2. PHYSICAL LAYER

The purpose of the physical layer is to transport raw bit stream from one device to another. Various physical mediums can be used for the actual transmission of data. Computers and other telecommunication devices use signal to represent data. These signals are transmitted from one device to another by using electromagnetic energy. Electro magnetic signals can pass through vacuum, air or other transmission media.

Electromagnetic energy is a combination of electrical and magnetic fields vibrating with each other, includes power, voice, radio, waves, infrared light, visible light, ultraviolet, x, gamma, and cosmic rays. Voice band frequencies are generally transmitted as current over metal cables, such as twisted pair or co-axial cable. Radio frequencies can travel through air or space but require specific transmitting and receiving mechanisms. Visible light, the third type of electro magnetic energy is currently used for communications via fiber optic cables. Each of these take part in electro magnetic spectrum.

Power, voice	Radio communication Radio, Microwave, satellite	Infrared Light		Ultraviolet Light	X, Gamma , Cosmic rays

0 3Khz 300Khz 430 750

(Visible Light)

Each one has its own bandwidth, cost, delay and ease of installation and maintenance. So these media are roughly grouped into two broad categories.

Transmission Media:

Transmission Media

Guided **Unguided**

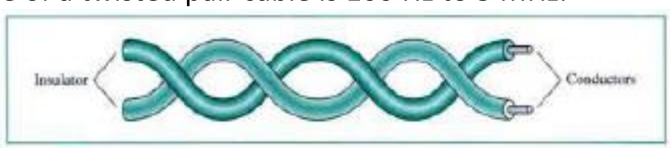
Guided Transmission Media: These provide a medium from one device to another, which include magnetic media, twisted pair, co-axial cable and fiber optical cable. Twisted pair and co-axial cable use metallic (copper) conductors that accept and transport signals from one device to other. Optical cable is a glass or plastic material that accepts and transports signals in the form of light.

Guided Media

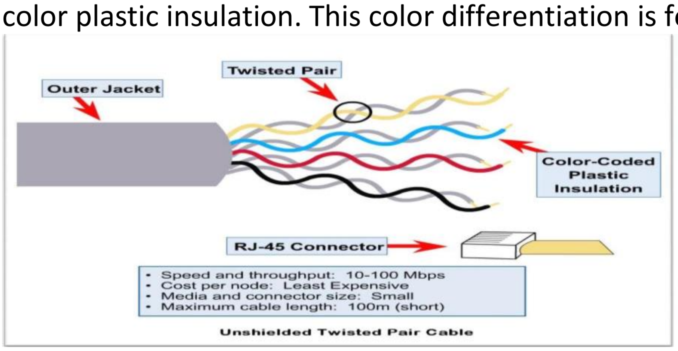
- **Magnetic Media**
- **Twisted Pair**
- **Co-axial Cable**
- **Fiber Optic Cable**

Magnetic Media : This is one of the most common way to transport data from one device to other. To do this it is to wire the two devices with a magnetic tape or it has to provide a floppy disk or compact disk. We have to physically (manually) transport these devices to the destination machine. But the method of transporting data in this way is not sophisticated especially in the case of long range distribution and huge amount of data. It is highly expensive and more cost effective in high bandwidth applications.

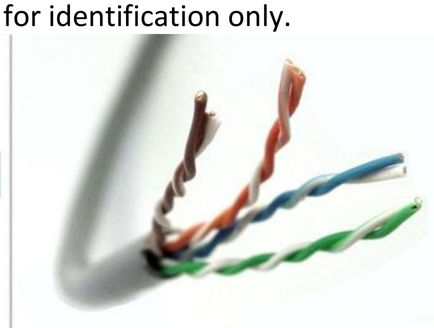
Twisted Pair : It was invented by Alexander Graham Bell. Though the bandwidth characteristics of magnetic tape are excellent, the delay characteristics are very poor. Twisted pair cable comes in two forms. They are shielded and unshielded. The frequency range of a twisted pair cable is 100 Hz to 5 MHz.



Unshielded Twisted Pair Cable (UTP): This is the most common type of telecommunication medium which we are using today. Though it is most familiar in using telephone systems, its frequency range is suitable for transmitting both data and voice. A twisted pair consists of two conductors (usually copper) each with different color plastic insulation. This color differentiation is for identification only.



Unshielded Twisted Pair Cable



Twisted pair frequencies range from 100 Hz to 5 MHz. In our olden days we use two flat parallel wires for communication. Electromagnetic interference from devices such as motor can create noise over both the wires. If the 2 wires are parallel, the wire which is very close to the noise(motor) gets more interference and produce a higher voltage level than the wire farther away, which produces a damaged signal as a result. By twisting the two wires, we can reduce the intensity of such interferences. Twisting does not always eliminate the impact of noise but significantly reduces. Advantage of UTP is its cost and ease of use. It is very cheap, flexible, and easy to install. Higher capacities of

UTP are used in many LAN technologies, like Ethernet, Token Ring. The above diagram shows four unshielded twisted pairs.

The EIA (Electronic Industries Association) has developed certain grades to these cables to grade them by quality. Those grades are of 5 types.

Category 1: This is a basic twisted pair cabling used in telecommunications. At this level quality is good for voice but inadequate for all type of data and low speed for data communications.

Category 2 : This is the next higher grade and is suitable for voice and data transmission. It provides data transmission rate up to 4 Mbps.

Category 3: It requires at least 3 twists per foot and can be used for data transmission of up to 10 Mbps. This is the current standard for telephones.

Category 4: This also must have 3 twists per foot and it supports data transfer rate up to 16 Mbps.

Category 5: It provides 100Mbps data transmission rate.

