COMPUTER SCIENCE

12

COMPUTER NETWORKS

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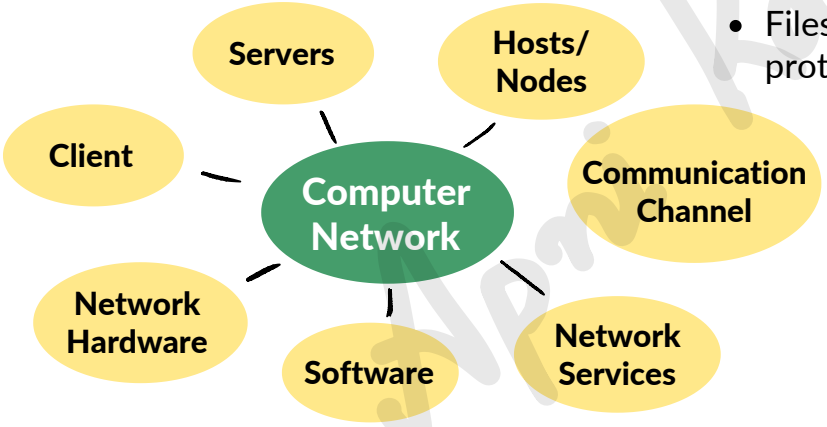
Computer Networks

Introduction

Connections among computers makes computer networks. In a computer network, two or more autonomous computing devices are connected to each other to exchange information or share resources.

Advantages	Disadvantages
• Resources such as printer, scanner, projector, etc. are shared among devices which is cheaper than buying separately for each computer. • Software can be installed centrally rather than on each computer. It's cheaper than buying licenses for every computer. • Shared storages can be used to access files and data from any machine on the network.	• Systems are more complex to run. Specialists might be required for managing which increases the cost. • If networks are badly managed, it can become unusable and productivity may fall. • If the central server fails, it becomes impossible for other machines to carry out any work. • Files' security is harder to implement, e.g. protection from viruses.



A **server** is the computer which facilitates the sharing of data, software and hardware resources on the network.

Host or **node** or **workstation** refers to the computers/devices that are attached to the network.

A **client** is a host computer that requests for services from a server.
A **server** serves the requests of the **clients**.

Other than wiring and computers, **Network Hardware** consists of :

- **NIC**(Network Interface Unit) : Network Card connected to the host to establish network connections.
- **Hub**, **Switch**, **Router**.

Hosts in a network interact with other hosts and server(s) through a **Communication Channel.** It can be:

- **Wired** : When connections are through **guided media** like **twisted-pair**, **coaxial**, **optical fiber**.
- **Wireless** : When connections are through unguided media like **Microwaves**, **radio waves**, **satellites**, **infrared waves**, **lasers** etc.

Types of Networks

1. **Local Area Network (LAN)**

Small computers networks that are confined to a localized area. Data, information, programs, printers, storage, modems, etc. are shared.
e.g. **office**, **building**, **industry**.

2. **Wide Area Network (WAN)**

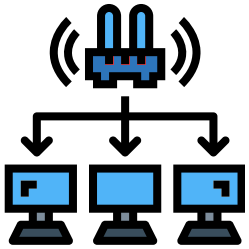
These networks spread across countries or on a very big geographical area. It can even be a group of LANs that are spread across several locations. Internet is the largest WAN.

3. **Metropolitan Area Network (MAN)**

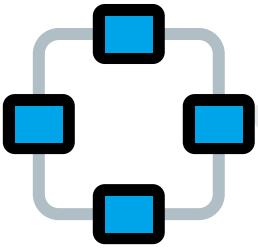
These networks spread across an area as big as a city. Now, this term has become redundant. WAN is generally used.

4. **Personal Area Network(PAN)**

It's an interconnection of devices within the range of an individual person, typically within a range of 10m.

