NETWORKING FUNDAMENTALS

Unit Structure

1.0 OBJECTIVES:

- ✓ Introduce the readers to data communication and its fundamentals
- ✓ Define networks
- ✓ Define protocols
- ✓ Standards in networking

1.1 INTRODUCTION

This Lecture provides an introduction to computer networks and covers fundamental topics like data, information to the definition of communication and computer networks.

The main objective of data communication and networking is to enable seamless exchange of data between any two points in the world.

This exchange of data takes place over a computer network.

1.2 DATA & INFORMATION

Data refers to the raw facts that are collected while **information** refers to processed data that enables us to take decisions.

Ex. When result of a particular test is declared it contains data of all students, when you find the marks you have scored you have the information that lets you know whether you have passed or failed.

The word ***data*** refers to any information which is presented in a form that is agreed and accepted upon by is creators and users.

1.3 DATA COMMUNICATION

Data Communication is a process of exchanging data or information

In case of computer networks this exchange is done between two devices over a transmission medium.

This process involves a communication system which is made up of hardware and software. The hardware part involves the sender and receiver devices and the intermediate devices through which the data passes. The software part involves certain rules which specify what is to be communicated, how it is to be communicated and when. It is also called as a Protocol.
The following sections are describes the fundamental characteristics that are important for the effective working of data communication process and is followed by the components that make up a data communications system.

1.3.1 Characteristics of Data Communication

The effectiveness of any data communications system depends upon the following four fundamental characteristics:
1. **Delivery**: The data should be delivered to the correct destination and correct user.
2. **Accuracy**: The communication system should deliver the data accurately, without introducing any errors. The data may get corrupted during transmission affecting the accuracy of the delivered data.
3. **Timeliness**: Audio and Video data has to be delivered in a timely manner without any delay; such a data delivery is called real time transmission of data.
4. **Jitter**: It is the variation in the packet arrival time. Uneven Jitter may affect the timeliness of data being transmitted.

1.3.2 Components of Data Communication

A Data Communication system has five components as shown in the diagram below:

Fig(1) Components of a Data Communication System

1. **Message:** Message is the information to be communicated by the sender to the receiver.
2. **Sender**: The sender is any device that is capable of sending the data (message).
3. **Receiver**: The receiver is a device that the sender wants to communicate the data (message).
4. **Transmission Medium:** It is the path by which the message travels from sender to receiver. It can be wired or wireless and many subtypes in both.
5. **Protocol:** It is an agreed upon set or rules used by the sender and receiver to communicate data.

- A protocol is a set of rules that governs data communication.
- A Protocol is a necessity in data communications without which the communicating entities are like two persons trying to talk to each other in a different language without know the other language.

1.4 DATA REPRESENTATION

Data is collection of raw facts which is processed to deduce information. There may be different forms in which data may be represented. Some of the forms of data used in communications are as follows:
1. **Text: Text** includes combination of alphabets in small case as well as upper case. It is stored as a pattern of bits. Prevalent encoding system : ASCII, Unicode

2. **Numbers:** Numbers include combination of digits from 0 to 9. It is stored as a pattern of bits. Prevalent encoding system : ASCII, Unicode

3. **Images**

- An image is worth a thousand words‖ is a very famous saying. In computers images are digitally stored.
- A Pixel is the smallest element of an image. To put it in simple terms, a picture or image is a matrix of pixel elements.
- The pixels are represented in the form of bits. Depending upon the type of image (black n white or color) each pixel would require different number of bits to represent the value of a pixel.
- The size of an image depends upon the number of pixels (also called resolution) and the bit pattern used to indicate the value of each pixel.
- Example: if an image is purely black and white (two color) each pixel can be represented by a value either 0 or 1, so an image made up of 10 x 10 pixel elements would require only 100 bits in memory to be stored.
- On the other hand an image that includes gray may require 2 bits to represent every pixel value (00 - black, 01 – dark gray, 10 light gray, 11 white). So the same 10 x 10 pixel image would now require 200 bits of memory to be stored.
- Commonly used Image formats : jpg, png, bmp, etc

4. Audio: Data can also be in the form of sound which can be recorded and broadcasted. Example: What we hear on the radio is a source of data or information.

Audio data is continuous, not discrete.

