UNIT I

FOUNDATIONS OF COMPUTER NETWORKS

A computer network or data network is a telecommunications network which allows computers to exchange data. In computer networks, networked computing devices pass data to each other along network links (data connections). Data is transferred in the form of packets. The connections between nodes are established using either cable media or wireless media. The best- known computer network is the Internet.

To build a computer network is defining what a network is and understanding how it is used to help a business meet its objectives. A network is a connected collection of devices and end systems, such as computers and servers, which can communicate with each other.

In the simplest form, data transfer can take place between two devices which are directly connected by some form of communication medium. But it is not practical for two devices to be directly point to point connected. This is due to the following reasons:

i) The devices are situated at remote places.

ii) There is a set of devices, each of whom may require connecting to others at various times.

iii) Solution to this problem is to connect each device to a communication network.

Computer Networks means interconnected set of autonomous systems that permit distributed processing of information.

These are the four major categories of physical components in a computer network:

- Personal computers (PCs): The PCs serve as endpoints in the network, sending and receiving data.
- Interconnections: The interconnections consist of components that provide a means for data to travel from one point to another point in the network. This category includes components such as the following:
  - Network interface cards (NICs) that translate the data produced by the computer into a format that can be transmitted over the local network
  - Network media, such as cables or wireless media, that provide the means by which the signals are transmitted from one networked device to another

- Connectors that provide the connection points for the media
- Switches: Switches are devices that provide network attachment to the end systems and intelligent switching of the data within the local network.
- Routers: Routers interconnect networks and choose the best paths between networks.
- The best-known computer network is the Internet.

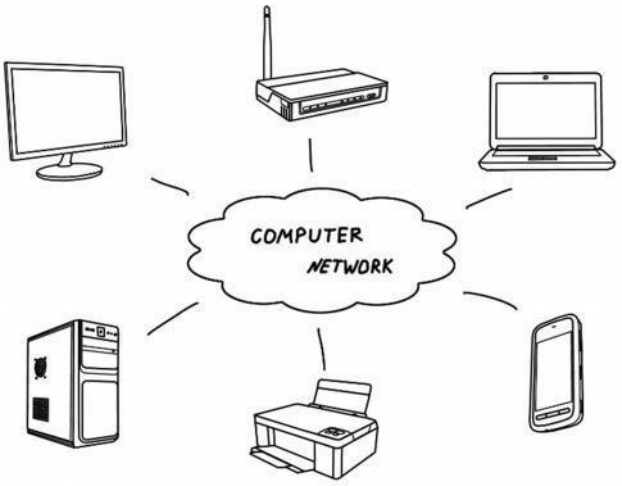


Figure 1 : Computer Network

Advantages of Computer Networks

- File sharing

  The major advantage of a computer network is that is allows file sharing and remote file access. A person sitting at one workstation that is connected to a network can easily see files present on another workstation, provided he is authorized to do so.

- Resource sharing

  All computers in the network can share resources such as printers, fax machines, modems, and scanners.

- Better connectivity and communications

  It allows users to connect and communicate with each other easily. Various communication applications included e-mail and groupware are used. Through e-mail, members of a network can send message and ensure safe delivery of data to other members, even in their absence.

- Internet access

  Computer networks provide internet service over the entire network. Every single computer attached to the network can experience the high speed internet.

- Entertainment

  Many games and other means of entertainment are easily available on the internet. Furthermore, Local Area Networks (LANs) offers and facilitates other ways of enjoyments, such as many players are connected through LAN and play a particular game with each other from remote location.

- Inexpensive system

  Shared resources mean reduction in hardware costs. Shared files mean reduction in memory requirement, which indirectly means reduction in file storage expenses. A particular software can be installed only once on the server and made available across all connected computers at once. This saves the expense of buying and installing the same software as many times for as many users.

- Flexible access

  A user can log on to a computer anywhere on the network and access his files. This offers
  flexibility to the user as to where he should be during the
  course of his routine.

- Instant and multiple access

  Computer networks are multiply processed .many of users can access the same information
  at the same time. Immediate commands such as printing commands can be made with the help of computer networks.

Disadvantages of Computer Networks

- Lack of data security and privacy

  Because there would be a huge number of people who would be using a computer network
  to get and share some of their files and resources, a certain user's security would be always at risk. There might even be illegal activities that would occur, which you need to be careful about and aware of.

- Presence of computer viruses and malwares

  If even one computer on a network gets affected by a virus, there is a possible threat for the
  other systems getting affected too. Viruses can spread on a network easily, because of the inter- connectivity of workstations. Moreover, multiple systems with common resources are the perfect breeding ground for viruses that multiply.

- Lack of Independence

  Since most networks have a centralized server and dependent clients, the client users lack any freedom whatsoever. Centralized decision making can sometimes hinder how a client user wants to use his own computer.

- Lack of Robustness

As previously stated, if a computer network's main server breaks down, the entire system would become useless. Also, if it has a bridging device or a central linking server that fails, the entire network would also come to a standstill.

- Need an efficient handler

For a computer network to work efficiently and optimally, it requires high technical skills and know-how of its operations and administration. A person just having basic skills cannot do this job. Take note that the responsibility to handle such a system is high, as allotting permissions and passwords can be daunting. Similarly, network configuration and connection is very tedious and cannot be done by an average technician who does not have advanced knowledge.