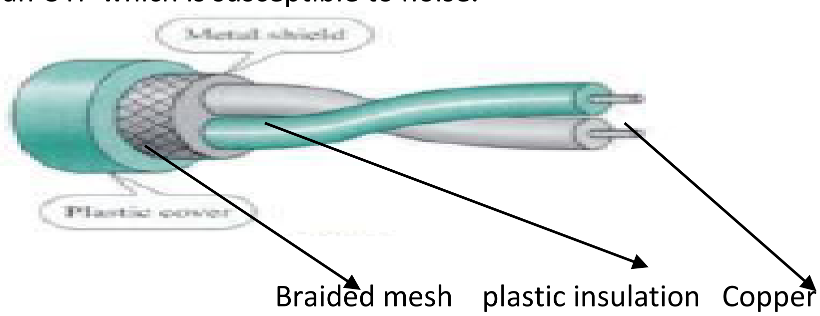
Advantages of UTP:

1. It is cheaper than other communication media.
2. It is easy to install and repair.
3. It provides good data transmission in short distance networks.

Disadvantages of UTP:

1. It is more susceptible to crosstalk, EMI and RFI.
2. It is not suitable for outdoor use and long distance networks.

Shielded Twisted Pair Cable (STP) : It has a metal foil and braided mesh to cover each pair of the insulated conductors. This casing prevents the presentation of electro magnetic noise and also eliminates crosstalks. Crosstalk occurs when one line picks up signals traveling down another line. This can occur during telephone conversations. Here one can hear other conversations in the background. Shielding prevents most crosstalks. STP has same quality like UTP. Materials and manufacturing requirements make STP more expensive than UTP which is susceptible to noise.



Advantages of STP

1. It is less susceptible to EMI, RFI and crosstalk than UTP.
2. It provides good data transmission in short distance networks.
3. It is easy to install than other media.

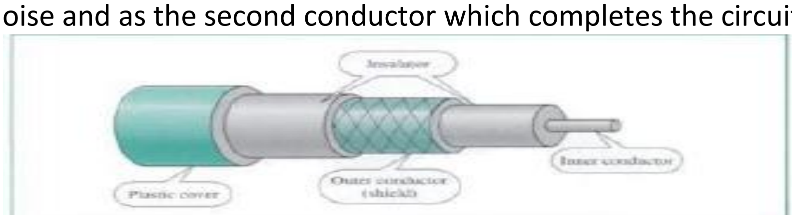
Disadvantages of STP

1. It is more expensive than UTP.
2. It is relatively hard to install and repair than UTP.

Co-axial Cable : Coaxial cable was invented by English engineer and mathematician Oliver Heaviside, who first patented the design in 1880. Coaxial cable is used as a transmission line for radio frequency signals, in applications such as connecting radio transmitters and receivers with their antennas, computer network (Internet) connections, and distributing cable television signals. One advantage of coax over other types of radio transmission line is that in an ideal coaxial cable the electromagnetic field carrying the signal exists only in the space between the inner and outer conductors. This allows coaxial cable runs to be installed next to metal objects such as gutters without the power losses that occur in other types of transmission lines, and provides protection of the signal from external electromagnetic interference.

Coaxial cable differs from other shielded cable used for carrying lower frequency signals such as audio signals, in that the dimensions of the cable are controlled to give a precise, constant conductor spacing, which is needed for it to function efficiently as a radio frequency transmission line.

It carries signals of higher frequencies ranges than twisted pair cables. Instead of having two wires, coax has a central core conductor enclosed in an insulating sheath, which in turn encased in an outer conductor metal foil. The outer metallic wrapping serves both a shield against noise and as the second conductor which completes the circuit.



Coaxial cable frequencies range from 100 KHz to 500 KHz. It has various standards. Different coaxial cable designs are categorized by the radio government (RG) ratings. Each RG number denotes a unique set of physical specifications. Each cable is defined by RG ratings and is used for a special function.

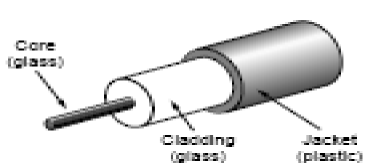
RG 8 → Thick Ethernet
RG 9 → Thick Ethernet
RG 11 → Thick Ethernet
RG 58 → Thin Ethernet
RG 59 → TV

Fiber Optic Cables: An **optical fiber** is a thin, flexible, transparent fiber that acts as a waveguide, or "light pipe", to transmit light between the two ends of the fiber. The field of applied science and engineering concerned with the design and application of optical fibers is known as **fiber optics**. Optical fibers are widely used in fiber-optic communications, which permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communication. Fibers are used instead of metal wires because signals travel along them with less loss and are also immune to electromagnetic interference. Fibers are also used for illumination, and are wrapped in bundles. so they can be used to carry images, thus allowing viewing in tight spaces. Specially designed fibers are used for a variety of other applications, including sensors and fiber lasers.

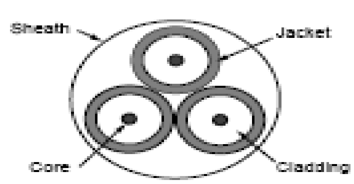
Optical fiber typically consists of a transparent core surrounded by a transparent cladding material with a lower index of refraction. Light is kept in the core by total internal reflection. This causes the fiber to act as a waveguide. Fibers which support many propagation paths or transverse modes are called multi-mode fibers (MMF), while those which can only support a single mode are called single-mode fibers (SMF). Multi-mode fibers generally have a larger core diameter, and are used for short-distance communication links and for applications where high power must be transmitted. Single-mode fibers are used for most communication links longer than 1,050 meters (3,440 ft).