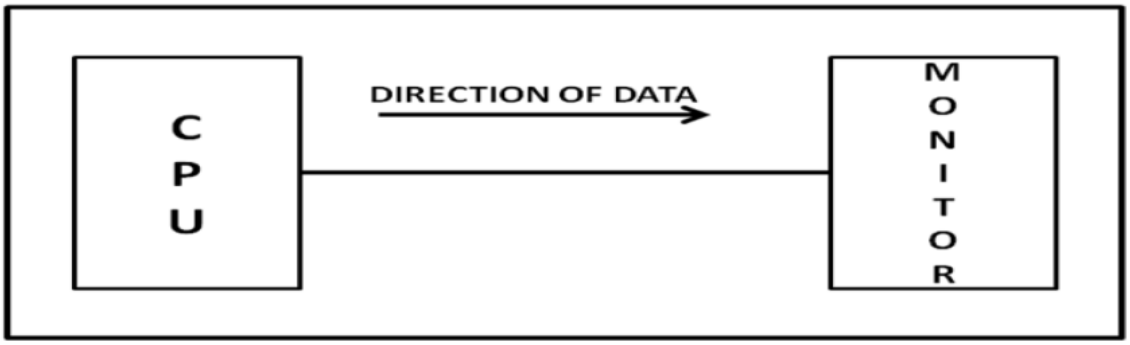
5. Video: Video refers to broadcasting of data in form of picture or movie

1.5 DATA FLOW

Two devices communicate with each other by sending and receiving data. The data can flow between the two devices in the following ways.

1. Simplex
2. Half Duplex
3. Full Duplex

1.5.1 Simplex

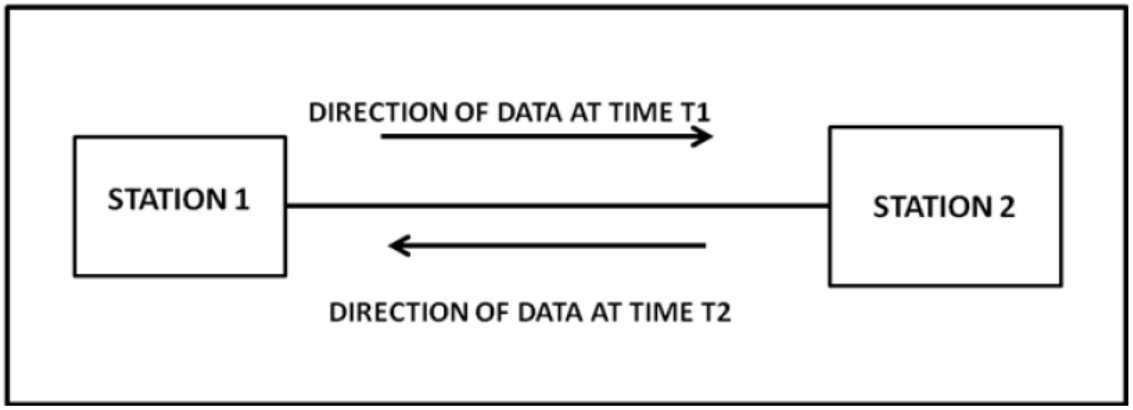


Fig(2): Simplex mode of communication

- **In Simplex**, communication is unidirectional

• Only one of the devices sends the data and the other one only receives the data.
• Example: in the above diagram: a cpu send data while a monitor only receives data.

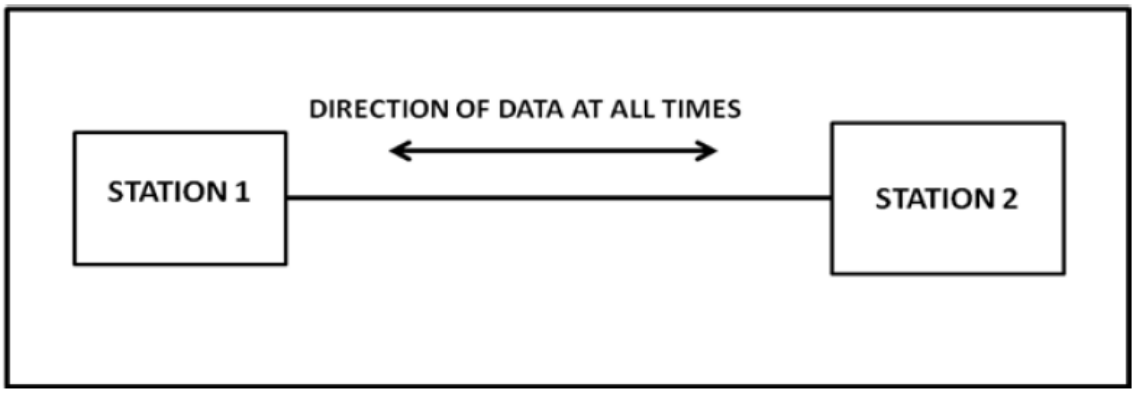
1.5.2 Half Duplex



Fig(3) Half Duplex Mode of Communication

• **In half duplex** both the stations can transmit as well as receive but not at the same time.
• When one device is sending other can only receive and vice-versa (as shown in figure above.)
• Example: A walkie-talkie.

