Communication Technologies - Networking Concepts and Fundamentals

Contents

1. What is a Network?

Source: Wikipedia

A computer network is a digital telecommunications network for sharing resources between nodes, which are computing devices that use a telecommunications technology.

Data transmission between nodes is supported over data links consisting of physical cable media, such as twisted pair or fibre-optic cables, or by wireless methods, such as Wi-Fi, microwave transmission, or free-space optical communication.

Source: CBSE

A network is any collection of independent computers that communicate with one another over a shared network medium. In simple terms, a computer network is a collection of two or more computers linked together for the purpose of sharing information and resources.

1.1. Need for Networking

1. Resource sharing - files and peripherals
    i. Sharing of files and software - data files
    ii. Sharing Peripherals - printers, fax systems, audio/video
    iii. Sharing storage
2. Improving Communication - powerful, fast and reliable communication medium among the users via email, instant messaging, chat rooms, telephone
3. Access to Remote database

1.2. Requirements of a Network

1. At least two computers - Server or Client workstation
2. Network Interface Cards (NIC)
3. A connection medium, usually a wire or cable, although wireless communication between networked computers and peripherals is also possible
4. Network Operating system software

1.3. Network Terminologies

1. **Nodes (Workstations):** A computer becomes a node (also called a workstation) as soon as it is attached to a network. Each user on a network works on a workstation. If there are no nodes there would be no network.
2. **Server**: A computer that facilitates sharing of data, software and hardware resources on the network is known as the server. A network can have more than one server. Each server has a unique name by which it is identified by all the nodes on the network.
   Servers can be of two types:
   i. *Dedicated Servers*: One computer is reserved for server's job. It helps all nodes access data, software and hardware resources.
   ii. *Non Dedicated Servers*: A workstation can double up as a server.
3. **Network Interface Unit (NIU)**: A network interface unit is a device that is attached to each of the workstations and the server which helps to establish communication between the server and workstations.
   As soon as a standalone computer becomes a workstation, it needs an interface to help establish connection with the network because without this the workstations will not be able to share network resources or communicate with each other.

   The **Network Interface Card/Controller (NIC)** basically acts like an interpreter and is also known as **Terminal Access Point (TAP).** The NIC manufacturer assigns a unique physical address to each NIC known as **Media Access Control (MAC)** address.

1.4. Switching Techniques

Switching techniques are used to efficiently transmit data across the network. The two types of switching techniques are employed nowadays to provide communication between two computers on a network are: CircuitSwitching and PacketSwitching.

Circuit Switching

Circuit Switching is a technique in which a dedicated and complete physical connection is established between two nodes and through this dedicated communication channel, the nodes may communicate.

The circuit guarantees the full bandwidth of the channel and remains connected for the duration of the communication session. Even if no communication is taking place in a dedicated circuit, that channel still remains unavailable to other users (idle channels).

Packet Switching

Packer switching is a switching technique in which packets (discrete blocks of data of fixed size and of any content, type or structure) are routed between nodes over data links shared with other traffic.

The term “packets” refers to the fact that the data stream from your computer is broken up into packets of about 200 bytes (on average), which are then sent out onto the network. Each packet contains a “header” with information necessary for routing the packet from source to destination. Each packet in the data stream is independent.

The main advantage of packet-switching is that the packets from many different sources can share a line, allowing for very efficient use of the communication medium.

Packets are generally accepted onto the network on a first-come, first-served basis. If the network becomes overloaded, packets are delayed or discarded (“dropped”).

1.5. Types of Networks

A network may be a small group of interlinked computers to a change of a few hundred computers of different types. Networks vary in terms of their size and complexity.

PAN (Personal Area Network)

A Personal Area Network is a computer network organized around an individual person. Personal area networks typically involve a mobile computer, a cell phone and or a handheld computing device.

Personal are networks can be constructed with cables or be wireless. Wireless PANs typically use bluetooth or sometimes infrared connections. Bluetooth PANs generally cover a range of less than 10 meters.

LAN (Local Area Network)

In a LAN, network devices are connected over a relatively short distance. They are privately owned networks within a single building or campus, of up to a few kilometers in size.

We also have **WLAN (Wireless LAN)** which is based on wireless network.