Joining lengths of optical fiber is more complex than joining electrical wire or cable. The ends of the fibers must be carefully cleaved, and then spliced together either mechanically or by fusing them together with heat. Special optical fiber connectors are used to make removable connections.

These are similar to coax, except without the braid. The following diagram shows a single fiber from side view. At the center we have a glass core, through this light travels. In multimode fibers, the core is 50 microns in diameter that is about the thickness of a human hair. In single mode fibers, the core is 8 to 10 microns. The core is surrounded by a glass cladding with a lower index of refraction than the core, to keep all the light in the core. Next one is a thin plastic jacket which protects the cladding. Fibers are typically grouped together in bundles, protected by an outer sheath. The following diagram shows 3 fibers.



Side view of a single fiber



End view of a sheath with 3 fibers

Comparison of Fiber Optic and Copper Cables :

Fiber	**Copper**
It handles more bandwidth	It handles less bandwidth
Due to low attenuation, repeaters are required for each 30 kms on long lines.	Repeaters are required for each 5 Km.
It will not be affected by power surges, electromagnetic interferences or power failures.	It will be affected by power surges, electromagnetic interferences or power failures.
It will not be affected by corrosive chemicals in the air. So it makes ideal for the harsh factory environments.	It will be affected.
These are very thin and light weight to carry	Heavy
They do not leak light and are quite difficult to tap. So it gives excellent security against wire tappers.	It leaks information and wire tapping is also possible.

Unguided Transmission Media: They transmit electromagnetic waves without using a physical conductor. Signals are broadcast through air or through water. So these are available to anyone who has a device that is capable of receiving these signals.

Radio Frequency Allocation: This is divided into 8 ranges, called bands regulated by government authorities. These bands are rated from VLF (Very Low Frequency) to EHF (Extremely High Frequency)

Power, voice	Radio communication Radio, Microwave, satellite	Infrared Light		Ultraviolet Light	X, Gamma , Cosmic rays

VLF	**LF**	**MF**	**HF**	**VHF**	**UHF**	**SHF**	**EHF**

3k 30k 300k 3M 30M 300 M 3G 30G 300GHz

Propagation of Radio Waves: Radio wave transmission utilizes five different types of propagation: surface, troposphere, ionosphere, line-of-sight and space.

Radio technology considers the earth is surrounded by two layers of atmosphere: the troposphere and the ionosphere. The troposphere is the portion of the atmosphere extending outward approximately 30 miles from the earth's surface. Cloud's wind, temperature variations, and weather in general occur are in the troposphere, as the jet planes travel. The ionosphere is the layer of atmosphere just above the troposphere and below the space.

Surface Propagation: Here, radio waves travel through the lowest portion of the atmosphere, hugging the earth. Surface propagation can also take place in sea water.

Troposphere Propagation: It works in two ways. Either a signal can be directed in a straight line from antenna to antenna. Antennas must be directional facing each other, and either tall enough or close enough together not be affected by the curvature of the earth.

Space Propagation: These utilizes satellite relays in place of atmospheric refraction. Satellite communication is basically a line of sight transmission with an intermediary satellite.

Propagation of Specific Signals:

VLF: Very Low Frequency propagates usually through air, but sometimes through sea water. These are mostly used for long range radio navigation and submarine communication. They range from 3KHz to 30 KHz. They do not suffer much attenuation in transmission, but are susceptible to the high levels of atmospheric noise.

LF: (30KHZ to 300 KHz) These are used for long range radio navigation and for radio beacons or navigational locators. Attenuation is greater during day time.

MF: (300 KHz to 3MHz) Troposphere signals. They are used for line of sight antennas, AM Radio, Maritime radio, radio direction finding, and emergency frequencies.

HF: (3 MHz to 30 MHz) Ionosphere signals. Used in amateur radio, citizen’s band radio, international broadcasting, military communication, long distance aircraft and ship communication, telephone, telegraph, and facsimile.
VHF: (30 MHz to 300 MHz) Line of sight propagation. VHF Television, FM Radio, aircraft AM radio, and aircraft navigational aid are the examples.

UHF: (300 MHZ to 3GHz) Line of sight propagation. UHF Television, mobile telephone, cellular radio, paging, and micro wave links.

SHF: (3 GHz to 30GHz) Line of sight and space propagation. Used for terrestrial satellite microwave and radar communication.

EHF: (30GHz to 300 GHz) these are meant for scientific including radar, satellite, and experimental communications.

Microwave Transmission: Microwave signals propagate in one direction at a time, which means that two frequencies are necessary for two-way communication such as a telephone conversation. One frequency is reserved for microwave transmission in one direction and the other for transmission in other direction.

Before fiber optics, for decades, these microwaves formed the heart of the long-distance telephone transmission system.

Microwaves do not pass through buildings well. In addition, even though the beam is well focused, there is still some divergence in space. Some waves may be refracted off low lying atmospheric layers and may take slightly longer to arrive than direct waves. Being out of phase they can cancel the signal. This effect is called multipath fading and is often a serious problem. It is weather and frequency dependent.

Bands up to 10 GHz are now in routine use, but at about 8 GHz a new problem sets in: absorption by water (rain). The only solution is to shut off links that are being rained on and route around them.

Microwave is also relatively inexpensive. Putting up two simple towers (maybe just big poles with four guy wires) and putting antennas on each one may be cheaper than burying 50 km of fiber through a congested urban area, and it may also be cheaper than leasing the telephone company fiber.

Microwaves have also another important use. We are speaking about cordless telephones, garage door openers, wireless hi-fi speakers, security gates etc. These devices use so called Industrial/Scientific/Medical bands forming an exception to the licensing rule: transmitters using these bands do not require government licensing. One band is allocated world-wide: 2.400-2.484 GHz. These bands are popular also for various forms of short-range wireless networking.

