LECTURE NOTES

UNIT-I

Network hardware, Network software, OSI, TCP/IP Reference models,
Example Networks:ARPANET, Internet.
Physical Layer: Guided Transmission media: twisted pairs, coaxial cable, fiber optics,
Wireless transmission.

Network Hardware

Types of Connection: A network is two or more devices connected through links. A link is a communications pathway that transfers data from one device to another.

There are two possible types of connections: **point-to-point and multipoint.**

Point-to-Point

A point-to- point connection provides a dedicated link between two devices. The entire capacity of the link is reserved for transmission between those two devices. Most point-to-point connections use an actual length of wire or cable to connect the two ends, but other options, such as microwave or satellite links, are also possible When you change television channels by infrared remote control, you are establishing a point-to-point connection between the remote control and the television's control system.

Multipoint

A multipoint (also called multi-drop) connection is one in which more than two specific devices share a single link In a multipoint environment, the capacity of the channel is shared, either spatially or temporally. If several devices can use the link simultaneously, it is a spatially shared connection. If users must take turns, it is a timeshared connection.

- **Netwroks based on scale:**

  The networks are classified based on their physical size. They are divided into

  LAN (local area network)

  MAN (metropolitan area network)

  WAN (wide area network).

Local area network:

- Lan's are privately owned networks with in a single buildings or campus of up to a few kilo meters in size.
- They are widely used to connect personal computers & workstations in company offices and factories to share resources (E.g.: printers) & exchange information.
- Lan's are distinguished from other kinds of network by three characters tics.

  1. Their size.

2. Their transmission technology.

3. Their topology.

- Lan's are restricted in size, which means that the worst-case transmission time is bounded and known in advance.
- It also simplifies network management.
- Lan's may use a transmission technology consisting of a cable to which all the machines are attached, like the telephone company party lines ones used in rural areas.
- Lan's used various topologies like BUS, RING, STAR, MESH and HYBRID .

Broad cast networks can be further divided into static& dynamic.

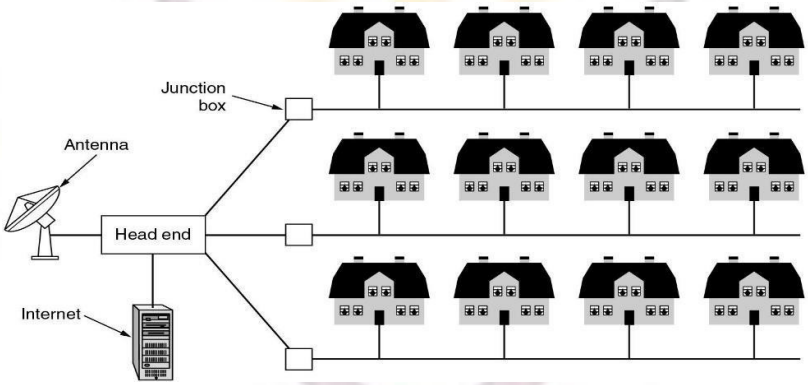
- Static allocation would be to divide time into discrete intervals and use a round robin algorithm, allowing each machine to broad cast only .when its time slot comes up.
- In dynamic system attempts to allocate the channel on demand.

Dynamic allocation divided into 2 types

- Centralized.
- Decentralized.
- In centralized channel allocation method, there is a single entity, for example, a bus arbitration unit, which determines who goes next. It might do this by accepting requests and making a decision according to some internal algorithm.
- In decentralized channel allocation method, there is no central entity; each machine must decide for itself whether to transmit.

MAN(METROPOLITAN AREA NETWORK):

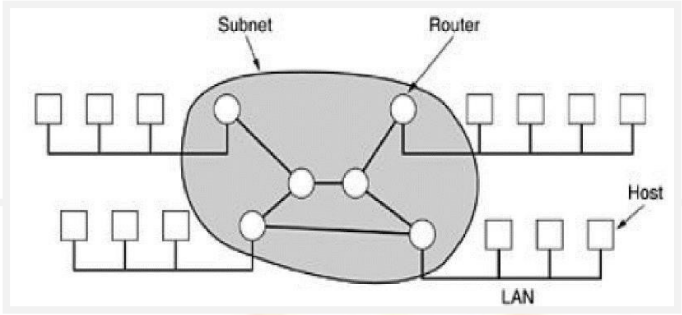
- It is basically bigger version of LAN and uses similar technology.
- It covers a city cable television network is the best example .
- Man is simplified network with no switching elements.
- Man has just one or two cables which is sent packets over one of several output lines.
- Best example for man is DQDB(distributed queue dual bus)
- DQDB consists of two unidirectional buses to which all computers are connected as shown in figure below.
- Each bus has head end, a device that initiates transmission activity.
- Traffic that is destined for a computer to the right of a center uses the upper bus; traffic to the left uses the lower bus.

