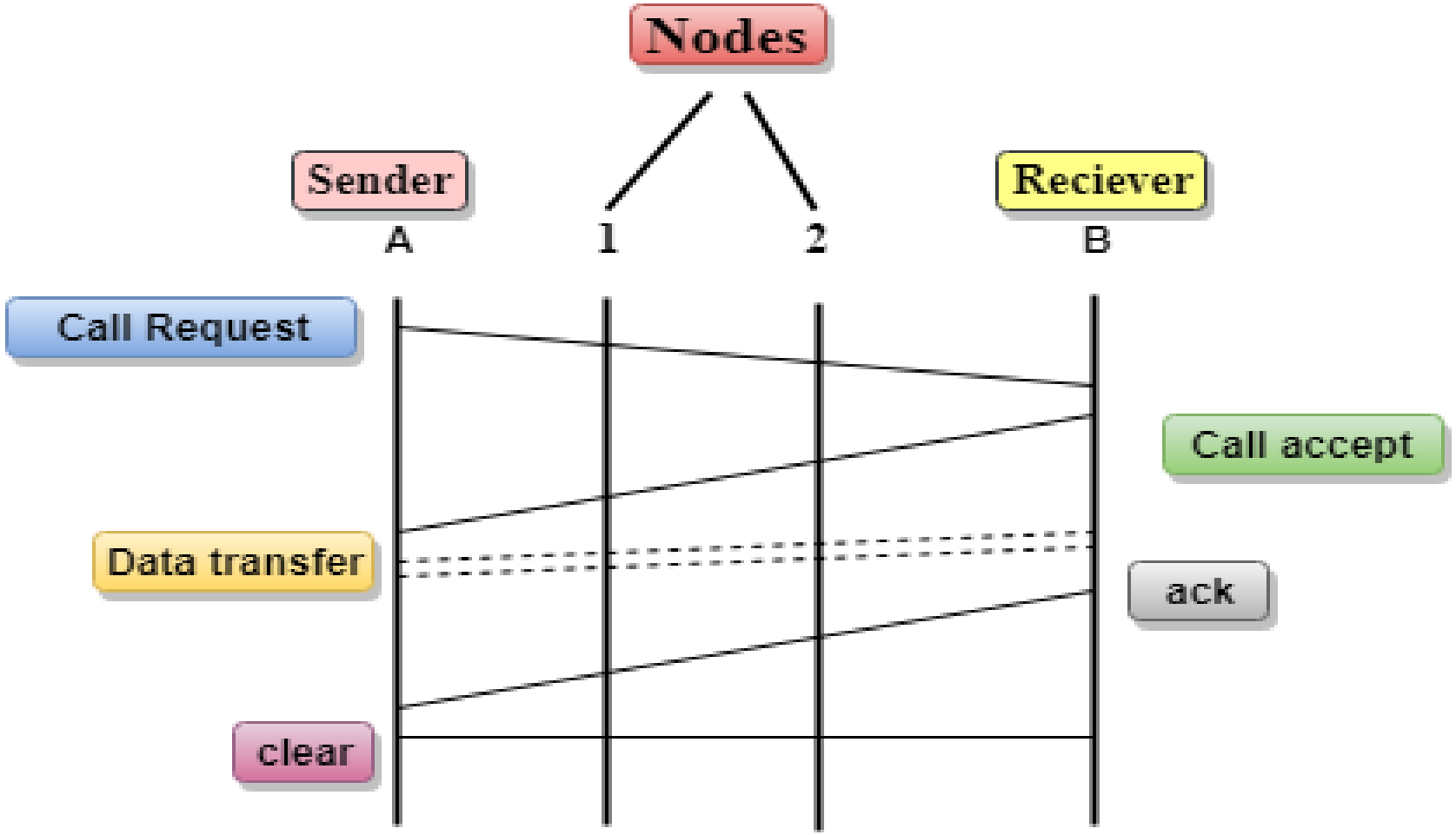
Packet Switching:

- Approaches Of Packet Switching: There are two approaches to Packet Switching:
- **Datagram Packet switching:**
  - In this packet is known as a datagram, is considered as an independent entity. **Each packet contains the information about the destination** and switch uses this information to forward the packet to the correct destination.
  - The **packets are reassembled at the receiving end in correct order.**
  - In Datagram Packet Switching technique, **the path is not fixed.**
  - **Intermediate nodes take the routing decisions to forward the packets**.
  - Datagram Packet Switching **is also known as connectionless switching.**

Packet Switching:

- **Virtual Circuit Switching**
  - Virtual Circuit Switching **is also known as connection-oriented switching.**
  - In the case of Virtual circuit switching, **a pre planned route is established before the messages are sent.**
  - **Call request and call accept packets are used to establish the connection** between sender and receiver.
  - **In this case, the path is fixed for the duration of a logical connection.**

Packet Switching



Packet Switching

- In the above diagram, A and B are the sender and receiver respectively. 1 and 2 are the nodes.
- Call request and call accept packets are used to establish a connection between the sender and receiver.
- When a route is established, data will be transferred.
- After transmission of data, an acknowledgment signal is sent by the receiver that the message has been received.
- If the user wants to terminate the connection, a clear signal is sent for the termination.