Infrared and Millimeter Waves

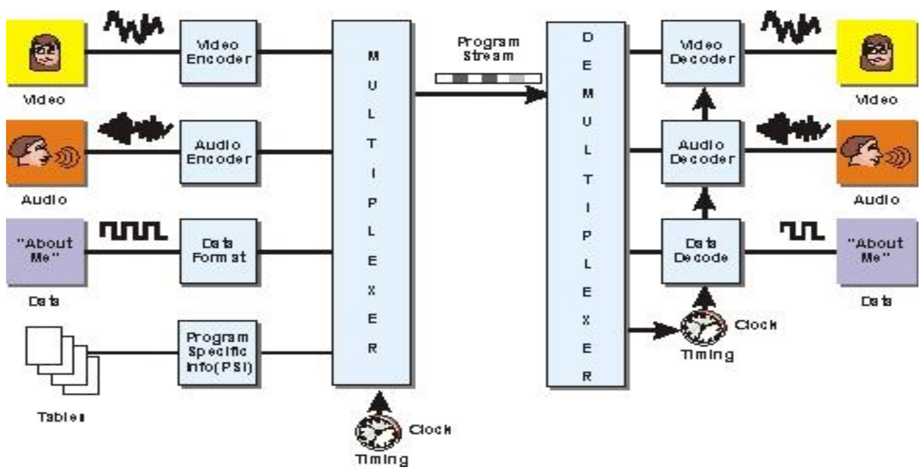
Unguided infrared and millimeter waves are widely used for short-range communication (remote control of televisions and stereos). They are relatively directional, cheap and easy to build, but they do not pass through the solid objects. On the other hand it is good advantage also. It means that an Infrared system (TV) in one room should not interfere with another Infrared system in another room. The security of Infrared systems against eavesdropping is better than general radio communication.

For this reason, no government license is needed to operate an infrared system.

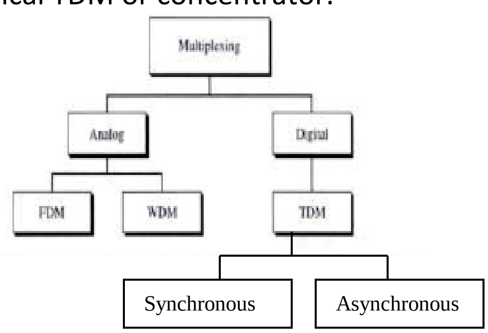
These properties have made infrared an interesting candidate for indoor wireless LANs (i.e. portable computers with infrared capability can be on local LAN without having to physically connect to it.

Infrared communication cannot be used outdoors because the sun shines as brightly in the infrared as in visible spectrum.

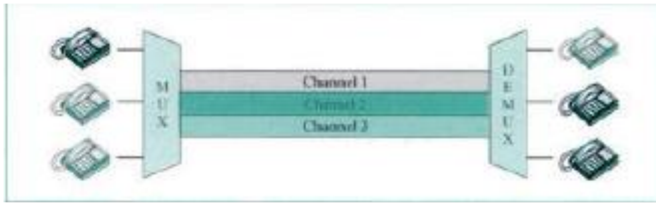
Multiplexing: When the transmission capacity of a medium that links two devices is greater than the needs of the devices, then the link bandwidth can be shared. Multiplexing is the set of techniques that allows the simultaneous transmission of multiple signals across a single data link. In a multiplexing system, n devices share the capacity of one link. The following figure shows the basic format of a multiplexer which combines them into a single stream. At the receiving end, the stream is fed into a de multiplexer, which separates the stream back into its component transmissions and directs them to their intended receiving devices. In short, the multiplexer is represented as MUX.



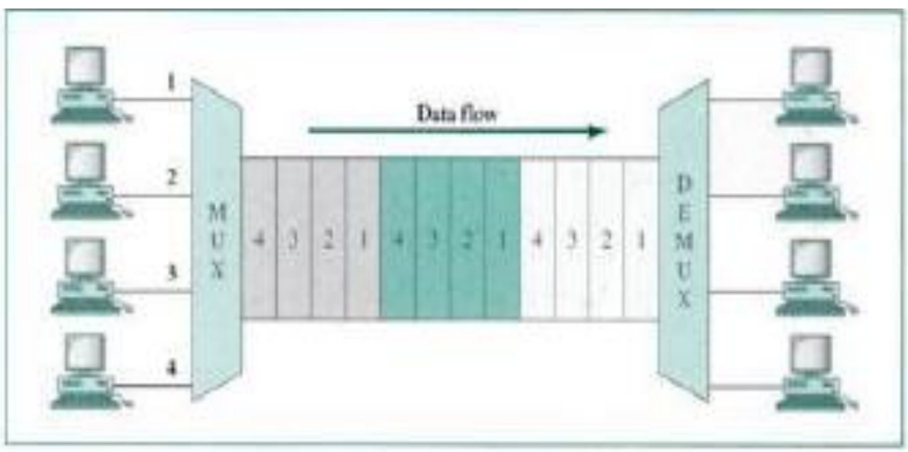
Categories of Multiplexing: signals are multiplexed using three basic techniques that is FDM, TDM and WDM. FDM is subdivided into synchronous TDM and asynchronous TDM which is also known as statistical TDM or concentrator.



Frequency Division Multiplexing: This is an analog technique that can be applied when the bandwidth of a channel or link is greater than the combined bandwidth of the signals to be transmitted. In FDM signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are separated by enough bandwidth to accommodate the modulated signal. These bandwidth ranges are the channels through which the various signals travel. Channels must be separated by strips of unused bandwidths to prevent signals from overlapping.

