

## CHAPTER—1. WIRELESS COMMUNICATION

---

### INTRODUCTION

Guglielmo Marconi invented the wireless telegraph in 1896. The signals were sent across the Atlantic Ocean to provide continuous contact with ships sailing the English channels. Wireless Communication methods and services have been adopted by people throughout the world. There are various factors responsible for the speedy developments in mobile or wireless Communication and the main factors are digital and RF circuit fabrication, large scale circuit integration, portable radio equipment, smaller, cheaper, and reliable. Digital switching techniques have made easy to use radio Communication networks and it has bright future.

### Basics

- Wireless Communication is the transfer of information over a distance without using electrical conductors or wires.
- The term “wireless” describes the communication in which electromagnetic waves or RF (Radio Frequency) carry a signal over part or the entire communication path. The main reasons for the development of the wireless Communication are:
  - 1) Limitations of conventional mobile telephone system i.e limited service capability, poor service performance and inefficient frequency spectrum.
  - 2) Spectrum efficiency approach considerations should be to achieve to an ideal mobile telephone system. This is possible using single sideband (SSB), to reuse allocated frequency band in different geographic locations and to use spread spectrum or frequency hopped, which generates many codes over a wide frequency band.
  - 3) To match with latest technologies.
- Wireless Communication can be via:
  - 1) Radio frequency communication
  - 2) Microwave communication
  - 3) Infrared (IR) short range communication
- The term “wireless” came into public use to refer to a radio receiver or transceiver. Earlier, it was used in the field of wireless telegraphy and now a days this term is used to describe modern wireless connections such as in cellular networks and wireless broadband internet.
- The wireless communication devices are in the process of a global wireless network. The development of highly reliable, miniature, solid-state radio frequency systems made the wireless communication system to come into existence.
- In 1935, Edwin Armstrong demonstrated frequency modulation (FM) and since then the FM technique is used for the mobile communication system.
- The first aim on wireless was for voice and now the focus is on data. Wireless users use the internet facility but wireless devices have limited display and inputs as compared to fixed devices such as PC.

- The “First - generation” (1G) digital wireless network in North America, used Cellular Digital Packed Data (CDPD) and that provides 19.2 kbps data.
- The “Second - generation” (2G) wireless systems are the Global Systems for Mobile Communication (GSM). Personal Communication Service (PCS) etc. used time division multiplexing TDMA while PCS IS-95 uses code division multiple access (CDMA).
- In third - generation (3G) wideband direct-sequence code division multiple access (DS-SS-CDMA) is being used.
- In fourth - generation (4G) digital, multimedia and high data rates is in use. Fourth - generation (4G) cellular system applications need high speed data rates.

## ADVANTAGES OF WIRELESS COMMUNICATION

1. **Anywhere, Anytime Work:-** Working professionals through wireless communication can access the internet and mobile anywhere, anytime without any problem of wire and cables.
2. **Enhanced Productivity:-** Wired internet or dialup connectivity increases the cost, whereas using wireless internet not only reduces the cost but also it is possible for a student or any person to complete an assignment or work at any time. This ultimately improves Productivity.
3. **Remote Area Connectivity:-** Wireless Communication makes possible for the doctors, engineers and other professionals working in remote areas to keep in touch with each other.
4. **On Demand Entertainment:-** Persons who are unable to spare time from their busy working schedule can have reality programs, online TV shows and internet surfing or download activities on their demand anytime.
5. **Emergency Alerts:-** It is possible to address emergency situations quickly through wireless communication. With the help of wireless communication help and assistance can reach the affected areas in emergency and crisis situation.
6. **Accelerated Business Process:-** Wireless Communication can increase the number of sales opportunities. A single sales person can meet sales goals successfully.
7. **Industrial Use:-** Specialised mobile radio and land line mobile radio can be used in certain industrial situations for the safety.
8. **Worldwide Connectivity:-** Wireless Communication is the best technology to connect billions of people worldwide.
9. **Multiple Usage And Low Interference:-** Cell handsets can continuously change frequencies as per the requirement. Multiple Usage and low Interference rates are achieved through the use of low power transmitters.
10. **Device Mobility:-** In the wireless communication there is Mobility of the devices with in the environment. It is a simple matter to add or remove a device from the system without any disturbance to the remaining devices.
11. **Easier Transmission:-** Data transmission is easier in wireless communication.
12. **Cost:-** Setting up the cell sites and the cost of running and maintaining a wireless based communication is very less as compared to the Wired communication system.