LANs can be small, linking as few as three computers, but often link hundreds of computers used by thousands of people.

MAN (Metropolitan Area Network)

This is basically a bigger version of LAN and normally uses similar technology. It might cover few buildings in a city and might either be private or public. This is a network which spans a physical area (~ 5 to 50 km diameter) that is larger than a LAN.

MANs are usually characterized by very high-speed optical connections or other digital media and provides up-link services to wide area networks (WANs) and the internet.

WAN (Wide Area Network)

WAN spans a large geographical area, often a country or a continent and uses various commercial and private communication lines to connect computers. Typically, a WAN combines multiple LANs that are geographically separated.

This is accomplished by connecting the different LANs using services such as dedicated leased phone lines, dial-up phone lines, satellite links, fibre optic cables and data packet carrier services.

1.6. Data Communication Terminologies

Channel

A communication channel is a medium that is used in the transmission of a message from one point to another. It may refer to the entire physical medium, such as a telephone line, optical fibre, or, it may refer to one of the several carrier frequency transmitted simultaneously within the line.

Depending on the speed, we have three broad categories of communication channels - **narrow band** which is slow and used for telegraph lines and low speed terminals; **voice band** used for ordinary telephone communication and **broad band** which is fastest and is used for transmitting large volumes of data at high speed.

Bandwidth

Bandwidth refers to the range of frequencies available for transmission of data. It is expressed as the difference in Hertz(Hz) between the highest frequency and the lowest frequency.

Wider the bandwidth of a communication system, greater is the capacity and hence greater is the amount of data that can be transmitted over a period of time.

Data Transfer Rate (DTR)

DTR is the amount of data in digital form that is moved from one place to another in a given time on a network. The greater the bandwidth of a given medium, the higher is the data transfer rate. This can also be referred to as throughput, although data transfer rate applies specifically to digital data streams.

DTR is often measured in bits per second (bps) - which is a measure of how fast data is transferred from one location to another.

2. Transmission Medium

A transmission medium is one which carries a signal from one computer to another. It is also known as communication channel. It can wired or wireless. We also name them as Guided and Unguided Media respectively.

2.1. Wired Transmission Media

The wired of guided transmission media physically connects the two computers. The data signal physically gets transferred from the transmitting computer to the receiving computer through the wired transmission medium.

2.1.1. Twisted Pair Cables

This is one of the most common forms of wiring in networks, especially in LANs and it consists of two insulated wires arranged in a regular spiral pattern (double helix). It is generally used for telephone communications in offices and also in modern Ethernet networks.

Advantages:

1. It is capable of carrying a signal over long distances without amplification.
2. It is simple, low weight, easy to install and easy to maintain.
3. It is an adequate and least expensive medium for low speed (up to 10 mbps) applications where the distance between the nodes is relatively small.

Disadvantages:

1. It can easily pick up noise signals.
2. Being thin in size, it is likely to break easily.
3. It is unsuitable for broadband applications.

Types of Twisted Pair Cables:

1. Shielded Twisted Pair (STP) Cable
2. Unshielded Twisted Pair (UTP) Cable

The STP cable comes with shielding of the individual pairs of wires, which further protects it from external interference and crosstalk. But STP is heavier and costlier than UTP and also requires proper grounding at both the ends.

2.1.2. Coaxial Cables

It is the most commonly used transmission media for LANs. It consists of solid wire cores surrounded by one or more foil or wire shields, each separated by some kind of plastic insulator. The inner core carries the signal and the shield provides the ground.

Advantages:

1. Data transmission characteristics are better than that of twisted pair.
2. It can be used for broadband communication i.e. several channels can be transmitted simultaneously.
3. It offers high bandwidth (up to 400 mbps)
4. It can be used as the basis for shared cable network.

Disadvantages:

1. It is expensive as compared to twisted pair cables

Types of Coaxial Cables:

Two most common types: Thick-net and Thin-net. As the name suggests, thick-net is thicker and its cable segments can be up to 500 meters long, the thin-net is thinner and it can have a maximum segment length of 185 meters.

