Computer Networks

Unit : Computer Network

- Introduction to Data Communication and Computer Network, Network Topologies, classification of computer network, Parallel & Serial Transmission, Transmission Models, Transmission Channel, Data Rate, Bandwidth Signal Encoding Schemes, Data Compression, Transmission Impairments, Layering and Design Issues, OSI Model and TCP/ IP model.

Unit : Computer Network

- Data Link Layer: Need for Data Link Control, Frame Design Consideration, Flow Control & Error Control. MAC sublayer, contention based and polling based MAC protocols.

- Network Layer: Routing, Congestion control, Internetworking principles, Internet Protocols (IPv4, packet format, Hierarchal addressing sub netting, ARP, PPP), Bridges, Routers. Classless IP address.

Unit : Computer Network

- Datalink Layer: Process to process communication. Socket meaning and socket address. Upward and downwards multiplexing. UDP and TPDU.

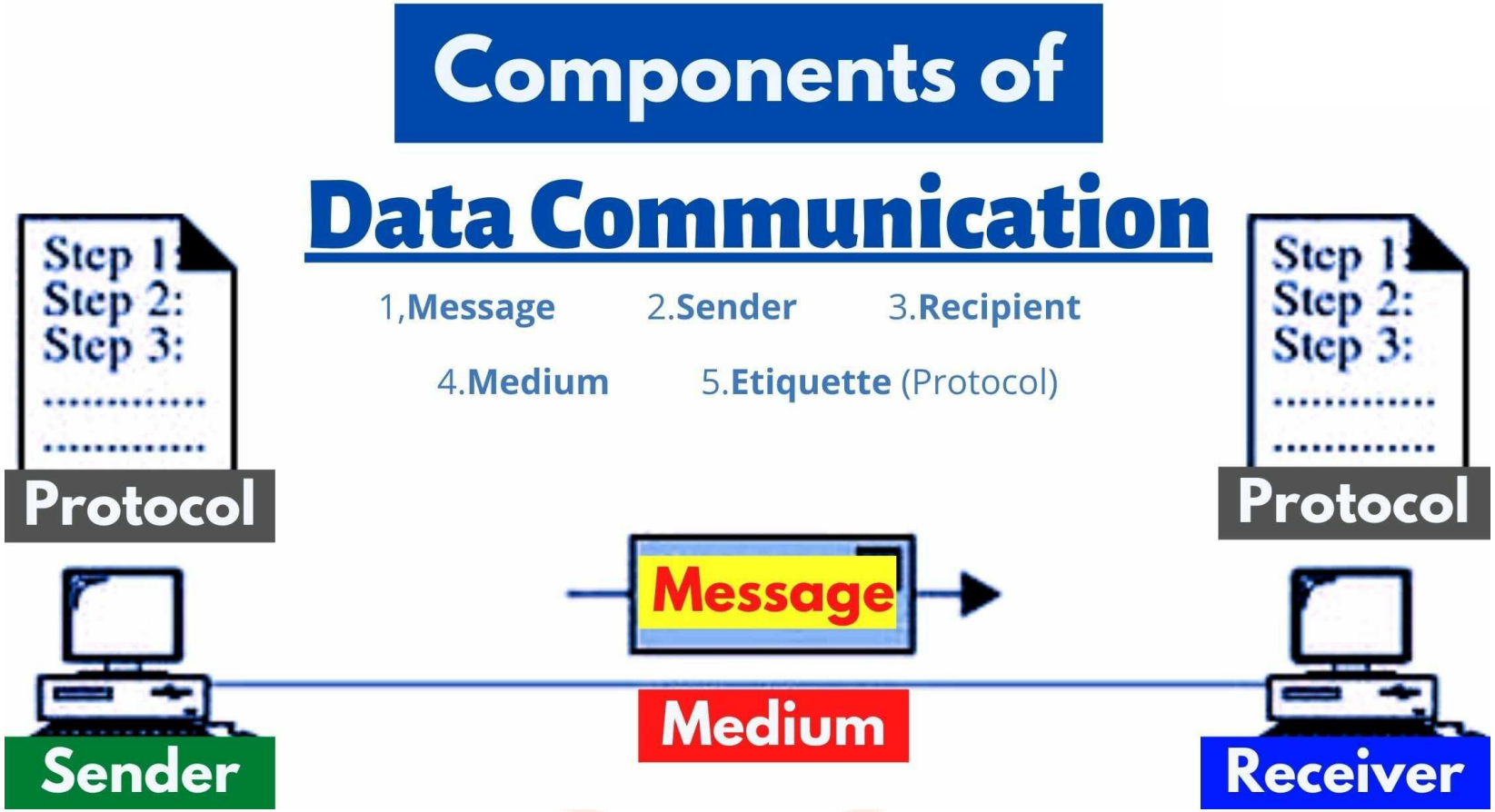
- Application Layer: HTTP, FTP, Telnet, SMTP, SNMP

Components of Data Communication

- Whenever we talk about communication between two computing devices using a network, five most important aspects come to our mind. These are sender, receiver, communication medium, the message to be communicated, and certain rules called protocols to be followed during communication.

- The communication media is also called transmission media.

Components of Data Communication



Components of Data Communication

- **Sender:** A sender is a computer or any such device which is capable of sending data over a network. It can be a computer, mobile phone, smartwatch, walkie-talkie, video recording device, etc

- **Receiver:** A receiver is a computer or any such device which is capable of receiving data from the network.

- It can be any computer, printer, laptop, mobile phone, television, etc. In computer communication, the sender and receiver are known as nodes in a network

Components of Data Communication

- **Message:** It is the data or information that needs to be exchanged between the sender and the receiver.

- Messages can be in the form of text, number, image, audio, video, multimedia, etc

- **Communication media:** It is the path through which the message travels between source and destination.
- It is also called medium or link which is either wired or wireless. For example, a television cable, telephone cable, Ethernet cable, satellite link, microwaves, etc.

Components of Data Communication

- **Protocols:** It is a set of rules that need to be followed by the communicating parties in order to have successful and reliable data communication.

Network Devices

Network Devices

- Network devices, also known as networking hardware, are physical devices that allow hardware on a computer network to communicate and interact with one another.

- For example Repeater, Hub, Bridge, Switch, Routers, Gateway and NIC, etc

Network Devices

Modem

NIC

Repeater

Hub

Switch

Router

Bridge

Gateway

Types of Network Devices

NETWORK INTERFACE CARD

- A network interface card (NIC) is a hardware component without which a computer cannot be connected over a network.

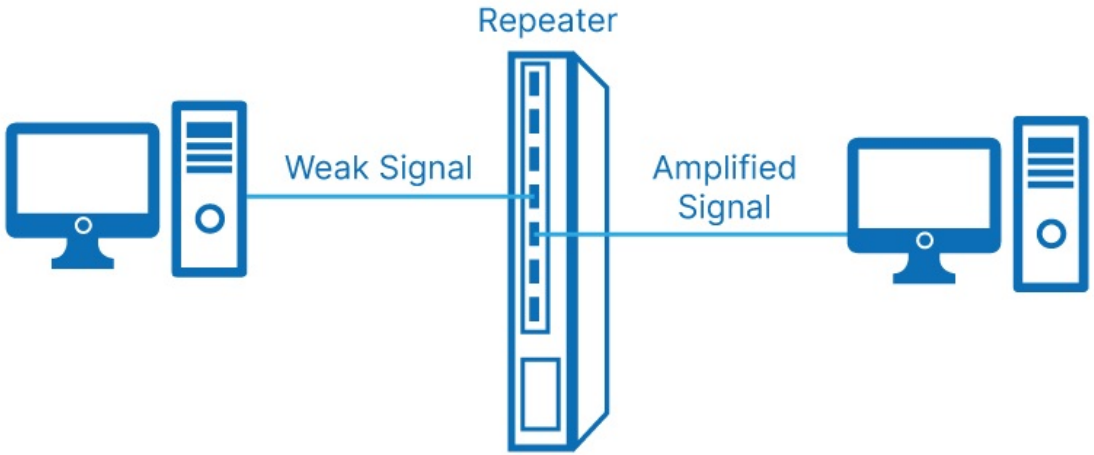
- It is a circuit board installed in a computer that provides a dedicated network connection to the computer. It is also called network interface controller, network adapter or LAN adapter.

PURPOSE OF NETWORK INTERFACE CARD

- NIC allows both wired and wireless communications.
- NIC allows communications between computers connected via local area network (LAN) as well as communications over large-scale network through Internet Protocol (IP).
- NIC is both a physical layer and a data link layer device, i.e. it provides the necessary hardware circuitry so that the physical layer processes and some data link layer processes can run on it

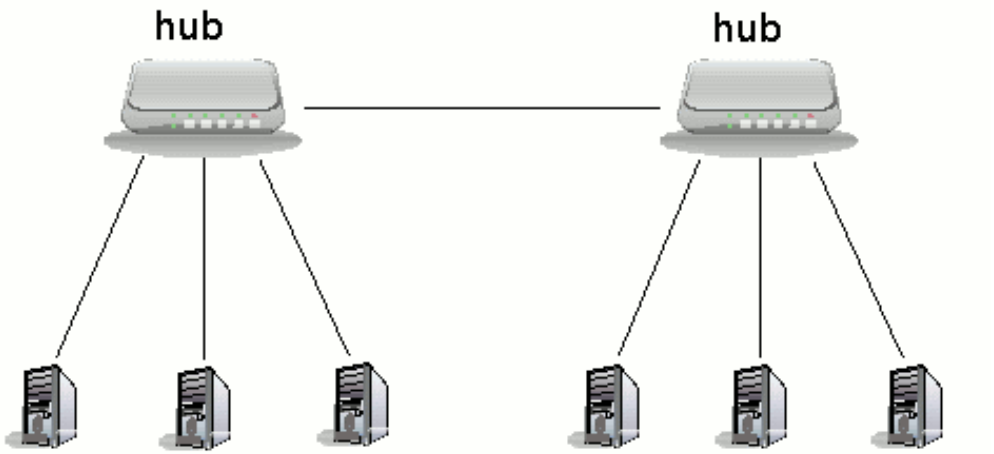
REPEATER

- A repeater operates at the physical layer.
- Its job is to regenerate the signal over the same network before the signal becomes too weak or corrupted to extend the length to which the signal can be transmitted over the same network.



Hub

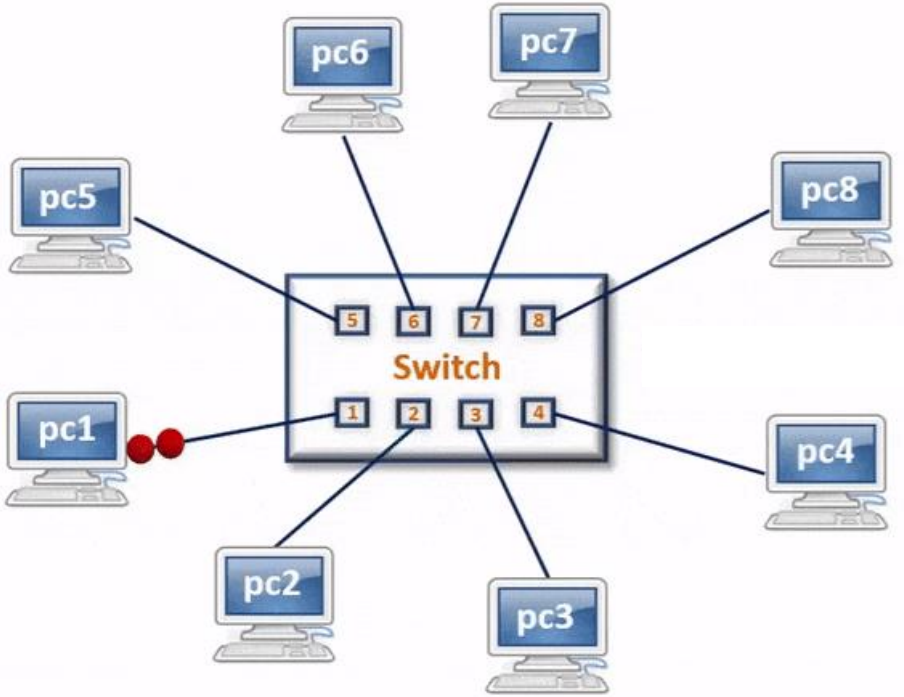
- A network hub is a node that broadcasts data to every computer or Ethernet-based device connected to it.
- They are generally used to connect computers in a LAN.



SWITCHES

- A switch is a data link layer networking device which connects devices in a network and uses packet switching to send and receive data over the network.

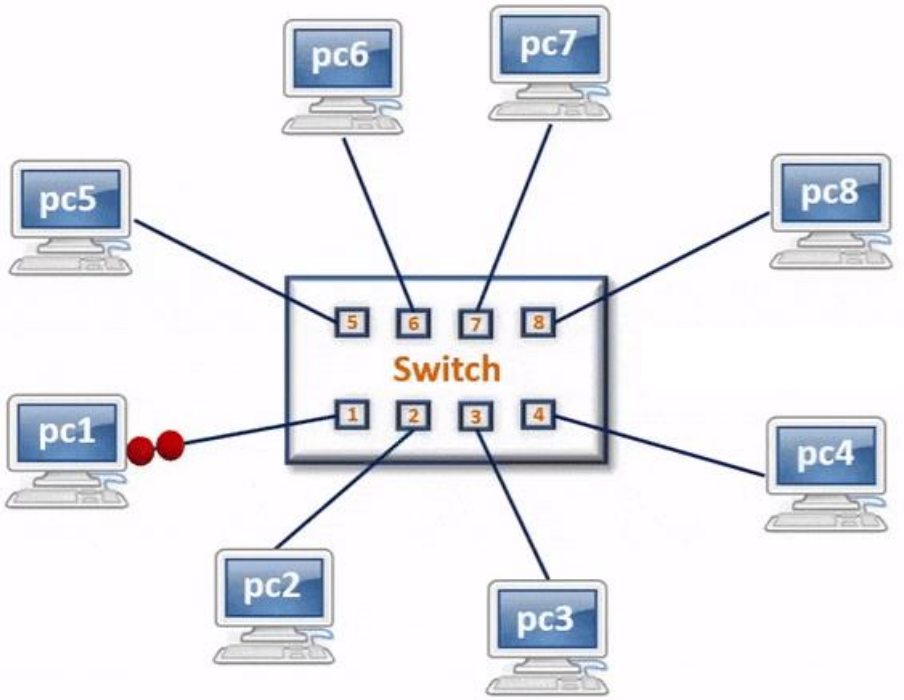
- Like a hub, a switch also has many ports, to which computers are plugged in.



