University of Technology
الجامعة التكنولوجية

Computer Science Department
قسم علوم الحاسوب

Computer Network 1
شبكات الحاسوب 1

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Data Communications and Networking

NETWORKING FUNDAMENTALS

Unit Structure

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1.0 OBJECTIVES:

- Introduce the readers to data communication and its fundamentals
- Define networks.
- Define protocols .
- Standards in networking.
- Network topology.
- Transmissions Media

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.

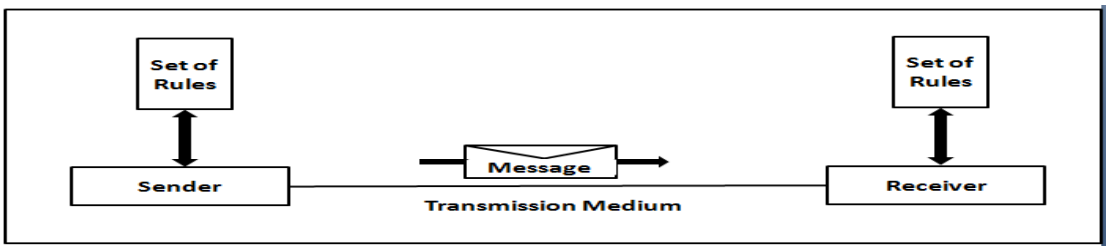
1.3.1 Characteristics of Data Communication

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

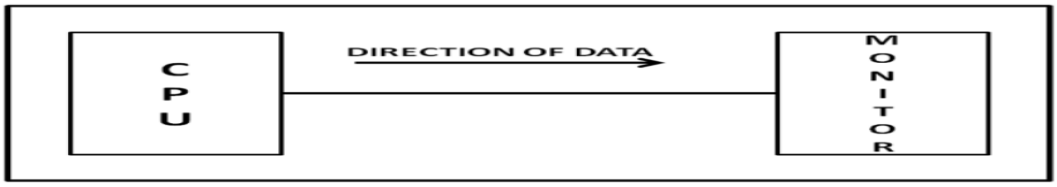
4. **Audio:** Data can also be in the form of sound which can be recorded and broadcasted. Example: What we hear on the radio is a source of data or information.
   Audio data is continuous, not discrete.
5. **Video: Video** refers to broadcasting of data in form of picture or movie

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

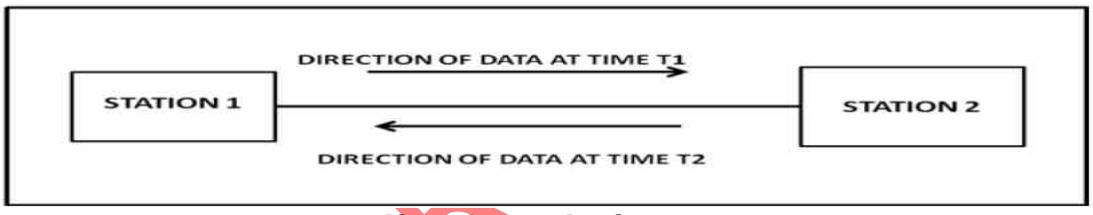
1.5.1 Simplex



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.

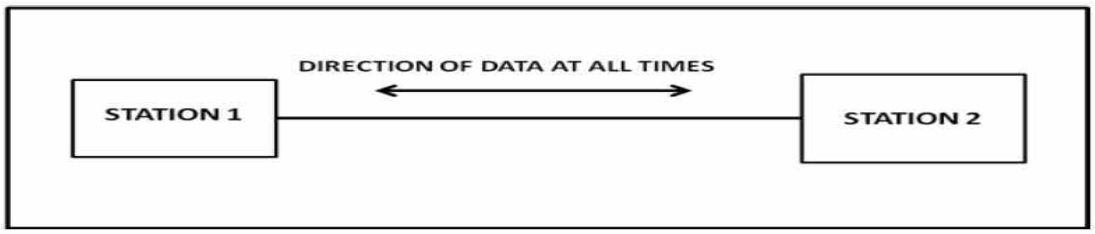
1.5.2 Half Duplex



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.

1.7 STANDARDS IN NETWORKING

- Standards are necessary in networking to ensure interconnectivity and interoperability between various networking hardware and software components.
- Without standards we would have proprietary products creating isolated islands of users which cannot interconnect.

1.7.1 Concept of Standard

- Standards provide guidelines to product manufacturers and vendors to ensure national and international interconnectivity.
- Data communications standards are classified into two categories:

1. De facto Standard

- These are the standards that have been traditionally used and mean **by fact** or **by convention.**
- These standards are not approved by any organized body but are adopted by widespread use.

2. De jure standard

- It means by **law** or **by regulation.**
  - These standards are legislated and approved by a body that is officially recognized.

1.7.2 Standard Organizations in field of Networking

- Standards are created by standards creation committees, forums, and government regulatory agencies.
- **Examples of Standard Creation Committees** :
  1. International Organization for Standardization(ISO)
  2. International Telecommunications Union Telecommunications Standard (ITU-T)
  3. American National Standards Institute (ANSI)
  4. Institute of Electrical & Electronics Engineers (IEEE)
  5. Electronic Industries Associates (EIA)

o **Examples of Forums**

1. ATM Forum
2. MPLS Forum
3. Frame Relay Forum

Examples of Regulatory Agencies:

1. Federal Communications Committee (FCC)

1.9 REFERENCES

1. Data Communication & Networking – Behrouz Forouzan

2. Data Communications (More Details)

1.1 Data Communication Model
1.2 Signal Conversions
1.3 Analog signal
1.4 Waveforms of different parameters
1.5 Bandwidth
1.6 Noise
1.7 Channel Capacity
1.8 Types Of Communications
1.9 Modes of transmission
1.10 Multiplexing
1.11 Network Models

1. Data Communications

Communication is defined as transfer of information, such as thoughts and messages between two entities. The invention of telegraph, radio, telephone, and television made possible instantaneous communication over long distances.

In the context of computers and information technology (IT), the data are represented by **bi**nary digi**t** or **bit** has only two values 0s and 1s. In fact anything the computer deals with are 0s and 1s only. Due to this it is called discrete or digital. In the digital world messages, thoughts, numbers.. etc can be represented in different streams of 0s and 1s.

Data communications concerns itself with the transmission (sending and receiving) of information between two locations by means of electrical signals. The two types of electrical signals are analog and digital. Data communication is the name given to the communication where exchange of information takes place in the form of 0s and 1s over some kind of media such as wire or wireless. The subject-Data Communications deals with the technology, tools, products and equipment to make this happen.

Entire data communication system revolves around three fundamental concepts.

- **Destiny:** The system should transmit the message to the correct intended destination. The destination can be another user or another computer.
- **Reliability:** The system should deliver the data to the destiny faithfully. Any unwanted signals (noise) added along with the original data may play havoc!
- **Fast:** The system should transmit the data as fast as possible within the technological constraints. In case of audio and video data they must be received in the same order as they are produced without adding any significant delays.

1.1 Data Communication model

The figure 1.1(a) shows the block diagram of a typical communication model. The communication model has five sub systems viz., user, transmitter, communication channel, receiver and destiny.

- **User:** There will be a source that generates the message and a transducer that converts the message into an electrical signal. The source can be a person in front of a microphone or a computer itself sending a file. The user terminal is known as Data Terminal Equipment (DTE).
- **Transmitter:** Can be a radio frequency modulator combining the signal coming out of the data equipment terminal. Here the radio frequency is acting as the carrier for the data signal. Or in case of direct digital transmission the transmitter can be Manchester encoder transmitting digital signals directly.
- **Communication channel: C**an be **guided media** (twisted pair, coaxial cable, fiber optic.) or **unguided media** (air, water .,). In both the cases communication is in the form of electromagnetic waves. With guided media the electromagnetic waves are guided along a physical path. **Unguided media** also called wireless the transmitting electromagnetic waves are not guided along with a physical path. They are radiated through air/vacuum/water., etc.
- **Receiver:** The receiver amplifies the received signals removes any unwanted signals (noise) introduced by the communication channel during propagation of the signal and feeds to the destiny.
- **Destiny:** The user at the other end finally receives the message through the data terminal equipment stationed at the other side.

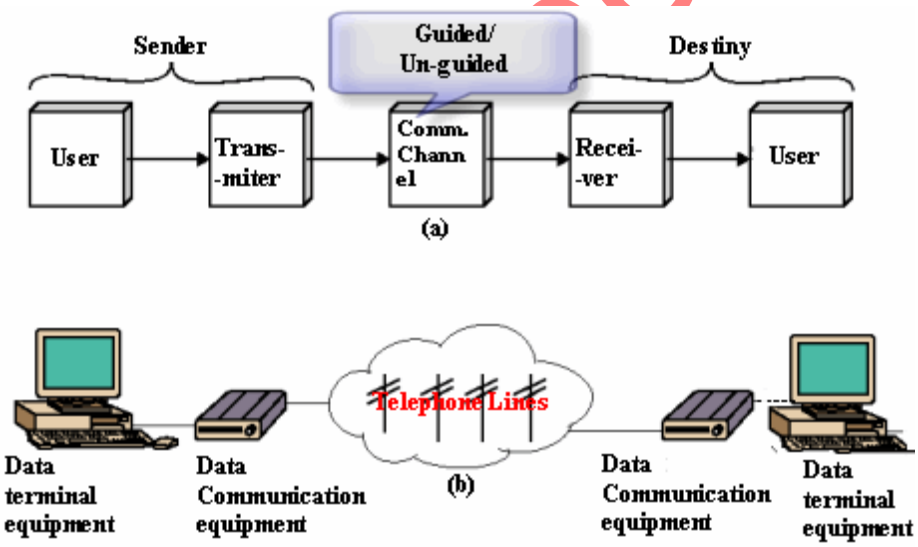


Fig 1.1 (a) The block diagram of a data communication model
(b) A typical dial-up network

Fig 1.1 (b) shows a typical dial-up network setup. The Data Communication Equipment (DCE) at the transmitting end converts the digital signals into audio tones (modulation) so that the voice grade telephone lines can be used as guided media during transmission. At the far end the receiving audio tones, they are converted back to digital signals (Demodulation) by the *data communication equipment* (DCE) and fed to the far end data terminal equipment (DTE).