1.5.3 Full Duplex



Fig(4): **Full Duplex**

• **In Full duplex mode**, both stations can transmit and receive at the same time.
• Example: mobile phones

1.6 COMPUTER NETWORK

• Computer Networks are used for data communications
• **Definition:** A computer network can be defined as a collection of nodes. A node can be any device capable of transmitting or receiving data. The communicating nodes have to be connected by communication links.
• A Compute network should ensure
✓ **reliability** of the data communication process
✓ **security** of the data

✓ **performance** by achieving higher throughput and smaller delay times

1.6.1 Categories of Network

Networks are categorized on the basis of their size. The three basic categories of computer networks are:

A. **Local Area Networks (LAN)** is usually limited to a few kilometers of area. It may be privately owned and could be a network inside an office on one of the floor of a building or a LAN could be a network consisting of the computers in a entire building.

B. **Wide Area Network (WAN)** is made of all the networks in a (geographically) large area. The network in the entire state of Maharashtra could be a WAN.

C. **Metropolitan Area Network (MAN)** is of size between LAN & WAN. It is larger than LAN but smaller than WAN. It may comprise the entire network in a city like Mumbai.

1.7 PROTOCOL

- A Protocol is one of the components of a data communications system. Without protocol communication cannot occur. The sending device cannot just send the data and expect the receiving device to receive and further interpret it correctly.
- When the sender sends a message it may consist of text, number, images, etc. which are converted into bits and grouped into blocks to be transmitted and often certain additional information called control information is also added to help the receiver interpret the data.

- For successful communication to occur, the sender and receiver must agree upon certain rules called protocol.
- **A Protocol is defined as a set of rules that governs data communications.**
- A protocol defines what is to be communicated, how it is to be communicated and when it is to be communicated.

1.7.1 Elements of a Protocol

There are three key elements of a protocol:

A. **Syntax:**

- It means the structure or format of the data.
- It is the arrangement of data in a particular order.

B. **Semantics** :

- It tells the meaning of each section of bits and indicates the interpretation of each section.
- It also tells what action/decision is to be taken based on the interpretation.

C. **Timing**

- It tells the sender about the readiness of the receiver to receive the data
- It tells the sender at what rate the data should be sent to the receiver to avoid overwhelming the receiver.

Data Transmission

Analog and Digital Transmission:-

Data can be transmitted either in the form of analog and digital data or analog and digital signal using Analog / Digital Transmission.

Analog Data and Digital Data

Data :- data are raw facts that are meaningless . they are processed to form Information .

Analog Data :-

Data that is continuous and have magnitude directly proportional to the data function is known as analog data . it is generally used to transmit real time data such as audio and video which changes the pattern of signal depending on intensity .

Digital Data :-

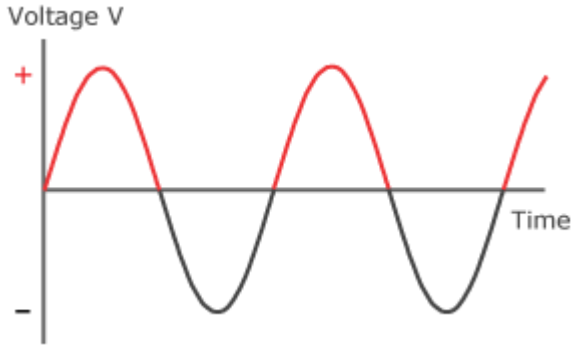
Data that uses discrete or uneven spectrum that if there is no continuity in data , then it is called Digital Data . it is used for transmitting text , integers or string of characters . it can be send , received and recreated no loss of content . data in digital form is represented in the form of binary number 0 and 1 .

Analog Signal and Digital Signal

Signal :- signals are the physical representation of data . data is exchanged in the form of signal through the transmission media . signals can be in the form of electrical impulse , radio wave or electromagnetic waves . signal can either be analog signal or digital signal .

