

Course Material

Description	Page No.
CONCEPTS OF COMMUNICATION	
Analog and digital communication	1-14
Wired and wireless communications including mobile communication and latest technology	15-22
Basics of TDMA, FDMA, CDMA and GSM	23-27
Concept of 2G, 3G & other latest communication systems	28-31
OPTICAL FIBER COMMUNICATION	
Overview of optical communications	32-32
Optical fibers and its types and properties	32-35
Signal degradation	36-36
International standards	36-37
The advantages and disadvantages of optical fiber communication over copper wire communication	37-39

ANALOG AND DIGITAL COMMUNICATION

Analog communication

Analog communication is a communication method of conveying voice, data, image, signal or video information using a continuous signal which varies in amplitude, phase, or some other property in proportion to that of a variable. It could be the transfer of an analog source signal using an analog modulation method such as FM or AM, or no modulation at all.

Analog transmission is still very popular, in particular for shorter distances, due to significantly lower costs and complex multiplexing and timing equipment is unnecessary, and in small "short-haul" systems that simply do not need multiplexed digital transmission.

However, in situations where a signal often has high signal-to-noise ratio and cannot achieve source linearity, or in long distance, high output systems, analog is unattractive due to attenuation problems. Furthermore, as digital techniques continue to be refined, analog systems are increasingly becoming legacy equipment.

Digital communication

Digital communications is the physical transfer of data (a digital bit stream) over a point-to-point or point-to-multipoint transmission medium. Examples of such media are copper wires, optical fibers, wireless communication media, and storage media. The data is often represented as an electro-magnetic signal, such as an electrical voltage signal or an infra-red signal.

Digital communication enables the data to be transmitted in an efficient manner through the use of digitally encoded information sent through data signals. These data signals are easily compressed and, as such, can be transmitted with accuracy and speed. Unlike in an analog communications where the continuity of a varying signal cannot be broken, in a digital communication a digital transmission can be broken down into packets as discrete messages. Transmitting data in discrete messages not only facilitates the error detection and correction but also enables a greater signal processing capability.

The information source generates particular symbols at a particular rate. The source encoder translates these symbols in sequences of 0's and 1's. The channel encoder is oriented towards translating sequences of 0's and 1's to other sequences of 0's and 1's, to realize high transmission reliability and efficiency. The modulator accepts streams of 0's and 1's, and converts them to electrical waveforms suitable for transmission. The communication channel provides the electrical connection between the source and destination. The

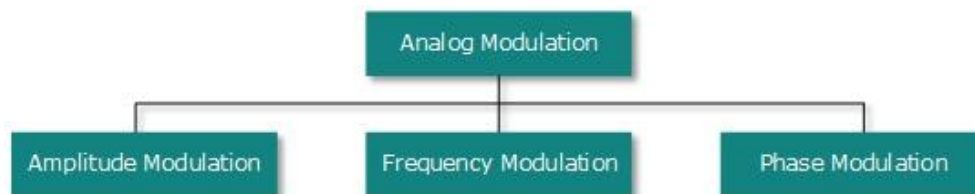
inverse process takes place at the destination side. The demodulator converts the electrical waveforms to sequences of 0's and 1's, the channel decoder translates the sequence of 0's and 1's to the original sequence of 0's and 1's. It also performs error correction and clock recovery. The source decoder finally translates the sequence of 0's and 1's into symbols.

Modulation

Modulation is the process of varying one or more properties of a periodic waveform, called the *carrier signal*, with a modulating signal that typically contains information to be transmitted. The aim of **analog modulation** is to transfer an analog baseband (or lowpass) signal, for example an audio signal or TV signal, over an analog bandpass channel at a different frequency, for example over a limited radio frequency band or a cable TV network channel. The aim of **digital modulation** is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where a bandpass filter limits the frequency range to 300–3400 Hz), or over a limited radio frequency band. The aim of **digital baseband modulation** methods, also known as line coding, is to transfer a digital bit stream over a baseband channel, typically a non-filtered copper wire such as a serial bus or a wired local area network. The aim of **pulse modulation** methods is to transfer a narrowband analog signal, for example a phone call over a wideband baseband channel or, in some of the schemes, as a bit stream over another digital transmission system.

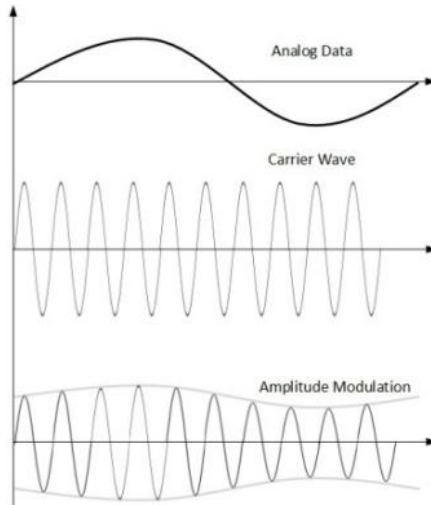
Analog modulation methods

In analog modulation, the modulation is applied continuously in response to the analog information signal. Analog modulation can be done in three ways:



- **Amplitude Modulation**

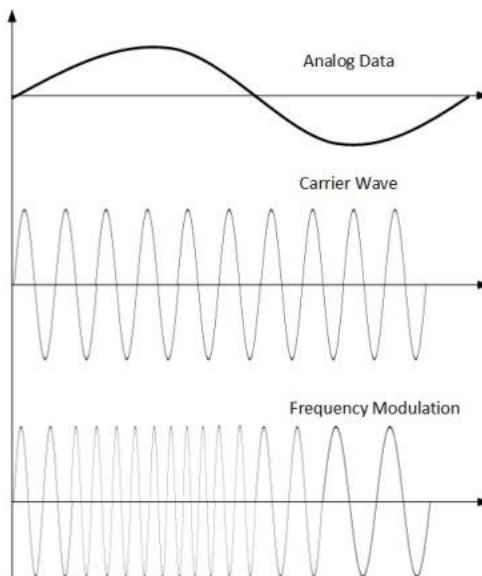
In this modulation, the amplitude of the carrier signal is modified to reflect the analog data. In other words, the amplitude of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal.



Amplitude modulation is implemented by means of a multiplier. The amplitude of modulating signal (analog data) is multiplied by the amplitude of carrier frequency, which then reflects analog data. The frequency and phase of carrier signal remain unchanged.

- **Frequency Modulation**

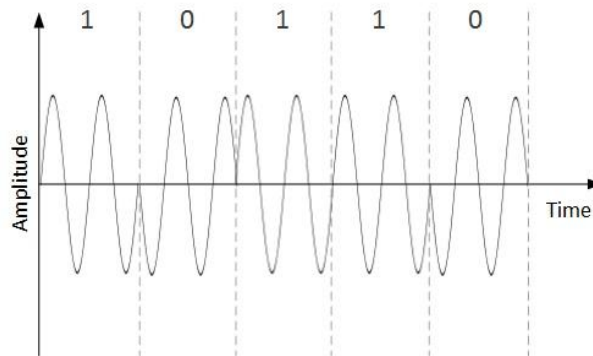
In this modulation technique, the frequency of the carrier signal is modified to reflect the change in the voltage levels of the modulating signal (analog data). In other words, the frequency of the carrier signal is varied in accordance to the instantaneous amplitude of the modulating signal



The amplitude and phase of the carrier signal are not altered.

- **Phase Modulation**

In the modulation technique, the phase of carrier signal is modulated in order to reflect the change in voltage (amplitude) of analog data signal. In other word, the phase shift of the carrier signal is varied in accordance with the instantaneous amplitude of the modulating signal)

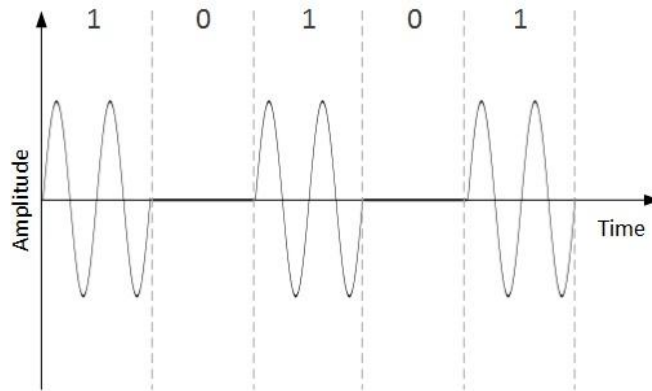


Phase modulation is practically similar to Frequency Modulation, but in Phase modulation frequency of the carrier signal is not increased. Frequency of carrier is signal is changed (made dense and sparse) to reflect voltage change in the amplitude of modulating signal.

Digital modulation methods

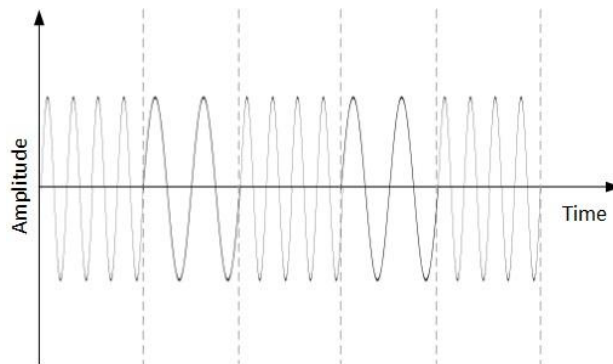
In digital modulation, an analog carrier signal is modulated by a discrete signal. Digital modulation methods can be considered as digital-to-analog conversion, and the corresponding demodulation or detection as analog-to-digital conversion. There are three major classes of digital modulation techniques used for transmission of digitally represented data:

- ASK (amplitude-shift keying): a finite number of amplitudes are used.
 - FSK (frequency-shift keying): a finite number of frequencies are used.
 - PSK (phase-shift keying): a finite number of phases are used.
- **Amplitude Shift Keying (ASK):** In this conversion technique, the amplitude of analog carrier signal is modified to reflect binary data. It is a form of amplitude modulation that represents digital data as variations in the amplitude of a carrier wave. If the signal value is 1 then the carrier signal will be transmitted; otherwise, a signal value of 0 will be transmitted. ASK uses a finite number of amplitudes, each assigned a unique pattern of binary digits. Usually, each amplitude encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular amplitude.



When binary data represents digit 1, the amplitude is held; otherwise it is set to 0. Both frequency and phase remain same as in the original carrier signal.

- **Frequency Shift Keying (FSK):** In this conversion technique, the frequency of the analog carrier signal is modified to reflect binary data. It is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The time domain of an FSK modulated carrier is illustrated in the figures to the right.

