Computer Networks

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Course Syllabus

Unit No.	Unit Content
1	**Introduction:** Networking goals, Networking Topologies, Network Architecture - Interfaces and services, ISO-OSI Reference Model, TCP/IP Protocol suite. Comparison of OSI and TCP/IP. **Signals:** Analog Signals and Digital Signals, Characteristics of Analog Signals, Frequency Modulation (FM), Amplitude, Modulation (AM), Phase Modulation (PM), Quadrature Amplitude Modulation QAM. **Encoding and Modulation:** Digital to Digital signal conversion, Digital to Analog signal conversion, Analog to Analog signal conversion, Analog to Digital signal conversion
2	**Physical Layer:** Transmission Media - Guided Transmission Media – Twisted pair, Coaxial Cable, Fiber Optics , Unguided Media–Radio waves, Microwaves, Infrared. **Switching:** Packet and Circuit Switching **Data Link Layer:** Framing, Flow and Error Control, Error Detection and Correction - Types of Errors, Redundancy, LRC, CRC, Checksum. Flow and Error control Protocols: Stop and Wait, Stop and Wait ARQ, Go back-N ARQ, Selective repeat ARQ.
1st Half of 3rd Unit	**Local Area Network: Ethernet:** Multiple Access Links and Protocols – ALOHA, CSMA, CSMA/CD, CSMA/CA. 802.3 IEEE standard, Token Bus: 802.4 IEEE standard, Token Ring: 802.5 IEEE standard, Wireless LAN Protocols. **Logical Addressing:** IPv4 Addresses, Ipv6 Addresses.

Course Syllabus

Unit No.	Unit Content
2nd Half of 3rd Unit	**INTER Networking Devices:** Layer 1 connections- Repeater, Hubs, Layer 2 connections- Bridges, Switches, Layer 3 connections- Routers, Gateways. **Unicast Routing Protocols:** Distance Vector Routing, Link State Routing. Internet Protocols: Class A, B, C, D, E traffic, IPV4, IPV6. Address Mapping: ARP, RARP- ICMP- IGMP.
4	**Transport Layer:** Services, Multiplexing and Demultiplexing, Process to process delivery –User Datagram Protocol (UDP) – Transmission Control Protocol (TCP) – Congestion Control Techniques– Congestion Prevention Policies - Quality of services (QoS) – Techniques to improve QoS - Integrated Services.
5	**Principles of Networking Applications:** Web, FTP, E-mail, DNS, PeertoPeer applications, Creating Networking Applications, Telnet, SNMP, Recent trends in Computer Networks. **Recent Trends in Network Security:** Cryptography, Substitution and Transposition Ciphers, Data encryption standard (DES), breaking DES, Public Key Cryptography, Network layer security (IPSec), Transport Layer Security (TLS/SSL, HTTPS)
6	Guest Lecture on Contemporary Topics in Data communication and Networks

Text Books

Text Book(s):	
1.	Larry L.Peterson, Bruce S.Davie, Computer Networks: A System Approach, Fifth Edition, 2012.
2.	James F.Kurose and Keith W.Ross, Computer Networking: A Top-Down Approach, Sixth Edition, Pearson Education, 2013.
Reference Book(s):	
1.	Behrouz A. Forouzan, Data Communications and Networking, Fifth Edition, McGraw-Hill, 2012.
2	Behrouz A.Forouzan, TCP/IP Protocol Suite, 5th Edition, Tata McGraw-Hill, 2012
3	W.Richard Stevens, TCP/IP Illustrated, The Protocols, 2nd Edition, Prentice Hall 2012
4.	Andrew S.Tenanbaum, Computer Networks, Fifth Edition, Prentice Hall, 2012

LTP COURSE

Tutorials (Assignments/Class works)

Group Activities (Home-works / Presentations)

LAB Assessments (Implement works / Experiments)

Unit - I

► **Introduction:** Networking goals, Networking Topologies, Network Architecture - Interfaces and services, ISO-OSI Reference Model, TCP/IP Protocol suite. Comparison of OSI and TCP/IP.

► **Signals:** Analog Signals and Digital Signals, Characteristics of Analog Signals, Frequency Modulation (FM), Amplitude, Modulation (AM), Phase Modulation (PM), Quadrature Amplitude Modulation QAM.

► **Encoding and Modulation:** Digital to Digital signal conversion, Digital to Analog signal conversion, Analog to Analog signal conversion, Analog to Digital signal conversion

Computer Network

A **computer network** is a group of computers/devices(Nodes) that are connected by communication facilities and are able to exchange information

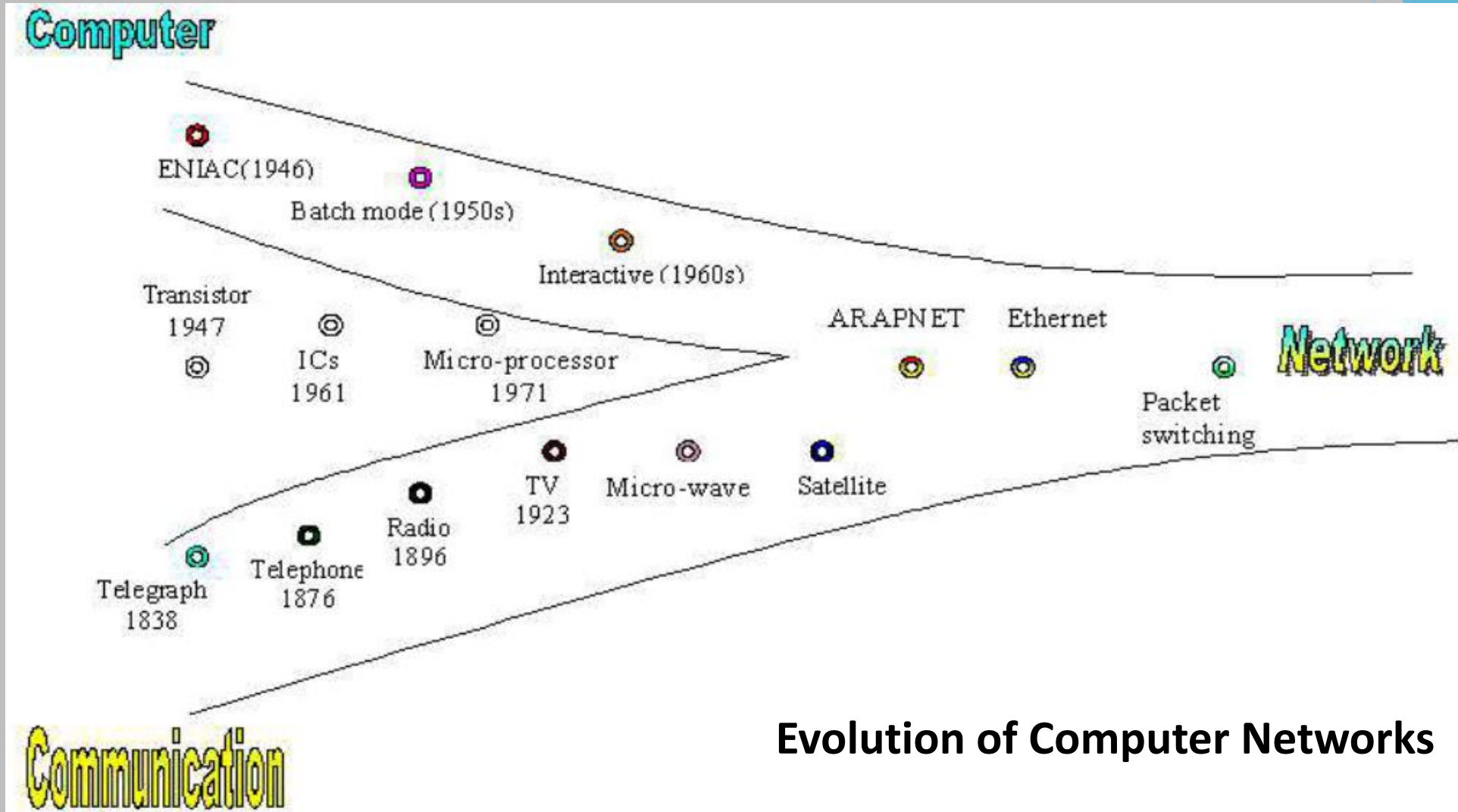*A popular example of a computer network is the Internet, which allows millions of users to share information.*

Computer Network

➢ Network is an inter connected collection of autonomous devices

➢ When two or more computers/devices are joined together so that they are capable of exchanging information, they form a network

➢ The nodes of a computer network may include personal computers, servers, networking hardware, or other specialised or general-purpose hosts.

➢ The communication facilities are any data communication link, physically wired like cables, telephone lines, optical fibres, or wireless technologies like radio waves, satellites, WiFi, Bluetooth, GPS etc.

➢ The connected devices use a set of common communication protocols over digital interconnections.

➢ A communication protocol is a set of rules for exchanging information over a network. physically wired, optical, and wireless

Computer Network

Wired Network **PC** **Firewall** **The Internet**

Fiber Optic Network Cable

Switch

Router

Server

Other LANS

Wireless Network

Computer Network
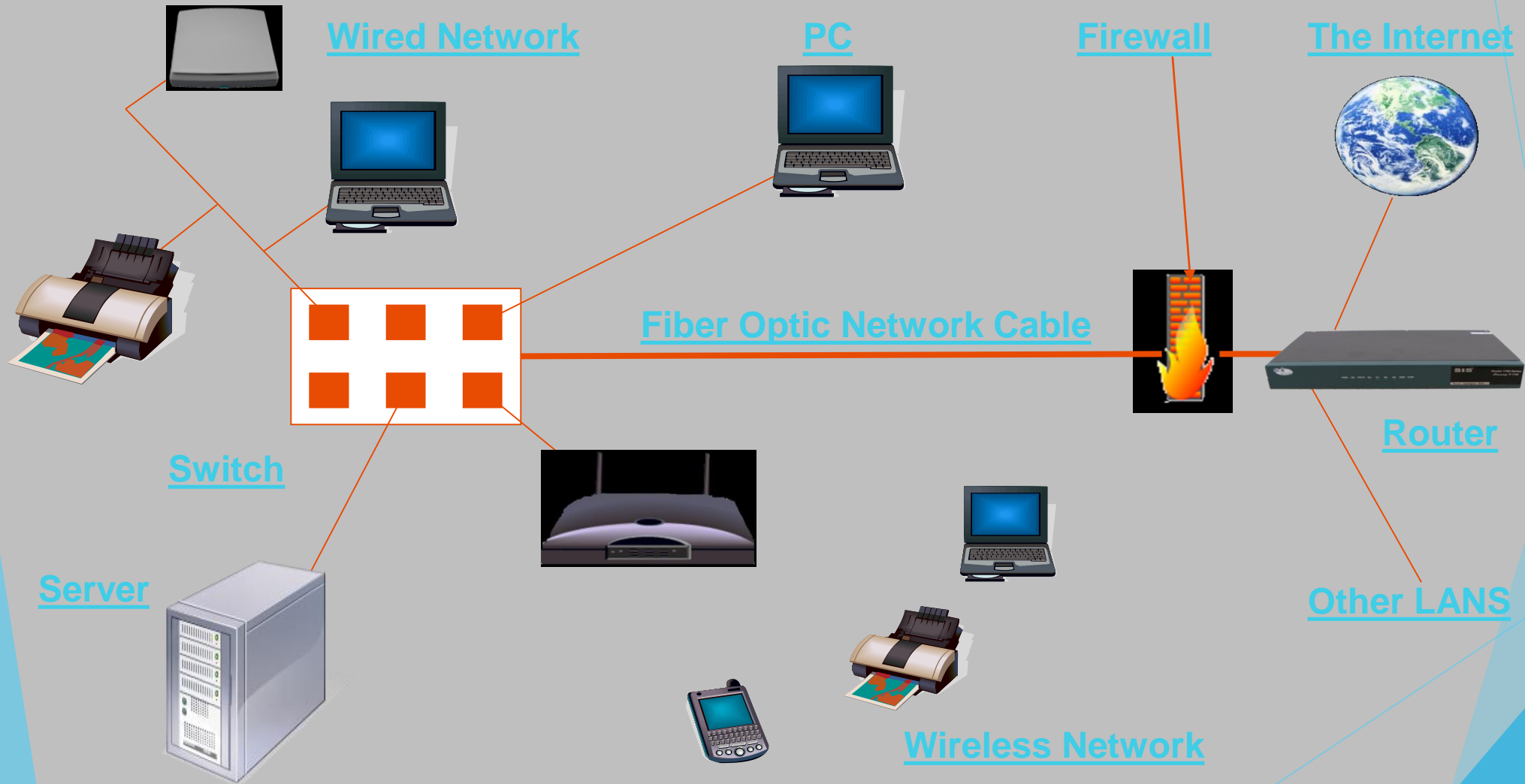
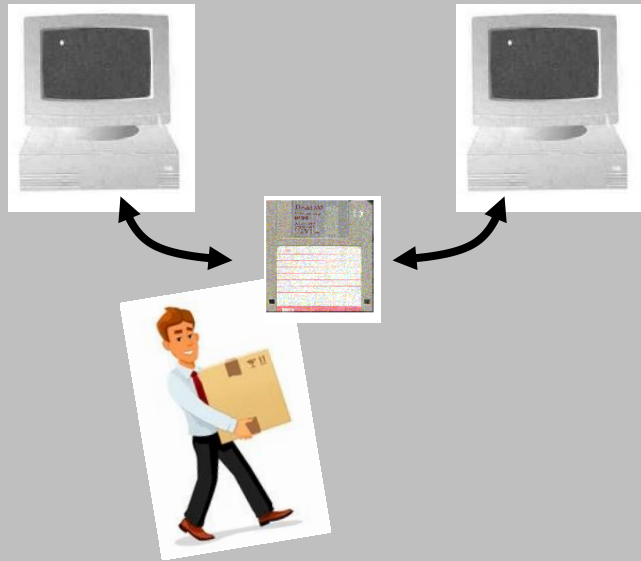**Evolution of Computer Networks**

Computer Network

Goals:

▶ To make all programs, equipment, and especially data available to anyone on the network without regard to the physical location of the resource and the user.

• **Do you prefer this?**   • **Or this?**

Computer Network

Goals:

▶ Another goal of setting up a computer network has to do with people rather than information or even computers. A computer network can provide a powerful communication medium among people/employees.

  ▶ Email
  ▶ Cooperate with other to work
  ▶ VoIP
  ▶ Videoconferencing

▶ For business : many companies are doing business electronically with other companies, especially suppliers and customers.

  ▶ **e-Commerce**
    ▶ B2B: Manufacturers and its suppliers.
    ▶ B2C: companies and its customers.

Computer Network

Advantages:

▶ **Provide convenience**: Computers on a network can back up their files over the network.

▶ **Allow** Resource **sharing**: Through a network Data/Information, S/W and H/W resources can be shared irrespective of the physical location of the resources and the user.

  ▶ **H/W:** Printers, Scanner, CD-Burners, Fax machines etc…

  ▶ **Data/Information:** Customer records, Product information, inventories, financial statements, tax information

▶ **Facilitate fast communication**: Networks facilitate the communication such as sending and receiving email, transferring files and video conferencing i.e. Information can be exchanged at a very fast speed

Computer Network

Advantages:

▶ **Generate savings/Reduced Cost**: Networked computers can provide more computing power for less money. Since resources can be shared, not everyone need their own peripherals which can result in cost savings.

▶ **Provide reliability**: A file can have its copies on two or more computers of the network. If one part of a network is down, useful work may be still possible using a different network path.

▶ **Simplifying scalability**: It is easy to add more computers to an existing network.

▶ **Flexible Access:** Networks allow their users to access files from computers throughout the network

Computer Network

Applications:

- **Home Applications**
  - Access to remote information
    - Web
  - Person-to-person communication
    - Email, VoIP
  - e-commerce
  - Interactive entertainment
    - IPTV, Gaming E-mail
  - P2P - Peer to Peer

Applications:

- **Other applications**
  - Ubiquitous computing
    - IoT (Internet of Things)
      - Sensor Networks
      - RFID (Radio Frequency IDentification)
- **Mobile Users**
- **SoLoMo (Social Local Mobile)**

Computer Network

How many kinds of Networks?

Depending on one's perspective, we can classify networks in different ways

- Based on network size: LAN, MAN, WAN, PAN, etc.

- Based on management/communication method: Peer-to-peer and Client/Server

- Based on topology (connectivity): Bus, Star, Ring, etc.