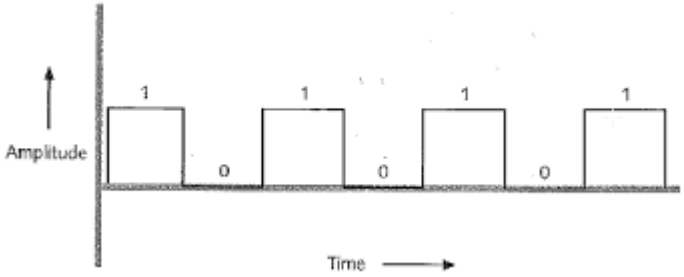
Analog Signal :-

Analog Signal is continuous signal that depends on intensity. Analog Signal is transmitted in the form of electromagnetic waves over the transmission media which is either guided transmission media such as twisted pair , coaxial cable or unguided media that include satellite communication , terrestrial microwave . Analog Signals are easily effected by noise that decrease the resolution of Analog Signal. Analog Signals are represented using sine waves .



Digital Signal:-

Digital Signals are discrete signals that are independent of time and intensity . Digital Signals are transmitted in the form of sequence voltage pulses represented in binary form containing (0,1). Unlike analog signals that changes over a period of time, digital signals remain static and value of signals noted at fixed interval rather than using continuous interval. Digital Signals are not easily affected by an non linearity such as noise. Error in Digital Signal can be detected and corrected which is not possible in analog signals.



Advantages of Digital Signal:-

- Inexpensive than analog signals .
- Digital Signals are not affected or harmed due to noise interference .

Disadvantages of Digital Signal:-

Attenuation impairment is the major Advantages of Digital Signal, due to which the strength of signal is degraded which can result in loss of data at receiving end .

Transmission Link :-

- **Point-to-point link:-** in this link , there will be peer-to-peer connection in which only two devices are present , that share the communication channel .

- **Multipoint Link:-** in this link , there will be more than two devices that shares the communication channel.

Transmission Media :-

It can be broadly classified into two types

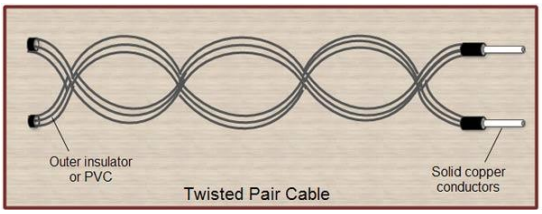
- **Guided Transmission Media:-** in this type of media , a physical path is established between source and destination. The signal or electrical impulse uses this path for transmission which is in the form of electromagnetic waves. Different types of guided Transmission Media are twisted pair, coaxial cable, optical fiber.

- **Unguided Transmission Media:-** in this type of media , there is no physical path between source and destination. this media is also known as wireless Transmission Media which does not guide the waves but provides a method or a way for transmitting them. Waves are propagated through air, vacuum, atmosphere. Different types of unguided Transmission Media are satellite microwave transmission, terrestrial microwave transmission, radio waves transmission and infrared waves.

Types of Guided Transmission Media:-

1- Twisted Pair Cable:-

Twisted Pair Cables are most commonly used guided transmission media. In twisted pair cable, two ordinary copper wires which acts as conductors are twisted around one another, so as to reduce the disturbance caused by electromagnetic waves or due to crosstalk between two adjacent circuits.



Usage of **Twisted Pair Cable:-**

1- Twisted Pair Cables are used both for analog and digital signals transmission.

2- They are generally used in homes and business computers for connecting them to telephone exchange network.

3- Higher grade of twisted wire is used for horizontal wiring in LAN installation.

4- Twisted Pair Cables are used for supporting voice data that is transmitted using analog signals.

Twisted Pair Cables are less expensive than coaxial cable and fiber optics.
There are two types of twisted pair cables.

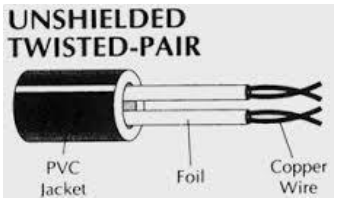
- **Unshielded Twisted Pair (UTP)Cable :-** In UTP , there is no shielding around the twisted pair.UTP are generally used In telephone companies and for computer networking.

Advantages of UTP:-

- It is very easier to work.
- Installation procedure is easy.

Disadvantage of UTP:-

Due to lack of shield UTP is highly susceptible to the electromagnetic interference.



- **Shielded Twisted Pair (STP)Cable :-** In STP there is a tough protected shield over each pair of copper wire that is used to reduce the electromagnetic interference that occurs during transmission.

Advantages of STP:-

Reduces the external interferences.

Disadvantages of STP:-

- Harder to work.
- Expensive when compared to UTP.
-

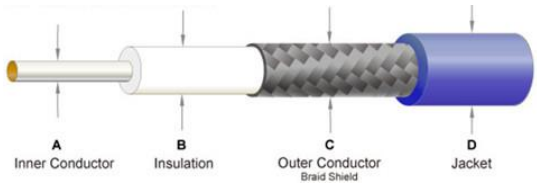
2- Coaxial Cable:-

It is most preferred guided transmission media for transmitting signals. It comprises of two conductors.