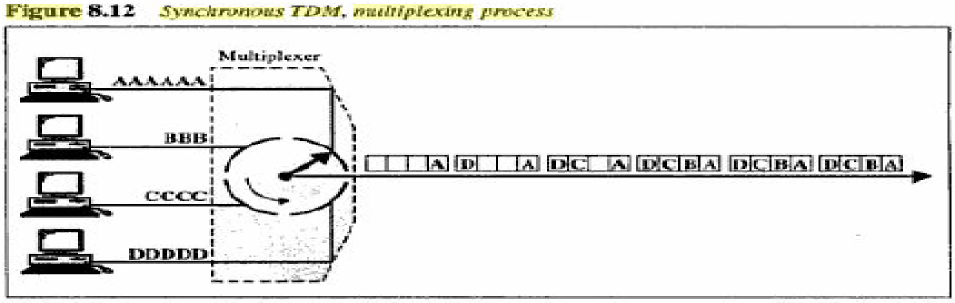


Time Division Multiplexing: TDM is a digital process that allow multiple connections to share the high bandwidth of a channel. Instead of sharing the high bandwidth of the channel as in FDM, time is shared here. Each connection occupies a portion of time in the channel. It is a process that can be applied, when the data transmission rate of the transmission medium is greater than the data transmission rate required by the source and destination devices. In such a case, multiple transmissions can occupy a single channel by subdividing them and interleaving the portions. In the following figure, the channel is divided into various time slots by TDM. In the TDM, the slots of signals 1,2,3, and 4 occupy the channel sequentially. TDM can be implemented in two ways: Synchronous and Asynchronous.



Synchronous TDM: Here the term synchronous has a different meaning from the term used in the area of telecommunications. Here synchronous means multiplexer allocates exactly the same time slot to each device at all times, though they have any data to transfer or not. For example, if slot A is assigned to A, then A alone can use and it can not be used by any other devices at any cost, even A has no data to transfer. If any one is unable to transmit or does not have data to transfer, its time slot remains empty.

Figure 8.12 *Synchronous TDM, multiplexing process*

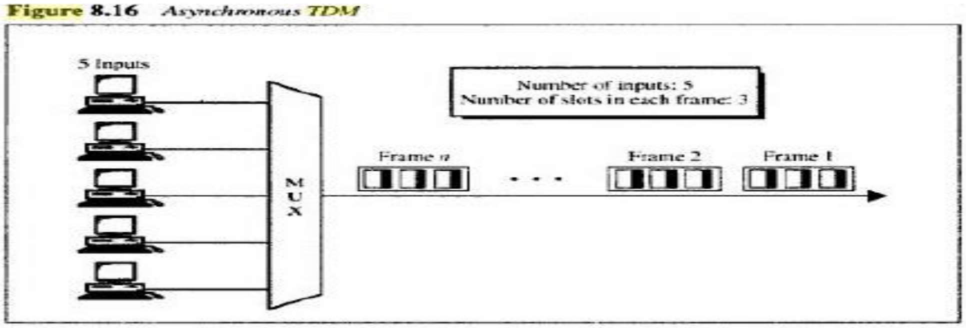


Time slots are grouped into frames. A frame consists of one complete cycle of time slots, including one or more slots dedicated to each source. For example here in the following figure there are 4 stations to transfer information. The frame length of the channel is four characteristics. So in the first three frames all four station transfer their data. Starting from the 4th frame, A, C, and D distribute the data since b do not have any data to transfer, and in fifth only A and D, and so on.

Asynchronous TDM: Synchronous TDM does not guarantee that the full capacity of channel will be utilized. In fact, here only a few time slots are in use at any time. Because the time slots are pre assigned and fixed, whenever a connecting station is not transmitting, the corresponding slot is empty and that much path bandwidth is wasted.

Asynchronous TDM is designed to avoid this type of wastage. Here asynchronous means flexible or not fixed. Like synchronous TDM, asynchronous also allows a number of i/p lines to be multiplexed into a single high speed o/p line. In a synchronous system, if we have n i/p lines, the frame contains a fixed number of at least n time slots. But in an asynchronous system, this is not the case, which is if we have n i/p lines, the frame may have less than n number of time slots.

Figure 8.16 *Asynchronous TDM*

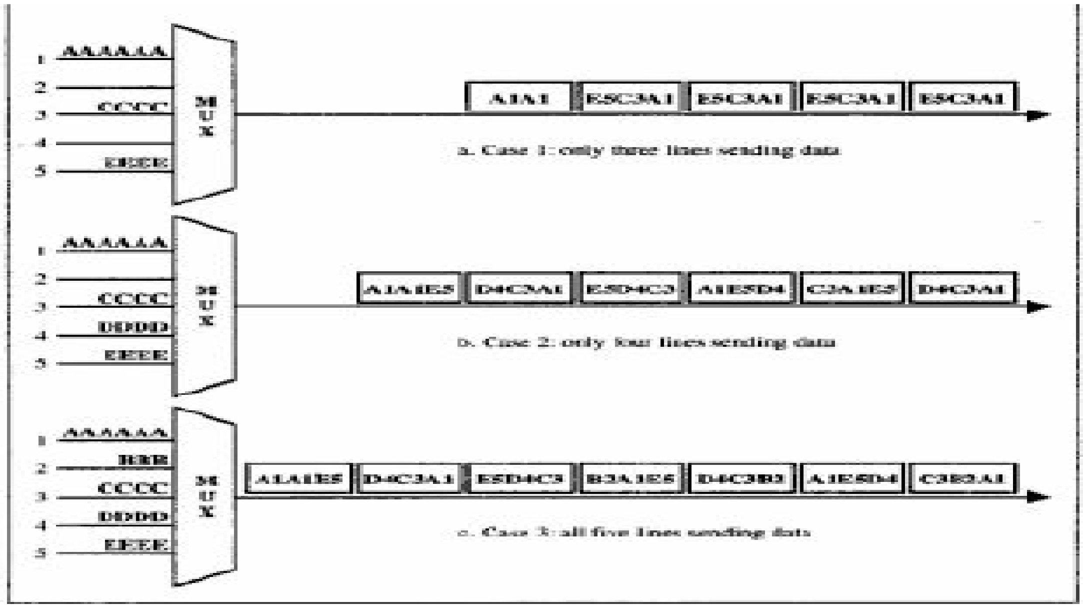


In the following figure, we have 5 stations to transfer data with a frame size of 3 slots. Here we have 3 cases.