13. **Other Features/Benefits:-** Internet Surfing, high speed Wi-Fi system, downloading activities, live TV shows, matches etc. are available on one device with wireless communication.

### **Wireless Communication System Definatio:-**

To understand the subject “Wireless Communication”, it is better to go through some important definitions, which we will come across frequently.

- 1) **Base Station :** It is a Fixed mobile radio system and it is used for radio Communication with mobile stations. Base stations are situated at the center on the edge of coverage area.
- 2) **Transceiver :** It is a device which is capable to transmit and receive the signal at the same time.
- 3) **Mobile Station :** It is a station in the cellular radio service and it is used in motion at unspecified locations.
- 4) **Control Channel :** This Channel is used for the control of call set up, call request, call initiate and other signal for control purposes.
- 5) **Forward Channel :** This channel is used for the transmission of signal from the base station to mobile.
- 6) **Reverse Channel :** Function of the reverse Channel is opposite of the forward channel i.e it's function is to transmit signal from mobile to base station.
- 7) **Half Duplex Systems :** These systems allows one way communication i.e user can only either transmit or receive information.
- 8) **Full Duplex Systems :-** Communication system which allows two way communication i.e user can transmit and receive the information at the same time, using this system.
- 9) **Hand Off :** It is the process of transferring the call of a mobile station from one channel or base station to another.
- 10) **Mobile Switching Center (MSC) :-** Its function is to provide route to the calls in large service area.
- 11) **Subscriber :-** It is the name given to the user who pays subscription charges for using mobile communication system.
- 12) **Page :-** It is the brief message which is sent over the entire service area simultaneously by many base stations.
- 13) **Simplex Systems :-** These systems provide one way communication.
- 14) **Roamer :-** It is basically a mobile station and it operates in a service area other than that for which services have been prescribed.
- 15) **Mobile :-** It is the term used to classify any radio channel that can be moved during operation
- 16) **Mobile or users :-** Collective group of users in a wireless system are called mobiles or users.
- 17) **IMTS :-** This term is used for improved mobile telephone services.
- 18) **CDMA :-** This term is used for code division multiple access.
- 19) **MIN :-** This term is used for the mobile identification number i.e it is user mobile number.

20) **PSTN :-** This term is used for the public switched telephone network.

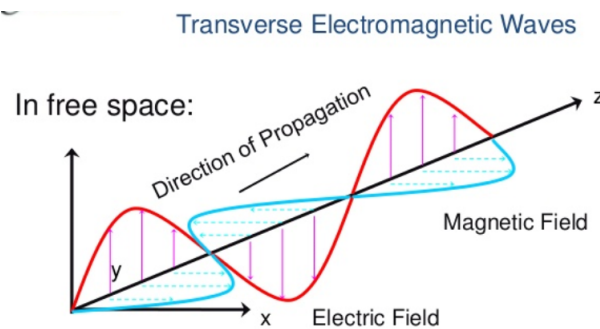
## ELECTROMAGNETIC WAVES

- If electrons are moving in a wire, say a radio transmitting antenna, they will set up changing electric field. The changing electric fields correspondingly set up changing magnetic fields.
- The changing electric and magnetic fields propagated through the space and form ELECTROMAGNETIC waves are also called electromagnetic radiation.

- In waves the fields are other.

direction propagate

in" free space.

