Chapter1: Basics of Computer Networking

A computer network is a network of computer devices like computers, servers, routers, switches, or other related hardware's that are interlinked with one another to communicate and share resources, exchange data, and shared services.

Characteristics of a Computer Network

The following are the characteristics of a computer network −

- Share resources from one computer to another.
- Create files and store them in one computer, access those files from the other computer(s) connected over the network.
- Connect a printer, scanner, or a fax machine to one computer within the network and let other computers of the network use the machines available over the network.

Types of a Computer Network

A computer network can be categorized into three main categories −

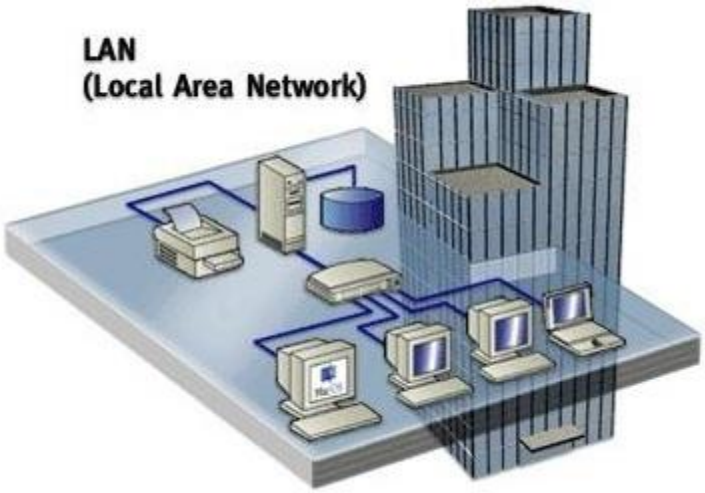
- LAN (Local Area Network)
- MAN (Metropolitan Area Network)
- WAN (Wide Area Network)

These networks can be built using geographical scope and the medium of connection (wired or wireless). A computer network allows to access network, file sharing, printing and collaboration between users at a time. Computer networks can be designed using network topologies (star, bus, ring, mesh) and protocols (TCP/IP, Ethernet, Wi-Fi) depending on the specific requirements and constraints of the environment they serve.

Description of LAN, MAN and WAN are as follows −

1. Local Area Network (LAN)

As its name implies, A LAN is a network which is limited to local area only for example home, office building, school, or campus. Hence, any network that exists within a single building, or even a group of adjacent buildings, is considered as LAN. It is often used to connect separate LANs together so they can communicate and exchange data. In a LAN, limited computer and networking devices are connected because its geographical area is small; it is specifically design for shorter distance and used for sharing resources like files, printers, and internet connections among connected devices; the devices are physically connected with cables in wired LAN while in wireless LAN; devices are connected using wireless media.



Overall, LANs are essential for communication, sharing of resources and communication between devices within a given area and facilitate its users for file sharing, printing, multimedia and streaming, which are common tasks for commercial and home networks.

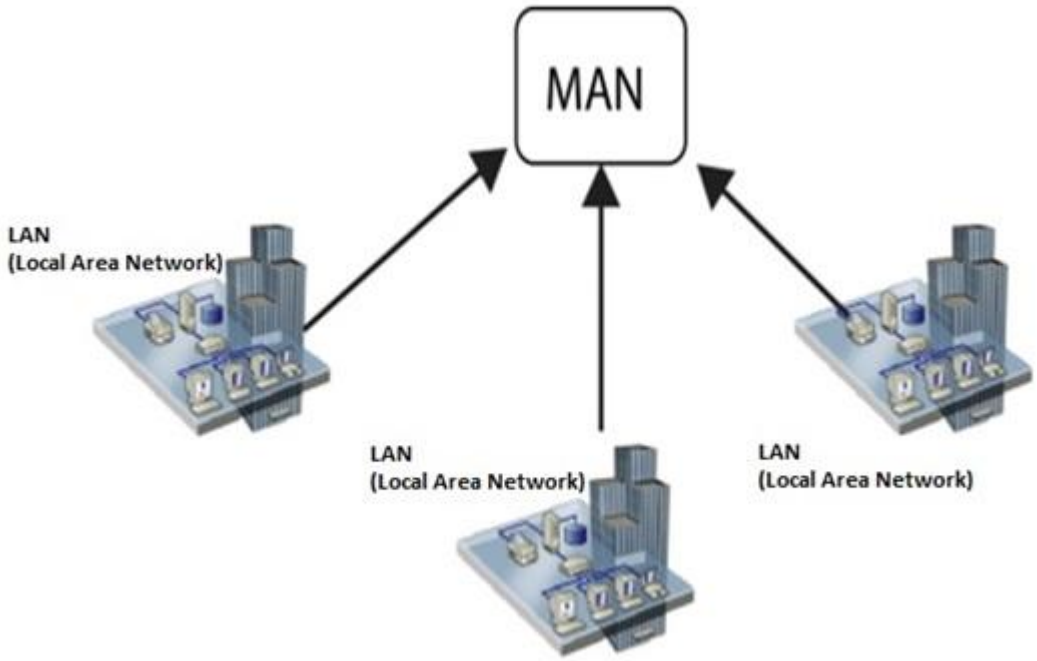
Characteristics of LANs

- **Limited Geographic Area** − A LAN network is dedicated for small area like a single building, campus, school, hospital.
- **High Data Transfer Rates** − A LAN network covers a short distance so the data transmits with high speed as compare to MANs and WANs.
- **Ownership and Control** − Because of its local network and small size; they are owned, controlled, and managed by individuals or organizations with full control over the network, access and security policies.
- **Connectivity** − Generally, A LAN connects using Ethernet cables, Wi-Fi, or both.
- **Topology** − Its a method to making a LAN; some common topologies are bus, star, ring, or mesh.