Use (Applications) of Computer Networks

The key to utilizing multiple resources on a data network is having applications that are aware of these communication mechanisms. Although many applications are available for users in a network environment, some applications are common to nearly all users.

- Financial services

Nowadays, almost all the financial services depend on the computer network. You can access the financial services across the world. For example, a user can transfer money from one place to another by using the electronic fund transfer feature. You can use networking in various financial areas such as ATM, foreign exchange and credit history search.

- Business

Nowadays, most of the works of businesses are done over the computers. To exchange the data and ideas, you need an effective data and resources sharing features. To do this, you need to connect the computer with each other through a network. For example, a person of one department of an organization can share or access the electronic data of other department through network.

- Email services

A computer network provides you the facility to send or receive mails across the globe in few seconds.

- Mobile applications

By using the mobile applications, such as cellular or wireless phones, you can communicate

(exchange your views and ideas) with one other.

- Directory services
  It provides you the facility to store files on a centralized location to increase the speed of search operation worldwide.
- Teleconferencing
  It contains voice conferencing and video conferencing which are based in networking. In teleconferencing the participants need not to be presented at the same location.

Types of Computer Networks

LAN (Local Area Network)

- It is privately-owned networks within a single building or campus of up to a few kilometres in size.
- They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information.
- LANs are easy to design and troubleshoot
- In LAN, all the machines are connected to a single cable.
- Different types of topologies such as Bus, Ring, Star and Tree are used.
- The data transfer rates for LAN is up to 10 Gbits/s.
- They transfer data at high speeds. High transmission rate are possible in LAN because of the short distance between various computer networks.
- They exist in a limited geographical area.
- Advantages
  - LAN transfers data at high speed.
  - LAN technology is generally less expensive.

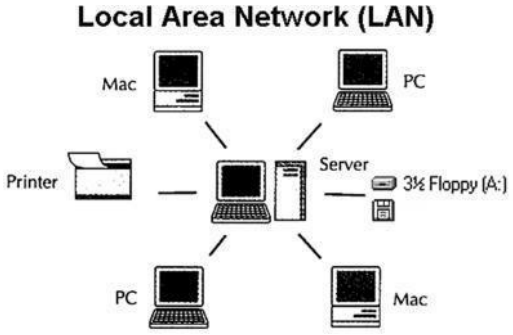


Figure 2: Local Area Network

MAN (Metropolitan Area Network)

- MAN is a larger version of LAN which covers an area that is larger than the covered by LAN but smaller than the area covered by WAN.
- A metropolitan area network or MAN covers a city. The best-known example of a MAN is the cable television network available in many cities.
- MAN connects two or more LANs.
- At first, the companies began jumping into the business, getting contracts from city governments to wire up an entire city.
- The next step was television programming and even entire channels designed for cable only.

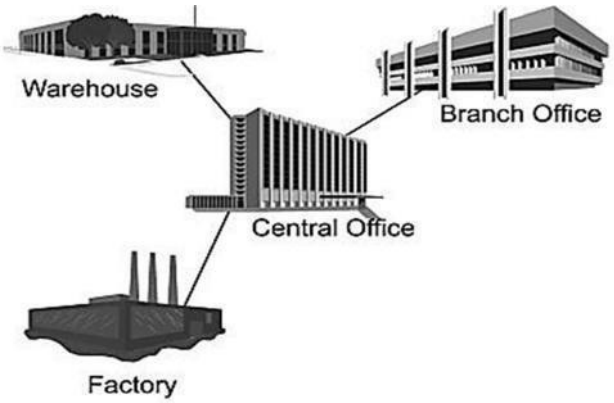


Figure 3: Metropolitan Area Network

WAN (Wide Area Network)

- WAN spans a large geographical area, often a country or region.
- WAN links different metropolitan's countries and national boundaries there by enabling easy communication.
- It may be located entirely with in a state or a country or it may be interconnected around the world.
- It contains a collection of machines intended for running user (i.e., application) programs. We will follow traditional usage and call these machines hosts.
- The communication between different users of WAN is established using leased telephone lines or satellite links and similar channels.

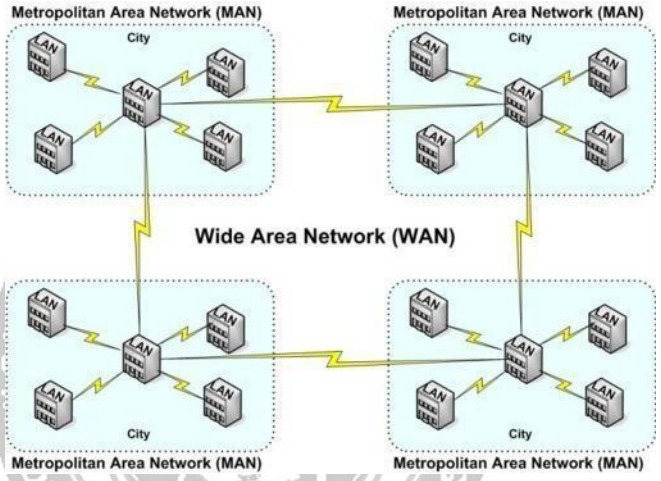


Figure 4: Wide Area Network

Difference between LAN, MAN and WAN.

Parameter	LAN	MAN	WAN
Area covered	Covers small area. i.e. within building	Covers larger than LAN & smaller than WAN	Covers large area
Error rates	Lowest	Moderate	Highest
Transmission speed	High speed	Moderate speed	Low speed
Equipment cost	Inexpensive	Moderate expensive	Most expensive
Design & maintenance	Easy	Moderate	Difficult

Internet

- The internet is a type of world-wide computer network.
- The internet is the collection of infinite numbers of connected computers that are spread across the world.