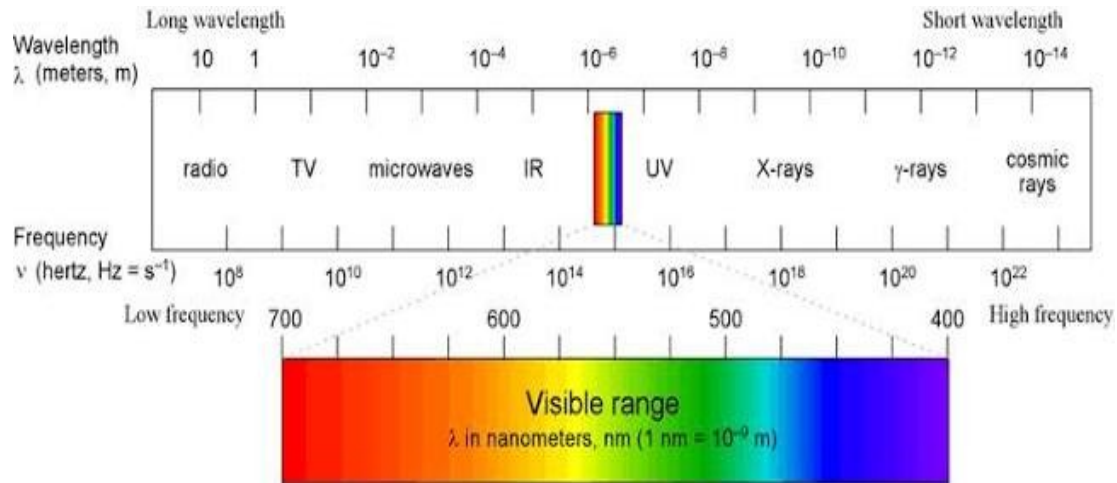


Electromagnetic electric and magnetic mutually perpendicular to each other. They are perpendicular to the direction in which waves or travel. Fig. Shows "transverse electromagnetic wave

- The electric and magnetic fields oscillate together between maximum positive and maximum negative values. The frequency of these oscillations and wavelength of the wave determines whether electromagnetic wave is visible light, 'ultraviolet light, infrared light, radio waves, X-rays or gamma rays.
- The electromagnetic spectrum is just a name given to a bunch of radiations.
- Electromagnetic radiations are visible light, radio waves, microwaves, infrared, ultraviolet light, X-rays and gamma rays.

## ELECTROMAGNETIC FREQUENCY SPECTRUM

- Frequency is simply the number of times a periodic motion, such as a sine wave of

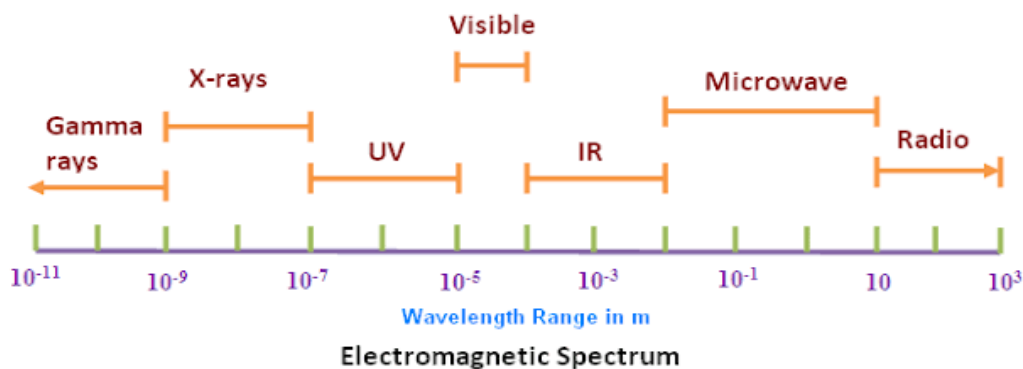


voltage of current, occur in a given period of time.

- The electromagnetic frequency spectrum is divided into subsections or bands and each band is having a different name and boundary.
- The international Telecommunication Union (ITU) and the Federal Communication Commission (FCC) assign frequencies and communication services for free space radio propagation.
- Fig. Shows the useful electromagnetic frequency spectrum.

- The total usable radio frequency (RF) spectrum is divided into narrow frequency bands and several of these bands are further subdivided into various types of services.
- The frequency spectrum is divided as:
  - Extremely Low frequencies (ELFS) :** Extremely low frequency (ELF) is the ITU designation for electromagnetic radiation (radio waves) with frequencies from 3 to 30 Hz.

2. **Voice frequencies (VFs)** : A voice frequency (VF) or voice band is one of the frequencies, within part of the audio range, that is being used for the transmission of speech. In telephony, the usable voice frequency band ranges from approximately 300 Hz to 3000 Hz.
3. **Very low frequencies (VLFs)** : Very low frequency or VLF is the ITU designation for radio frequencies (RF) in the range of 3 to 30 kilohertz (kHz).
4. **Low frequencies (LFs)** : Low frequency (low freq) or LF is the ITU designation for radio frequencies (RF) in the range of 30 kilohertz (kHz)–300 kHz.
5. **Medium frequencies (MFs)** : Medium frequency (MF) is the ITU designation for radio frequencies (RF) in the range of 300 kilohertz (kHz) to 3 megahertz (MHz).
6. **High frequencies (HF)** : High frequency (HF) is the ITU designation for the range of radio frequency electromagnetic waves (radio waves) between 3 and 30 megahertz (MHz).
7. **Very High frequencies (VHF)** : Very high frequency (VHF) is the ITU designation for the range of radio frequency electromagnetic waves (radio waves) from 30 to 300 megahertz (MHz)
8. **Ultrahigh frequencies (UHF)** : Ultra high frequency (UHF) is the ITU designation for radio frequencies in the range between 300 megahertz (MHz) and 3 gigahertz (GHz).
9. **Super High frequencies (SHFs)**: Super high frequency (SHF) is the ITU designation for radio frequencies (RF) in the range between 3 and 30 gigahertz (GHz).
10. **Extremely High frequencies (EHFs)** : Extremely high frequency (EHF) is the



