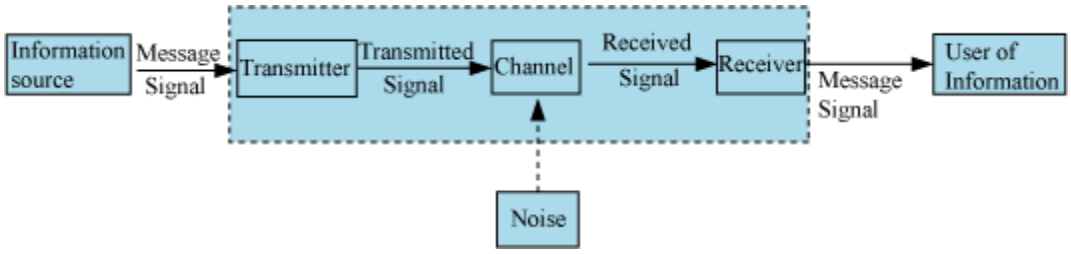
Communication Systems

Elements of Communication System

- Communication is the act of transmission of information.
- Communication system has three essential elements – transmitter, medium/channel, and receiver.



- Receiver and transmitter are located at different places and the channels connect them.
- Transmitter converts the message signal produced by the source of information into a form suitable for transmission through the channel.

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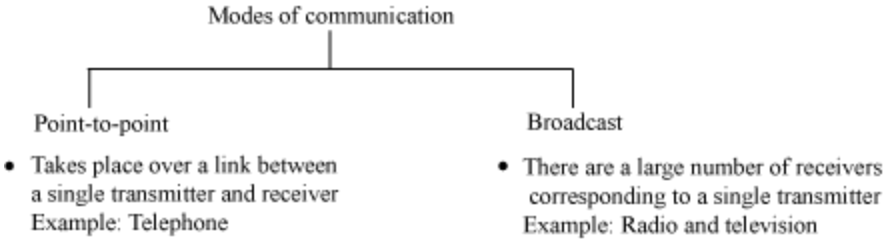
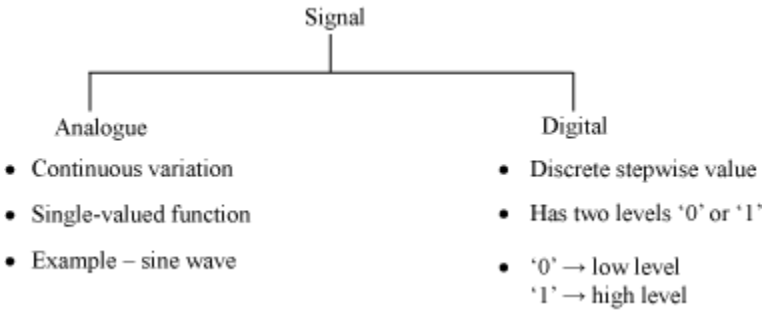
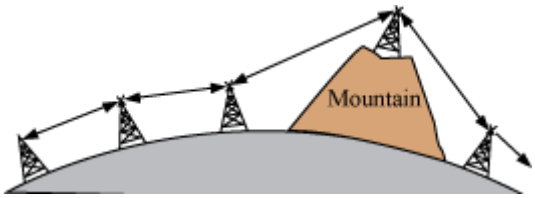


Some important terms

- Transducer – It converts one form of energy into another.
- Signal – It is information converted into electrical forms, which is suitable for transmission.



- Noise – It refers to the unwanted signal that tends to disturb the transmission and processing of message signal in a communication system.
- Transmitter – It processes the incoming message signal and makes it suitable for transmission through a channel to the receiver.
- Receiver – It extracts the desired message signal from the received signal at the output of the channel.
- Attenuation – It is the loss of strength of a signal while propagating through a medium.
- Amplification – It is the process of increasing the amplitude of a signal using an electronic circuit called the amplifier.
- Range – It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.
- Bandwidth – It is the portion of the spectrum occupied by the signal.
- Modulation – It is a process of superimposing the low frequency message/ information signal on a high frequence wave. This is done because the low frequency signal wave cannot be transmitted to long distance without the help of the carrier.
- Demodulation – It is the process of retrieval of information from the carrier wave at the receiver.
- Repeater – It is a combination of receiver and a transmitter. It is used to extend the range of a communication system.



Bandwidth of Signals

- Bandwidth – It is the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.
- Bandwidth of an analogue signal – It is the range over which the frequencies in an analogue signal vary.

In telephonic communication system, the frequency range of speech signals is from 300 Hz to 3100 Hz.

∴ Bandwidth of speech signals = 3100 − 300 = 2800 Hz

- Bandwidth of a digital signal - A digital signal is in the form of rectangular wave. It is a superposition of sinusoidal waves of different frequencies. The exact rectangular shape of the digital signal will be reproduced when all the infinite number of harmonics is added to the fundamental frequency. It implies that the bandwidth of a digital signal is infinite.