Case 1 : out of 5 stations only 3 stations transfer data

Case 2 : out of 5 stations, only 4 stations send data.

Case 3 : All stations(5) transfer data



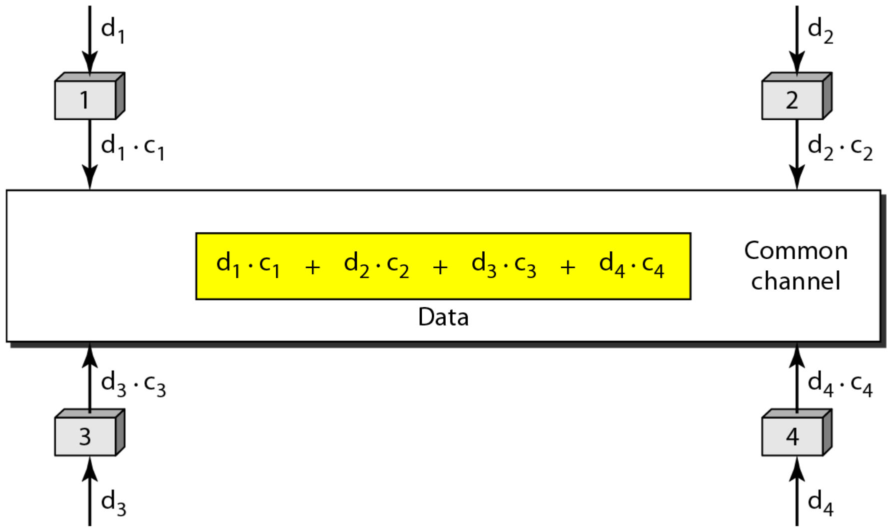
Wavelength Division Multiplexing: It is conceptually same as FDM except the multiplexing and de multiplexing involve light signals transmitted through fiber optic channels. The following figure gives an over view on WDM process. Very narrow band of light from different sources are combined to make a wider band of light. At the receiver the signals are separated by the de multiplexer.

CDMA:

In CDMA, one channel carries all transmissions simultaneously. CDMA simple means communication with different codes. Four stations namely 1,2,3,4 are connected to some channel. The data from station 1 is d1, from station 2 is d2, and so on. The code assigned to the first station is c1, to the second is c2, and so on. Assigned codes have the following properties.

1. If we multiply each code by another code, we get 0.
2. If we multiply each code by itself, we get 4.

Station 1multiplies its data by its code to get d1.c1. station 2 multiplies its data by its code to get d2.c2 and so on. The data that go on the channel is sum of all these products.

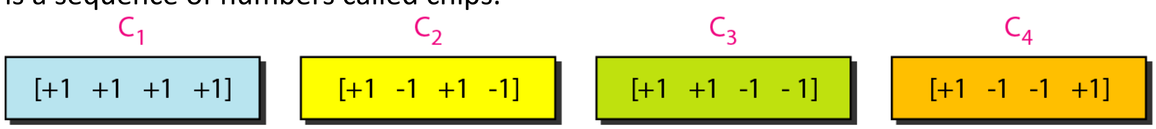


Any station that wants to receive data from one of the other three multiplies the data on the channel by the code of the sender.

Ex: suppose stations 1 and 2 are talking to each other. Station 2 wants to hear what station 1 is saying. It multiplies the data on the channel by c1.

Data=(d1.c1+d2.c2.+d3.c3+d4.c4).c1
=(d1.c1.c1+d2.c2.c1+d3.c3.c1+d4.c4.c1)
=(d1.4+0+0+0)
=4d1

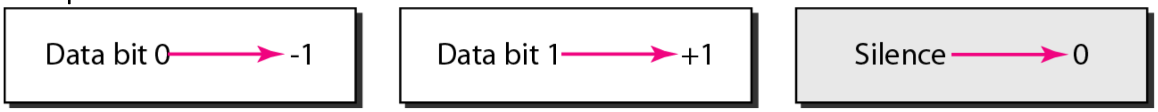
Chips: CDMA is based on the coding theory. Each station is assigned a chip code., which is a sequence of numbers called chips.



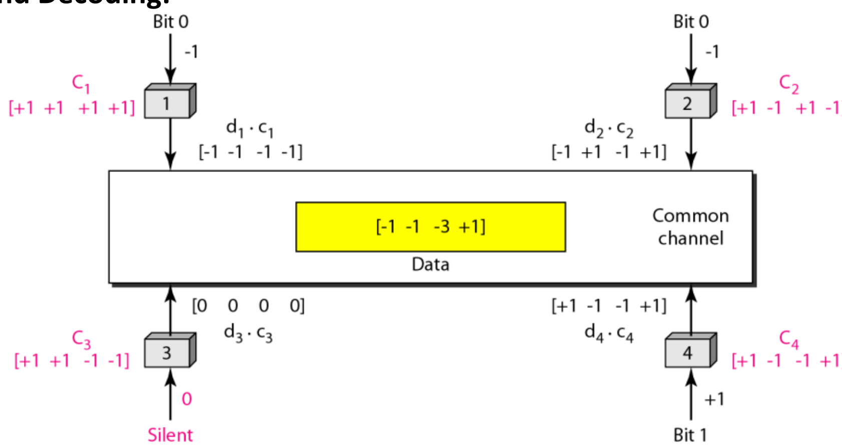
These codes are called orthogonal sequences.