- We can also say that, the Internet is a computer network that interconnects hundreds of millions of computing devices throughout the world.
- It is established as the largest network and sometimes called network of network that consists of numerous academic, business and government networks, which together carry various information.
- Internet is a global computer network providing a variety of information and communication facilities, consisting of interconnected networks using standardized communication protocols.
- When two computers 

end and receive all kinds of ir eo, and computer programs.

Figure 5: Some pieces of the Internet

Protocol

- A protocol is a set of rules that governs (manages) data communications.
- Protocols defines methods of communication, how to communicate, when to communicate etc.
- A protocol is an agreement between the communicating parties on how communication is to proceed.
- Important elements of protocols are
  1. Syntax
  2. Semantics
  3. Timing
- Syntax:- Syntax means format of data or the structure how it is presented e.g. first eight bits are for sender address, next eight bits are for receiver address and rest of the bits for message data.
- Semantics:- Semantics is the meaning of each section of bits e.g. the address bit means the route of transmission or final destination of message.
- Timing:- Timing means, at what time data can be sent and how fast data can be sent.
- Some protocols also support message acknowledgement and data compression designed for reliable and/or high-performance network communication.
- Example: HTTP, IP, FTP etc…

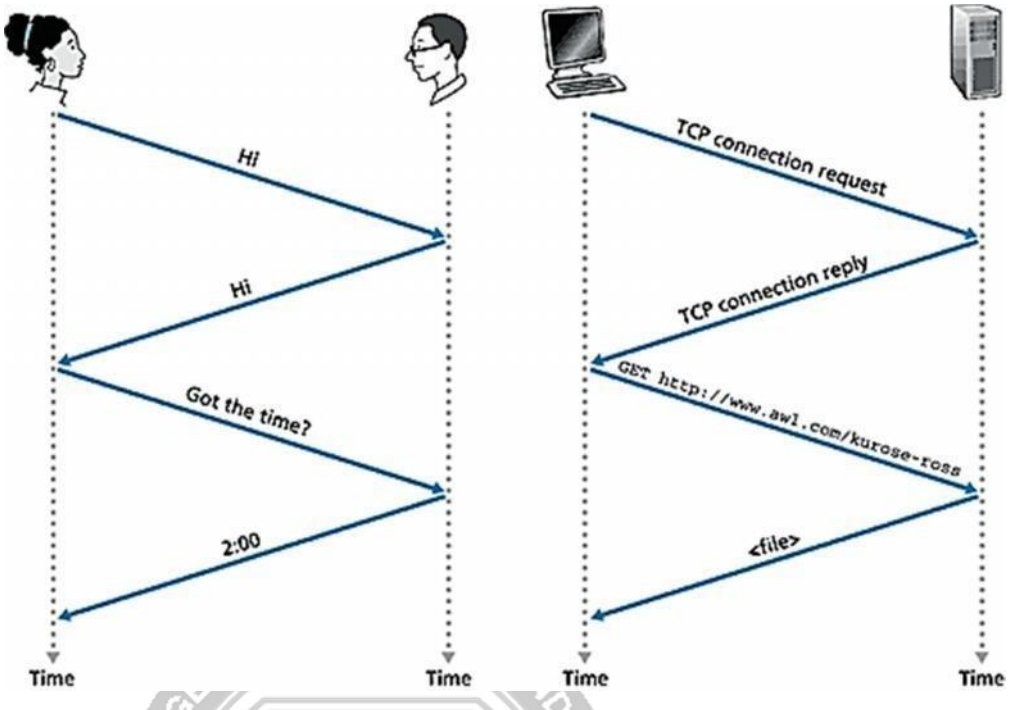


Figure 6: A human protocol and a computer network protocol

The Network Edge

- It defines those computers of the network used at the edge (end) of the network. These computers are known as hosts or end system.
- Host can be classified into the following two types:
  - Clients: Refer to the computer systems that request servers for the completion of a task. The clients are generally called desktop PCs or workstations.
  - Servers: Refer to the computer systems that receive requests from the clients and process them. After the processing is complete, the servers send a reply to the clients who sent the request.
- The concept of clients and servers is essential in the network design. The various networks design models are as follows:
  1. Peer to Peer network
  2. Client Server network

Peer to Peer network

- In this network group of computers is connected together so that users can share resources and information.
- There is no central location (server) for authenticating users, storing files, or accessing resources and each of them works as both client and server.
- This means that users must remember which computers in the workgroup have the shared resource or information that they want to access.
- Advantage:

- It is easy to setup.
- There is no need of any committed server as each peer acts as both server and client.
- The network implementation is quite cheap.
- The resources of a peer can be shared with other peers very easily in the network.

Disadvantage:

- The speed of the network decreases due to heavy usage.
- It is not easy to keep track of information on each computer.
- There is no central backup of files and folders.
- Network and data security are weak.