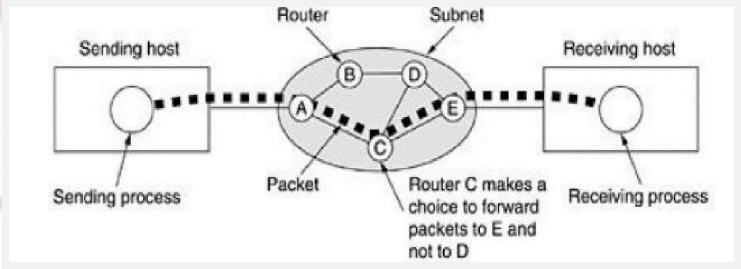


WAN(WIDE AREA NETWORK):

- Wan s are spans a large geographical area, often a country or continent.
- It contains a collection of machines intended for running user programs, call this machine hosts.
- The hosts are connected by a communication subnet
- The job of the subnet is carry messages from host to host, like telephone system carries words from speakers to listener.
- The subnet consists of two distinct components: those are transmission lines and switching elements.
- Transmission lines, move bits between machines. They can be made of copper wire, optical fiber, or even radio links.
- Switching elements are specialized computers that connect three or more transmission lines.
- When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them.
- These switching lines are also called routers.

Fig: Relations between hosts and LANs and subnets.





- Here collection of routers & communication lines that move packets from the source host to destination host.
- When a packet is sent from one router to another via one or more intermediate routers, the packets is received at each intermediate router in it's entirely, stored their until the required output line is free, and then forward.
- A subnet is organized according to this principle is called a "store-and-forward" or "packet –switched" subnet.
- When packets are small &all the same size, they are often called cells.
- When a process on some host has a message to be sent to a process on some other host, the sending host first cuts the message into packets, each one bearing its number in the sequence.
- These packets are then injected into the network one at a time in a quick succession.
- The packets are transported individually over the network &deposited at the receiving host, where they are reassembled into the original message and delivered to the receiving process.

NETWORK SOFTWARE

Network software is highly structured.

Protocol hierarchies:

- To reduce the design complexity, most networks are originated as a stack of layers or levels, each one built upon the one below it.
- The number of layers, the name of the each layer, the contents of each layer and the function of each layer differ from network to network.
- The purpose of each layer is to offer certain services to the higher layers.
- The fundamental ideas is that a particular piece of software or hard ware provides a service to its users but keeps the details of its internal state& algorithm hidden from them.
- A protocol is an agreement between the communicating parties on how communication is to proceed.
- The entities comprising the corresponding layers on different machines are called peers.
- The peer communicates by using protocol.
- In reality, no data are directly transferred from layer and on one machine to layer and on another machine.
- Instead, each layer passes data & control information to the layer immediately below it, until the lowest layer is reached.
- Below layer is the physical medium through which actual communication occurs.
- Between each pair of adjacent layers is an interface.
- The interface defines primitive operations & services. the lower layer makes available

to the upper one.

- **A set of layers and protocols is called network architecture.**
  - A list of protocols used by a certain system, one protocol per layer is called protocol stack.

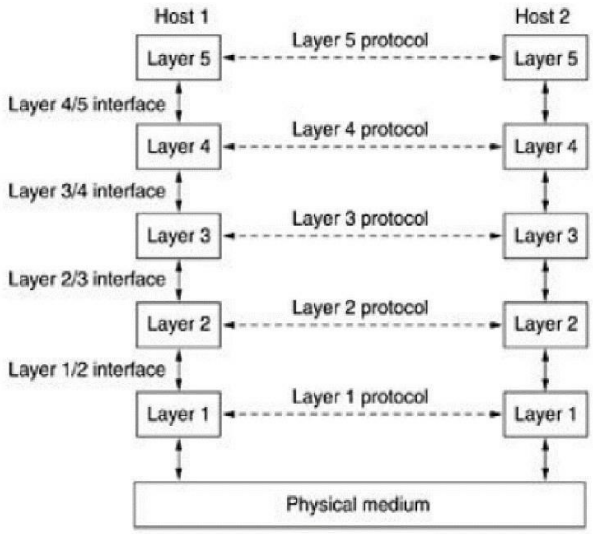
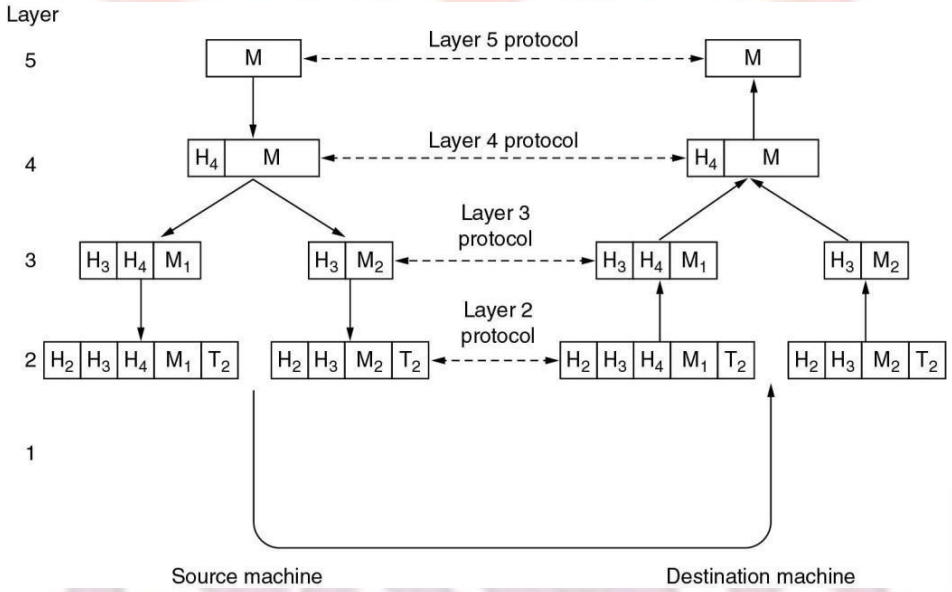


