Introduction to Electrical Engineering

Introduction to Communications

INTRODUCTION TO COMMUNICATIONS

Introduction

The word communication arises from the Latin word “commūnicāre”, which means “to share”. Communication is the basic step for the exchange of information. For example, a baby in a cradle, communicates with a cry that she needs her mother. A cow moos loudly when it is in danger. A person communicates with the help of a language.

Communication is the bridge to share.

Communication can be defined as the process of exchange of information through means such as words, actions, signs, etc., between two or more individuals.

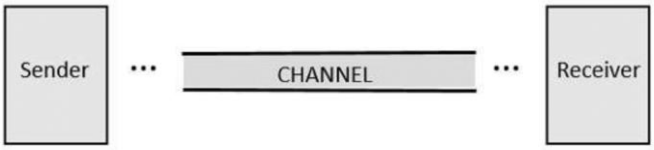
Need for Communication

For any living being, while co-existing, there occurs the necessity of exchange of some information. Whenever a need for exchange of information arises, some means of communication should exist. While the means of communication, can be anything such as gestures, signs, symbols, or a language, the need for communication is inevitable.

Language and gestures play an important role in human communication, while sounds and actions are important for animal communication. However, when some message has to be conveyed, a communication has to be established.

Parts of Communication System

Any system which provides communication, consists of the three important and basic parts as shown in the following figure.



- The Sender is the person who sends a message. It could be a transmitting station from where the signal is transmitted.
- The Channel is the medium through which the message signals travel to reach the destination.
- The Receiver is the person who receives the message. It could be a receiving station where the signal transmitted is received.

Historical Review of Communications

Due to a host of well-conceived ideas, indispensable discoveries, crucial innovations, and important inventions over the past two centuries, information transmission has evolved immeasurably. The technological advances in communications and their corresponding societal impacts are moving at an accelerating pace. To understand today’s modern communication systems, networks, and devices, and to help obtain a sense of perspective about future breakthroughs, it may be insightful to have a glance at the historical developments in the broad field of communications.

A number of people have made significant contributions to help pave the way for a multitude of technological revolutions in the arena of communications. The array of collective, and sometimes collaborative, achievements made in communications are, in essence, due to a team effort, a team whose knowledgeable, talented, and ingenious members lived at different times and in different places; however, we can only afford to mention a select few here. The nineteenth century witnessed scientists and discoverers, such as Oersted, who showed that electric currents can create magnetic fields, Faraday, who discovered that electric current can be induced in a conductor by a changing magnetic field, as well as Maxwell who developed the theory of electromagnetic waves and Hertz who experimentally verified it. Their collective contributions led to the foundation of wireless communications, more specifically, that an electric signal is transmitted by varying an electromagnetic field to induce current change in a distant device. The twentieth century brought researchers and theoreticians, such as Nyquist and Reeves, who respectively contributed to signal sampling process and pulse code modulation, as well as others, such as North, Rice, Wiener, and Kolmogorov, who made contributions to optimal signal and noise processing. Finally, it was Shannon, with his exceptional contribution to the mathematical theory of communications, who laid the unique foundation for digital transmission and today's information age. The table below highlights some of the major events in the history of telecommunications.

Some of the major events in the history of telecommunications

Year	Event
1820	Orested showed electric currents cause magnetic fields
1831	Faraday showed magnetic fields produce electric fields
1844	Morse perfected line telegraphy
1864	Maxwell developed the theory of electromagnetism
1866	First transatlantic telegraph cable became operational
1876	Bell invented telephone
1887	Hertz verified Maxwell's electromagnetic theory
1896	Marconi demonstrated wireless telegraphy
1907	First transatlantic radio telegraphy service implemented
1915	First continental telephone service (in US) deployed
1918	Armstrong devised superheterodyne radio receiver
1920	First commercial AM radio broadcasting began
1920s	Contributions on signal and noise by Nyquist, Hartley, and others
1933	Armstrong demonstrated FM radio
1936	First commercial TV broadcasting by BBC in England resumed
1937	Reeves proposed PCM
1941	NTSC black and white TV standard developed
1945	Clarke proposed geostationary satellite
1948	Shannon published the mathematical theory of communications
1948	Brattain, Bardeen, and Shockley invented transistor
1940s	Contributions on optimal filtering by Kolmogorov, Wiener, and others
1953	NTSC color TV standard developed
1953	First transatlantic telephone cable deployed
1957	First satellite (Sputnik I) launched
1960	Laser developed
1962	First dial-up (300-bps) modem developed
1962	First communication satellite (Telstar I) launched
1966	First facsimile (fax) machine developed
1969	ARPANET (precursor to Internet) developed
1970	Low-loss optic fiber developed
1971	Microprocessor invented
1976	Personal computers developed
1979	First (analog) cellular mobile telephone system (in Japan) deployed
1989	GPS developed
1992	First digital cellular mobile telephone system (in Europe) deployed
1993	HDTV standard developed
1997	Wireless LAN developed
1990s	Ubiquitous use of the Internet accelerated

The telegraph, which provides communications at a distance by coded signals, is considered as the first invention of major significance to communications. The first commercial electrical telegraph was constructed by Wheatstone and Cooke, and perfected by Morse. The telegraph was the forerunner of digital transmission in that Morse code was used to represent a variable-length binary code, where short sequences of dots (short beeps) and dashes (long beeps) represent frequent letters and long ones represent infrequent letters. In the midnineteenth century, the first permanent transatlantic telegraph cable became operational, and at the outset of the twentieth century, Marconi and others demonstrated wireless telegraphy, and the first transatlantic radio message was sent. The telegraph is hardly present today.