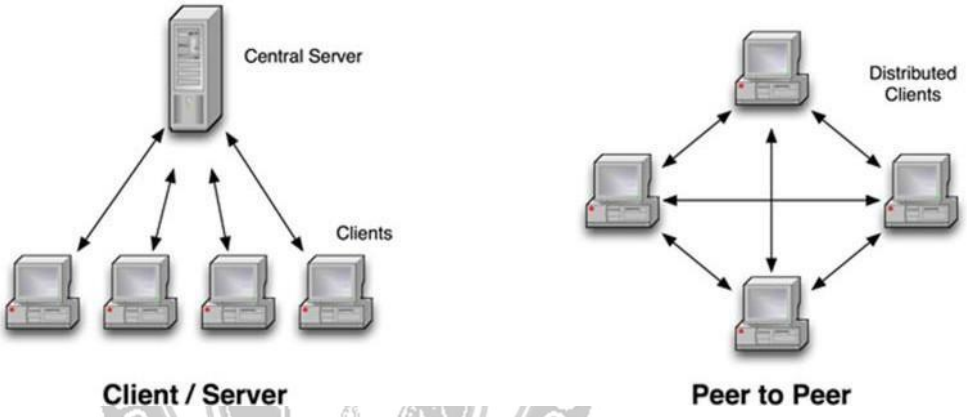


Figure 7: Network Edge - Client/Server Network and Peer to Peer

Client/Server network

- A client/server network is a system where one or more computers called clients connect to a central computer named as server to share or use resources.
- The client requests a service from server, which may include running an application, querying database, printing a document, performing a backup or recovery procedure. The request made by the client is handled by server.
- A client/server network is that in which the files and resources are centralized. This means that the server can hold them and other computers (Client) can access them.

- Advantage:
  - The server system holds the shared files.
  - The server system can be scheduled to take the file backups automatically.
  - Network access is provided only to authorize users through user security at the server.
  - The server system is a kind of central repository for sharing printer with clients.

- Internet access, e-mail routing and such other networking tasks are quite easily managed by the server.
- The software applications shared by the server are accessible to the clients.

- Disadvantage:
  - The implementation of the network is quite expensive.
  - An NOS (Network Operating System) is essential.
  - If server fails, the entire network crashes.
  - There may be congestion if more than one client requests for a service at the same time.

Techniques used in data communications to transfer data

1. Connection-oriented method
2. Connectionless method

Connection-oriented method

- Connection-oriented communication includes the steps of setting up a call from one computer to another, transmitting/receiving data, and then releasing the call, just like a voice phone call.
- However, the network connecting the computers is a packet switched network, unlike the phone system's circuit switched network.
- Connection-oriented communication is done in one of two ways over a packet switched network:
  1. Without virtual circuits
  2. With virtual circuits.

Without virtual circuits:

- This is what TCP does in the Internet.
- The only two machines in the Internet are aware about connection which is established between the two computers at the endpoints.
- The Internet itself, its routers and links have no information about the presence of a connection between the two computers.
- This means that all of the packets flowing between the two computers can follow different routes.
- One benefit of establishing the connection is that the flow of packets from the source to the destination can be slowed down if the Internet is congested and speeded up when congestion disappears.
- Another benefit is that the endpoints can anticipate traffic between them, and agree to cooperate to ensure the integrity and continuity of the data transfers. This allows the network to be treated as a "stream" of data.

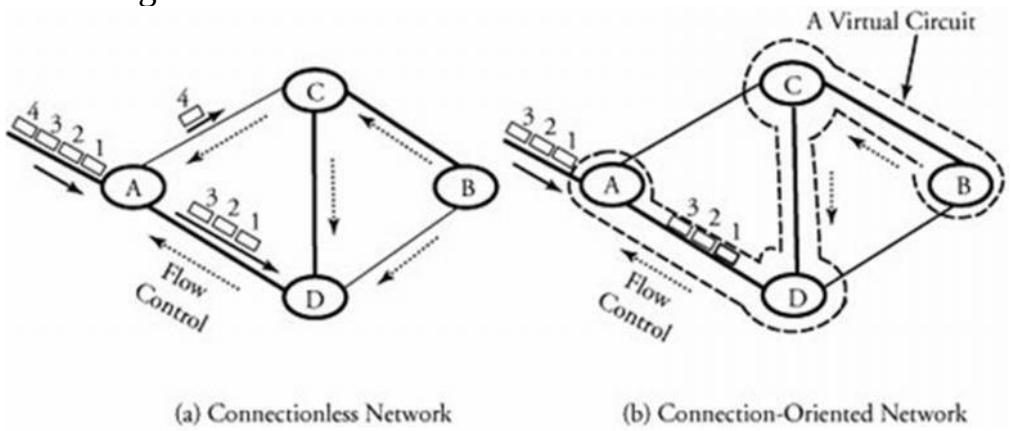
With virtual circuit:

- This is not used in the Internet, but is used in other types of networks (eg. the "X.25" protocol, still popular in Europe).

- The routers within the network route all packets in one connection over the same route. The advantage is that video and voice traffic are easier to carry, because routers can reserve memory space to buffer the transmission.

Connectionless method

- Connectionless communication is just packet switching where no call establishment and release occur.
- A message is broken into packets, and each packet is transferred separately. Moreover, the packets can travel different route to the destination since there is no connection.
- Connectionless service is typically provided by the UDP (User Datagram Protocol). The packets transferred using UDP are also called datagrams.