- Based on transmission media: Wired (UTP, coaxial cables, fiber-optic cables) and Wireless

Computer Network

Network Technology Classification Based on Scale:

- ➤ LAN: Local Area Network

- ➤ MAN: Metropolitan Area Network

- ➤ WAN: Wide Area Network

- ➤ PAN: Personal Area Network

Computer Network

Network Technology Classification Based on Scale:

Local Area Network:

- LAN is a computer network widely used for local communication.

- LAN is usually privately owned and links the devices in a single office, building or campus of up to few kilometers in size.

- **LANs are distinguished** from other kinds of networks by **three categories**: **their size, transmission technology and topology.**

Computer Network

Network Technology Classification Based on Scale:

Local Area Network**:**

- LAN typically uses **transmission technology** consisting of single cable to which all machines are connected.

- Traditional LANs run at **speeds of 10 to 100 Mbps** (but now much higher speeds can be achieved).

- The most **common LAN topologies** are bus, ring and star.

Computer Network

LAN

LAN
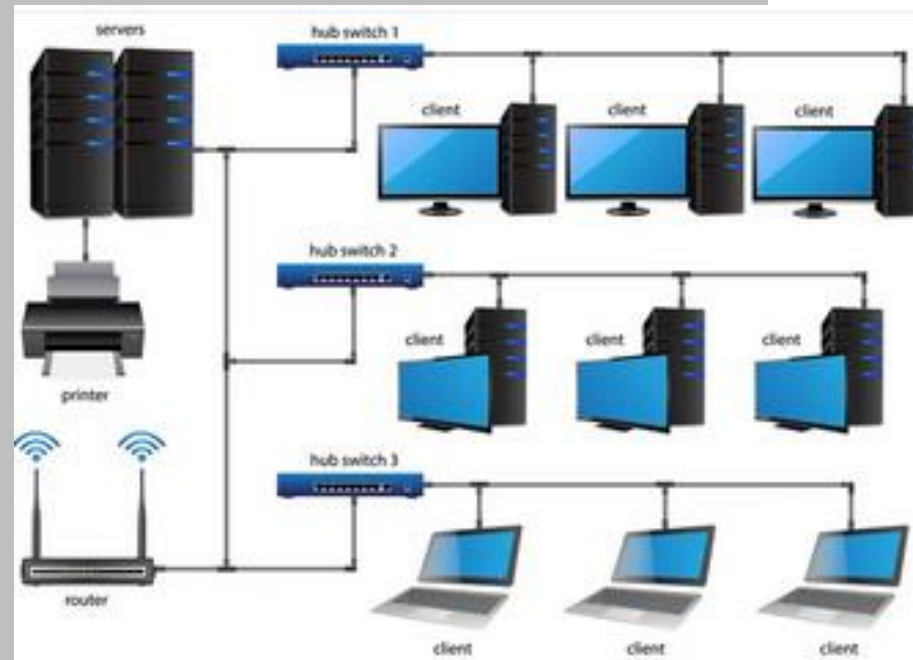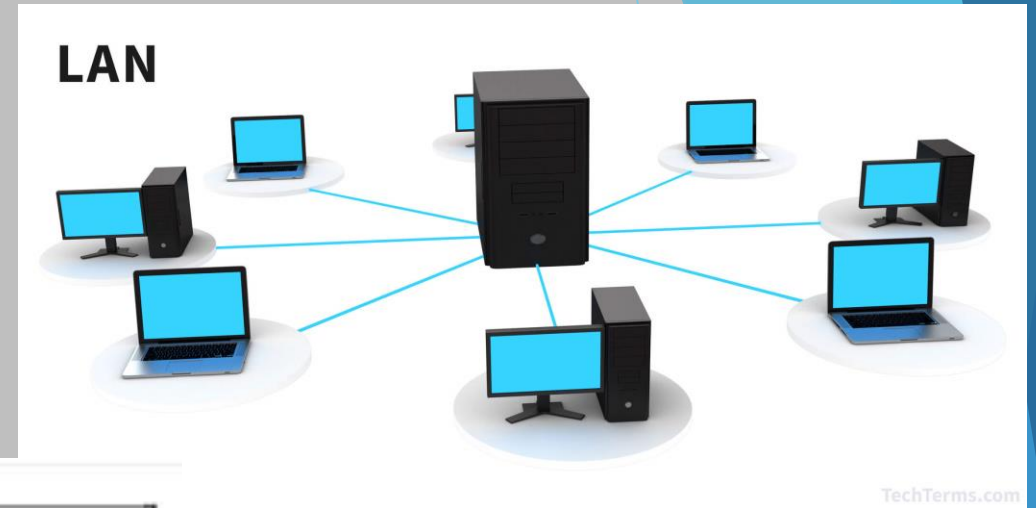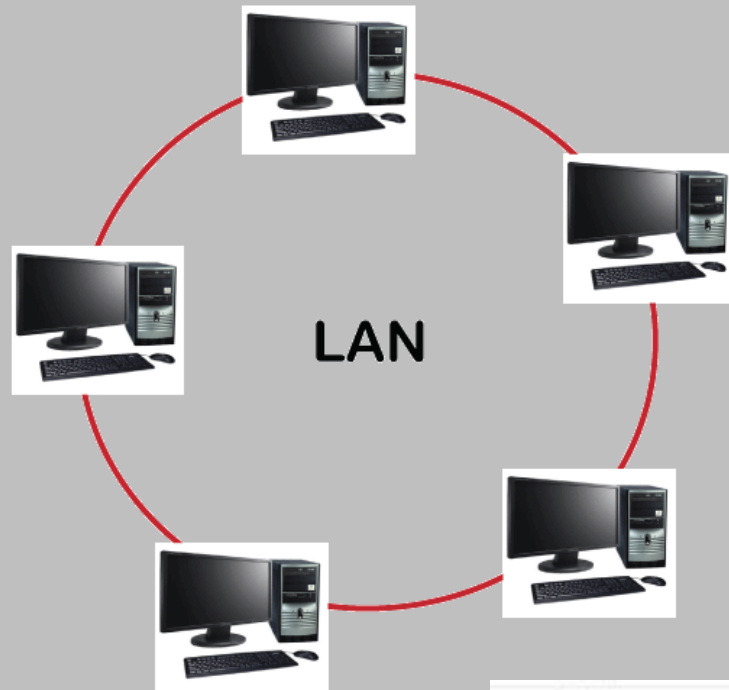
Computer Network

Network Technology Classification Based on Scale:

Metropolitan Area Network**:**

- MAN is designed to extend over the entire city.

- It may be a single network as a cable TV network or it may be means of connecting a number of LANs into a larger network so that resources may be shared.

- MAN is wholly owned and operated by a private company or may be a service provided by a public company.

Computer Network
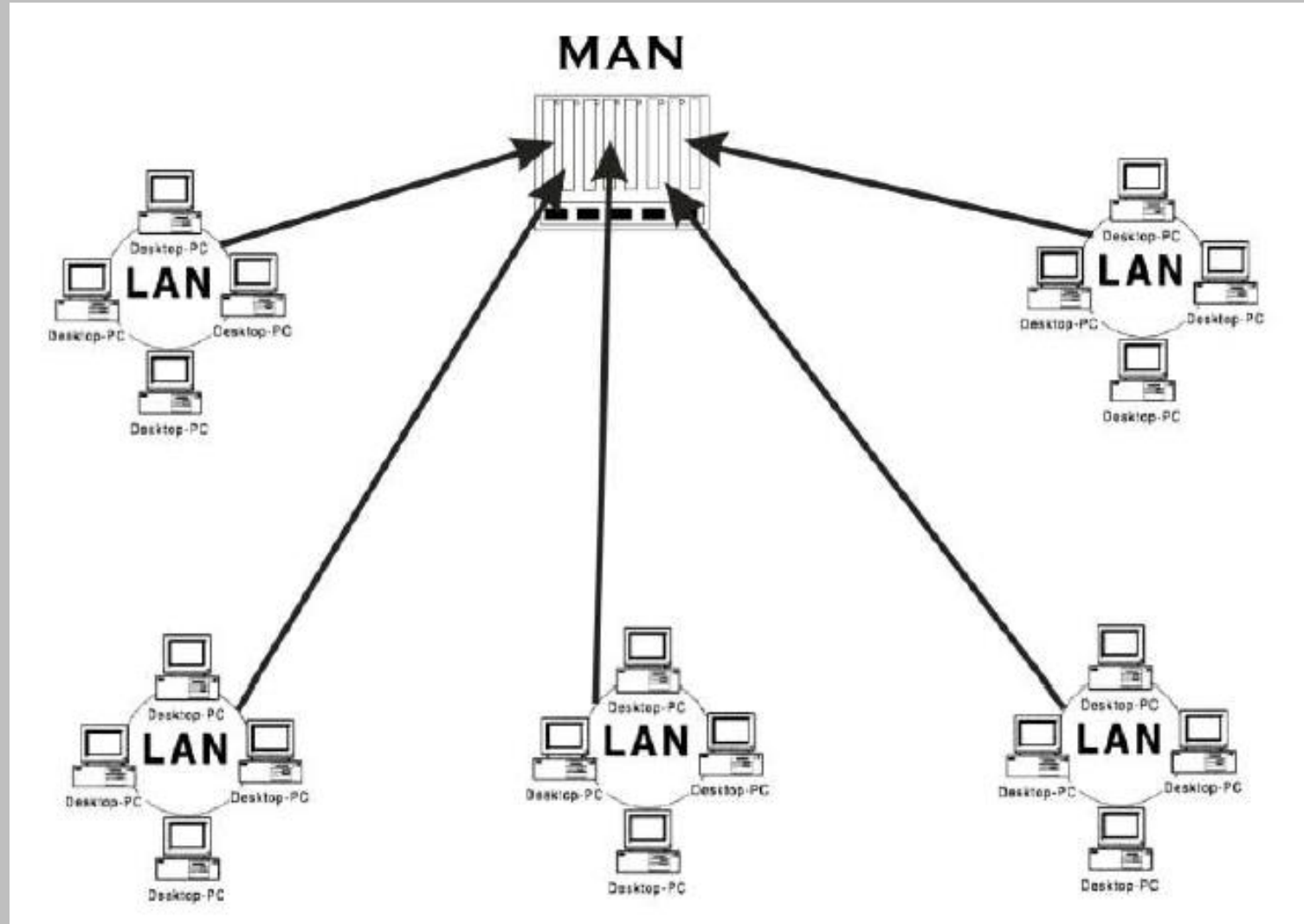
Computer Network

Network Technology Classification Based on Scale:

Wide Area Network**:**

- WAN provides long-distance transmission of data, voice, image and information over large geographical areas that may comprise a country, continent or even the whole world.

- WANs may utilize public, leased or private communication devices, usually in combinations, and can therefore span an unlimited number of miles.

- WAN uses telephone lines, satellite link and radio link to connect.

Computer Network
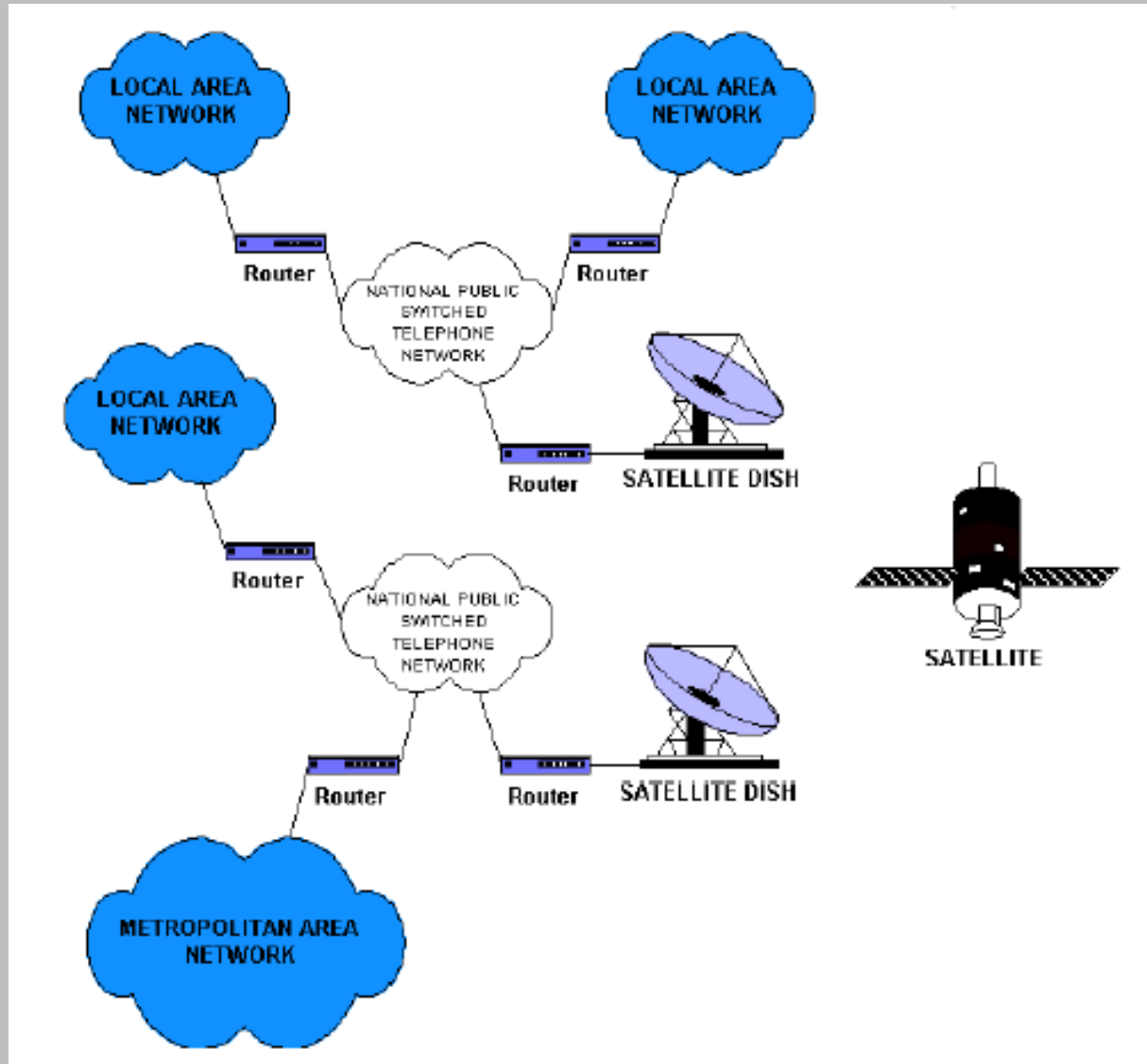
Computer Network

Network Technology Classification Based on Scale:

Personal Area Network**:**

- PAN is a computer network used for communication among computer devices, including telephones and personal digital assistants, in proximity to an individual's body.

- The devices may or may not belong to the person.

- The reach of a PAN is typically a few meters.