2. Metropolitan Area Network (MAN)

Metropolitan Area Network (MAN) is an extensive network that connects two or more LANs together within a specific geographical area, such as a city or a town. Usually MANs are not owned by sole organization. Their communication devices and equipment are maintained by

a group or single network provider that sells its networking services to corporate customers. MANs often take the role of high-speed network that allows sharing of regional resources. MANs also can provide a mutual connection between two or more local networks.



Characteristics of MANs

- **Geographical Coverage** − MANs cover a larger geographical as it combines multiple LANs across different locations; for example - a network of a city.
- **High-Speed Connectivity** − MANs provide high-speed data transmission between multiple LANs within interconnected devices in the metropolitan area.
- **Public or Private Ownership** − Municipal governments and telecommunications firms can own and operate MANs.
- **Scalability** − MANs are scalable networks, whenever network needs to span, MANs can be expanded or upgraded.
- **Reliability and Redundancy** − MANs use redundant network components and backup solutions to reduce network failure and down network. In case of equipment failure or network disturbances, alternate network paths, backup power sources, and failover processes preserve network availability.
- **Support for Various Technologies** − MANs support network technologies like Ethernet, fiber optics, wireless communication, and microwave links.
- **Service Provisioning** − A MAN provides services to its users like network access, data transfer, voice communication, video conferencing, and cloud services.
- **Security Measures** − MANs implement security measures to protect network resources, data, and communications from unauthorized access, cyber threats, and other security risks.

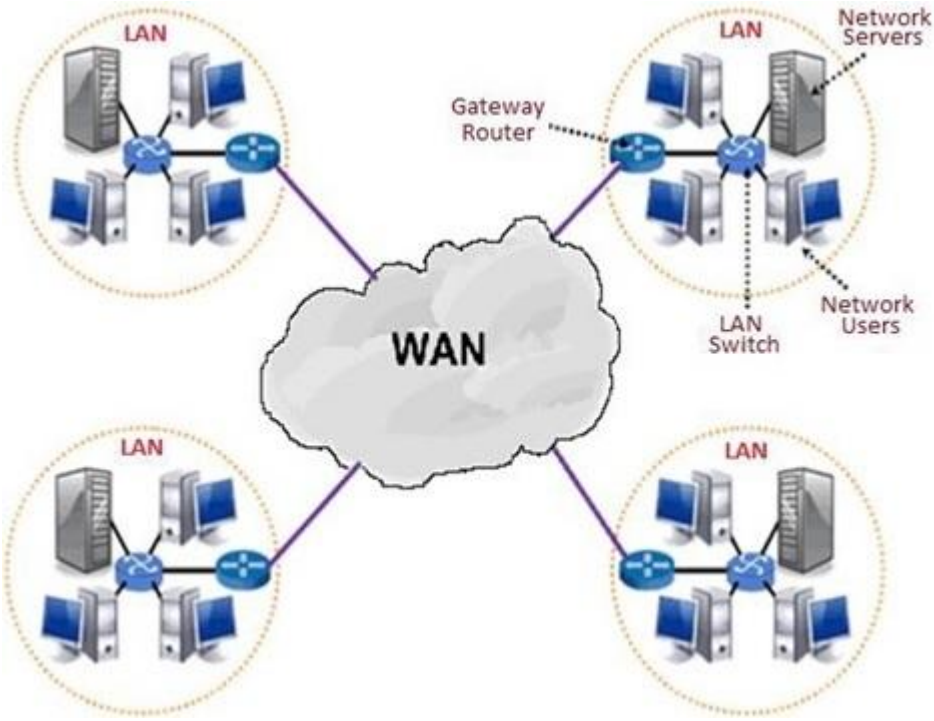
Overall, MANs are well-suited to providing fast, reliable, and scalable connectivity to users and organisations in metropolitan regions, allowing for efficient communication, collaboration, and access to network resources.

3. Wide Area Network (WAN)

A network which combines multiple MANs and LANs is known as Wide Area Network; a WAN network covers wide geographical area typically covering multiple cities, regions, countries, or even continents.

Example

A company may have its corporate headquarters and manufacturing plant located in one city and marketing office in another city. Each site needs resources, data and programs locally, but it also needs to share data with other sites. To accomplish this, the company can attach devices that connect over public utilities to create a WAN.



Characteristics of WANs

- **Large Geographical Coverage** − WANs includes cities, regions, and countries network and span it over the time as per the requirements increases. This covers worldwide geographical coverage.
- **Interconnection of LANs** − WANs interconnect geographically dispersed LANs. Users in one area can communicate with another whose location is different as well as access resources located in other locations.
- **Use of Public and Private Telecommunication Infrastructure** − WANs use leased lines, fibre optic cables, satellite links, and microwave links. The WAN's infrastructure allows long-distance data transfer.

- **High Bandwidth and Long-Distance Communication** − WANs provide quick data transfer and communication across vast distances with high-bandwidth connectivity. WAN bandwidth and speed depend on transmission medium and network technology.
- **Multiprotocol Support** − To fulfil communication needs, WANs enable multiple networking protocols and technologies. It includes TCP/IP, MPLS, Frame Relay, ATM etc.
- **Centralized Management and Control** − WANs use centralised administration and control to optimise performance, manage network resources, and enforce security regulations across different locations. Centralised management ensures network efficiency and consistency.
- **Security Considerations** − Encryption, virtual private networks (VPNs), firewalls, intrusion detection/prevention systems (IDS/IPS), and access control mechanisms are the security measures used by WANs to protect data and network resources against cyber threats and unauthorised access.
- **Scalability and Flexibility** − WANs are flexible and scalable, allows network growth, traffic volume, and new locations or users. WAN technologies can meet changing business needs and technology development.