SWITCHES

- However, when a data frame arrives at any port of a network switch, it examines the destination address and sends the frame to the corresponding device(s).

- Thus, it supports both unicast and multicast communications



BRIDGE

- A bridge operates at the data link layer. A bridge is a repeater, with add on the functionality of filtering content by reading the MAC addresses of the source and destination.
- It is also used for interconnecting two LANs working on the same protocol.

ROUTERS

- A router is a device like a switch that routes data packets based on their IP addresses.
- The router is mainly a Network Layer device.

ROUTERS

- A Router is a networking device that forwards data packets between computer networks.
- One or more packet-switched networks or subnetworks can be connected using a router.
- By sending data packets to their intended IP addresses, it manages traffic between different networks and permits several devices to share an Internet connection.

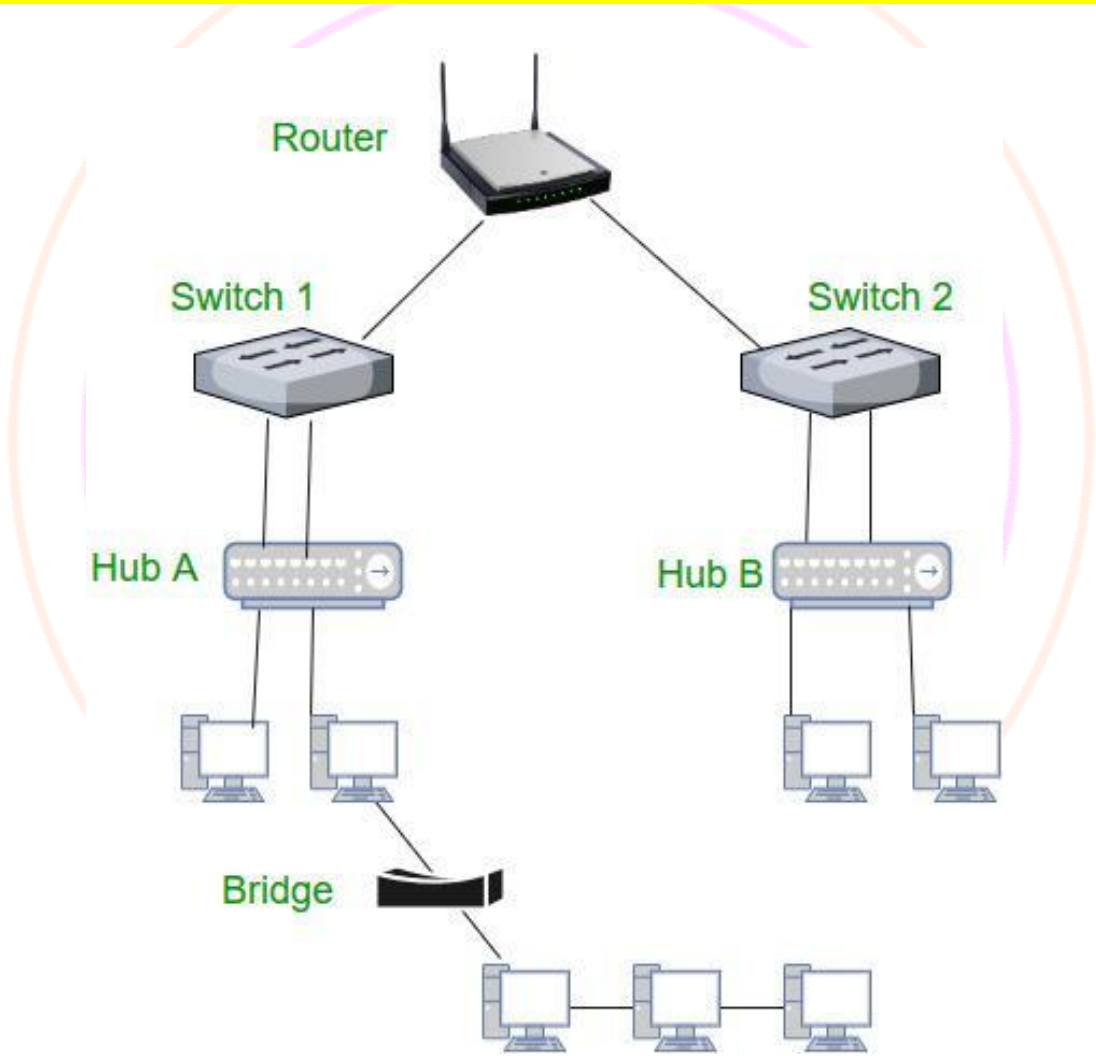
ROUTERS

- A router determines a packet's future path by examining the destination IP address of the header and comparing it to the routing database.

- The list of routing tables outlines how to send the data to a specific network location. They use a set of rules to determine the most effective way to transmit the data to the specified IP address.

Router	Switch
Router is used to connect multiple networks	Switch is used to connect multiple devices in a network
Router maintain Routing table	Switch maintain MAC address table for decision making
It supports Network Address Translation(NAT)	It does not support NAT
Routers works at Network Layer	Switch works at Data Link Layer
Routers are more expensive then Switches	Switches are less expensive then Routers.

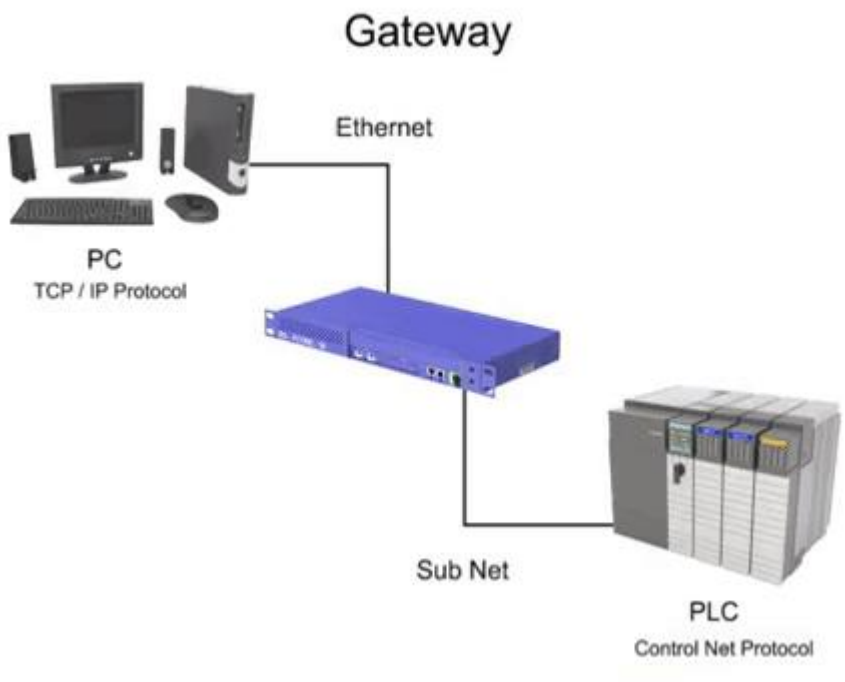
ROUTERS



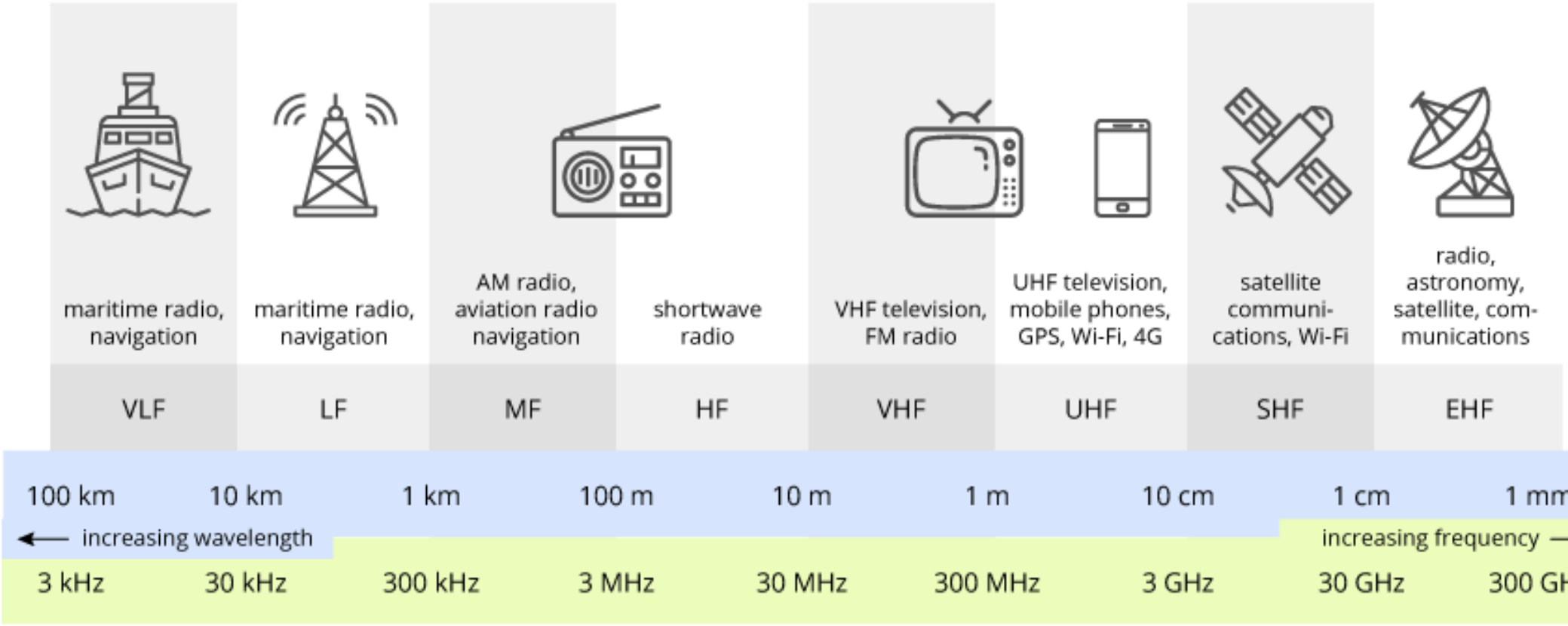
GATEWAY

- A gateway, as the name suggests, is a passage to connect two networks that may work upon different networking models.

- Gateways are also called protocol converters and can operate at any network layer.



Radio Frequency bands



Specifications of twisted pair cables

Category/name of the cable	Maximum supported speed	Bandwidth/support signals rate	Ethernet standard	Description
Cat 1	1Mbps	1MHz	Not used for data	This cable contains only two pairs (4 wires). This cable was used in the telephone network for voice transmission.
Cat 2	4Mbps	10MHz	Token Ring	This cable and all further cables have a minimum of 8 wires (4 pairs). This cable was used in the token-ring network.
Cat 3	10Mbps	16MHz	10BASE-T Ethernet	This is the first Ethernet cable that was used in LAN networks.
Cat 4	20Mbps	20MHz	Token Ring	This cable was used in advanced Token-ring networks.
Cat 5	100Mbps	100MHz	100BASE-T Ethernet	This cable was used in advanced (fast) LAN networks.
Cat 5e	1000Mbps	100MHz	1000BASE-T Ethernet	This cable/category is the minimum requirement for all modern LAN networks.

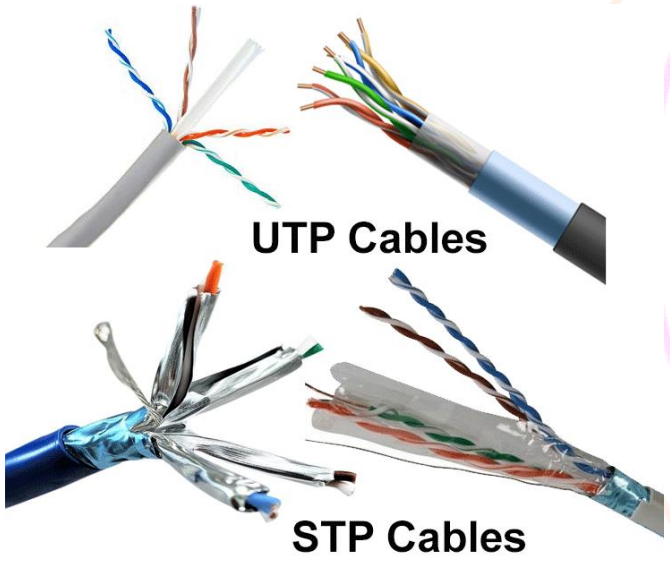
Specifications of twisted pair cables

Category/name of the cable	Maximum supported speed	Bandwidth/support signals rate	Ethernet standard	Description
Cat 5e	1000Mbps	100MHz	1000BASE-T Ethernet	This cable/category is the minimum requirement for all modern LAN networks.
Cat 6	10Gbps	250MHz	10GBASE-T Ethernet	This cable uses a plastic core to prevent cross-talk between twisted-pair. It also uses a fire-resistant plastic sheath.
Cat 6a	10Gbps	500MHz	10GBASE-T Ethernet	This cable reduces attenuation and cross-talk. This cable also potentially removes the length limit. This is the recommended cable for all modern Ethernet LAN networks.
Cat 7	10Gbps	600MHz	Not drafted yet	This cable sets a base for further development. This cable uses multiple twisted-pair and shields each pair by its plastic sheath.