1.2 Signal conversions

There are two types of signals analog and digital. All naturally available signals are analog in nature. In data communications these signals are converted into digital form by means of A-to-D converters (analog to digital converters).

==========Sheet N0. One==========

The following figure illustrates the analog output of microphone and subsequent conversion into its digital counter part by A-to-D converter.

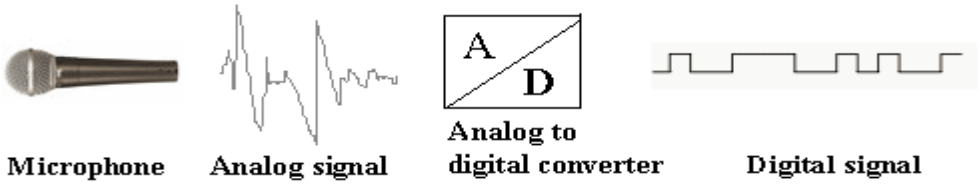


Fig 1.2.1 Example of analog and digital signal

1.3 Analog signal.

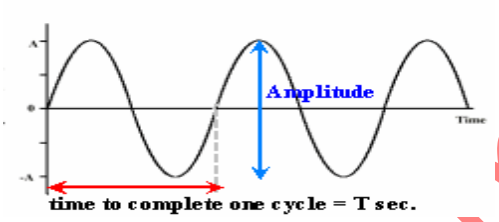


Fig 1.3.1 A simple sine wave and its parameters.

The sine wave is the simplest form of an analog signal. ***It has three parameters.*** Amplitude, frequency and phase. Normally amplitude in volts is denoted on Y-axis and time period is on X-axis. The time taken to complete one cycle is called time period and measured in seconds.
The reciprocal of time period is frequency and its unit is cycles per second(c/s) or Hz (Hertz).(See Fig.1.2).

1.4 Wave forms of different parameters

The following figures show the signals with different parameters and their inter-relationship

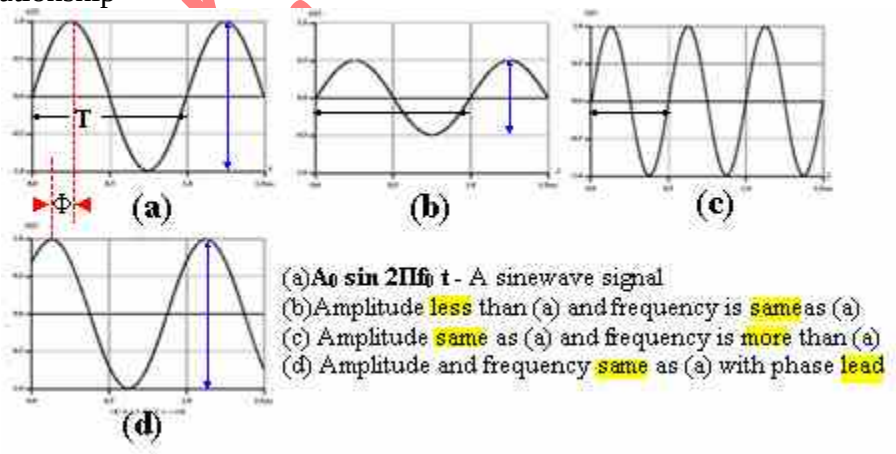


Fig 1.4.1 Different wave forms with different parameters

1.5 Bandwidth

Mathematically it can be shown that any complex waveform is a made of sine waveforms of different amplitudes and frequencies with varying phase relationships amongst each other.

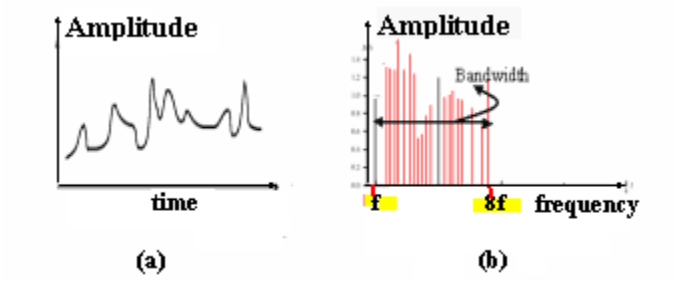


Fig 1.5.1 (a) An analog signal(b) Its various frequency components.

In the above figure the analog signal in fig 1.5(a) has several frequency components of different amplitude as shown in fig 1.5(b). Thus the analog signal encompasses a wide range of frequency spectrum. In analog systems the difference between highest frequency to lowest frequency component is called **bandwidth** (here it is 8f~f = 7f).

Bandwidth merely(مجرد) specifies a range of frequencies, from the lowest to the highest, that the channel can carry or that are present in the signal. It is one way of describing the maximum amount of information that the channel can carry.

Bandwidth is expressed differently for analog and digital circuits. In analog technology, the bandwidth of a circuit is the difference between the lowest and highest frequencies that can pass through the channel. Engineers measure analog bandwidth in kilohertz or megahertz.

Rate of transmission = (bits per second)

1kbps = 1000bps
1Mbps = 10^6 bps
1Gbps = 10^9 bps

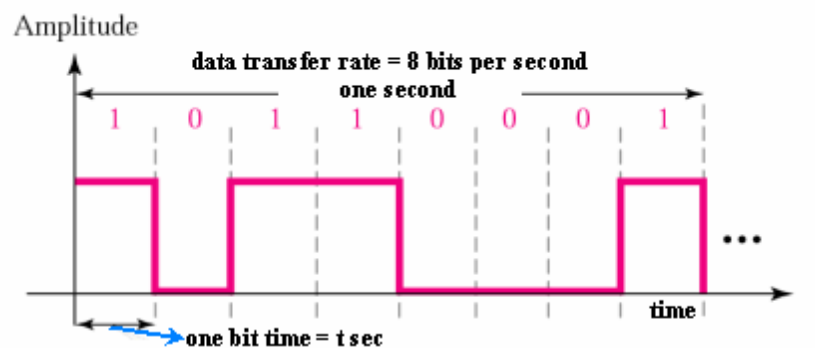


Fig 1.5.2 Relation between bit time and rate

In data communication, the bandwidth is the amount of information that can pass through the channel or medium. Engineers measure digital bandwidth in bits, kilobits, or megabits per second. The kilohertz of an analog bandwidth and the kilobits per second of digital bandwidth for the same circuit are not necessarily the same and often differ greatly.

In principle digital signals require a large bandwidth (theoretically infinite!). The medium has to be of better quality to send digital signals.
Most LANs use Manchester encoding because of its self-synchronizing property. Otherwise separate clock signals were to be transmitted along with data in order to

inform about sender's transmission clock. In Manchester encoding there is a transition in each bit interval and this property serves as clock also.

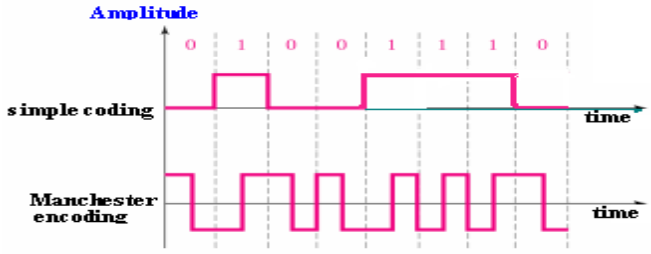


Fig 1.5.3 Manchester encoding

1.6 Noise

In any type of communication, noise is the biggest impairment (ضعف,اختلال). 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 (بشكل مفاجئ) affect the quality of reception signal. The following are some of them

- **Thermal noise:** Due to thermal agitation(هياج) 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(سرع) of signals of different frequencies traveling in a guided media. Various frequencies of a message signal will arrive at different delays resulting in distortion.

1.7 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.

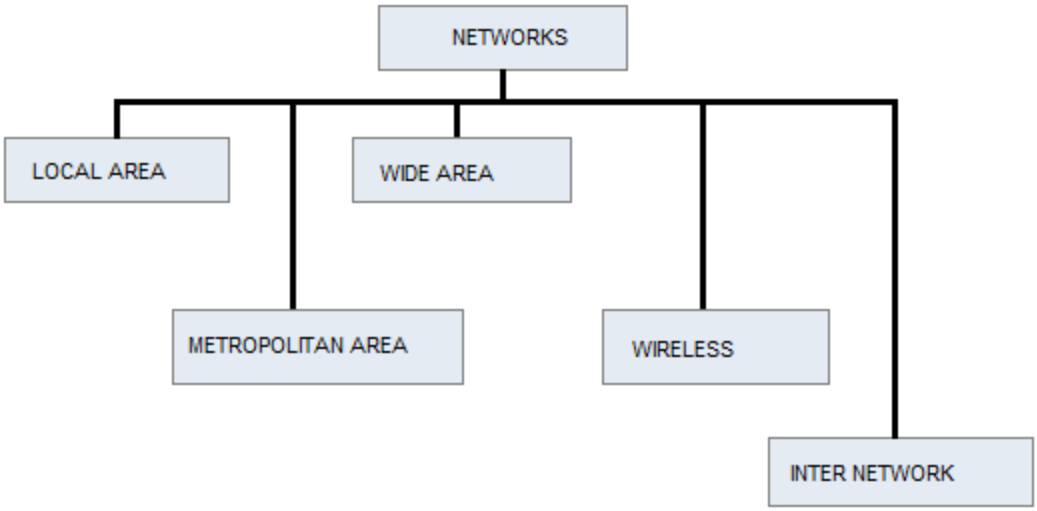
Then the channel capacity
(in cycles per second) according to **Shannon's** theorem is given by:

$$\mathbf{C = B \log_2 (1+SNR)}$$

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.