- **Some important wireless communication frequency bands**

Service	Frequency bands	Comments
Standard AM broadcast	540-1600 kHz	
FM broadcast	88-108 MHz	
Television	54-72 MHz	VHF (Very High Frequency)
	76-88 MHz	TV
	174-216 MHz	UHF (Ultra High Frequency)
	420-890 MHz	TV
Cellular Mobile Radio	896-901 MHz	Mobile to base station

	840-935 MHz	Base station to mobile
Satellite Communication	5.925-6.425 GHz	Uplink
	3.7-4.2 GHz	Downlink

Bandwidth of Transmission Medium

- Wire, free space, and fibre optic cable are the commonly used transmission media.
- A coaxial cable offers a bandwidth of approximately 750 MHz.
- Free space communication takes place over a wide range of frequency from a few hundred kHz to a few GHz.
- An optical fibre offers a transmission bandwidth in excess of 100 GHz.

Layers of atmosphere

- **Troposphere** is the lowest layer and extends up to a height of 12 km from the earth's surface. It contains most of the water vapour of the atmosphere.
- **Stratosphere** is the layer above the troposphere and extends from 10 km to 50 km from the surface of the earth. This region contains the ozone layer.
- **Mesosphere** is the layer above the stratosphere. It extends from 50 km to 80 km from the surface of the earth. Temperature begin to decrease with increase in height in this layer.
- **Ionosphere** extends from 80 km to thousands of km. It is composed of positive and negative ions that play an important role in radio and telecommunications.

Propagation of Electromagnetic Waves

- Radio waves (few Hz to about 10^{11} Hz) are used for transmission of information from one place to another.
- An antenna at the transmitter radiates the electromagnetic waves, which travel through space and reach the receiving antenna at the other end.
- Transmitting antenna - It converts electric signals to electromagnetic waves.

- Receiving antenna - It converts electromagnetic waves into electric signals.
- Ground wave propagation- In this type of wave propagation, the radio waves from the transmitting antenna propagate along the surface of the earth to reach the receiving antenna.

  Its frequency range is only a few Mhz.

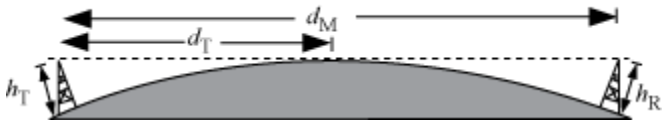
- Sky wave propagation – In this type of wave propagation, the radio waves from the transmitting antenna reach the receiving antenna after reflection from the ionosphere.

  Its frequency ranges from a few MHz up of 30 to 40 MHz.

- Space wave propagation – In this type of wave propagation, the radio waves from the transmitting antenna reach the receiving antenna directly.

  It is used for line of sight communication as well as satellite communication.

  Its frequency range is above 40 MHz.



$h_T \rightarrow$ Height of transmitting antenna

$d_T \rightarrow$ Its distance to the horizon

$R \rightarrow$ Radius of earth

$$\therefore d_T = \sqrt{2Rh_T}$$

$h_R \rightarrow$ Height of receiving antenna

$d_M \rightarrow$ Maximum line of sight distance

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$

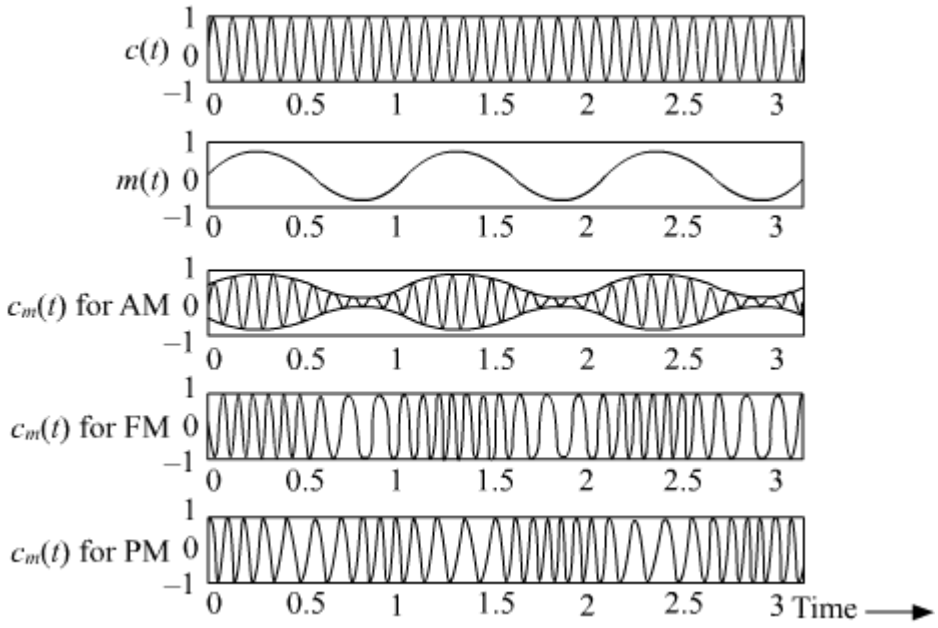
Modulation and Its Need

Factors which affect the transmission of an electronic signal in the audio frequency range over a long distance directly are:

- Size of the antenna or aerial
- Antenna should be comparable to the wavelength of signal.
- For electromagnetic wave of frequency 20 kHz, wavelength is 15 km and such a long antenna is not possible.
- Therefore, the low frequency base band signal has to be converted to high frequencies or radio frequencies.
- Effective power radiated by an antenna
- Power radiated by antenna is $(l/\lambda)^2$.
- Power radiated increases with decrease in λ i.e., increasing frequency.
- Good transmission requires high powers. Therefore, the frequency of transmission should be high.
- Mixing up of signals from different transmitters
- Low frequency base band signal has a chance of mixing up.
- Low frequency signal is translated into high frequency signal without affecting the original signal with the help of carrier wave.
- Carrier can be of sinusoidal or pulse form.

$$c(t) = A_c \sin(\omega_c t + \phi)$$

- In the process of modulation, three parameters (A_c, ω_c, Φ) can be controlled.
- **There are three types of modulation – amplitude modulation (AM), frequency modulation (FM), and phase modulation (PM).**
- In AM modulation, the amplitude of the carrier wave $c(t)$ is varied in accordance with the information signal $m(t)$. In AM, the ratio of signal to noise ratio is very low.
- In FM modulation, the frequency of the carrier wave $c(t)$ is varied in accordance with the information signal $m(t)$. In FM, the ratio of signal to noise ratio is very high.
- In PM, the phase of the carrier wave $c(t)$ is varied in accordance with the information signal $m(t)$.



Amplitude Modulation

Carrier wave, $c(t) = A_c \sin \omega_c t$

Modulating signal, $m(t) = A_m \sin \omega_m t$, where $\omega_m = 2\pi f_m$ is the angular frequency of the massage signal

Modulated signal $c_m(t)$ is given by

$$c_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

$$= A_c \left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t$$

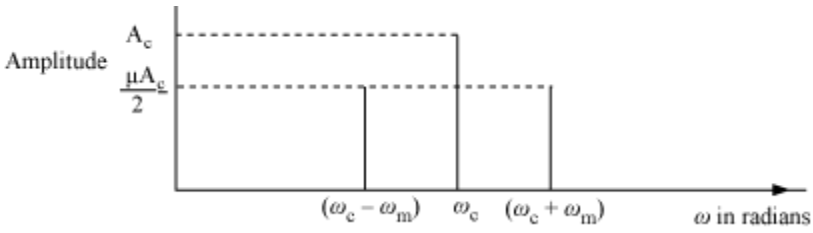
$$\therefore c_m(t) = A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$$

Here, $\mu = A_m / A_c$ is the modulation index.

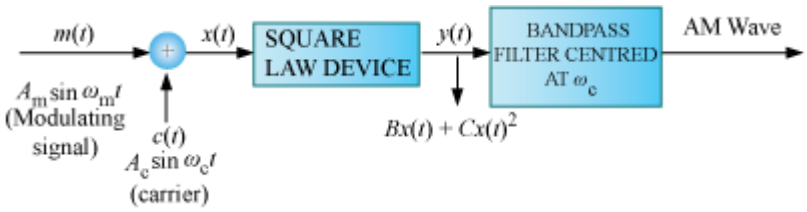
$\mu \leq 1$ to avoid distortion

$$C_m(t) = A_c \sin \omega_c t + \frac{\mu A_c}{2} \cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2} \cos(\omega_c + \omega_m)t$$

$\omega_c - \omega_m$ and $\omega_c + \omega_m$ are the lower side and the upper side frequencies, respectively.



Production of Amplitude Modulated Wave



$$x(t) = A_m \sin \omega_m t + A_c \sin \omega_c t$$

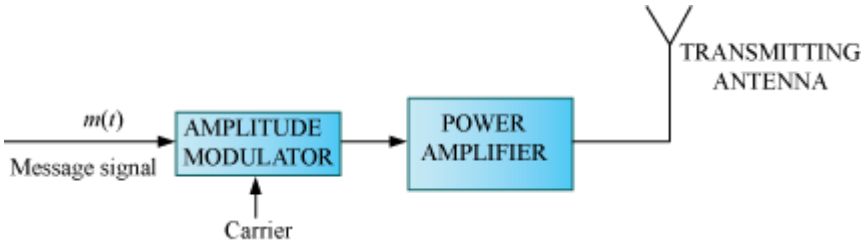
This signal is passed through a square law device, which is a non-linear device that produces an output.