Specifications of coaxial cables

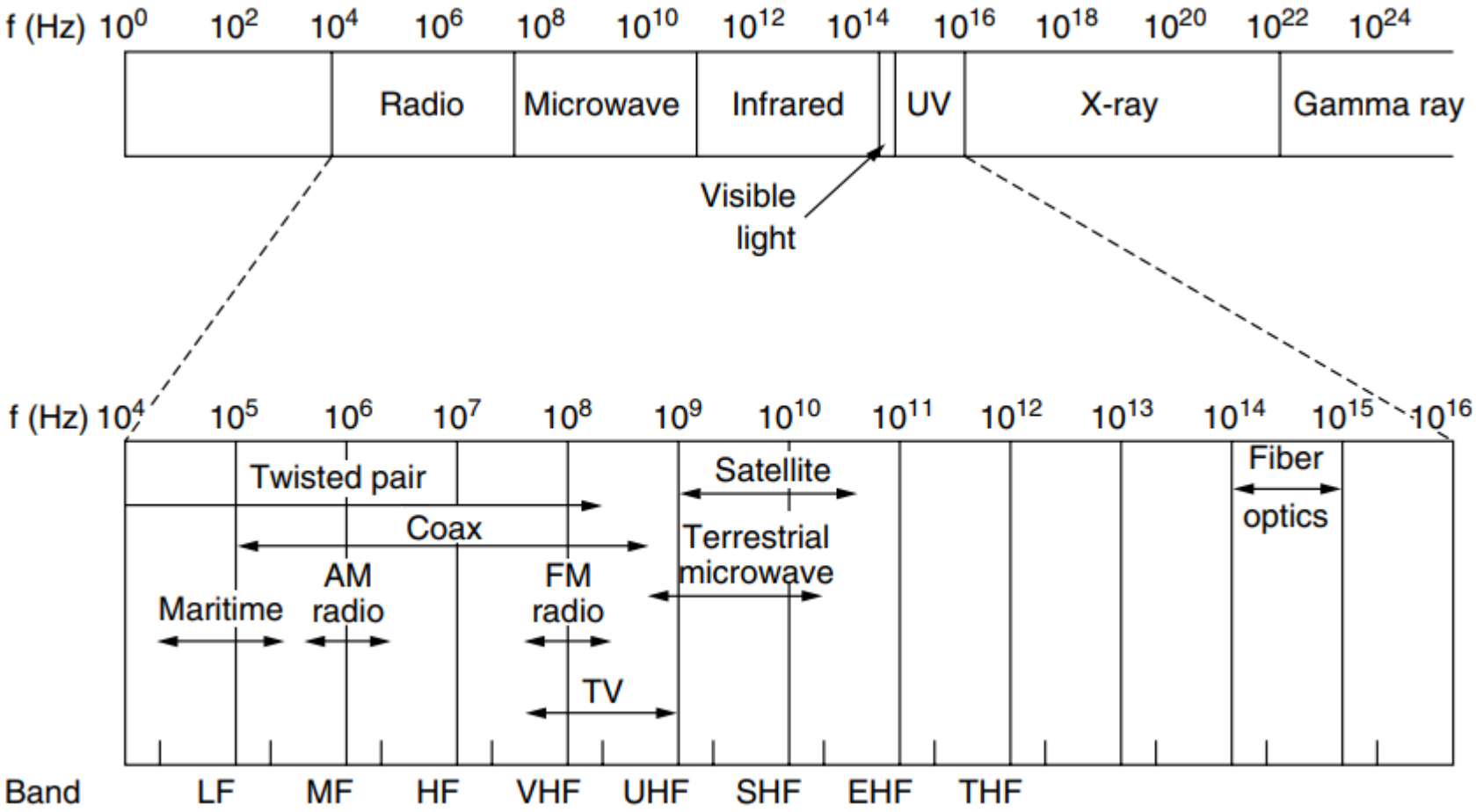
Type	Ohms	AWG	Conductor	Description
RG-6	75	18	Solid copper	Used in cable network to provide cable Internet service and cable TV over long distances.
RG-8	50	10	Solid copper	Used in the earliest computer networks. This cable was used as the backbone cable in the bus topology. In Ethernet standards, this cable is documented as the 10base5 Thicknet cable.
RG-58	50	24	Several thin strands of copper	This cable is thinner, easier to handle and install than the RG-8 cable. This cable was used to connect a system with the backbone cable. In Ethernet standards, this cable is documented as the 10base2 Thinnet cable.
RG-59	75	20 - 22	Solid copper	Used in cable networks to provide short-distance service.

Similarities and differences between STP and UTP cables



- Both STP and UTP can transmit data at 10Mbps, 100Mbps, 1Gbps, and 10Gbps.
- Since the STP cable contains more materials, it is more expensive than the UTP cable.
- Both cables use the same RJ-45 (registered jack) modular connectors.
- The STP provides more noise and EMI resistance than the UTP cable.
- The maximum segment length for both cables is 100 meters or 328 feet.

Radio Frequency bands



Multiplexing

What is Multiplexing?

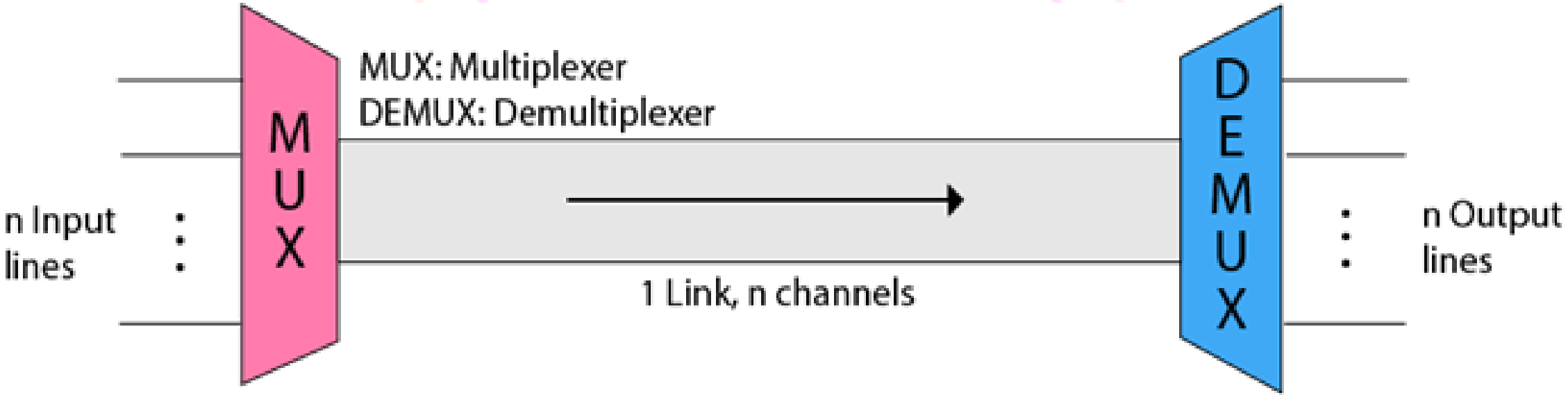
- Multiplexing is a technique used to combine and send the multiple data streams over a single medium. The process of combining the data streams is known as multiplexing and hardware used for multiplexing is known as a multiplexer.

- 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.

What is Demultiplexing?

- Demultiplexing is achieved by using a device called Demultiplexer (DEMUX) available at the receiving end.

- DEMUX separates a signal into its component signals (one input and n outputs). Therefore, we can say that demultiplexing follows the one-to-many approach.



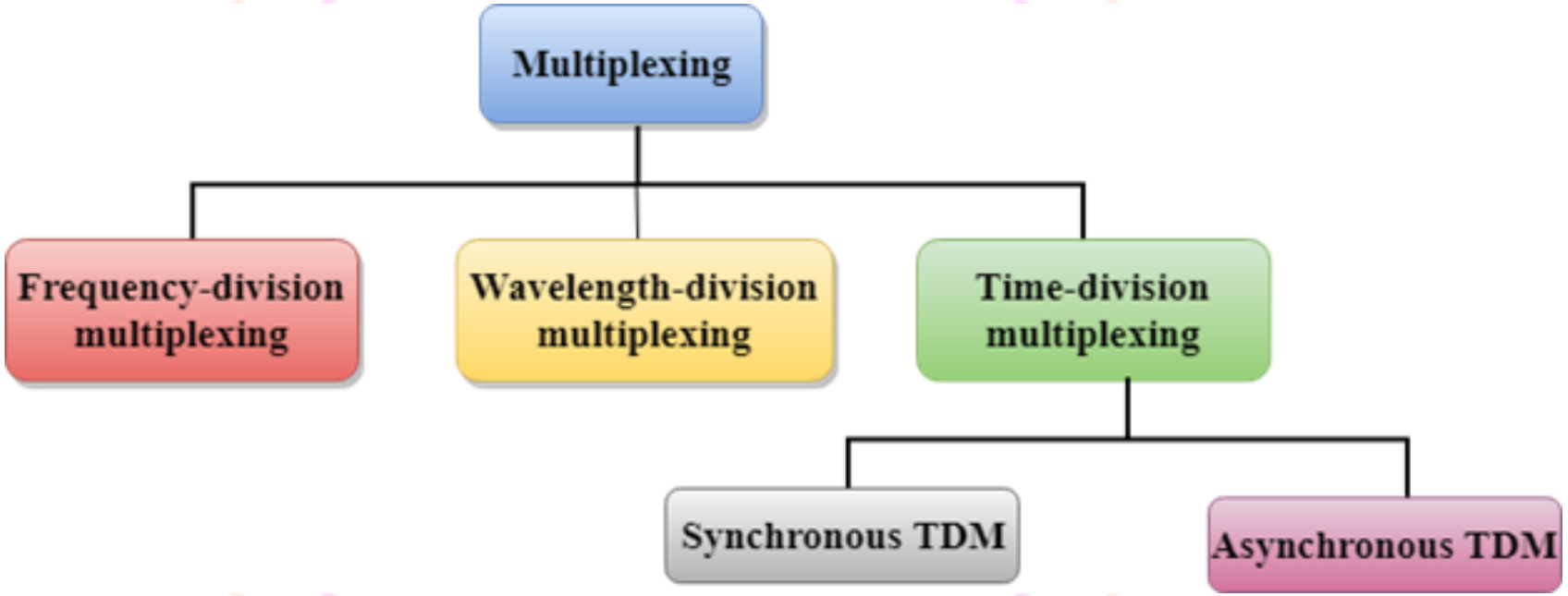
WHY MULTIPLEXING?

- The transmission medium is used to send the signal from sender to receiver. The medium can only have one signal at a time.

- If there are multiple signals to share one medium, then the medium must be divided in such a way that each signal is given some portion of the available bandwidth.

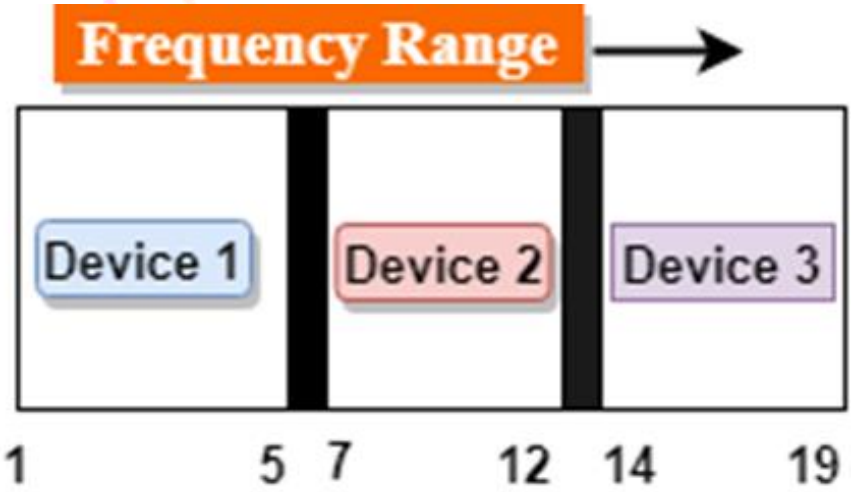
- For example: If there are 10 signals and bandwidth of medium is 100 units, then the 10 unit is shared by each signal.