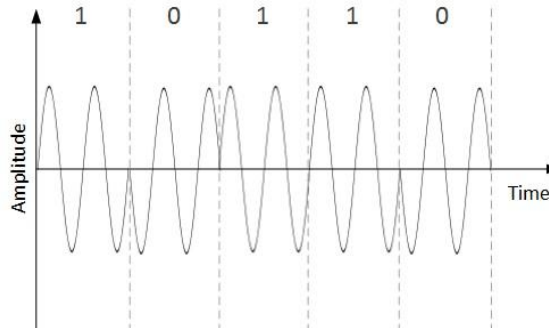


This technique uses two frequencies, f_1 and f_2 . One of them, for example f_1 , is chosen to represent binary digit 1 and the other one is used to represent binary digit 0. Both amplitude and phase of the carrier wave are kept intact.

- **Phase Shift Keying**

In this conversion scheme, the phase of the original carrier signal is altered to reflect the binary data. **Phase-shift keying (PSK)** is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). PSK uses a finite number

of phases; each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase.



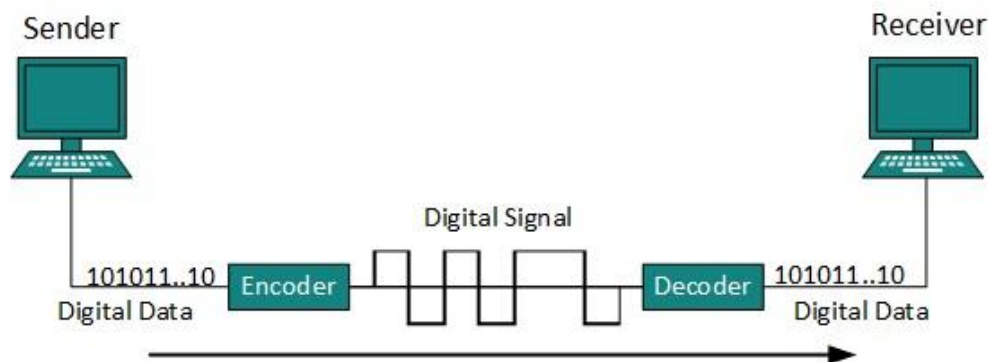
When a new binary symbol is encountered, the phase of the signal is altered. Amplitude and frequency of the original carrier signal is kept intact.

Digital baseband modulation or line coding

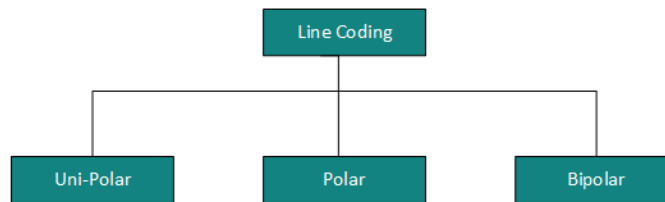
The term **digital baseband modulation** (or digital baseband transmission) is synonymous to line codes. These are methods to transfer a digital bit stream over an analog baseband channel (i.e. lowpass channel) using a pulse train, i.e. a discrete number of signal levels, by directly modulating the voltage or current on a cable. Common examples are unipolar, non-return-to-zero (NRZ), Manchester and alternate mark inversion (AMI) codings.

Line Coding

The process for converting digital data into digital signal is said to be Line Coding. Digital data is found in binary format. It is represented (stored) internally as series of 1s and 0s.

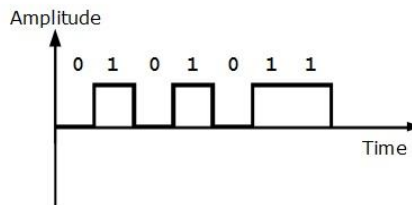


Digital signal is denoted by discrete signal, which represents digital data. There are three types of line coding schemes available:



Uni-polar Encoding

Unipolar encoding schemes use single voltage level to represent data. In this case, to represent binary 1, high voltage is transmitted and to represent 0, no voltage is transmitted. It is also called Unipolar-Non-return-to-zero, because there is no rest condition i.e. it either represents 1 or 0.

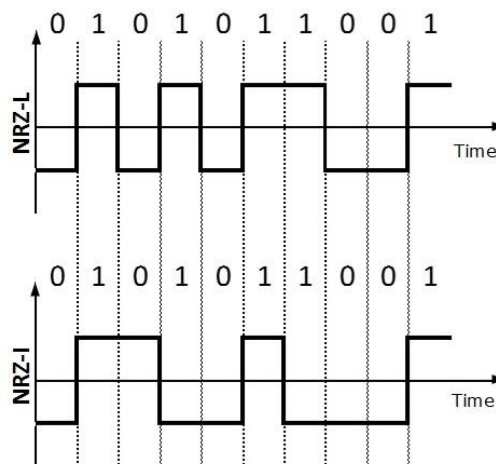


Polar Encoding

Polar encoding scheme uses multiple voltage levels to represent binary values. Polar encodings is available in four types:

- **Polar Non-Return to Zero (Polar NRZ)**

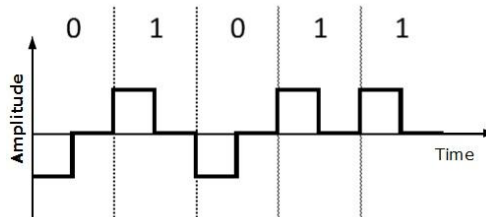
It uses two different voltage levels to represent binary values. Generally, positive voltage represents 1 and negative value represents 0. It is also NRZ because there is no rest condition. NRZ scheme has two variants: NRZ-L and NRZ-I.



NRZ-L changes voltage level at when a different bit is encountered whereas NRZ-I changes voltage when a 1 is encountered.

- **Return to Zero (RZ)**

Problem with NRZ is that the receiver cannot conclude when a bit ended and when the next bit is started, in case when sender and receiver's clock are not synchronized.



RZ uses three voltage levels, positive voltage to represent 1, negative voltage to represent 0 and zero voltage for none. Signals change during bits not between bits.

- **Manchester**

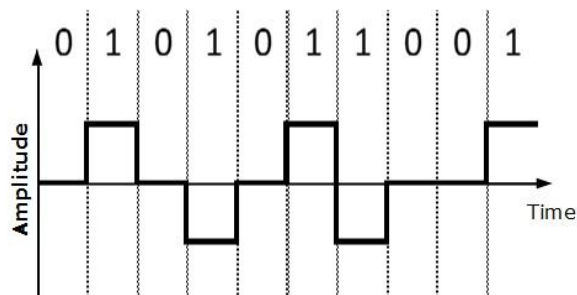
This encoding scheme is a combination of RZ and NRZ-L. Bit time is divided into two halves. It transits in the middle of the bit and changes phase when a different bit is encountered.

- **Differential Manchester**

This encoding scheme is a combination of RZ and NRZ-I. It also transit at the middle of the bit but changes phase only when 1 is encountered.

Bipolar Encoding

Bipolar encoding uses three voltage levels, positive, negative and zero. Zero voltage represents binary 0 and bit 1 is represented by altering positive and negative voltages.



Block Coding

To ensure accuracy of the received data frame redundant bits are used. For example, in even-parity, one parity bit is added to make the count of 1s in the frame even. This way the original number of bits is increased. It is called Block Coding. Block coding is represented by slash notation, mB/nB . Means, m -bit block is substituted with n -bit block where $n > m$. Block coding involves three steps:

- Division,
- Substitution
- Combination.

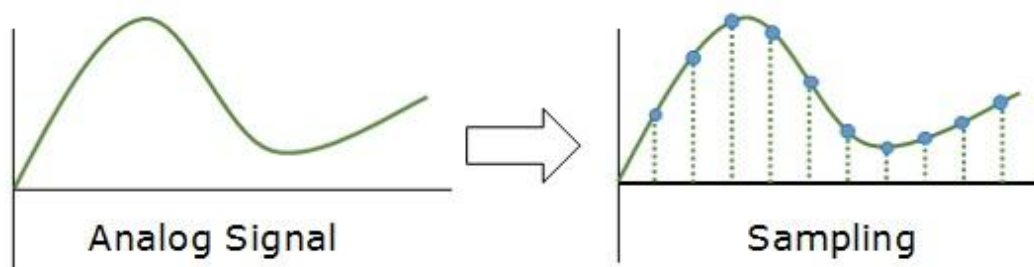
After block coding is done, it is line coded for transmission.

Analog-to-Digital Conversion

Microphones create analog voice and camera creates analog videos, which are treated as analog data. To transmit this analog data over digital signals, we need analog to digital conversion. Analog data is a continuous stream of data in the wave form whereas digital data is discrete. To convert analog wave into digital data, we use Pulse Code Modulation (PCM). PCM is one of the most commonly used methods to convert analog data into digital form. It involves three steps:

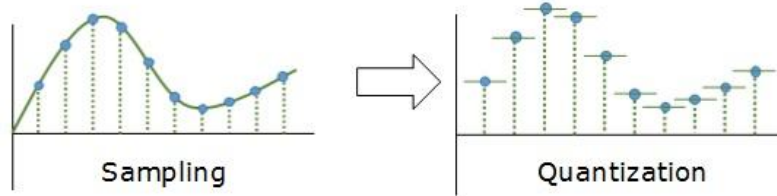
- Sampling
- Quantization
- Encoding.

Sampling



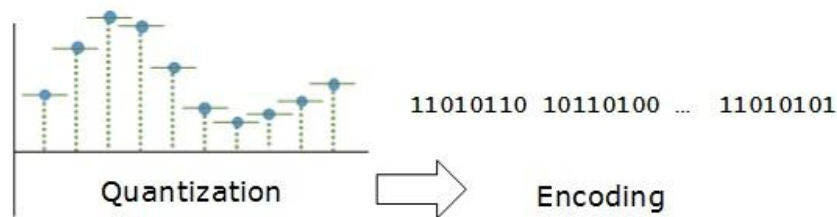
The analog signal is sampled every T interval. Most important factor in sampling is the rate at which analog signal is sampled. According to Nyquist Theorem, the sampling rate must be at least two times of the highest frequency of the signal.

Quantization



Sampling yields discrete form of continuous analog signal. Every discrete pattern shows the amplitude of the analog signal at that instance. The quantization is done between the maximum amplitude value and the minimum amplitude value. Quantization is approximation of the instantaneous analog value.