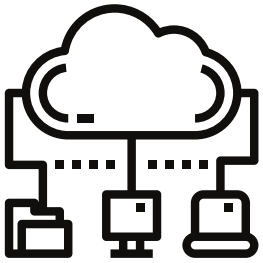


LAN



MAN

WAN



PAN

1. **Peer-to-Peer Network (P2P)**

As the name suggests, Each computer controls its own information and plays role of either a client or a server(due to which efficiency is lesser). There is no in-charge of the network.
Peer-to-peer computers are often termed as **non-dedicated** servers.
Such Networks are popular in home networks, small companies as they are easy to install and cheaper. Although the scope is limited.
Blockchain is the best example.

2. **The Client Server Network**

Bigger networks prefer to have **centralized** control. **Dedicated servers** and **clients** are there. Task specified servers also exists, e.g. *file server*, *printer server*, *modem server*. The key point of this model is that client is dependent on server to provide and manage information.
e.g. **Websites** are stored on **web servers**, **web browser** is the **client** which makes a request to the server.

They are also known as **Master-Slave networks.**

	Client-Server	P2P
Security Management	-The server controls security of the network. -Needs a team of people to manage the server.	-No central control over security. -No central control over network. Anyone can set up.
Dependency Performance	-Clients are dependent on the server. -The server can be upgraded to be made more powerful to cope with high demand.	-Clients are not dependent on the server. -If machines on network are slow they will slow down other machines.
Backups	-Data is all backed up on the main server.	-Each computer has to be backed up. Data can easily be deleted by users.

Types of Networks

1. Wired Networks

As the name suggests hosts and other devices are connected by **wires** or **cables**.
Mostly used in LANs. Although, these days there are *wireless LAN* too.

a. **Twisted Pair Cable** : It's a pair of insulated wires that are twisted together to improve electromagnetic capability and to reduce noise from outside sources.
These are available in *CAT1*, *CAT2*, *CAT3*, *CAT4*, *CAT5*, *CAT6*.

b. **Coaxial Cable(coax)** : It consists of a solid wire core surrounded by one or more foil or wire shields, each separated by some kind of plastic insulator.
Most commonly used are *thicknet*, *thinnet*.

c. **Fiber Optic Cable/ Optic Fiber Cable** : It consists of a bundle of glass threads, each thread is capable of transmitting information modulated onto light waves.
Common *Fiber Optic Cables* are **single node** and **multi-node**.

a

b

c

2. Wireless Networks

Information is transferred using electromagnetic waves like **IR**(Infrared), **RF**(Radio frequencies), **satellite**, etc. through environment/air as the media.
Wi-fi in home is an example of **Wireless LAN**. Satellites are used for **Wireless WAN**.
Most commonly used transmission media in wireless networks are :

a. **Microwave** : These are high frequency waves that can be used to transmit data over long distances. There's a *transmitter*, *receiver* & *atmosphere*.
e.g. ***Mobile phone calls***

b. **Radio waves** : These are waves of frequency range 30Hz - 300GHz, used to transmit television & radio. All radios use *continuous sine waves* to transmit information.
e.g. ***Wi-Fi also uses radio waves*** to transmit between devices and router.

c. **Satellite(Satellite Microwave)** : It's a microwave relay system which uses synchronous satellite to relay the radio signal transmitted from ground station. Communication satellites owned by both govt. and pvt. organizations have been places in stationary orbits about *22,300 miles* above the earth's surface. Satellite accepts signals transmitted from earth station, amplify them, and return them to another earth station.
It's used when we need to transmit data over a very large distance.

d. **Infrared** : It uses infrared light to send data. This is found in everyday life - TV remotes, automatic doors, wireless speakers. It transmits data through the air and can propogate throughout a room(bouncing off surfaces), but can't penetrate walls. It's become common in PDAs (*Personal Digital Assistant*). It's considered to be a secure one.
e.g. ***hand held devices like palm pilots, etc.***

Types of Networks

1. Circuit Switching

The **complete physical connection** between two computers is established and then data is transmitted from the source computer to the destination computer. *A proper end-to-end path (connection) using a physical copper wire is made.*

2. Message Switching

Source computer sends data or the message to the switching office first, which stores the data in its buffer. It then looks for a free link to another switching office and then sends the data to this office. This process is continued until the data is delivered to the destination computers. This is also known as *store and forward*.