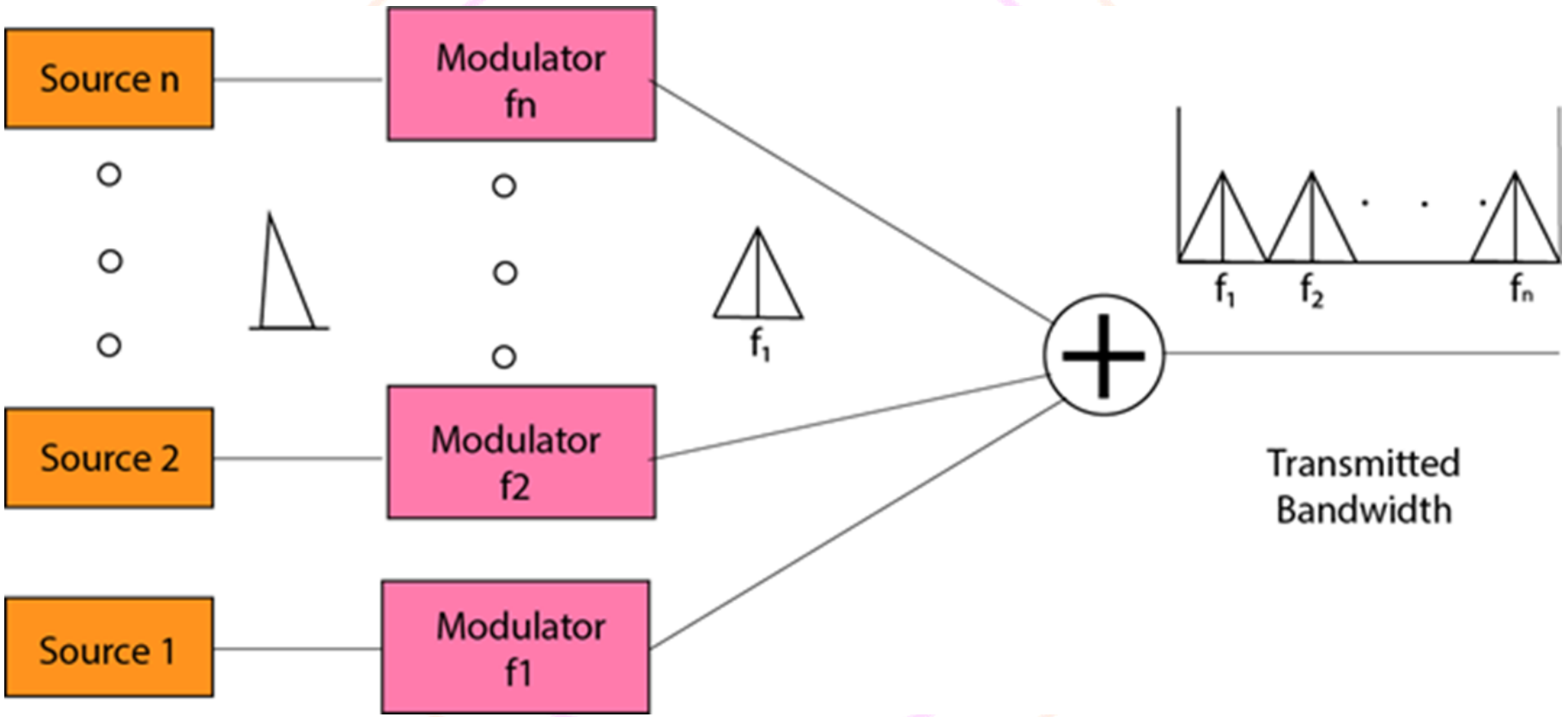
Multiplexing Techniques



FREQUENCY-DIVISION MULTIPLEXING (FDM)

- It is an analog technique.
- Frequency Division Multiplexing is a technique in which the available bandwidth of a single transmission medium is subdivided into several channels.

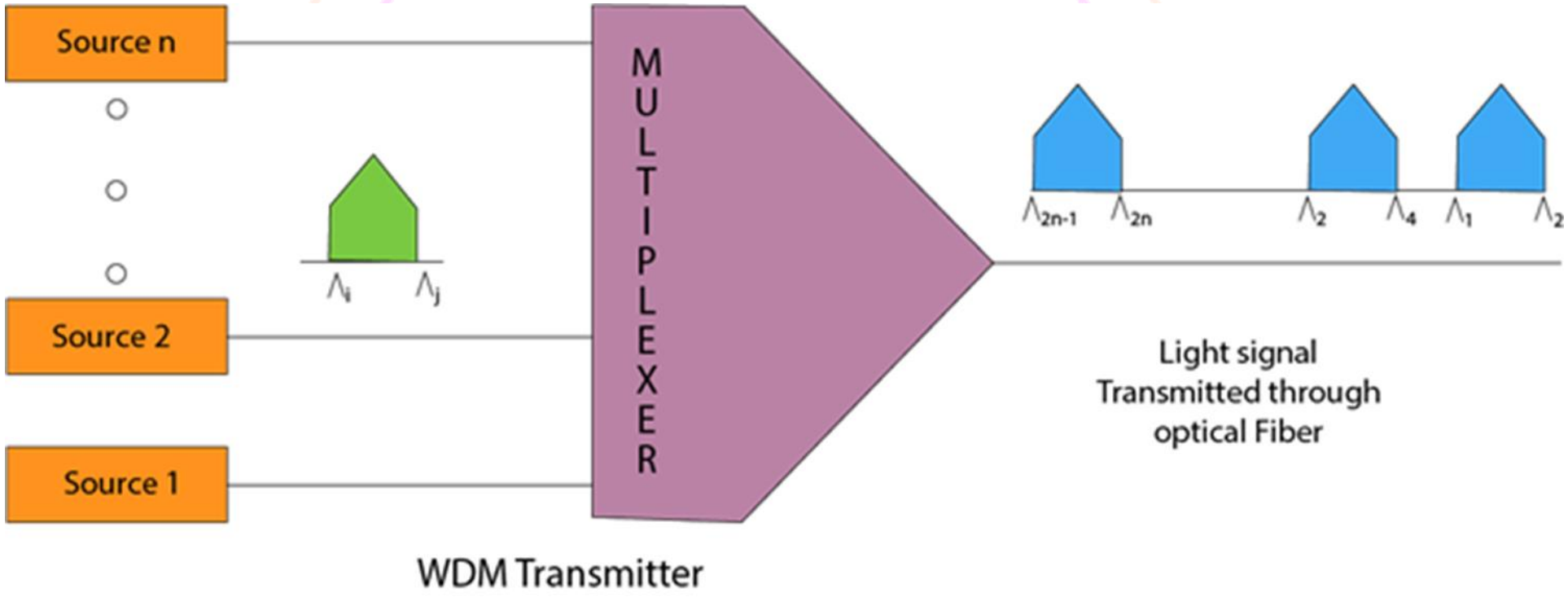




Applications Of FDM

- FDM is commonly used in TV networks.
- It is used in FM and AM broadcasting.
- Each FM radio station has different frequencies, and they are multiplexed to form a composite signal. The multiplexed signal is transmitted in the air.

Wavelength Division Multiplexing (WDM)



Wavelength Division Multiplexing (WDM)

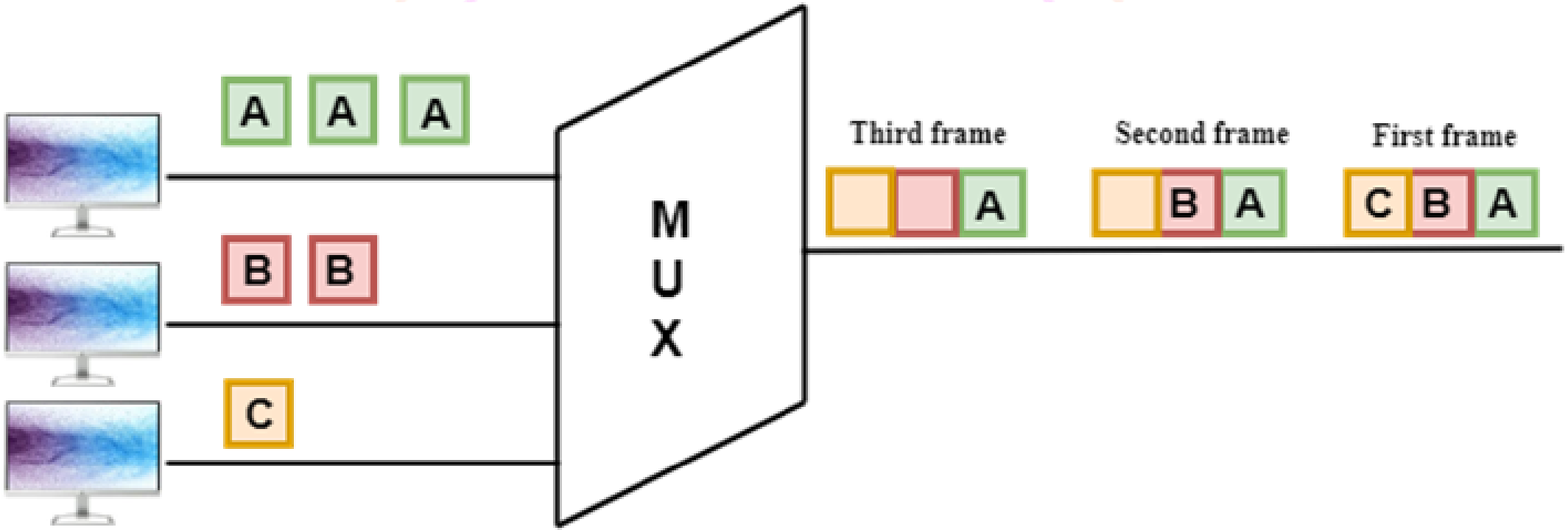
1. Wavelength Division Multiplexing is same as FDM except that the optical signals are transmitted through the fibre optic cable.
2. WDM is used on fibre optics to increase the capacity of a single fibre.
3. It is used to utilize the high data rate capability of fibre optic cable.
4. It is an analog multiplexing technique.
5. Optical signals from different source are combined to form a wider band of light with the help of multiplexer.
6. At the receiving end, demultiplexer separates the signals to transmit them to their respective destinations.

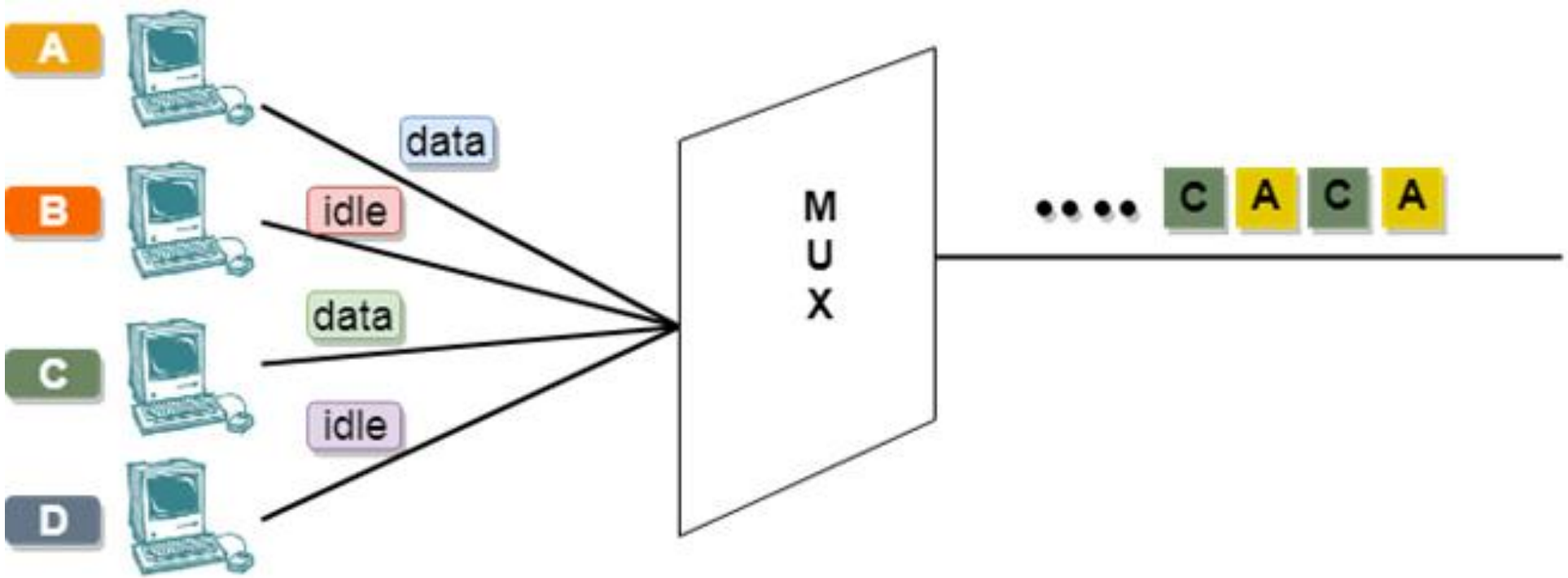
Time Division Multiplexing

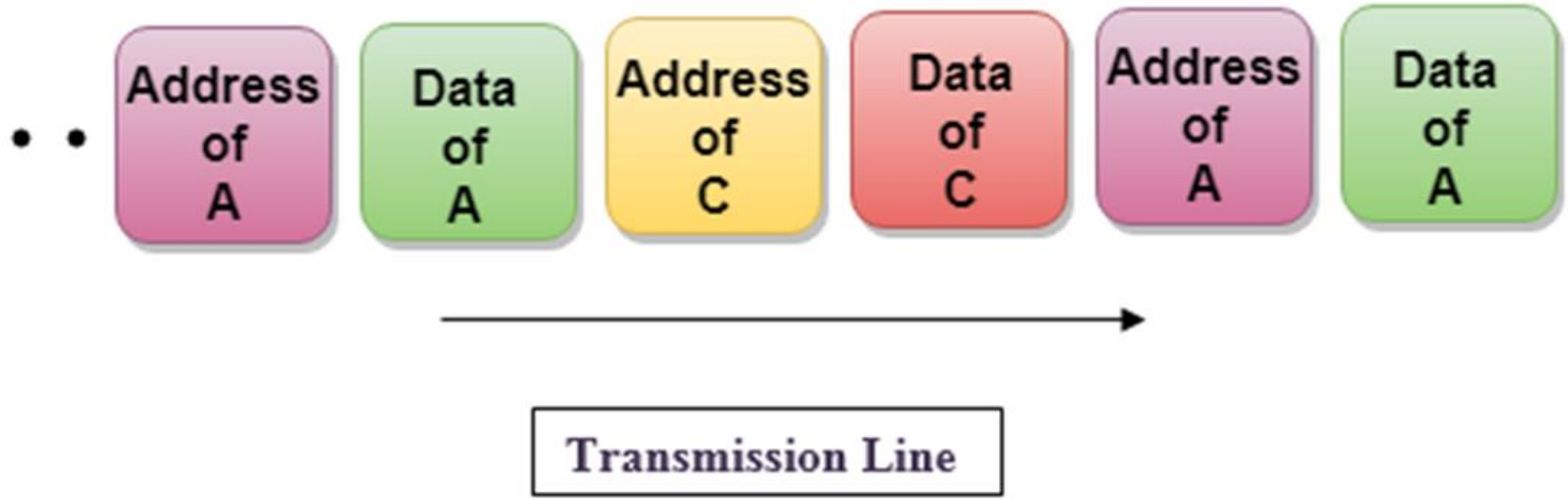
1. It is a digital technique.
2. In Frequency Division Multiplexing Technique, all signals operate at the same time with different frequency, but in case of Time Division Multiplexing technique, all signals operate at the same frequency with different time.
3. In Time Division Multiplexing technique, the total time available in the channel is distributed among different users. Therefore, each user is allocated with different time interval known as a Time slot at which data is to be transmitted by the sender.
4. A user takes control of the channel for a fixed amount of time.