3. Types of Communication Networks

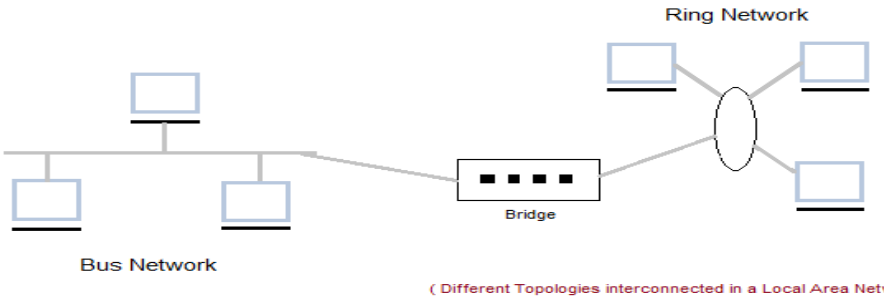


1.Local Area Network (LAN)

It is also called LAN and designed for small physical areas such as an office, group of buildings or a factory. LANs are used widely as it is easy to design and to troubleshoot. Personal computers and workstations are connected to each other through LANs. We can use different types of topologies through LAN, these are Star, Ring, Bus, Tree etc.

LAN can be a simple network like connecting two computers, to share files and network among each other while it can also be as complex as interconnecting an entire building.

LAN networks are also widely used to share resources like printers, shared hard-drive etc.



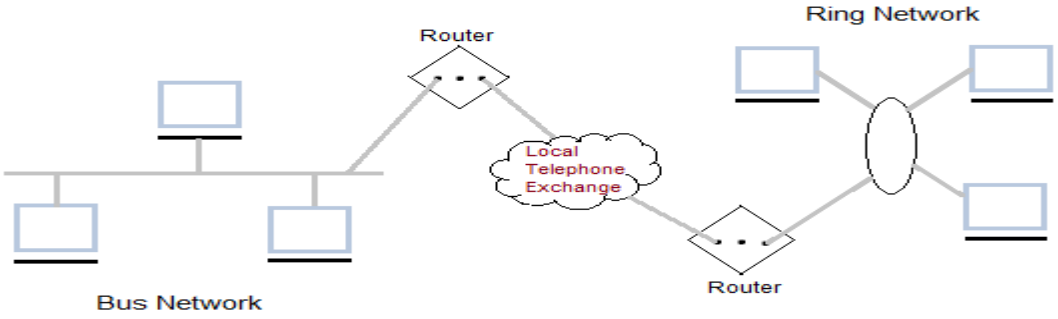
(Different Topologies interconnected in a Local Area Network)

3.1Applications of LAN

- One of the computer in a network can become a server serving all the remaining computers called clients. Software can be stored on the server and it can be used by the remaining clients.
- Connecting Locally all the workstations in a building to let them communicate with each other locally without any internet access.
- Sharing common resources like printers etc are some common applications of LAN.

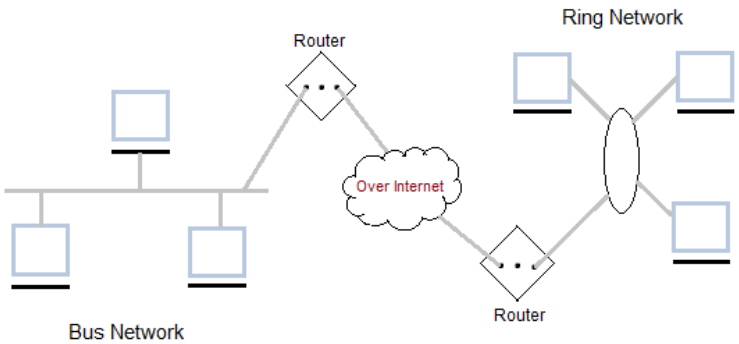
2.Metropolitan Area Network (MAN)

It is basically a bigger version of LAN. It is also called MAN and uses the similar technology as LAN. It is designed to extend over the entire city. It can be means to connecting a number of LANs into a larger network or it can be a single cable. It is mainly hold and operated by single private company or a public company.



3.Wide Area Network (WAN)

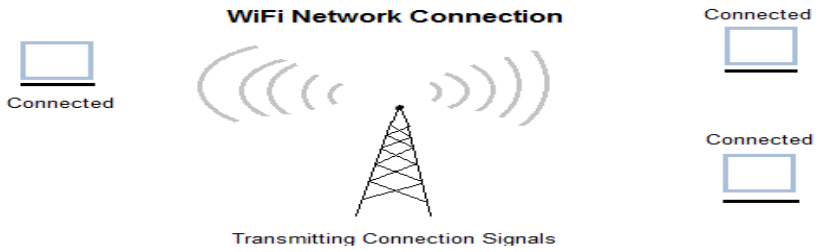
It is also called WAN. WAN can be private or it can be public leased network. It is used for the network that covers large distance such as cover states of a country. It is not easy to design and maintain. Communication medium used by WAN are PSTN or Satellite links. WAN operates on low data rates.



4.Wireless Network

It is the fastest growing segment of computer. They are becoming very important in our daily life because wind connections are not possible in cars or aeroplane. We can access Internet at any place avoiding wire related troubles. These can be used also

when the telephone systems gets destroyed due to some calamity/disaster. WANs are really important now-a-days.



5.Inter Network(InterNet)

When we connect two or more networks then they are called internetwork or internet. We can join two or more individual networks to form an internetwork through devices like routers gateways or bridges.

1.8 Types of communication

Based on the requirements, the communications can be of different types:

- **Point- to-point communication:** In this type, communication takes place between two end points. For instance, in the case of voice communication using telephones, there is one calling party and one called party. Hence the communication is point-to-point.
- **Point-to-multipoint communication:** In this type of communication, there is one sender and multiple recipients. For example, in voice conferencing, one person will be talking but many others can listen. The message from the sender has to be *multicast* to many others. Location from which information is sent to many recipients, as in the case of audio or video broadcasting. In a broadcasting system, the listeners are passive, and there is no reverse communication path.
- **Simplex communication:** In simplex communication, communication is possible only in one direction. There is one sender and one receiver; the sender and receiver cannot change roles.
- **Half-duplex communication:** Half-duplex communication is possible in both directions between two entities (computers or persons), but one at a time. A walkie-talkie uses this approach. The person who wants to talk presses a talk button on his handset to start talking, and the other person's handset will be in receive mode. When the sender finishes, he terminates it with an over message. The other person can press the talk button and start talking. These types of systems require limited channel bandwidth, so they are low cost systems.
- **Full-duplex communication:** In a full-duplex communication system, the two parties the caller and the called can communicate simultaneously, as in a telephone system. However, note that the communication system allows simultaneous transmission of data, but when two persons talk simultaneously, there is no effective communication! The ability of the communication system to transport data in both directions defines the system as full duplex.

Depending on the type of information transmitted, we have voice communication, data communication, fax communication, and video communication systems. When various types of information are clubbed together, we talk of multimedia communications. Even a few years ago, different information media such as voice, data, video, etc. were transmitted separately by using their own respective methods of transmission. With the advent of digital communication and "convergence technologies," this distinction is slowly disappearing, and multimedia communication is becoming the order of the day.

1.9 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(تبادليا) agreed set of(متفق عليه) 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**

1.9.1 Asynchronous transmission

In asynchronous transmission data is transferred character by character and each character (frame by frame i.e. each character is an asynchronous frame in asynchronous transmission) and can be 5 to 8 bits long. The term "Asynchronous" means it is asynchronous at frame level. The bits are still synchronized at bit level during reception.

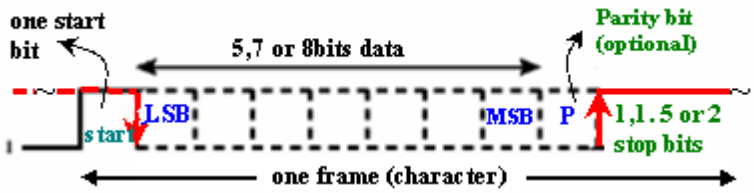


Fig 1.9.1 Asynchronous data format

- In a steady stream, interval between characters is uniform (length of stop element can be 1,1.5 or 2 stop bits - as programmed earlier)
- In idle state, receiver looks for transition 1 to 0 (start signal)
- Then samples next five, seven or eight intervals (as programmed earlier) Timing only needs maintaining within each frame (bit level).
- Looks for parity (if programmed earlier)
- Then looks for next 1 to 0 for next frame
- Simple
- Cheap. Minimum hardware & software requirement to impliment.
- Overhead of 2 or 3 bits per frame (~20%)
- Good for data with large gaps in between each frame (keyboard, low speed data..)