Hardware's / devices required to set up a computer network

- Network Cables
- Distributors
- Routers
- Internal Network Cards
- External Network Cards

Network Cables

Network cables are used to connect computers. The most commonly used cable is Category 5 cable RJ-45.

The solution is to use a central body to which other computers, printers, scanners, etc. can be connected and then this body will manage or distribute network traffic.

Router

A router is a type of device which acts as the central point among computers and other devices that are a part of the network. It is equipped with holes called ports. Computers and other devices are connected to a router using network cables. Now-a-days router comes in wireless modes using which computers can be connected without any physical cable.

Network Card

Network card is a necessary component of a computer without which a computer cannot be connected over a network. It is also known as the network adapter or Network Interface Card (NIC). Most branded computers have network card pre-installed. Network cards are of two types: Internal and External Network Cards.

Internal Network Cards

Motherboard has a slot for internal network card where it is to be inserted. Internal network cards are of two types in which the first type uses Peripheral Component Interconnect (PCI) connection, while the second type uses Industry Standard Architecture (ISA). Network cables are required to provide network access.

External Network Cards

External network cards are of two types: Wireless and USB based. Wireless network card needs to be inserted into the motherboard; however, no network cable is required to connect to the network.

Universal Serial Bus (USB)

USB card is easy to use and connects via USB port. Computers automatically detect USB card and can install the drivers required to support the USB network card automatically.

Chapter 2: Transmission Media

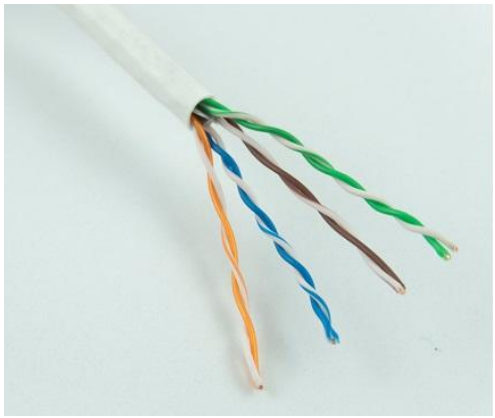
For any networking to be effective, raw stream of data is to be transported from one device to other over some medium. Various transmission media can be used for transfer of data. These transmission media may be of two types −

- **Guided** − In guided media, transmitted data travels through cabling system that has a fixed path. For example, copper wires, fibre optic wires, etc.
- **Unguided** − In unguided media, transmitted data travels through free space in form of electromagnetic signal. For example, radio waves, lasers, etc.

Each transmission media has its own advantages and disadvantages in terms of bandwidth, speed, delay, cost per bit, ease of installation and maintenance, etc. Lets discuss some of the most commonly used media in detail.

Twisted Pair Cable

Copper wires are the most common wires used for transmitting signals because of good performance at low costs. They are most commonly used in telephone lines. However, if two or more wires are lying together, they can interfere with each others signal. To reduce this electromagnetic interference, pair of copper wires are twisted together in helical shape like a DNA molecule. Such twisted copper wires are called twisted pair. To reduce interference between nearby twisted pairs, the twist rates are different for each pair.



Up to 25 twisted pair are put together in a protective covering to form twisted pair cables that are the backbone of telephone systems and Ethernet networks.

Advantages of twisted pair cable

Twisted pair cable are the oldest and most popular cables all over the world. This is due to the many advantages that they offer −

- Trained personnel easily available due to shallow learning curve
- Can be used for both analog and digital transmissions
- Least expensive for short distances
- Entire network does not go down if a part of network is damaged

Disadvantages of twisted pair cable

With its many advantages, twisted pair cables offer some disadvantages too −

- Signal cannot travel long distances without repeaters
- High error rate for distances greater than 100m
- Very thin and hence breaks easily
- Not suitable for broadband connections

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Shielding twisted pair cable

To counter the tendency of twisted pair cables to pick up noise signals, wires are shielded in the following three ways −

- Each twisted pair is shielded.
- Set of multiple twisted pairs in the cable is shielded.
- Each twisted pair and then all the pairs are shielded.

Such twisted pairs are called shielded twisted pair (STP) cables. The wires that are not shielded but simply bundled together in a protective sheath are called unshielded twisted pair (UTP) cables. These cables can have maximum length of 100 metres.

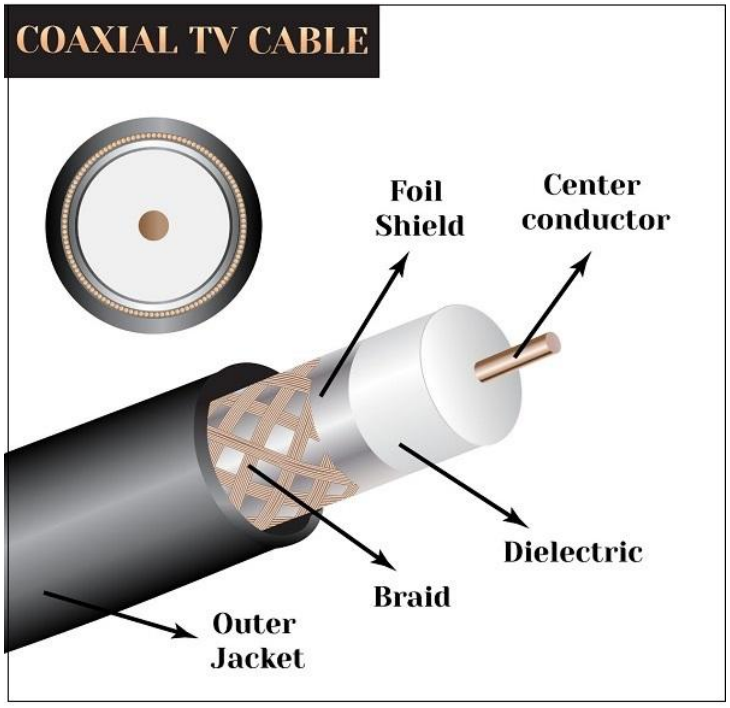
Shielding makes the cable bulky, so UTP are more popular than STP. UTP cables are used as the last mile network connection in homes and offices.