$$y(t) = B\,x(t) + C\,x^2(t)$$

$$y(t) = BA_m \sin \omega_m t + B\,A_c \sin \omega_c t + C\left[A_m^2 \sin^2 \omega_m t + A_c^2 \sin^2 \omega_c t + 2A_m A_c \sin \omega_m t \sin \omega_c t\right]$$

$$= B\,A_m \sin \omega_m t + B\,A_c \sin \omega_c t + \frac{CA_m^2}{2} + A_c^2 - \frac{CA_m^2}{2}\cos 2\omega_m t - \frac{CA_c^2}{2}\cos 2\omega_c t + C\,A_m A_c \cos(\omega_c - \omega_m)t - C\,A_m A_c \cos(\omega_c + \omega_m)t$$

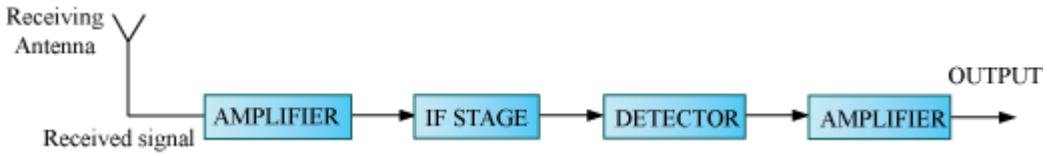
- When the above O/P is passed through the band pass filter, an AM wave is obtained.



- The modulator is followed by a power amplifier, which provides the necessary power. The modulated signal is then fed to an antenna of appropriate size for radiation.

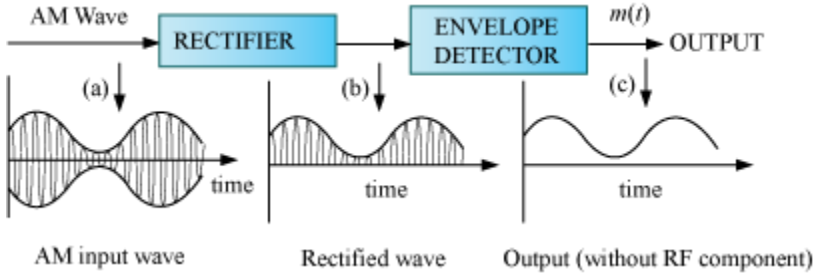
Detection of Amplitude Modulated wave

- The transmitted message gets attenuated in propagating through the channel.



- The receiving antenna is followed by an amplifier and a detector, which are followed by an intermediate frequency (IF) stage to change the carrier frequency to lower frequency.

- In this process, the modulated signal is detected.



- The modulated signal is passed through a rectifier to produce the output.

  An envelop signal is produced, which is the message signal. To retrieve $m(t)$, the signal is passed through an envelope detector.

AM waves are used:

- in AM radio broadcasting
- in computer modems with phase modulation
- in transmitting TV picture of videos
- in the transmission of digital data
- in sending multiple telephone calls through a single channel by modulating them on separate carrier frequencies
- in a two-way radio communication that is used in the following fields:
- aviation
- military
- amateur radio
- citizen's band radio

Drawbacks of AM waves:

- It has low efficiency. Only 20 to 30% of it is useful.

- Noisy reception: AM signal is easily affected by external atmosphere and electrical disturbances.
- It has a small operating range.
- The allowed bandwidth of AM is only 10 kHz. For the transmission of all audio frequencies, about 30 kHz bandwidth is required. This affects the fidelity of the radio.

Comparsion between FM and AM:

- FM has high signal to noise ratio as compared to AM.
- FM broadcast is done in UHF and VHF where effect of noise is minimal whereas AM operates in MF and HF where effect of noise is very high.
- FM requires larger channel bandwidth for its transmission as compared to AM.
- FM transmission and receiving equipments are relatively costlier and complex as compared to AM equipments.