There are two types of TDM:

1. Synchronous TDM
2. Asynchronous TDM







A network is a set of connected devices. Whenever we have multiple devices, we have the problem of how to connect them to make one-to-one communication possible.

One solution is to make a point-to-point connection between each pair of devices (a mesh topology) or between a central device and every other device (a star topology).

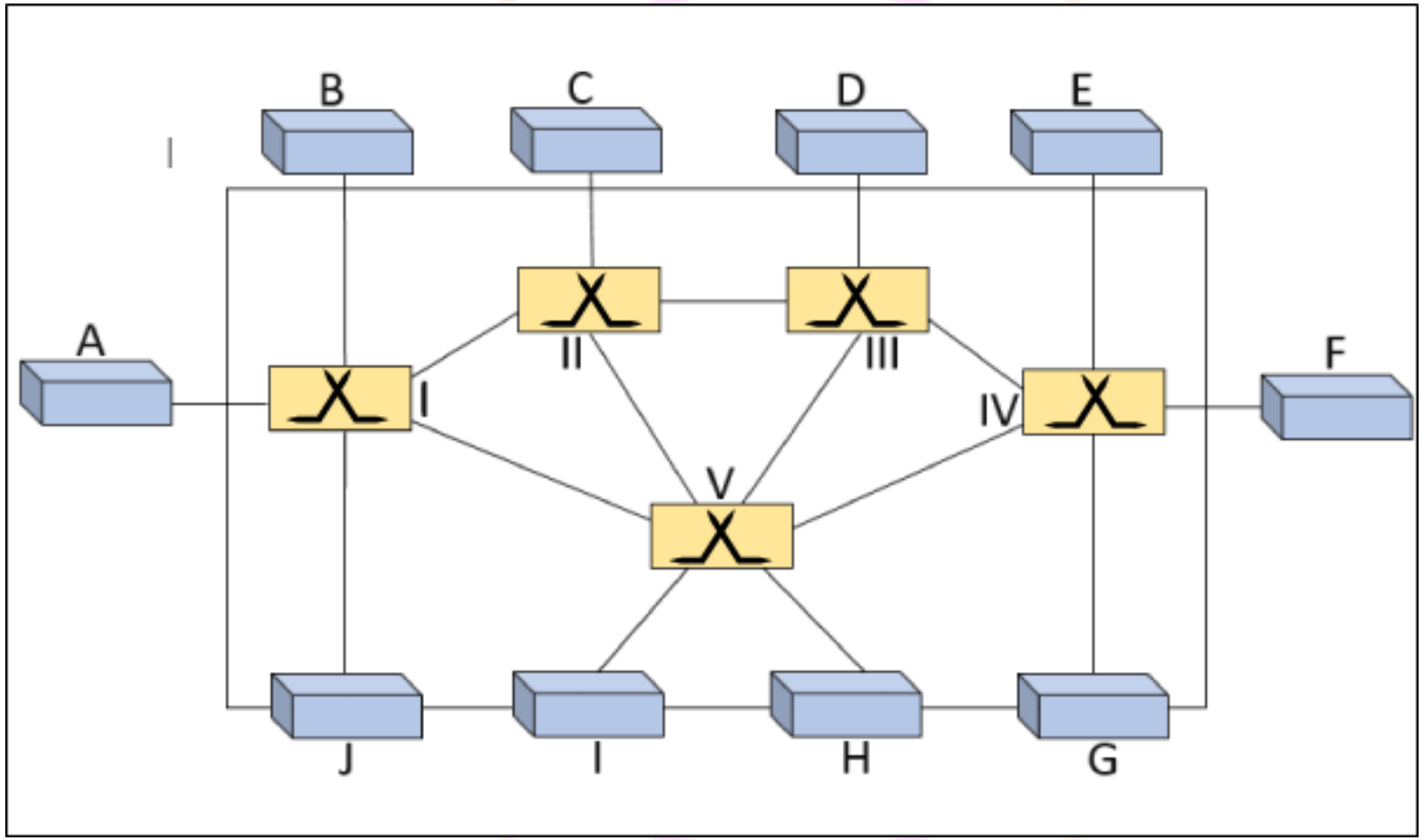
These methods, however, are impractical and wasteful when applied to very large networks.

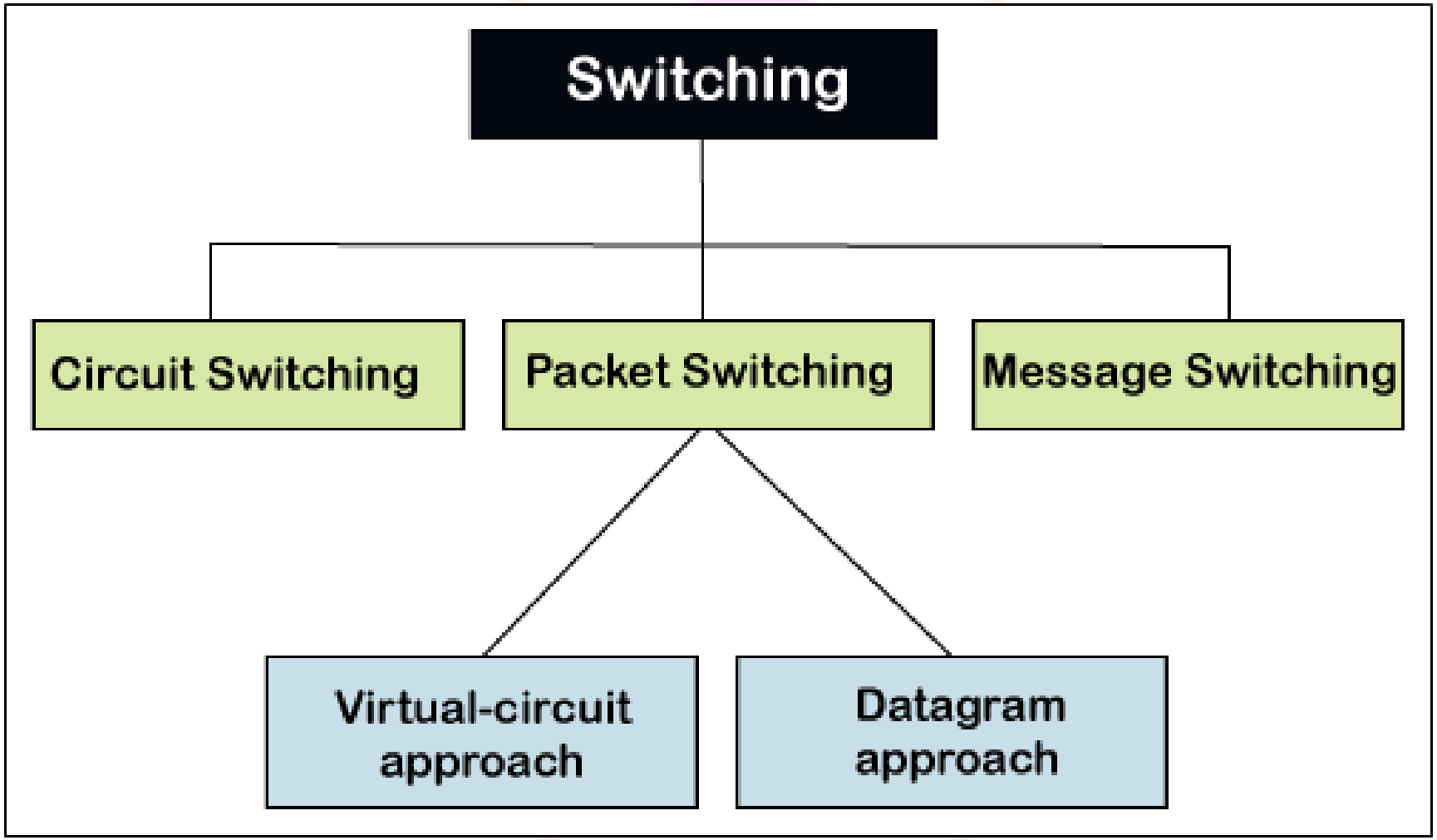
SWITCHING

1. A better solution is switching.

2. A switched network consists of a series of interlinked nodes, called switches.
3. Switches are devices capable of creating temporary connections between two or more devices linked to the switch.

4. In a switched network, some of these nodes are connected to the end systems

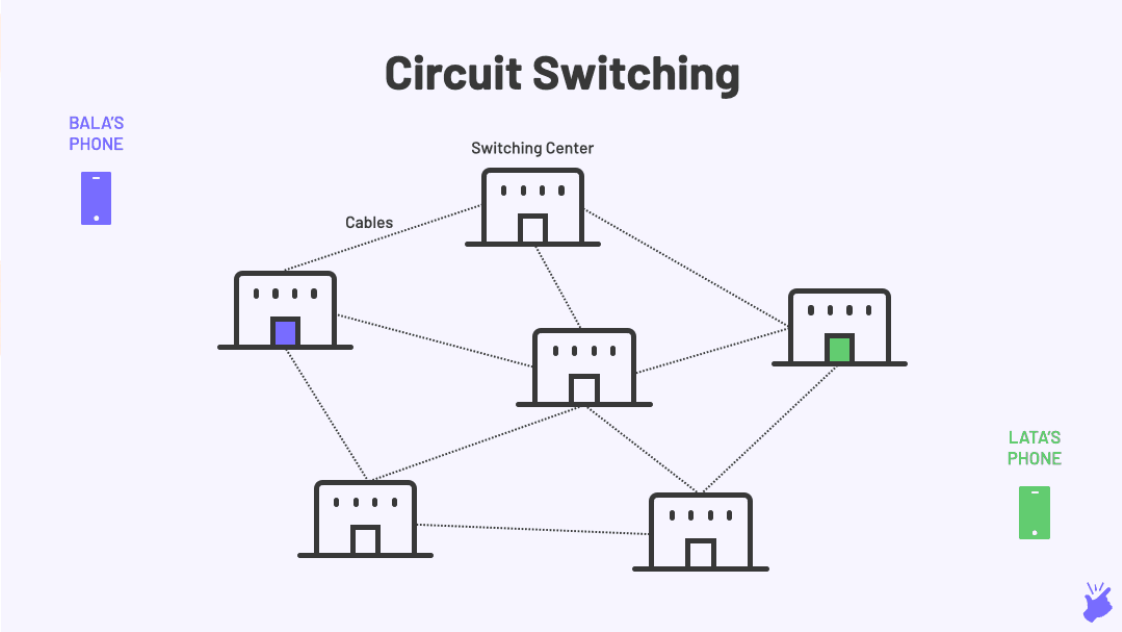




Circuit Switching

- Conceptually, when you or your computer places a telephone call, the switching equipment within the telephone system seeks out a physical path all the way from your telephone to the receiver's telephone.

- This technique is called circuit switching.

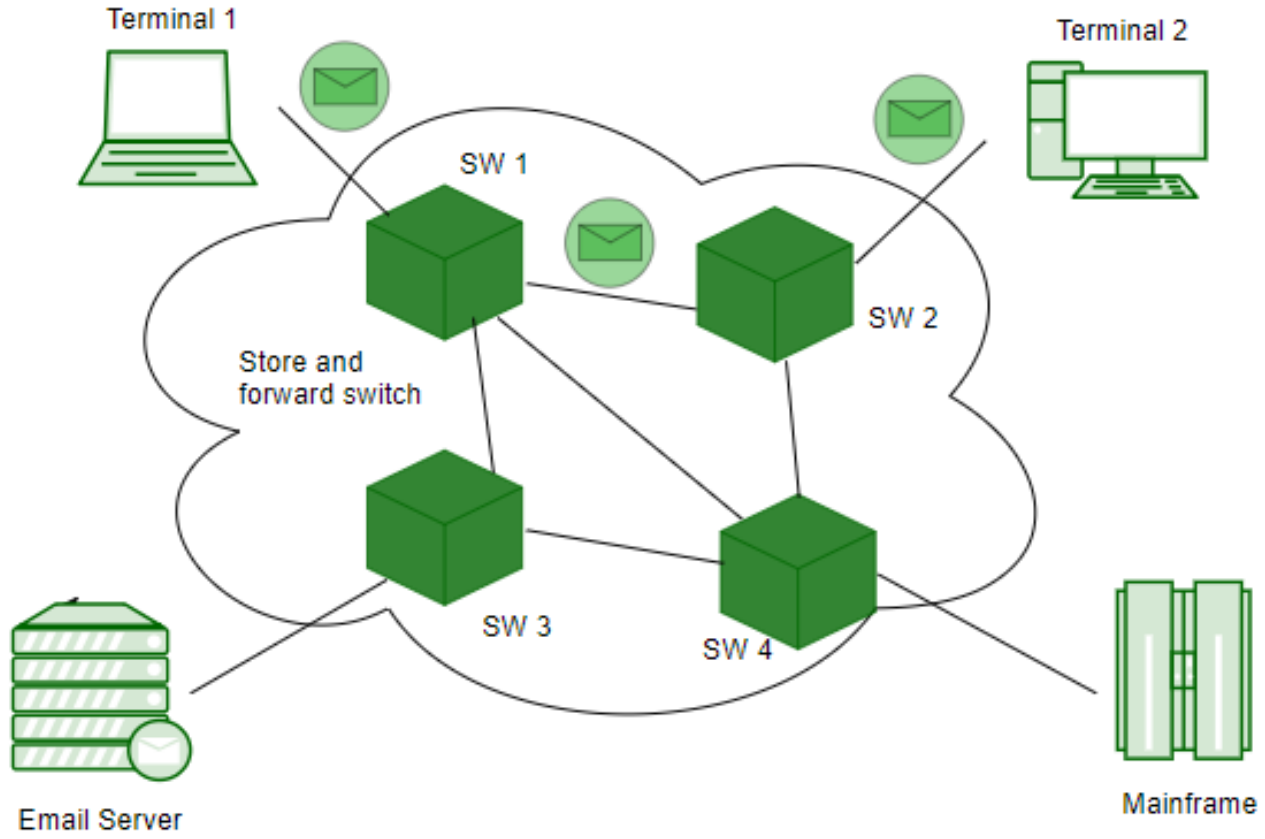


Message Switching

- Message switching was a technique developed as an alternative to circuit switching before packet switching was introduced. In message switching, end-users communicate by sending and receiving messages that included the entire data to be shared. Messages are the smallest individual unit.