Coaxial Cable

Coaxial cables are copper cables with better shielding than twisted pair cables, so that transmitted signals may travel longer distances at higher speeds. A coaxial cable consists of these layers, starting from the innermost −

- Stiff copper wire as core
- Insulating material surrounding the core
- Closely woven braided mesh of conducting material surrounding the insulator
- Protective plastic sheath encasing the wire

Coaxial cables are widely used for cable TV connections and LANs.



Advantages of Coaxial Cables

These are the advantages of coaxial cables −

- Excellent noise immunity
- Signals can travel longer distances at higher speeds, e.g. 1 to 2 Gbps for 1 Km cable
- Can be used for both analog and digital signals
- Inexpensive as compared to fibre optic cables
- Easy to install and maintain

Disadvantages of Coaxial Cables

These are some of the disadvantages of coaxial cables −

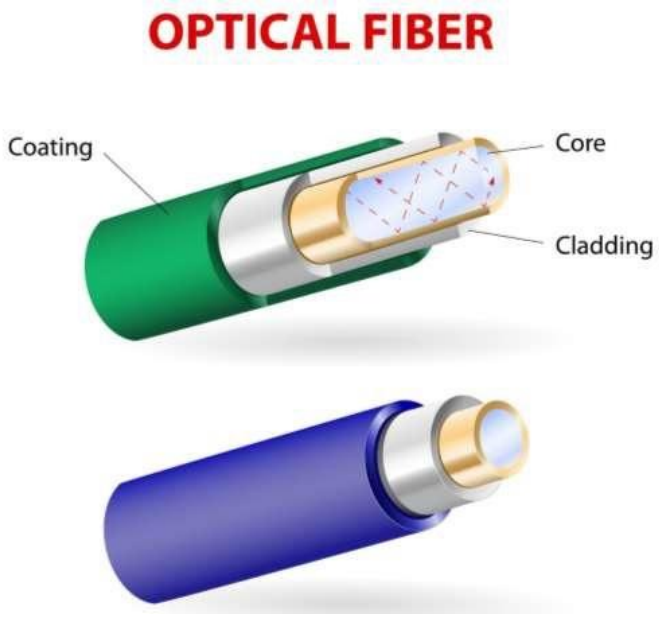
- Expensive as compared to twisted pair cables
- Not compatible with twisted pair cables

Optical Fibre

Thin glass or plastic threads used to transmit data using light waves are called optical fibre. Light Emitting Diodes (LEDs) or Laser Diodes (LDs) emit light waves at the source, which is read by a detector at the other end. Optical fibre cable has a bundle of such threads or fibres bundled together in a protective covering. Each fibre is made up of these three layers, starting with the innermost layer −

- Core made of high-quality silica glass or plastic
- Cladding made of high-quality silica glass or plastic, with a lower refractive index than the core
- Protective outer covering called buffer

Note that both core and cladding are made of similar material. However, as refractive index of the cladding is lower, any stray light wave trying to escape the core is reflected back due to total internal reflection.



Optical fibre is rapidly replacing copper wires in telephone lines, internet communication and even cable TV connections because transmitted data can travel very long distances without weakening. Single node fibre optic cable can have maximum segment length of 2 kms and bandwidth of up to 100 Mbps. Multi-node fibre optic cable can have maximum segment length of 100 kms and bandwidth up to 2 Gbps.

Advantages of Optical Fibre

Optical fibre is fast replacing copper wires because of these advantages that it offers −

- High bandwidth
- Immune to electromagnetic interference
- Suitable for industrial and noisy areas
- Signals carrying data can travel long distances without weakening

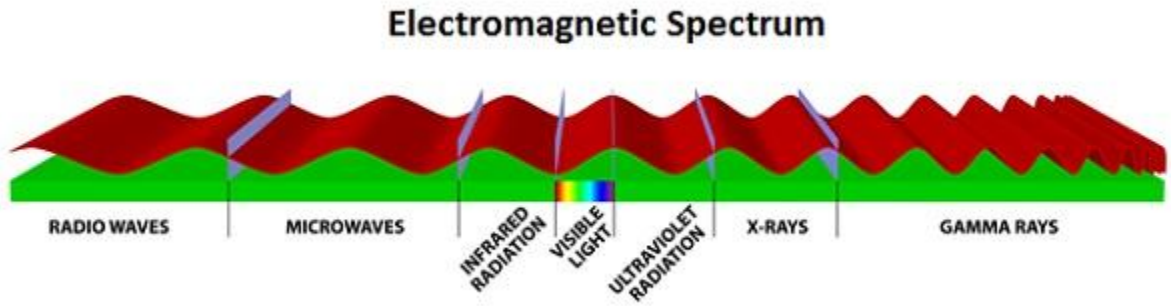
Disadvantages of Optical Fibre

Despite long segment lengths and high bandwidth, using optical fibre may not be a viable option for every one due to these disadvantages −

- Optical fibre cables are expensive
- Sophisticated technology required for manufacturing, installing and maintaining optical fibre cables
- Light waves are unidirectional, so two frequencies are required for full duplex transmission

Infrared

Low frequency infrared waves are used for very short distance communication like TV remote, wireless speakers, automatic doors, hand held devices etc. Infrared signals can propagate within a room but cannot penetrate walls. However, due to such short range, it is considered to be one of the most secure transmission modes.