- Inner conductor which is surrounded by dielectric system.
- Outer conductor which surrounds the dielectric system.

Outer conductor is covered by protective shield called jacket.

Types of Coaxial Cable:-



1- Flexible coaxial cable.
2- Rigid coaxial cable.

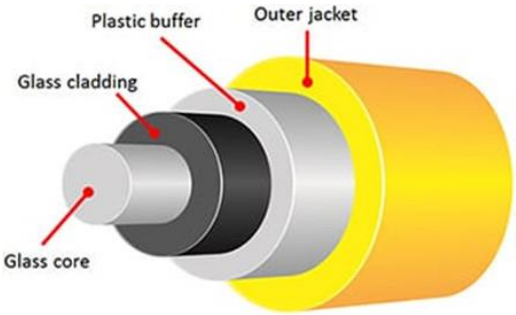
Flexible coaxial cable is most widely used coaxial cable.

Usage of Coaxial Cable:-

- Coaxial cables can be used for both long and short distance transmissions. In longer distance it used for connecting television and radio networks.
- Coaxial cables are used in telephone companies.
- They are used in business, installing Ethernet and other type of LAN.

3- **Fiber Optic Cable :-**

Fiber optics are constructed using plastic or glass fiber which transmit the data through light. It consists of three layers , the first layer is a thin strands of glass called core. The second layer that cover the core is a concentric layer called the cladding. The third layer acts as a protective sheath around cladding called jacket which is made of either glass or plastic.



Usage of Fiber Optics:-

- Because of the flexibility. optical fiber is used in telecommunication networking as well as fiber optics communication.
- Fiber optics are preferred while transmitting data over long distance due to its less susceptibility to attenuation and it requires very few repeaters .
- They are used in applications such as illumination, imaginary and for decorative purposes.

Bandwidth

Mathematically it can be shown that any complex waveform is a made of sine
Wave forms of different amplitudes and frequencies with varying phase relationships
Amongst each other. Look up bandwidth in Wiktionary, the free dictionary.

Bandwidth (signal processing) or analog bandwidth, frequency bandwidth or radio bandwidth: a measure of the width of a range of frequencies, measured in hertz

Bandwidth (computing), the rate of data transfer, bit rate or throughput, measured in bits per second (bit/s)

Noise

In any type of communication, noise is the biggest impairment. The received signal at the receiver end will consist of transmitted message plus additional unwanted signal that are inserted somewhere between transmitter and receiver distorting the message.
There are several types of noise sources, which can abruptly affect the quality of reception signal. The following are some of them

- **Thermal noise:** Due to thermal agitation of electrons. Present in all electronic devices and is the function of temperature.
- **Impulse noise:** Due to electromagnetic interference (EMI). They may be present in power lines, or in nature (lightning.. etc)
- **Delay distortion:** Due to non-uniform velocities of signals of different frequencies traveling in a guided media. Various frequencies of a message signal will arrive at different delays resulting in distortion.

Channel capacity

The maximum rate at which data can be transmitted over a communication channel under given conditions is referred as the channel capacity.
There are four parameters involved in the evaluation of channel capacity.

- **Data rate:** The rate at which data can be transmitted. Measured in bits per second
- **Bandwidth:** The bandwidth of the transmitted signal. Measured in cycles per second (Hz).
- **Noise:** The average level of unwanted signals over communication path. Expressed as the ratio between signal and noise.

• **Error rate:** The rate at which error can occur.
Then the channel capacity (in cycles per second) according to **Shannon's** theorem is given by: **$C = B \log_2 (1+SNR)$** Where
• **C** in Cycles per second and this is error free capacity
• **B** is the bandwidth in Hertz.
• **SNR** = $10 \log_{10}$ (Signal power/Noise power)

Normally this theorem represents maximum channel capacity. Actual values may be much less than as given by the formula. One reason for this is the SNR ratio. The SNR ratio assumes only white noise (thermal noise) where as other noise like impulse noise, attenuation noise and delay noise are not taken into account.

Types of Unguided Transmission Media:-

1- Satellite Microwave Transmission:-

Transmitting data using electro radio waves through free space is called satellite communication. In satellite communications there are many transponders (a device for receiving a radio signal and automatically transmitting a different signal) called frequency band. this type of transmission uses two types of frequencies .uplink frequency and downlink frequency. Satellites can be classified into two types:-

- C-band: the frequency range of C-band satellite is from 3.7 to 4.2 GHz and from 5.9 to 6.4 GHz. C-band are more reliable than Ku-band.
- Ku-band: the frequency range of Ku-band satellite is from 11 to 12 GHz.