- Also, the sender and receiver are not directly connected. There are a number of intermediate nodes that transfer data and ensure that the message reaches its destination. Message switched data networks are hence called hop-by-hop systems.

Message Switching



MESSAGE SWITCHING

- They provide 2 distinct and important characteristics:

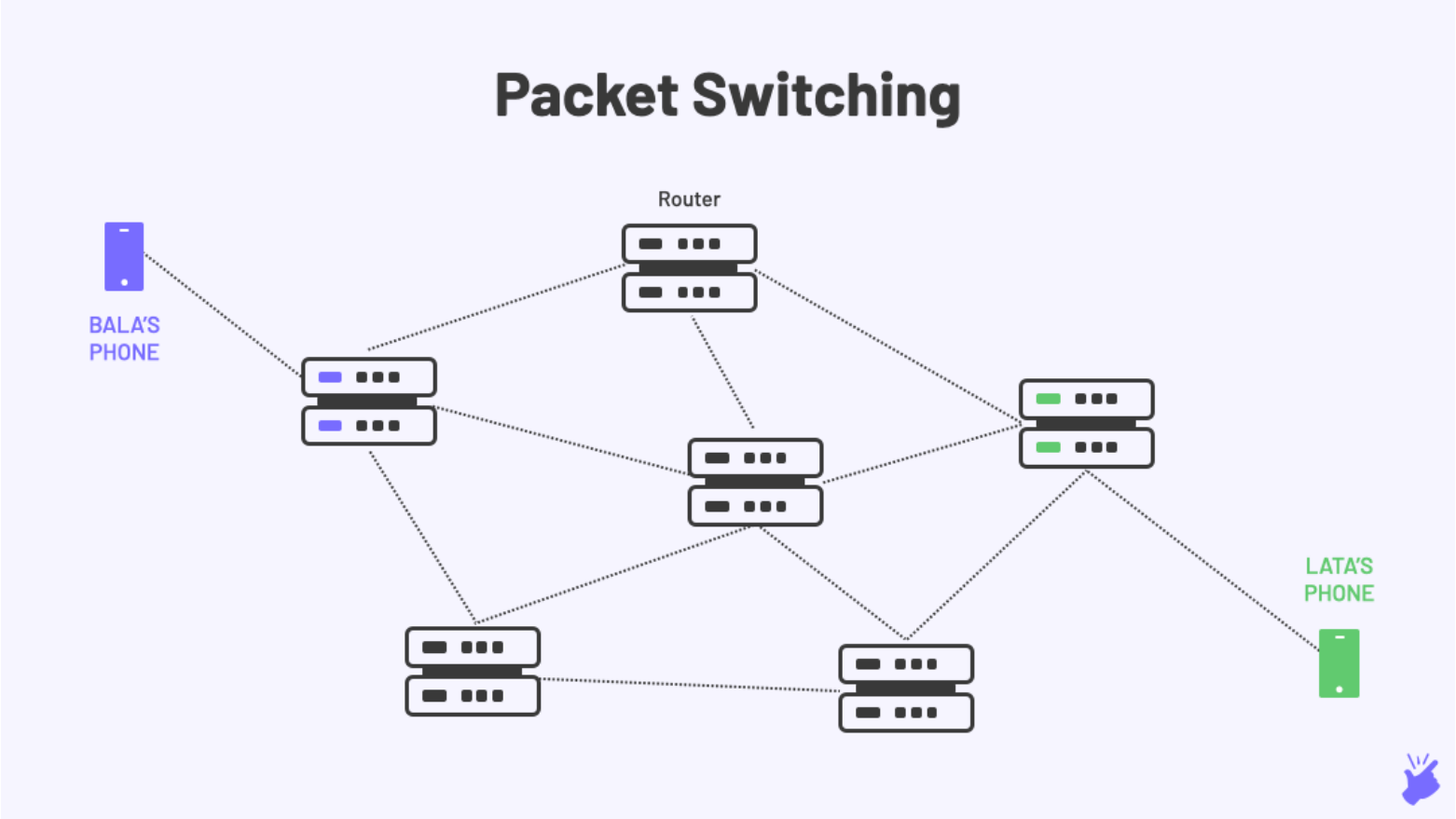
- **Store and forward** – The intermediate nodes have the responsibility of transferring the entire message to the next node. Hence, each node must have storage capacity. A message will only be delivered if the next hop and the link connecting it are both available, otherwise, it'll be stored indefinitely. A store-and-forward switch forwards a message only if sufficient resources are available and the next hop is accepting data. This is called the store-and-forward property.

Message Switching

- They provide 2 distinct and important characteristics:

- **Message delivery –** This implies wrapping the entire information in a single message and transferring it from the source to the destination node. Each message must have a header that contains the message routing information, including the source and destination.

Packet Switching



PACKET SWITCHING

- Packet switching is a method of transferring data to a network in form of packets.
- In order to transfer the file fast and efficiently 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) have to be reassembled, belonging to the same file.

PACKET SWITCHING

- A packet composes of a payload and various control information.
- No pre-setup or reservation of resources is needed.
- Packet Switching uses Store and Forward technique while switching the packets; while forwarding the packet each hop first stores that packet than forward.

Modes of Packet Switching

1. Connection-oriented Packet Switching (Virtual Circuit):

- Before starting the transmission, it establishes a logical path or virtual connection using a signaling protocol, between sender and receiver and all packets belongs to this flow will follow this predefined route.

- Virtual Circuit ID is provided by switches/routers to uniquely identify this virtual connection. Data is divided into small units and all these small units are appended with help of sequence numbers. Packets arrive in order at the destination.

Modes of Packet Switching

2. Connectionless Packet Switching (Datagram):

- Unlike Connection-oriented packet switching, In Connectionless Packet Switching each packet contains all necessary addressing information such as source address, destination address, port numbers, etc. In Datagram Packet Switching, each packet is treated independently.
- Packets belonging to one flow may take different routes because routing decisions are made dynamically, so the packets that arrived at the destination might be out of order.

Measuring Capacity of Communication Media

- **What is network bandwidth?**

- **When thinking about bandwidth, the key word is capacity. Bandwidth refers to the maximum amount of data that could, theoretically, travel from one point in the network to another in a given time.**

Measuring Capacity of Communication Media

- **What is network bandwidth?**

- **Bandwidth measurement units include bit, kilobit, megabit (Mb) and gigabit (Gb).**

- **Say, for example, a network has a bandwidth of 1 Gb per second (Gbps). This means 1 Gb is the maximum amount of data that could travel between links in one second, in an ideal situation.**

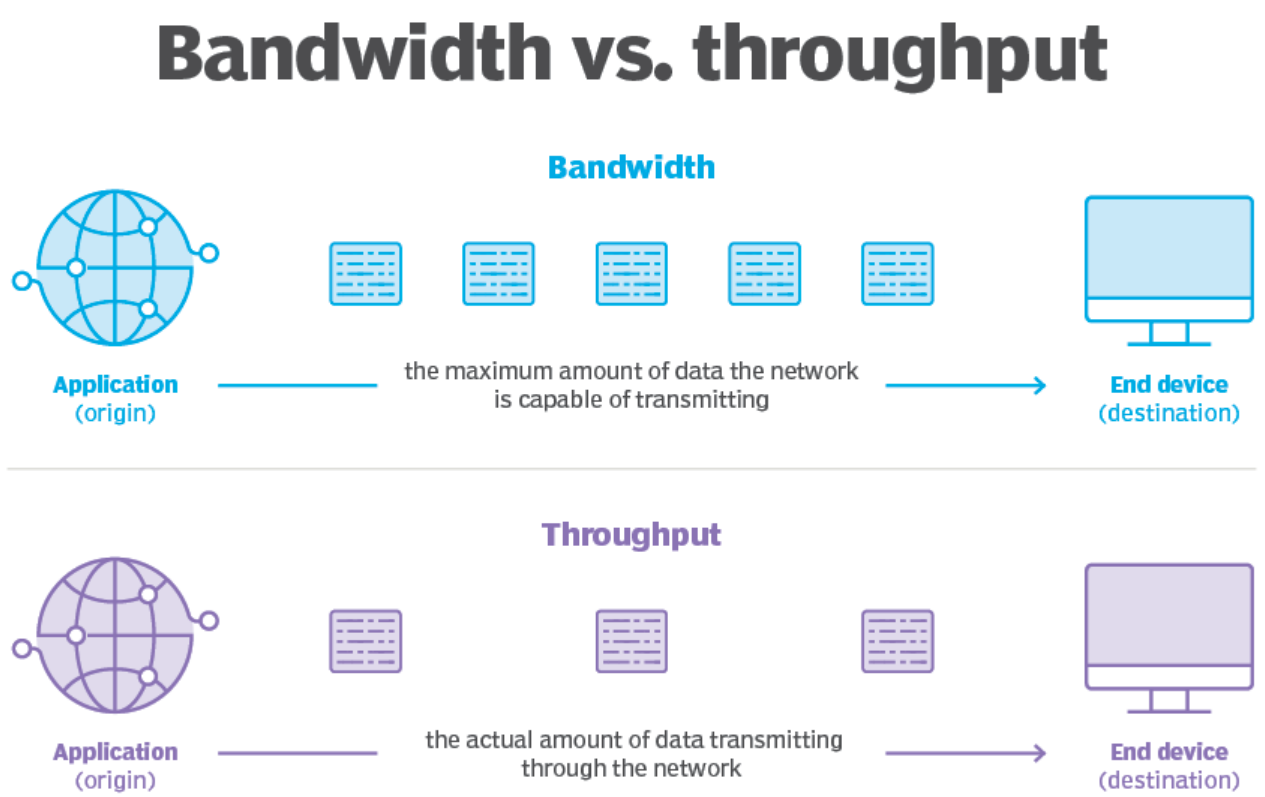
Measuring Capacity of Communication Media

- **What is Network throughput ?**

- Network throughput refers to how much data actually transfers during a period of time.

- Bandwidth and throughput are also sometimes conflated with latency, which refers to the speed at which data travels across the network to its destination.

Measuring Capacity of Communication Media



Measuring Capacity of Communication Media

- **What Is Latency?**

- **Latency measures delay. Delay is simply the time taken for a data packet to reach its destination after being sent. We measure network latency as round trips, although it may sometimes be measured in one-way trips.**

- **However, round-trip measurements are more common, because devices usually wait for an acknowledgment from the destination machine to be returned before transmitting the complete set of data.**

Measuring Capacity of Communication Media

- **Data Transfer Rate**
- **Data travels in the form of signals over a channel. One signal carries one or more bits over the channel. Data transfer rate is the number of bits transmitted between source and destination in one second. It is also known as bit rate. It is measured in terms of bits per second (bps). The higher units for data transfer rates are:**

$$1\ \text{Kbps} = 2^{10}\ \text{bps} = 1024\ \text{bps}$$
$$1\ \text{Mbps} = 2^{20}\ \text{bps} = 1024\ \text{Kbps}$$
$$1\ \text{Gbps} = 2^{30}\ \text{bps} = 1024\ \text{Mbps}$$
$$1\ \text{Tbps} = 2^{40}\ \text{bps} = 1024\ \text{Gbps}$$

Measuring Capacity of Communication Media

Full Form	Units	Bytes
1 Bit	Binary Digit (0/1)	
1 Nibble	4 bits	
1 Byte	8 bits	
1 kilobyte(KB)	1024 byte	2^{10} bytes
1 Megabyte(MB)	1024 KB	2^{20} bytes
1 Gigabyte (GB)	1024 MB	2^{30} bytes
1 Terabyte(TB)	1024 GB	2^{40} bytes
1 Petabyte(PB)	1024 TB	2^{50} bytes
1 Exabyte(EB)	1024 PB	2^{60} bytes
1 Zettabyte(ZB)	1024 EB	2^{70} bytes
1 Yottabyte(YB)	1024 ZB	2^{80} bytes
1 Brontobyte	1024 YB	2^{90} bytes
1 Geopbyte	1024 Brontobyte	2^{100} bytes

Measuring Capacity of Communication Media

- **Example:** A user wants to upload a text document at the rate of 10 pages per 20 second. What will be the required data rate of the channel? (Assume that 1 page contains 1600 characters and each character is of 8 bits).