The telephone, which provides two-way voice communications, was invented by Bell. Like telegraphy, the telephone was first viewed as a point-to-point communication system. But shortly after, the first telephone exchange was established. With the first transcontinental telephone service in the early twentieth century and the first transatlantic telephone cable in the mid-fifties, as well as inventions of the diode, triode, transistor, digital switch, and fiber optic cables, the telephone and the telephone network steadily evolved toward what it is today. Voice communications by telephone at its inception was analog in its entirety. However, half a century later, the transmission of speech signals over the backbone networks along with the switching of the signals became digital, yet the local loop remained analog. And now, for mobile telephones, even the signal between the mobile device and the network is in digital and hence, is an all-digital network.

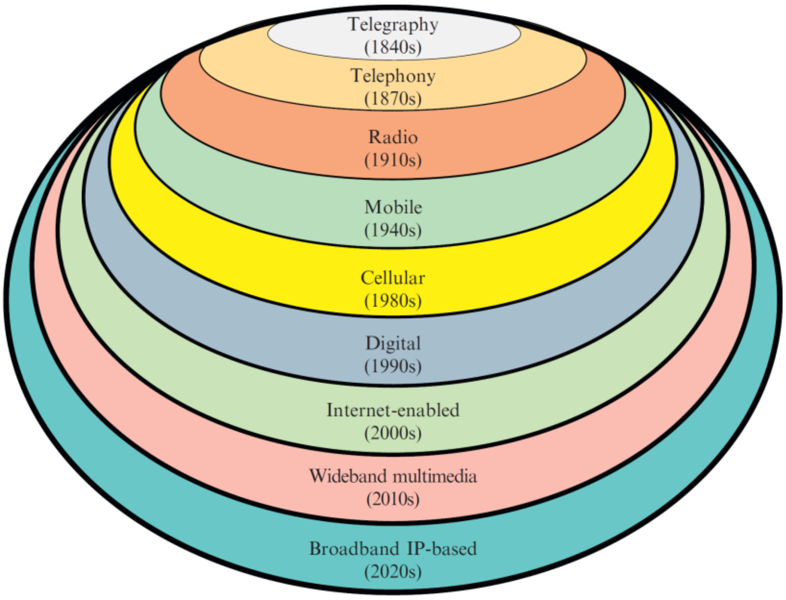
Radio broadcasting, a one-way wireless transmission of audio signals over radio waves intended to reach a wide audience, grew out of the vacuum tube and early electronics. Following the earlier work on radio, the first amplitude modulation (AM) radio broadcasting was introduced, and grew rapidly across the globe. Shortly after, Armstrong invented the superheterodyne radio receiver and the first frequency modulation (FM) system, and was the first to advocate the principle of power-bandwidth trade-off. FMradio broadcasting gained popularity in the mid-twentieth century, especially with the introduction of FM stereo.

Television is a medium that is used for transmitting and receiving video and sound. TV technology was based on the evolution of electronics that began with the invention of the vacuumtube. TV was invented in the United States in 1929, BBC began the first commercial TV broadcasting in monochrome in 1936, the NTSC color TV was introduced in 1953, and the first commercial HDTV broadcasting began in 1996. Today, there is no analog TV transmission, and TV signals are now exclusively digital.

In 1945, Clarke published his famous article to propose the idea of a geostationary satellite as a relay for communications between various points on Earth. In the late fifties, the former Soviet Union launched the first satellite, Sputnik I, and then the United States launched Explorer I. In 1962, the US launched Telstar I, the first satellite to relay TV programs across the Atlantic. Today, there are several hundreds of satellites employing various frequency bands (e.g., L-band, C-band, X-band, Ku-Band, and Ka-band) in various orbits (LEO, MEO, and GEO) to provide a multitude of services, such as radio and TV broadcasting, mobile and business communications, and GPS.

Following the earlier radio systems, the first public mobile telephone service was introduced in the mid-forties. The system had an interface with the public-switched telephone network (PSTN), the landline phone system. Each system in a city used a single, high-powered transmitter and large tower in order to cover distances of over 50 km. It began as a push-to-talk system (i.e., halfduplex mode) employing FM with 120 kHz of radio-frequency (RF) bandwidth. By the sixties, it had become a full-duplex, auto-dial system, but due to advances in RF filters and low-noise amplifiers, the FM bandwidth transmission was cut to 30 kHz. This mobile radio communication system, which lasted until the early eighties, was very spectrally inefficient, as very few in a geographical area could subscribe to it. These non-cellular mobile systems could now be referred to as 0G systems. Due to a vast level of basic research, in the fifties and sixties, companies such as AT&T and Motorola, NTT in Japan, and Ericson in Europe developed and demonstrated various cellular mobile systems in the seventies. These systems were all analog, and employed FM. In North America, the analog cellular mobile system, known as the advanced mobile phone system (AMPS), which used 30-kHz channels to employ frequency-division multiple access (FDMA), was deployed in 1983. The analog cellular mobile systems are referred to as 1G systems. Due to the lack of mobile roaming capability across Europe and the severe shortage of system capacity in North America, the need for digital cellular mobile systems was born. In North America, IS-54, which was based on a three-slot time-division multiple access (TDMA) scheme using a 30-kHz channel, and IS-95, which was based on many users employing a 1.25 MHz-channel using code-division multiple access (CDMA) scheme, were introduced. In Europe, the GSM, through which eight users employ a 200-kHz TDMA channel, was developed, and became the most widely-used mobile system in the world. Digital cellular mobile systems, such as the IS-54, IS-95, GSM, and some others, introduced in the nineties, are referred to as 2G systems. After that, 3G systems, which provided data transmission at high rates in addition to voice transmission, began to emerge. The figure below presents the trends in mobile communications.