Radio Wave

Transmission of data using radio frequencies is called radio-wave transmission. We all are familiar with radio channels that broadcast entertainment programs. Radio stations transmit radio waves using transmitters, which are received by the receiver installed in our devices.

Both transmitters and receivers use antennas to radiate or capture radio signals. These radio frequencies can also be used for direct voice communication within the allocated range. This range is usually 10 miles.

Advantages of Radio Wave

These are some of the advantages of radio wave transmissions −

- Inexpensive mode of information exchange
- No land needs to be acquired for laying cables
- Installation and maintenance of devices is cheap

Disadvantages of Radio Wave

These are some of the disadvantages of radio wave transmissions −

- Insecure communication medium
- Prone to weather changes like rain, thunderstorms, etc.

NETWORK DEVICES

Hardware devices that are used to connect computers, printers, fax machines and other electronic devices to a network are called **network devices**. These devices transfer data in a fast, secure and correct way over same or different networks. Network devices may be inter-network or intra-network. Some devices are installed on the device, like NIC card or RJ45 connector, whereas some are part of the network, like router, switch, etc. Let us explore some of these devices in greater detail.

Modem

Modem is a device that enables a computer to send or receive data over telephone or cable lines. The data stored on the computer is digital whereas a telephone line or cable wire can transmit only analog data.

Digital Data Waveform

Analog Data Waveform

The main function of the modem is to convert digital signal into analog and vice versa. Modem is a combination of two devices − **modulator** and **demodulator**. The **modulator** converts digital data into analog data when the data is being sent by the computer. The **demodulator** converts analog data signals into digital data when it is being received by the computer.

Types of Modems

Modem can be categorized in several ways like direction in which it can transmit data, type of connection to the transmission line, transmission mode, etc.

Depending on direction of data transmission, modem can be of these types −

- **Simplex** − A simplex modem can transfer data in only one direction, from digital device to network (modulator) or network to digital device (demodulator).
- **Half duplex** − A half-duplex modem has the capacity to transfer data in both the directions but only one at a time.
- **Full duplex** − A full duplex modem can transmit data in both the directions simultaneously.

RJ45 Connector

RJ45 is the acronym for **Registered Jack 45. RJ45 connector** is an 8-pin jack used by devices to physically connect to **Ethernet** based **local area networks (LANs)**. **Ethernet** is a technology that defines protocols for establishing a LAN. The cable used for Ethernet LANs are twisted pair ones and have **RJ45 connector pins** at both ends. These pins go into the corresponding socket on devices and connect the device to the network.

Ethernet Card

Ethernet card, also known as **network interface card (NIC)**, is a hardware component used by computers to connect to **Ethernet LAN** and communicate with other devices on the LAN. The earliest **Ethernet cards** were external to the system and needed to be installed manually. In modern computer systems, it is an internal hardware component. The NIC has **RJ45 socket** where network cable is physically plugged in.

Ethernet card speeds may vary depending upon the protocols it supports. Old Ethernet cards had maximum speed of **10 Mbps**. However, modern cards support fast Ethernets up to a speed of **100 Mbps**. Some cards even have capacity of **1 Gbps**.

Router

A **router** is a **network layer** hardware device that transmits data from one LAN to another if both networks support the same set of protocols. So a **router** is typically connected to at least two LANs and the **internet service provider** (ISP). It receives its data in the form of **packets**, which are **data frames** with their **destination address** added. Router also strengthens the signals before transmitting them. That is why it is also called **repeater**.

Routing Table

A router reads its routing table to decide the best available route the packet can take to reach its destination quickly and accurately. The routing table may be of these two types −

- **Static** − In a static routing table the routes are fed manually. So it is suitable only for very small networks that have maximum two to three routers.
- **Dynamic** − In a dynamic routing table, the router communicates with other routers through protocols to determine which routes are free. This is suited for larger networks where manual feeding may not be feasible due to large number of routers.

Switch

Switch is a network device that connects other devices to **Ethernet** networks through **twisted pair** cables. It uses **packet switching** technique to **receive, store** and **forward data packets** on the network. The switch maintains a list of network addresses of all the devices connected to it.

On receiving a packet, it checks the destination address and transmits the packet to the correct port. Before forwarding, the packets are checked for collision and other network errors. The data is transmitted in full duplex mode

Data transmission speed in switches can be double that of other network devices like hubs used for networking. This is because switch shares its maximum speed with all the devices connected to it. This helps in maintaining network speed even during high traffic. In fact, higher data speeds are achieved on networks through use of multiple switches.

Gateway

Gateway is a network device used to connect two or more dissimilar networks. In networking parlance, networks that use different protocols are **dissimilar networks**. A gateway usually is a computer with multiple **NICs** connected to different networks. A gateway can also be configured completely using software. As networks connect to a different network through gateways, these gateways are usually hosts or end points of the network.

Gateway uses **packet switching** technique to transmit data from one network to another. In this way it is similar to a **router**, the only difference being router can transmit data only over networks that use same protocols.

Wi-Fi Card

Wi-Fi is the acronym for **wireless fidelity. Wi-Fi technology** is used to achieve **wireless connection** to any network. **Wi-Fi card** is a **card** used to connect any device to the local network wirelessly. The physical area of the network which provides internet access through Wi-Fi is called **Wi-Fi hotspot**. Hotspots can be set up at home, office or any public space. Hotspots themselves are connected to the network through wires.