Feature	Connectionless	Connection-oriented
How is data sent?	one packet at a time	as continuous stream of packets
Do packets follow same route?	no	virtual circuit: yes without virtual
Are resources reserved in network?	no	virtual circuit: yes without virtual circuit: no
Are resources reserved in communicating hosts?	no	yes
Is connection establishment done?	no	yes
Is state information stored at network nodes?	no	virtual circuit: yes without virtual circuit: no
What is impact of node/switch crash?	only packets at node are lost	all virtual circuits through node fail

What addressing information is needed on each packet?	full source and destination address	virtual circuit: a virtual circuit number without virtual circuit: full source and

Transmission Media

- A transmission media can be defined as anything that can carry information from a source to a destination.
- On the basis of transmission of data, the transmission media can be classified in to two categories:
    1. Guided (Physical) transmission media
    2. Unguided (Wireless) transmission media

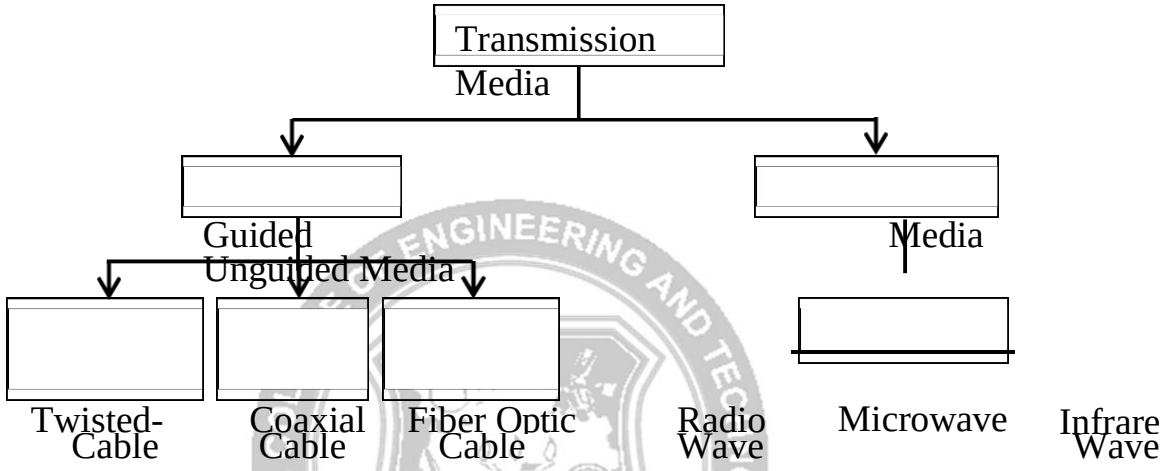


Figure 8: Classification Transmission Media

Guided Transmission Media

- Guided media are those that provide a channel from one device to another.
- The three Guided (Physical) media commonly used for data transmission are:
    1. Twisted-Pair
    2. Coaxial
    3. Fiber Optics

1. Twisted Pair
    - A twisted pair consists of two insulated copper wires, typically about 1 mm thick.
    - The wires are twisted together in a helical form, just like a DNA molecule.
    - Twisting is done because two parallel wires constitute a fine antenna.
    - When the wires are twisted, the waves from different twists cancel out, so the wire radiates less effectively.

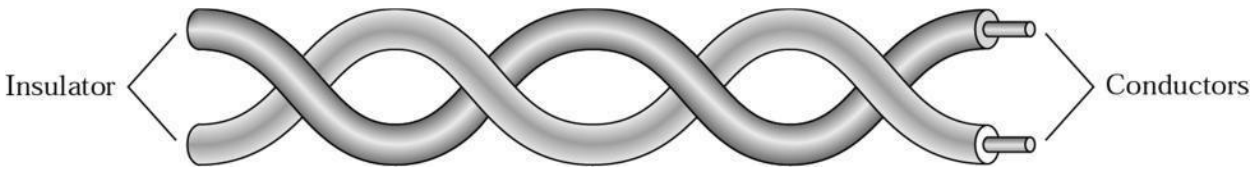


Figure 9: Twisted Pair Cable

Why cable is twisted?

- If the two wires are parallel, the effect of these unwanted signals is not the same in both wires because they are at different locations relatives to the noise or crosstalk sources.
- This results in a difference at the receiver.
- By twisting the pair, a balance is maintained.

Types of Twisted-Pair Cable

1) Unshielded twisted-pair (UTP)

- Twisted pair cabling comes in several varieties, two of which are important for computer networks.
- Category 3 twisted pairs consist of two insulated wires gently twisted together.
- Most office buildings had one category 3 cable running from a central wiring closet on each floor into each office.
- Category 5 is the more advanced twisted pairs were introduced.
- They are similar to category 3 pairs, but with more twists per centimetre, which results in less crosstalk and a better-quality signal over longer distances, making them more suitable for high- speed computer communication.
- Up-and-coming categories are 6 and 7, which are capable of handling signals with bandwidths of 250 MHz and 600 MHz, respectively (versus a mere 16 MHz and 100 MHz for categories 3 and 5 respectively).

Figure 10: Unshielded twisted-pair

2) Shielded twisted-pair (STP).

- STP cable has a metal foil or braided mesh covering that encases each pair of insulated conductors.
- Metal casing improves the quality of cable by preventing the penetration of noise or crosstalk.
- It is bulkier and more expensive.
- Applications:
  - Used in telephone lines to provide voice and data channels.
  - The DSL lines uses by telephone companies use the high-bandwidth capability of UTP cables.
  - LANs, such as 10Base-T, 100Base-T also uses twisted-pair cables.