Computer Network
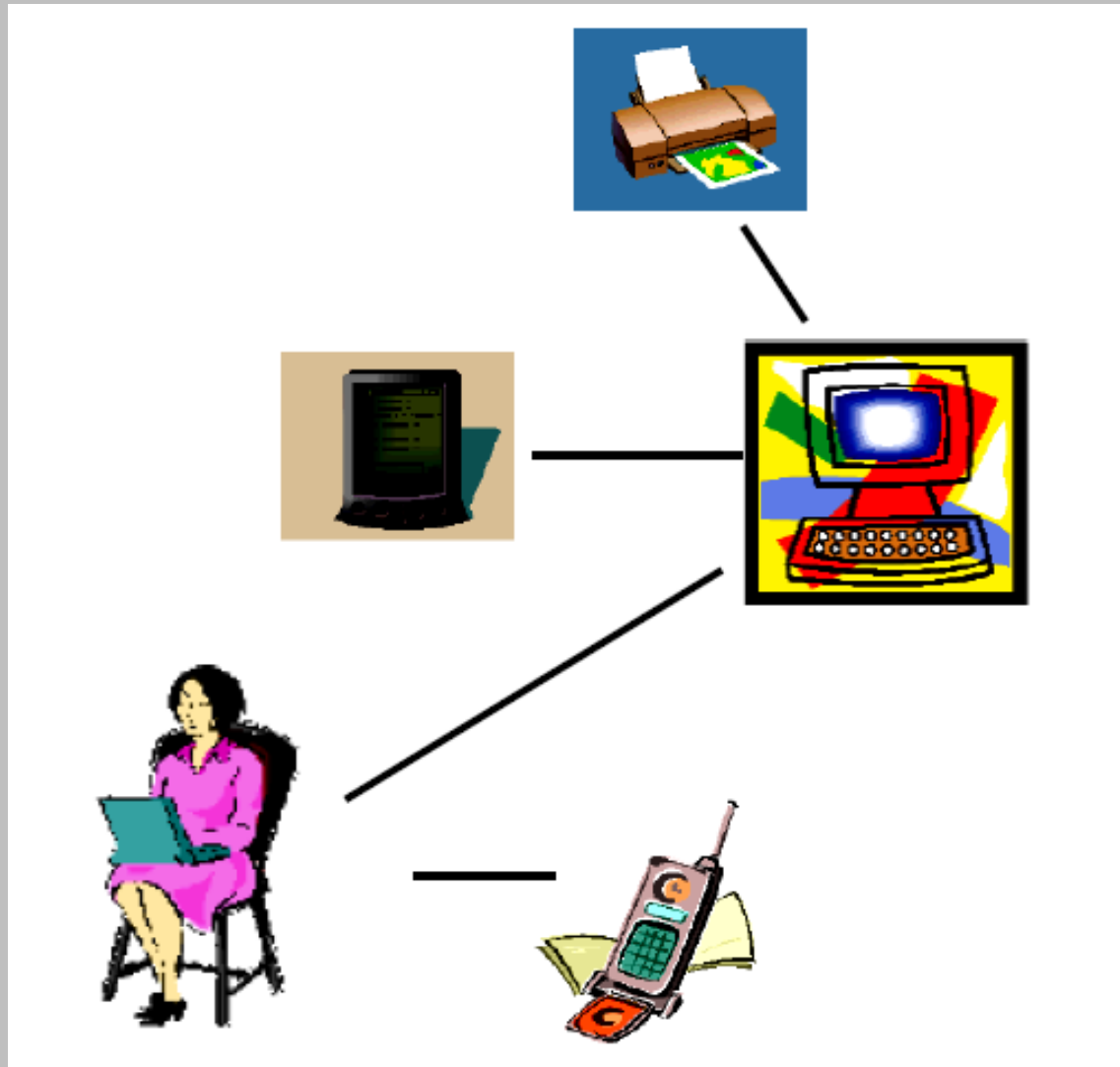
Computer Network

Network Technology Classification Based on Scale:

Internet:

- Internet is a collection of networks or network of networks.

- The basic difference between WAN and Internet is that WAN is owned by a single service provider while internet is not so.

- WAN service providers include carriers, such as a telephone network, cable company, or satellite service
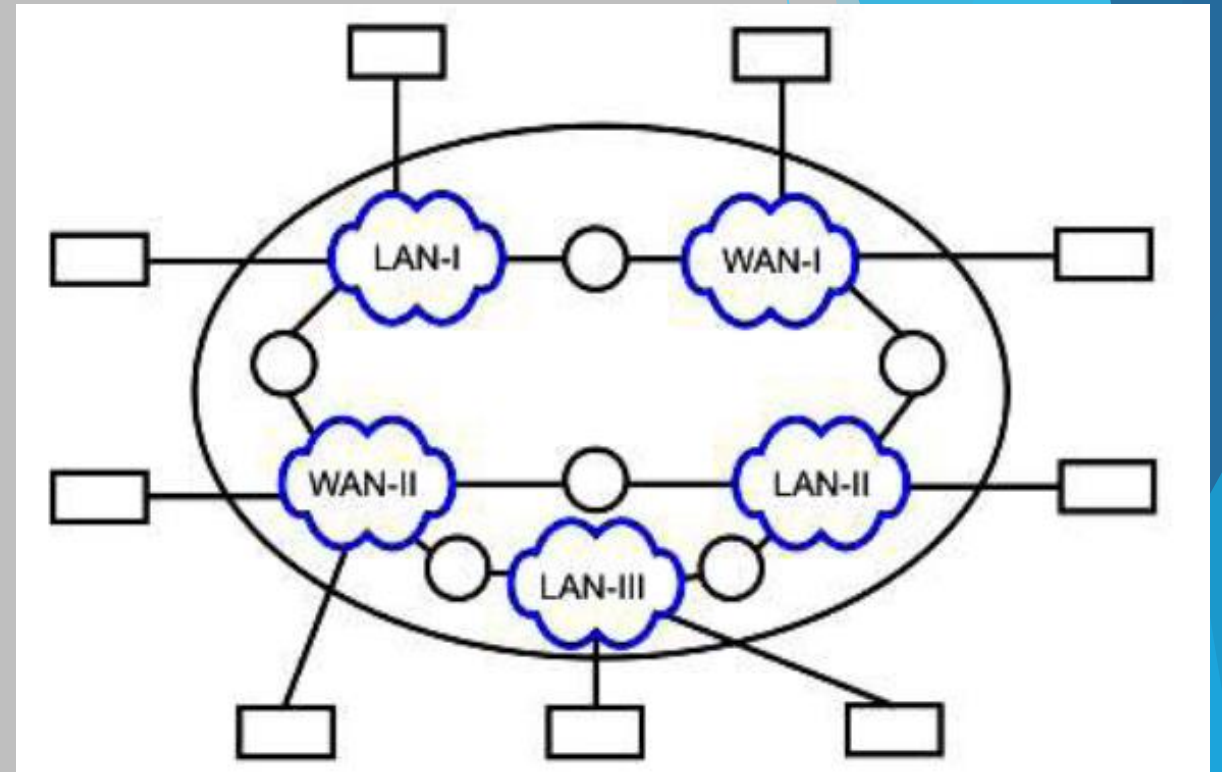
Computer Network

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	Local area network
1 km	Campus	Local area network
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	Wide area network
10,000 km	Planet	The Internet

Computer Network

Computing Models

Distributed Computing (Peer to Peer Network model)

Centralized Computing (Client Server Network model)

Computer Network

Centralized Computing (Client-Server Network):

- A client-server network is where every client is connected to the server

- Server or mainframe computer has huge storage and processing capabilities

- A client-server network is one on which all available network resources such as files, directories, applications and shared devices, are centrally managed and hosted and then are accessed by client
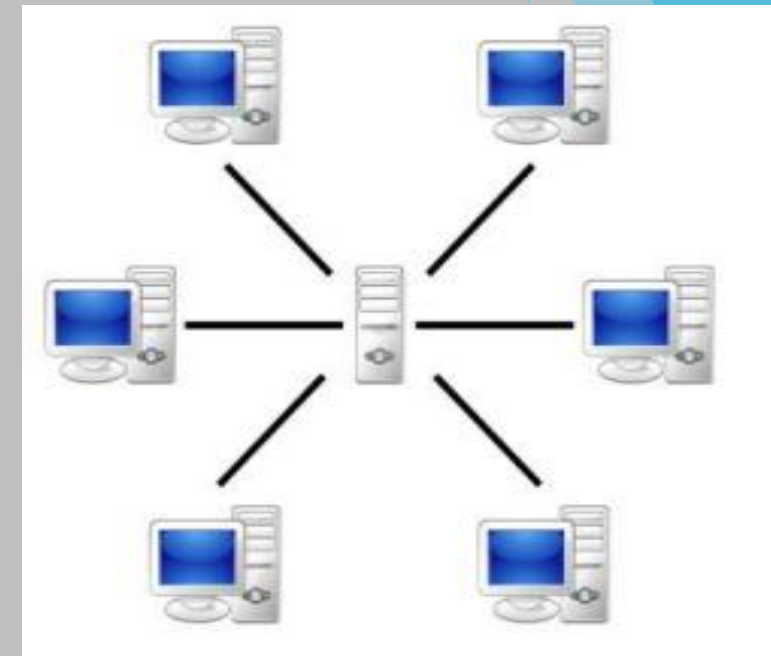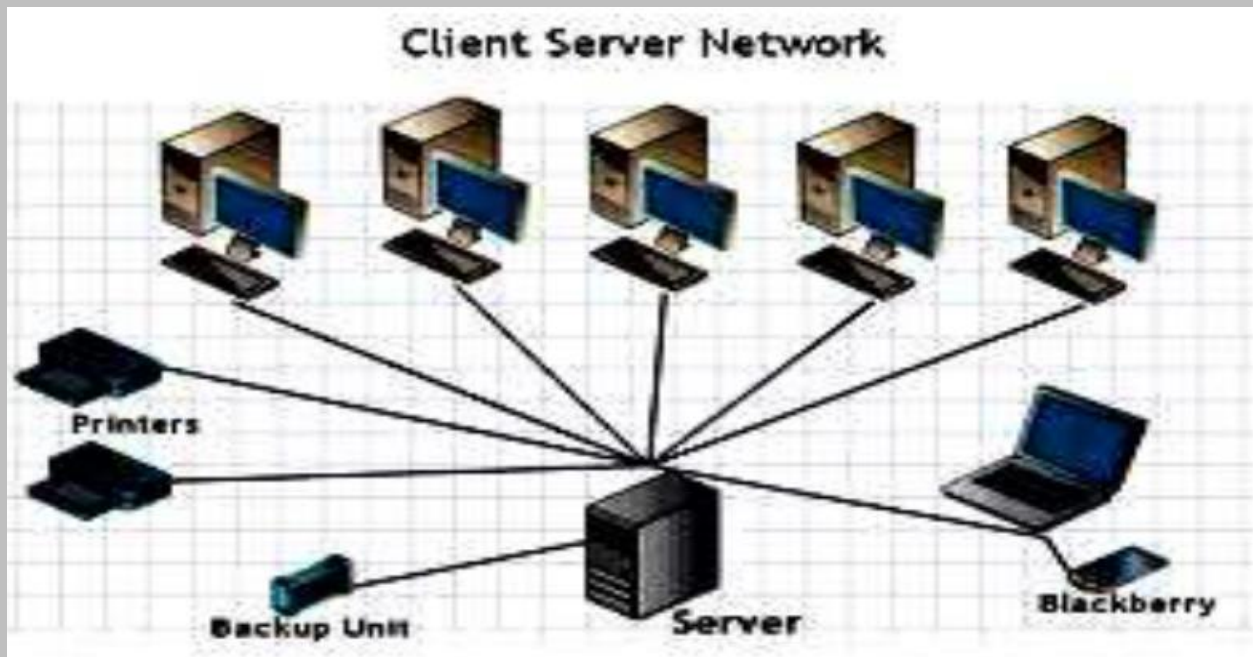
Computer Network

Distributed Computing (Peer to Peer Networks):

- All devices have same power

- It interconnects one or more computers

- Centralized backup is not possible

- In peer to peer network, each computer is responsible for making its own resources available to other computers on the network
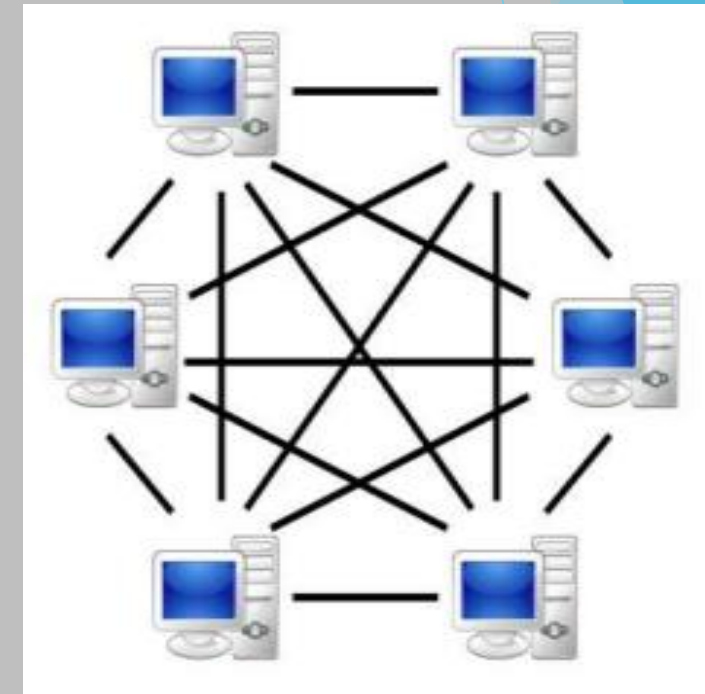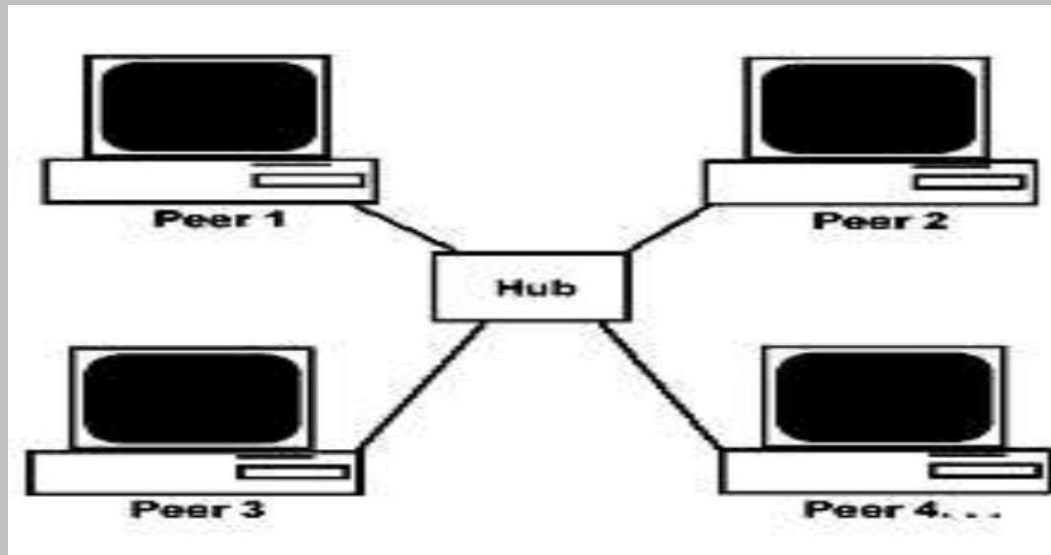
Computer Network

Network Technology Classification Based on Transmission:

Point to Point communication link:

- Point to point communication is the communication over a link between a single transmitter and a receiver

- There may exist multiple paths between a source-destination pair and the switching nodes are there to provide a switching facility that will move data from node to node until they reach the destination.