2.1.3. Optical Fibres

These consists of thin strands of glass or glass like material which are constructed that they carry light from a source at one end of the fibre to a detector at the other end. The light sources used are either light emitting diodes (LEDs) or laser diodes (LDs). The data to be transmitted is modulated onto a light beam using frequency modulation techniques. At the receiver's end, the signals are demodulated. Optical fibers offer a very high bandwidth and this makes it capable of multichannel communication.

The Optical Fibre consists of three layers:

1. Core - glass or plastic through which the light travels.
2. Cladding - covering of the core that reflects the light back to the core.
3. Protective (Buffer) Coating - protects the fibre cable from hostile environments.

Advantages:

1. It is immune to electrical and magnetic interferences.
2. It is highly suitable for harsh industrial environments.
3. It guarantees secure transmission and has a very high transmission capacity.

4. It can be used for broadband transmission where several channels can be handled in parallel.

Disadvantages:

1. It is difficult to install and maintain since they are quite fragile.
2. It is most expensive of all cables.
3. Connecting two fires together or even connecting the light source with the cable is a difficult process. Hence connection loss is a common problem.
4. Light can reach the receiver out of phase.

Types of Fibre Optics:

1. Single node fibre optic cable: It supports a segment length of up to 2 kms and bandwidth of up to 100 Mbps.
2. Multi-node fibre optic cable: It has a segment length of 100 kms and a bandwidth of 2 Gbps.

2.2. Wireless Transmission Media

Wireless or unbounded or unguided media transport electromagnetic waves without using a physical conductor. The signals are broadcasted through air or water and thus are available to anyone that has a device capable of receiving them.

2.2.1. Infrared

Infrared is the frequency of light that is not visible to human eye. It has a range of wavelength and are thermal (the reason why we feel heat from sunlight, fire or a radiator). Shorter, near infrared waves are not hot at all - in fact we can't even feel them. These shorter wavelengths are the ones used by the TV remotes.

Infrared communication requires a transceiver (a combination of transmitter and receiver) in both devices that communicate. Infrared communication plays an important role in wireless data communication due to the popularity of laptop computers, digital cameras, mobile phones, papers and other devices but being a line-of-sight transmission, it is sensitive of fog and other atmospheric conditions.

Advantages:

1. Since it is having short range of communication, it is considered to be a secure mode of transmission.
2. It is quite inexpensive transmission medium.

Disadvantages:

1. It can only be used for short range communication
2. Infrared wave transmission cannot pass through obstructions like walls, buildings, etc.

2.2.2. Radio-waves

Certain radio frequencies are allocated to private/government organizations for direct voice communications. Each radio signal uses a different frequency and this differentiates it from others. The transmitter takes some message, encodes it and then transmits it with radio wave. The receiver on the other hand receives the radio waves and decodes it. Both the transmitter and receiver use antennas to radiate and capture the radio signal.

Advantages:

1. It is easy to communicate through radio waves in difficult terrains since there is no need of digging and laying cables.
2. Radio waves can travel through long distances in all directions. Also they can easily pass through obstacles like building so they can be used for both indoor and outdoor communication.

Disadvantages:

1. It is susceptible to weather effects like rain, thunderstorm etc.
2. Data transmitted through radio waves is not secure.

2.2.3. Micro-waves

Permits data transmission rates of about 16 gigabits per second. This type of transmission uses high frequency radio signals to transmit data through space. Micro-waves can pass through obstacles and offer a line of sight method of communication. A transmitter and receiver of a microwave system are mounted on very high towers and both should be visible to each other (line of sight). Several repeater station are required for long distance transmission as the curvature of earth, mountains and other structures often block the line of sight.

Advantages:

1. Microwave transmission does not require the expense of laying cables.
2. It can carry 25000 voice channels at the same time.
3. Since no cables are to be laid down, it offers ease of communication over difficult terrains.

Disadvantages:

1. Signals become weak after traveling certain distance and so require amplification. To overcome this problem, repeaters are used at regular intervals (25-30 kms). The data signals are received, amplified and then retransmitted. This is a very expensive mode of communication.
2. Installation and maintenance of microwave links is an expensive affair.
3. The transmission is affected by weather conditions like rain, thunderstorms, etc.