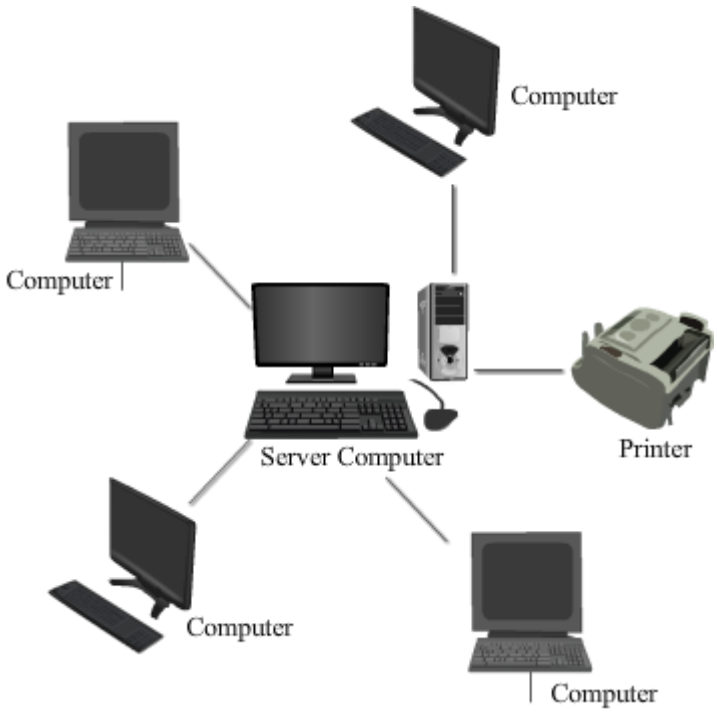
Internet

Internet

The working style of people in the 20th century has changed considerably by the invention of computers. The lifestyle of the people has also entirely changed. A computer's capability to do fast arithmetical and logical operations has made human life simpler. Now, the computers are used in almost all offices, universities, banks, schools, etc. Before the end of the 20th century, we were successful in creating a global network of computers that provided ways of exchanging information and communicating among all computers connected to the network. This global network of computers came to be known as the Internet (or simply net). The Internet is, in fact, the short form of INTER-NETwork, which is the interconnected network of all worldwide servers.

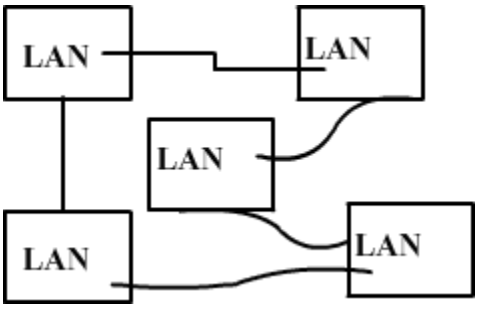
Networking of Computers: The Way Internet Works

A computer network is a communication network that allows various computers to exchange information with one other. Various computers are said to be networked when they are exchanging information. Information can be shared by connecting computers through wires or some wireless means of communication like Wi-Fi.



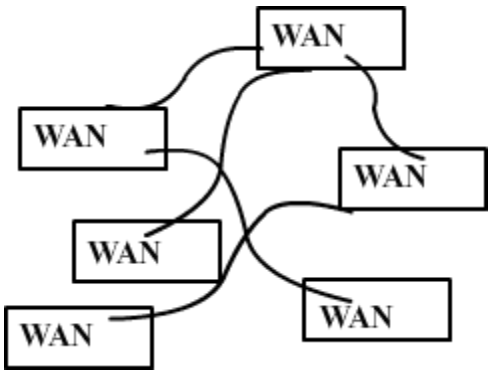
A Local Area Network (LAN)

At small scale, for example, within school, hospital or an office, networking of computers is called local area network (LAN). One can also connect devices like printers and scanners to a LAN.



Formation of a WAN

By connecting many computers within an office, one can build a local area network. Every LAN has some main computers that are known as server computers. These server computers connect the LAN to other networks through telephone lines or satellites. Therefore, by connecting various LANs, a wide area network (WAN) is created as shown in the figure below.



Formation of Internet

When various WANs are interlinked, the network so formed is called the Internet.

The server computers of LAN store all information related to a local network. They act like channels through which information can be exchanged between computers connected to LAN and servers of the other networks. Every computer that extracts information from a server is known as a client computer.

The US Department of Defense, in 1969, developed the first network of computers called Advanced Research Projects Agency NETwork (ARPANET). By 1990, many countries came up with a common set of rules for Internet communication among computers called protocols. Today, the standard sets of protocols called transmission control protocol/internet protocol (TCP/IP) are used for exchanging information through Internet.

The information is exchanged at a fast speed (at the speed of light) on Internet as all the electronic signals (messages) of computers are communicated through electromagnetic waves. In India, the Videsh Sanchar Nigam Limited (VSNL) in Mumbai started Internet in November 1988.

Using the Internet, all the information is provided through web pages that may contain text, images, videos, etc. It is easy to move from one web page on the Internet to another through a system called interlinked hypertext documents. The web pages are linked with one another through hyperlinks that are the references to the text, image or video on the other web page. The way of accessing information on the Internet through interlinking of web pages is called World Wide Web (www). A set of web pages together constitute a website. One can design a website of one's own organisation containing information about its different aspects and its activities. The computer in any location in the world can be connected to the Internet network through various Internet service providers (ISPs) by paying a prescribed fee. Commonly, the mobile network companies act as the ISPs.

Applications of Internet

The Internet has many applications nowadays. It is used for many purposes like searching and viewing information on any topic of interest, sending electronic mails (emails), for e-banking, e-shopping (e-commerce) and e-booking (e-ticketing). This list of the uses of the Internet is endless.

(i) **E-banking**: It is an electronic payment system that enables customers of a financial institution (usually a bank) to proceed for financial transactions on a website operated by that institution. To bank online with an institution, the customer should be a member of that institution and should have access to the Internet. For this, the customer must register with the institution for the service. The login number and password are provided to the customer by the financial institution for his/her unique identification. Using this facility, the customer can link his account with other facilities such as checking status of the balance online, cheque book requisition, loan, credit card and debit card. etc.