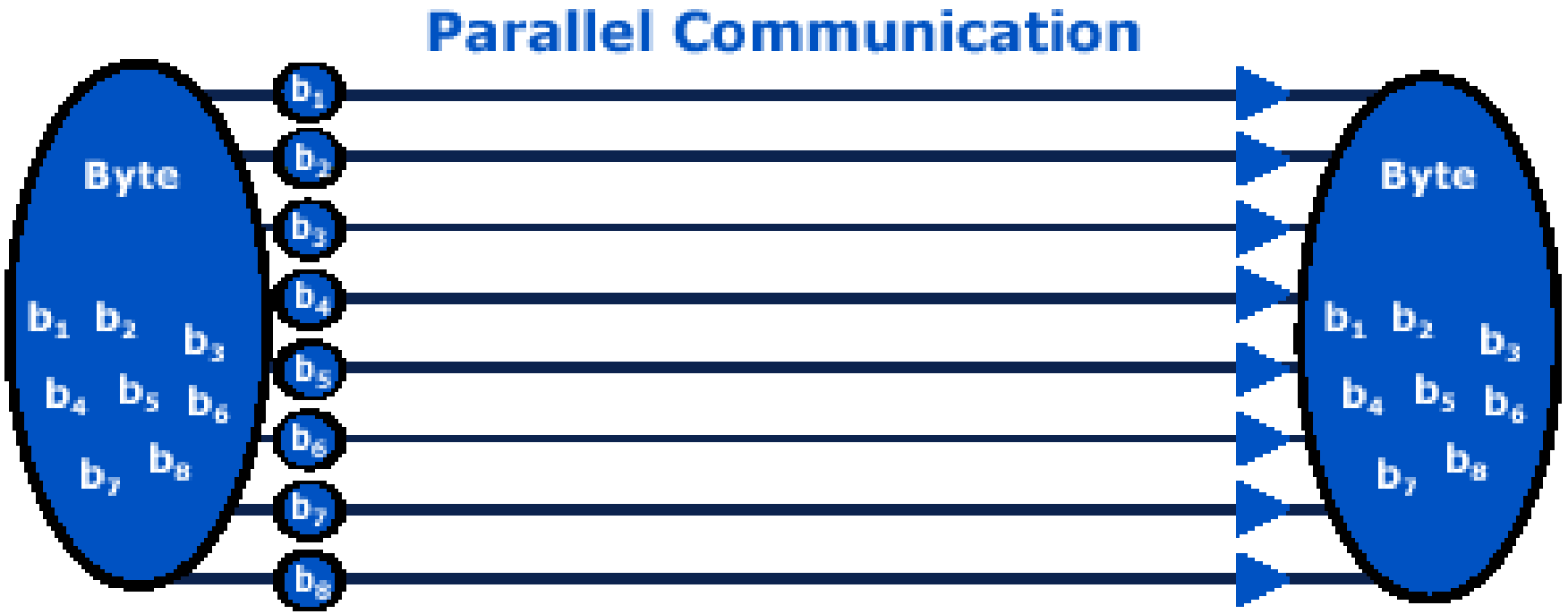
- **The Baud rate refers to the total number of signal units transmitted in one second.**

- **The Bit rate refers to the total Bits transmitted in one unit time.**

S.NO	Bit Rate	Baud Rate
1.	Bit rate is defined as the transmission of a number of bits per second.	Baud rate is defined as the number of signal units per second.
2.	Bit rate is also defined as per second travel number of bits.	Baud rate is also defined as per second number of changes in signal.
3.	Bit rate emphasized computer efficiency.	While the baud rate emphasized data transmission.
4.	The formula of Bit Rate is: `= baud rate x the number of bit per baud`	The formula of Baud Rate is: `= bit rate / the number of bit per baud`
5.	Bit rate is not used to decide the requirement of bandwidth for transmission of the signal.	While baud rate is used to decide the requirement of bandwidth for transmission of the signal.
6.	Bit Rate cannot determine the bandwidth.	Baud rate can determine the amount of bandwidth necessary to send the signal.
7.	It counts the number of bits traveled per second such as Kbps, Mbps, Gbps, etc	It counts how many times the state of a signal is changing.

- **If a link transmits 4000 frames per second, and each slot has 8 bits, what is the transmission rate of the circuit using Time Division Multiplexing (TDM)?**

a) 500kbps
b) 32kbps
c) 32bps
d) 500bps



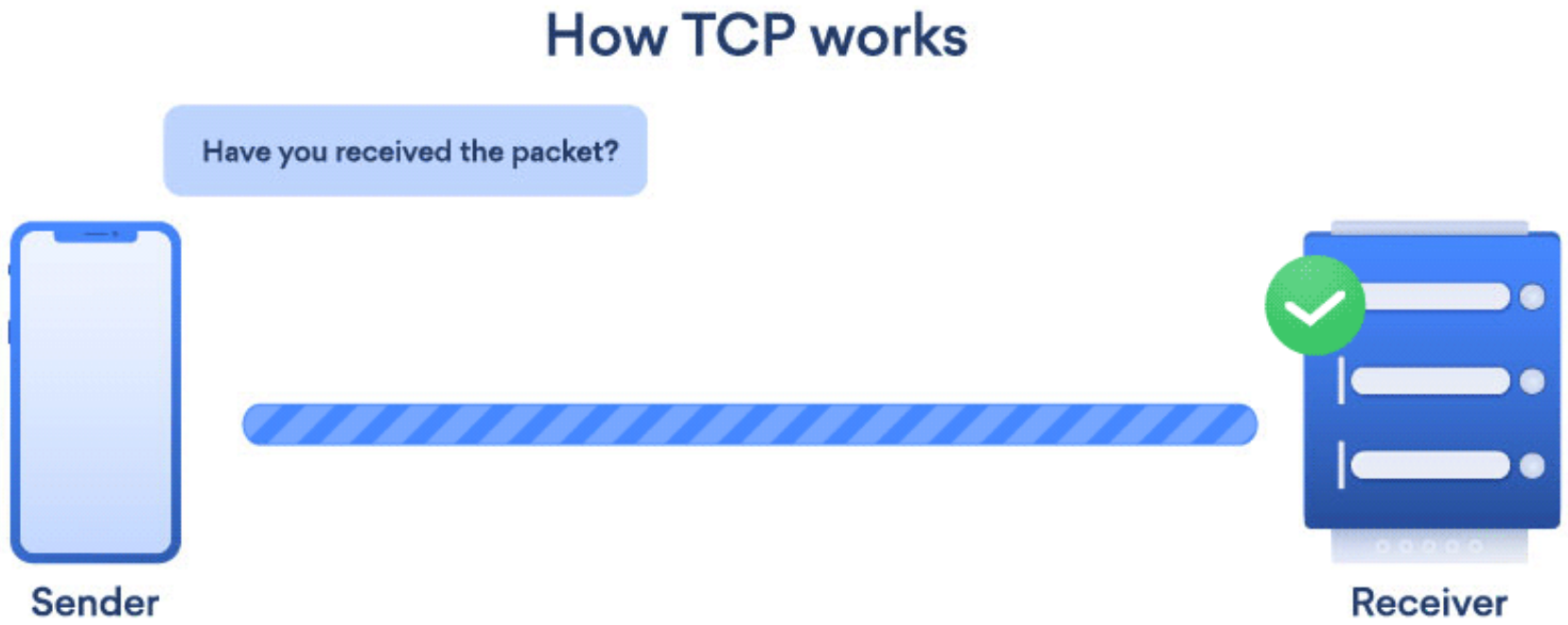
Serial Communication	Parallel Communication
Data transmitted serially, one bit at a time.	Data is transmitted parallely, all bits at a time.
Low Speed	High Speed
It has single transmission line.	It has multiple transmission lines
Serial communication do not have any crosstalk problem.	Parallel communication may have crosstalk problem
Less expensive	More expensive
The bandwidth is higher	The bandwidth is lower
It is not affected with noise problems.	It may suffer with noise problems
Serial communication even works at high frequencies.	Parallel communication may not work properly at high frequencies
It covers long distance when compared to parallel communication.	It is used for short distances
Example: Serial communication between a computer and modem	Example: Parallel communication between a motherboard and hard disk

INTERNET PROTOCOLS

- Internet Protocols are a set of rules that governs the communication and exchange of data over the internet.

- Both the sender and receiver should follow the same protocols in order to communicate the data.

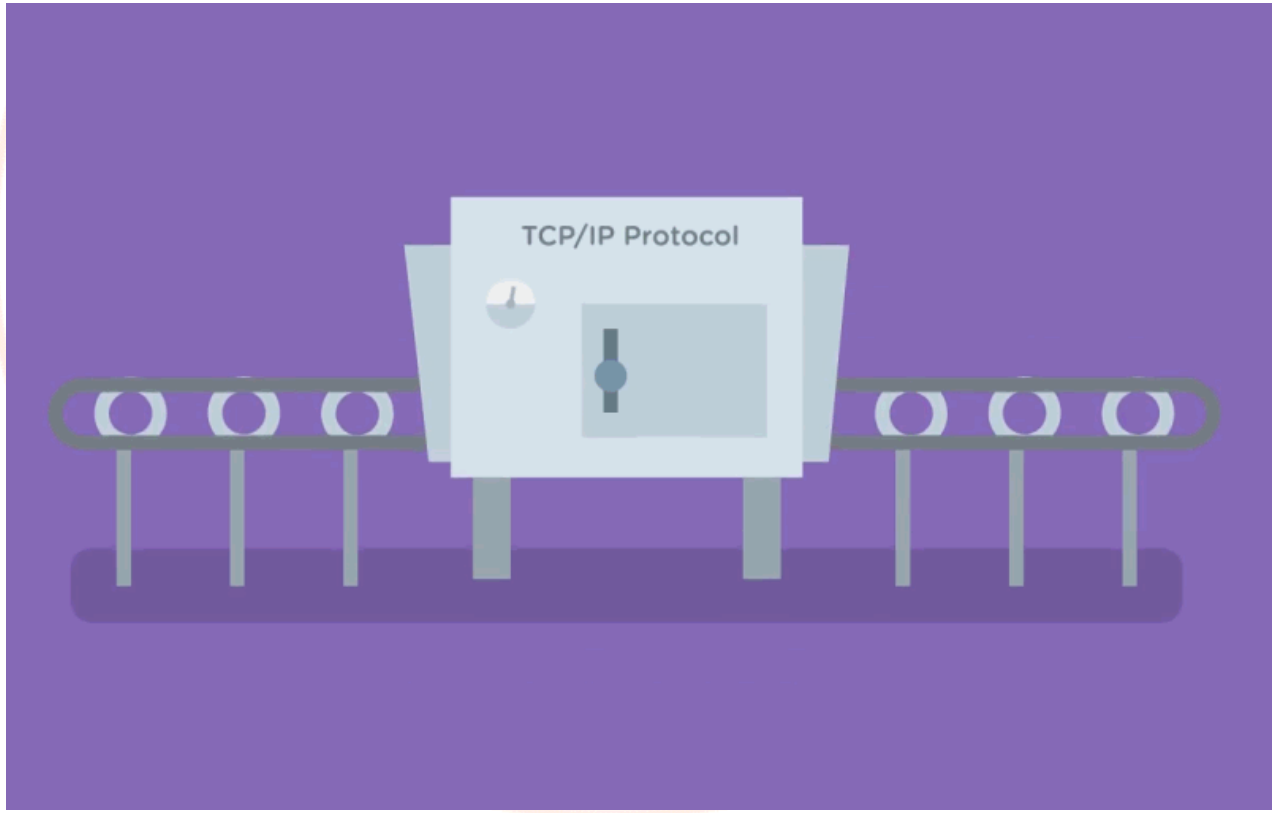
Working of Internet Protocol



WORKING OF INTERNET PROTOCOL

- The internet and many other data networks work by organizing data into small pieces called packets.
- Each large data sent between two network devices is divided into smaller packets by the underlying hardware and software.
- Each network protocol defines the rules for how its data packets must be organized in specific ways according to the protocols the network supports

TCP/IP(Transmission Control Protocol/ Internet Protocol)



TCP/IP(Transmission Control Protocol/ Internet Protocol)

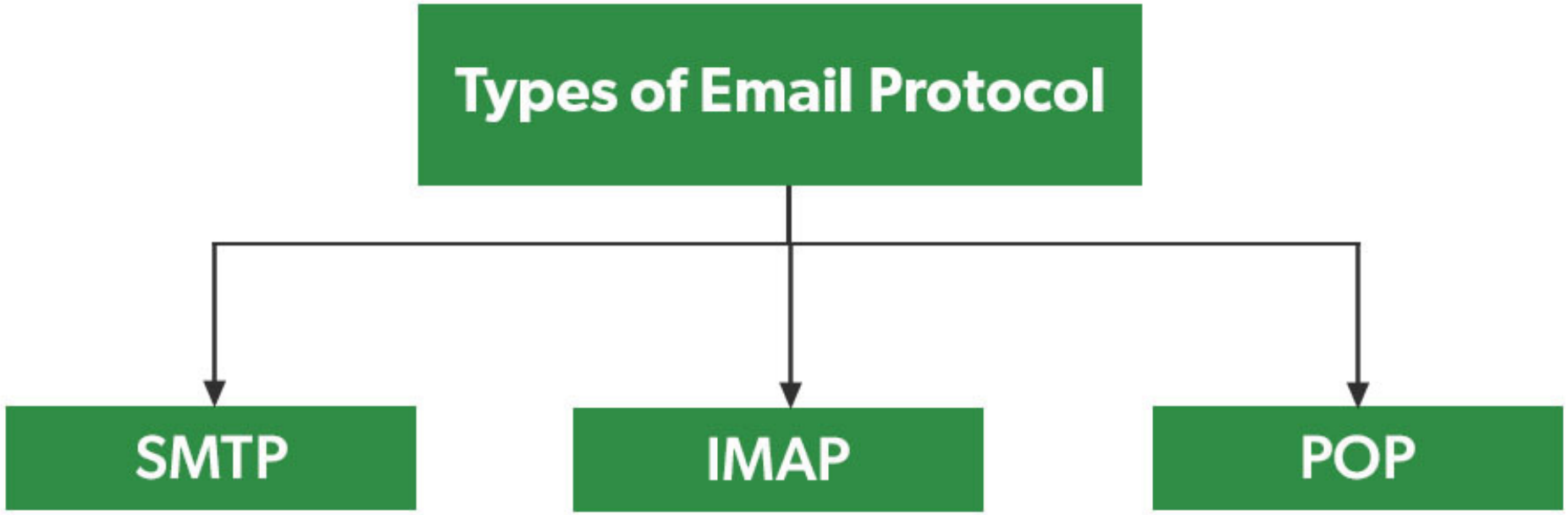
- These are a set of standard rules that allows different types of computers to communicate with each other.