3. Packet Switching

In Message switching, *there's no limit on block size*. Packet switching places a **tight upper limit on block size**. Also in message switching, data packets are stored on the disk in message switching whereas in packet switching, all packets of fixed size are stored in main memory. This improves the performance as the *access time is reduced*, thus the overall performance of the network is improved.

4. Bandwidth

Bandwidth(*Width of allocated band of frequencies*) is the difference between the *highest* and *lowest* frequencies. High bandwidth channels are called **Broadband**. Low bandwidth channels are called **narrowband** channels. It's unit is **Hertz**(*same as frequency*) which represents cycles per second. A kilohertz(**KHz**) represents a thousand Hertz(**Hz**).

Similarly, 1 MegaHertz(**MHz**) = 1000 KiloHertz(**KHz**)
1 GigaHertz(**GHz**) = 1000 MegaHertz(**MHz**)
1 TetraHertz(**THz**) = 1000 GigaHertz(**MHz**)

5. Data Transfer Rates

It represents the amount of data transferred per second by a communication channel or a computing or storage device.
It's measured in units of *bits per second*(**bps**), *bytes per second*(**Bps**), or **baud**.
When "Kilo", "Mega", "Giga" prefixes are applied they denote power of *1000*. Whereas in units of storage they stand for powers of *1024*. e.g. **1Kbps = 1000bps | 1KB = 1024bytes**

1 Bps = 8 bps	**1 KB = 1024 bytes**
1 Kbps = 1000 bps	**1 MB = 1024 KB**
1 Mbps = 1000 Kbps	**1 GB = 1024 MB**
1 Gbps = 1000 Mbps	**1 TB = 1024 GB or 2^40 bytes**

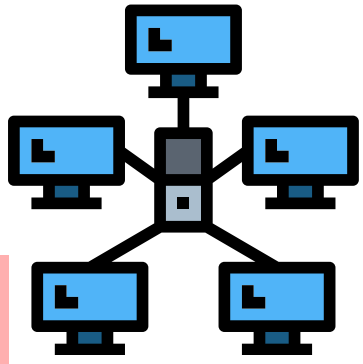
Network Topologies

Topology

The pattern of interconnection of nodes in a network is called **Network Topology**.

1. Star topology

It consists of a **central node** to which all other nodes are connected by a single path.
e.g. data processing, voice communication, etc.

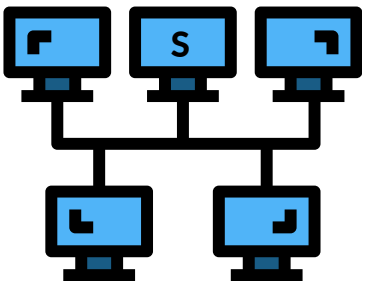


- It is easy to install and wire.
- If one node fails, network stays stable.
- Connecting or removing devices doesn't affect the network.
- Diagnosis is easy.

- Requires more cable length.
- If hub, switch, or concentrator fails, nodes attached are disabled.
- More expensive than linear topology.

2. Bus or Linear Topology

It consists of a **single transmission medium**(generally coaxial cable) onto which various nodes are attached. Transmission from any node travels in **both directions** to the **whole bus**, and can be received by all other stations. At both ends there are **terminators** which removes the travelling data token from the network.

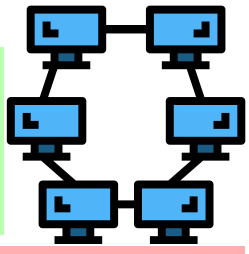


- It's easy to connect a computer to a linear bus.
- Requires less cable length than a start topology.