Differences b/w Datagram approach and Virtual Circuit approach

Datagram approach	Virtual Circuit approach
Node takes routing decisions to forward the packets.	Node does not take any routing decision.
Congestion cannot occur as all the packets travel in different directions.	Congestion can occur when the node is busy, and it does not allow other packets to pass through.
It is more flexible as all the packets are treated as an independent entity.	It is not very flexible.

Packet Switching:

- **Advantages Of Packet Switching:**
  - **Cost-effective:** In packet switching technique, switching devices do not require massive secondary storage to store the packets, so cost is minimized to some extent. Therefore, we can say that the packet switching technique is a cost-effective technique.
  - **Reliable:** If any node is busy, then the packets can be rerouted. This ensures that the Packet Switching technique provides reliable communication.
  - **Efficient:** Packet Switching is an efficient technique. It does not require any established path prior to the transmission, and many users can use the same communication channel simultaneously, hence makes use of available bandwidth very efficiently.

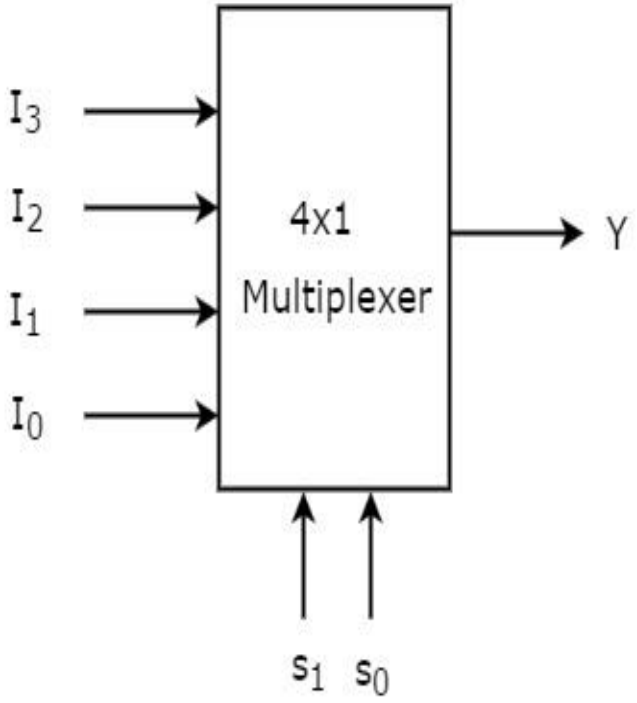
Packet Switching:

- **Disadvantages Of Packet Switching:**
  - Not suited for those applications that require low delay and high-quality services.
  - The protocols used in a **packet switching technique are very complex and requires high implementation cost.**
  - **If the network is overloaded or corrupted, then it requires retransmission of lost packets.**
  - It **can also lead to the loss of critical information if errors are nor recovered.**

What is Multiplexing?

- Multiplexing is a technique used to combine and send the multiple data streams over a single medium.
- The **process of combining the data streams is known as multiplexing** and hardware used for multiplexing is known as a **multiplexer.**
- Multiplexing is achieved by using a device called **Multiplexer (MUX) that combines n input lines to generate a single output line**. **Multiplexing follows many-to-one**, i.e., n input lines and one output line.

Multiplexer



4-1 Multiplexer

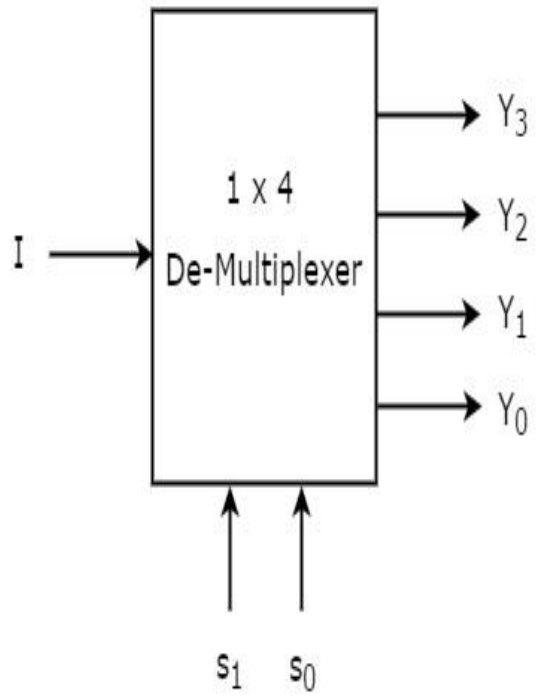
Selection Lines		Output
S_1	**S_0**	**Y**
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

Truth Table 4-1 Multiplexer

What is De multiplexing?

- De multiplexing is achieved by using a device called De multiplexer (**DEMUX**) available at the receiving end. DEMUX separates a signal into its component signals (one input and n outputs). Therefore, we can say that de multiplexing follows the one-to-many approach.

1-4 De Multiplexer



1x4 De-Multiplexer

Selection Inputs		Outputs			
S_1	**S_0**	**Y_3**	**Y_2**	**Y_1**	**Y_0**
0	0	0	0	0	**I**
0	1	0	0	**I**	0
1	0	0	**I**	0	0
1	1	**I**	0	0	0

Truth Table - 1x4 De-Multiplexer