Fig: layers, protocals, interfaces



DESIGN ISSUES FOR THE LAYERS:

- As a consequence of having multiple destinations, addressing is needed in order to specify a specific destination.
- Another set of design decision concerns the rules for data transfer.
- In some systems, data only travel in one direction, in other, data can go both ways.
- Many networks provide at least two logical channels per connection, one for normal data &one for urgent data.Error control is an important issue because physical communication circuits arenot perfect. Many error –detecting &error –

correcting codes are known, but both ends of the connection must agree on which one is being used.

- The receiver must have some way of telling the sender which messages have been correctly received & which has not.
- Flow control it occurs at every level how to keep a fast sender from swapping a slow receiver with data.
- Accepting long messages, this property lead to the mechanisms for disassembling, transmitting & then reassembling messages.

Connection –oriented & connectionless services:

- In connection oriented service, the service user first establishes a connection, uses the connection, and the releases the connection.
- The essential aspect of a connection is that it acts like a tube; the sender pushes objects (bits) in at one end, and receiver takes out at the other end.
- In most cases order is presented so that the bits arrive in order they were sent.
- Advantage is guarantee of data delivery.

  Ex: telephone system.

- In connection less service, no need of establishment the connection, uses the connection, the user just sends the data.
- Here no guarantee of data delivery.

  Ex: postal system.

- Each service can be characterized by quality of service.
- Services are reliable in the sense that they never lose data.
- A reliable service implemented by having the receiver acknowledges the receipt of each message so that sender is sure that it arrived.
- Reliable connection oriented service have two minor variations: message sequences & byte stream.
- Connection less service is also called datagram service.
- Connection oriented service is also called acknowledged datagram service.

  Ex: register post.

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

SERVICE PRIMITIVES:

- A service is formally specified by a set of primitives (operations) available to a user process to access the service.
- The set of primitives available depends on the nature of the service being provided.
- The primitives for connection –oriented service are different from those of connectionless service.
- As a minimal example of the service primitives that might provided to implement a reliable byte stream in a client-server environment is listed below.

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Fig: five service primitives for implementing a simple connection-oriented service.

Listen: executed by server. It means server is ready to accept connection. It blocks the process of server until connection request comes.

Connect: executed by client to request the connection. It sends connection req. TPDU(transport protocol data unit) (packet) to server. If server is able to handle connection then it sends Connection accepted TPDU.

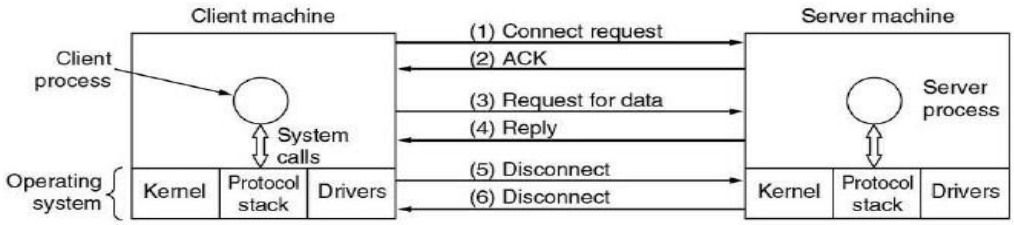
Send: executed to send data to other end.

Receive: when ever client or server is waiting for data, It executes Receive primitive. This is also blocking primitive.

Disconnect: to disconnect connection. Two variants of disconnect.