The Internet, composed of thousands interconnected networks, is a classic example of an innovation that originated in many different places. To connect computers with their bursty traffic, the sixties witnessed the birth of packet-switched networks and the development of the Advanced Research Projects Agency Network (ARPANET). After Vint Cerf and Bob Kahn, known as the Internet pioneers, devised the protocols to achieve end-to-end delivery of computer data in the midseventies, the transmission control protocol and Internet protocol (TCP/IP) became the official protocol for the ARPANET, and ARPANET was renamed the Internet in the mid-eighties. In the early nineties, a hypermedia software interface to the Internet, named the World Wide Web (WWW), was proposed by Tim Berners-Lee. This was the turning point that resulted in the explosive growth of the Internet and yielded numerous commercial applications for the Internet. The Internet has evolved at a faster rate and become more widely-used than any other innovation, invention, or technology in the history of telecommunications. The set of cultural, educational, political, and financial impacts of the Internet on our way of lives is and will remain unparalleled for many years to come.



Signals and Modulation

What is a Signal?

Conveying an information by some means such as gestures, sounds, actions, etc., can be termed as signaling. Hence, a signal can be a source of energy which transmits some information. This signal helps to establish communication between a sender and a receiver.

An electrical impulse or an electromagnetic wave which travels a distance to convey a message, can be termed as a signal in communication systems. Depending on their characteristics, signals are mainly classified into two types: Analog and Digital.

Analog Signal

A continuous time varying signal, which represents a time varying quantity can be termed as an Analog Signal. This signal keeps on varying with respect to time, according to the instantaneous values of the quantity, which represents it.

Example

Let us consider, a tap that fills a tank of 100 liters capacity in an hour (6 am to 7 am). The portion of filling the tank is varied by the varying time. Which means, after 15 mins (6:15 am) the quarter portion of the tank gets filled, whereas at 6:45 am, 3/4th of the tank is filled. The portion of water in the tank varies (increases) according to time, this time varying quantity can be understood as Analog quantity. The signal which represents this condition is an Analog Signal. The communication based on analog signals and analog values is called as Analog Communication.

Digital Signal

A signal which is discrete in nature or which is non-continuous in form can be termed as a Digital signal. This signal has individual values, denoted separately, which are not based on the previous values, as if they are derived at that particular instant of time.

Example

Let us consider a classroom having 20 students. If their attendance in a week is plotted, it would look like the following figure. In this figure, the values are separately stated. For instance, the attendance of the class on Wednesday is 20 whereas on Saturday is 15. These values can be considered individually and separately or discretely, hence they are called as discrete values. The binary digits which has only 1s and 0s are mostly termed as digital values. Hence, the signals which represent 1s and 0s are also called as digital signals. The communication based on digital signals and digital values is called as Digital Communication.

Modulation

A signal can be anything like a sound wave which comes out when you shout. This shout can be heard only up to a certain distance. But for the same wave to travel over a long distance, you'll need a technique which adds strength to this signal, without disturbing the parameters of the original signal.

What is Signal Modulation?

A message carrying signal has to get transmitted over a distance and for it to establish a reliable communication, it needs to take the help of a high frequency signal which should not affect the original characteristics of the message signal.

The characteristics of the message signal, if changed, the message contained in it also alters. Hence it is a must to take care of the message signal. A high frequency signal can travel up to a longer distance, without getting affected by external disturbances. We take the help of such high frequency signal which is called as a carrier signal to transmit our message signal. Such a process is simply called as Modulation. Modulation is the process of changing the parameters of the carrier signal, in accordance with the instantaneous values of the modulating signal.

Need for Modulation

The baseband signals are incompatible for direct transmission. For such a signal, to travel longer distances, its strength has to be increased by modulating with a high frequency carrier wave, which doesn't affect the parameters of the modulating signal.

Advantages of Modulation

The antenna used for transmission, had to be very large, if modulation was not introduced. The range of communication gets limited as the wave cannot travel to a distance without getting distorted. Following are some of the advantages for implementing modulation in the communication systems.

- Antenna size gets reduced.
- No signal mixing occurs.
- Communication range increases.
- Multiplexing of signals occur.
- Adjustments in the bandwidth is allowed.
- Reception quality improves.

Signals in the Modulation Process

Following are the three types of signals in the modulation process.

- **Message or Modulating Signal**

  The signal which contains a message to be transmitted, is called as a message signal. It is a baseband signal, which has to undergo the process of modulation, to get transmitted. Hence, it is also called as the modulating signal.

- **Carrier Signal**

  The high frequency signal which has a certain phase, frequency, and amplitude but contains no information, is called a carrier signal. It is an empty signal. It is just used to carry the signal to the receiver after modulation.

- **Modulated Signal**

  The resultant signal after the process of modulation, is called as the modulated signal. This signal is a combination of the modulating signal and the carrier signal.