- Only one receiver is involved here

- Telephone is an example of such a system
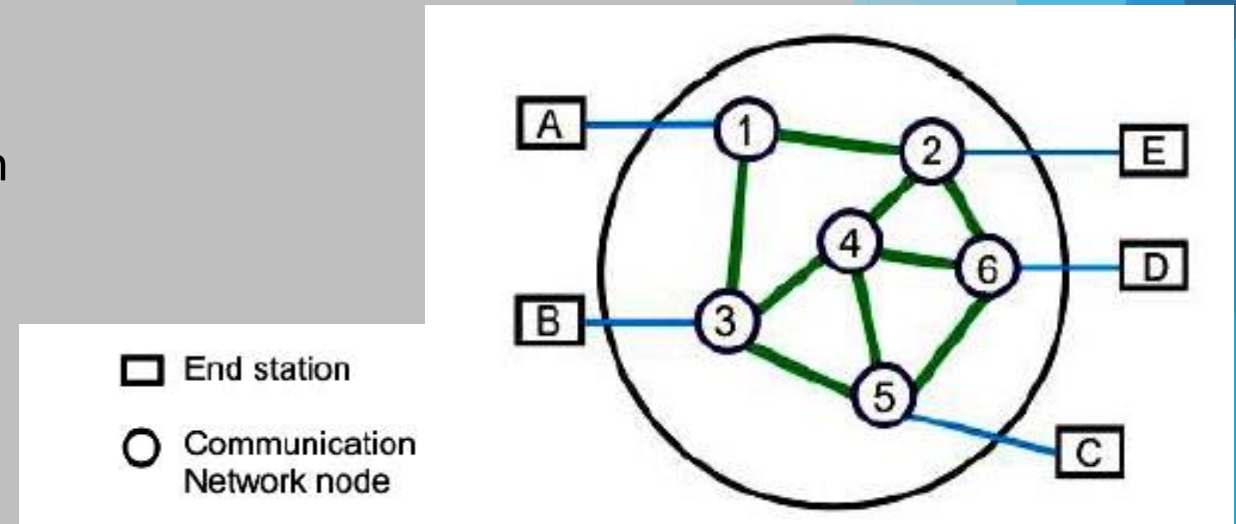
Computer Network

Network Technology Classification Based on Transmission link:

Broadcast communication link:

- In broadcast mode large number of receivers are linked to a single transmitter

- Broadcast network have a single communication channel that is shared by all the machines on the network

- A large number of receivers may be involved
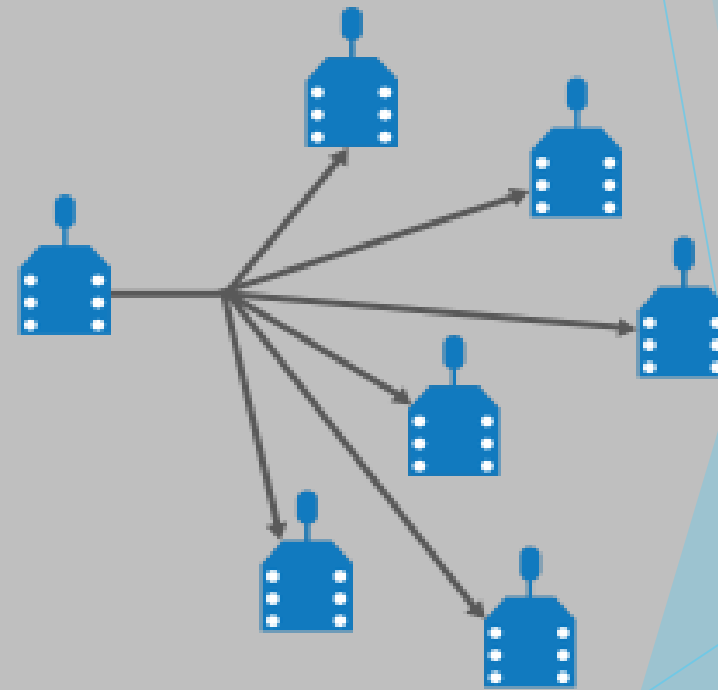
- Radio, TV telecast is example of such system
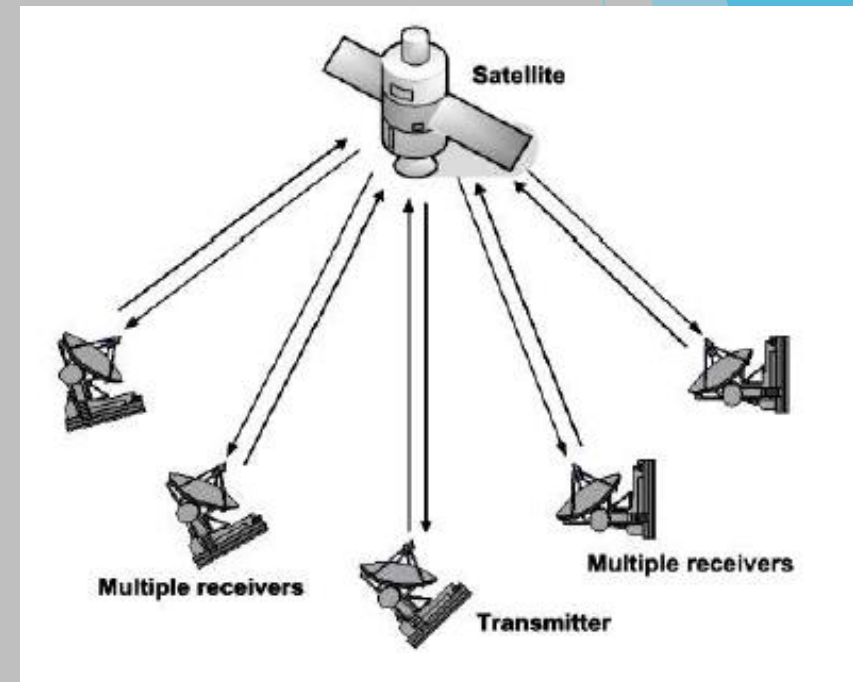
Computer Network

Network Technology Classification Based on Transmission/mode of communication:
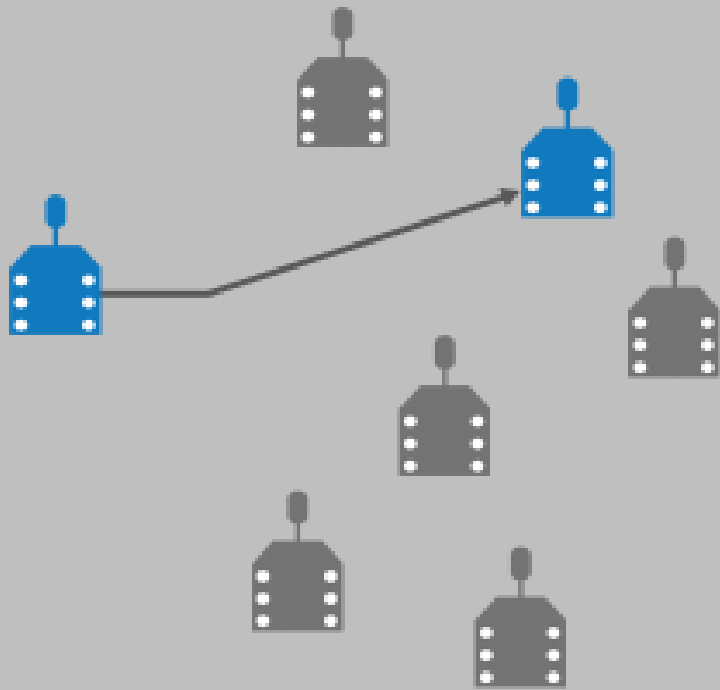
Point to Point   **Broadcast**

Computer Network

How many kinds of Networks?

Depending on one's perspective, we can classify networks in different ways

- Based on network size: LAN, MAN, WAN, PAN, etc.

- Based on management/communication method: Peer-to-peer and Client/Server

- Based on transmission media: Wired (UTP, coaxial cables, fiber-optic cables) and Wireless

- Based on topology (connectivity): Bus, Star, Ring, etc.

Computer Network

Network Transmission Media

Two main categories:

- Guided— wires, cables

- Unguided— wireless transmission, e.g. radio, microwave, infrared, sound, sonar

First we will concentrate on guided media:

- Twisted-Pair cables:

  - Unshielded Twisted-Pair (UTP) cables

  - Shielded Twisted-Pair (STP) cables

- Coaxial cables

- Fiber-optic cables

Computer Network

Network Transmission Media

Twisted-Pair cables

- If the pair of wires are not twisted, electromagnetic noises from, e.g., motors, will affect the closer wire more than the farther one, thereby causing errors
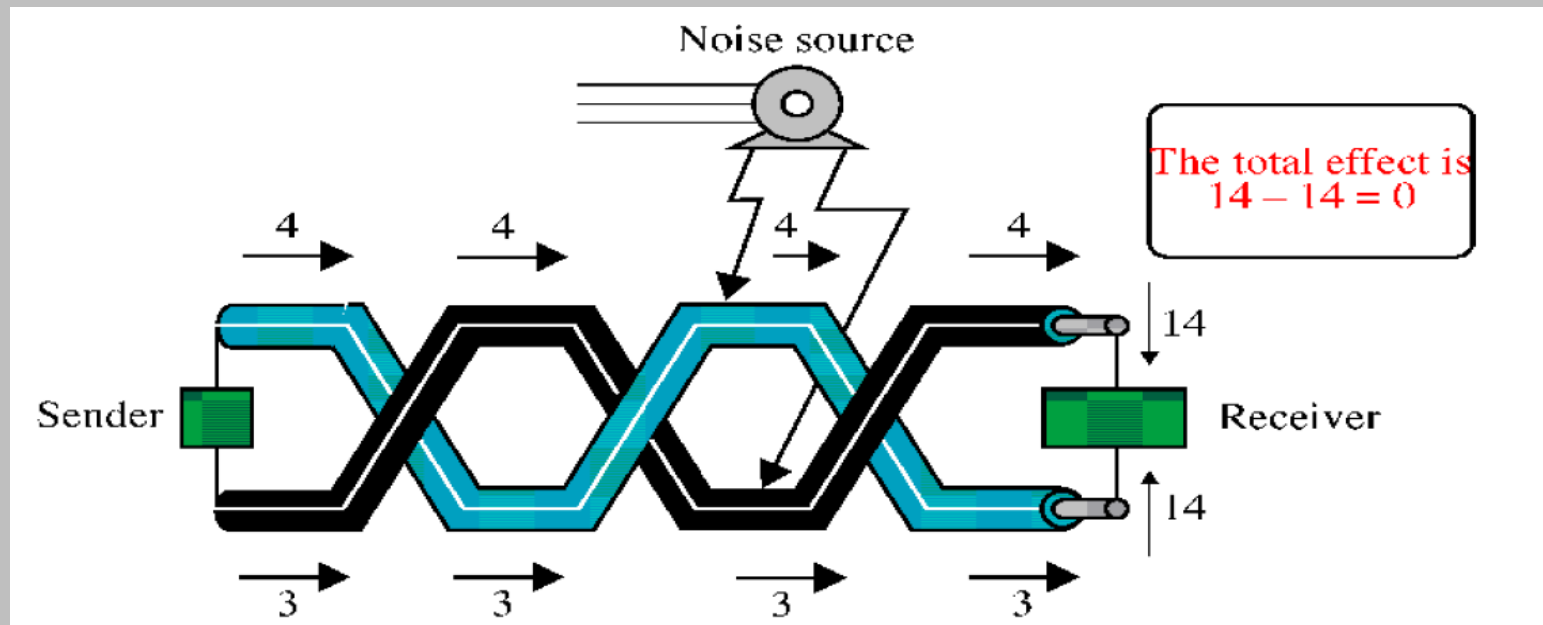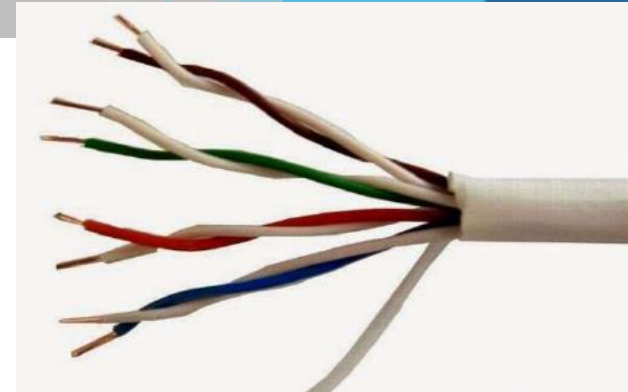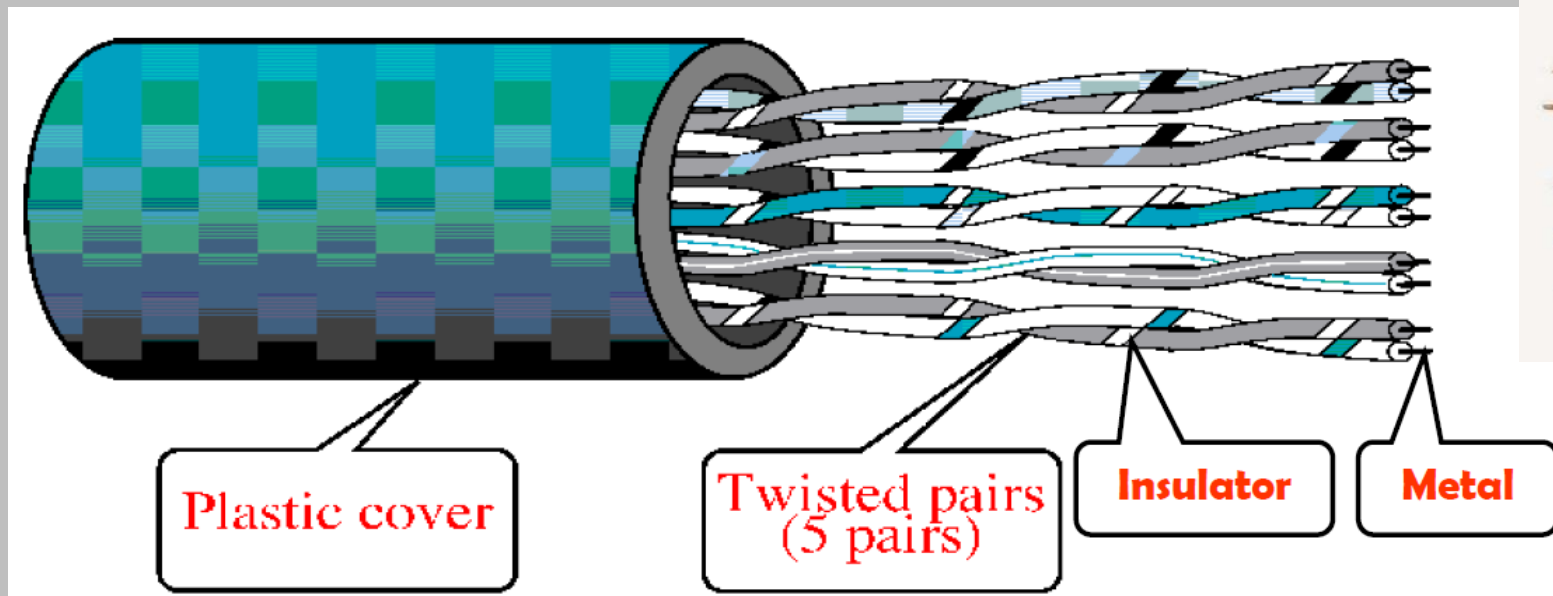
Computer Network

Network Transmission Media

Unshielded Twisted-Pair (UTP) cables

- Typically wrapped inside a plastic cover (for mechanical protection)
- A sample UTP cable with 5 unshielded twisted pairs of wires

Plastic cover
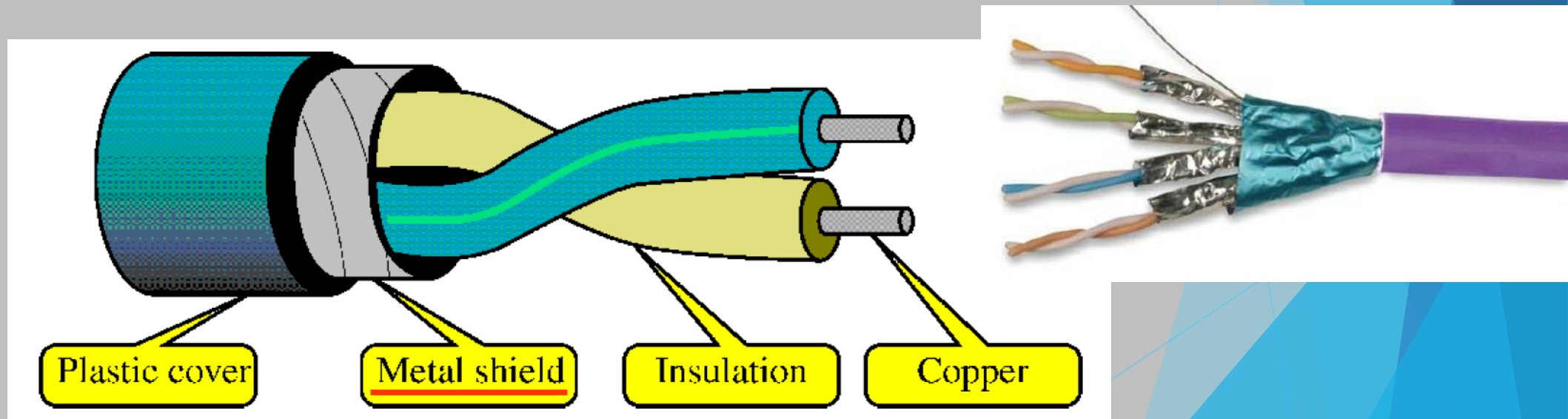
Twisted pairs (5 pairs)