2. Coaxial Cable

- It has better shielding than twisted pairs, so it can span longer distances at higher speeds.
- Two kinds of coaxial cable are widely used. One kind is 50-ohm cable which is commonly used when it is intended for digital transmission from the start.
- The other kind is 75-ohm cable which is commonly used for analog transmission and cable television but is becoming more important with the advent of Internet over cable.
- A coaxial cable consists of a stiff copper wire as the core 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.
- The construction and shielding of the coaxial cable give it a good combination of high bandwidth and excellent noise immunity.
- The bandwidth possible depends on the cable quality, length and signal-to-noise ratio of the data signal. Modern cables have a bandwidth of close to 1 GHz.

- Coaxial cables used is widely used within the telephone system for long-distance lines but have now largely been replaced by fiber optics on long-haul routes.

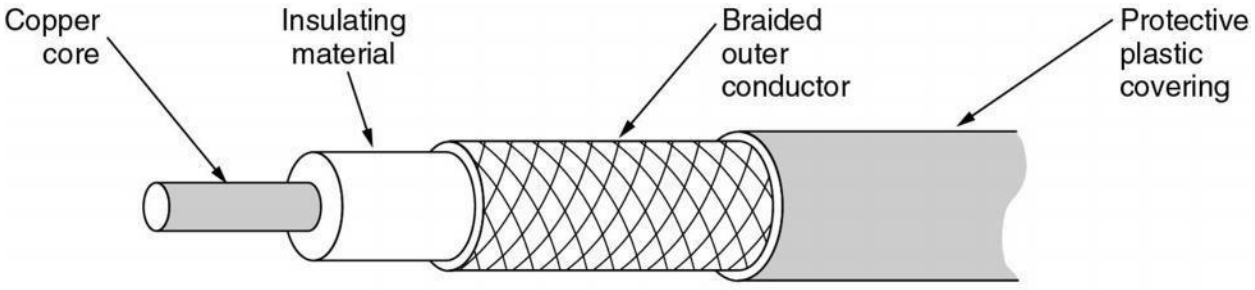


Figure 11: Coaxial Cable

3. Fiber Optics

- A fiber-optic cable is made of glass or plastic and transmits signals in the form of light.

- Optical fibers use reflection to guide light through a channel.
- A glass or plastic core is surrounded by a cladding of less dense glass or plastic.
- The difference in density of the two materials must be such that a beam of light moving through a core is reflected off the cladding instead of being refracted into it.

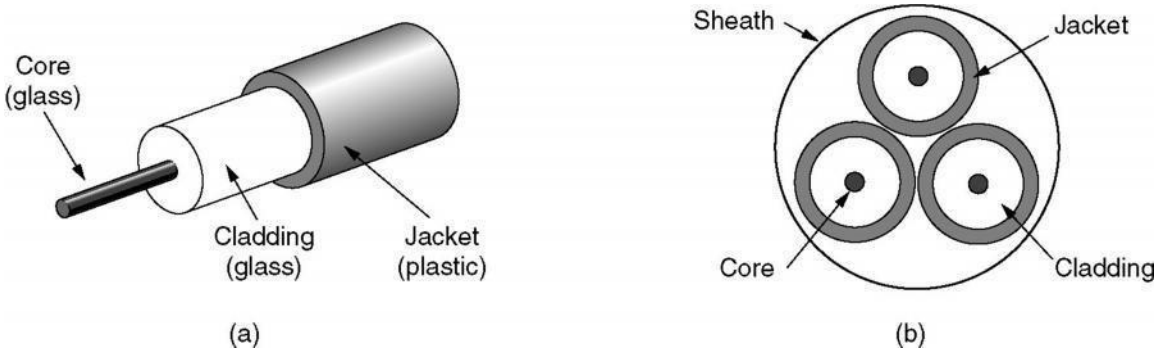


Figure 12: Fiber Optic Cable

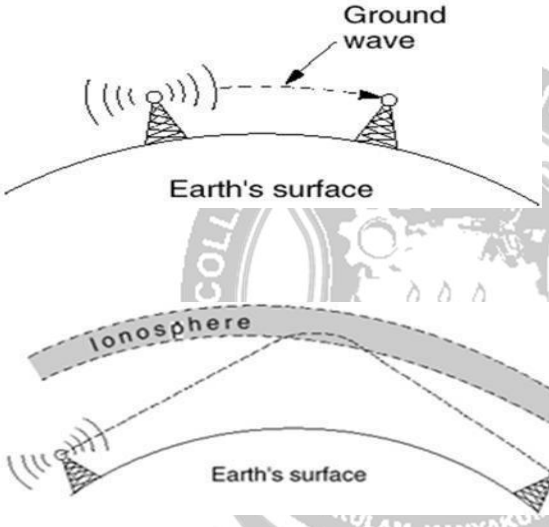
- Fiber optic cables are similar to coax, except without the braid.
- Figure shows a single fiber viewed from the side. At the centre is the glass core through which the light propagates.
- The core is surrounded by a glass cladding with a lower index of refraction than the core, to keep all the light in the core.
- Next comes a thin plastic jacket to protect the cladding.Fibers are typically grouped in bundles, protected by an outer sheath. Figure shows a sheath with three fibers.

Unguided (Wireless) transmission media

- Unguided media transport electromagnetic waves without using a physical conductor. This type of communication is often referred to as wireless communication.