- TCP specifies how data is exchanged over the internet and how it should be broken into IP packets.

TCP/IP(Transmission Control Protocol/ Internet Protocol)

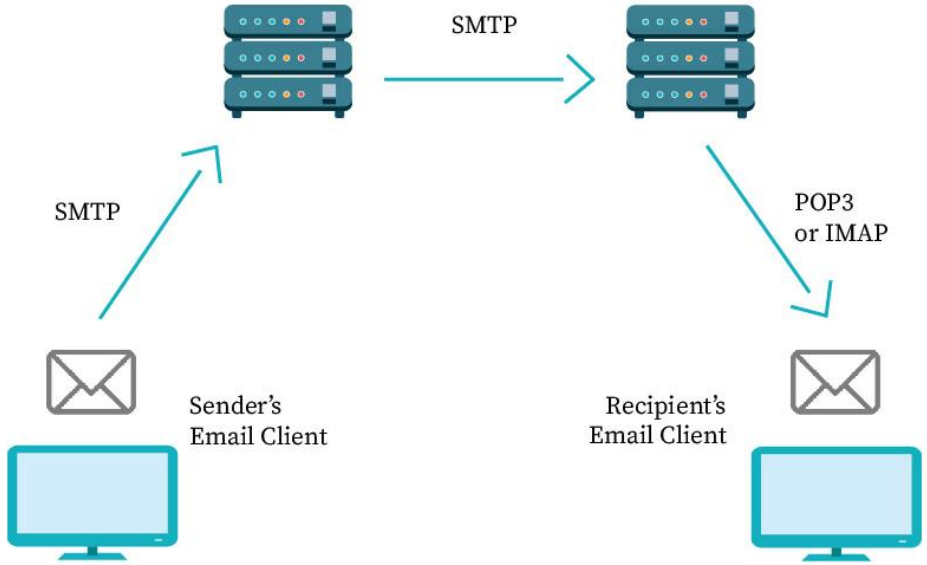
- It also makes sure that the packets have information about the source of the message data, the destination of the message data, the sequence in which the message data should be re-assembled, and checks if the message has been sent correctly to the specific destination.

- The TCP is also known as a connection-oriented protocol.



SMTP(Simple Mail Transfer Protocol)

- These protocols are important for sending and distributing outgoing emails.



SMTP(Simple Mail Transfer Protocol)

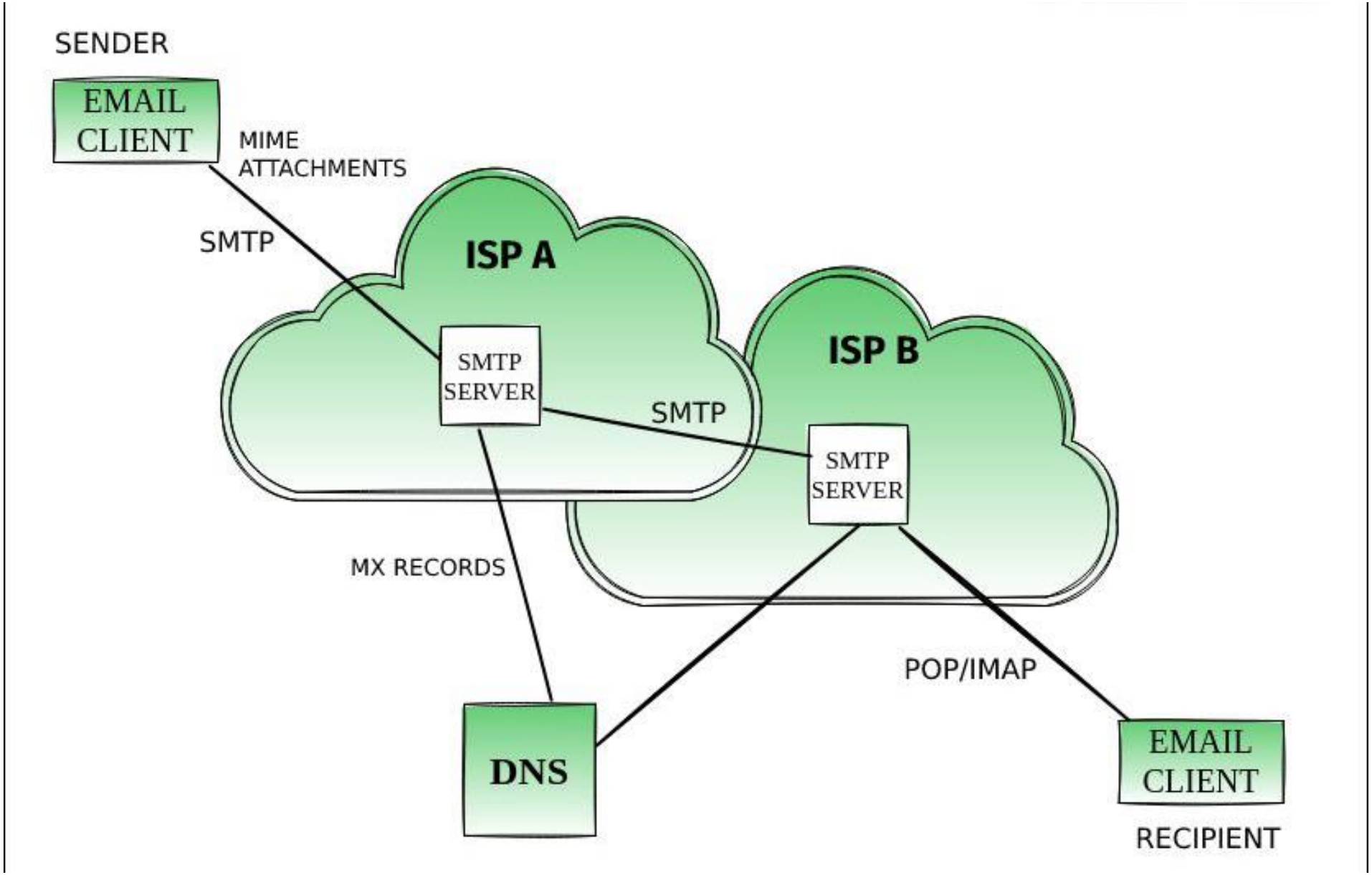
- Simple Mail Transfer Protocol is used to send mails over the internet.
- SMTP is an application layer and connection-oriented protocol. SMTP is efficient and reliable for sending emails.
- SMTP uses TCP as the transport layer protocol. It handles the sending and receiving of messages between email servers over a TCP/IP network.

POP(Post Office Protocol):

- Post Office Protocol is used to retrieve email for a single client.
- POP3 version is the current version of POP used. It is an application layer protocol.
- It allows to access mail offline and thus, needs less internet time. To access the message it has to be downloaded.

IMAP(Internet Message Access Protocol):

- Internet Message Access Protocol is used to retrieve mails for multiple clients.
- There are several IMAP versions: IMAP, IMAP2, IMAP3, IMAP4, etc.
- IMAP is an application layer protocol. IMAP allows to access email without downloading them and also supports email download. The emails are maintained by the remote server. It enables all email operations such as creating, manipulating, delete the email without reading it. IMAP allows you to search emails



HTTP(Hyper Text Transfer Protocol)

- HTTP stands for HyperText Transfer Protocol. It is the primary protocol used to access the World Wide Web.
- Tim Berners-Lee led the development of HTTP at CERN in 1989 in collaboration with Internet Engineering Task Force (IETF) and the World Wide Web Consortium (W3C).
- HTTP is a request-response (also called client-server) protocol that runs over TCP. The common use of HTTP is between a web browser (client) and a web server (server).

HTTP(Hyper Text Transfer Protocol)

- This protocol is used to transfer hypertexts over the internet and it is defined by the www(world wide web) for information transfer.
- This protocol defines how the information needs to be formatted and transmitted.
- And, it also defines the various actions the web browsers should take in response to the calls made to access a particular web page.

HTTP(HYPER TEXT TRANSFER PROTOCOL)

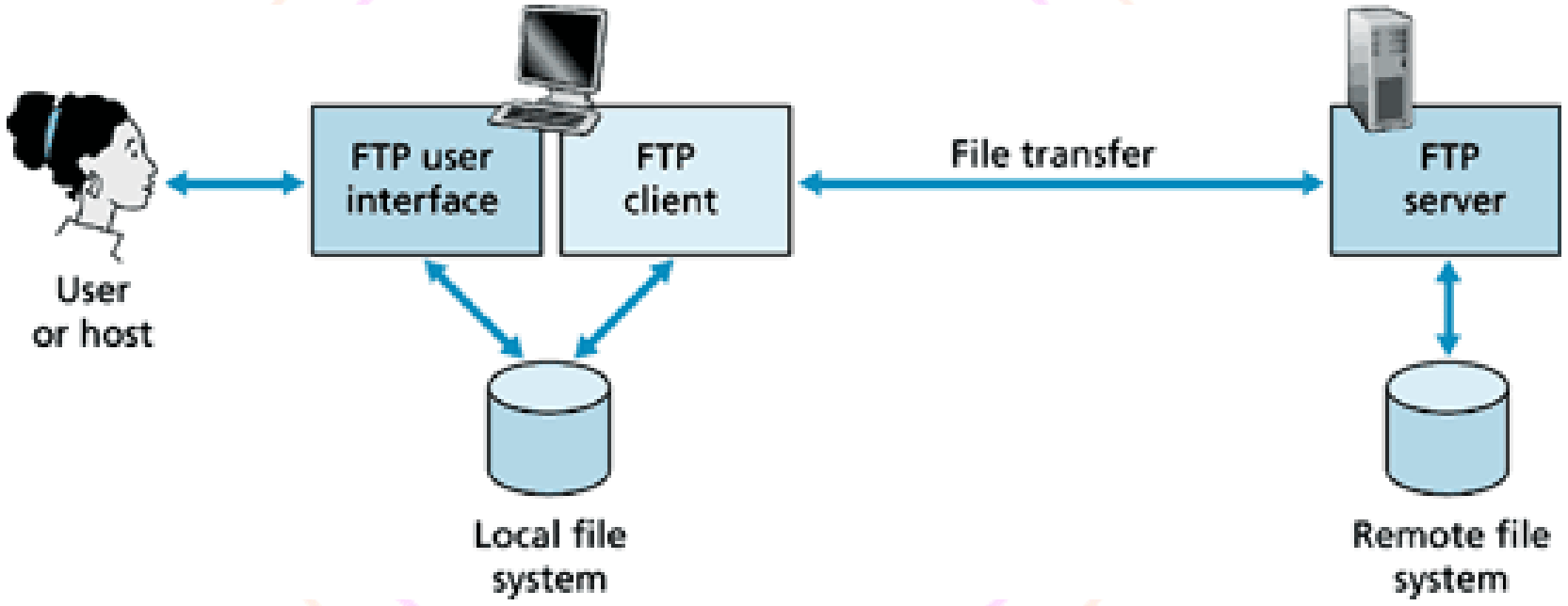
- A web page is written using a markup language like HTML and is stored on a web server for access via its URL.
- Once a user opens a web browser and types in the URL of the intended web page, a logical communication link between the user machine (client) and the web server is created using HTTP.
- For example, whenever we enter the URL http//www.ncert.nic.in in a browser, it sends HTTP request to the web-server where ncert.nic.in is hosted. The HTTP response from the web-server fetches and sends the requested Web-page, which is displayed on your browse.

HTTPS (Hypertext Transfer Protocol Secure)

- HTTPS is an extension of the Hypertext Transfer Protocol (HTTP).

- It is used for secure communication over a computer network with the SSL/TLS protocol for encryption and authentication.
- So, generally, a website has an HTTP protocol but if the website is such that it receives some sensitive information such as credit card details, debit card details, OTP, etc then it requires an SSL certificate installed to make the website more secure. So, before entering any sensitive information on a website, we should check if the link is HTTPS or not.

FTP (File Transfer Protocol)



FTP (File Transfer Protocol)

- This protocol is used for transferring files from one system to the other.

- This works on a client-server model. When a machine requests for file transfer from another machine, the FTO sets up a connection between the two and authenticates each other using their ID and Password. And, the desired file transfer takes place between the machines.

TELNET(TERMINAL NETWORK)

- TELNET is a standard TCP/IP protocol used for virtual terminal service given by ISO.
- This enables one local machine to connect with another.
- The computer which is being connected is called a remote computer and which is connecting is called the local computer.

INTERNET PROTOCOL

- An IP stands for internet protocol.
- An IP address is assigned to each device connected to a network.
- Each device uses an IP address for communication.
- It also behaves as an identifier as this address is used to identify the device on a network.

An IP address consists of two parts, i.e., the first one is a network address, and the other one is a host address.

Internet Protocol

IPv4	vs.	IPv6
Deployed 1981		Deployed 1998
32-bit IP address		128-bit IP address
4.3 billion addresses Addresses must be reused and masked		$7.9x10^{28}$ addresses Every device can have a unique address
Numeric dot-decimal notation 192.168.5.18		Alphanumeric hexadecimal notation 50b2:6400:0000:0000:6c3a:b17d:0000:10a9 (Simplified - 50b2:6400::6c3a:b17d:0:10a9)
DHCP or manual configuration		Supports autoconfiguration