International Telecommunication Union (ITU) designation for the band of radio frequencies in the electromagnetic spectrum from 30 to 300 gigahertz (GHz).

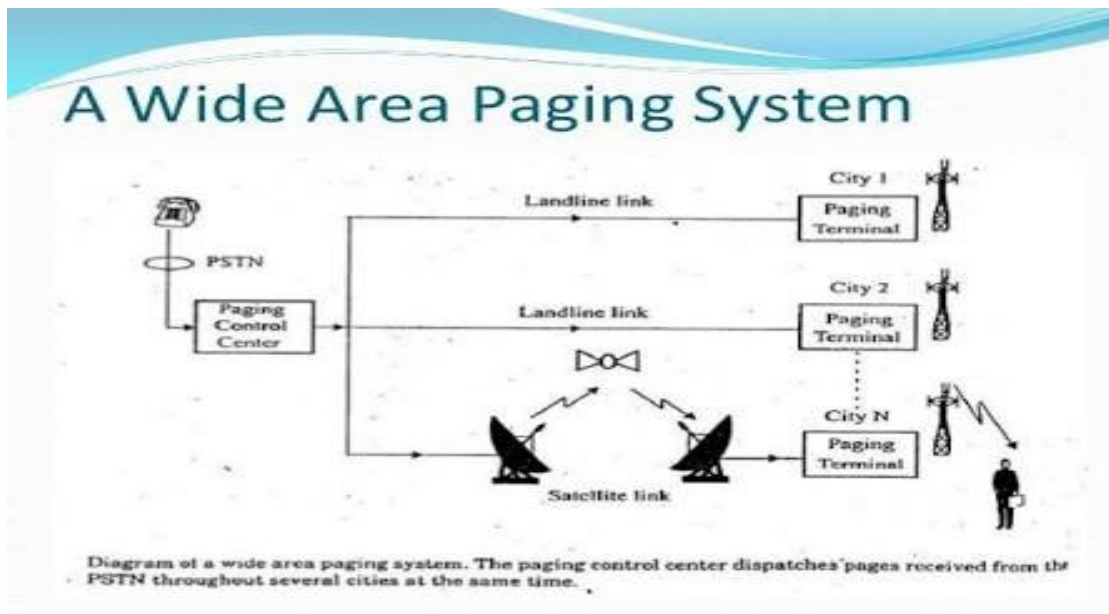
11. **Infrared (IR)** : IR signals are in the 0.3 THz to 300 THz range and these are not generally referred to as radio waves.
12. **Visible light** : The visible spectrum is the portion of the electromagnetic spectrum that is visible to the human eye. (0.3 PHz to 3PHz).
13. **Ultraviolet, X-rays, Gamma rays and cosmic rays** : These waves have very little use in electronics and communication.

## ELECTROMAGNETIC WAVELENGTH SPECTRUM

## **PAGER**

**Paging System :** Paging Systems are wireless communication systems that are designed to send brief messages to a subscriber. ... The Paging System transmits the message also known as Page, along with Paging System access number, throughout the service area using Base Station, which broadcast the page on a radio link.

- Paging Systems are of two types :
  1. Simple Paging System
  2. Wide Area Paging System
- 1) **Simple Paging System :** Simple paging system covers a limited range of 2 to 5 km or confined to a building.
- 2) **Wide area paging systems :** Wide area paging system provide worldwide coverage and a paging system consists of a network of telephone lines, base station transmitters and large radio towers. Towers simultaneously broadcast a page from each base station and this is called simulcasting. Simulcasting transmitters may be located within the same service area or in different cities or countries.