2.2.4. Satellites

Satellite communication is a special use of microwave transmission system. A satellite is place precisely at 36000 km above the equator where its orbit speed exactly matches the earth's rotation speed. Hence it always stays over the same point with respect to earth. This allows the ground station to aim its antenna at a fixed point in the sky. The ground station consists of a satellite dish that functions as an antenna and communication equipment to transmit (called Uplink) and receive (called Downlink) data from satellites passing overhead.

Capacity or number of channels used in satellite communications depends on the frequency used. Typical data transfer rates are 1 to 10 Mbps.

Advantages:

1. Satellite communication is very economical keeping in mind the fact that the area covered through satellite transmission is quite large. For e.g., satellites used for national transmission are visible from all parts of the country.
2. Transmission and reception costs are independent of the distance between two points.

Disadvantages:

1. Placing the satellite into its orbit involves very high cost.
2. Since signals sent to a satellite are broadcasted to all receivers, so necessary security measures have to be taken to prevent unauthorized tampering of data.
3. Transmission is affected by weather conditions like rain, thunderstorm etc.

3. Network Topologies

Topology is the pattern of interconnection of nodes in a local area network (LAN). The topology used helps to select the communication medium and other network devices. Which choosing a topology, care has to be taken that the installation cost is minimum, the network so designed should be reliable and flexible. Addition and removal of nodes and fault detection and removal should be simple.

3.1. Point to Point Link

Point to point link has two ends: Ltransmitter and receiver. The main characteristic of Point to Point link is that each transmitter transmits to exactly one receiver and each receiver receives exactly form one transmitter. The transmission might occur on a single medium i.e. single wire or over separate wires.

3.2. Bus Topology

Bus topology is also known as Linear Topology. In this type of topology, each node attaches directly to a common cable which acts as the backbone and therefore functions as a shared communication medium onto which various nodes are attached.

A device wanting to communicate with another device on the network sends a broadcast message in both directions onto the wire that all other devices see, but only the intended recipient actually accepts and processes the message.

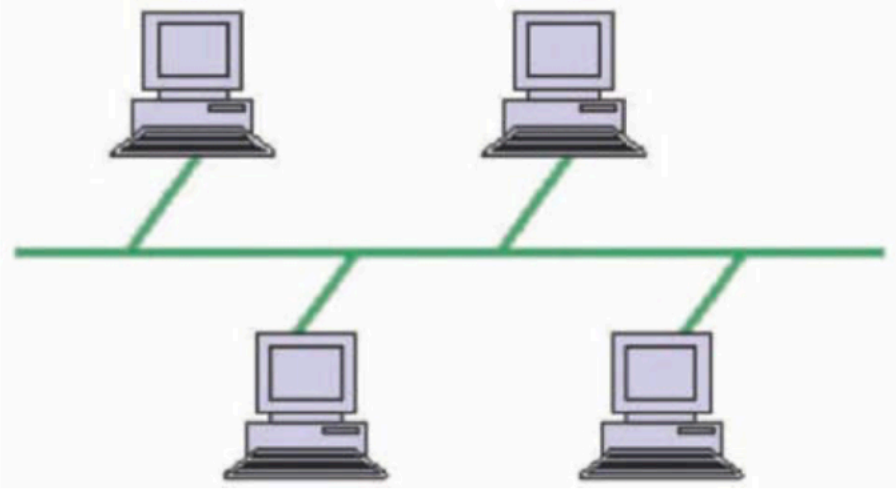
Data is transmitted in small blocks called packets. Each packet has a header containing the destination address. When data is transmitted on the cable, the destination node identifies the address on the packet and thereby processes the data.

Advantages of Bus Topology :

1. Since there is a single common data path connecting all the nodes, the bus topology uses a very short cable length which considerably reduces the installation cost.
2. The linear architecture is very simple and reliable.
3. Additional nodes can be easily connected to the existing bus network at any point along the length of the transmission medium.

Disadvantages of Bus Topology:

1. Fault detection and isolation is difficult. This is because control of the network is not centralized in any particular node. If a node is faulty on the bus, detection of fault may have to be performed at many points on the network. The faulty node has then to be rectified at that connection point.
2. If the central bus length becomes too long, then repeaters might have to be used to amplify the signal. The use of repeaters makes reconfiguration necessary.
3. Since each node is directly connected to the central bus, so there has to be some way of deciding who can use the network at any given time.



http://compnetworking.about.com/library/graphics/topology_bus.gif

Fig: Bus Topology

3.3. Star Topology

A star network features a central connection point called a "hub node" to which all other nodes are connected by a single path. Each node has a dedicated set of wires connecting it to a central network hub.