Types of Modulation

There are many types of modulations. They are classified depending upon the modulation techniques used. The types of modulations are broadly classified into continuous-wave modulation and pulse modulation.

- **Continuous-wave Modulation**

  In the continuous-wave modulation, a high frequency sine wave is used as a carrier wave. This is further divided into amplitude and angle modulation.

  - If the amplitude of the high frequency carrier wave is varied in accordance with the instantaneous amplitude of the modulating signal, then such a technique is called as Amplitude Modulation.
  - If the angle of the carrier wave is varied, in accordance with the instantaneous value of the modulating signal, then such a technique is called as Angle Modulation. The angle modulation is further divided into frequency and phase modulation.
    - If the frequency of the carrier wave is varied, in accordance with the instantaneous value of the modulating signal, then such a technique is called as Frequency Modulation.
    - If the phase of the high frequency carrier wave is varied in accordance with the instantaneous value of the modulating signal, then such a technique is called as Phase Modulation.

- **Pulse Modulation**

  In Pulse modulation, a periodic sequence of rectangular pulses, is used as a carrier wave. This is further divided into analog and digital modulation. In analog modulation technique, if the amplitude, duration or position of a pulse is varied in accordance with the instantaneous values of the baseband modulating signal, then such a technique is called as Pulse Amplitude Modulation (PAM) or Pulse Duration/Width Modulation (PDM/PWM), or Pulse Position Modulation (PPM).

  In digital modulation, the modulation technique used is Pulse Code Modulation (PCM) where the analog signal is converted into digital form of 1s and 0s. As the resultant is a coded pulse train, this is called as PCM. This is further developed as Delta Modulation (DM), which will be discussed in subsequent chapters. Hence, PCM is a technique where the analog signals are converted into a digital form.

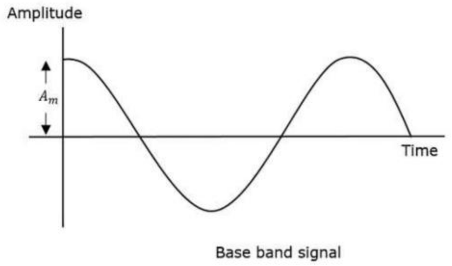
Continuous-wave Modulation

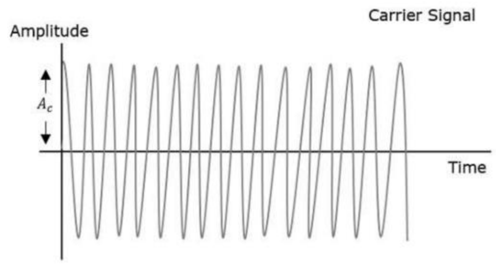
Among the types of modulation techniques, the main classification is Continuous-wave Modulation and Pulse Modulation. The continuous wave modulation techniques are further divided into Amplitude Modulation and Angle Modulation.

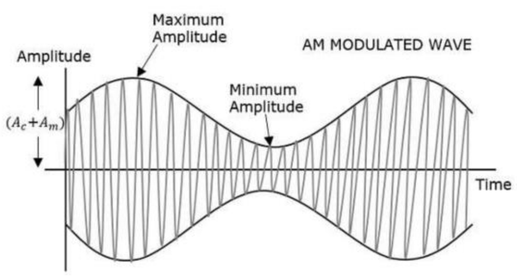
Amplitude Modulation

A continuous-wave goes on continuously without any intervals and it is the baseband message signal, which contains the information. This wave has to be modulated. According to the standard definition, “The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.” Which means, the amplitude of the carrier signal which contains no information varies as per the amplitude of the signal, at each instant, which contains information. This can be well explained by the following figures.

The modulating wave which is shown first is the message signal. The next one is the carrier wave, which is just a high frequency signal and contains no information. While the last one is the resultant modulated wave. It can be observed that the positive and negative peaks of the carrier wave, are interconnected with an imaginary line. This line helps recreating the exact shape of the modulating signal. This imaginary line on the carrier wave is called as Envelope. It is the same as the message signal.







Angle Modulation

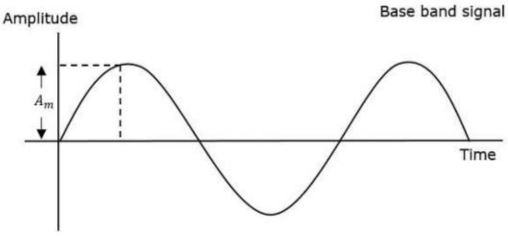
The other type of modulation in continuous-wave modulation is the Angle Modulation. Angle Modulation is the process in which the frequency or the phase of the carrier varies according to the message signal. This is further divided into frequency and phase modulation.

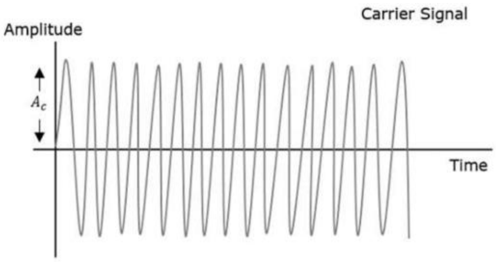
- Frequency Modulation is the process of varying the frequency of the carrier signal linearly with the message signal.
- Phase Modulation is the process of varying the phase of the carrier signal linearly with the message signal.