- Each sequence is made of N elements, where N is the number of stations.
- If we multiply a sequence by a number, every element in the sequence is multiplied by that element. This is called multiplication of a sequence by a scalar.
  2[+1 +1 -1 -1] = [+2 +2 -2 -2]
- If we multiply two equal sequences, element by element, and add the results, we get N, where N is the number of elements in each sequence. This is called the inner product of two equal sequences.
  [+1 +1 -1 -1].[+1 +1 -1 -1] = 1+1+1+1 =4
- If we multiply two different sequences, element by element and add the results, we get 0, this is called inner product of two different sequences.
  [+1 +1 -1n -1].[+1 +1 +1 +1] = 1+1-1-1= 0
- Adding two sequences means adding the corresponding elements. The result is another sequence.
  [+1 +1 -1 -1]+[+1 +1 +1 +1]= [+2 +2 0 0]

Data Representation: If a station needs to send a 0 bit, it encodes it as -1; if it needs to send a 1 bit, it encodes it as a +1. When a station is idle, it sends no signal which is interpreted as a 0.



Encoding and Decoding:



Here station 3 is silent and is listening to station 2. Station 3 multiplies the total data on the channel by the code for station 2, to get.

[-1 -1 -3 +1].[+1 -1 +1 +1]=-4/4=-1 → means bit 0

Sequence Generation:

To generate chip sequences, we use a walsh table, a two dimensional table with an equal number of rows and columns.

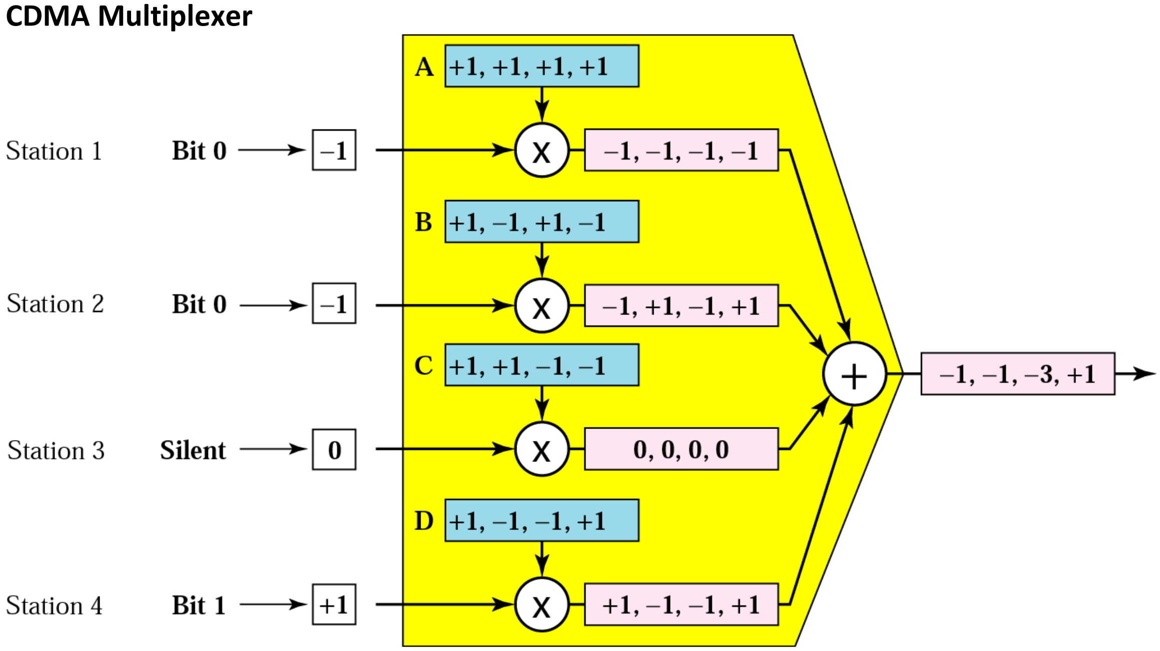
$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_{2N} = \begin{bmatrix} W_N & W_N \\ W_N & \overline{W_N} \end{bmatrix}$$