A **Wi-Fi card** is used to add capabilities like **teleconferencing, downloading** digital camera images, **video chat**, etc. to old devices. Modern devices come with their in-built **wireless network adapter**.

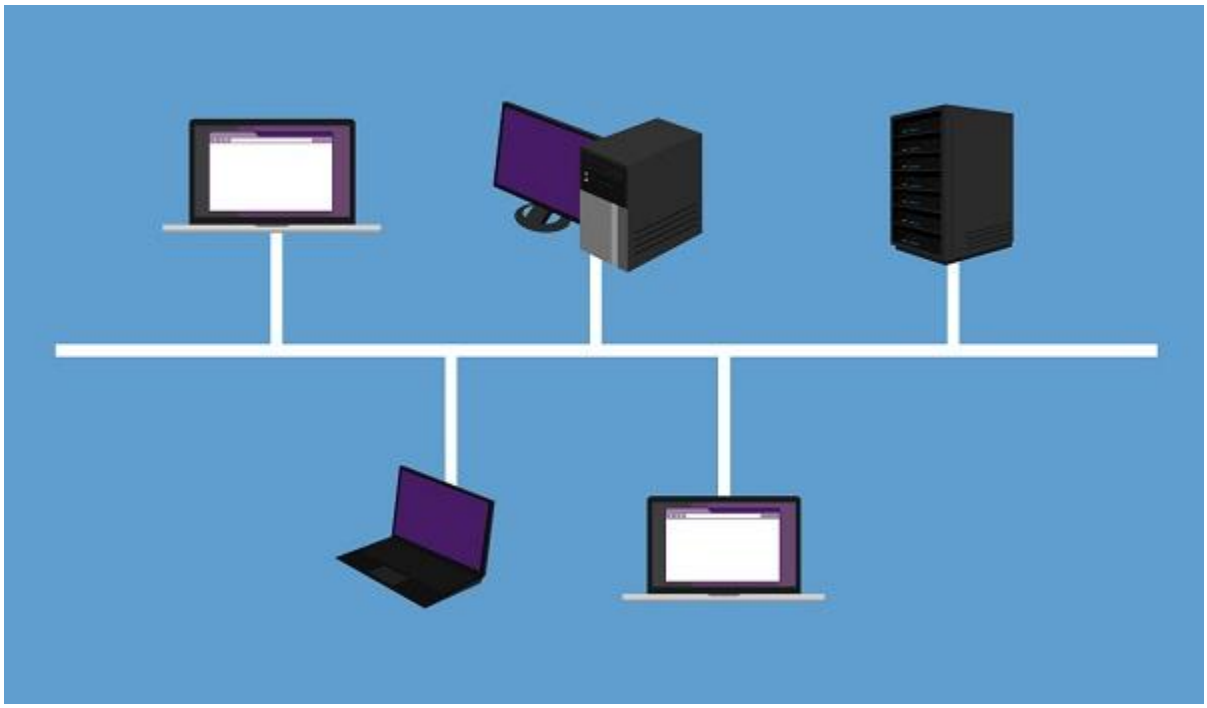
CHAPTER 3: NETWORK TOPOLOGY

The way in which devices are interconnected to form a network is called network topology. Some of the factors that affect choice of topology for a network are −

- **Cost** − Installation cost is a very important factor in overall cost of setting up an infrastructure. So, cable lengths, distance between nodes, location of servers, etc. have to be considered when designing a network.
- **Flexibility** − Topology of a network should be flexible enough to allow reconfiguration of office set up, addition of new nodes and relocation of existing nodes.
- **Reliability** − Network should be designed in such a way that it has minimum down time. Failure of one node or a segment of cabling should not render the whole network useless.
- **Scalability** − Network topology should be scalable, i.e. it can accommodate load of new devices and nodes without perceptible drop in performance.
- **Ease of installation** − Network should be easy to install in terms of hardware, software and technical personnel requirements.
- **Ease of maintenance** − Troubleshooting and maintenance of network should be easy.

Bus Topology

Data network with bus topology has a **linear transmission cable**, usually **coaxial**, to which many **network devices** and **workstations** are attached along the length. **Server** is at one end of the bus. When a workstation has to send data, it transmits **packets** with **destination address** in its header along the bus.



The data travels in both the directions along the bus. When the destination terminal sees the data, it copies it to the local disk.

Advantages of Bus Topology

These are the advantages of using bus topology −

- Easy to install and maintain
- Can be extended easily
- Very reliable because of single transmission line

Disadvantages of Bus Topology

These are some disadvantages of using bus topology −

- Troubleshooting is difficult as there is no single point of control
- One faulty node can bring the whole network down
- Dumb terminals cannot be connected to the bus

Ring Topology

In **ring topology** each terminal is connected to exactly **two nodes**, giving the network a circular shape. Data travels in only one pre-determined direction.

When a terminal has to send data, it transmits it to the neighboring node which transmits it to the next one. Before further transmission data may be amplified. In this way, data raverses the network and reaches the destination node, which removes it from the network. If the data reaches the sender, it removes the data and resends it later.