- Entire network shuts down, if main cable fails.
- Terminators are required at both ends.
- Diagnosis is difficult if entire network shuts down.
- Can't use it as a stand-alone topology in a large building.

3. Ring or Circular Topology

Each node is connected to **exactly two neighboring** nodes. Data is accepted from one of the neighboring nodes and is transmitted onwards to another. Generally, **data tokens** travels in one direction(**unidirectional ring**) from node to node around the ring. After passing through each node, it returns to the sending node, which removes it or it stops until it has reached destination.



- All packets flow in one direction, reducing chances of packet collisions.
- A server is not needed to control connectivity.
- Transfer speed is good.
- New nodes can be added without impacting performance of the network.

- Data transferred must pass through each node which makes it slower than star topology.
- Entire network will be impacted if one workstation shuts down.
- Hardware needed to connect each workstation to the network is more expensive than hubs/switches and ethernet cards.

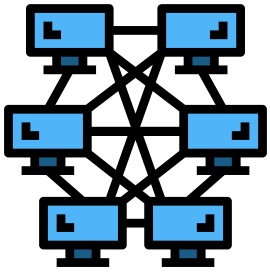
Network Topologies

4. Mesh Topology

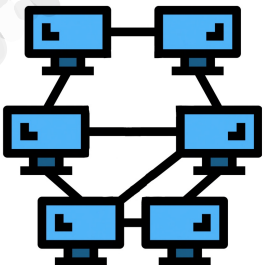
Each node is connected to more than one node, which provides and alternative route in the case host is either down or busy. It's excellent for long distance networking as it provides back-up & rerouting which is ideal for distributed networks.

- Each connection can carry its own data load.
- It can mange high traffic as multiple devices can transmit work simultaneously.
- It's robust, provides security and privacy.
- Diagnosis is easy.

- Installation, configuration & Management is difficult.
- Bulk wiring is required, cables cost is more.
- Chances of redundancy is high which leads to higher cost and lower effeciency.



Fully connected Mesh



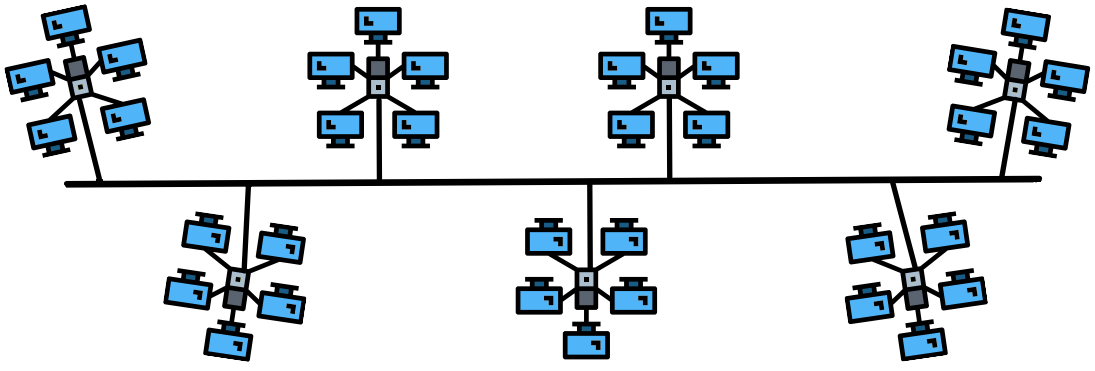
Partially connected Mesh

5. Tree or Expanded Star Topology

It's the **combination of linear bus and star topologies**. Groups of star-configured workstations connected to a linear bus backbone.

- It provides high security.
- Scalability is high as more leaf nodes(star-configured nodes) can be added.
- It uses point-to-point wiring for individual segments.
- It's supported by several hardware and software vendors.
- If backbone falls, individual star groups keep on working.