## CORDLESS TELEPHONE

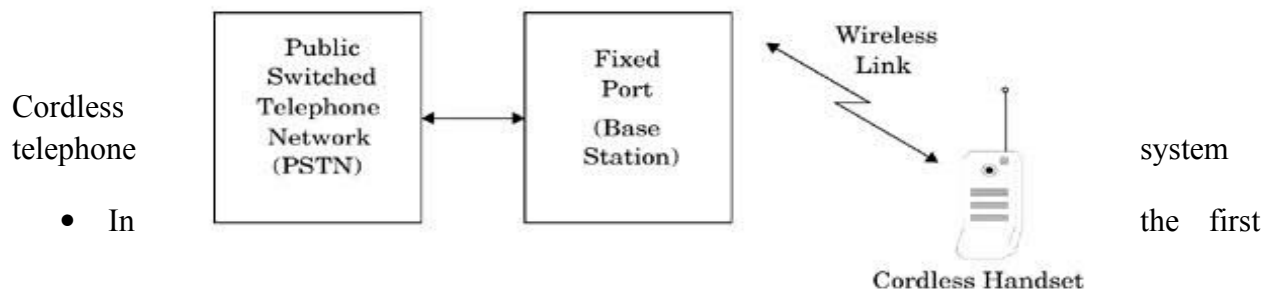
### INTRODUCTION

A cordless telephone or portable telephone is a telephone in which the handset is portable and communicates with the body of the phone by radio, instead of being attached by a cord. The base station is connected to the telephone network through a telephone line as a corded telephone is, and also serves as a charger to charge the handset's batteries. The range is limited, usually to the same building or some short distance from the base station.

### History



- In 1980, a number of manufacturers, including Sony, introduced cordless telephone. They used a base station that was connected to a telephone line and a handset with microphone, speaker, keypad and telescoping antenna.
- The handset contained a battery, typically NiCd. The base unit was powered by household current. The base unit included a charging cradle on which the handset rested when not in use.
- VTech, Uniden, Philips, Gigaset and Panasonic are the main cordless telephone manufacturing companies.
- Cordless telephone system are Full Duplex Systems and use radio signal to connect a portable handset to a dedicated base station. Base station is connected to a dedicated telephone line with a specific telephone number on the public switched telephone network (PSTN).
- Fig Shows a cordless telephone system.



generation cordless telephone systems, manufactured in the 1980s, the portable unit communicates only to the dedicated base unit for the distance of a few tens of meters. Early cordless telephone operate solely as extension telephones to a transceiver connected to a subscriber line on the PSTN.

- Second generation cordless telephones recently introduced allow subscriber to use their handsets at many outdoor locations.
- Modern cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged and then respond to the page using cordless telephone.
- Cordless telephone systems can be used for the limited range and it is not possible to maintain a cell if the travels outside the range of the base station. Second generation cordless can cover ranges up to a few hundred of meters.

## PERFORMANCE

**Limitations of Cordless telephone :** The main constraints (limitations) of cordless telephone :

1. **Sidetone :** Hearing one's own voice echoed in the receiver speaker.
2. **Background Noise :** There is a noticeable amount of constant background noise. This is not the Interference from outside sources but this is the noise with in the cordless telephone system.
3. **Frequency Response :**
  - a) Frequency response is not full as compared to the frequency response available in a wired landline telephone.
  - b) Performance of the cordless telephone depends upon the signal strength, antenna quality, modulation method and Interference.
  - c) Most of the manufacturers claim a range of about 30 m (100 ft) for their 2.4 GHz and 5.8 GHz systems.
  - d) Cordless telephone in the early 21st century are of digital type. Digital technology provides clear sound.
  - e) The most common technology used is DECT (2.4 GHz) or 802.11 a/b/g standard based wireless LAN technology.

## CELLULAR TELEPHONE SYSTEM

- Cellular telephone system provides a wireless connection to the public switched telephone network (PSTN) for a user within the radio range of the system.
- These systems can accommodate large number of users over a large geographic area, using limited frequency spectrum.
- Cellular telephone system provides high quality of services in comparison to landline telephone system. Not only high quality but also high capacity is feasible (possible) by limiting the coverage area of each base station transmitter to a small geographic area called a cell. This enables the same radio channels, may be used by another base station located at some distance away. This process is carried using highly developed and complex system called as hand Off.
- Fig Shows a Basic cellular telephone system.