Usages of satellite microwave :-

- Distributing signal over television channel.
- Telephone transmission over long distance.
- Networks that are used for private business.

2- Radio wave transmission :-

Its broadcast signals only in single direction which is in contrast with the microwave transmission that broadcast in both directions. One of the advantage of radio wave transmissions is that it does not require any antennas. Radio waves are propagated using ground wave and sky wave. Radio waves performs modulation of electromagnetic waves using the frequency that is below the range of visible light.

Usages of radio microwave:-

- Radio waves are generally used for transmitting sound, images that include both voice signal and television signals. These signals are converted into electrical signals by performing modulation, the modulated signals are amplified and

transmitted to antennas that converts the electrical signals to electromagnetic signals that are used for radiation into ionosphere.

- Radio waves are used for directing the movement of ships and aircraft with the help of radio compass or radio time signals.

3- Terrestrial microwave transmission :-

Microwave transmission make use of microwave link for transmitting information. Terrestrial microwave use large height antennas to cover long sight distances. It is more suitable for line-of-sight transmission link.

Usages of Terrestrial microwave transmission:-

- Microwave relay links are used for television and telephone transmission.
- Microwave act as a backbone carrier in cellular network.
- They are used both for larger heave telecommunication services as well as short heave by-pass applications.

4- Infrared wave transmission:-

Infrared waves are electromagnetic waves that have the wavelength longer than visible light but shorter than radio wave. One of the advantage of infrared waves over other unguided media is that it cannot pass through walls due to which the security is more and the impairment such as interference is not present.

Modes of transmission

When we talk of data communication we are primarily concerned with serial transmission although other types of transmission does exists. In serial transmission the data is transmitted bit by bit as a stream of 0s and 1s. **Protocols** are implemented for these types of transmissions so that the communication takes place in a well-defined manner. Protocols are mutually agreed set of rules and are necessary because the format of transmission should be understood by the receiver
The following key factors have to be observed regarding serial transmission:

• **Timing problem:** There should be some mechanism to know when the bit has arrived and at what rate the next bit is going to arrive at the serial input terminal of the receiver. We will see this can be accomplished in two ways.

• **Error detection:** Provision should be made (during transmission itself) to verify the integrity of the received data. Like parity, checksum bits.

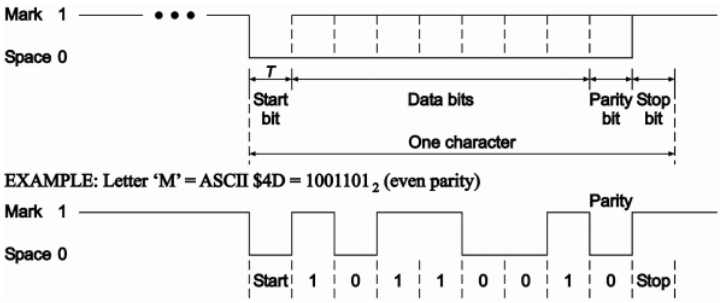
• **Error correction:** Ability to correct the data in case of corrupted data reception.
Timing problems require a mechanism to synchronize the transmitter and receiver. There are two approaches regarding transmission of serial data.

- **Asynchronous transmission**
- **Synchronous transmission**

1. Asynchronous transmission

Asynchronous transmission is a type of transmission mode in which data is transmitted along with start and stop bits to indicate beginning and end of data. Also The data is send one character or bit at a time i.e. , each character act as individual unit. It make use of two additional bits called stare and stop bit, where binary '0' is used to represent start bit and binary '1' is used to represent stop bit.

The most common usage of asynchronous transmission is seen in land line communication system. In order to ensure accuracy, parity bit may also be included in the data that is being transmitted. Start and stop bits provide synchronization by indicating when the data character have been sent or received. Timing for each character in data stream is initiated with start bit and ends with stop bit. It is also possible for gaps or spaces to exist in the data stream.



Asynchronous transmission

Advantage :-

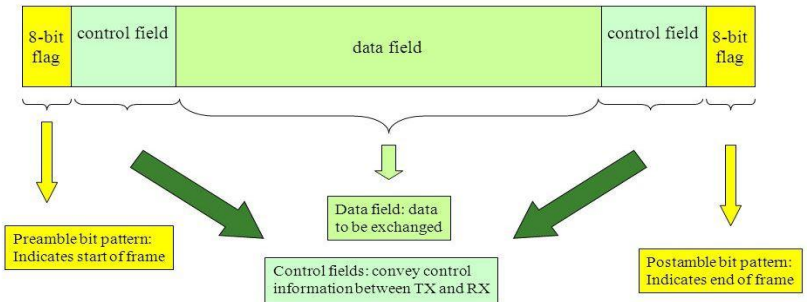
- Asynchronous transmission is cheap and effective.
- It is used for low-speed transmission.