- Overall cable length increases.
- If backbone falls all leaf nodes gets disconnected.
- Difficult to configure and wire than other topologies.
- If hub, switch or concentrator fails, attached nodes gets disconnected.



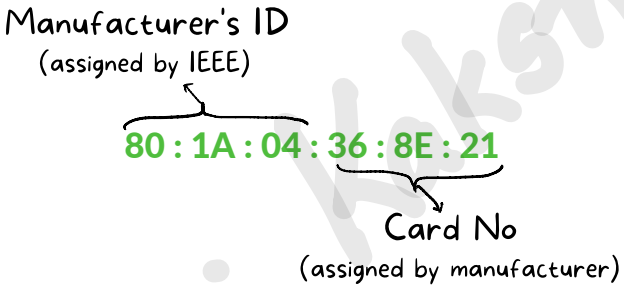
Network Devices & Hardware

1. NIC (Network Interface Card)

It's a special device attached to each **node** and the **server** which helps them **establish all important connections with the network.** Each node's NIC has a unique number identifying it, known as the *node address*.
NIC is also known as *Terminal Access Point*(**TAP**) or *Network Interface Unit*(**NIU**).

2. MAC address

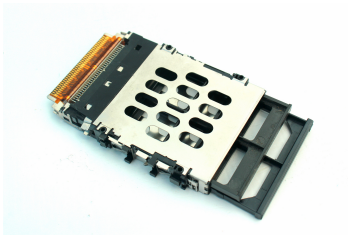
Manufacturers assigns a **unique physical address** to each NIC card known as **MAC address**(*Media Access Control Address*). It's a 6-byte address, each byte separated by a colon.



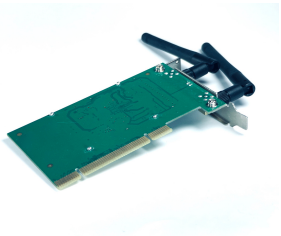
3. WiFi card

It's either an internal or external LAN(*Local Area Network*) *adapter* with a built-in **wireless radio** and **antenna**. There are multiple types. Most common Wi-Fi cards used in desktop computers are *PCI-Express Wi-Fi cards* made to fit the slot in motherboards.

USB WiFi Card



PCMCIA WiFi Card



PCI-Express WiFi Card

4. MODEM(Modulator Demodulator)

This device is used to convert the **digital signals** into **analog signals**(Audio Frequency tones) and vice versa. Mainly used to connect telephone/radio lines to a computer terminal.
Internal modems are fixed within the computer.
External modems are connected externally as other nodes.

5. RJ45(Registered Jack 45) Connector

This 8-pin plug or jack is commonly used to connect computers onto Ethernet-based local area networks.

RJ45

MODEM

Network Devices & Hardware

6. Ethernet Card

It's a **NIC** that connects a computer to a computer network**.** In most of the new computers the ethernet port is built into computer ,whereas in the earlier computer it was available on an expansion card that used to be plugged into the motherboard.

7. Router

As the name suggests, it handles **routes of the data packets**. It's a networking device, that forwards data packet between computer networks. This creates an overlay internet connection which connects multiple independent networks. It's basic role is to determine **best possible route**(*shortest path*) for the data packets to be transmitted.

8. Hub

A hub is a connecting device which connects multiple computers together to form a LAN. It connects multiple devices through **RJ45** connectors in a **star topology**. Signal entering any port is broadcasted out on all other ports.

9. Switch

It's a multi-ported device which connects multiple computers together to form a LAN similar to hub, but ***switch is a smart hub***. It has the **intelligence to send the data directly** to the destination rather than broadcast to whole network. *Data packets received from one end are refreshed and delivered to address of the destination.*

10. Gateway

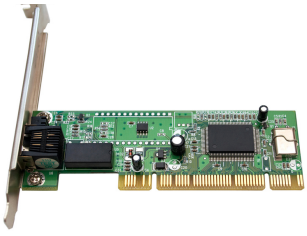
It's a device that **connects dissimilar networks**. As the name suggests it acts as an entrance to another network(maybe with different protocol structure). It's also called **protocol converter** as it convert data packets from one protocol to other. It also **conceals the IP address** of the user sending out information, outsiders can only see the IP address of the gateway.