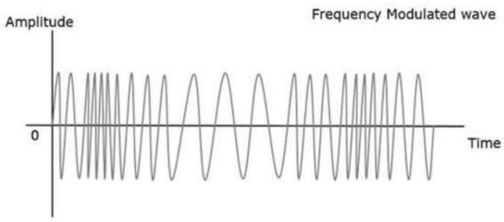
Frequency Modulation

In amplitude modulation, the amplitude of the carrier varies. But in Frequency Modulation (FM), the frequency of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal. The amplitude and the phase of the carrier signal remains constant whereas the frequency of the carrier changes. This can be better understood by observing the following figures.

The frequency of the modulated wave remains constant as the carrier wave frequency when the message signal is at zero. The frequency increases when the message signal reaches its maximum amplitude. Which means, with the increase in amplitude of the modulating or message signal, the carrier frequency increases. Likewise, with the decrease in the amplitude of the modulating signal, the frequency also decreases.







Multiplexing

Multiplexing is the process of combining multiple signals into one signal, over a shared medium.

- The process is called as analog multiplexing if these signals are analog in nature.
- If digital signals are multiplexed, it is called as digital multiplexing.

Multiplexing was first developed in telephony. A number of signals were combined to send through a single cable. The process of multiplexing divides a communication channel into several number of logical channels, allotting each one for a different message signal or a data stream to be transferred. The device that does multiplexing, can be called as a MUX. The reverse process, i.e., extracting the number of channels from one, which is done at the receiver is called as demultiplexing. The device which does demultiplexing is called as DEMUX.

The following figure illustrates the concept of MUX and DEMUX. Their primary use is in the field of communications.

Analog Multiplexing

The analog multiplexing techniques involve signals which are analog in nature. The analog signals are multiplexed according to their frequency (FDM) or wavelength (WDM).

Frequency Division Multiplexing

In analog multiplexing, the most used technique is Frequency Division Multiplexing (FDM). This technique uses various frequencies to combine streams of data, for sending them on a communication medium, as a single signal.

Example: A traditional television transmitter, which sends a number of channels through a single cable uses FDM.

Wavelength Division Multiplexing

Wavelength Division multiplexing (WDM) is an analog technique, in which many data streams of different wavelengths are transmitted in the light spectrum. If the wavelength increases, the frequency of the signal decreases. A prism which can turn different wavelengths into a single line, can be used at the output of MUX and input of DEMUX.

Example: Optical fiber Communications use the WDM technique, to merge different wavelengths into a single light for the communication.

Digital Multiplexing

The term digital represents the discrete bits of information. Hence, the available data is in the form of frames or packets, which are discrete.

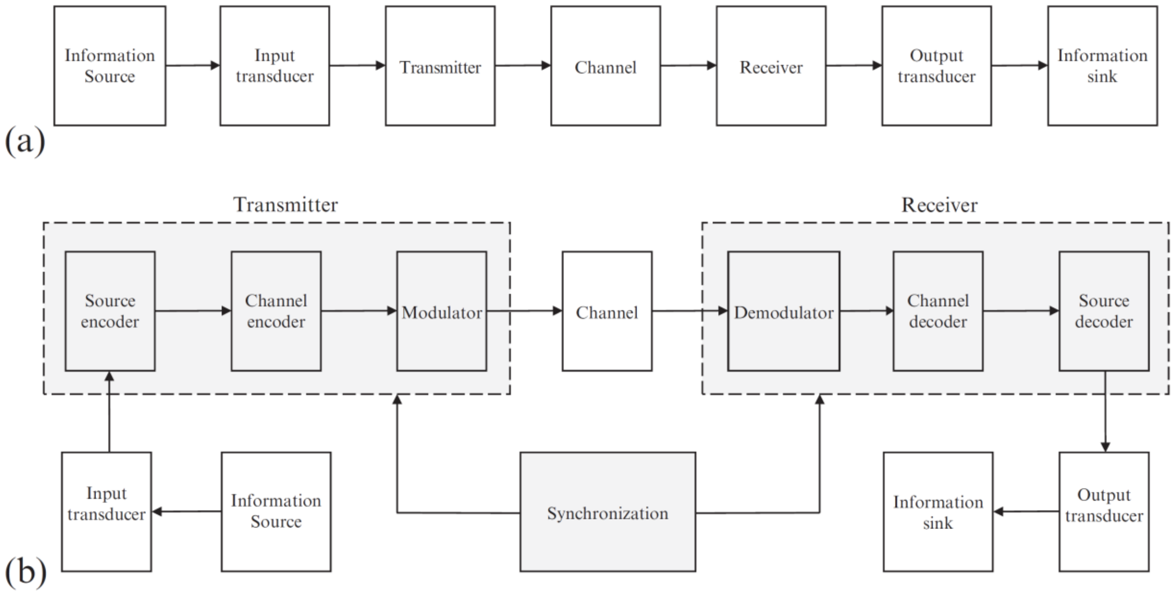
Time Division Multiplexing (TDM)

In TDM, the time frame is divided into slots. This technique is used to transmit a signal over a single communication channel, by allotting one slot for each message. Of all the types of TDM, the main ones are Synchronous and Asynchronous TDM.