Disadvantage:-

- It require more overhead of 2 to 3 bits/character.
- Its efficiency is less when compared to synchronous transmission.

2. Synchronous transmission

Synchronous transmission refers to continuous and consistent time transfer of data blocks. Here data is transmitted at regular intervals. Asynchronous transmission doesn't use start and end bits but synchronizes the speed of transmission at both sender receiving end using clock signals.However,synchronization using clock signal is suitable over shorter distance but not for longer because these clock signals are more susceptible to impairments, due to which more errors are generated. This problem can be solved by resynchronization of clocks and through the use of check digits that ensure that byte is correctly interpreted and received.



frame format of synchronous transmission

Advantage:-

- The timing information is accurately maintained at receiver end that allow higher data rate operations.
- Synchronous character transmission is more efficient than asynchronous character transmission.

Disadvantage:-

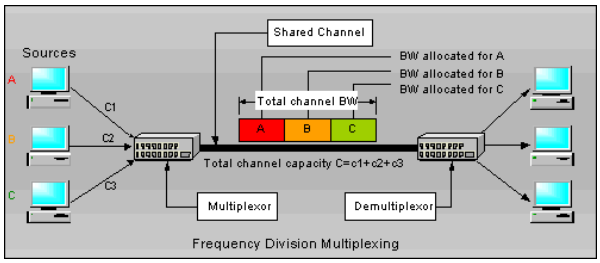
- It requires a complex design of interface.

Multiplexing

By Multiplexing different message signals can share a single transmission media (The media can be guided or unguided). All they need is they should either differ in their frequency slot or wavelength slot or in time slot.

1. **Frequency domain multiplexing (FDM)**

   In this each message signal is modulated by different radio frequency signals called RF carriers. At the receiving end filters are used to separate the individual message signals. Then they are demodulated (removing the RF carrier) to retrieve back the original messages.

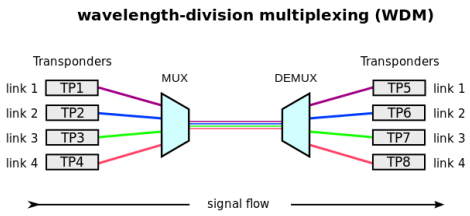


The Radio /TV broadcasting are the best examples for frequency domain multiplexing. Several individual stations broadcast their programs in their own allotted frequency band sharing the same unguided media. The receiver tunes his set according to his choice. The cable TV network is another example of Frequency domain multiplexing employing guided media.

2. **Wavelength division multiplexing (WDM)**

   Wavelength division multiplexing is a type of FDM scheme used in fiber optical communications where various wavelengths of infrared light are combined over strands of fiber.

   Optical communication with few exceptions are digital since light transmitters and receivers are usually poorly suited for analog modulation.

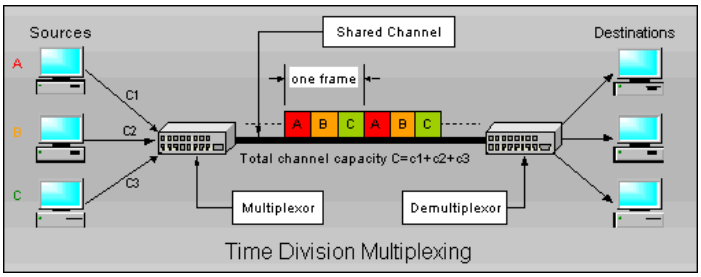


3. Time domain multiplexing (TDM)

A type of multiplexing where two or more channels of information are transmitted over the same media by allocating a different time interval ("slot" or "slice") for the transmission of each channel. The channels take turns to use the media. Some kind of periodic synchronizing signal or distinguishing identifier is usually required so that the receiver can tell which channel is which.

A typical practical setup combines a set of low-bit-rate streams, each with a fixed and pre-defined bit rate, into a single high-speed bit stream that can be transmitted over a single channel.

The main reason to use TDM is to take advantage of existing transmission lines. It would be very expensive if each low-bit-rate stream were assigned a costly physical channel (say, an entire fiber optic line) that extended over a long distance.