Since all traffic passes through the hub, the hub becomes a central point for isolating network problems and gathering network statistics.

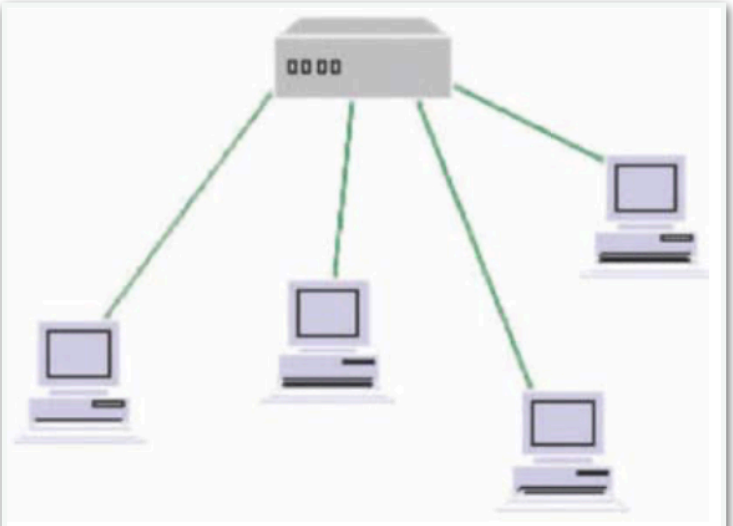
Compared to the bus topology, a star network generally requires more cable, but a failure in any star network cable will only take down one computer's network access and not the entire LAN. On the other hand if the hub fails, the entire network also fails.

Advantages of Star Topology:

1. Failure of a single connection does not affect the entire network. It just involves disconnecting one node from an otherwise fully functional network. This also helps in easy reconfiguration of the network.
2. Fault detection is easier.
3. Access protocols being used in a Star network are very simple since the central node has the control of the transmission medium.

Disadvantages of Star Topology:

1. Since every node is directly connected to the center, large amount of cable is required which increases the installation cost of the network.
2. The entire network is dependent on the central node. If the central node fails, the entire network goes down.



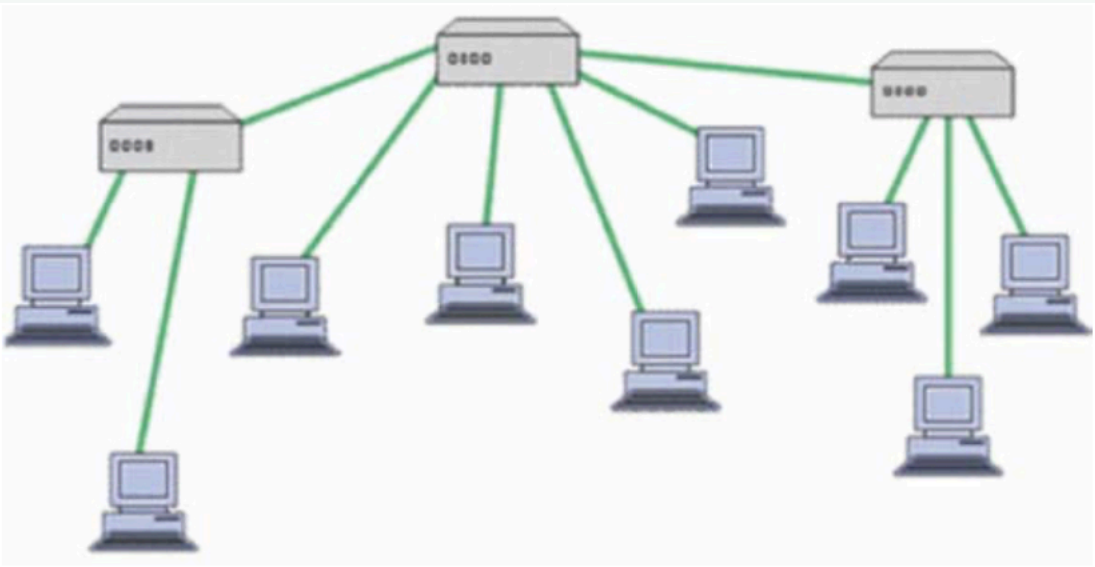
http://compnetworking.about.com/od/networkdesign/ig/Computer-Network-Topologies/Star-Network-Topology-Diagram.htm

Fig: Star Topology

3.4. Tree Topology

Tree topology is a combination of bus and star topology. The network looks like an inverted tree with the central root branching and sub-branching down to the nodes. It integrates multiple star topologies together onto a bus.