- Synchronous TDM: In Synchronous TDM, the input is connected to a frame. If there are ‘n’ number of connections, then the frame is divided into ‘n’ time slots. One slot is allocated for each input line. In this technique, the sampling rate is common for all signals and hence the same clock input is given. The MUX allocates the same slot to each device at all times.
- Asynchronous TDM: In Asynchronous TDM, the sampling rate is different for each of the signals and a common clock is not required. If the allotted device, for a time slot transmits nothing and sits idle, then that slot is allotted to another device, unlike synchronous. This type of TDM is used in Asynchronous transfer mode networks.

Digital Communications

Part (a) of the figure below shows the basic functional blocks of a typical communication system. Regardless of the particular application and configuration, all information transmission systems involve three major subsystems: the transmitter, the channel, and the receiver.



The information source produces its output, which is in probabilistic form, as there is no need to convey deterministic source outputs. An input transducer, such as a microphone, converts the source output into a time-varying electrical signal, referred to as the message signal. The transmitter then converts the message signal into a form suitable for transmission through a physical channel, such as a cable. The transmitter generally changes the characteristics of the message signal to match the characteristics of the channel by using a process called modulation. In addition to modulation, other functions, such as filtering and amplification, are also performed by the transmitter.

The communication channel is the physical medium between the transmitter and the receiver, where they are physically separated. No communication channel is ideal, and thus a message signal undergoes various forms of degradation. Sources of degradation may include attenuation, noise, distortion, and interference. As some or all of these degradations are present in a physical channel, a paramount goal in the design of a communication system is to overcome the effects of such impairments.

The function of the receiver is to extract the message signal from the received signal. The primary function is to perform the process of demodulation, along with a number of peripheral functions, such as amplification and filtering. The complexity of a receiver is generally more significant than that of the transmitter, as a receiver must additionally minimize the effects of the channel degradations. The output transducer, such as a loudspeaker, then converts the receiver output into a signal suitable for the information sink.

Part (b) of the figure shows the basic functional elements of a digital communication system. In a simple, yet classical fashion, the transmitter or the receiver each is subdivided into three blocks. The transmitter consists of the source encoder, channel encoder, and modulator, and the receiver consists of the demodulator, channel decoder, and source decoder. At the receiver, the received signal passes through the inverse of the operations at the transmitter, while minimizing the effects of the channel impairments. The three functions of source coding, channel coding, and modulation may be designed in concert with one another to better meet the system design goals, yet accommodating the overall system design constraints.

The information may be inherently digital, such as computer data, or analog, such as voice. If the information is in analog form, then the source encoder at the transmitter must first perform analog-to-digital conversion to produce a binary stream, and the source decoder must then perform digital-to-analog conversion to recover the analog signal. The source encoder removes redundant information from the binary stream so as to make efficient use of the channel.

Source coding, also known as data compression, leads to bandwidth conservation, as the spectrum is always at a premium. The important parameters associated with source coding are primarily the efficiency of the coder (i.e., the ratio of actual output data rate to the source information rate) and the encoder/decoder complexity.

The channel encoder at the transmitter introduces, in a controlled fashion, redundancy. The additional bits are used by the channel decoder at the receiver to overcome the channel-induced errors. The added redundancy serves to enhance the performance by reducing the bit error rate, which is the ultimate performance measure in a digital communication system. The important parameters associated with channel coding are primarily the efficiency of the coder (i.e., the ratio of data rate at the input of the encoder to the data rate at its output), error control capability, and the encoder/decoder complexity.

The modulator at the transmitter and the demodulator at the receiver serve as the interface to the communication channel. The modulator accepts a sequence of bits, and maps each sequence into a waveform. A sequence may consist of only one or several bits. At the receiver, the demodulator processes the received waveforms, and maps each to the corresponding bit sequence. The important parameters of modulation are the number of bits in a sequence represented by a waveform, the types of waveforms used, the duration of the waveforms, the power level and the bandwidth used, as well as the demodulation complexity.

There are, of course, other functional blocks, not shown in the figure, that are required in a practical digital communication system. They may include synchronization, an essential requirement for all digital commination systems, as well equalization, amplification, and filtering, to name a few.

Transmission Media

When we speak of transmission media, we usually mean a mix of physical lines ranging from wire pairs to cable, and over the air transmission media, such as microwave and satellites.

The transmission media used in telecommunications networks vary both physically and in their carrying capacity. The "commonly used performance measurement of a telecommunications link is its bandwidth. This gives an indication of the range of frequencies which can be transmitted by these channels. The greater the bandwidth, the greater the rate at which data can be transmitted.

The channels or media can be grouped into two main divisions, i.e., line and' free space. In the line group, we have two metallic media, twisted pairs and coaxial cables and one optical medium - glass or optical fibres. In the free space category, we have radio propagation which includes broadcast (e.g., TV) and point to point (e.g., microwave signals). Let us discuss these in a greater detail.

Twisted Pairs

Twisted pairs are familiar to all of us as the copper wire telephone lines. These are of low frequency, and support a limited bandwidth (one voice channel) but can also be used for data communication at the lower speeds of 300bps. For higher speed or rates of data transfer, 4-wire leased lines may be used. The problems associated with this kind of transmission are: noise on the line, parity errors and so on. Twisted pairs are used for conventional voice telephone and telex services.