1. Asymmetric: either side issues disconnect, connection will be released.

2. Symmetric: both the side need to separately execute disconnect.



Packets sent in a simple client-server interaction on a connection-oriented network.

The relationship of services to protocols:

- A service is a set of primitives (operations) that a layer provides to the layer above it.
- The service defines what operations the layer is prepared to perform on behalf of its users.
- A protocol is a set of rules used on how the communication should proceed.
- Lower layer is always a service provider.
- Upper layer is an always a service user.
- Protocol is used for implementation purpose.
- Service is not used for implementation purpose.

OSI REFERENCE MODEL

The OSI reference model:

The protocol associated with the OSI model are rarely used any more, the model itself is actually quit general and still valid.

- This model is developed by international standards organization.
- This model is also called ISOOSI model (open system interconnection).
- It deals with connecting open systems-that is, systems that are open for communication with other systems.
- The OSI model has several layers.

Principles:

1. Each layer should be created where a different level of abstraction is needed.
2. Each layer should perform well defined functions.
3. Each layer should define internationally standardized protocols.
4. Layer boundaries should be chosen to minimize the information flow across the interfaces.
5. The no .of layers should be appropriate for the requirements.

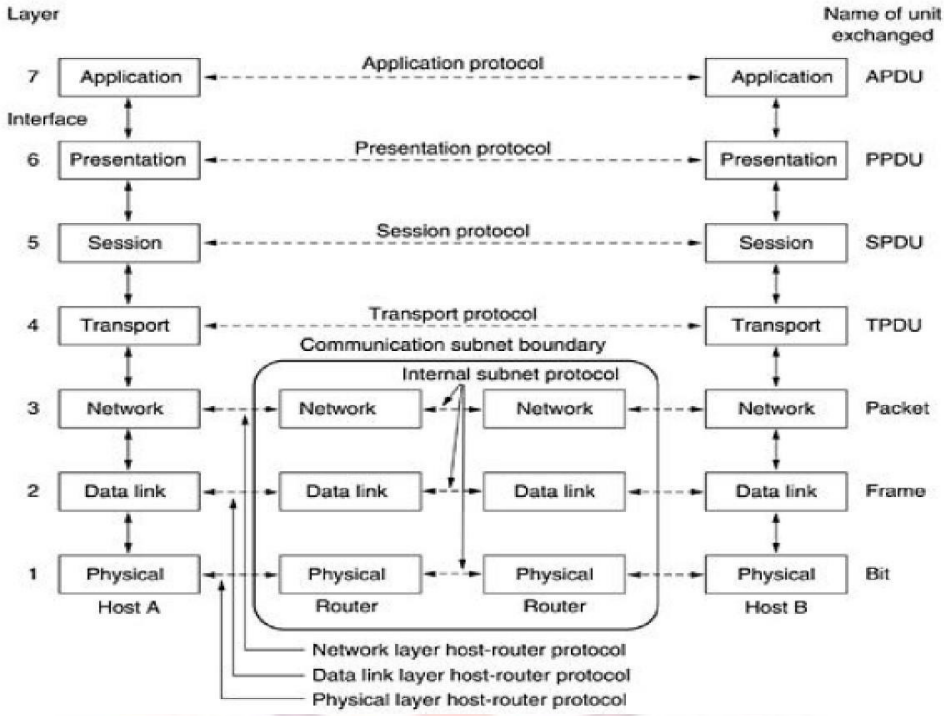


Fig: OSI reference model.

Physical layer:

- It is concerned with transmitting raw bits over a communication channel.
- It is concerned with insuring that when one side sends a 1 bit, the otherside receives a 1 bit, not a '0' bit.
- Physical layer covers the interface between devices.
- It identifies the rules to pass bits from source to destination
- The design issues deal with mechanical, electrical, timing interfaces & the physical transmission medium.

Data link layer:

- The data link layer converts the raw transmission of bots into an error free data communication channel.
- It accomplishes this task by having the sender break up the input data into data frames & transmits the frames sequentially.
- If the service is reliable, the receiver confirms correct receipt of each frame by sending back an acknowledgement frame.
- It handles loss, damage & duplicated frames. This process is called the error control.
- Handles slowing down a fast transmitter due to the slow receiver using the methods such as buffering. This process is called flow control.

- A sub layer of the data link layer called medium access control sub layer deals with the problems in broadcast network.

Network layer:

- The network layer controls the operation of the subnet.
- It routs packets from source to destination host.
- It controls the congestion, caused by hosts sending too many data packets into the network at a rate faster than the network can handle.
- Deals with addressing problem that arises when more than two dissimilar networks are connected together.
- In a broadcast network the routing problem is simple, so the network layer is often thin or no existing.