Encoding

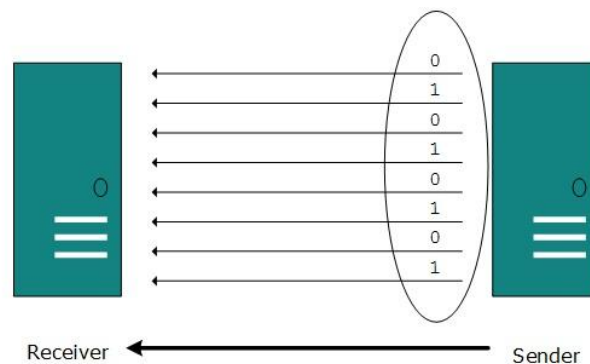


In encoding, each approximated value is then converted into binary format.

Transmission Modes

The transmission mode decides how data is transmitted between two computers. The binary data in the form of 1s and 0s can be sent in two different modes: Parallel and Serial.

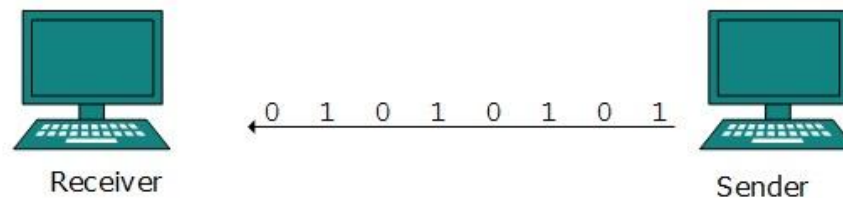
Parallel Transmission



The binary bits are organized in-to groups of fixed length. Both sender and receiver are connected in parallel with the equal number of data lines. Both computers distinguish between high order and low order data lines. The sender sends all the bits at once on all lines. Because the data lines are equal to the number of bits in a group or data frame, a complete group of bits (data frame) is sent in one go. Advantage of Parallel transmission is high speed and disadvantage is the cost of wires, as it is equal to the number of bits sent in parallel.

Serial Transmission

In serial transmission, bits are sent one after another in a queue manner. Serial transmission requires only one communication channel.



Serial transmission can be either asynchronous or synchronous.

Asynchronous Serial Transmission

It is named so because there is no importance of timing. Data-bits have specific pattern and they help receiver recognize the start and end data bits. For example, a 0 is prefixed on every data byte and one or more 1s are added at the end. Two continuous data-frames (bytes) may have a gap between them.

Synchronous Serial Transmission

Timing in synchronous transmission has importance as there is no mechanism followed to recognize start and end data bits. There is no pattern or prefix/suffix method. Data bits are sent in burst mode without maintaining gap between bytes (8-bits). Single burst of data bits may contain a number of bytes. Therefore, timing becomes very important. It is up to the receiver to recognize and separate bits into bytes. The advantage of synchronous transmission is high speed, and it has no overhead of extra header and footer bits as in asynchronous transmission.

Pulse modulation methods

Pulse modulation schemes aim at transferring a narrowband analog signal over an analog baseband channel as a two-level signal by modulating a

pulse wave. Some pulse modulation schemes also allow the narrowband analog signal to be transferred as a digital signal (i.e. as a quantized discrete-time signal) with a fixed bit rate, which can be transferred over an underlying digital transmission system, for example some line code. These are not modulation schemes in the conventional sense since they are not channel coding schemes, but should be considered as source coding schemes, and in some cases analog-to-digital conversion techniques.

Analog-over-analog methods:

- **Pulse-amplitude modulation (PAM):** It is a form of signal modulation where the message information is encoded in the amplitude of a series of signal pulses. It is an analog pulse modulation scheme in which the amplitudes of a train of carrier pulses are varied according to the sample value of the message signal. Demodulation is performed by detecting the amplitude level of the carrier at every symbol period.
- **Pulse-width modulation (PWM) or pulse-duration modulation (PDM):** It is a technique used to encode a message into a pulsing signal. It is a type of modulation. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors.
- **Pulse-position modulation (PPM):** It is a form of signal modulation in which M message bits are encoded by transmitting a single pulse in one of 2^M possible time-shifts. This is repeated every T seconds, such that the transmitted bit rate is M/T bits per second. It is primarily useful for optical communications systems, where there tends to be little or no multipath interference.

Analog-over-digital methods:

- **Pulse-code modulation (PCM):** It is a method used to digitally represent sampled analog signals. It is the standard form of digital audio in computers, Compact Discs, digital telephony and other digital audio applications. In a PCM stream, the amplitude of the analog signal is sampled regularly at uniform intervals, and each sample is quantized to the nearest value within a range of digital steps. PCM is of two types
 - **Differential pulse-code modulation (DPCM):** It is a signal encoder that uses the baseline of pulse-code modulation (PCM) but adds some functionalities based on the prediction of the samples of the signal. The input can be an analog signal or a digital signal. If the input is a continuous-time analog signal, it needs to be sampled

first so that a discrete-time signal is the input to the DPCM encoder.

- **Adaptive differential pulse-code modulation (ADPCM):** It is a variant of differential pulse-code modulation (DPCM) that varies the size of the quantization step, to allow further reduction of the required bandwidth for a given signal-to-noise ratio.
- **Delta modulation (DM or Δ -modulation):** It is an analog-to-digital and digital-to-analog signal conversion technique used for transmission of voice information where quality is not of primary importance. DM is the simplest form of differential pulse-code modulation (DPCM) where the differences between successive samples are encoded into n-bit data streams. In delta modulation, the transmitted data are reduced to a 1-bit data stream.
- **Delta-sigma ($\Delta\Sigma$; or sigma-delta, $\Sigma\Delta$):** It is a digital signal processing, or DSP method for encoding analog signals into digital signals as found in an ADC. It is also used to transfer higher-resolution digital signals into lower-resolution digital signals as part of the process to convert digital signals into analog.
- **Continuously variable slope delta modulation (CVSD or CVSDM):** It is a voice coding method. It is a delta modulation with variable step size (i.e., special case of adaptive delta modulation).
- **Pulse-density modulation (PDM):** It is a form of modulation used to represent an analog signal with digital data. In a PDM signal, specific amplitude values are not encoded into codewords of pulses of different weight as they would be in pulse-code modulation (PCM). Instead, it is the relative density of the pulses that corresponds to the analog signal's amplitude.

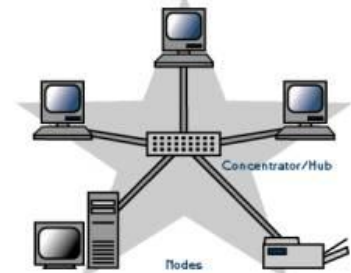
Miscellaneous modulation techniques

- **Link adaptation, or adaptive modulation and coding (AMC):** It is a term used in wireless communications to denote the matching of the modulation, coding and other signal and protocol parameters to the conditions on the radio link (e.g. the pathloss, the interference due to signals coming from other transmitters, the sensitivity of the receiver, the available transmitter power margin, etc.).
- **Space modulation:** A method whereby signals are modulated within airspace, such as that used in Instrument landing systems.

WIRED AND WIRELESS COMMUNICATIONS INCLUDING MOBILE COMMUNICATION AND LATEST TECHNOLOGY

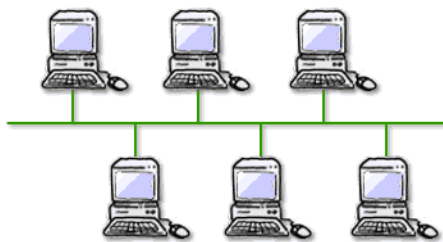
Wired Networks

Wired networks, also called Ethernet networks, are the most common type of local area network (LAN) technology. A wired network is simply a collection of two or more computers, printers, and other devices linked by Ethernet cables. Ethernet is the fastest wired network protocol, with connection speeds of 10 megabits per second (Mbps) to 100 Mbps or higher. Wired networks can also be used as part of other wired and wireless networks. To connect a computer to a network with an Ethernet cable, the computer must have an Ethernet adapter (sometimes called a network interface card, or NIC). Ethernet adapters can be internal (installed in a computer) or external (housed in a separate case). Some computers include a built-in Ethernet adapter port, which eliminates the need for a separate adapter (Microsoft). There are three basic network topologies that are most commonly used today. (Homenthelp.com)



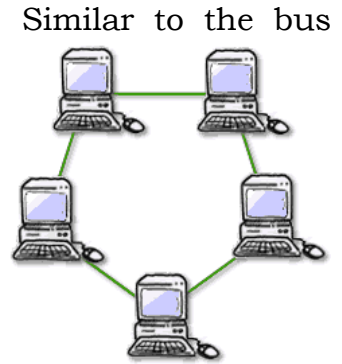
The **star network**, a general more simplistic type of topology, has one central hub that connects to three or more computers and the ability to network printers. This type can be used for small businesses and even home networks. The star network is very useful for applications where some processing must be centralized and some must be performed locally. The major disadvantage of the star network is its vulnerability. All data must pass through one central host computer and if that host fails the entire network will fail.

On the other hand the **bus network** has no central computer and all computers are linked on a single circuit. This type broadcasts signals in all



directions and it uses special software to identify which computer gets what signal. One disadvantage with this type of network is that only one signal can be sent at one time, if two signals are sent at the same time they will collide and the signal will fail to reach its destination. One advantage is that there is no central computer so if one computer goes down others will not be affected and will be able to send messages to one another.

The third type of network is the **ring network**. Similar to the bus network, the ring network does not rely on a central host computer either. Each computer in the network can communicate directly with any other computer, and each processes its own applications independently. A ring network forms a closed loop and data is sent in one direction only and if a computer in the network fails the data is still able to be transmitted.



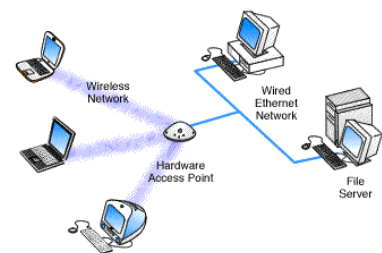
Typically the range of a wired network is within a 2,000-foot-radius. The disadvantage of this is that data transmission over this distance may be slow or nonexistent. The benefit of a wired network is that bandwidth is very high and that interference is very limited through direct connections. Wired networks are more secure and can be used in many situations; corporate LANs, school networks and hospitals. The biggest drawback to this type of network is that it must be rewired every time it is moved.