This bus/star hybrid approach supports future expandability of the network much better than a bus (limited in the number of devices due to the broadcast traffic it generates) or a star (limited by the number of hub connection points) alone. Data transmission takes place in the same way as in bus topology. When the signal reaches the end of the transmission medium, it is absorbed by the terminators.



http://compnetworking.about.com/od/networkdesign/ig/Computer-Network-Topologies/Tree-Network-Topology-Diagram.htm

Fig: Tree Topology

4. Network Devices

For efficient working of any network, many devices are required.

4.1. Modem

A modem (Modulator-Demodulator) is a peripheral device that enables a computer to transmit data over telephone or cable lines.

The computers operate digitally using binary language, but transmission mediums are analogue. The digital signals when pass from one value to another, there is no middle or half way point, it's All or Nothing (1 or 0).
Conversely, analogue does not change "per step", it converts all the values, so you can have 0, 0.1, 0.2, 0.3, …, 1.0 and all values in between.

A modem converts between these two forms. It modulates an analogue carrier signal to encode digital information, and also demodulates such a carrier signal to decode the transmitted information.

The goal of modulation-demodulation is to produce a signal that can be transmitted easily and decoded to reproduce the original digital data.

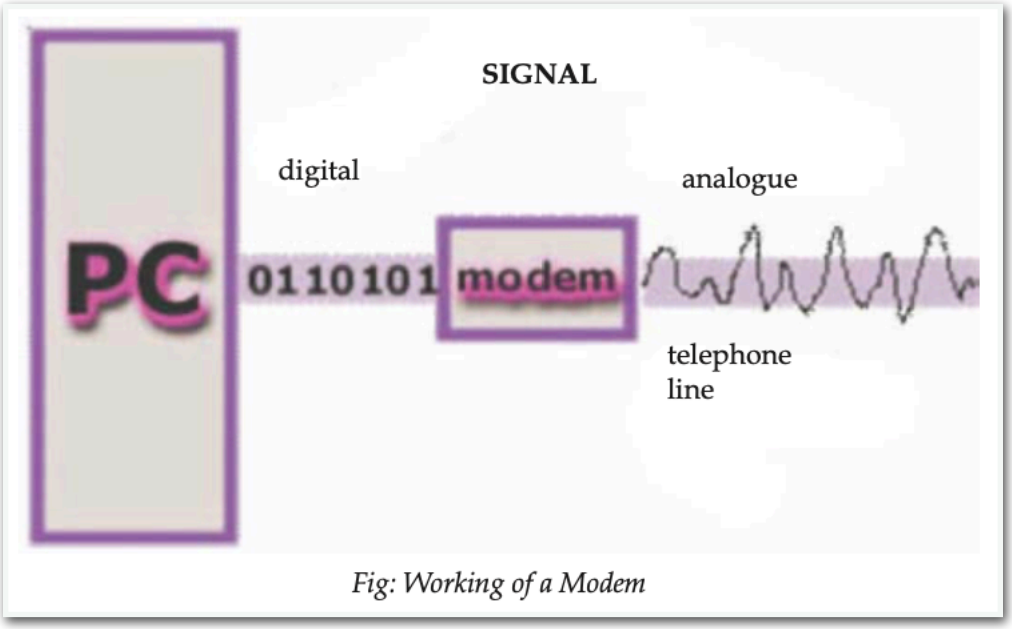


Fig: Working of a Modem

4.2. RJ-45

RJ-45, short form of Registered Jack-45, is an eight wired connector that is used to connect computers on a local area network (LAN), especially Ethernet.

RJ-45 connectors look similar to the RJ-11 connector used for connecting telephone equipment, but they are somewhat wider.