---

## Cellular telephone system

---

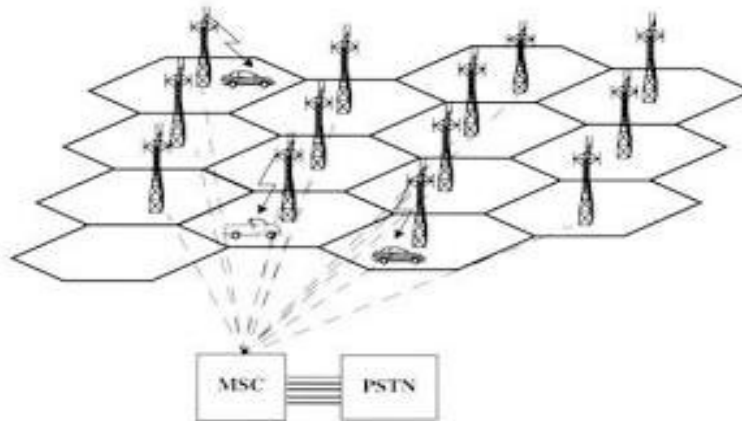


Figure 1.5 A cellular system. The towers represent base stations which provide radio access between mobile users and the mobile switching center (MSC).

---

Basic cellular system consists of :

1. Mobile stations
2. Base stations
3. Mobile telephone switching office (MTSO)

**Mobile Station :** A mobile station (MS) comprises all user equipment and software needed for communication with a mobile network.

**Base Station :** A base station is a fixed point of communication for customer cellular phones on a carrier network.

The base station is connected to an antenna (or multiple antennae) that receives and transmits the signals in the cellular network to customer phones and cellular devices. That equipment is connected to a mobile switching station that connects cellular calls to the public switched telephone network (PSTN). A single base station may extend the service providers network by blocks or by miles. Base stations are company-specific. However, a single site may host multiple base stations from competing telecommunication companies.

**Mobile telephone Switching Office (MTSO) :** The Mobile Telephone Switching Office (MTSO) is the mobile equivalent to a PSTN Central Office. The MTSO contains the switching

equipment or Mobile Switching Center (MSC) for routing mobile phone calls. It also contains the equipment for controlling the cell sites that are connected to the MSC.

### Communication Between the Base Station And Mobiles

- Communication between the base station and mobiles is defined by a standard common air interface (CAI).
- CAI specifies the 4-channel and these are :
  - 1) **Forward voice channel (FVC)** : The forward control channel (FVC) is for the voice transmission from the base station to mobiles.
  - 2) **Reverse voice channel (RVC)** : This channel is used the voice transmission from mobiles to the base station.
  - 3) **Forward control channel (FCC)** : They are responsible for initiating the call from base station to mobile.
  - 4) **Reverse control channel (RCC)** : They are responsible for initiating the call from mobile to base station.

### How a Cellular Telephone Call is Made

Fig. Shows how a Cellular Telephone Call is Made.

- When a cellular phone is turned on and is not yet engaged in a call, it first scans the group of forward control channels to find out the one with the strongest signal. Control channels are scanned in the search of the strongest base station.
- When a telephone call is placed to a mobile user, the mobile switching center (MSC) sends the request to all the base stations in the cellular system.
- The mobile identification number (MIN), which is the subscribers telephone number, is sent as a paging message over all of the forward control channels throughout the cellular system.
- The mobile receive the paging message sent by the base station. The received message is monitored and responds by identifying itself over the reverse control channel.
- The base station sends the acknowledgement sent by the mobile and informs MSC regarding this.
- The MSC, then instructs the base station to move the call to an unused voice channel within the cell. In each cell base station between ten to sixty voice channels and one control channel is used.
- At this point, the base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair. At this stage another data message called an alert

Standards	CT2, DECT, PACS, GSM	POCSAG, FLEX, GSC	AMPS, NAMPS, USDC, IS-95
Multiple Access	FDMA, TDMA	Simplex	FDMA, CDMA, TDMA
Used For	Short distance	Country to country	Within network

signal is transmitted over the forward voice channel to instruct the mobile to ring. This ultimately asks the mobile user to answer the phone.

## **COMPARISON OF CORDLESS TELEPHONE SYSTEM AND CELLULAR TELEPHONE SYSTEM**

<b>Parameters</b>	<b>Cordless Telephony</b>	<b>Paging System</b>	<b>Cellular System</b>
Description	Cordless telephone is telephone with wireless handset that communicates using radio waves with base station	A paging system gives indications like musical alerts, name calling, audio signals to a particular individual whom system wants at telephone. These indications are given to radio receiver carried in the individual's pocket.	A cellular system is a radio network distributed over areas called cells, each served by at least one transceiver known as base station.