Wireless Networks

A wireless network, which uses high-frequency radio waves rather than wires to communicate between nodes, is another option for home or business networking. Individuals and organizations can use this option to expand their existing wired network or to go completely wireless. Wireless allows for devices to be shared without networking cable which increases mobility but decreases range. There are two main types of wireless networking; peer to peer or ad-hoc and infrastructure.

An ad-hoc or peer-to-peer wireless network consists of a number of computers each equipped with a wireless networking interface card. Each computer can communicate directly with all of the other wireless enabled computers. They can share files and printers this way, but may not be able to access wired LAN resources, unless one of the computers acts as a bridge to the wired LAN using special software.

An infrastructure wireless network consists of an access point or a base station. In this type of network the access point acts like a hub, providing connectivity for the wireless computers. It can connect or bridge the wireless LAN to a wired LAN, allowing wireless computer access to LAN resources, such as file servers or existing Internet Connectivity.



Wireless networks are reliable, but when interfered with it can reduce the range and the quality of the signal. Interference can be caused by other devices operating on the same radio frequency and it is very hard to control the addition of new devices on the same frequency. Usually if your wireless range is compromised considerably, more than likely, interference is to blame. A major cause of interference with any radio signals are the materials in your surroundings, especially metallic substances, which have a tendency to reflect radio signals. Needless to say, the potential sources of metal around a home are numerous things like metal studs, nails, building insulation with a foil backing and even lead paint can all possibly reduce the quality of the wireless radio signal. Materials with a high density, like concrete, tend to be harder for radio signals to penetrate, absorbing more of the energy. Other devices utilizing the same frequency can also result in interference with your wireless.

On the other hand, many wireless networks can increase the range of the signal by using many different types of hardware devices. A wireless extender can be used to relay the radio frequency from one point to another without losing signal strength. Even though this device extends the range of a wireless signal it has some drawbacks. One drawback is that it extends the signal, but the transmission speed will be slowed.

There are many benefits to a wireless network. The most important one is the option to expand your current wired network to other areas of your organization where it would otherwise not be cost effective or practical to do so. An organization can also install a wireless network without physically disrupting the current workplace or wired network. Wireless networks are far easier to move than a wired network and adding users to an existing wireless network is easy. Organizations opt for a wireless network in conference rooms, lobbies and offices where adding to the existing wired network may be too expensive to do so.

Wired vs. Wireless Networking

The biggest difference between these two types of networks is one uses network cables and one uses radio frequencies. A wired network allows for a faster and more secure connection and can only be used for distances shorter than 2,000 feet. A wireless network is a lot less secure and transmission speeds can suffer from outside interference. Although wireless networking is a lot more mobile than wired networking the range of the network is usually 150-300 indoors and up to 1000 feet outdoors depending on the terrain.

The cost for wired networking has become rather inexpensive. Ethernet cables, hubs and switches are very inexpensive. Some connection sharing software packages, like ICS, are free; some cost a nominal fee. Broadband

routers cost more, but these are optional components of a wired network, and their higher cost is offset by the benefit of easier installation and built-in security features. Wireless gear costs somewhat more than the equivalent wired Ethernet products. At full retail prices, wireless adapters and access points may cost three or four times as much as Ethernet cable adapters and hubs/switches, respectively.

Wired LANs offer superior performance. A traditional Ethernet connection offers only 10 Mbps bandwidth, but 100 Mbps Fast Ethernet technology costs a little more and is readily available. Fast Ethernet should be sufficient for file sharing, gaming, and high-speed Internet access for many years into the future. Wired LANs utilizing hubs can suffer performance slowdown if computers heavily utilize the network simultaneously. Use Ethernet switches instead of hubs to avoid this problem; a switch costs little more than a hub.

The greater mobility of wireless LANs helps offset the performance disadvantage. Mobile computers do not need to be tied to an Ethernet cable and can roam freely within the wireless network range. However, many computers are larger desktop models, and even mobile computers must sometimes be tied to an electrical cord and outlet for power. This undermines the mobility advantage of wireless networks in many organizations and homes.

For any wired network connected to the Internet, firewalls are the primary security consideration. Wired Ethernet hubs and switches do not support firewalls. However, firewall software products like Zone Alarm can be installed on the computers themselves. Broadband routers offer equivalent firewall capability built into the device, configurable through its own software.

In theory, wireless LANs are less secure than wired LANs, because wireless communication signals travel through the air and can easily be intercepted. The weaknesses of wireless security are more theoretical than practical. Wireless networks protect their data through the Wired Equivalent Privacy (WEP) encryption standard that makes wireless communications reasonably as safe as wired ones.

No computer network is completely secure. Important security considerations for organizations tend to not be related to whether the network is wired or wireless but rather ensuring that the firewall is properly configured, employees are aware of the dangers of spoof emails, they are away of spy ware and how to avoid and that anyone outside the organization does not have unauthorized access to the network.

Wireless Network Security

Network security is a big concern for individuals and organizations because vital information is stored on the network and most critical process of the business are done through the network. If a network is to fail or security is compromised an organization could be completely crippled. Also at risk is employee and client privacy. If an organization's network is hacked into they would have access to client databases as well as employee databases. The most important thing to keep in mind when it comes to wireless network security is keeping unauthorized users from accessing your network. The first step is to know your wireless network's range and to use specific software to grant access only to authorized users.

Mobile communication and latest technology

Communication is one of the integral parts of science that has always been a focus point for exchanging information among parties at locations physically apart. After its discovery, telephones have replaced the telegrams and letters. Similarly, the term 'mobile' has completely revolutionized the communication by opening up innovative applications that are limited to one's imagination. Today, mobile communication has become the backbone of the society.

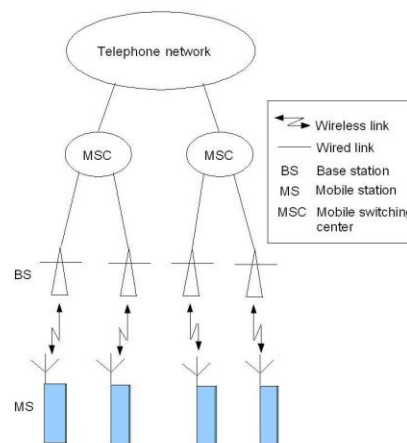
The first wireline telephone system was introduced in the year 1877. Mobile communication systems as early as 1934 were based on Amplitude Modulation (AM) schemes and only certain public organizations maintained such systems. With the demand for newer and better mobile radio communication systems during the World War II and the development of Frequency Modulation (FM) technique by Edwin Armstrong, the mobile radio communication systems began to witness many new changes. Mobile telephone was introduced in the year 1946. However, initially it found very less market owing to high costs and numerous technological drawbacks. But with the development of the cellular concept in the 1960s at the Bell Laboratories, mobile communications began to be a promising field of expanse which could serve wider populations. Initially, mobile communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the Public Switched Telephone Network (PSTN), there has been an astronomical growth in the cellular radio and the personal communication systems. Advanced Mobile Phone System (AMPS) was the first U.S. cellular telephone system and it was deployed in 1983. Wireless services have since

then been experiencing a 50% per year growth rate. The number of cellular telephone users grew and the demand rate is increasing day by day.

Initially the mobile communication was limited between one pair of users on single channel pair. The range of mobility was defined by the transmitter power, type of antenna used and the frequency of operation. With the increase in the number of users, accommodating them within the limited available frequency spectrum became a major problem. To resolve this problem, the concept of cellular communication was evolved. The present day cellular communication uses a basic unit called cell. Each cell consists of small hexagonal area with a base station located at the center of the cell which communicates with the user. To accommodate multiple users, Time Division multiple Access (TDMA), Code Division Multiple Access (CDMA), Frequency Division Multiple Access (FDMA) and their hybrids are used.

Fundamental Techniques

By definition, mobile radio terminal means any radio terminal that could be moved during its operation. Depending on the radio channel, there can be three different types of mobile communication. In general, however, a Mobile Station (MS) or subscriber unit communicates to a fixed Base Station (BS) which in turn communicates to the desired user at the other end. The MS consists of transceiver, control circuitry, duplexer and an antenna while the BS consists of transceiver and channel multiplexer along with antennas mounted on the tower. The BS is also linked to a power source for the transmission of the radio signals for communication and connected to a fixed backbone network. Figure shows a basic mobile communication with low power transmitters/receivers at the BS, the MS and also the Mobile Switching Center (MSC).

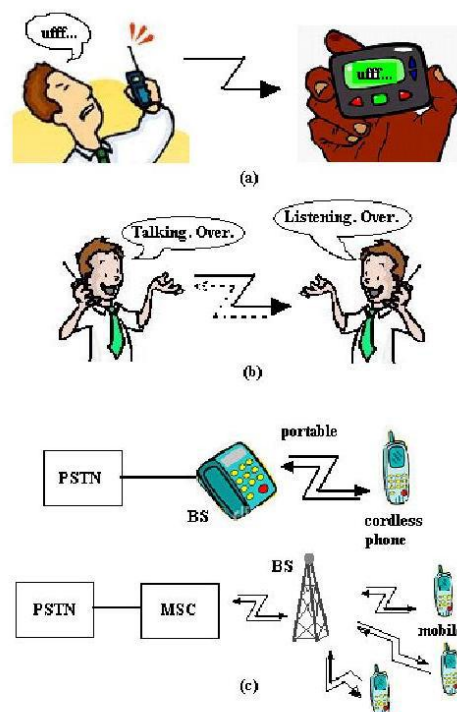


Basic mobile communication

The MSC is sometimes also called Mobile Telephone Switching Office (MTSO). The radio signals emitted by the BS decay as the signals travel away from it. A minimum amount of signal strength is needed in order to be detected by the mobile stations or mobile sets which are the hand-held personal units (portables) or those installed in the vehicles (mobiles). The region over which the signal strength lies above such a threshold value is known as the coverage area of a BS. The fixed backbone network is a wired network that links all the base stations and also the landline and other telephone networks through wires.

Radio Transmission Techniques

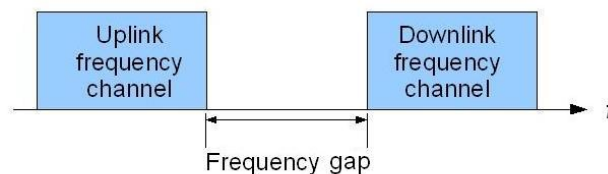
Based on the type of channels being utilized, mobile radio transmission systems may be classified as the following three categories which are also shown below



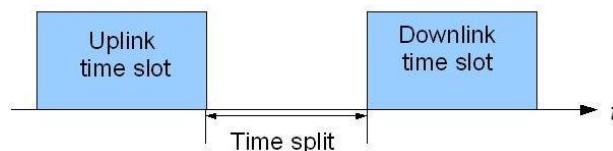
Basic techniques: (a) simplex, (b) half duplex and (c) full duplex.