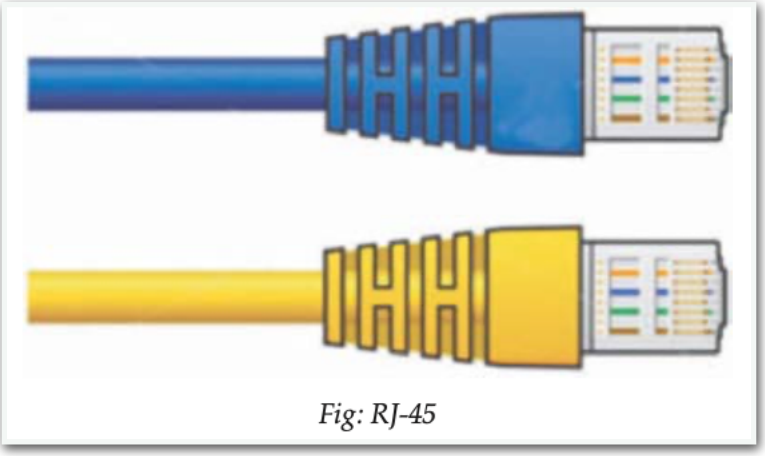


Fig: RJ-45

4.3. Ethernet Card

An Ethernet Card is a kind of network adapter and is also known as Network Interface Card (NIC). These adapters support the Ethernet standard for high-speed network connections via cables. An Ethernet Card contains connections for either coaxial or twisted pair cables or even for fibre optic cable.

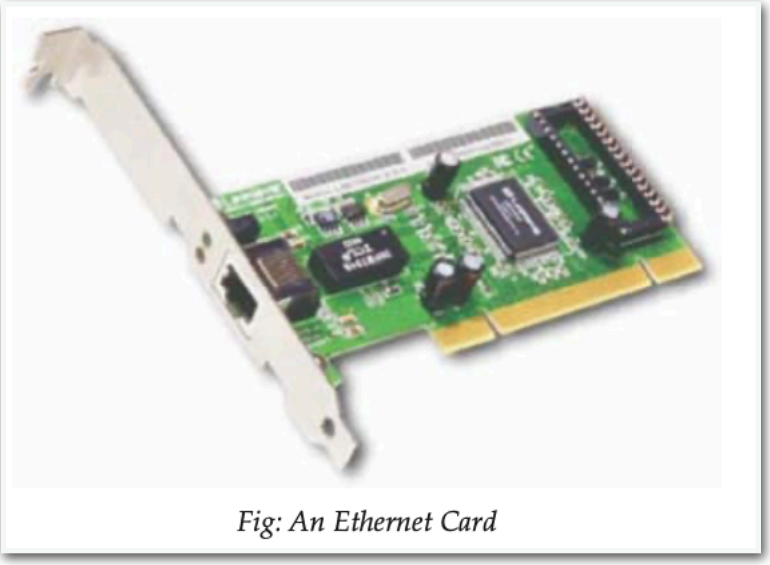


Fig: An Ethernet Card

4.4. Switch

A switch is a device that is used to break a network into different sub-networks called subnet or LAN segments. This prevents traffic overloading on the network. Switches allow different nodes of a network to communicate directly with one other in a smooth and efficient manner.

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. By delivering messages only to the connected device intended, a network switch conserves network bandwidth and offers generally better performance than a hub.

4.5. Repeater

A repeater is an electronic device that receives a signal, amplifies it and then retransmits it on the network so that the signal can cover longer distances.

An electrical signal in a cable gets weaker with the distance it travels, due to energy dissipated in conductor resistance and dielectric losses. Similarly a light signal traveling through an optical fibre suffers attenuation due to scattering and adsorption. With physical media like Ethernet or WiFi, data transmissions can only span a limited distance before the quality of the signal degrades.

Repeaters attempt to preserve signal integrity by periodically regenerating the signal and extend the distance over which data can safely travel.

4.6. Routers

A router is a network device that works like a bridge to establish connection between two networks but it can handle networks with different protocols. For example, a router can link an Ethernet network to a mainframe or to internet.