11. Protocol

A *protocol* means the **rules** that are applicable for a network. It defines standardized formats for data packets, techniques for detecting and correcting errors and so on. It's a *formal description of message formats and rules that devices must follow* to exchange data seamlessly without any interruptions and contradictions.

12. FTP(File Transfer Protocol)

It's a standard for the **exchange of files** across internet. Files of any type can be transferred, although type of file needs to be specified. It's useful in transferring files from one network to other. Different groups can co-operate on a same project even from long distances.



Ethernet Card

Router

Switch/Hub

Network Protocols

13. HTTP(Hypertext Transfer Protocol)

It's the set of rules for transferring **hypertext** that is *text*, *graphic*, *image*, *sound*, *video*, etc. on **WWW**(World Wide Web). It has the required lightness and speed for distributive, collaborative, hypermedia information systems. HTTP is also used as a generic protocol for communication between user agents and gateways to other internet protocols such as SMTP, FTP, etc.

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

It's the base communication protocol of the internet. **IP** uses numeric *IP addresses* to join network segments and **TCP** provides *reliable delivery of messages between computers on the network*. It makes sure all the data packets are sent and received correctly. TCP/IP is a layered set of protocols.

15. PPP(Point to Point Protocols)

It's the Internet Standard for *transmission of IP packets* over serial lines. As the name suggests it's a protocol used to establish direct connection between two computers(points) using telephone lines.

16. SMTP(Simple Mail Transfer Protocol)

It's the **internet standard for electronic mail**(e-mail) transmission across *IP(Internet Protocols) networks*. E-mail server uses **SMTP** to send and receive mail messages, although user-level applications use SMTP only for sending messages. For receiving messages, they usually use either POP(Post Office Protocol) or iMAP(internet Message Access Protocol).

17. POP(Post Office Protocol)

It's the standard protocol used by local e-mails clients to **retrieve emails** from a remote server over a *TCP/IP* connection. **POP**(*Post Office Protocol*) or **iMAP**(*internet Message Access Protocol*) are the most prevalent Internet standard protocols for email retrieval. **POP3** is the current latest version which is used by most webmail services like *Gmail*, *Hotmail* and *Yahoo mail*.

18. Remote Login(Telnet)

It's a program that allows user to **establish a virtual terminal connection between two machines** using TCP/IP. It's an internet utility that lets you log onto remote computer systems.

19. ARPANET(Advanced Research Projects Agency Network)

The U.S. *Department of Defense* sponsored a project named a ARPANET(**Advanced Research Projects Agency NETwork**) to connect computers at different universities and U.S. defense, messages and data were exchanged. It was the first wide-area packet-switching network with distributed control, it was the first network to implement the TCP/IP protocol.

20. Internet

It's a *worldwide network of computer networks* that evolved from the first network **ARPANET.** It's an **interconnection of large and small networks around the globe** that allows all the computers to exchange information with each other.
To accomplish connections between all computers there must be a *common set of rules for communication*, known as **protocols**.

Network Terminologies

21. Wireless/Mobile Communication

It refers to the method of transferring information between devices without any physical connection. e.g. *Wi-Fi*, *Bluetooth*, *Radio Waves*, *etc*.

22. GSM(Global System for Mobile communication)

GSM(*Global System for Mobile communication*) is a **wide area wireless communications system** that uses *digital radio transmission* to provide *voice*, *data*, *and multimedia communication services*. It's one of the leading digital cellular system. It uses TDMA(*Time Division Multiple Access*), which allows eight simultaneous calls on the same radio frequency.