Parameters	Cordless Telephony	Paging System	Cellular System
Standards	CT2, DECT, PACS, GSM	POCSAG, FLEX, GSC	AMPS, NAMPS, USDC, IS-95
Multiple Access	FDMA, TDMA	Simplex	FDMA, CDMA, TDMA
Used For	Short distance	Country to country	Within network
Mobile station	Mobile station coverage area is low. Fewer infrastructures are required. Mobile station complexity is moderate and hardware cost is low.	Mobile,station coverage area is high. High infrastructures are required. Mobile,station complexity is low and hardware cost is low.	Mobile station coverage area is high. High infrastructures are required. Mobile station complexity is high and hardware cost is moderate
Base station	Mobile station coverage area is low. Fewer infrastructures are required. Mobile station complexity is low and hardware cost is moderate.	Mobile station coverage area is high. High infrastructures are required. Mobile station complexity is high and hardware cost is high.	Mobile station coverage area is high. High infrastructures are required. Mobile station complexity is high and hardware cost is high.

## CHAPTER 2 CELLULAR TELEPHONE SYSTEM

### **First Generation**

1G refers to the first generation of [wirelesscellulartechology](#) ([mobiletelecommunications](#)). These are the [analog](#) telecommunications standards that were introduced in the 1980s and continued until being replaced by [2Gdigital telecommunications](#). The main difference between the two mobile cellular systems (1G and 2G), is that the radio signals used by 1G networks are analog, while 2G networks are digital.

Although both systems use digital signalling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G is only [modulated](#) to higher frequency, typically 150 MHz and up. The inherent advantages of digital technology over that of analog meant that 2G networks eventually replaced them almost everywhere.

### **Second generation**

2G (or 2-G) is short for second-generation [cellulartechology](#). Second-generation 2G cellular networks were commercially launched on the [GSM](#) standard in [Finland](#) by [Radiolinja](#) (now part of [Elisa Oyj](#)) in 1991.<sup>[1]</sup> 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 enabling far greater wireless penetration levels; and 2G introduced data services for mobile, starting with [SMS](#) text messages. 2G technologies enabled the various networks to provide the services such as text messages, picture messages, and MMS (multimedia messages). All text messages sent over 2G are digitally encrypted, allowing the transfer of data in such a way that only the intended receiver can receive and read it.

After 2G was launched, the previous mobile wireless network systems were retroactively dubbed [1G](#). While radio signals on 1G networks are [analog](#), radio signals on 2G networks are [digital](#). Both systems use digital signalling to connect the radio towers (which listen to the devices) to the rest of the mobile system.

2G has been superseded by newer technologies such as [2.5G](#), [2.75G](#), [3G](#), and [4G](#); however, 2G networks are still used in most parts of the world.<sup>[citation needed]</sup>

With [General Packet Radio Service](#) (GPRS), 2G offers a theoretical maximum [transfer speed](#) of 50 Kbit/s (40 Kbit/s in practice).<sup>[2][not in citation given]</sup> With [EDGE](#) (Enhanced Data Rates for GSM Evolution), there is a theoretical maximum transfer speed of 1 Mbit/s (500 Kbit/s in practice).<sup>[2]</sup>  
<sup>[not in citation given]</sup>

The most common 2G technology was the [time division multiple access](#) (TDMA)-based [GSM](#), originally from Europe but used in most of the world outside North America. Over 60 GSM operators were also using [CDMA2000](#) in the 450 MHz frequency band (CDMA450) by 2010.

### **Third generation**

**3G**, short for third generation, is the third generation of [wireless](#) mobile telecommunications technology. It is the upgrade for [2G](#) and [2.5GGPRS](#) networks, for faster internet speed. This is based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (IMT-2000) specifications by the [International Telecommunication Union](#). 3G finds application in wireless voice telephony, [mobile Internet](#) access, fixed wireless Internet access, video calls and mobile TV.

3G telecommunication networks support services that provide an information transfer rate of at least 0.2 [Mbit/s](#). Later 3G releases, often denoted [3.5G](#) and [3.75G](#), also provide [mobile broadband](#) access of several [Mbit/s](#) to [smartphones](#) and [mobile modems](#) in laptop computers. This ensures it can be applied to wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV technologies.