1. Radio Transmission
2. Microwave Transmission
3. Infrared
4. Light wave Transmission

1. Radio Transmission
   - Radio waves are easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors.
   - Radio waves also are omnidirectional, meaning that they travel in all directions from the source, so the transmitter and receiver do not have to be carefully aligned physically.
   - The properties of radio waves are frequency dependent.
   - At low frequencies, radio waves pass through obstacles well, but the power falls off sharply with distance from the source, roughly as $1/r^2$ in air.
   - At high frequencies, radio waves tend to travel in straight lines and bounce off obstacles. They are also absorbed by rain.
   - At all frequencies, radio waves are subject to interference from motors and other electrical equipment.



   - In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.
   - In the HF they bounce off the ionosphere

2. Microwave Transmission
   - Since the microwaves travel in a straight line, if the towers are too far apart, the earth will get in the way. Consequently, repeaters are needed periodically.
   - Unlike radio waves at lower frequencies, microwaves do not pass through buildings well. In addition, even though the beam may be well focused at the transmitter, there is still some divergence in space.
   - Above 100 MHz, the waves travel in straight lines and can therefore be narrowly focused. Concentrating all the energy into a small beam using a parabolic antenna gives a much higher signal to noise ratio.

   - Advantages:
     - No right way is needed (compared to wired media).
     - Relatively inexpensive.
     - Simple to install.

   - Disadvantages:
     - Do not pass through buildings well.

- Multipath fading problem (the delayed waves cancel the signal).
- Absorption by rain above 8 GHz.
- Severe shortage of spectrum.

3. Infrared

- Unguided infrared and millimetre waves are widely used for short-range communication.
- The remote controls used on televisions, VCRs, and stereos all use infrared communication.
- They are relatively directional, cheap, and easy to build but have a major drawback: they do not pass through solid objects (try standing between your remote control and your television and see if it still works).
- In general, as we go from long-wave radio toward visible light, the waves behave more and more like light and less and less like radio.
- On the other hand, the fact that infrared waves do not pass through solid walls well is also a plus.
- It means that an infrared system in one room of a building will not interfere with a similar system in adjacent rooms or buildings.
- Furthermore, security of infrared systems against eavesdropping is better than that of radio systems precisely for this reason.
- Therefore, no government license is needed to operate an infrared system, in contrast to radio systems, which must be licensed outside the ISM bands.

Topologies (Network Topologies)

- Network Topology is the schematic description of a network arrangement, connecting various nodes (sender and receiver) through lines of connection.
- A Network Topology is the arrangement with which computer systems or network devices are connected to each other.
- Types of network topologies :

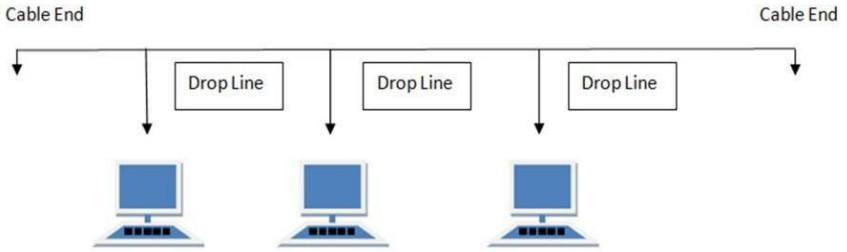
1. Bus
2. Ring
3. Star
4. Mesh
5. Tree
6. Hybrid

5. Tree

Hy

Bus Topology

- Bus topology is a network type in which every computer and network device is connected to single cable.



Features:

- It transmits data only in one direction.
- Every device is connected to a single cable.

Advantages:

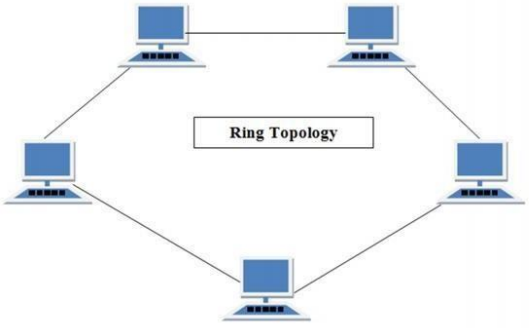
- It is cost effective (cheaper).
- Cable required is least compared to other network topology.
- Used in small networks.
- It is easy to understand.
- Easy to expand joining two cables together.

Disadvantages:

- Cables fails then whole network fails.
- If network traffic is heavy or nodes are more the performance of the network decreases.
- Cable has a limited length.

Ring Topology

- It is called ring topology because it forms a ring as each computer is connected to another computer, with the last one connected to the first. Exactly two neighbours for each device.



Features:

- A number of repeaters are used and the transmission is unidirectional.
- Date is transferred in a sequential manner that is bit by bit.

Advantages:

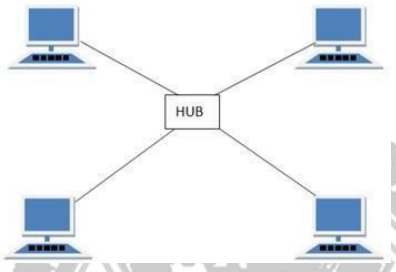
- Transmitting network is not affected by high traffic or by adding more nodes, as only the nodes having tokens can transmit data.
- Cheap to install and expand.

Disadvantages:

- Troubleshooting is difficult in ring topology.
- Adding or deleting the computers disturbs the network activity.
- Failure of one computer disturbs the whole network.

Star Topology

- In this type of topology all the computers are connected to a single hub through a cable. This hub is the central node and all others nodes are connected to the central node.