- **Simplex System:** Simplex systems utilize simplex channels i.e., the communication is unidirectional. The first user can communicate with the second user. However, the second user cannot communicate with the first user. One example of such a system is a pager.

- **Half Duplex System:** Half duplex radio systems that use half duplex radio channels allow for non-simultaneous bidirectional communication. The first user can communicate with the second user but the second user can communicate to the first user only after the first user has finished his conversation. At a time, the user can only transmit or receive information. A walkie-talkie is an example of a half duplex system which uses ‘push to talk’ and ‘release to listen’ type of switches.
- **Full Duplex System:** Full duplex systems allow two way simultaneous communications. Both the users can communicate to each other simultaneously. This can be done by providing two simultaneous but separate channels to both the users. This is possible by one of the two following methods.
 - **Frequency Division Duplexing (FDD):** FDD supports two-way radio communication by using two distinct radio channels. One frequency channel is transmitted downstream from the BS to the MS (forward channel). A second frequency is used in the upstream direction and supports transmission from the MS to the BS (reverse channel). Because of the pairing of frequencies, simultaneous transmission in both directions is possible. To mitigate self-interference between upstream and downstream transmissions, a minimum amount of frequency separation must be maintained between the frequency pair, as shown below.
 - **Time Division Duplexing (TDD):** TDD uses a single frequency band to transmit signals in both the downstream and upstream directions. TDD operates by toggling transmission directions over a time interval. This toggling takes place very rapidly and is imperceptible to the user.



(a) FDD



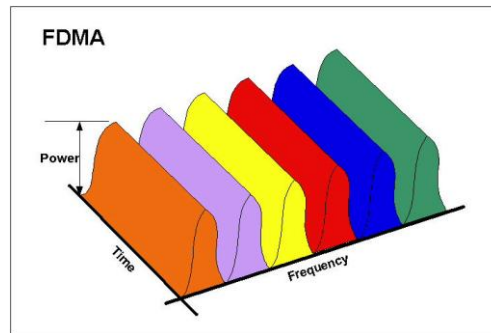
(b) TDD

(a) Frequency division duplexing and (b) time division duplexing.

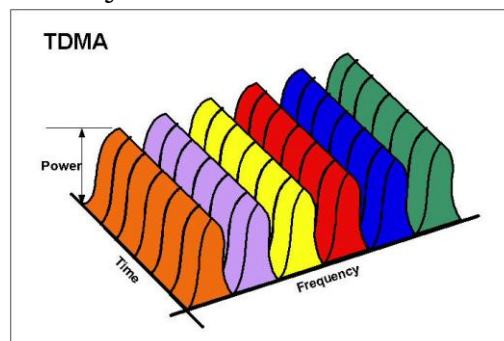
BASICS OF TDMA, FDMA, CDMA AND GSM

As one of the major problems facing the development of telecommunications, bandwidth demand has driven the search for protocols that could be used to maximize bandwidth efficiency. Multiple accesses ("multiplexing" for short) enable multiple signals to occupy a single communications channel. There are three basic types of division-based protocols used to do this: frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA).

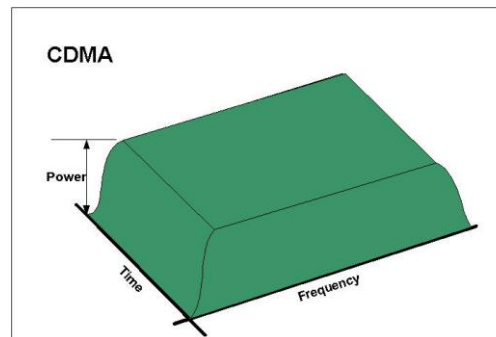
With **Frequency Division Multiple Access (FDMA)**, different signals are assigned frequency channels. A channel is a frequency. FDMA is a basic technology in the analog Advanced Mobile Phone System (AMPS). With FDMA, each channel can be assigned to only one user at a time. FDMA is also used in the Total Access Communication System (TACS).



In **Time Division Multiple Access (TDMA)**, it makes use of the same frequency spectrum but allows more users on the same band of frequencies by dividing the time into "slots" and shares the channel between users by assigning them different time slots. TDMA is utilized by Digital-Advanced Mobile Phone System (D-AMPS) and Global System for Mobile communications (GSM). However, each of these systems implements TDMA in a somewhat different and incompatible way.



In **Code Division Multiple Access (CDMA)**, each user is assigned a different pseudorandom binary sequence that modulates the carrier, spreading the spectrum of the waveform and giving each user a unique code pattern. This technology is used in ultra-high-frequency (UHF) cellular telephone systems in the 800-MHz and 1.9-GHz bands.



Global system for mobile communication (GSM)

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. GSM is the name of a standardization group established in 1982 to create a common European mobile telephone standard that would formulate specifications for a pan-European mobile cellular radio system operating at 900 MHz. It is estimated that many countries outside of Europe will join the GSM Partnership.

GSM was devised as a cellular system specific to the 900 MHz band, called "The Primary Band". The primary band includes two sub bands of 25 MHz each, 890 to 915 MHz and 935 MHz to 960 MHz. GSM-PLMN has allocated 124 duplex carrier frequencies over the following bands of operation.

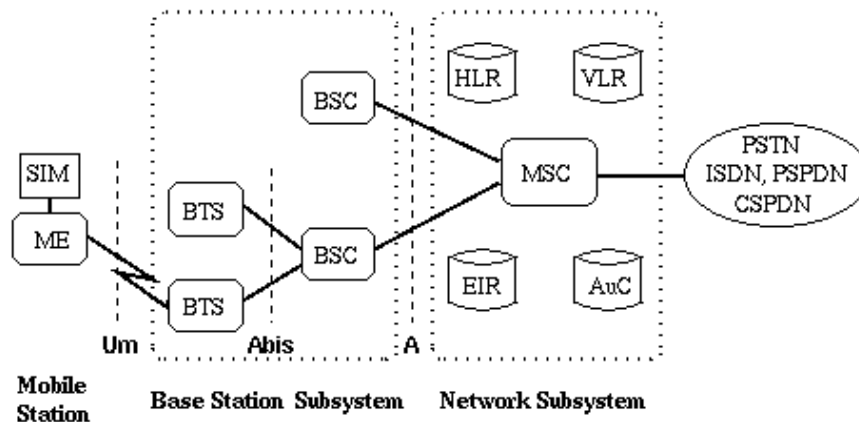
Uplink frequency band: 890 to 915 MHz (MS transmits, BTS receives).

Downlink frequency band: 935 to 960 MHz (BTS transmits, MS receives).

Carrier spacing: 200 KHz.

A GSM network is composed of several functional entities, whose functions and interfaces are specified. The GSM network can be divided into three broad parts. The Mobile Station is carried by the subscriber. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Center (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio

link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface.



SIM	Subscriber Identity Module	BSC	Base Station Controller	MSC	Mobile services Switching Center
ME	Mobile Equipment	HLR	Home Location Register	EIR	Equipment Identity Register
BTS	Base Transceiver Station	VLR	Visitor Location Register	AuC	Authentication Center

General architecture of a GSM network

The **Mobile Station (MS)** consists of the mobile equipment (the terminal) and a smart card called the Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to subscribed services irrespective of a specific terminal. By inserting the SIM card into another GSM terminal, the user is able to receive calls at that terminal, make calls from that terminal, and receive other subscribed services.

The mobile equipment is uniquely identified by the International Mobile Equipment Identity (IMEI). The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other information. The IMEI and the IMSI are independent, thereby allowing personal mobility. The SIM card may be protected against unauthorized use by a password or personal identity number.

The **Base Station Subsystem** is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). These communicate across the standardized Abis interface, allowing (as in the rest of the system) operation between components made by different suppliers. The Base Transceiver Station houses the radio transceivers that define a cell and handles the radio-link protocols with the Mobile Station. In a large urban area, there will potentially be a large number of BTSs deployed, thus the requirements for a BTS are ruggedness, reliability, portability, and minimum

cost. The Base Station Controller manages the radio resources for one or more BTSs. It handles radio-channel setup, frequency hopping, and handovers. The BSC is the connection between the mobile station and the Mobile service Switching Center (MSC).

The central component of the **Network Subsystem** is the Mobile services Switching Center (MSC). It acts like a normal switching node of the PSTN or ISDN, and additionally provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers, and call routing to a roaming subscriber. The MSC provides the connection to the fixed networks (such as the PSTN or ISDN). Signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7), used for trunk signaling in ISDN and widely used in current public networks.

The Home Location Register (HLR) and Visitor Location Register (VLR), together with the MSC, provide the call-routing and roaming capabilities of GSM. The HLR contains all the administrative information of each subscriber registered in the corresponding GSM network, along with the current location of the mobile. The location of the mobile is typically in the form of the signaling address of the VLR associated with the mobile station. There is logically one HLR per GSM network, although it may be implemented as a distributed database.

The Visitor Location Register (VLR) contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each mobile currently located in the geographical area controlled by the VLR. The geographical area controlled by the MSC corresponds to that controlled by the VLR. Note that the MSC contains no information about particular mobile stations, this information is stored in the location registers.

The other two registers are used for authentication and security purposes. The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI). An IMEI is marked as invalid if it has been reported stolen or is not type approved. The Authentication Center (AuC) is a protected database that stores a copy of the secret key stored in each subscriber's SIM card, which is used for authentication and encryption over the radio channel.

How a call is made?

Suppose if a call has come for mobile B, then the base station indicates this signal using paging channel. This paging information may also contain dedicated channel on which further signaling information has to take place.

The paging information may contain caller-id. This information will be used the caller to decide whether to proceed for communication or not.

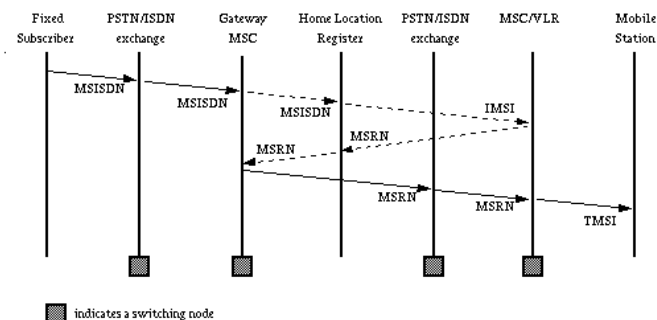
Call routing

Unlike routing in the fixed network, where a terminal is semi-permanently wired to a central office, a GSM user can roam nationally and even internationally. The directory number dialed to reach a mobile subscriber is called the Mobile Subscriber ISDN (MSISDN), which is defined by the E.164 numbering plan. This number includes a country code and a National Destination Code which identifies the subscriber's operator. The first few digits of the remaining subscriber number may identify the subscriber's HLR within the home PLMN.