Advantages of Ring Topology

These are the advantages of using ring topology −

- Small cable segments are needed to connect two nodes
- Ideal for optical fibres as data travels in only one direction
- Very high transmission speeds possible

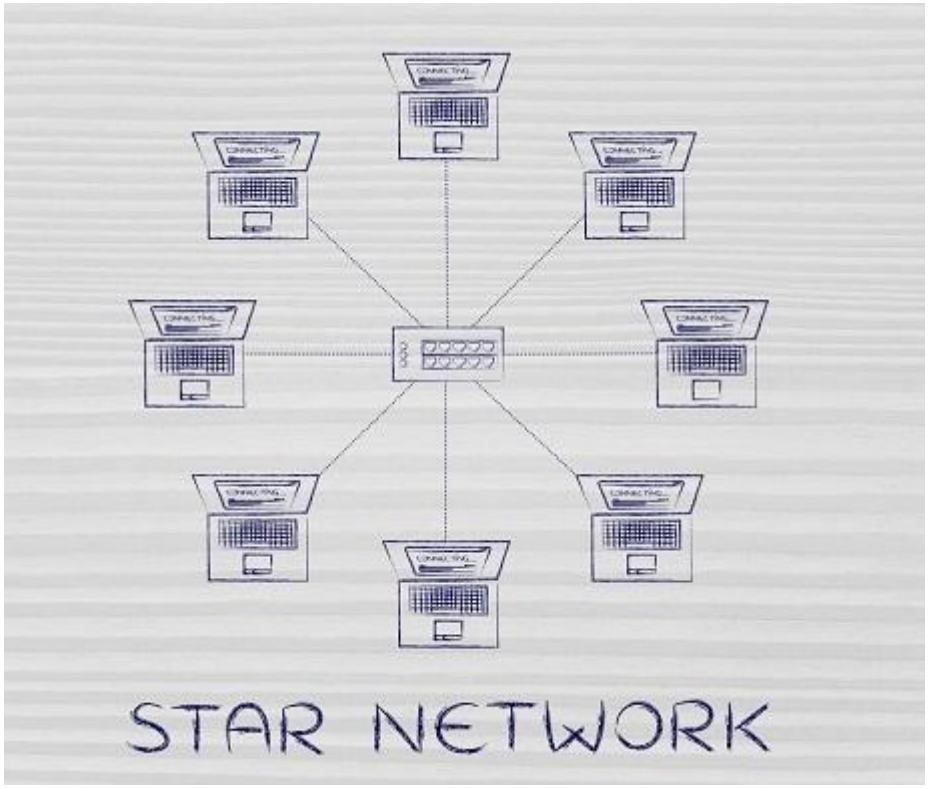
Disadvantages of Ring Topology

These are some the disadvantages of using ring topology −

- Failure of single node brings down the whole network
- Troubleshooting is difficult as many nodes may have to be inspected before faulty one is identified
- Difficult to remove one or more nodes while keeping the rest of the network intact

Star Topology

In star topology, server is connected to each node individually. Server is also called the central node. Any exchange of data between two nodes must take place through the server. It is the most popular topology for information and voice networks as central node can process data received from source node before sending it to the destination node.



Advantages of Star Topology

These are the advantages of using star topology −

- Failure of one node does not affect the network
- Troubleshooting is easy as faulty node can be detected from central node immediately

- Simple access protocols required as one of the communicating nodes is always the central node

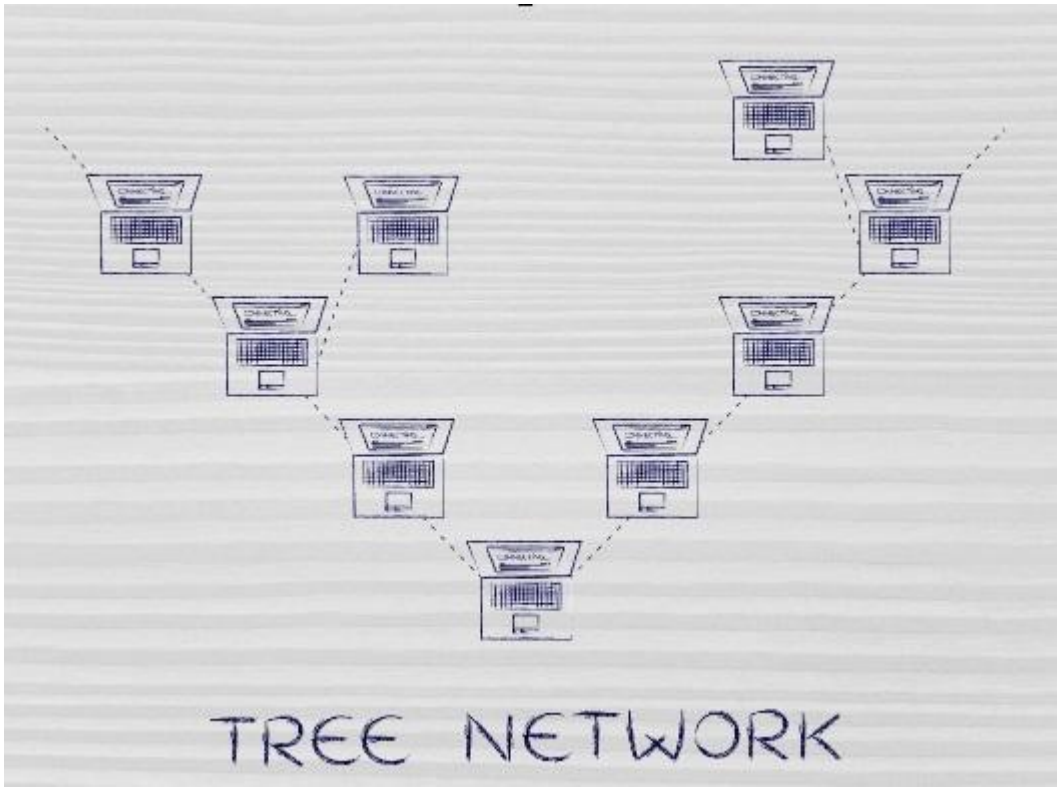
Disadvantages of Star Topology

These are the disadvantages of using star topology −

- Long cables may be required to connect each node to the server
- Failure of central node brings down the whole network

Tree Topology

Tree topology has a group of star networks connected to a linear bus backbone cable. It incorporates features of both star and bus topologies. Tree topology is also called hierarchical topology.