If the destination is unknown to the router, it sends the traffic to another router which knows the destination. The data is sent to the router which determines the destination address (using logical address) and then transmits data accordingly. Hence routers are smarter than hubs and switches. If a link between two routers fails, the sending router can determine an alternate route to keep traffic moving.

4.7. Gateway

A gateway is a network device that establishes an intelligent connection between a local network and external networks with completely different structures, i.e., it connects two dissimilar networks. It acts as a node on a network that serves as an entrance to another network.

A computer server acting as a gateway node is often also acting as a **proxy serve**r and a **firewall server**. A proxy server is a node that is not actually a server but just appears to be so and a firewall is a system designed to prevent unauthorized access to or from a private network.

A gateway is often associated with both a router, which knows where to direct a given packet of data that arrives at the gateway, and a switch, which furnishes the actual path in and out of the gateway for a given packet.

A **default gateway** is the device that passes traffic from the local subnet to devices on other subnets. The default gateway often connects a local network to the Internet, although internal gateways for local networks also exist.

4.8. Wi-Fi Card

Wi-Fi cards are small and portable cards that allow your desktop/laptop to connect to the internet through a wireless network.

Wi-Fi transmission is through radio waves. The antenna transmits the radio signals and these signals are picked up by Wi-Fi receivers such as computers and cell phones equipped with Wi-Fi Cards. These devices have to be within the range of a Wi-Fi network to receive the signals. The Wi-Fi card then reads the signals and produces a wireless internet connection.

Wi-FI cards can be external or internal. If a Wi-Fi card is not installed in your computer, you may purchase a USB antenna attachment and have it externally connected to the device.

5. Network Protocols

A protocol is the special set of rules that two or more machines on a network follow to communicate with each other. They are the standard that allow computers to communicate.

A protocol defines how computers identify one another on a network, the form that the data should take in transit, and how this information is processed once it reaches its final destination.

5.1. Transmission Control Protocol/ Internet Protocol (TCP/IP)

TCP/IP are the two protocols that are used together and they form backbone protocol of the internet.

The Transmission Control Protocol (TCP) breaks the data into packets that the network can handle efficiently. It manages the assembling of a message or file into small packets that are transmitted over the Internet. It verifies all the packets when they arrive at the destination computer and then reassembles them in proper order. Data can be lost in the intermediate network. So TCP adds support to detect errors or lost data and to trigger retransmission until the data is correctly and completely received.

The Internet Protocol (IP) handles the address part of each packet so that it reaches to the right destination. It gives distinct address - called IP address - to each data packet. Each gateway computer on the network checks this address to see where to forward the message.

An IP address is a unique identifier for a node or host connection on an IP Network. It is a 32 bit binary number usually represented as 4 decimal values, each representing 8 bits, in the range 0 to 255 separated by decimal points.

TCP/IP uses the client/server mode of communication in which a computer user (a client) makes a request and the server provides the requested service such as send a Web page. Also TCP/IP communication is primarily point-to-point transmission of data which means each communication is from one computer in the network to another.

5.2. File Transfer Protocol (FTP)

FTP is an application protocol that uses the Internet's TCP/IP protocols. It is based on Client/Server principle. In any FTP interface, clients identify the FTP server either by its IP address or by its host name. It is an efficient means to send and receive files from a remote host. FTP establishes two connections between the hosts. One is used for data transfer and the other for control information. The control connection remains connected during the entire interactive FTP session while the data connection is opened and closed for each file transfer.

5.3. HyperText Transfer Protocol (HTTP)

HTTP is the protocol that is used for transferring hypertext (i.e. text, graphic, image, sound, video, etc.) between two computers and is particularly used on the World Wide Web. It is a TCP/IP based protocol and provides a standard for web browsers and servers to communicate.

HTTP is based on Client/Server principle. Communication between the host and the client occurs through a request/response pair. A connection is established between the two computers - out of which one is client (generally the browser) that initiates the request and the other is the server that responds to the request.

- HTTP is connectionless. After a request is made, the client disconnects from the server and waits for a response. To process the request, the server has to re-establish the connection with the client.
- HTTP is media independent. Any type of data (Text, images, sound, video, etc) can be sent by HTTP as long as both the client and server know how to handle the data content.
- HTTP is stateless. This is because the server and the client are aware of each other only during a request.