1.9.2 Synchronous transmission

In Synchronous transmission a block of data in the form of bits stream is transferred without start / stop bits. The block can be of any arbitrary length. In order to establish synchronization with remote computer the transmitter transmits synch pulses initially. When the receiver locks to the transmitter's clock frequency a block of data gets transmitted. See fig.1.9.2

The Characteristics are as follows

- Block of data transmitted without start or stop bits
- Initially synch pulses are transmitted (Clocks must be synchronized)
- Can use separate clock line (In that case synch pulses are not needed!)
- Good over short distances
- Subject to impairments
- Embed clock signal in data (Manchester encoding)
- Carrier frequency (analog) is used
- Need to indicate start and end of block
- Use preamble and post amble (to leave sufficient space between blocks)
- More efficient (lower overhead) than asynchronous transmission.

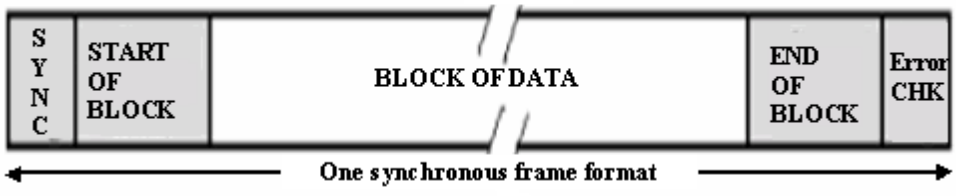


Fig 1.9.2 The synchronous frame format

1.10 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.

1.10.1 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.

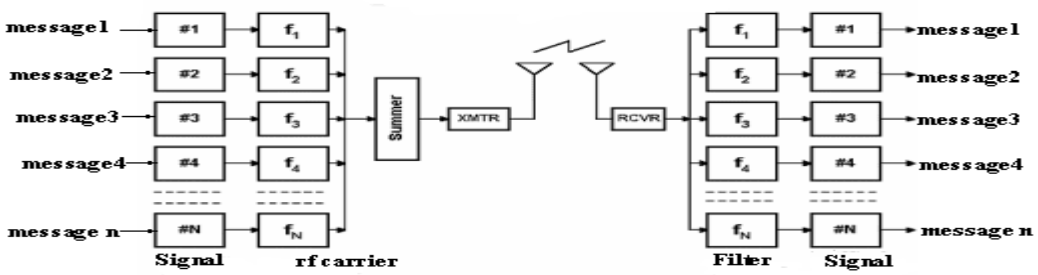


Fig 1.10.1 Frequency domain multiplexing

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.

1.10.2 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.

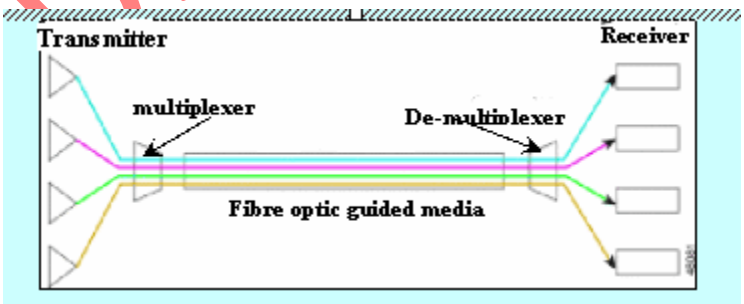


Fig 1.10.2 A Typical wavelength division multiplexer

1.10.3 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.

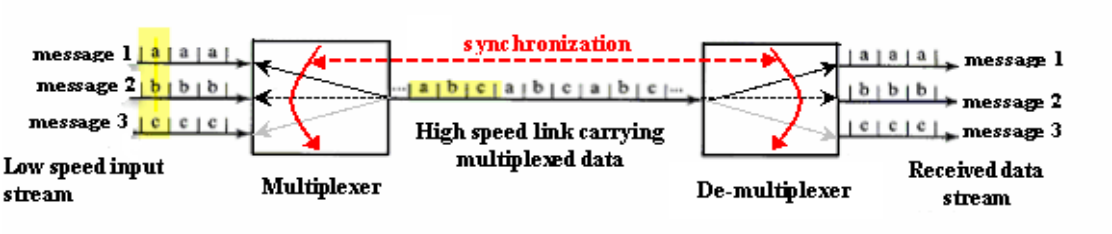


Fig. 1.10.3 Time division multiplexing.

1.11 Network Models

When people to people, machines to machines started communicating with each other the networking technology started picking up. Different vendors started manufacturing their proprietary configurations. In order to communicate systems with heterogeneous configurations there was a need for standardization.

TCP/IP(Transmission Control Protocol / Internet Protocol) is the oldest one and has become defacto standard for all networks. OSI model is much more refined and let us hope all future models will be based on this.

Especially in data communications the way data traverses from the user to the destiny is a complex task that can be broken into several sub tasks, built one over the other like layers. Each layer takes input from the upper layer, performs its duty and hands over to the lower layer.

Several models were suggested out of which the Internet model is widely accepted. Later OSI (open systems interconnection) was developed as a theoretical model. Studying OSI model gives better perception of the various intricacies involved in data communication and networking.

1.11.1 The OSI Model

It has seven layers. They are separate but related. Each layer has well defined tasks and provides services to the corresponding lower layer while in transmission. In receiving mode the lower layer provides the necessary services to the upper layer.
Any changes in one layer should not require changes in other layers.
This kind of standardization allows communication across all types of computers.

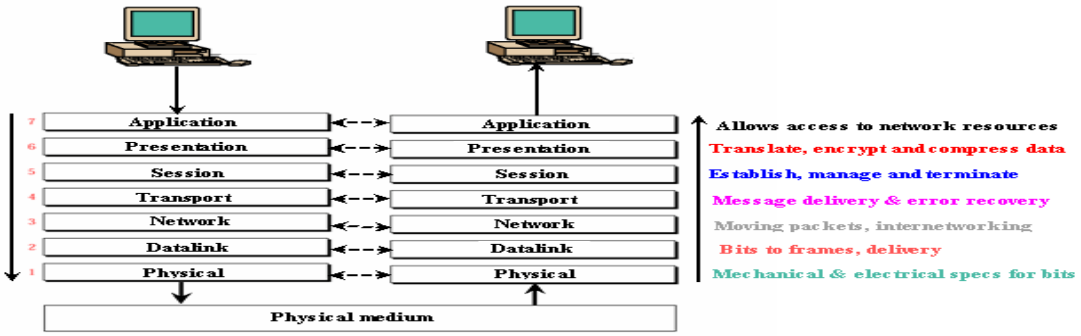


Fig 1.11.1 The OSI Layers and their functions

==========Sheet N0. One==========

Easy to remember these layers!……
Please **D**o **N**ot **T**ouch **S**hiva's **P**et **A**lligator

The Seven Layers of OSI and their conceptual services -

- **Application - (layer 7)** Allows applications to use the network. The user may want to access the network for various purposes. Like for sending e-mail, transferring a file, surfing the web, accessing remote computer's resources etc.. For every task mentioned above there is a dedicated service.

Services – e-mail, news groups, web applications, file transfer, remote host, directory services, network management, file services

- **Presentation - (layer 6)** Translates data into a form usable by the application layer. The redirector operates here. Responsible for protocol conversion, translating and encrypting data, and managing data compression. Messages are sent between layers

Services – POP, SMTP (e-mail, Post office protocol, Simple Mail Transfer Protocol), Usenet (for news groups), HTTP (hypertext transfer protocol for web applications), FTP, TFTP (File transfer protocol, trivial FTP for file transfer), Telnet (Terminal Network,
A general purpose program enabling remote login into some other computer and function as if it is directly connected to that remote computer), Domain name server (finding ip addresses for domain names), SNMP (Simple Network Management Protocol).

- **Session - (layer 5)** Allows applications on connecting systems to standard ports & establish a session. Provides synchronization between communicating computers. Messages are sent between layers

Services – Various port numbers are POP(25), USENET(532), HTTP(80), FTP(20/21), Telnet(23), DNS(53), SNMP(161/162) etc..

- **Transport - (layer 4)** Responsible for packet handling. Ensures error-free delivery. Repackages messages (while receiving), divides messages into smaller packets (while transmitting), and handles error handling. segments of message fragments are sent between layers

Services - TCP - connection-oriented communication for applications to ensure error free delivery;
UDP - connectionless communications and does not guarantee packet delivery between transfer points

- **Network - (layer 3)** Translates system names into addresses. Responsible for addressing, determining routes for sending, managing network traffic problems, packet switching, routing, data congestion, and reassembling data. Datagrams are sent between layers.

Services - Software & hardware addresses and packet routing between hosts and networks (IP). Two versions IP4(32 bits) & IP6(128 bits)

- **Data link - (layer 2)** Sends data from network layer to physical layer. Manages physical layer communications between connecting systems. Data frames are sent between layers

Services – SLIP/PPP, 802.2 SNAP, Ethernet

- **Physical - (layer 1)** Transmits data over a physical medium. Defines cables, cards, and physical aspects. Data bits are sent.