Transport layer:

- The basic functions of the transport layer is to accept the data from above layer & split it up into smaller units, passes these to the network layer, and ensure that the pieces all arrive correctly at the other end.
- It provides some services to the session layer.
- The most popular type of service is an error free point-to-point channel that delivers messages or bytes in the order in which they were sent.
- Transport layer is a true end-to-end layer, all the from source to destination.
- A program on the source machine carries on a conversation with a similar program on the destination machine, using the message headers & control messages.

The session layer:

- The session layers allow users on different machines to establish sessions between them.
- Sessions offer various services.
- Dialog control: keeping track of whose turn it is to transmit.
- Token management: preventing two parties from attempting the same critical operation at the same time.
- Synchronization: check pointing long transmissions to allow them to continue from where they were after a crash.

Presentation layer:

- The presentation layer deals with the syntax and semantics of the information transmitted.

- The presentation layer allows higher level data structure to be defined & exchanged.

Application layer:

- This layer contains protocols that are commonly needed by users.
- Widely used application protocol is HTTP (hyper text transfer protocol) which is basis for www.
- Other application protocols are used for file transfer, electronic mail & network news.

1.5.TCP/IP

The TCP/IP reference model:

This models it self is not of much use but the protocols are widely used.

TCP/IP transmission control protocol / internet protocol.

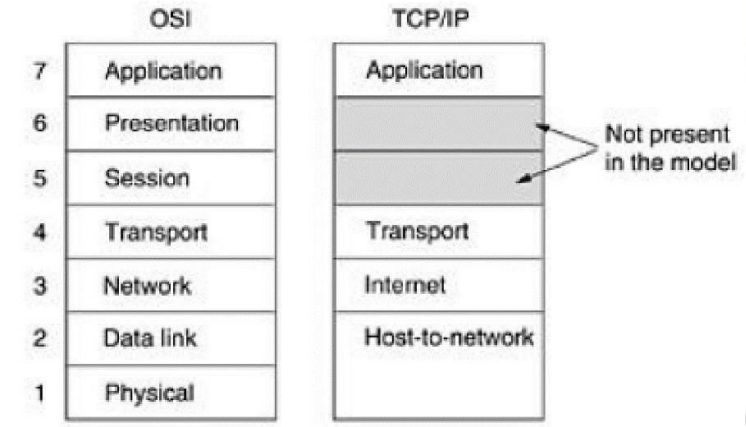
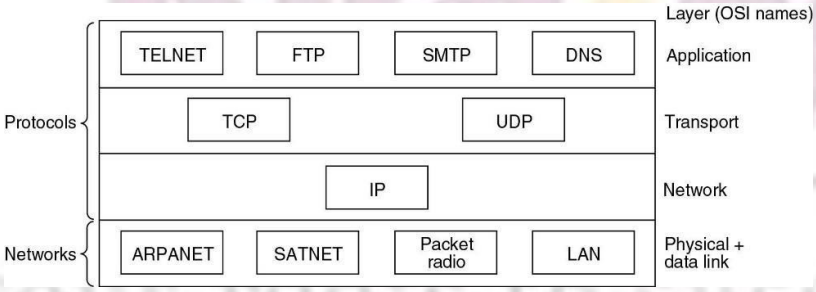


Fig:TCP/IP reference model.



Protocols and networks in the TCP/IP model

Host-to-network layer:

- It corresponds to physical & data link layer of OSI model.

- It does not say what happens here, except that host has to connect to the network using some protocol. So it can send IP packets to it.
- This protocol various from host to host and network to network.

Internet layer:

- It is similar to the network layer in the OSI reference model.
- The difference is it provides only connectionless service it is based on packet switching.
- The internet layer injects packets on the network and they travelled independently to destination.
- The internet layer defines an official packet format & protocol called IP.
- The job of the internet layer is to deliver IP packets to the destination and achieve congestion control.

Transport layer:

- It is equivalent to the transport layer in the OSI reference model except that it provides 2 types of services both connections oriented & connection less services.
- Connection oriented services is implemented by TCP.
- This allows a bytes stream originating on one machine to be delivered without error on any other machine in the internet.
- Connectionless service is implemented by UDP.
- It provides unreliable service & does not provide sequence & flow control.
- It is used in application such as client-server type reply quires & application in which prompt delivery is more important than accuracy.

Application layer:

- It contains all the higher level protocols dealing with applications such as file transferring, e-mails, telnet.
- The FTP provides where to move data efficiently from one machine to another.
- Other protocols SMTP, DNS, are also present in the application layer.

Difference between OSI and TCP/IP:

- Concepts of services, interfaces, protocols are not explained in TCP/IP.
- We can change the protocols easily in OSI than TCP/IP
- We can maintain sub layers in OSI & no need of maintaining sub layers in TCP/IP.
- In OSI reference network we are using both connection oriented and connection less services.

- In OSI transport layer we are using only connection oriented service.
- In TCP/IP network layer we are using only connection less service.
    - In TCP/IP transport layer we are using both connection less and connection orientedservices.