An incoming mobile terminating call is directed to the Gateway MSC (GMSC) function. The GMSC is basically a switch which is able to interrogate the subscriber's HLR to obtain routing information, and thus contains a table linking MSISDNs to their corresponding HLR. A simplification is to have a GSMC handle one specific PLMN. It should be noted that the GMSC function is distinct from the MSC function, but is usually implemented in an MSC.

The routing information that is returned to the GMSC is the Mobile Station Roaming Number (MSRN), which is also defined by the E.164 numbering plan. MSRN are related to the geographical numbering plan, and not assigned to subscribers, nor are they visible to subscribers.

The most general routing procedure begins with the GMSC querying the called subscriber's HLR for an MSRN. The HLR typically stores only the SS7 address of the subscriber's current VLR, and does not have the MSRN (see the location updating section). The HLR must therefore query the subscriber's current VLR, which will temporarily allocate an MSRN from its pool for the call. This MSRN is returned to the HLR and back to the GMSC, which can then route the call to the new MSC. At the new MSC, the IMSI corresponding to the MSRN is looked up, and the mobile is paged in its current location area.



Call routing

CONCEPT OF 2G, 3G & OTHER LATEST COMMUNICATION SYSTEMS

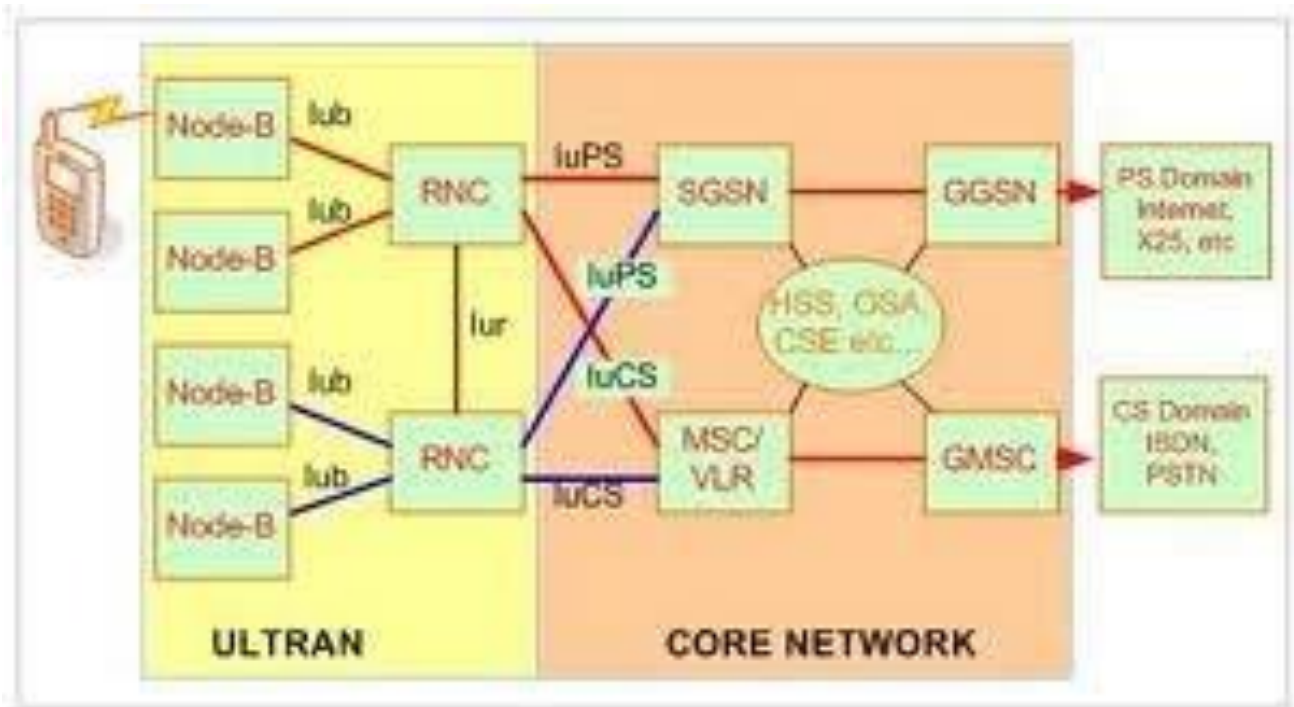
At the initial phase, mobile communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available. Moreover, even the growth in the cellular networks was very slow. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the PSTN, there has been a remarkable growth in the cellular radio. In the present time, there are four generations in the mobile industry. These are respectively 1G the first generation, 2G the second generation, 3G the third generation, and then the 4G the fourth generation.

1G (or 1-G) refers to the first-generation of wireless telephone technology, mobile telecommunications. These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The main difference between two succeeding mobile telephone systems, 1G and 2G, is that the radio signals that 1G networks use are analog, while 2G networks are digital.

2G (or **2-G**) is short for second-generation wireless telephone technology. Second generation 2G cellular telecom networks were commercially launched on the GSM standard in Finland by Radiolinja in 1991. Three primary benefits of 2G networks over their predecessors were that phone conversations were digitally encrypted; 2G systems were significantly more efficient on the spectrum allowing for far greater mobile phone penetration levels; and 2G introduced data services for mobile, starting with SMS text messages.

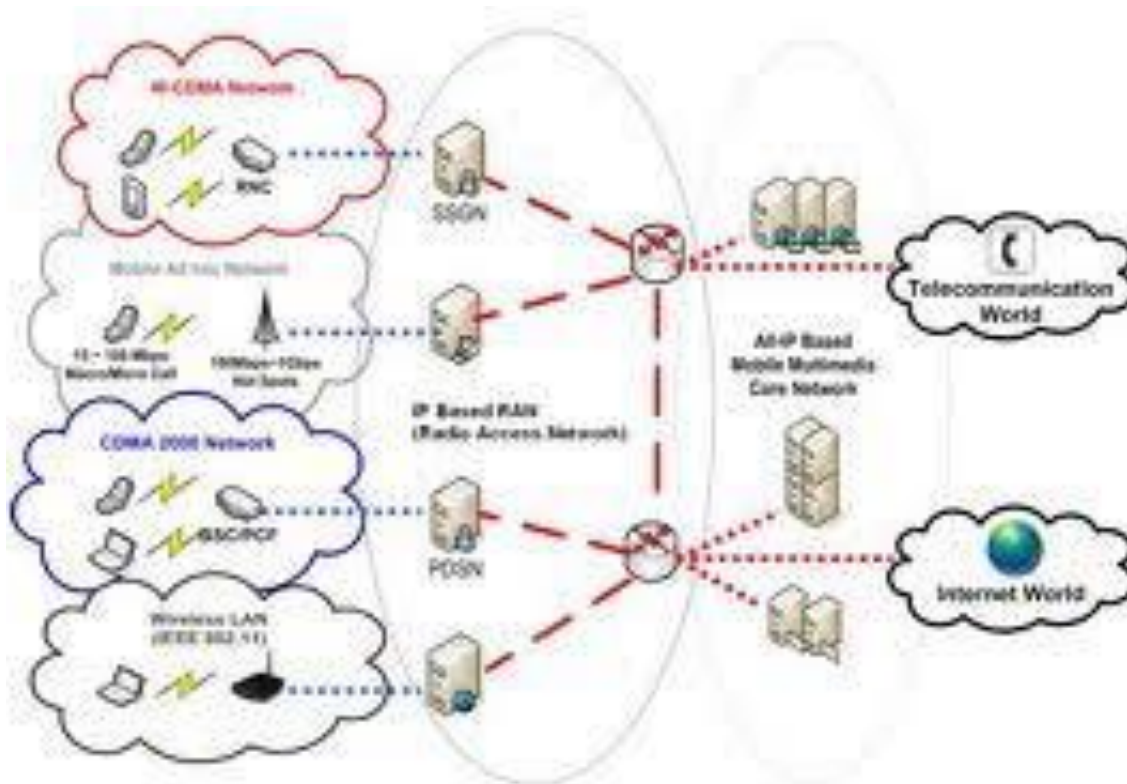
3G or 3rd generation mobile telecommunications is a generation of standards for mobile phones and mobile telecommunication services fulfilling the International Mobile Telecommunications- 2000 (IMT-2000) specifications by the International Telecommunication Union. Application services include wide area wireless voice telephone, mobile Internet access, video calls and mobile TV, all in a mobile environment. ITU has not provided a clear definition of the data rate users can expect from 3G equipment or providers.

3G networks offer greater security than their 2G predecessors. By allowing the UE (User Equipment) to authenticate the network it is attaching to, the user can be sure the network is the intended one and not an impersonator. 3G networks use the KASUMI block crypto instead of the older A5/1 stream cipher. 3G can implement various network technologies such as UMTS, GSM, CDMA, WCDMA, CDMA200, TDMA and EDGE.



3G Network model

4G Fourth generation (4G) also called Next Generation Network (NGN) offers one platform for different wireless networks. A successor of 2G and 3G, 4G promises a downloading speed of 100Mbps and is yet to show its wonders on. then with the case of Fourth Generation that is 4G in addition to that of the services of 3G some additional features such as Multi-Media Newspapers, also to watch T.V programs with the clarity as to that of an ordinary T.V. In addition, we can send Data much faster than that of the previous generations. A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, Smartphone's, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users. In 4G the integration of network and its applications is seamless therefore there is no risk of delay. While implementing 4G the cost issue needs to be taken into consideration so that users can benefit from this technological development fully.



4G mobile Network

Present technology especially in areas of memory, bandwidth, and power, as well as new technological solution that should be available in near future are investigated in this paper. This paper should be able to present a picture of the physical constraints of MANET at present and also suggests some areas where previously considered as limitations may no longer exist, or will vanish in the near future.