(ii) **Email**: Electronic mail, most commonly referred to as email, is a way of sending texts written on computers through the Internet. Images and videos can also be sent along with the text. Email is the fastest and the cheapest way of sending messages.

In order to use this facility, one needs to create a personal email account with an email address. It is like an identity card through which people can identify and communicate with each other through the Internet. An email account is password protected, and thus, no one, other than the person it belongs to, can use it.
Every email address has two parts separated by a sign '@'. For example, 'abc@yahoo.com' is an email address and following are its two parts:

(i) Part before @ sign - abc
It is the personal information part. Here, it denotes a name 'abc'.
(ii) Part after @ sign - yahoo.com
It is called a domain name. It provides information about the server that is providing this email facility.

The messages sent through email are delivered instantly to the addressees because the communication of messages is done by means of electromagnetic waves through the Internet.
The received messages remain stored in an email account even when the user of that email account is not connected to the Internet. These messages can be viewed later.

(iii) **Internet surfing**: Navigation over the World Wide Web (WWW) from one web page/website to another is called Internet surfing. It is an interesting way of searching and viewing information on any topic of interest.

(iv) **E-shopping (E-commerce)**: It is a form of electronic commerce by which the consumers can

buy the products or the services over the Internet. Buying products through product-selling websites is called e-shopping. On these websites, the buyer gets the facility to pay cash on delivery or make online payments (using e-banking/credit cards or debit cards) for the purchases made. Similarly, there are different websites where one can sell different items by uploading photographs of products.

(v) **Social networking**: It is a web-based service that allows people with the same interests to build a social network. Using this service, an individual can create his/her own profile and a list of users with whom he/she wants to connect. One can also share his/her ideas, pictures, events, activities, etc. with his/her group. Facebook, Twitter, Google+, etc. are some popular social networking sites.

(vi) **E-booking (e-ticketing)**: Using the Internet, consumers can book flight tickets, railway tickets, hotels, holiday packages, insurance, other services, etc. online. In order to book an e-ticket, a customer has to visit the home page of an airlines company or Indian Railways. As the customer enters the travel preference, he/she can view the available flights/trains through an appropriate interface. Once the choice is fixed, the customer has to select the mode of transfer of money. An online ticket is issued to the customer after making the payment through an authentic mode (like e-banking).

Mobile Telephony

Mobile Telephony

Introduction

Mobile telephony is the method of providing telephone services to phones that can be moved around freely and does not require to stay fixed in one location. The use of mobile phones is common these days. These phones have changed the way we live and communicate. With the advancement in technology, the look and utility of a mobile phone has undergone a huge change. These days, apart from making phone calls, one can access the Internet, listen to radio/music, see live TV and do many such things using different applications on the mobile phone. It can be said that a mobile phone is like a handy computer equipped with the Internet.

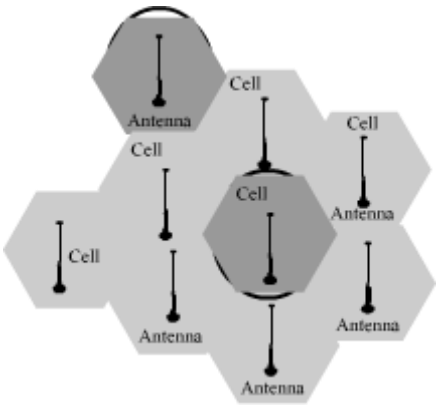
We initially used landline phones; even today, they are in use. In landline phones, the instrument is connected to a telephone exchange through electric wires that connect phone calls to other phones. However, with a wired connection, there is a limitation; since the instrument is fixed, it cannot be moved from one place to another. The mobile phone technology has successfully overcome this limitation.

A mobile phone or a cell phone is a low power operated device that is wireless and can make

and receive telephone calls over a radio link while moving around a wide area. Earlier, the wireless technology was also in use; a walkie-talkie is a wireless system of communication, which was invented before the mobile phone. It is still used by policemen and in various military applications. In a walkie-talkie, after completing one sentence, the user says 'over' and then listens. This is because the same radio frequency is used for sending and receiving the audio signals. However, when using mobile phones, two persons can talk and listen at the same time because the outgoing and incoming signals use different frequencies.

Working Principle of Mobile Phones

Mobile phones can be used while moving from one place to another because of the cellular radio network technology, which is a replacement of the telephone exchange system. In a cellular radio network, the given physical area is divided into smaller call cells (or cell zones). To cover the given area completely, hexagonal cells are used.