Criticism Of The TCP/IP Model And Its Protocols

The TCP/IP model and protocols have their problems too.

1. The model does not clearly distinguish the concepts of services, interfaces, and protocols.
2. TCP/IP model is not at all general and is poorly suited to describing any protocol stack other than TCP/IP.
3. **T**he link layer is not really a layer at all. The distinction between an interface and layer is crucial.

The TCP/IP model does not distinguish between the physical and data link layers. These are completely different. The physical layer has to do with the transmission characteristics of copper wire, fiber optics, and wireless communication. The data link layer's job is to delimit the start and end of frames and get them from one side to the other with the desired degree of reliability. A proper model should include both as separate layers. The TCP/IP model does not do this.

EXAMPLE NETWORKS

ARPANET stands for **Advanced Research Projects Agency NET**. ARPANET was first network which consisted of distributed control. It was first to implement TCP/IP protocols. It was basically beginning of Internet with use of these technologies. It was designed with a basic idea in mind that was to communicate with scientific users among an institute or university.

History of ARPANET :

ARPANET was introduced in the year 1969 by Advanced Research Projects Agency (ARPA) of US Department of Defense. It was established using a bunch of PCs at various colleges and sharing of information and messages was done. It was for playing as long separation diversions and individuals were asked to share their perspectives. In the year 1980, ARPANET was handed over to different military network, Defense Data Network.

Characteristics of ARPANET :

1. It is basically a type of WAN.
2. It used concept of Packet Switching Network.
3. It used Interface Message Processors(IMPs) for sub-netting.
4. ARPANETs software was split into two parts- a host and a subnet.

Advantages of ARPANET :

- ARPANET was designed to service even in a Nuclear Attack.
- It was used for collaborations through E-mails.
- It created an advancement in transfer of important files and data of defense.

Limitations of ARPANET :

- Increased number of LAN connections resulted in difficulty handling.
- It was unable to cope-up with advancement in technology.

INTERNET

Internet is a world-wide global system of interconnected computer networks. Internet uses the standard Internet Protocol (TCP/IP). Every computer in internet is identified by a unique IP address.

- Internet is a world-wide global system of interconnected computer networks.
- Internet uses the standard Internet Protocol (TCP/IP).
- Every computer in internet is identified by a unique IP address.
- IP Address is a unique set of numbers (such as 110.22.33.114) which identifies a computer location.
- A special computer DNS (Domain Name Server) is used to give name to the IP Address so that user can locate a computer by a name.
- For example, a DNS server will resolve a name **http://www.google.com** to a particular IP address to uniquely identify the computer on which this website is hosted.
- Internet is accessible to every user all over the world.

The concept of Internet was originated in 1969 and has undergone several technological & Infrastructural changes as discussed below:

- The origin of Internet devised from the concept of **Advanced Research Project Agency Network (ARPANET).**
- **ARPANET** was developed by United States Department of Defense.
- Basic purpose of ARPANET was to provide communication among the various bodies of government.
- Initially, there were only four nodes, formally called **Hosts.**
- In 1972, the **ARPANET** spread over the globe with 23 nodes located at different countries and thus became known as **Internet.**
- By the time, with invention of new technologies such as TCP/IP protocols, DNS, WWW, browsers, scripting languages etc.,Internet provided a medium to publish and access information over the web.

Advantages

Internet covers almost every aspect of life, one can think of. Here, we will discuss some of theadvantages of Internet:

- Internet allows us to communicate with the people sitting at remote locations. There arevarious apps available on the wed that uses Internet as a medium for communication. One can find various social networking sites such as:
  - Facebook
  - Twitter
  - Yahoo
  - Google+
  - Flickr
  - Orkut
- One can surf for any kind of information over the internet. Information regarding various topics such as Technology, Health & Science, Social Studies, Geographical Information, Information Technology, Products etc can be surfed with help of a searchengine.
- Apart from communication and source of information, internet also serves a medium for entertainment. Following are the various modes for entertainment over internet.
  - Online Television
  - Online Games
  - Songs
  - Videos
  - Social Networking Apps
- Internet allows us to use many services like:
  - Internet Banking

- Matrimonial Services
- Online Shopping
- Online Ticket Booking
- Online Bill Payment
- Data Sharing
- E-mail

- Internet provides concept of **electronic commerce**, that allows the business deals to beconducted on electronic systems

Disadvantages

However, Internet has prooved to be a powerful source of information in almost every field, yet thereexists many disadvanatges discussed below:

- There are always chances to loose personal information such as name, address, credit card number. Therefore, one should be very careful while sharing such information. One should use credit cards only through authenticated sites.
- Another disadvantage is the **Spamming**.Spamming corresponds to the unwanted e- mails in bulk. These e-mails serve no purpose and lead to obstruction of entire system.
- **Virus** can easily be spread to the computers connected to internet. Such virus attacks may cause your system to crash or your important data may get deleted.
- Also a biggest threat on internet is pornography. There are many pornographic sites that can be found, letting your children to use internet which indirectly affects the children healthy mental life.
- There are various websites that do not provide the authenticated information. This leadsto misconception among many people.