Coaxial Cables

Another metallic transmission medium which offers a large bandwidth, is the coaxial cable. Such cables consist of an outer protective shell made of copper tube, less than one inch in diameter, which actually carries messages. There are two types of coaxial cables- the base band and the broad band. Base band cables use digital transmission and are suitable for fairly short distances. These have a data rate of about 50 Mb/s in half-duplex mode. Broad band coaxial cable on the other hand, is more familiar as CATV and is suitable for long distance (up to 15 KM) transmission. It can support data rates of over 100 Mb/s. Coaxial cables, with their better electrical properties, can transmit at much higher frequencies and support wider bandwidth than the twisted pairs. They are suitable, therefore, for high quality bulk transmission of data at high speeds as well as text, picture and voice. For example, one such cable can support the equivalent of up to 10800 telephone (voice) channels.

Optical Fibres

Coaxial cables have limitations such as broadband transmission medium which can be overcome by the use of optical fibres. Optical fibres carry light waves (representing electrical impales) by the principle of internal reflection. These fibres carry signals in the form of light, and hence can carry large volumes of data at high speed, and are resistant to interference. Thus, they are `clearer' lines with less noise. Though they were expensive when first introduced, but nowadays costs hive fallen to such a level that they are being used by some organisations for their local area networks.

Microwave Transmission

Using space as transmission medium, microwave emanates from an origination point on earth, such as telephone exchange, where many individual messages have been concentrated. Because the microwave beam travels in a straight line, it is advantageous to place microwave towers on hills or mountains to minimise interference from land mass. Usually, towers are placed between 25 to 30 miles apart to remain in sight of each other (`line-of-sight'). Microwave transmission can carry 600 to 1800 voice channels. Advantages of microwave transmission include lower cost than coaxial cable, where right-of-way must be obtained and higher costs are incurred when the physical cable is laid over long distances. As with other systems that transmit through free space the signals are subject to fading caused by absorption and scattering from moisture and precipitation in the air. In other words, atmospheric interference is greater and rain can cause. severe transmission problems.

The great advantage is that the microwave transmission is a broad band facility able to carry several thousand channels. It is suitable for bulk transmission data over long distances.

Satellite Transmission

Satellites use microwave frequencies and techniques. Satellites used for message transmission (as opposed to those, which travel around the earth on strategic and meteorological missions) remain in constant position in relation to a fixed location on earth; they are said to be in a geostationaty orbit. This position allows the satellite to of data over a long distance.

Used extensively for general telecommunications, as well as for television, satellites were originally contemplated only for long distance transworld links but are now increasingly employed for high speed; high volume transfer for example document delivery, electronic publishing. In some countries like India, satellites are used instead of underground cables because of the high cost of installing the latter.

Choice of Medium

All the transmission channels discussed in the foregoing paragraphs can be used as point to point connections or as broadcast systems. Transmitting information electronically or photonically is considered in two aspects - telecommunications and broadcasting. The former is a direct interchange of information within limited groups of talkers and listeners (which may be terminals of computers as well as people). Thus, there is a certain amount of interaction. Broadcasting is the mass distribution of information to large markets with one `speaker' and many "listeners' and no real interaction.

Because of the increasing linking up of the two forms with computers, the traditional distinction is being blurred and now you get systems like electronic mail, which can either he broadcast of telecommunication and cable TV broadcasting systems which carry telecommunications. And any given transmission circuit could be made up of a mixture of terrestial microwaves, cable and satellite links. Thus, a given service could be transmitted over more than one of channel. For example, a television program can be broadcast let us say normally - as you get it at home via satellite or via broadband coaxial cable using radio frequency.

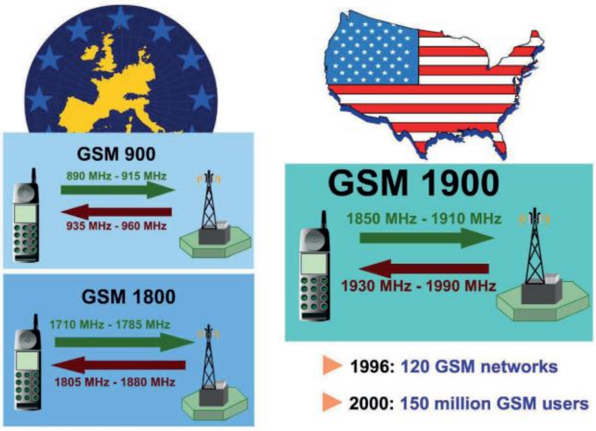
The decision on which medium to use is determined by factors such as the distance involved, the area to be covered and the type of information to be sent. For example, terrestial microwave radio transmission requires line-of-sight communication and for long distances repeaters must be added. If the medium has to accommodate video or high speed data then a broad bandwidth such as is provided by satellite and coaxial, fibre optical cables will be required.

Mobile Communications

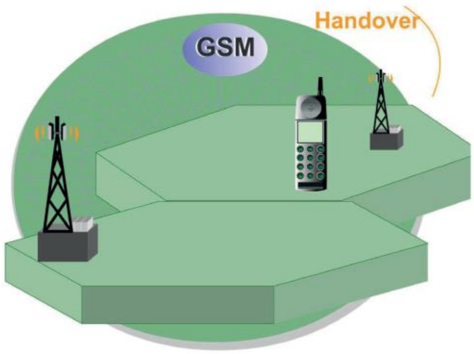
By 1979 several mobile radio networks already existed worldwide. They operated on different frequency bands and were based on different standards. A mobile phone user in Britain could not use his mobile phone in Sweden, because the British and the Swedish mobile radio networks were each based on their own standards, with different signaling protocols, and were incompatible with each other.