Services - ISDN, ADSL, ATM, FDDI, CAT 1-5, Coaxial cable

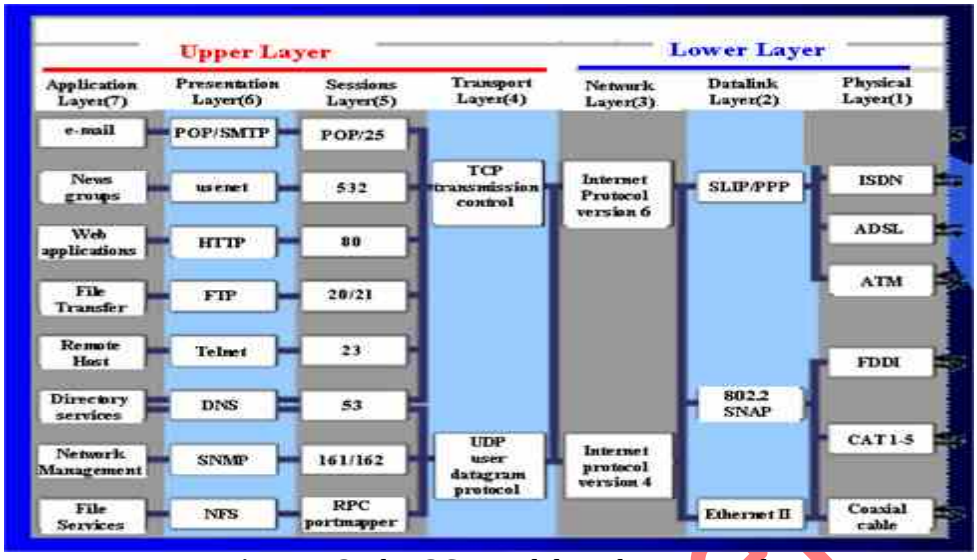


Fig 1.11.2 The OSI Model an their example services

1.11.2 The Internet model

There are four layers in this model. They are:

I) Application Layer
II) Transport Layer
III) Network Layer
IV) IV) Data Link
V) & Physical Layer.

1. **Application Layer:** Most of the responsibilities of the three top most layers of OSI model are in application layer of Internet model. The services are as depicted in the fig(1.14).
2. **Transport Layer:** It has two protocols. TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). TCP is a reliable protocol that allows two application layers to converse with (التحدث مع) each other. While transmitting it divides the stream of characters into manageable segments. While receiving it creates stream of characters for application layer from received segments from network layer. Its function is much more than as depicted in OSI model. Some of the responsibilities of OSI's session layer are dissolved into Internet model's transport layer. The other protocol UDP is a simpler protocol. It ignores (يتجاهل) some of the duties of the transport layer defined in OSI model. It is used when fast delivery of packets is needed without worrying much about error control.
3. **Network Layer:** The main protocol is IP (Internet Protocol) is responsible for creating network layer packets called IP datagrams. The datagrams travel network to network or LAN to WAN and the packets may reach out of sequence. It is the responsibility of upper layers to put them into proper order.

4. **Datalink & physical Layer:** The Internet model does not discuss much about these layers making this protocol machine independent to a large extent. It is left to the user to choose the proper standard or protocol according to what they desire.

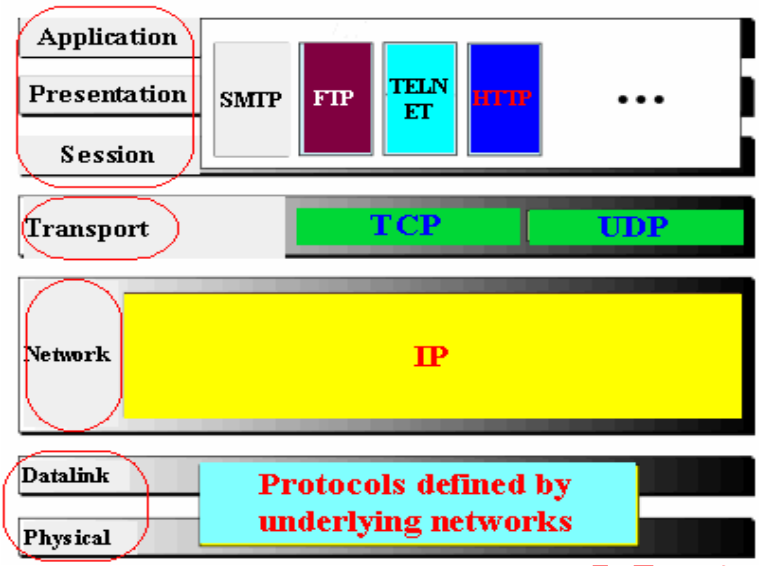


Fig 1.14 The Internet model

4.Network Topologies

4.1 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

I) Bus II) Ring III) Star IV)Mesh

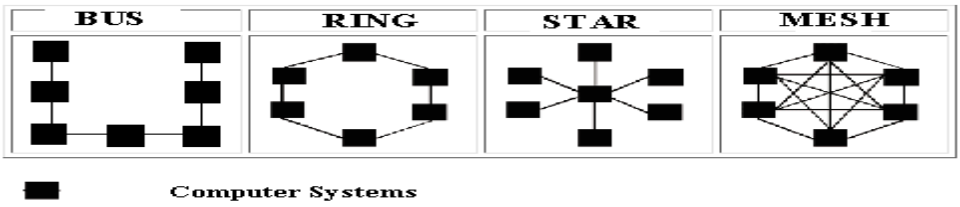


Fig 2.7.1 Outlines of various types of topologies

4.1 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.

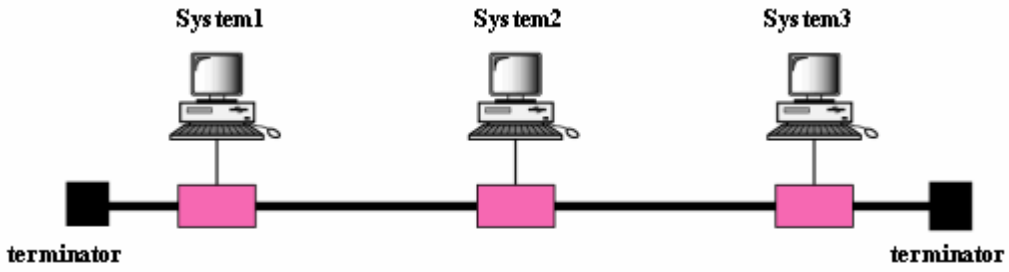


Fig 2.7.2 Physical topology of bus topology.

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 shutdown 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.

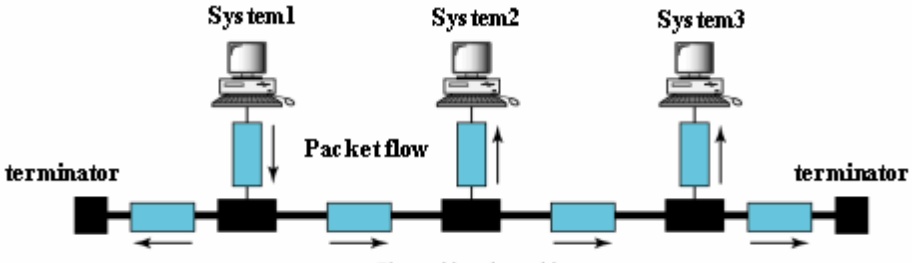


Fig 4.1 Logical topology illustration of bus topology.

4.2 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.

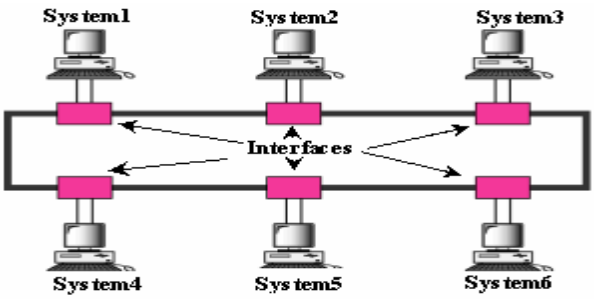


Fig. 4.2 Ring topology illustration.

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.

4.3 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.

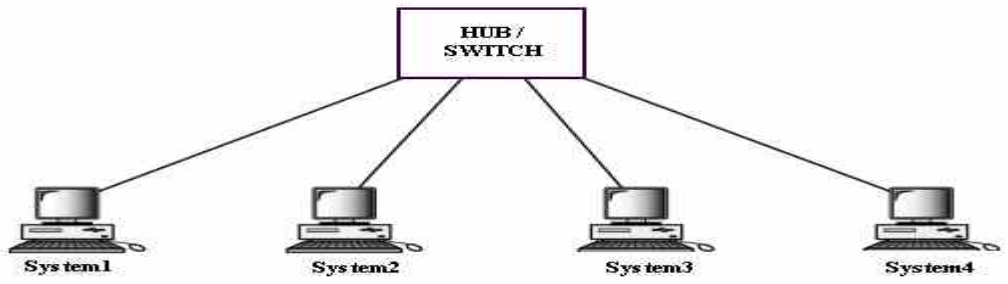


Fig 4.3. Physical topology of Star topology.

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.

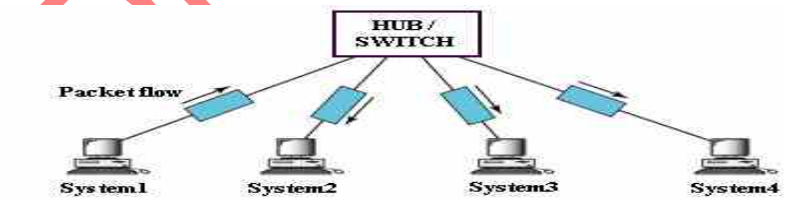


Fig 4.4 Logical topology of Star topology.

This topology is the dominant physical topology today.

4.5 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.

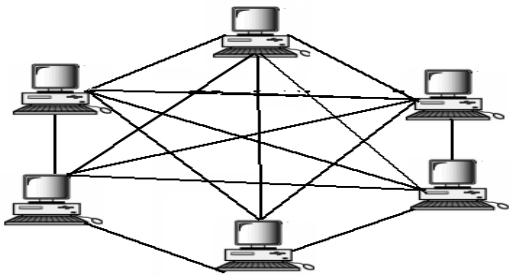


Fig 4.5 Physical topology of Mesh topology.