PHYSICAL LAYER

The purpose of the physical layer is to transport a raw bit stream form one machine to another fortransmission of data various physical media can be used.

- Media are roughly grouped into guided media and unguided media.
- In guided media the information is passed from source to destination using wires.
- In unguided media the information is passed from source to destination without using any wires.

GUIDED TRANSPORT MEDIA:

Guided media are of four types

1. Magnetic media

2. Twisted media
3. Coaxial media
4. Fiber optics.

Magnetic media:

- In this method the data is transmitted by writing them onto magnetic tape or removable mediaand transport the tape or disks physically to the destination machine.
- It is more cost effective for applications in which high bandwidth is the key factor.
- The delay characteristics are poor as the time measured in minutes or hours.
- The bandwidth characteristics of magnetic tape are excellent.

Twisted pair:

- Twisted pair consists of two insulated copper wires typically about 1mm thick.
- The two wires are twisted together because twisting two parallel line wires constitute a fineantenna.
- The main application is telephone system.
- For longer distances repeaters are needed.
- Can transmit either analog or digital signals.
- Bandwidth depends on the thickness of the wire and the distance traveled.
- These are widely used due to their adequate performance and low cost.
- Category 3 twisted pairs consist of two insulated wires gently twisted together.
- In a plastic sheath four such pairs are grouped to keep them together and to protect the wires.
- Category 5 twisted pairs are more advanced.

- These are similar to category 3 pairs but with more twists per centimeter.
- Over longer distances it provides better quality signal and suitable for high speed computer communication.

Fig: Category 3 Fig: Category 5

Coaxial cable:

- Coaxial cables can transmit data over longer distances at higher speeds. Two kinds of coaxial cable are used.
- 50-ohm cable is used for digital transmission.
- 75-onm cable is commonly used for analog transmissions and cable television.
- Coaxial cable consists of a shift copper wire as the surrounded by an insulating material.
- The insulator is encased by a cylindrical conductor, often as a closely woven braided mesh.
- The outer conductor is covered in a protective plastic sheath.
- Possibility of bandwidth depends on cable quality, length and data signal.
- Coaxial is still widely used for cable television and metropolitan area networks.

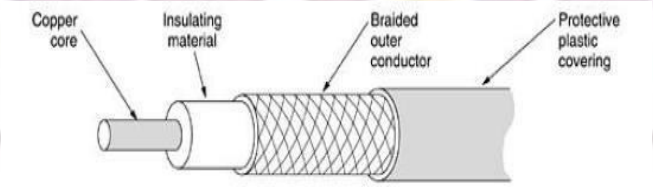


Fig: Coaxial Cable

Fiber optics:

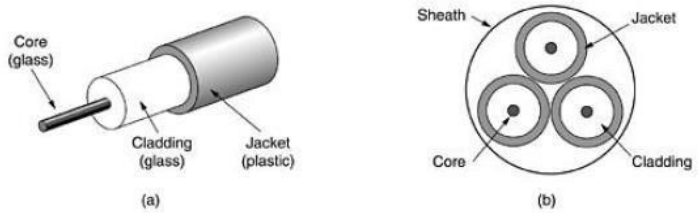


Fig: Side view of a single fiber **Fig: End view of sheath with 3 fibers**

- In this transmission medium we have three key components: light source, transmission medium and detector.
- Here pulse of light indicates a 1 bit and the absence of light indicates a 0 bit.
- Transmission medium is an ultra thin fiber of glass.
- Detector generates an electrical pulse when light falls on it.
- To an optical fiber one end is attached a light source and detector to the other end.
- Unidirectional data transmission we have it accepts an electrical signal converts & transmission by light pulses & then reconverts the o/p to an electrical signal at the receiving end.
- When a light ray passes from one medium to another the ray is refracted at the boundary
- Any light ray incident on the boundary above the critical angle will be reflected internally
- Many different rays will be bouncing around at different angles. Each ray is having a differentmode.
- It fibers diameter is reduced to a few wave lengths of light. The fiber acts like a wave guide &light travel in straight line.
- If light travel in it line in fiber is called " Single mode fiber"
- Single mode fibers are more expensive and are used for longer distances.
- The attenuation of light through glass depends on the wavelength of the light.
- Through fiber light pulses are sent they spread out in length as they propagate
- This spreading is called "chromatic dispersion" .