Advantages of Tree Topology

These are some of the advantages of using tree topology −

- Existing network can be easily expanded
- Point-to-point wiring for individual segments means easier installation and maintenance
- Well suited for temporary networks

Disadvantages of Tree Topology

These are some of the disadvantages of using tree topology −

- Technical expertise required to configure and wire tree topology
- Failure of backbone cable brings down entire network

- Insecure network
- Maintenance difficult for large networks

CHAPTER 4: TYPES OF NETWORKS

Networks can be categorized depending on size, complexity, level of security, or geographical range. We will discuss some of the most popular topologies based on geographical spread.

PAN

PAN is the acronym for Personal Area Network. PAN is the interconnection between devices within the range of a person's private space, typically within a range of 10 metres. If you have transferred images or songs from your laptop to mobile or from mobile to your friend's mobile using Bluetooth, you have set up and used a personal area network.

A person can connect her laptop, smart phone, personal digital assistant and portable printer in a network at home. This network could be fully Wi-Fi or a combination of wired and wireless.

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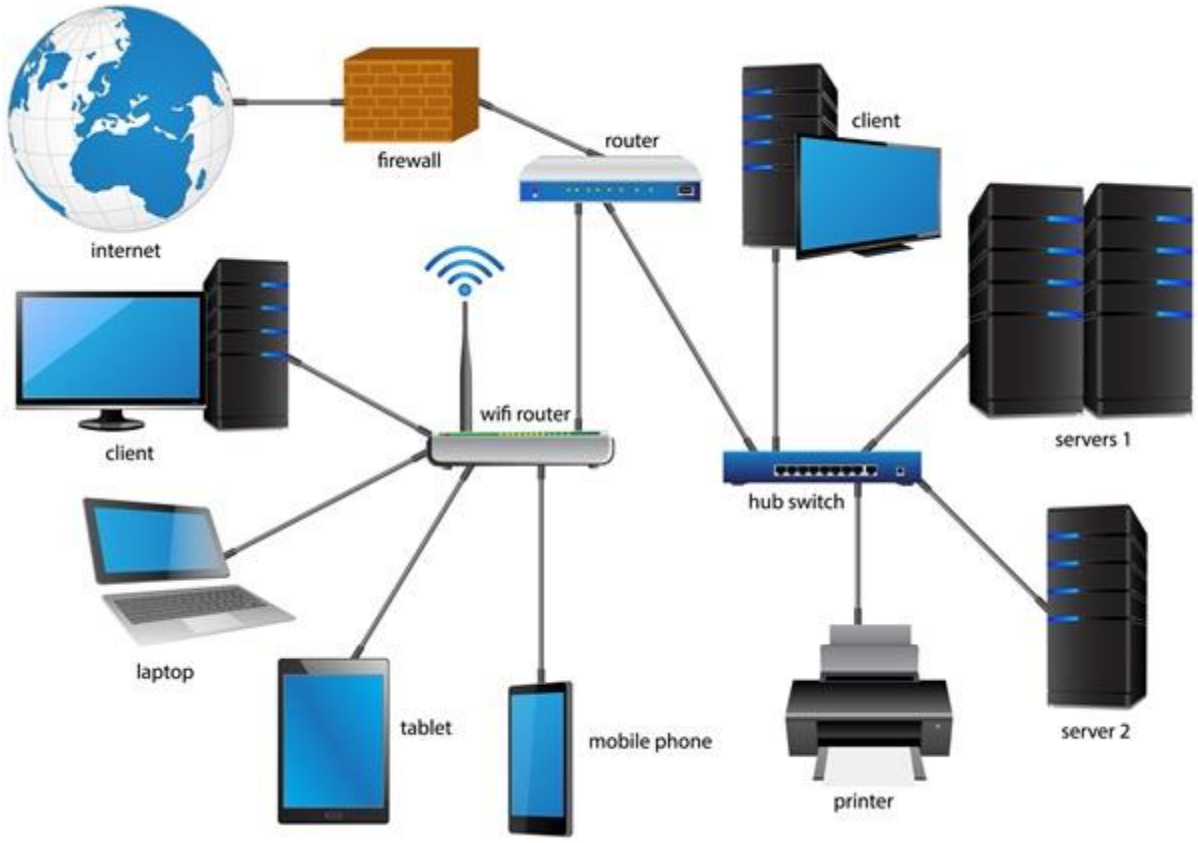
LAN

LAN or Local Area Network is a wired network spread over a single site like an office, building or manufacturing unit. LAN is set up to when team members need to share software and hardware resources with each other but not with the outside world. Typical software resources include official documents, user manuals, employee handbook, etc. Hardware resources that can be easily shared over the network include printer, fax machines, modems, memory space, etc. This decreases infrastructure costs for the organization drastically.



A LAN may be set up using wired or wireless connections. A LAN that is completely wireless is called Wireless LAN or WLAN.

MAN

MAN is the acronym for Metropolitan Area Network. It is a network spread over a city, college campus or a small region. MAN is larger than a LAN and typically spread over several kilometres. Objective of MAN is to share hardware and software resources, thereby decreasing infrastructure costs. MAN can be built by connecting several LANs.

The most common example of MAN is cable TV network.

WAN

WAN or Wide Area Network is spread over a country or many countries. WAN is typically a network of many LANs, MANs and WANs. Network is set up using wired or wireless connections, depending on availability and reliability.

The most common example of WAN is the Internet.