4.6 Hybrid topology

A hybrid topology is a combination of any two or more network topologies in such a way that the resulting network does not have one of the standard forms. For example, a tree network connected to a tree network is still a tree network, but two star networks connected together exhibit hybrid network topologies. A hybrid topology is always produced when two different basic network topologies are connected.

Why networking?

A network is a set of equipment (often referred as Data Terminal Equipment / DTE, or simply terminals or nodes ..) connected by a communication channel, which can be either guided/unguided media. DTE equipment can be a computer, printer or any device capable of sending and/or receiving data generated by other nodes on the network.

a. Why networking?

- **Sharing of hardware: Computer** hardware resources (Disks, Printers..)
- **Sharing of software:** Multiple single user licenses are more expensive than multi-user license. Easy maintenance of software
- **Sharing of information:** Several individuals can interact with each other Working in groups can be formed**.**
- **Communication: (**e-mail, internet telephony, audio conferencing video conferencing
- **Scalability:** Individual subsystems can be created and combine it into a main system to enhance the overall performance.
- **Distributed systems:** In a networked environment computers can distribute the workload among themselves keeping transparency to the end user**.**

5. Types of networks

5.1 Point to point

Figure 5.1 shows a communication system used to interconnect two computers. The computers output electrical signals directly through the serial port. The data can be

passed directly through the communication medium to the other computer if the distance is small (less than 100 meters).

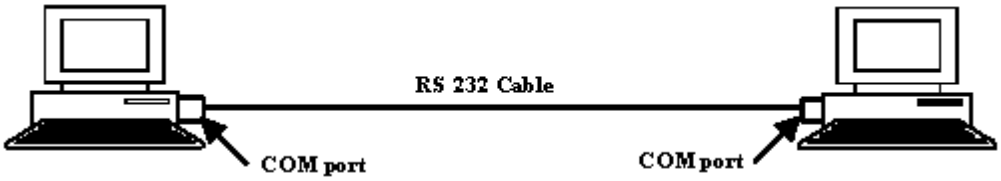


Fig. 5.1 PC to PC communication using com ports

Figure 5.1 shows a communication system in which two PCs communicate with each other over a existing say local telephone exchange (PABX) network. In this system, we introduced device called DTE data terminal equipment. The example here for DTE is modem (modulator demodulator) connected at both ends. The PCs send digital signals, which the modem converts into analog signals and transmits through the medium (copper wires). At the receiving end, the modem converts the incoming analog signal into digital form and passes it on to the PC.

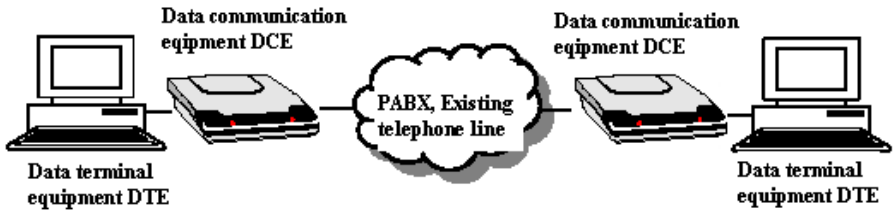


Fig.5.2 PC to PC communication over existing telephone network

5.3 Local Area Network (LAN)

A LAN is a local area network that is a small collection of computers in a small geographic area of less than couple of kilometers and is very fast in data transfer. Depending on technology implementation a LAN can be as simple as two PCs and a printer got connected in a small office or it can extend through out an organization and include multimedia (text, voice, video) data transfers.

The LANs may be configured in many ways. The peer-to-peer configuration is the simplest form. In this configuration computers are connected together to share their recourses among themselves. In such configurations it is very difficult impose security features.

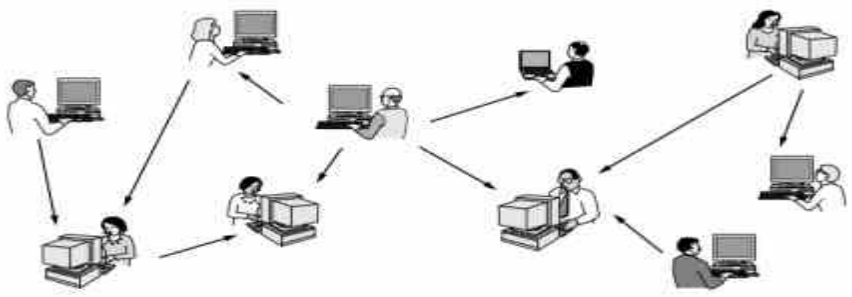


Fig 5.3 In a peer-to-peer configuration there is no security

On the other hand LANs can also be architectured in a client server model with full control over security and protection. Today Ethernet is a dominant LAN technology.

Client/server describes the relationship between two computer programs in which one program, the client, makes a service request from another program, the server, which fulfills(يستوفي) the request. Although the client/server idea can be used by programs within a single computer, it is a more important idea in a network. In a network, the client/server model provides a convenient way to interconnect programs that are distributed efficiently across different locations. Computer transactions using the client/server model are very common. For example, to check your bank account from your computer, a client program in your computer forwards your request to a server program at the bank. That program may in turn forward the request to its own client program that sends a request to a database server at another bank computer to retrieve your which in turn serves it back to the client in your personal computer, which displays the information for you.

The client/server model has become one of the central ideas of network computing. Most business applications being written today use the client/server model. So does the Internet's main program, TCP/IP. In marketing, the term has been used to distinguish distributed computing by smaller dispersed computers from the "monolithic" centralized computing of mainframe computers. But this distinction has largely disappeared as mainframes and their applications have also turned to the client/server model and become part of network computing.

In the usual client/server model, one server, sometimes called a daemon, is activated and awaits client requests. Typically, multiple client programs share the services of a common server program. Both client programs and server programs are often part of a larger program or application. Relative to the Internet, your Web browser is a client program that requests services (the sending of Web pages or files) from a Web server (which technically is called a Hypertext Transport Protocol or HTTP server) in another computer somewhere on the Internet.

Similarly, your computer with TCP/IP installed allows you to make client requests for files from File Transfer Protocol (FTP) servers in other computers on the Internet.

Other program relationship models included master/slave, with one program being in charge of all other programs, and peer-to-peer, with either of two programs able to initiate a transaction.

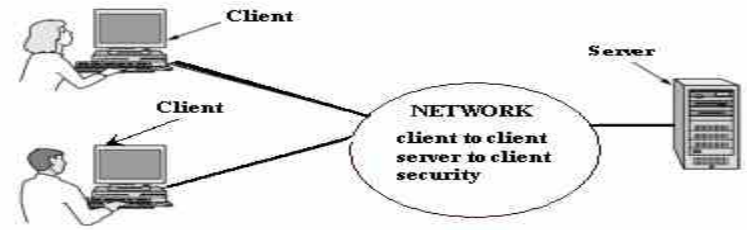


Fig 5.4 Client server model

A typical LAN in a corporate office links a group of related computers, workstations. One of the best computers may be given a large capacity disk drive and made as server and remaining computers as clients.

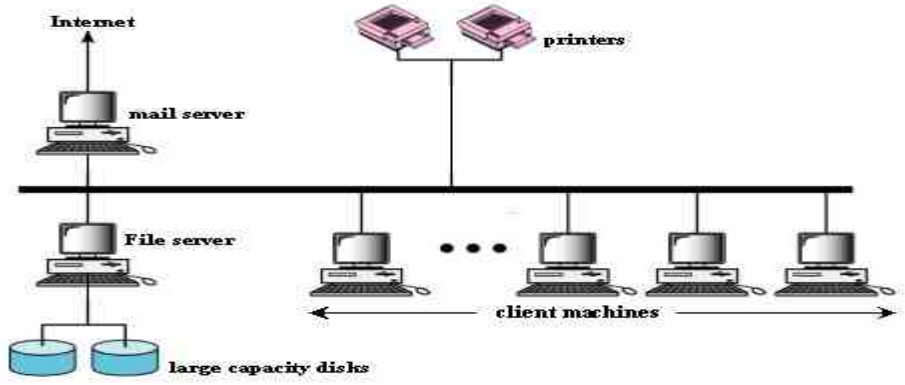


Fig. 5.5 A LAN setup

5.4 Metropolitan Area Network (MAN)

The metropolitan area network is designed to cover an entire city. It can be a single network such as cable TV or a number of LANs connected together within a city to form a MAN. Privately laid cables or public leased lines may be used to form such network. For instance a business organization may choose MAN to inter connect all its branch offices within the city.

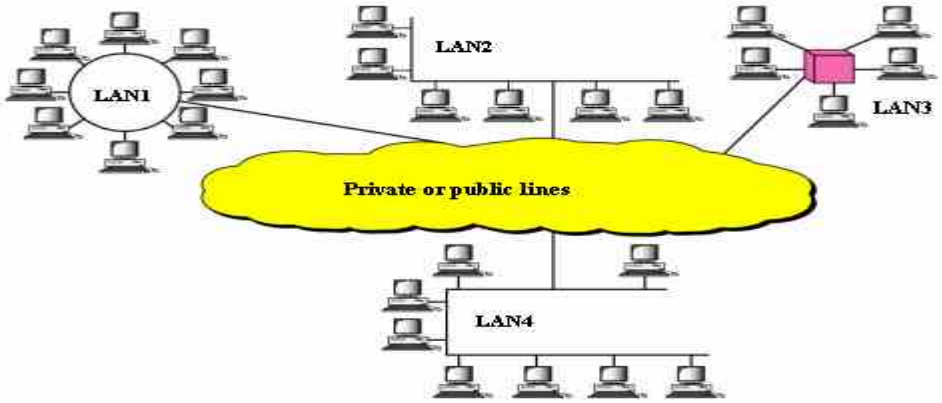


Fig 5.6 Typical Metropolitan area network

5.6 Wide Area Network (WAN)

A WAN is a data communications network that covers a relatively broad geographic area, often a country or continent. It contains a collection of machines intended for running user programs. These machines are called hosts.