Applications of 4G

With the increase in the data rates, the mobile phones are made to perform higher performance applications. In 4G the mobile phone is not only for calling but its something extraordinary device that can be used for variety of purposes. One such application in 4G is context awareness. For example if the mobile user is passing by an office where he/she is having an appointment to meet someone and they have forgotten the appointment. If the office location, address and geographical location matches the one user has already stored in the phone, he/she will receive information about the appointment and will be reminded that you need to perform this activity. Telemedicine is another application of 4G. Using telemedicine a patient can send general reading like temperature, glucose level and blood pressure to the doctor online. Or if

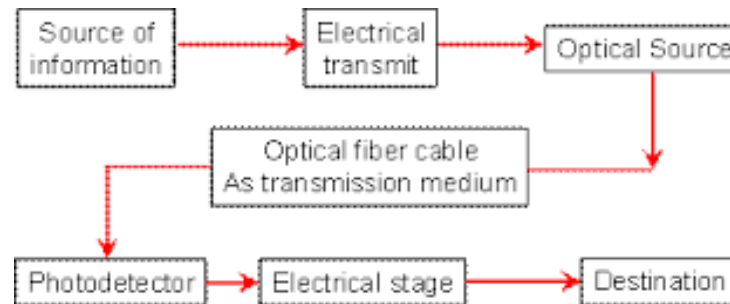
someone needs to know about their family member's health continuously they can receive all the information through telemedicine by using 4G technology.

- **LTE: Long Term Evolution (LTE)** is an emerging technology for higher data rates. It is also referred as 3.9 G or super 3G technology. LTE is developed as an improvement to Universal Mobile Telecommunication System by 3G Generation Partnership Project (3GPP). LTE uses Orthogonal Frequency Division Multiple Access (OFDMA). The download rate in LTE is 150 Mbps and it utilizes the available spectrum in a very sophisticated way. In LTE the IP packet delay is less than 5 mille seconds which provides the experience of wired broadband internet access in wireless environment. The mobile TV broadcast is facilitated by LTE over LTE network. LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. The goal of LTE is to increase the capacity and speed of wireless data networks using new DSP (Digital Signal Processing) techniques and modulations that were developed in the beginning of the new millennium. Its wireless interface is incompatible with 2G and 3G networks, and so it must be operated on a separate wireless spectrum. The LTE specification provides down-link peak rates of 300 Mbit/s, uplink peak rates of 75 Mbit/s and QoS provisions permitting round-trip times of less than 10 ms.
- **WiMAX: Worldwide Interoperability for Microwave Access (WiMAX)** is a communication technology for wirelessly delivering high speed Internet service to large geographical areas. It is a part of a “fourth generation,” or 4G, of wireless-communication technology, WiMAX far surpasses the 30-metre (100-foot) wireless range of a conventional Wi-Fi local area network (LAN), offering a metropolitan area network with a signal radius of about 50 km (30 miles). WiMAX is based upon IEEE Std 802.16.

OPTICAL FIBER COMMUNICATION

OVERVIEW OF OPTICAL COMMUNICATIONS

Optical communication, also known as optical telecommunication, is communication at a distance using light to carry information. It can be performed visually or by using electronic devices. The earliest basic forms of optical communication date back several millennia, while the earliest electrical device created to do so was the photophone, invented in 1880.



An optical communication system uses a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. When electronic equipment is not employed the 'receiver' is a person visually observing and interpreting a signal, which may be either simple (such as the presence of a beacon fire) or complex (such as lights using color codes or flashed in a Morse code sequence).

Free-space optical communication has been deployed in space, while terrestrial forms are naturally limited by geography, weather and the availability of light.

OPTICAL FIBERS AND ITS TYPES AND PROPERTIES

Fiber optics (optical fibers) are long, thin strands of very pure glass about the diameter of a human hair. They are arranged in bundles called **optical cables** and used to transmit light signals over long distances. Optical fiber is the most common type of channel for optical communications. The transmitters in optical fiber links are generally light-emitting diodes (LEDs) or laser diodes. Infrared light, rather than visible light is used more commonly, because optical fibers transmit infrared wavelengths with less attenuation and dispersion. The signal encoding is typically simple intensity modulation, although historically optical phase and frequency modulation have been demonstrated in the lab. The need for periodic signal regeneration was largely

superseded by the introduction of the erbium-doped fiber amplifier, which extended link distances at significantly lower cost.

Types of Optical fibers

Optical fibers are of two types:

- **Single-mode fibers**
- **Multi-mode fibers**

Single-mode fibers have small cores (about 3.5×10^{-4} inches or 9 microns in diameter) and transmit infrared laser light (wavelength = 1,300 to 1,550 nanometers). **Multi-mode fibers** have larger cores (about 2.5×10^{-3} inches or 62.5 microns in diameter) and transmit infrared light (wavelength = 850 to 1,300 nm) from light-emitting diodes (LEDs).



LEDs



Multimode fibers

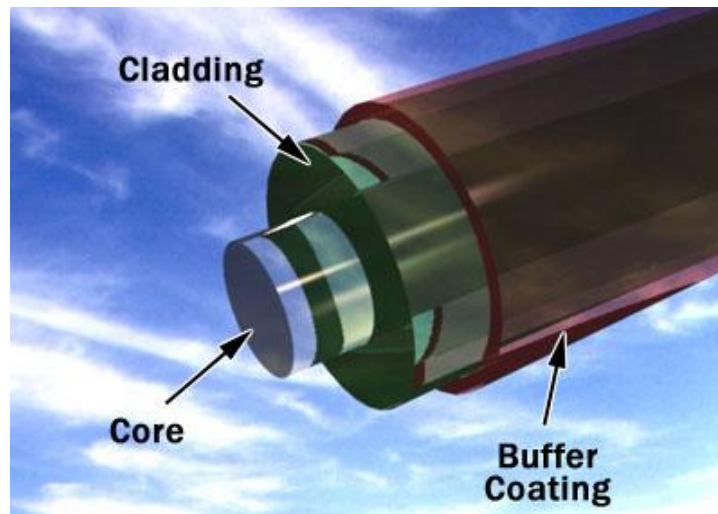
Some optical fibers can be made from **plastic**. These fibers have a large core (0.04 inches or 1 mm diameter) and transmit visible red light (wavelength = 650 nm) from LEDs.

Parts of a single optical fiber

If you look closely at a single optical fiber, you will see that it has the following parts:

- **Core** - Thin glass center of the fiber where the light travels
- **Cladding** - Outer optical material surrounding the core that reflects the light back into the core

- **Buffer coating** - Plastic coating that protects the fiber from damage and moisture



Hundreds or thousands of these optical fibers are arranged in bundles in optical cables. The bundles are protected by the cable's outer covering, called a **jacket**.

The Properties of Optical Fibers as Communication Carriers

The main job of an optical fiber is to guide light with a minimum loss of signal. Optical fibers have a number of properties that allow them to act as communication carriers as follows:

- An optical fiber is made from very pure, almost mineral free glass. This purity means that light can travel through an optic fiber for hundreds of kilometers.
- An optic fiber cable is flexible and can be easily bent. This flexibility makes the fiber very useful. It means that the cable can be laid so that it bends around obstacles without the need for special relay (reflection) devices.
- The structure of an optic fiber results in light rays undergoing total internal reflection. This is an important property of the fiber as it means light is transmitted with very little loss of energy over long distances.
- Optical fibers are capable of transmitting light at about $\frac{2}{3}$ the speed of light in a vacuum. This means that communication using optic fiber is very fast.
- When an optical fiber transmits light there must be some loss of signal strength. Attenuation is the loss of signal strength. The amount of light

coming out at the end of the fiber is less than the amount of light originally transmitted.

Certain properties of the fiber cause a loss of signal strength. (i.e. attenuation).

- Impurities in the glass absorb some of the light. The impurities are mostly heavy metals such as iron, copper, vanadium, cobalt, nickel, manganese and Chromium. OH^- ions that come from water are also impurities that absorb signal strength. Certain wavelengths must be avoided 1.37, 1.23, $0.95\mu\text{m}$ because of absorption by the OH^- ions.
- Changes in density of the glass can cause the light to scatter.
- Light is lost at bends. At a bend, the angle at which the light hits the core/cladding interface results in transmission, not reflection. Light entering the cladding glass is lost.

How Does an Optical Fiber Transmit Light?

Suppose you want to shine a flashlight beam down a long, straight hallway. Just point the beam straight down the hallway light travels in straight lines, so it is no problem. What if the hallway has a bend in it? You could place a mirror at the bend to reflect the light beam around the corner. What if the hallway is very winding with multiple bends? You might line the walls with mirrors and angle the beam so that it bounces from side-to-side all along the hallway. This is exactly what happens in an optical fiber.