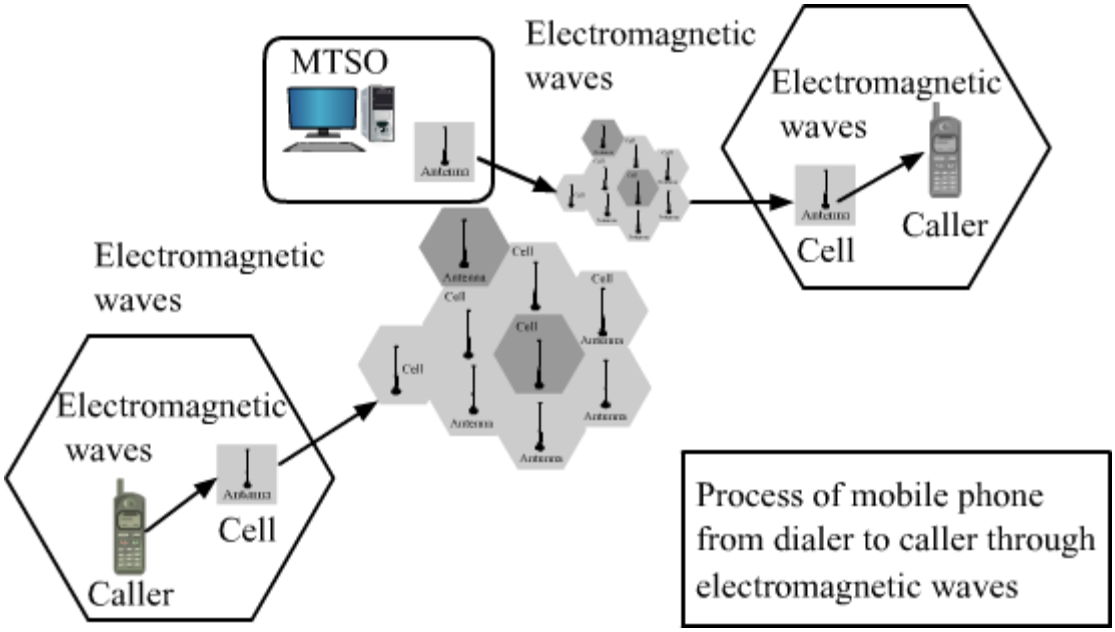


A radio antenna is installed in every hexagonal cell for receiving and sending radio signals from and to the mobile phones physically present in the cell. In a particular area, all cell antennas are connected to each other through a network.

The Mobile Telephone Switching Office (MTSO) handles all network-related works. All the incoming and outgoing calls are handled by MTSO. It is just like a telephone exchange for mobile phone calls.

The working range of every cell antenna is at least from 1.5 km to 2 km and at most from 47 km to 57 km. MTSO recognises the mobile phone as it is switched on; it records its location by identifying the cell in which it is present.
When the person using a mobile phone moves from one cell zone to another, MTSO switches the mobile phone link to the new cell antenna. This is how a mobile user gets an uninterrupted link to talk while moving. For a conversation, mobile phones use high-frequency radio waves, as the audio signals of these waves are better. As the working of mobile phones is based on the cell division of the physical areas, they are referred to as cell phones.

Scientific Process of Mobile Phone Call



When someone dials a mobile number from his/her mobile phone, an electromagnetic wave of particular frequency is generated by an electronic oscillator circuit (frequency generator) inside the phone. The electromagnetic wave, which was generated, carries dialled number's information and is transmitted to cell antenna through antenna of the dialled mobile. Then the signal received by the cell antenna is transferred to MTSO. The computer system of MTSO identifies the location of the dialled mobile number and connects the two mobile phones. As the dialled mobile phone receives the signal, the system generates the mobile number of the dialler through an oscillator circuit and displays it. This is a very fast process; all this happens within a few seconds as all the signals are transferred through electromagnetic waves, which travel at the speed of light. The mobile phone call is transferred from dialler cell antenna to MTSO and from MTSO to dialled cell antenna. This is done through cell antennas lying in between.

Mobile Phone Numbering System

To identify every mobile phone, a subscriber identity module (SIM) card in inserted in every mobile phone. It is like an identity card of its user. It is a small integrated circuit (IC) having a unique SIM number and a mobile phone number.
Mobile operator companies issue all SIM cards and provide their information to MTSO. After SIM verification, MTSO activates the mobile number of the user. This makes a mobile phone usable. In India, every mobile number is of 10 digits and have prefix 9, 8 or 7. According to National Numbering Plan, 2003, the way of splitting mobile numbers is YYYY-ZZZZZZ, where

YYYY is network operator digits and ZZZZZZ is subscriber number digits. Telecom Regulatory Authority of India (TRAI) regulates the use of mobile phones system in India.

Mobile Network Generations (1G, 2G, 3G and 4G)

In order to improve the efficiency of the mobile network, many attempts have been made. We have different generations of the wireless technology, such as 1G, 2G, 3G and 4G. The word 'Generation' (G) describes the efficiency of mobile networks. 1G was the first generation of mobile networks, which was based on analogue radio signals. 2G networks were based on narrow band digital signal that provided good quality of calls and global connectivity. For efficient Internet usage, 3G networks increased the data transfer speed. 4G networks are going to provide a high-speed Internet facility on mobile phones for running various applications.