Network Topology

The topology defines how the devices (computers, printers..etc) are connected and how the data flows from one device to another. There are two conventions while representing the topologies. The physical topology defines how the devices are physically wired. The logical topology defines how the data flows from one device to another. **Broadly categorized into**

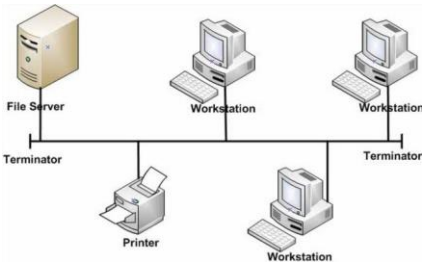
- Bus
- Ring
- Star
- Mesh
- Tree
- hybrid

1. Bus topology:

In a bus topology all devices are connected to the transmission medium as backbone. There must be a terminator at each end of the bus to avoid signal reflections, which may distort the original signal. Signal is sent in both directions, but

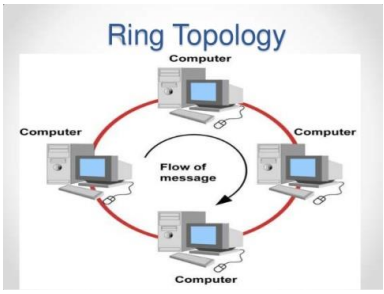
some buses are unidirectional. Good for small networks. Can be used for 10BASE5 (thick net), 10BASE2(thin net) or 10BROAD36 (broad band) co-axial bus standards.

The main problem with the bus topology is failure of the medium will seriously affect the whole network. Any small break in the media the signal will reflect back and cause errors. The whole network must be shut down and repaired. In such situations it is difficult to troubleshoot and locate where the break in the cable is or which machine is causing the fault; when one device fails the rest of the LAN fails.



2. Ring Topology

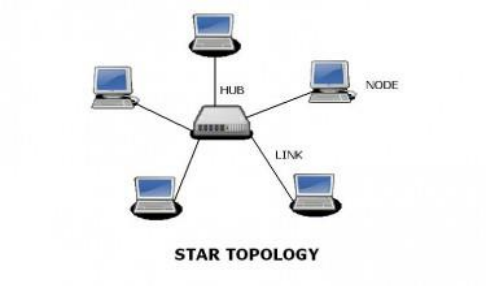
Ring topology was in the beginning of LAN area. In a ring topology, each system is connected to the next as shown in the following picture.



Each device has a transceiver which behaves like a repeater which moves the signal around the ring; ideal for token passing access methods.
In this topology signal degeneration is low; only the device that holds the token can transmit which reduces collisions. If you see its negative aspect it is difficult to locate a problem cable segment; expensive hardware.

3. Star topology

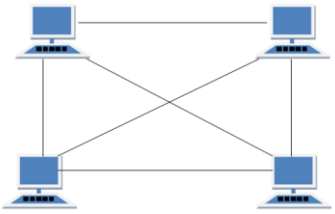
In a star topology each station is connected to a central node. The central node can be either a hub or a switch. The star topology does not have the problem as seen in bus topology. The failure of a media does not affect the entire network. Other stations can continue to operate until the damaged segment is repaired.



Commonly used for 10BASE5, 10BASE-T or 100BASE-TX types.
The advantages are cabling is inexpensive, easy to wire, more reliable and easier to manage because of the use of hubs which allow defective cable segments to be routed around; locating and repairing bad cables is easier because of the concentrators; network growth is easier.
The disadvantages are all nodes receive the same signal therefore dividing bandwidth; Maximum computers are 1,024 on a LAN.
Maximum UTP (Un shielded twisted pair) length is 100 meters; distance between computers is 2.5 meters.

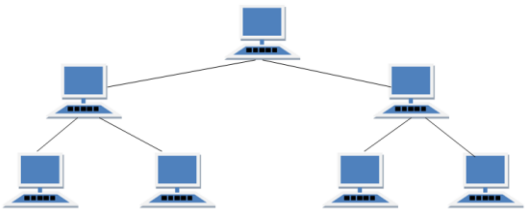
4. Mesh topology

A mesh physical topology is when every device on the network is connected to every device on the network; most commonly used in WAN configurations Helps find the quickest route on the network; provides redundancy. Very expensive and not easy to set up.



5. Tree topology

It is a hierarchy of a various hubs. All the nodes are connected to one hub or the other. There is a central hub to which only a few nodes are connected directly.
The central hub, also called active hub, looks at the incoming bits and regenerates them so that they can traverse over longer distances. The secondary hubs in tree topology may be active or passive hubs. The failure of a transmission line separates a node from the network.



6. Hybrid topology

It is formed by connecting two or more topologies together for example, hybrid topology can be created by using the bus, star and ring topologies.