Insulator

Metal

Computer Network
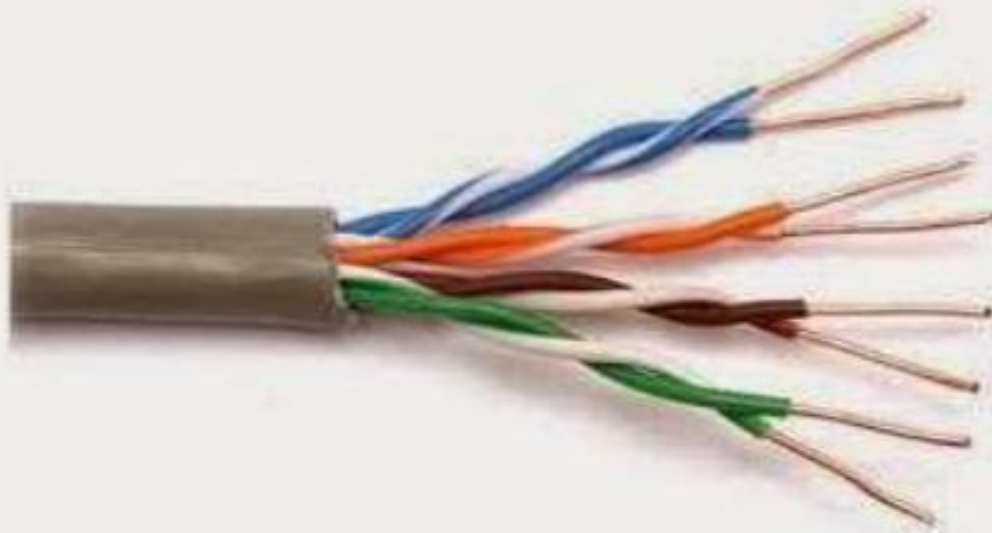
Network Transmission Media

Shielded Twisted-Pair (STP) cables

STP cables are similar to UTP cables, except there is a metal foil or braided-metal-mesh cover that encases each pair of insulated wires

Plastic cover   Metal shield   Insulation   Copper
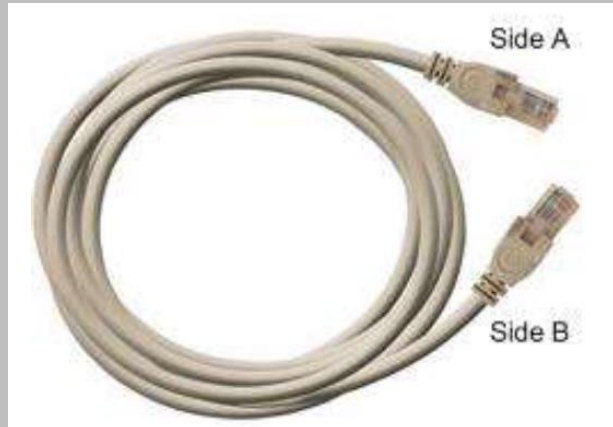
Computer Network

Network Transmission Media

Computer Network

Network Transmission Media

Ethernet Straight Through Cable

- You usually use straight cable to connect different type of devices. This type of cable will be used most of the time and can be used to:
    - Connect a computer to a switch/hub's normal port.
    - Connect a computer to a cable/DSL modem's LAN port.
    - Connect a router's WAN port to a cable/DSL modem's LAN port.
    - Connect a router's LAN port to a switch/hub's uplink port. (normally used for expanding network)
    - Connect 2 switches/hubs with one of the switch/hub using an uplink port an other one using normal port.
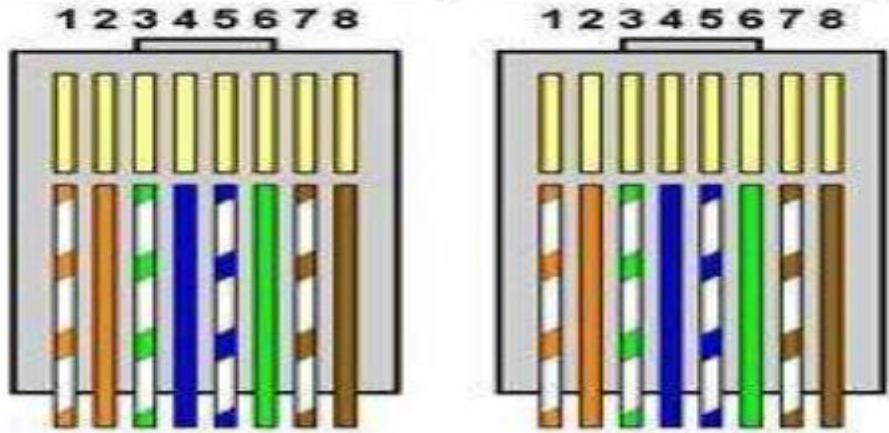
Computer Network

Network Transmission Media

Ethernet Straight Through Cable

Both side (side A and side B) of cable have wire arrangement with same color.

| Pin ID	Side A	Side B
1	Orange-white	Orange-white
2	Orange	Orange
3	Green-white	Green-white
4	Blue	Blue
5	Blue-white	Blue-white
6	Green	Green
7	Brown-white	Brown-white
8	Brown	Brown

Computer Network

Network Transmission Media

Ethernet Cross Over Cable

- Sometimes you will use crossover cable, it's usually used to connect same type of devices. A crossover cable can be used to:
  - Connect 2 computers directly.
  - Connect a router's LAN port to a switch/hub's normal port. (normally used for expanding network)
  - Connect 2 switches/hubs by using normal port in both switches/hubs.
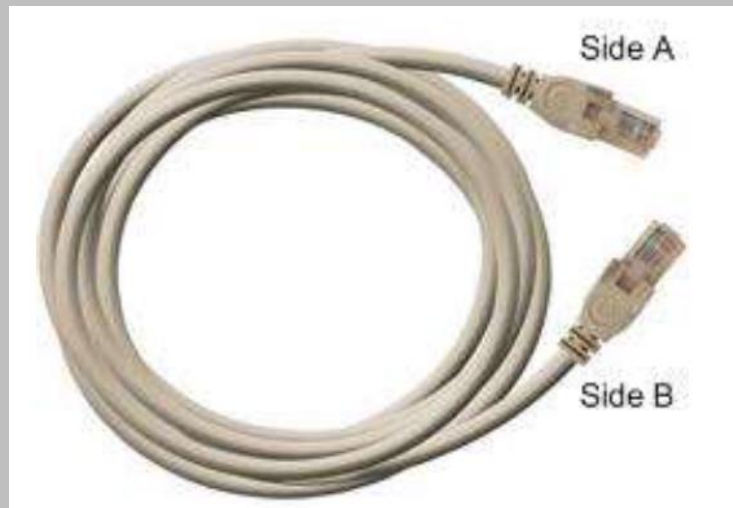
Computer Network

Network Transmission Media

Ethernet Cross Over Cable

Both side (side A and side B) of cable have wire arrangement with following different colors.
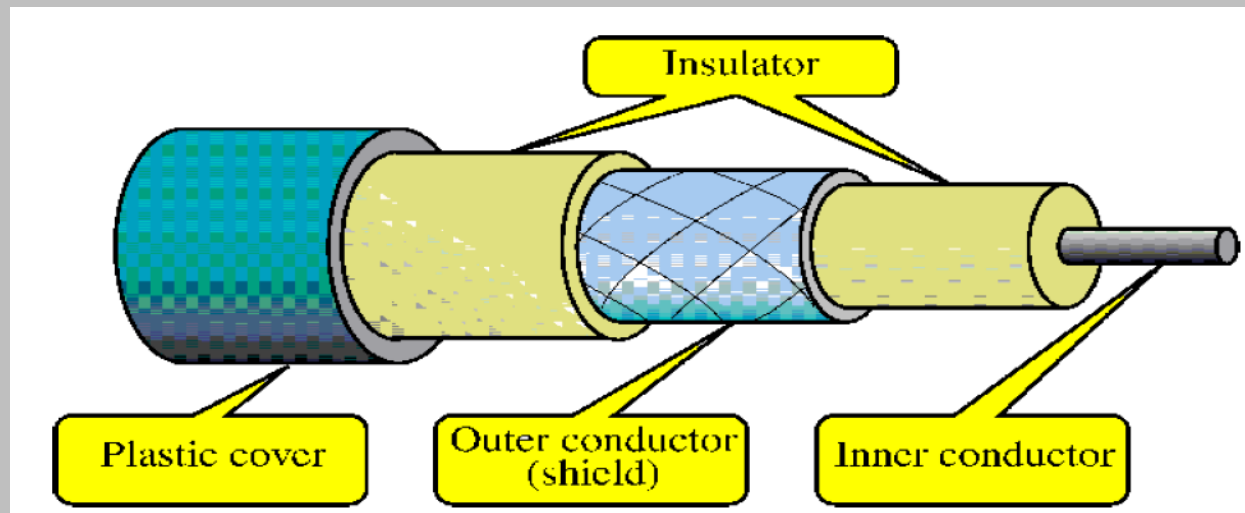
Network Transmission Media

Coaxial cables

- In general, coaxial cables, or coax, carry signals of higher freq. (100KHz–500MHz) than UTP cables
- Outer metallic wrapping serves both as a shield against noise and as the second conductor that completes the circuit
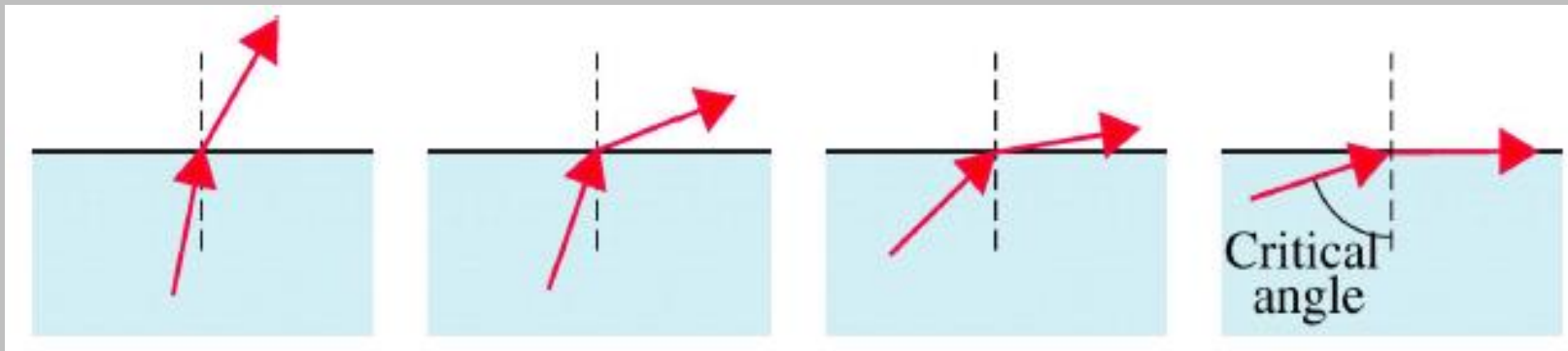
Computer Network

Network Transmission Media

Fiber-optic cables

- Light travels at $3 \times 10^8 ms^{-1}$ in free space and is the fastest possible speed in the Universe

- Light slows down in denser media, e.g. glass

- Refraction occurs at interface, with light bending away from the normal when it enters a less dense medium

- Beyond **critical angle** = **total internal reflection**

Common light sources: LEDs and lasers

Computer Network

Network Transmission Media

Fiber-optic cables

- An optical fiber consists of a core (denser material) and a cladding (less dense material)

- Simplest one is a multimode step-index optical fiber

- Multimode = multiple paths, whereas step-index = refractive index follows a step-function profile (i.e. an abrupt change of refractive index between the core and the cladding)
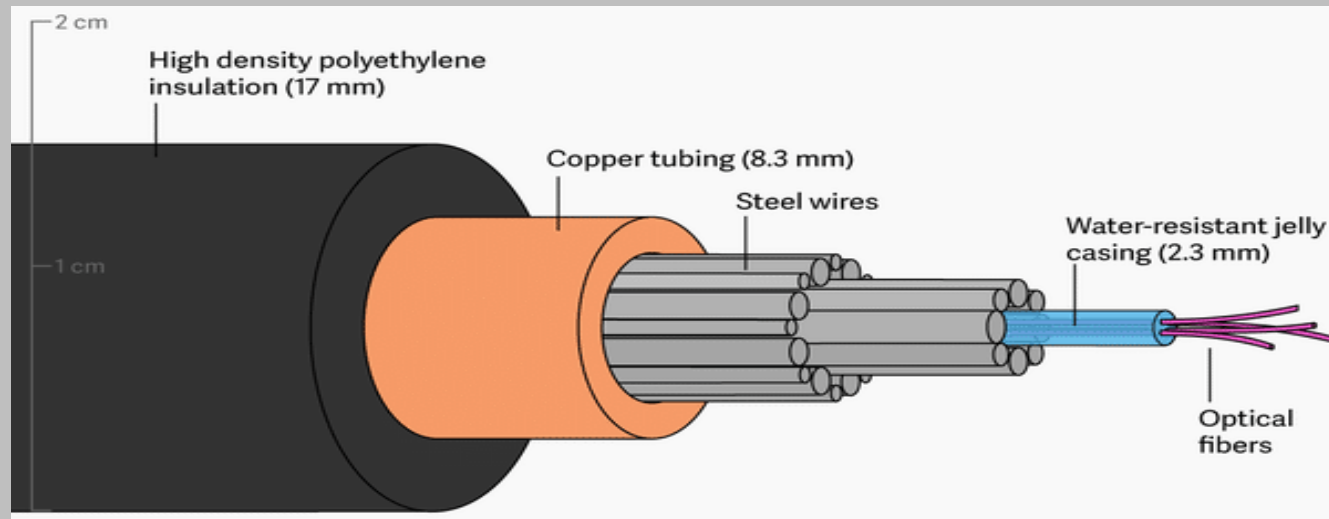
Light bounces back and forth along the core

Computer Network

Network Transmission Media

Implementation Points	Copper	Fiber Optic
Bandwidth Supported	10 Mbps – 10 Gbps	10 Mbps – 100 Gbps
Range	Relatively short (upto 100 meters)	Relatively High (upto 100,000 meters)
Immunity To EMI And RFI	Low	High (Completely immune)
Immunity To Electrical Hazards	Low	High (Completely immune)
Media And Connector Costs	Lowest	Highest
Installation Skills Required	Lowest	Highest
Safety	Lowest	Highest

Computer Network

Network Components/Hardware

- Repeaters

- Hubs

- Switches

- Bridges

- Routers (Gateways)

Computer Network

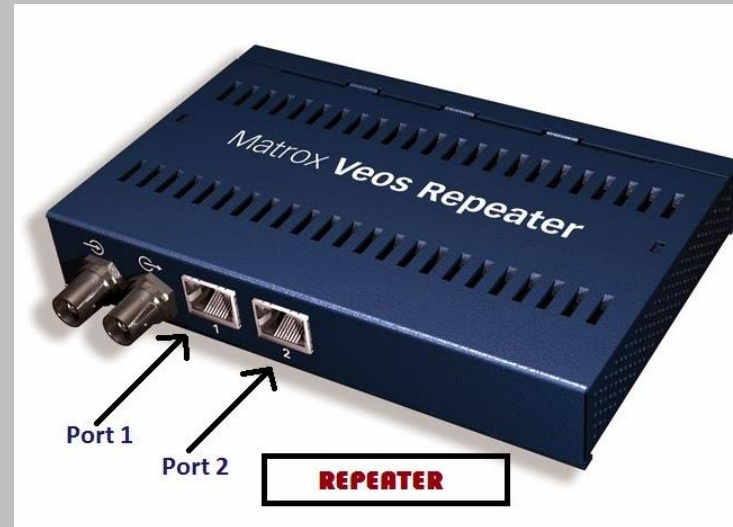Network Components/Hardware

Repeater

- Since a signal loses strength as it passes along a cable, it is often necessary to boost the signal with a device called a repeater.

- A repeater is an electronic device that receives a signal, cleans it of unnecessary noise, regenerates it, and retransmits it at a higher power level so that the signal can cover longer distances without degradation.
  - *i.e. Repeater boost or amplifies the signal before passing it through to the next section of cable.*

- A good example of the use of repeaters would be in a local area network using a star topology with unshielded twisted-pair cabling.

Computer Network

Network Components/Hardware

Repeater

Computer Network

Network Components/Hardware

Hub

- A hub is a multiport connecting device that is used to interconnect LAN devices, i.e. A hub joins multiple computers (or other network devices) together to form a single network.

- On this network, all computers can communicate directly with each other.

- The networking hub is a junction box with several ports in the back for receiving the Ethernet cables that are plugged into each computer on the LAN.

- A hub can be used to extend the physical length of a network.