23. GPRS(General Packet Radio System)

GPRS is a *third-generation* technology for radio transmission of small packets of data especially between mobile devices and internet. It's also known as GSM-IP(*Global System Mobile Communications Internet Protocol*) as it keeps user online and allows them to make voice calls and access internet.

24. WLL(Wireless in Local Loop)

WLL/WiLL is the system which connects subscribers to the *Public Switched Telephone Network*(**PSTN**) through a **radio link** instead of copper wires. It's analogous to telephone service but wireless and more capable. It's more reliable and enhanced technology which offers high quality data transmission. It has *much better bandwidth* than traditional telephone system.

25. CDMA(Code Division Multiple Access)

This digital wireless telephony transmission technique uses *spread-spectrum* allows multiple frequencies to be used simultaneously. *Unlike* ***GSM***, *that uses TDMA*, **CDMA** doesn't assign a specific frequency to each user. Instead, every channel uses the *full available spectrum*.

26. 1G

1G networks(*NMT*, *C-Nets*, *AMPS*, *TACS*) are considered to be the *first analog cellular systems* started in 1980s. It was purely designed for voice calls with almost no consideration of data services.

27. 2G(GSM)

2G networks(*GSM*, *CDMAOne*, *D-AMPS*) are the *first digital cellular systems* launched early 1990s, offering improved sound quality, better security and higher total capacity. In CDMA technology, data and voice packets are separated using codes and then transmitted using a wide frequency range.

28. 2.5G

2.5G networks(*GPRS*, *CDMA2000 1x*) are **enhanced versions of 2G networks** with data rates upto 144kbps. GPRS offered first always-on data service.

29. 3G

3G networks(*UMTS FDD and TDD*, *CDMA2000 1x EVDO*, *CDMA2000 3x*, *TD-SCDMA*, *Arib WCDMA*, *EDGE*, *IMT-2000 DECT*) are 3rd generation wireless technologies with enhancements like high-speed transmission, advanced multimedia access and global roaming. Stationary speeds of 2Mbps and mobile speeds of 384kbps for a true 3G.

Network Terminologies

30. 4G

4G is an improved version of 3G but only in terms of fast web-experience. It offers downlink data rates over 100Mbps, low latency, very efficient spectrum use and low-cost implementations. It's also referred as MAGIC(*Mobile Multimedia*, *Anywhere*, *Global Mobility*, *Integrated Wireless & Customized Services*). 4G is convergence of wired and wireless networks, including GSM, WLAN and bluetooth as well as computers, communication devices and others.

31. 5G

5G is the fifth generation of broadband cellular networks began worldwide in 2019. 5G's service area is divided into small geographical areas called *cells*. Devices in a cell are connected to network by radio waves through a local antenna in the cell. Greater bandwidth and higher download speeds eventually upto 10Gbps. This increased speed is achieved partly by using higher frequency radio waves than previous cellular networks. However they have a shorter range, requiring smaller geographic cells.

32. Mobile Processors

A mobile processor is a **CPU chip designed for portable computers/mobile phones**. It's typically housed in a smaller chip package without fan, in order to run cooler it uses lower voltages than other components. They have more sleep mode capabilities to conserve power and prolonged battery life.
e.g. *Qualcomm Snapdragon 865*, *Exynos 990*, *Apple A14*, *etc.*

33. Chat

It's an application to **communicate with a person, group on internet in real time by typing text**. We type a message in our device which is immediately received by the recipient, then recipient can respond to our message, which is received by us immediately.

34. Video Conferencing

It's a two-way video conversation between two or more participants on the internet or a private network. Each user has a video camera, microphone and speaker on his/her computer, participants speak to one another, they hear each other's voices and see a video image of other participants.

35. Voice over Internet Protocol(VoIP)

It's communication protocols and transmission technologies for delivery of voice communications and multimedia sessions over Internet Protocol(IP) networks, such as the internet. VoIP is also known as *IP telephony*, *Internet telephony* and *broadband telephony*.