In view of the European unification process, it became clear that mobile telephony, too, had to overcome national borders. A new European standard was due. For this purpose, the Conférence Européenne des Administrations des Postes et des Télécommunications established a workgroup, whose task was to work out specifications for a standard Western European mobile system. This was the Groupe Spécial Mobile, GSM, after which the new standard - the Global System for Mobile Communications - was named.

In 1988, the European Telecommunications Standards Institute (ETSI) was founded. Its task was to work out the GSM standard for a digital radio telephone network. In the GSM 900 standard, a frequency range between 890 and 915 MHz was assigned to the uplink, and a range between 935 and 960 MHz was assigned to the downlink. In GSM 1800, the frequency ranges 1710 - 1785 MHz were added in the uplink and 1805 -1880 MHz in the downlink. In 1995, GSM 1900, with its own frequency range from 1850 to 1910 MHz in the uplink and 1930 to 1990 MHz in the downlink, was implemented in America. At the end of 1996, there were already 120 GSM networks in operation, and within the year 2000 there were already 150 million GSM users all over the world.

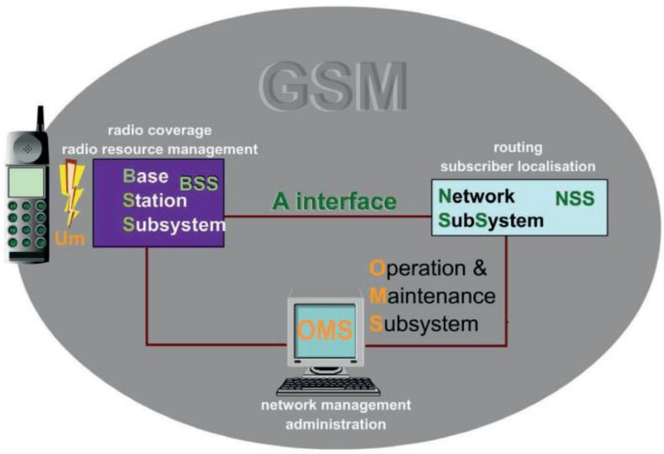


The cellular structure in GSM provides an almost complete radio coverage. The system allows a maximum distance of 35 kilometers between the mobile station and the base station. Therefore, the geographical area where GSM is used must be subdivided into smaller areas, which are known as cells. The cell size must be adjusted to the subscriber density and to the environment. If a subscriber moves from one cell to another during a call, the connection is handed over from the old radio station to the new radio station, without any interruptions. This procedure is called « handover ».



GSM distinguishes different channels on the basis of their frequency. Each cell is assigned one or more frequencies, which it uses to serve active subscribers. An uplink/downlink frequency pair can be used by up to 8 mobile stations practically simultaneously. This is done with the help of the Time Division Multiple Access (TDMA). Since there is only a limited amount of available traffic channels, high subscriber numbers require that the frequencies be used several times. This is not an insoluble problem, since several cells can use the same frequency, provided that the distance between the cells is sufficient. But it sometimes makes network planning a very complex task. Thus GSM offers capacity for more subscribers than one would expect in view of the very limited supply of frequency resources.

To guarantee flexibility, open interfaces are specified in GSM between particular network elements. This way, network operators can be supplied by different producers. Nevertheless, the interfaces functionality is very well specified, to guarantee a smooth data transmission. In GSM, there are two truly open interfaces. The first one is the air interface, located between the mobile and the base station. The other one is the A-interface between the Base Station Subsystem (BSS) and the Network Subsystem (NSS). The GSM network structure is decentralized, and consists of three separate subsystems communicating with each other over a series of interfaces. Apart from the Network Subsystem for routing, and subscriber localisation, and the Base Station Subsystem (BSS) for radio coverage and radio resource management, there is also the Operation & Maintenance Subsystem (OMS), which guarantees network management and administration.



GSM has been designed, above all, for speech communication. Although the standard also offers data services, their possibilities are limited by a data rate of 9.6 kbps. To meet the growing demands of increasingly complex data applications, e.g. in the multimedia or Internet sector, higher data rates are necessary. Therefore, the system›s capacity is constantly being enhanced.

Fourth Generation (4G) networks are IP-based (Internet protocol), meaning that it uses a standard communications protocol to send and receive data in packets. 4G offers speeds that are about 10 times faster than they are on current third-generation, or 3G, networks. Its higher data speeds could make smartphones much more comparable to PCs, giving them better multimedia and gaming capabilities.

4G technologies fork into two broad camps: LTE and WiMax. WiMax has its roots in the wireless broadband access industry while the LTE standard has been created by a consortium of mobile companies. Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals, based on the GSM and UMTS technologies. It increases the capacity and speed using a different radio interface together with core network improvements. WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless broadband communication standards based on the IEEE 802.16 set of standards, which provide multiple physical layer (PHY) and Media Access Control (MAC) options. WiMax requires a new network to be built whereas LTE is an evolution of existing CDMA/HSPA networks. WiMax can offer peak download data speeds of up to 6 Mbps and up to 1 Mbps for uploading data. LTE says it can do much better. It has peak download speeds of 100 Mbps and can support uploads at the rate of up to 50 Mbps. But remember, these are theoretical speeds. Add a million devices on the network, downloading YouTube clips, video chatting, streaming movies and uploading parodies of the latest Lady Gaga release, and those speeds will drop.