Computer Network

Network Components/Hardware

Hub
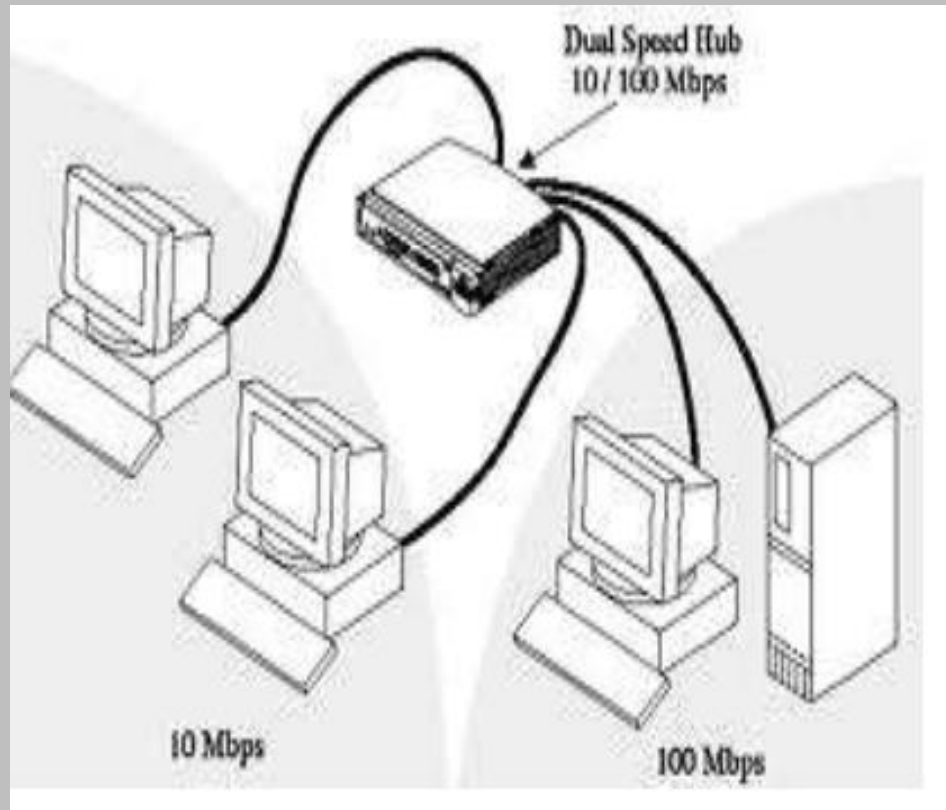
Computer Network

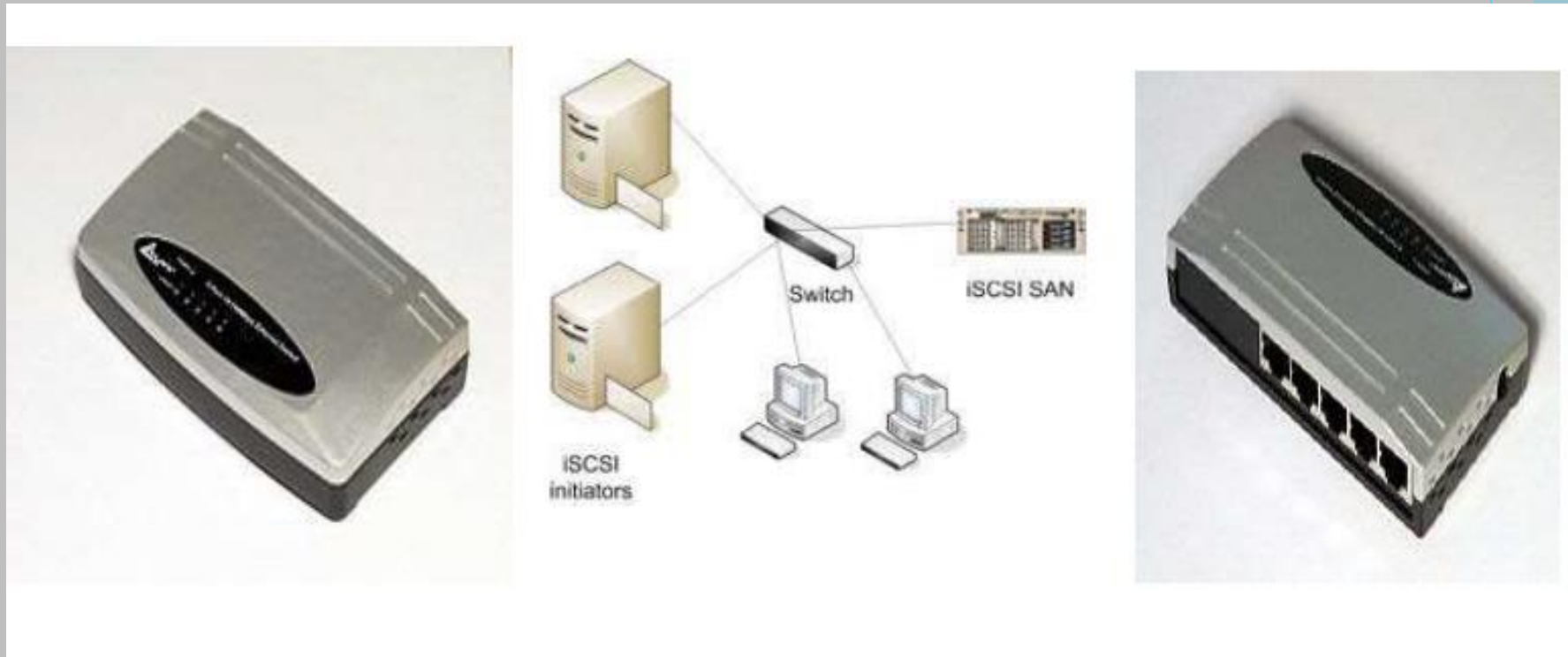Network Components/Hardware

Switch

- A network switch is a small hardware device that joins multiple computers together within one local area network (LAN).

- Network switches appear nearly identical to network hubs, but a switch generally contains more intelligence than a hub.

- Unlike hubs, network switches are capable of inspecting data packets as they are received, determining the source and destination device of each packet, and forwarding them appropriately.

- Allow several users to send information over a network at the same time without slowing each other down.

Computer Network

Network Components/Hardware

Switch

Computer Network

Network Components/Hardware

Bridge

- It connects the network with same protocol and topology.

- The main task of a bridge computer is to receive and pass data from one LAN to another.

Bridges come in three basic types:

- Local bridges: Directly connect local area networks (LANs)

- Remote bridges: Can be used to create a wide area network (WAN) link between LANs. Remote bridges have been replaced with routers.

- Wireless bridges: Can be used to join LANs or connect remote stations to LANs.

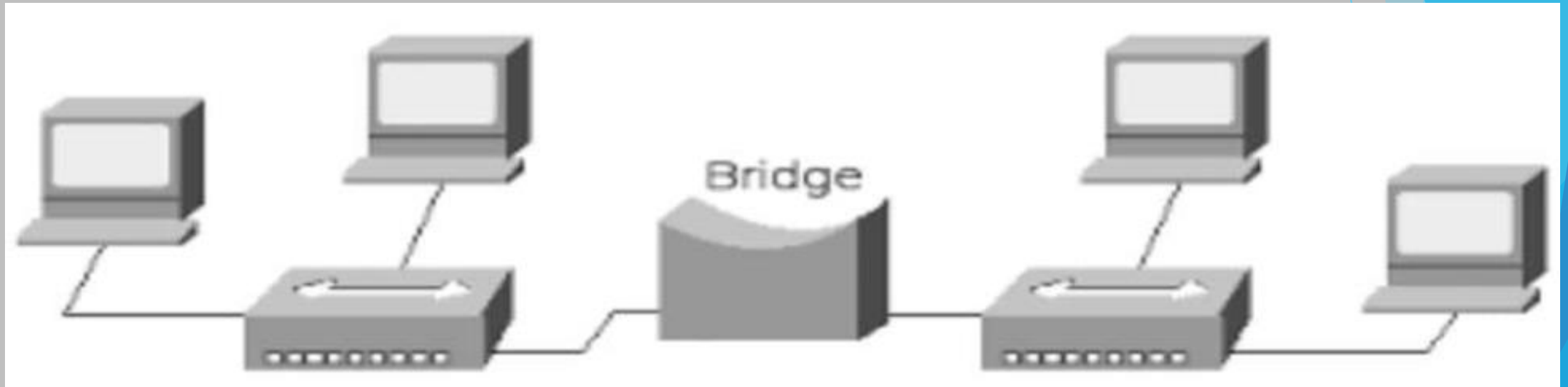# Computer Network

Network Components/Hardware

Bridge

- A bridge is a device that connects a local area network (LAN) to another local area network that uses the same protocol (for example, Ethernet or token ring).

- The function of a bridge is to connect separate networks together. Bridges connect different networks types (such as Ethernet and Fast Ethernet) or networks of the same type.

- Bridges map the Ethernet addresses of the nodes residing on each network segment and allow only necessary traffic to pass through the bridge. When a packet is received by the bridge, the bridge determines the destination and source segments.

Computer Network

Network Components/Hardware

Bridge

Computer Network

Network Components/Hardware

Router

- A router is a device that connects multiple networks using similar or different protocols.

- Routers are used when several networks are connected together.

- A router is an electronic device that interconnects two or more computer networks, and selectively interchanges packets of data between them.

- Each data packet contains address information that a router can use to determine if the source and destination are on the same network, or if the data packet must be transferred from one network to another.

Computer Network
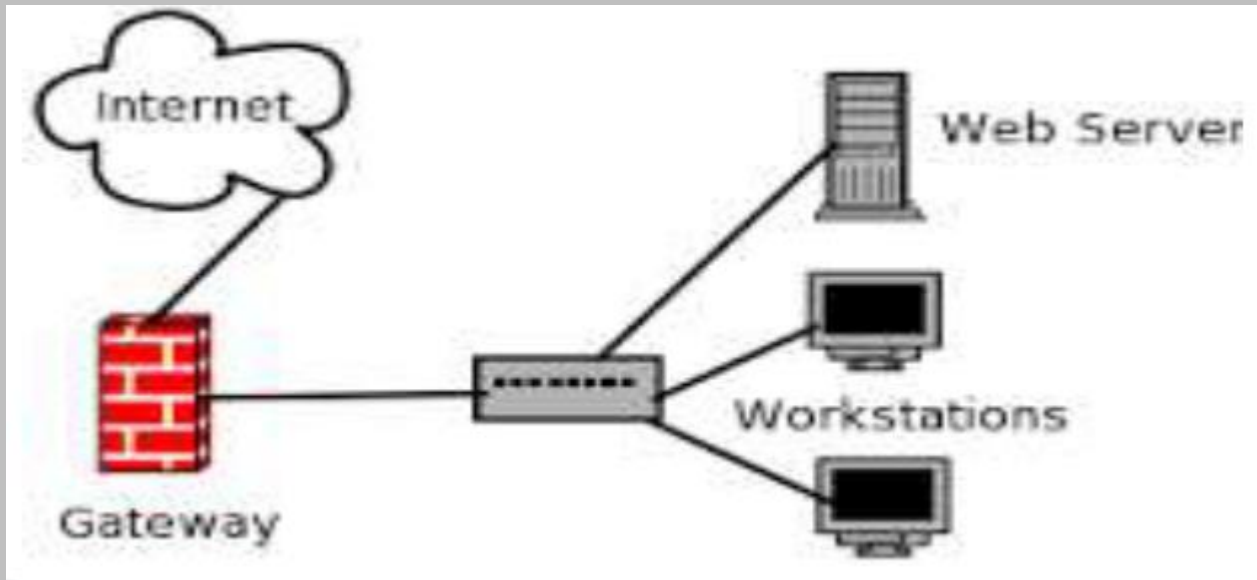
Network Components/Hardware

Router

Computer Network

Network Components/Hardware

Gateway (also called protocol converters; acts as an entrance to another network)

- Gateway is a device that connects two or more networks with different types of protocol.

- It receives data from one network and converts it according to the protocol of other network.

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How many kinds of Networks?

Depending on one's perspective, we can classify networks in different ways

- Based on network size: LAN, MAN, WAN, PAN, etc.

- Based on management/communication method: Peer-to-peer and Client/Server

- Based on transmission media: Wired (UTP, coaxial cables, fiber-optic cables) and Wireless

- Based on topology (connectivity): Bus, Star, Ring, etc.

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Network Topologies: What is Topology?

- Network topology refers to the way in which a network is laid out physically.

- The physical topology of a network refers to the configuration of cables, computers, and other peripherals

- The topology of a network is the geometric representation of the relationship of all the links and linking devices (nodes) to one another.

There are different types of topologies

- Bus Topology
- Star Topology
- Ring Topology
- Mesh Topology
- Tree Topology
- Hybrid Topology

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Bus Topology:

- A bus Topology is multipoint connection

- All the nodes (file server, workstations, and peripherals) on a bus topology are connected by one single cable.

- This one long single cable acts as a backbone to link all the devices in a network.

- A bus topology consists of a main run of cable with a terminator at each end.

- Popular on LANs because they are inexpensive and easy to install.
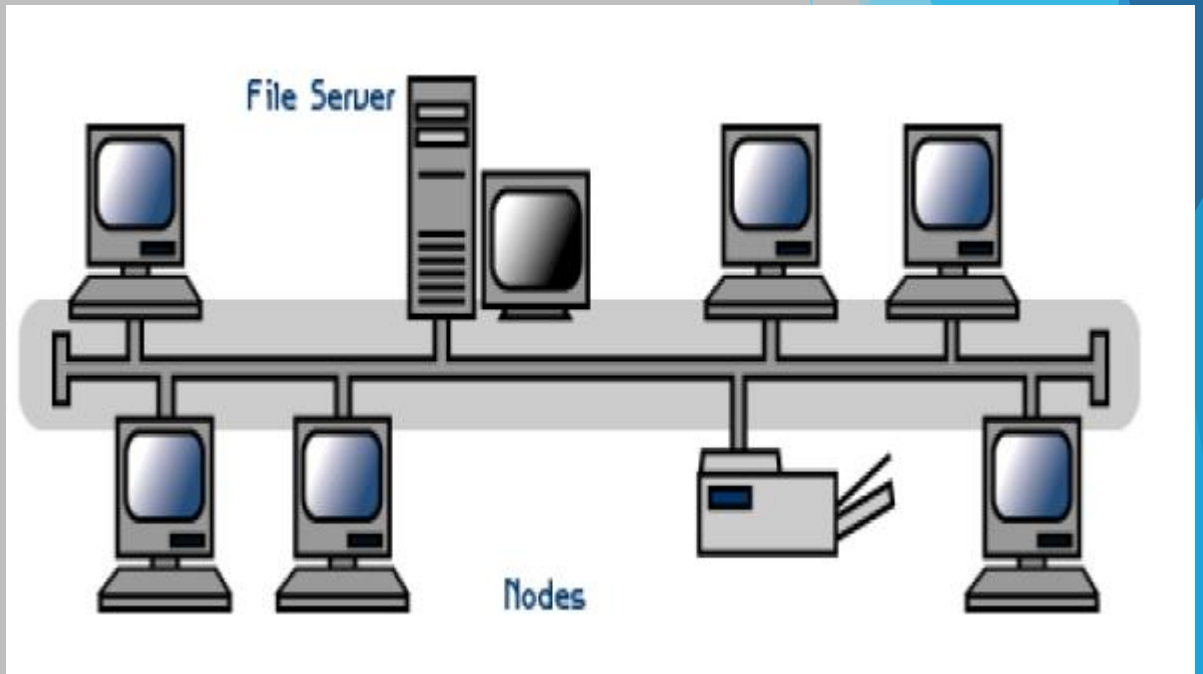
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Bus Topology:

- Nodes are connected to the bus cable by drop lines and taps.

- A drop line is a connection running between the device and the main cable.