The hosts are connected by subnet. The purpose of subnet is to carry messages from hosts to hosts. The subnet includes transmission facilities, switching elements and routers provided by common agencies, such as telephone companies. Now days, routers with satellite links are also becoming part of the WAN subnet. All these machines provide long distance transmission of data, voice, image and video information.

Unlike LAN which depend on their own hardware for transmission, WANs may utilize public, leased, or private communication devices when it come across and therefore span an unlimited number of kilometers. A network device called a router connects LANs to a WAN.

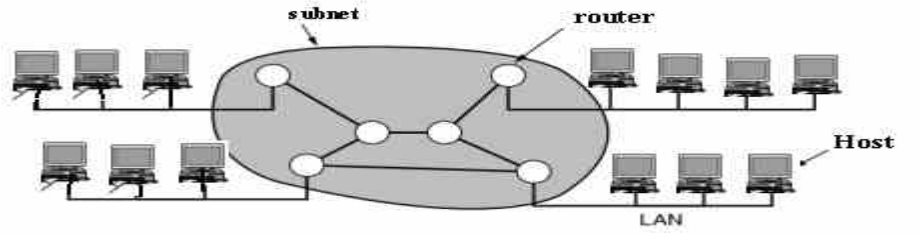


Fig 5.7 Typical WAN setup with hosts, routers and subnet.

The Internet is the largest WAN in existence.

5.6 Value added Network (VAN)

Value-added networks (VAN) are communications networks supplied and managed by third-party companies that facilitate electronic data interchange, Web services and transaction delivery by providing extra networking services.

A value-added network (VAN) is a private network provider (sometimes called a turnkey communications line) that is hired by a company to facilitate electronic data interchanges (EDI) or provides other network services. Before the arrival of the World Wide Web, some companies hired value-added networks to move data from their company to other companies. With the arrival of the World Wide Web, many companies found it more cost-efficient to move their data over the Internet instead of paying the minimum monthly fees and per-character charges found in typical VAN contracts. In response, contemporary value-added network providers now focus on offering EDI translation, encryption, secure email, management reporting, and other extra services for their customers.

Value-added networks got their first real foothold in the business world in the area of electronic data interchange (EDI). VANs were deployed to help trading and supply chain partners automate many businesses-to business communications and thereby reduce the number of paper transfers needed, cut costs and speed up a wide range of tasks and processes, from inventory and order management to payment.

Transaction Delivery Networks (TDN): The newest evolution of VANs, which first appeared in 2000, are the transaction delivery networks (TDN) that provide services for secure end-to-end management of electronic transactions. Also called transaction processing networks or Internet utility platforms, TDNs can guarantee delivery of messages in addition to providing high security and availability, network performance monitoring and centralized directory management.

TDNs typically use a store-and-forward messaging architecture that's designed to adapt readily to a wide range of disparate systems and support any kind of

transaction. Most TDNs offer secure encryption using a public-key infrastructure and certificate authorization for trading partners.

Internetworks: Internetwork or simply the internet are those when two or more networks are get connected. Individual networks are combined through the use of routers. Lowercase internet should not be confused with the worldwide Internet.

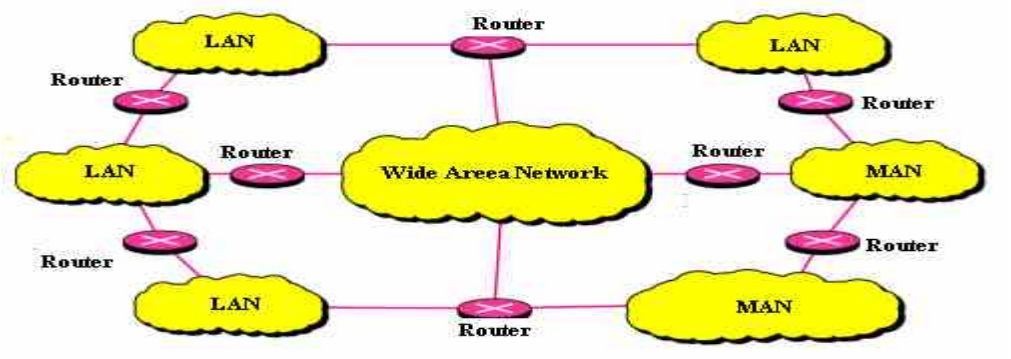
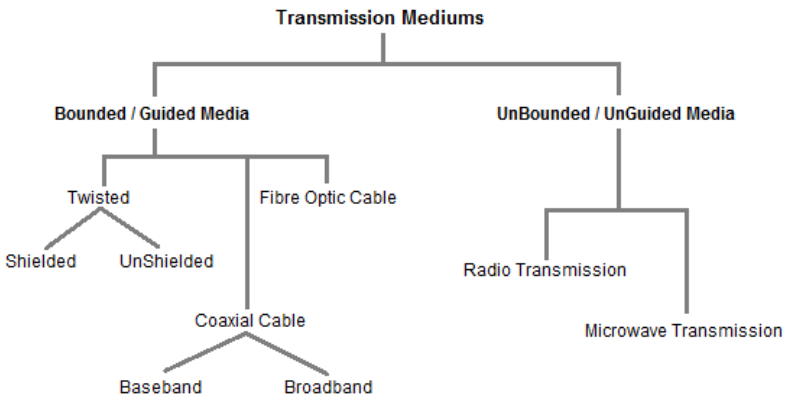


Fig 5.8 Typical internetwork connecting LANs and MANs

6.Transmission Mediums in Computer Networks

Data is represented by computers and other telecommunication devices using signals. Signals are transmitted in the form of electromagnetic energy from one device to another. Electromagnetic signals travel through vacuum, air or other transmission mediums to travel between one point to another (from source to receiver).Electromagnetic energy (includes electrical and magnetic fields) includes power, voice, visible light, radio waves, ultraviolet light, gamma rays etc.Transmission medium is the means through which we send our data from one place to another. The first layer (physical layer) of Communication Networks OSI Seven layer model is dedicated to the transmission media, we will study the OSI Model later.



Factors to be considered while choosing Transmission Medium

1. Transmission Rate
2. Cost and Ease of Installation
3. Resistance to Environmental Conditions
4. Distances

6.1.Bounded/Guided Transmission Media

It is the transmission media in which signals are confined to a specific path using wire or cable. The types of Bounded/ Guided are discussed below.

A.Twisted Pair Cable

This cable is the most commonly used and is cheaper than others. It is lightweight, cheap, can be installed easily, and they support many different types of network. Some important points:

- Its frequency range is 0 to 3.5 kHz.
- Typical attenuation is 0.2 dB/Km @ 1kHz.
- Typical delay is 50 µs/km.
- Repeater spacing is 2km.

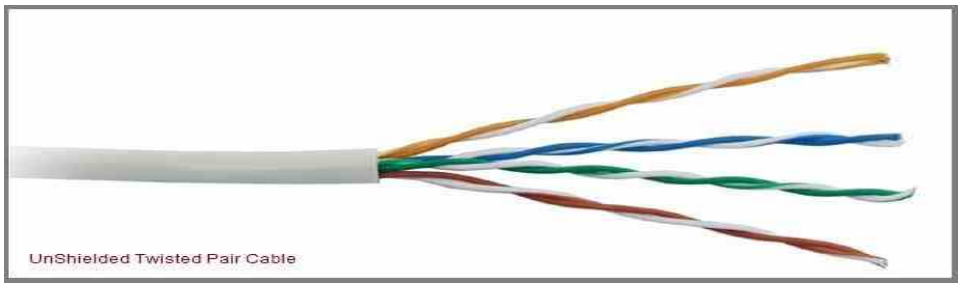
Twisted Pair is of two types :

a.Unshielded Twisted Pair (UTP)

b.Shielded Twisted Pair (STP)

a.Unshielded Twisted Pair Cable

It is the most common type of telecommunication when compared with Shielded Twisted Pair Cable which consists of two conductors usually copper, each with its own colour plastic insulator. Identification is the reason behind coloured plastic insulation.UTP cables consist of 2 or 4 pairs of twisted cable. Cable with 2 pair use **RJ11** connector and 4 pair cable use **RJ-45** connector.



Advantages :

- Installation is easy
- Flexible
- Cheap
- It has high speed capacity,
- 100 meter limit
- Higher grades of UTP are used in LAN technologies like Ethernet.

It consists of two insulating copper wires (1mm thick). The wires are twisted together in a helical form to reduce electrical interference from similar pair.

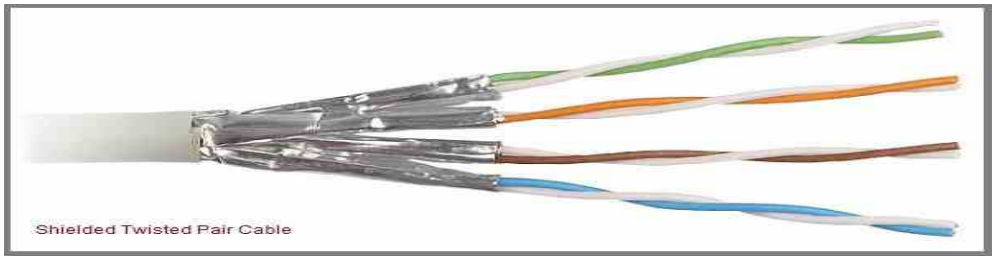
Disadvantages :

- Bandwidth is low when compared with Coaxial Cable
- Provides less protection from interference.

b.Shielded Twisted Pair Cable

This cable has a metal foil or braided-mesh covering which encases each pair of insulated conductors. Electromagnetic noise penetration is prevented by metal casing. Shielding also eliminates crosstalk (explained in KEY TERMS Chapter).