Features:

- Every node has its own dedicated connection to the hub.
- Acts as a repeater for data flow.
- Can be used with twisted pair, Optical Fibre or coaxial cable.

Advantages:

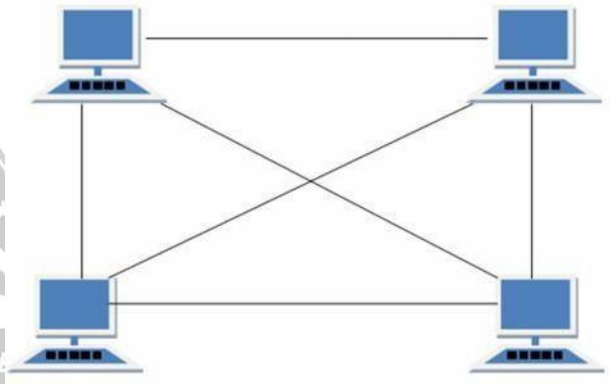
- Fast performance with few nodes and low network traffic.
- Hub can be upgraded easily.
- Easy to troubleshoot.
- Easy to setup and modify.
- Only that node is affected which has failed rest of the nodes can work smoothly.

Disadvantages:

- Cost of installation is high.
- Expensive to use.
- If the hub is affected then the whole network is stopped because all the nodes depend on the hub.
- Performance is based on the .

Mesh Topology

- It is a point-to-point connection to other nodes or devices.
- Traffic is carried only between two devices or nodes to which it is connected.



Features:

- Fully connected.
- Robust.
- Not flexible.

Advantages:

- Each connection can carry its own data load.
- It is robust.
- Fault is diagnosed easily.
- Provides security and privacy.

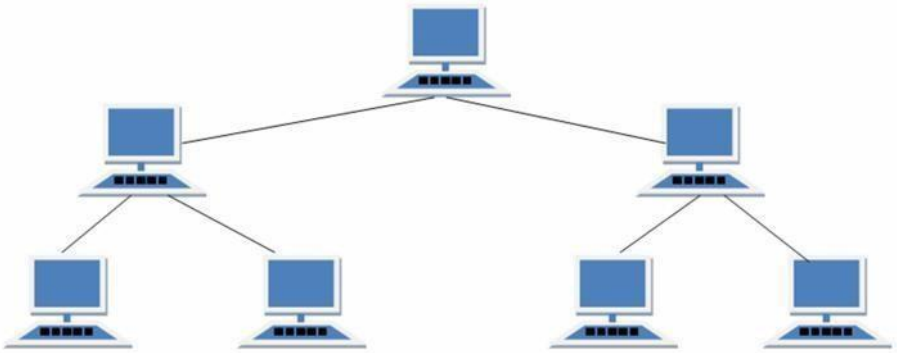
Disadvantages:

- Installation and configuration is difficult.
- Cabling cost is more.
- Bulk wiring is required.

Tree Topology

- It has a root node and all other nodes are connected to it forming a hierarchy.

- It is also called hierarchical topology.
- It should at least have three levels to the hierarchy.



Features:

- Ideal if workstations are located in groups.
- Used in Wide Area Network.

Advantages:

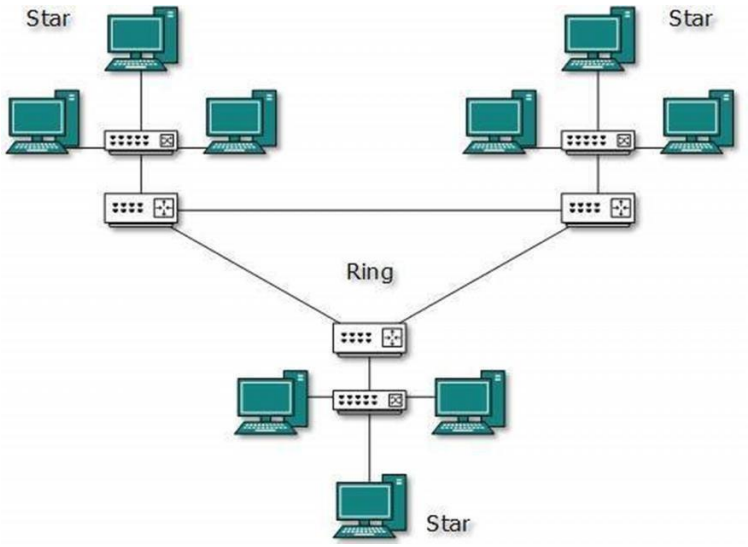
- Extension of bus and star topologies.
- Expansion of nodes is possible and easy.
- Easily managed and maintained.
- Error detection is easily done.

Disadvantages:

- Heavily cabled.
- Costly.
- If more nodes are added maintenance is difficult.
- Central hub fails then network fails.

Hybrid Topology

- A network structure whose design contains more than one topology is said to be hybrid topology.
- For example if in an office in one department ring topology is used and in another star topology is used, connecting these topologies will result in Hybrid Topology (ring topology and star topology).



Features:

- It is a combination of two or more topologies
- Inherits the advantages and disadvantages of the topologies included

Advantages:

- Reliable as error detecting and trouble shooting is easy.
- Scalable as size can be increased easily.
- Flexible.

Disadvantages:

- Complex in design.
- Costly.

The Network Core

- Network core defines the connection of different network segments together and the process to transmit the data packets across the network.
- The network core is implemented through the use of switching techniques.