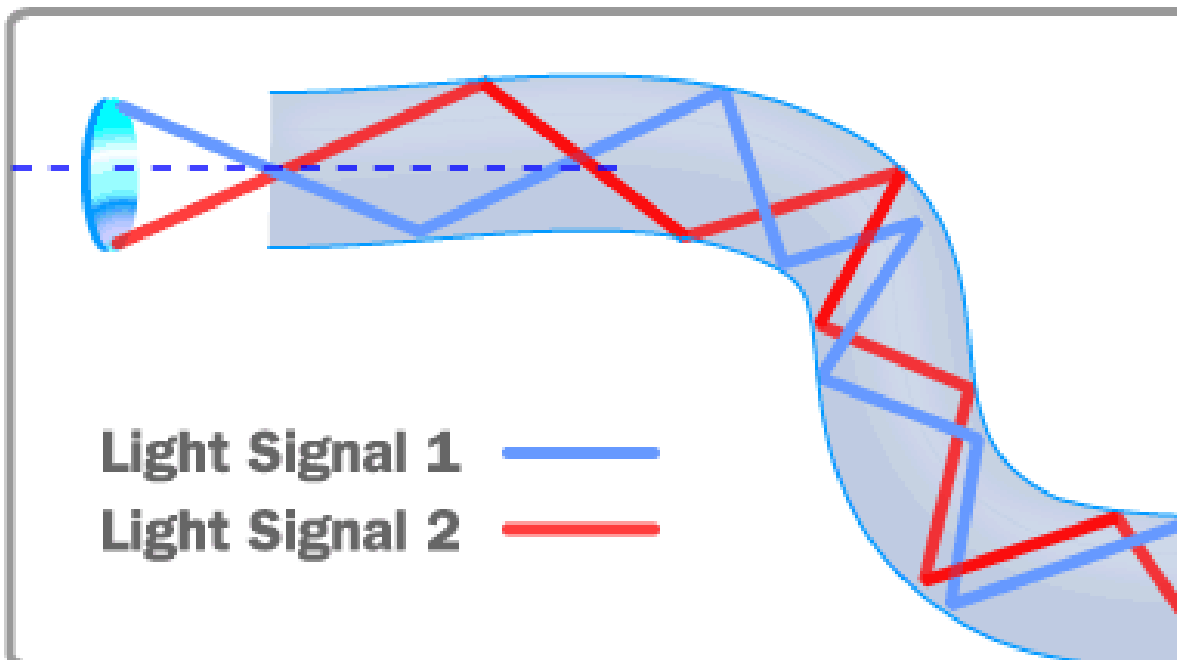
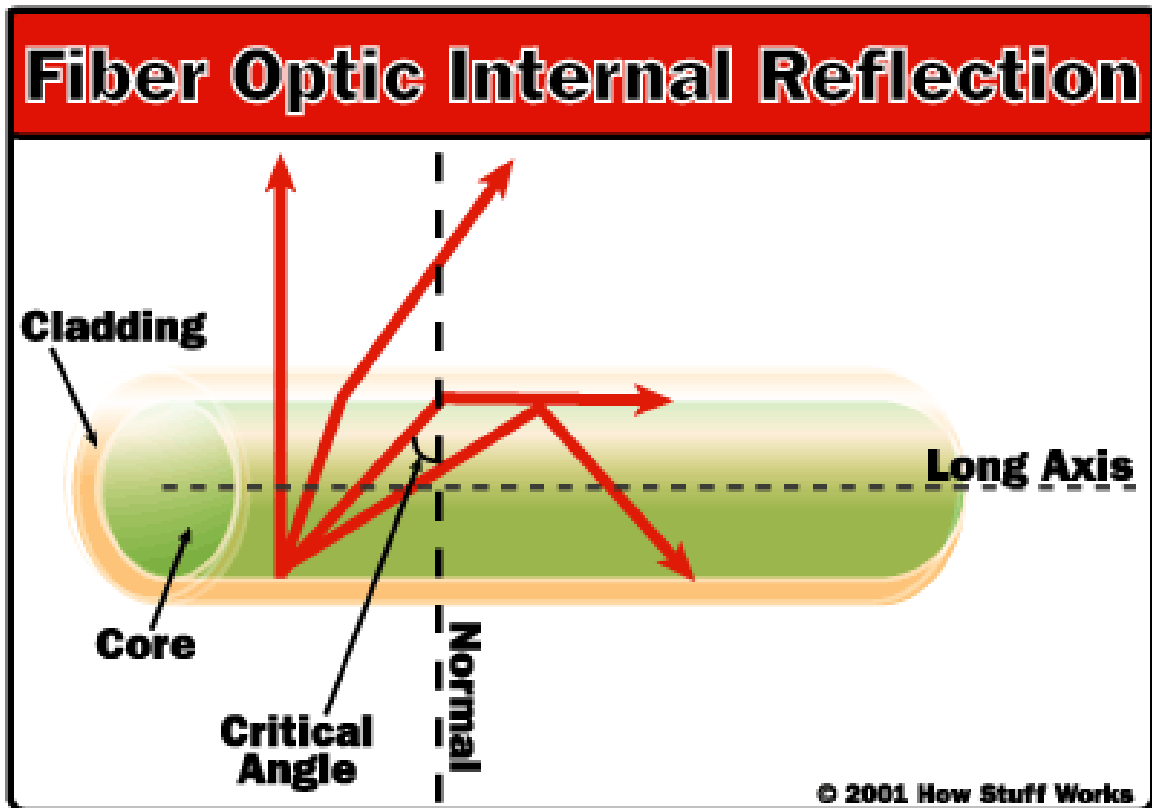


Diagram of total internal reflection in an optical fiber

SIGNAL DEGRADATION

The light in a fiber-optic cable travels through the core (hallway) by constantly bouncing from the cladding (mirror-lined walls), a principle called **total internal reflection**. Because the cladding does not absorb any light from the core, the light wave can travel great distances. However, some of the light **signal degrades** within the fiber, mostly due to impurities in the glass.



Total Internal Reflection

The extent that the signal degrades depends on the purity of the glass and the wavelength of the transmitted light (for example, 850 nm = 60 to 75 percent/km; 1,300 nm = 50 to 60 percent/km; 1,550 nm is greater than 50 percent/km). Some premium optical fibers show much less signal degradation less than 10 percent/km at 1,550 nm.

INTERNATIONAL STANDARDS

ITU-T G.651	Multimode fiber standard
ITU T G 652	Standard Single mode fiber. 4 different categories (A, B, C, D) differ in the water peak attenuation around the 1383nm window

Equivalent standards:	Telcordia GR-20, IEC 60793-2, TIA/EIA-492CAAB
ITU-T G.653	Zero Dispersion Shifted Fiber (ZDSF), having zero dispersion around the 1550nm window
ITU-T G.654	C t ff Cutoff shifted and low attenuation fiber, designed mainly for submarine applications
ITU-T G.655	Non-zero Dispersion Shifted Fiber (NZDSF), having low dispersion in the 1550nm and 1625nm windows, the DWDM region. Suited for long haul and backbone applications. Categories A, B, C, D, E differ in PMD and dispersion values
ITU-T G.656	Medium Dispersion Fiber (MDF), designed for local access and long haul fiber
ITU-T G.657	Latest standard (from 2008 Jan) for FTTH application. Designed to bend at small radius of down to 10mm radius and 7.5mm radius

THE ADVANTAGES AND DISADVANTAGES OF OPTICAL FIBER COMMUNICATION OVER COPPER WIRE COMMUNICATION

Optical fiber cable/communication is less expensive, non-flammable, lightweight and flexible with higher carrying capacity, compared to conventional metal wire (copper wire). Advantages and disadvantages of optical fiber communication are as follows:

Advantages of Optical Fiber Cable / Communications:

- Optical Fiber Cables can run massive distances like 40 Km or much more (Single Mode Fiber Cables) without having to repeat the signal anywhere in-between.
- Normally, the Optical Fiber Cables do not have speed limits or bandwidth limitations. They can support any speed/ bandwidth depending only on the type of optics (active components) used at either end. But the distance over which they can support such speeds varies for each fiber material.
- It's normally enough to replace the optics (active components) at either end in order to upgrade the fiber communication to support higher bandwidths. There is no need to change all the underlying cabling.
- Optical Fiber Cables support duplex communications (simultaneous upstream and downstream), but they use two cores for doing so. One core is used for Transmission (Tx) and the other core is used for Reception (Rx).

- Optical Fiber Cables are flexible and can be laid both within the buildings (Indoor Fiber Cables) and outside the buildings (Shielded Fiber Cables). In most of the cases, they are buried under the ground (with a depth of minimum 3 feet) using a Trench and protective materials.
- Multiple cores are built into each optical fiber cable (like 6/12/24 cores) and hence each optical cable can support multiple individual connections (3/6/12).
- Optical Fiber Cables are not affected by EMI – Electromagnetic Interference as they carry light, and hence can be used even for the most demanding industrial applications.
- They can also be used in lightning prone areas as they do not carry the electrical signals as such to affect switch ports, etc during a lightning.
- The danger of ignition during a fire is much less with optical fiber cables.
- There are optical taps that can be inserted in-between long running optical cables. There are two types of taps – Passive optical taps that do not require electrical power and are used for simple monitoring of OFC networks & Active optical taps that require electrical power and are used for manipulation or boosting of signals sent to the monitoring port.
- The low cost 850 nm Laser optimized 50/125 micro meter Multi-Mode Fiber (OM3 type) gives 10 GE performance for up to 300 meters. The optics associated with it is also moderately priced. So, these fibers can be used in the enterprise LAN segment for short distances, where the single mode optics might turn out more expensive. OM4 Laser Optimized Multi-Mode Fiber supports even higher bandwidths like 40/100 Gbps.
- Even if many fibers run alongside each other, the chances of cross talk (and hence signal loss) is very less, unlike Copper UTP Cables.
- Wire tapping with Optical Fiber Cables is more difficult.
- Optical Fiber Cables (Especially Passive Optical Networks) are used for providing high speed broadband to homes, these days (FTTH).
- Trouble shooting an Optical Fiber Network is possible with equipments like the OTDR Tester (Optical Time Domain Reflectometer). Using this, one could measure the optical power loss and locate the faults caused due to fiber breaks, connectors or splicing.

Disadvantages/ Limitations of Optical Fiber Cable Networks:

- Optical Fiber cables have limited bend radius (about 30 mm). So, if they are bent more, it might lead to some signal loss. But recently, bend resistant fibers have been introduced which have higher tolerance to bending.

- Copper UTP cables can carry data as well as power. Some POE enabled IP devices like IP Phones, Wireless Access Points etc are powered directly using the UTP Cables/ POE switches. This is not supported by the optical fiber cables as they carry only data.
- Unlike Copper UTP cables which have standard RJ-45 Jacks and connectors (mostly), optical fiber cables have many types of connectors and this lack of standardization adds confusion.
- By bending the normal optical fiber cables, some leakage of signal could be induced and that can be used for hacking the information in them. So, even though doing that might be difficult, they are not totally tamper proof.
- Single mode cables and their associated optics (active components) are very expensive. Even though multi-mode cables/ optics are less expensive, they are not even close to the costs of copper UTP cables/ ports. Moreover, multi-mode cables have restrictions in distance for supporting higher bandwidth (like 1 Gbps and 10 Gbps).
- There are outdoor fiber cables but they need to be shielded well. This shielding makes them less agile/ flexible to run in all the places and it increases the cost of cables as well.
- Fiber cables cannot be directly terminated on to the network/ optical switches. They need a whole array of active/ passive components like SFP Modules, Fiber Patch Cords, appropriate connectors, Fiber Patch Panel (LIU), Pigtails and Couplers. All these components add the cost of fiber network implementation at each location.
- Each Core of the Optical Fiber cable needs to be spliced in order to complete the connection to the network/optical switch. Both the splicing equipment and the cost of installation (for splicing) per core are quite high.
- Fiber splicing is a complicated procedure and requires skilled manpower to achieve. If it is not done properly, there will be performance degradation.
- An outdoor shielded fiber cable cannot just be laid in a trench. It requires, at minimum, external HDPE pipe surrounding it over the entire length, bricks/ concrete slabs over the fiber cable/ HDPE pipe also extending the entire length through which they are laid, outdoors. This, no need to mention, further increases the cost.
- After installation and also during trouble shooting, the fiber cores need to be tested using testing equipments like OTDR. But these equipments are quite expensive to procure, and if rented, the charges for testing each core could be considerable.