It has same attenuation as unshielded twisted pair. It is faster the unshielded and coaxial cable. It is more expensive than coaxial and unshielded twisted pair.



Advantages :

- Easy to install
- Performance is adequate
- Can be used for Analog or Digital transmission
- Increases the signalling rate
- Higher capacity than unshielded twisted pair
- Eliminates crosstalk

Disadvantages :

- Difficult to manufacture
- Heavy

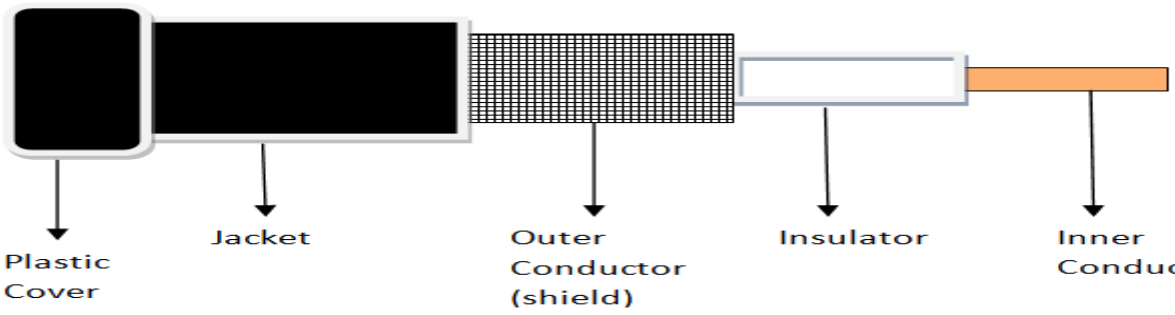
B.Coaxial Cable

Coaxial is called by this name because it contains two conductors that are parallel to each other. Copper is used in this as centre conductor which can be a solid wire or a standard one. It is surrounded by PVC installation, a sheath which is encased in an outer conductor of metal foil, barid or both.

Outer metallic wrapping is used as a shield against noise and as the second conductor which completes the circuit. The outer conductor is also encased in an insulating sheath. The outermost part is the plastic cover which protects the whole cable.

Here the most common coaxial standards.

- 50-Ohm RG-7 or RG-11 : used with thick Ethernet.
- 50-Ohm RG-58 : used with thin Ethernet
- 75-Ohm RG-59 : used with cable television
- 93-Ohm RG-62 : used with ARCNET.



There are two types of Coaxial cables :

A.BaseBand

This is a 50 ohm (Ω) coaxial cable which is used for digital transmission. It is mostly used for LAN's. Baseband transmits a single signal at a time with very high speed. The major drawback is that it needs amplification after every 1000 feet.

B.BroadBand

This uses analog transmission on standard cable television cabling. It transmits several simultaneous signal using different frequencies. It covers large area when compared with Baseband Coaxial Cable.

Advantages :

- Bandwidth is high
- Used in long distance telephone lines.

- Transmits digital signals at a very high rate of 10Mbps.
- Much higher noise immunity
- Data transmission without distortion.
- The can span to longer distance at higher speeds as they have better shielding when compared to twisted pair cable

Disadvantages :

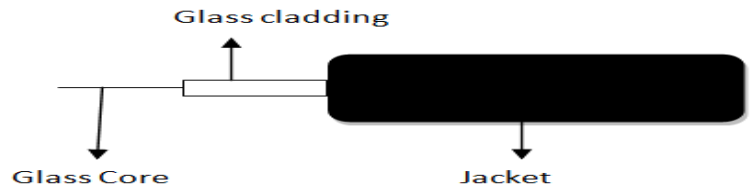
- Single cable failure can fail the entire network.
- Difficult to install and expensive when compared with twisted pair.
- If the shield is imperfect, it can lead to grounded loop.

C.Fiber Optic Cable

These are similar to coaxial cable. It uses electric signals to transmit data. At the centre is the glass core through which light propagates.

In multimode fibres, the core is 50microns, and In single mode fibres, the thickness is 8 to 10 microns.

The core in fiber optic cable is surrounded by glass cladding with lower index of refraction as compared to core to keep all the light in core. This is covered with a thin plastic jacket to protect the cladding. The fibers are grouped together in bundles protected by an outer shield. Fiber optic cable has bandwidth more than **2 gbps (Gigabytes per Second)**



Advantages :

- Provides high quality transmission of signals at very high speed.
- These are not affected by electromagnetic interference, so noise and distortion is very less.
- Used for both analog and digital signals.

Disadvantages :

- It is expensive
- Difficult to install.
- Maintenance is expensive and difficult.
- Do not allow complete routing of light signals.

2.UnBounded/UnGuided Transmission Media

Unguided or wireless media sends the data through air (or water), which is available to anyone who has a device capable of receiving them. Types of unguided/ unbounded media are discussed below :

- Radio Transmission
- MicroWave Transmission

a.Radio Transmission

Its frequency is between 10 kHz to 1GHz. It is simple to install and has high attenuation. These waves are used for multicast communications.

Types of Propogation

Radio Transmission utilizes different types of propogation :

- **Troposphere :** The lowest portion of earth's atmosphere extending outward approximately 30 miles from the earth's surface. Clouds, jet planes, wind is found here.
- **Ionosphere :** The layer of the atmosphere above troposphere, but below space. Contains electrically charged particles.

b.Microwave Transmission

It travels at high frequency than the radio waves. It requires the sender to be inside of the receiver. It operates in a system with a low gigahertz range. It is mostly used for unicast communication.

There are 2 types of Microwave Transmission:

1. Terrestrial Microwave
2. Satellite Microwave

Advantages of Microwave Transmission

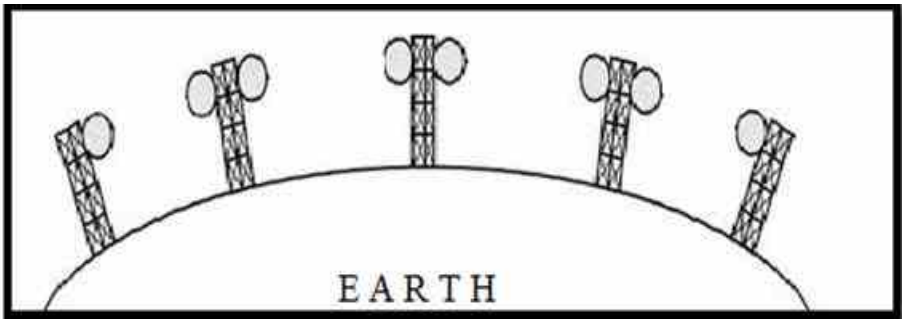
- Used for long distance telephone communication
- Carries 1000's of voice channels at the same time

Disadvantages of Microwave Transmission

- It is Very costly.

C.Terrestrial Microwave

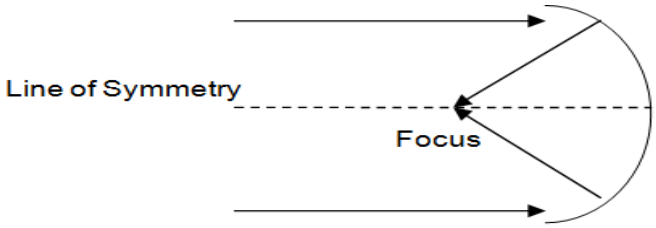
For increasing the distance served by terrestrial microwave, repeaters can be installed with each antenna .The signal received by an antenna can be converted into transmittable form and relayed to next antenna as shown in below figure. It is an example of telephone systems all over the world



There are two types of antennas used for terrestrial microwave communication :

1. Parabolic Dish Antenna

In this every line parallel to the line of symmetry reflects off the curve at angles in a way that they intersect at a common point called focus. This antenna is based on geometry of parabola.



2. Horn Antenna

It is a like gigantic scoop. The outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by curved head.

d.Satellite Microwave

This is a microwave relay station which is placed in outer space. The satellites are launched either by rockets or space shuttles carry them.

These are positioned 36000KM above the equator with an orbit speed that exactly matches the rotation speed of the earth. As the satellite is positioned in a geo-synchronous orbit, it is stationery relative to earth and always stays over the same point on the ground. This is usually done to allow ground stations to aim antenna at a fixed point in the sky.

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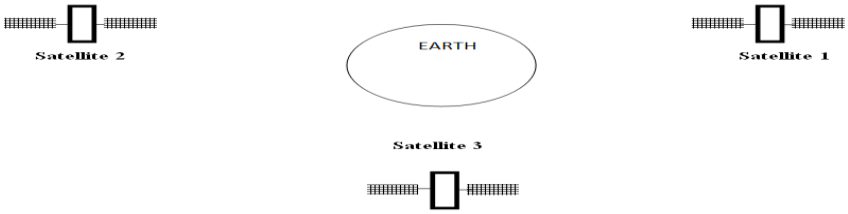

Features of Satellite Microwave:

- Bandwidth capacity depends on the frequency used.
- Satellite microwave deployment for orbiting satellite is difficult.

Advantages of Satellite Microwave :

- Transmitting station can receive back its own transmission and check whether the satellite has transmitted information correctly.
- A single microwave relay station which is visible from any point.

Disadvantages of Satellite Microwave :

- Satellite manufacturing cost is very high
- Cost of launching satellite is very expensive
- Transmission highly depends on whether conditions, it can go down in bad weather