- A tap is a connector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core.
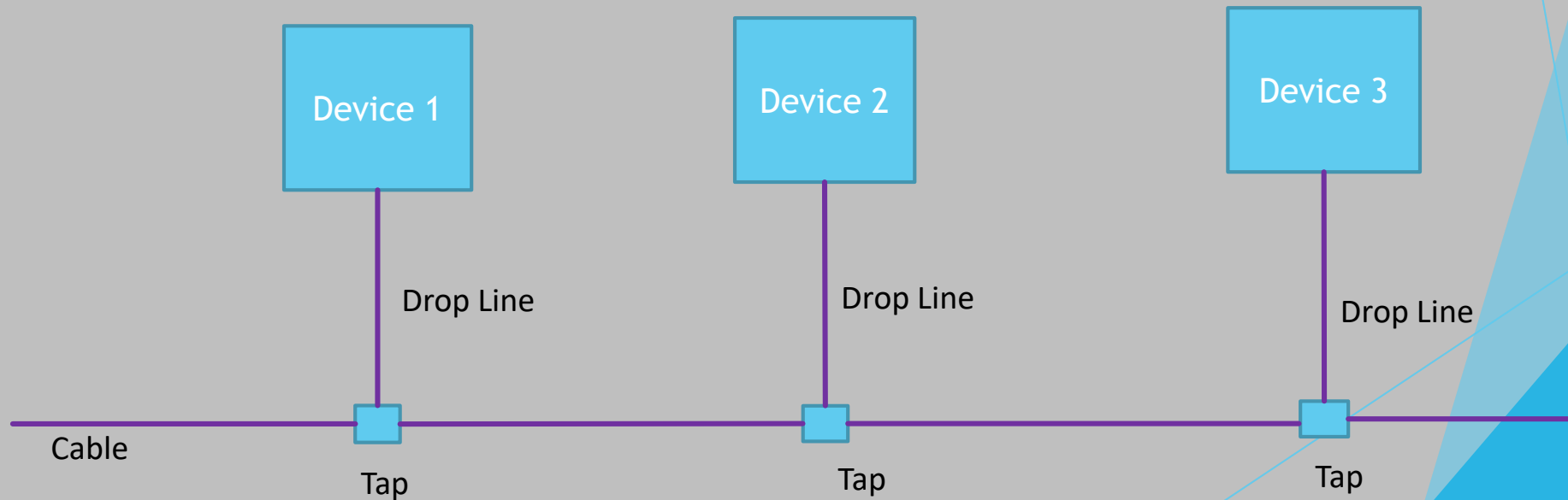
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Bus Topology:

- **Advantages:**

  - Ease of installation

  - Bus topology uses less cabling than mesh or star topologies.

- **Disadvantages:**

  - Difficult reconnection and fault isolation

  - Difficult to add new devices

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Ring Topology:

- In a ring network, every device has exactly two neighbours for communication purposes.

- All messages travel through a ring in the same direction.

- A signal is passed along the ring in one direction, from device to device, until it reaches its destination.

- Each device in the ring incorporates a repeater. When a device receives a signal intended for another device, its repeater regenerates the messages and passes them along path.

- Example:
  - To implement a ring network we use the Token Ring technology

  - A token, or small data packet, is continuously passed around the network. When a device needs to transmit, it reserves the token for the next trip around, then attaches its data packet to it.

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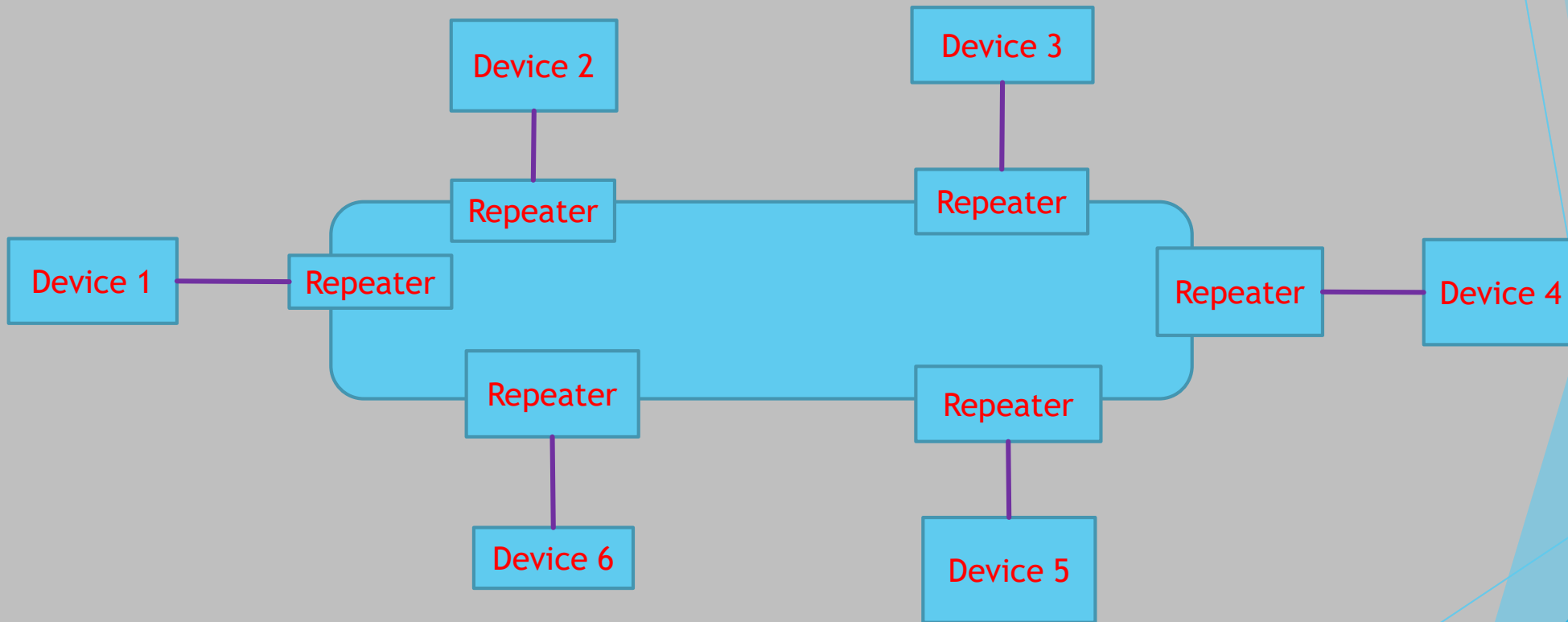
Ring Topology:

Advantage of Ring Topology

- Very orderly network where every device has access to the token and the opportunity to transmit.
- Easier to Manage than a Bus Network
- Good Communication over long distances
- Handles high volume of traffic

Disadvantages of Ring Topology

- The failure of a single node of the network can cause the entire network to fail.
- The movement or changes made to network nodes affects the performance of the entire network.
- Unidirectional traffic
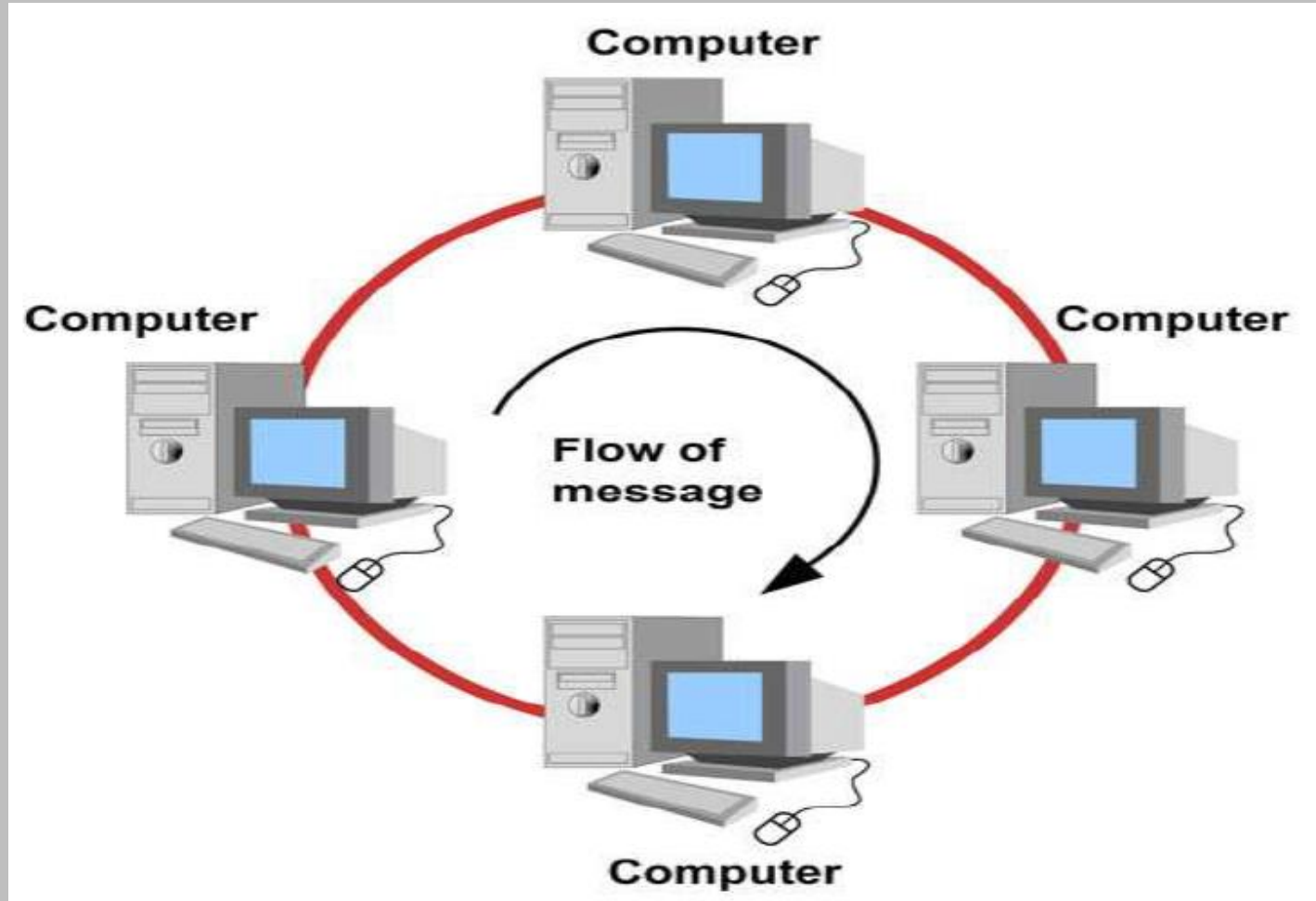- Break in the ring disable the entire network

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Ring Topology:

Computer Network

Star Topology:

- In a star topology, each device has a dedicated point-to-point link only to a central controller, called a hub.

- The devices are not directly linked to one another.

- A star topology does not allow direct traffic between devices. The controller acts as an exchange.

- If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device.

- Example: The star topology is used in local-area networks (LANs). High-speed LANs often use a star topology with a central hub.
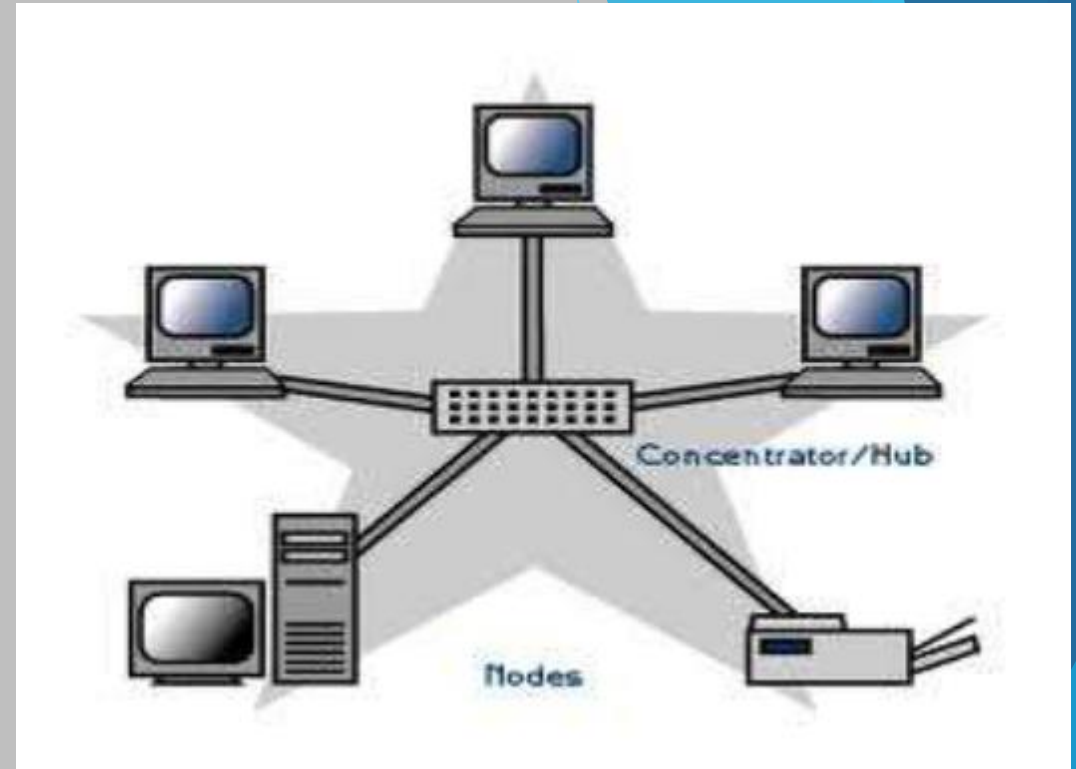
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Star Topology:

Advantages of Star Topology

- Easy to manage
- Easy to locate problems (cable/workstations)
- Easier to expand than a bus or ring topology.
- Easy to install and wire.
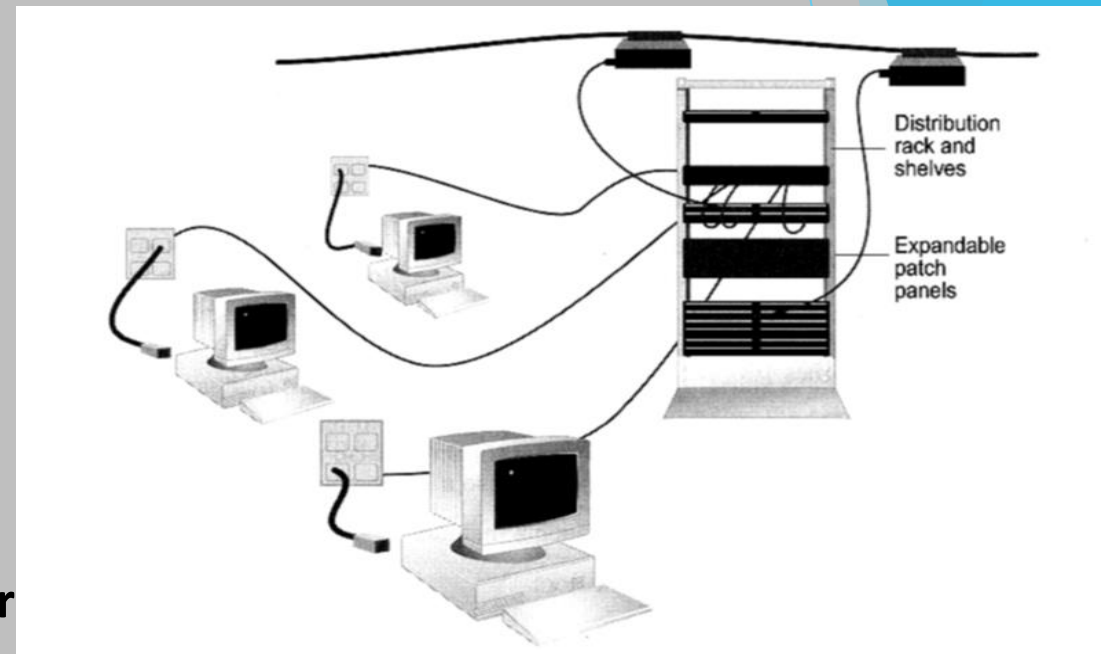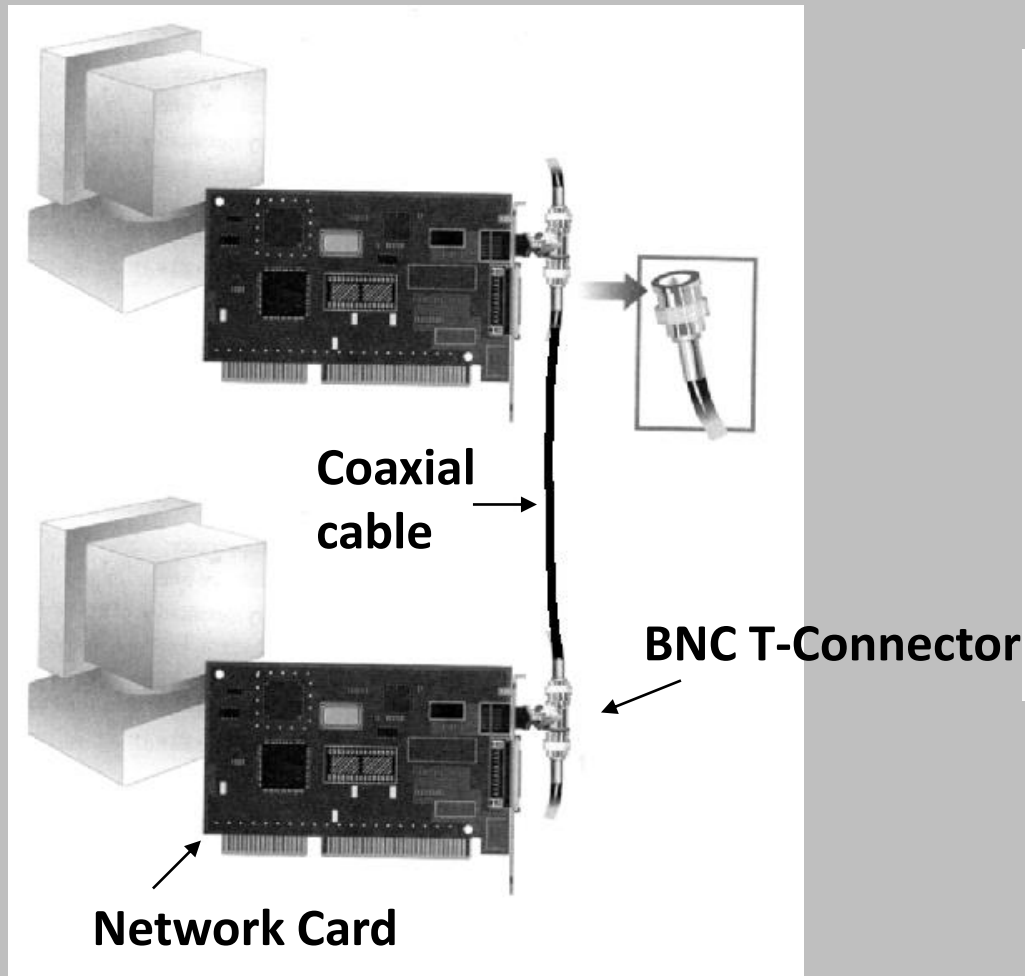- Easy to detect faults and to remove parts.