36. Wi-Fi(Wireless Fidelity)

Wi-Fi is a family of wireless network protocols, based on IEEE 802.11 family of standards, which are commonly used for local area networking of devices and internet access. Wi-Fi is a trademark of Wi-Fi Alliance, it's not a technical term, alliance has enforced its use to describe only a narrow range of connectivity technologies including wireless local area network(WLAN).

Network Terminologies

37. WiMAX

WiMAX(Worldwide Interoperability for Microwave Access) is a family of wireless broadband digital communication system. It can provide broadband wireless access(BWA) up to 50km for fixed stations and 5-15km for mobile stations which is significantly larger than WiFi(30-100m). WiMax requires a tower called *WiMax Base Station*, similar to a cellphone tower, which is connected to the Internet using a standard wired high-speed connection.

39. WWW(World Wide Web)

WWW is a set of protocols that allows you to access any document on the internet through a naming system based on URLs. It also specifies a way(HTTP) to request and send a document over the internet. Before WWW, Internet was mainly used for obtaining textual information. After WWW internet popularity grew tremendously.

40. HTML(Hyper Text Markup Language)

HTML is the **coding language used to create Hypertext documents** for use on the World Wide Web. It's the standard markup language for web pages.

41. XML(Extensible Markup Language)

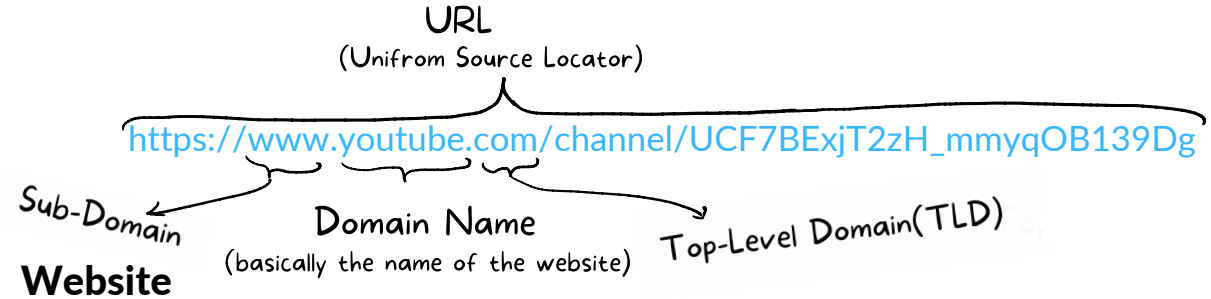
It's a **markup language** that defines a set of rules for encoding documents in a format that is **both human-readable and machine-readable**. It was designed to store and transport data. It doesn't do anything, it's just information wrapped in tags.

42. URL(Uniform Resource Locator)

URL is a **complete web address used to find a particular web page**. It depends on several factors such as type of server or protocol, name/address of the server on the internet, location of the file on the server.

43. Domain Name

Domain name is a component of a URL, it's the identification string that defines the name of the particular website.



44. Website

A website is a **collection of web** pages usually containing hyperlinks to each others representing information of a company or individual on the World Wide Web. It's a location on a net server which has a unique URL.

45. Web Browser

It's a *client software* that is used to **access various kinds of internet resources using HTTP** which also helps us navigate through World Wide Web and display web pages.
e.g. *Google Chrome*, *Mozilla Firefox*, *Opera*, *Safari*, *etc*.

46. **Web Servers**

It's a computer **that stores data and makes them available** to rest of the world(Internet). A server may be dedicated, meaning its sole purpose is to be a web server. A non-dedicated server can be used for basic computing in addition to acting as a server. It responds to the requests made by web browsers.

47. **Web Hosting**

It's a **service that allows user to upload and store a website's HTML documents** and other data on a web server. It makes the file available on the World Wide Web to be used by public. It's also known as site hosting.