Global Positioning System

Global Positioning System

It is a navigation system based on satellite communication. It provides exact information about any location and time on or near the Earth.
Human beings have always wanted to discover and navigate various places on the Earth. For this, they invented various instruments to assist them in navigation on the Earth. One of the oldest navigational instruments is a magnetic compass that has been in use for many centuries for direction identification on the Earth's surface. These days, devices based on the global positioning system (GPS) are used for navigation. Using such devices, the user can have an accurate real-time information on any location for easy and comfortable navigation even through the local streets of any city. The figure given below is of a GPS device. When this device is fitted in a car, it shows the speed of the car, time, longitude coordinates and map of the nearby area.

What is a GPS?

It is a method by which the location or position of any point (or a person) on the Earth can be identified using a system of 24 satellites, which are continuously orbiting, observing, monitoring and mapping the Earth's surface. Every satellite revolves around the Earth twice a day. The figure given below is a sketch of 24 GPS satellites orbiting the Earth. The GPS satellites are distributed uniformly in six orbits, with four satellites in each orbit. The orbits of the satellites are aligned in such a way that at least four of them always keep observing at any given point on the surface of the Earth. This is a necessary condition for the accurate location identification using this system.

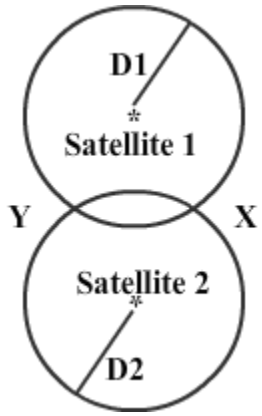
Working principle of a GPS device

To use the GPS system of satellites, one needs a GPS device fitted with a transmitter/receiver for sending/receiving signals, which are in the form of electromagnetic radio waves. Through this, the device can link up with the GPS satellites in real time.
At least, three GPS satellites measure the distance of a GPS user on the Earth to determine his/her location. On the basis of these distance measurement, the microprocessor (computing device) fitted in the GPS device can locate the GPS device.
The GPS device records the time taken by a radio signal to travel from the device to the satellites and back to the device. It also helps to measure the distance of three GPS satellites from it.
For example, the time taken by a radio signal to travel back from Satellite 1 to its GPS user is 0.120 s.

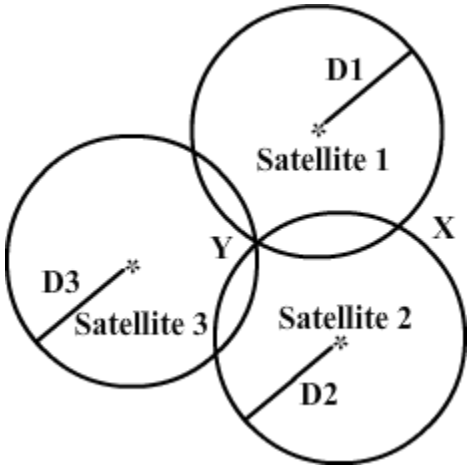
Then,
Distance of Satellite 1 from the user =Speed of light×Time2=Speed of light×Time2
=3×10$_8$ m/s×0.145 s2=21,750 km=3×108 m/s×0.145 s2=21,750 k
m

Now, let the distance of the GPS-device user from the three satellites be D_1, D_2 and D_3. The unique location of the GPS-device user can be found in the following way:
(1) If the distance of Satellite 1 from the GPS device is D_1, then the location of the user can be anywhere on the
circumference of the circle of radius D_1 from Satellite 1.

(2) If the distance of the user from Satellite 2 is D_2, then the location of the user will be at either of the intersecting points (X and Y) of the circumferences of circles of radii D_1 and D_2 from Satellites 1 and 2, respectively.



(3) If the distance of the user from Satellite 3 is D_3, then the location of the user will be at the intersecting point (Y) of the circumferences of the circles of radii D_1, D_2 and D_3 from Satellites 1, 2 and 3, respectively.



In this way, the exact location of the GPS-device user can be determined using at least three satellites together. If a person is at a height from the surface of the Earth, then the altitude of the person can be determined using the information on the distance of the person from at least four GPS satellites.

As all 24 GPS satellites orbit in predefined orbits, their locations are precisely predetermined. The known locations of 3 or 4 GPS satellites and their distance from the GPS device assist a GPS user in locating his/her location (longitude coordinates).

Applications of the GPS

The GPS has many day-to-day applications. Some of them are given below.
1. It assists visually impaired people in identifying a location.
2. It helps in tracking animals and birds and studying their movements when a GPS device is attached to their body.
3. It assists in airplane traffic movement.
4. It assists in maintaining a standard time world over.
5. It helps in determining heights of mountains and change in the position of glaciers.
6. It helps in determining the speed of any moving body.
7. It assists in designing a map of a location.
8. It helps in automatic vehicle movements.
9. It helps in navigating in air, in water and on land.

These days, devices like mobile phones, iPad, tablets, etc. are already equipped with pre-loaded geographical maps and GPS software.