a. Two basic rules

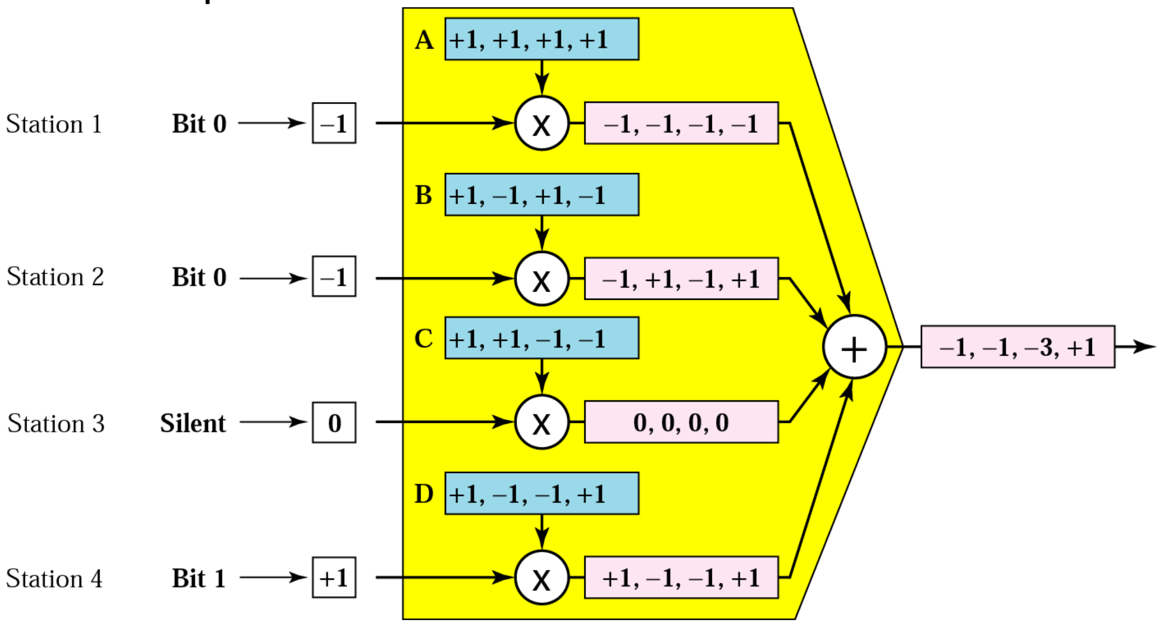
$$W_1 = \begin{bmatrix} +1 \end{bmatrix} \qquad W_2 = \begin{bmatrix} +1 & +1 \\ +1 & -1 \end{bmatrix} \qquad W_4 = \begin{bmatrix} +1 & +1 & +1 & +1 \\ +1 & -1 & +1 & -1 \\ +1 & +1 & -1 & -1 \\ +1 & -1 & -1 & +1 \end{bmatrix}$$

b. Generation of W_1, W_2, and W_4

CDMA Multiplexer



CDMA Demultiplexer



UNIT-2 QUIZ QUESTIONS

1. The Physical layer transports ------------
   a. Character streams b. ray bytes c**. raw bit streams** d. All of the above

2. Transmission media is divided into the following two types:
   a. directional or unidirectional **b. guided or unguided** c. fixed or unfixed d.All

3. At the starting of the lower end of the electro magnetic spectrum we have
   a. radio waves b. UV rays c. Infrared d. **Power and Voice**

4. ----- waves are the highest frequency electro magnetic waves.
   a. UV rays b. **Gamma rays** c. x rays d. infrared

1. If we transport data using a floppy disk, then that kind of network is
   a. **sneakernet** b. Internet c. Arpanet d. Intranet

2. The use of twists in twisted pair cables is
   a. increases speed b. decreases time delay c. **reduces cross talks** d. All

3. In fiber optics, the signals are represented as
   a. radio b. infrared c. Electric d. **Light**

4. This cable consists of inner copper core and an outer plastic insulation
   a. co axial b. **Twisted pair** c. Fiber Optic d. STP

5. This kind of cable does not affects with electrical & magnetic interferences
   a. co axial b. Twisted Pair c. **Fiber Optic** d. All

6. RG 59 cable is used for this kind of transmission
   a. Textual data b. telephone voice c. Images d. **TV broadcasting**

7. The following cable needs less number of repeaters
   a. **Fiber Optic** b. Co axial c. Twisted Pair d. All

8. Infrared waves are
   a. Omni directional b. bi directional c. **Unidirectional**

9. when we consider unguided media, usually we are referring to ------------
   a. metallic wires b. non metallic wires c. **Atmosphere** d. none of these

10. In cellular telephony, the service area is divided into small regions called -------
    a. **cells** b. cell offices c. MTSO d. relay sites.

11. The MTSO is responsible for
    a. **connecting the cell with central telephone office**
    b. assigns channels to transfer c. billing functions d. All of these

12. Searching the location of a mobile phone by MTSO is known as
    a. hand on b. **handoff** c. paging d. receiving

13. The size of a cell is determined by
    a. area terrain b. **area population** c. no of MTSO's d. All of these

14. The sharing of a medium and its path by two or more devices is known as
    a. encoding b. modulation c. line discipline d. **Multiplexing**

15. The following technique transmits analog signals
    a. **FDM** b. Synchronous TDM c. Asynchronous TDM d. b&c

16. Which one transmits digital signals
    a. FDM b. **TDM** c. WDM d. a&b

17. In synchronous TDM, for n sources, each frame contains atleast ---- slots.
    a. **n** b. n+1 c. n-1 d. 0

18. In asynchronous TDM, for n sources, each frame contains m slots, and m is –
    a. 1 less than n b. greater than n c. equal to n d. **less than n**

19. Which one transports optical signals
    a. FDM b. **WDM** c. TDM d. ALL

20. Which one needs a dedicated copper path
    a. **circuit switching** b. packet switching c. message switching d. All

21. Telegraph writers use this code
    a. Hamming code b. Encode c. **Morse code** d. Cipher

22. This kind of switching is charged based on the amount of data
    a. circuit b. **packet** c. virtual d. ATM

23. cross bar switches are feasible to
    a. large offices b. medium offices **c. small offices** d. for all

24. The switch will never block when it has --------- number of crossbars
    a. **2n-1** b. n-1 c. 2n+1 d. 2nX1

25. The time division switch works with-------------
    a. frequency slot interchanger b. **time slot interchanger** c. bandwidth

26. Which switch will have the same no of input lines and output lines
    a. **ATM switch** b. space divison c. time division

27. ATM switches face with this problem
    a. Tail blocking b. blocking c**. Head of line blocking** d. All

28. To avoid head of line blocking, queues are maintained at
    a. input line b. **output line** c. cross bars d. switches