Disadvantages of Star Topology

- Requires more cable length than a linear topology.
- If the hub fails, nodes attached are disabled.
- More expensive because of the cost of the hub.

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How to construct a network with Bus / Star Topology?

Coaxial cable

BNC T-Connector

Network Card

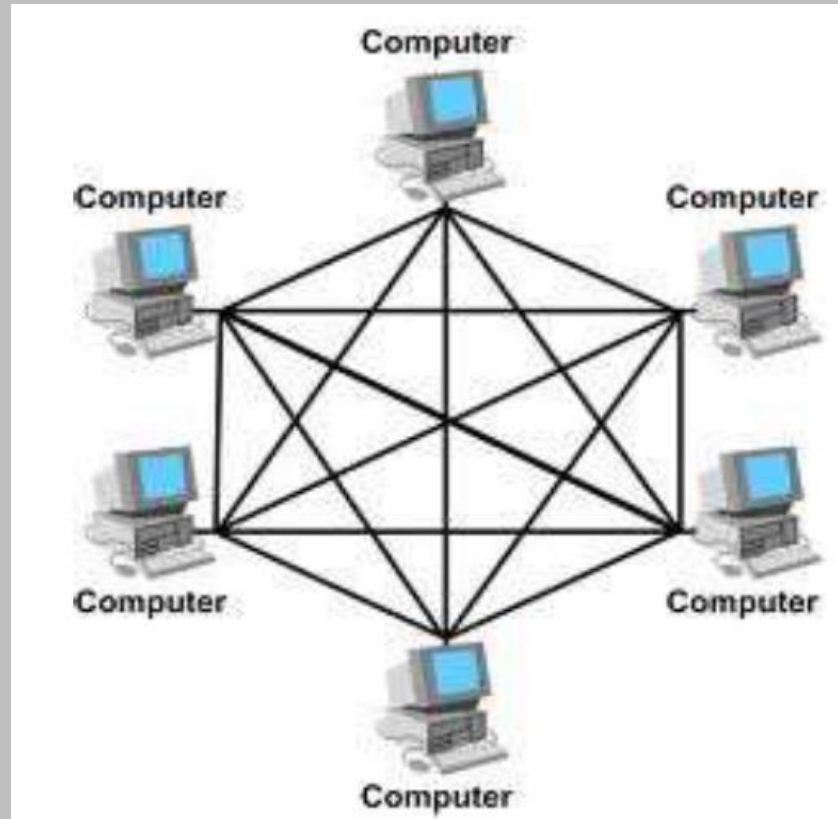Distribution rack and shelves

Expandable patch panels

Star Topology

Computer Network

Mesh Topology:

In a mesh topology, every device has a dedicated point-to-point link to every other device. The term dedicated means that the link carries traffic only between the two devices it connects.

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Mesh Topology:

Example: connection of telephone regional offices in which each regional office needs to be connected to every other regional office.
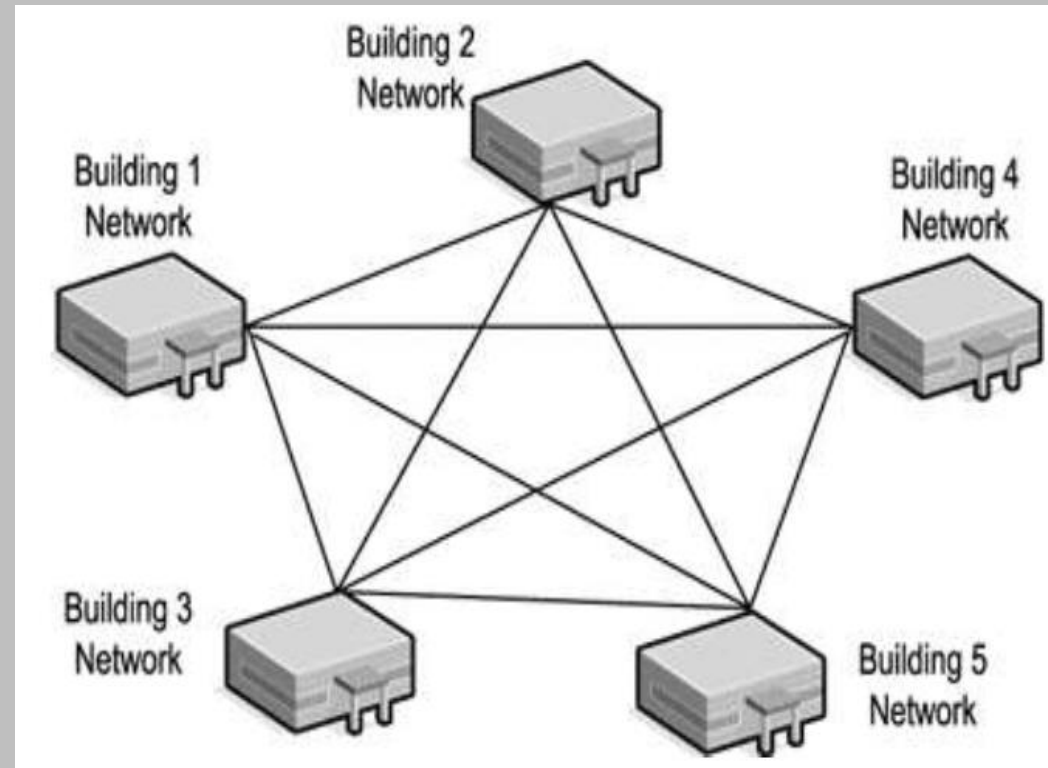
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Mesh Topology:

Advantages of Mesh Topology:

- Eliminate the traffic problems that can occur when links shared by multiple devices. (Can follow any path)

- Mesh topology is robust.

- Privacy and Security

- Point-to-point links make fault identification and fault isolation easy.

Disadvantages of Mesh Topology :

- More amount of cabling and the number of I/O ports required.

- The hardware required to connect each link (I/O ports and cable) can be expensive.

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Tree Topology:

- A tree topology (hierarchical topology) can be viewed as a collection of star networks arranged in a hierarchy.

- This tree has individual peripheral nodes which are required to transmit to and receive from one other only and are not required to act as repeaters or regenerators.

- The tree topology arranges links and nodes into distinct hierarchies in order to allow greater control and easier troubleshooting.

- This is particularly helpful for colleges, universities and schools so that each of the connect to the big network in some way.

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Tree Topology:

### *Advantages of a Tree Topology*

- Point-to-point wiring for individual segments.

- Supported by several hardware and software vendors.

- All the computers have access to the larger and their immediate networks.

Disadvantages of a Tree Topology

- Overall length of each segment is limited by the type of cabling used.

- If the backbone line breaks, the entire segment goes down.

- More difficult to configure and wire than other topologies.

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Tree Topology:
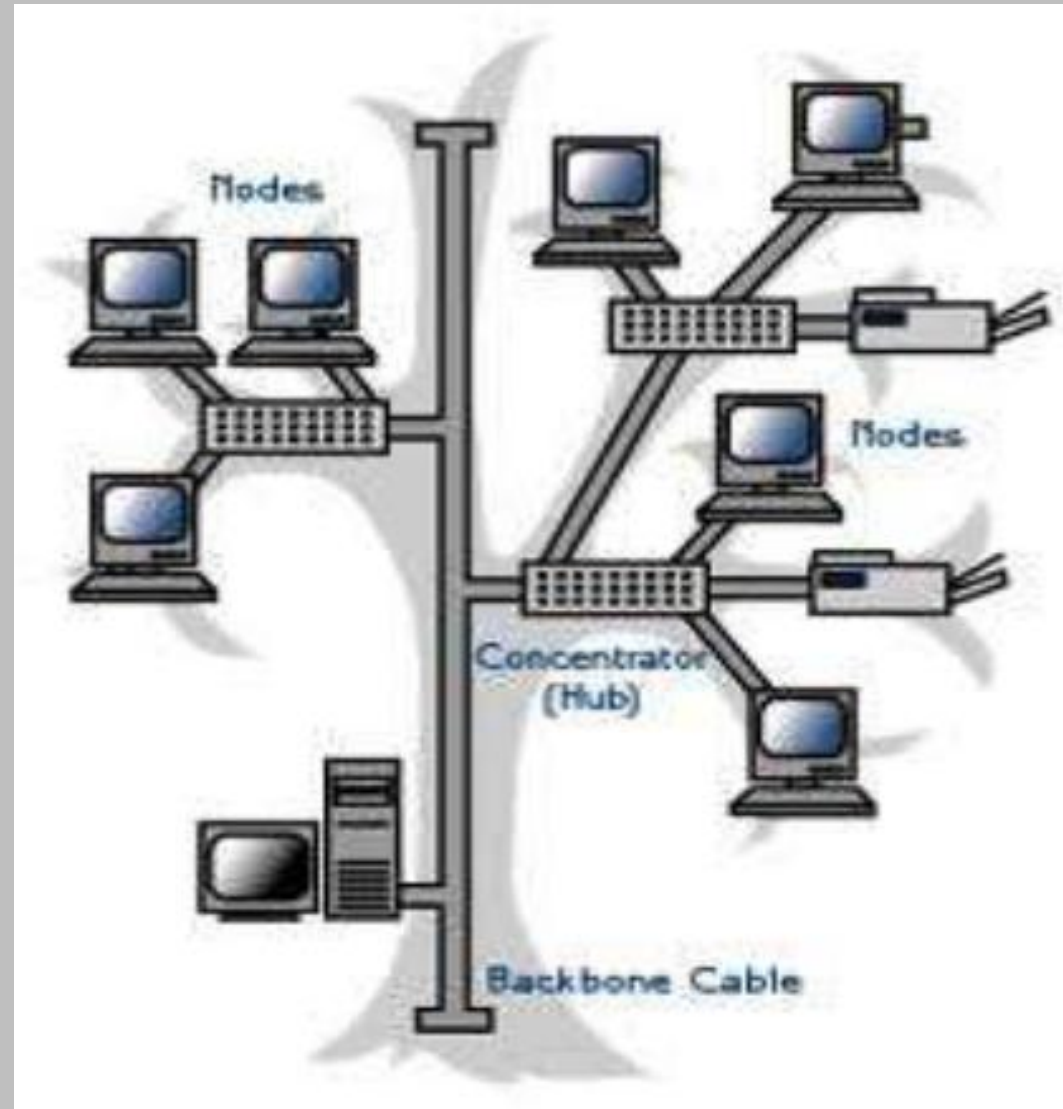
Hybrid Topology:

- A combination of any two or more network topologies

- A hybrid topology always accrues when two different basic network topologies are connected.

- It is a mixture of above mentioned topologies. Usually, a central computer is attached with sub-controllers which in turn participate in a variety of topologies
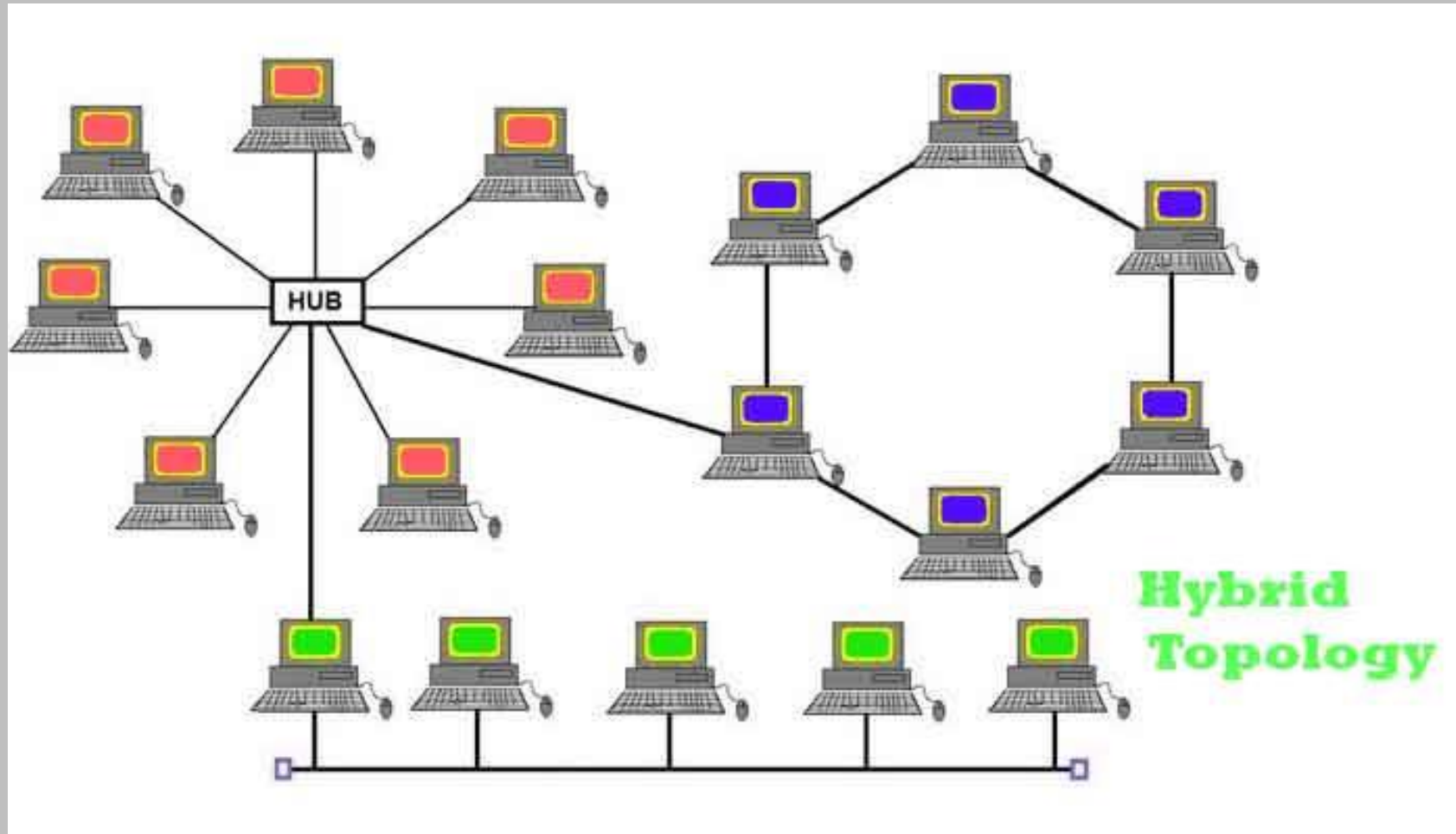
Advantages of a Hybrid Topology

- It is extremely flexible.

- It is very reliable.

Disadvantages of a Hybrid Topology

- Expensive

Hybrid Topology:

The Computer Network

- Network Architecture - Interfaces and services

- Protocol and Standards

- ISO-OSI Reference Model

- TCP/IP Protocol suite

- Comparison of OSI and TCP/IP