Fiber cables:

Fibers can be connected in three different ways

1. They can terminate in connectors and plugged into fiber sockets. Connections lose about 10 to 20 %of light.
2. They can be spliced mechanically mechanical splices lay the carefully cut ends next to each other ina special sleeve and clamp them in place
3. Two pieces of fiber can be fused to form a connection.

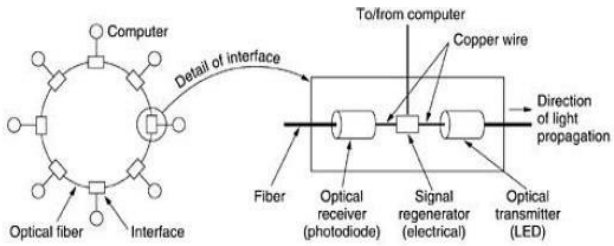


Fig: A Fiber Optic Ring with Active Repeaters

- LED's (Light emitting Diodes) and semiconductor lasses are the two light sources used to dothe signaling.
- The receiving end of an optical fiber consists photodiode, which gives of an electrical pulsewhen struck by light.
- Fiber optics can be used for LANS.
- The problem is to realize that a ring network is just a collection of point-to-point links.
- The interface at each computer passes the light stream through the next link and allowcomputer to send and accept messages.
- Two types of interfaces are used
- A passive interface consists of taps fused on to the main fiber.
- One tap has an LED or laser diode at the end of it(for transmitting) and the other has a photodiode (for receiving)
- The tap is completely passive and reliable because a broken LED and photodiode does notbreak the ring. It just takes one computer offline.
- The other interface is active repeater. In this incoming light is converted into electrical signal,if the signal is weak, it is regenerated to full strength, and retransmitted as light.
- If an active repeater fails, the ring is broken and network goes down.
- There is no limit on the total size of the ring as the signal is regenerated at each interface theindividual computer links can be kilometers long with no limit.
- The passive interface loses light at each junction the no of computers and ring lengths aregreatly restricted.
- We can build a LAN by using fiber optics other than ring topology.
- It is possible to have hardware broadcasting by using the passive star construction.
- Each interface has a fiber running from its transmitter to a silica cylinder, the incoming fiber are fused to one end of the cylinder.

- Fibers fused to other end of the cylinder are run to each of the receivers.
- In this broadcast is achieved, whenever an interface emits a light pulse. It is diffused insidethe passive star to illuminate all the receivers.

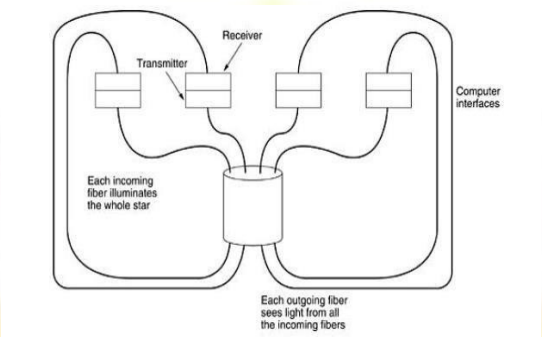


Fig: A Passive star connection with a fiber optics

Unguided transmission media (or) wireless transmission:

Radio transmission:

These are widely used for communication because these waves are easy to generate, travel longdistances and penetrate buildings easily.

- Radio waves are Omni directional, means that the waves travel in all directions from thesource.
- No need to align the transmitter & receiver physically.
- Radio waves are frequency dependent.
- At low frequencies, radio waves pass through obstacles well, at high frequencies the wavestravel in straight lines and bounce off obstacles.

Microwave transmission:

- The waves travel in straight lines at above 100MHZ.
- The energy is concentrated into a small beam by means of a parabolic antenna.
- Here the transmitting and receiving antennas must be accurately aligned with each other.
- This allows multiple transmitters lined up in a row to communicate with multiple receivers ina row.
- At lower frequencies, microwaves do not pass through buildings.
- Even through the beam may be well focused at the transmitter there is some divergence inspace.
- Some waves may reflect and may take slightly longer to arrive than the direct waves.

- The delayed waves arrive out of phase with the direct waves and cancel the signal. This effectis called "multipath fading".
- It is frequently and weather dependent.
- Microwave communication is widely used for long distance communication.
- It is also inexpensive.

Infrared and millimeter waves:

- In fared and millimeter waves are widely used for short range communication.
- These waves are directional, cheap and easy to build.
- These3 waves are used in remote controls used on television VCR's and stereos.
- These infrared waves do not pass through solid objects.
- Infrared system in one room of a building will not interface with a similar system in adjacentrooms.

Light wave transmission:

- Main application is to connect the LAN's in two buildings via lasers placed on their roof tops.
- Optical signaling using lasers is unidirectional.
- So each building needs its own laser & its own photo detector.
- This is of low cost and offers high band width and also easy to install.
- Disadvantage is that laser beams cannot penetrate rain or fog but normally work well on sunnydays.