A new generation of cellular standards has appeared approximately every tenth year since [1G](#) systems were introduced in 1981/1982. Each generation is characterized by new frequency bands, higher data rates and non-backward-compatible transmission technology. The first 3G networks were introduced in 1998 and fourth generation [4G](#) networks in 2008.

### **Fourth generation**

**4G** is the fourth generation of [broadbandcellular network](#) technology, succeeding [3G](#). A 4G system must provide capabilities defined by [ITU](#) in [IMT Advanced](#). Potential and current applications include amended [mobile web](#) access, [IP telephony](#), gaming services, [high-definitionmobile TV](#), [video conferencing](#), and [3D television](#).

The first-release [Long Term Evolution](#) (LTE) standard (a 4G candidate system) has been commercially deployed in Oslo, Norway, and Stockholm, Sweden since 2009. It has, however, been debated whether first-release versions should be considered 4G, as discussed in the [technical understanding](#) section below.



## **Fifth generation**

**5th generation wireless systems**, abbreviated **5G**, are improved wireless network technologies deploying in 2018 and later.<sup>[1]</sup> The primary technologies include: [Millimetre wave](#) bands (26, 28, 38, and 60 GHz) offer performance as high as 20 gigabits per second<sup>[2]</sup>; Massive [MIMO](#) (Multiple Input Multiple Output - 64-256 antennas) offers performance "up to ten times current 4G networks;"<sup>[3][4][5]</sup> "Low-band 5G" and "Mid-band 5G" use frequencies from 600 MHz to 6 GHz, especially 3.5-4.2 GHz.<sup>[6][7]</sup>

The [3GPP](#) Release 15<sup>[8]</sup> of December, 2017 is the most common definition of 5G. Some prefer the more rigorous [ITU](#) IMT-2020 definition,<sup>[9]</sup> which only includes the high-frequency bands for much higher speeds.

The millimetre wave systems are designed for 20 gigabit peak downloads.<sup>[10]</sup> Their estimated median bandwidth is 3.5 gigabits.<sup>[11]</sup> The estimated median bandwidth for the band of 3.5 GHz-4.2 GHz with additional MIMO antennas is 490 megabits.<sup>[12]</sup> In mid-band frequencies, the modelled 5G speed is very similar to the 4G LTE speed, assuming the same bandwidth and antenna configuration.<sup>[13]</sup>

Most large mobile networks are testing all three approaches. Verizon<sup>[14]</sup> and AT&T<sup>[15]</sup> announced millimetre wave commercial deployments for 2018. Softbank deployed Massive MIMO beginning in 2016. In 2018 T-Mobile announced low band 5G for 30 cities.<sup>[16]</sup> China Telecom's initial 5G buildout will be mid-band.<sup>[17]</sup>

As of 2017, development of 5G is being led by several companies, including [Samsung](#), [Intel](#), [Qualcomm](#), [Nokia](#), [Huawei](#), [Ericsson](#), [ZTE](#) and others.<sup>[18]</sup> Although 5G is planned to be commercially available worldwide by 2020, [South Korea](#) demonstrated 5G at the [2018 Winter Olympics](#) for the visitors.

## **CHAPTER 3 CELLULAR CONCEPT**

### **Cellular Concept**

The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. It offered very high capacity in a limited spectrum allocation without any major technological changes. The cellular concept is a system-level idea which calls for replacing a

single, high power transmitter (large cell) with many low power transmitters (small cells), each providing coverage to only a small portion of the service area. Each base station is allocated a portion of the total number of channels available to the entire system, and nearby base stations are assigned different groups of channels so that all the available channels are assigned to a relatively small number of neighboring base stations. Neighboring base stations are assigned different groups of channels so that the interference between base stations (and the mobile users under their control) is minimized. By systematically spacing base stations and their channel groups throughout a market, the available channels are distributed throughout the geographic region and may be reused as many times as necessary so long as the interference between cochannel stations is kept below acceptable levels. As the demand for service increases (i.e., as more channels are needed within a particular market), the number of base stations may be increased (along with a corresponding decrease in transmitter power to avoid added interference), thereby providing additional radio capacity with no additional increase in radio spectrum. This fundamental principle is the foundation for all modern wireless communication systems, since it enables a fixed number of channels to serve an arbitrarily large number of subscribers by reusing the channels throughout the coverage region. Furthermore, the cellular concept allows every piece of subscriber equipment within a country or continent to be manufactured with the same set of channels so that any mobile may be used anywhere within the region.

## The Cellular Concept Frequency Reuse Pattern for $N = 7$

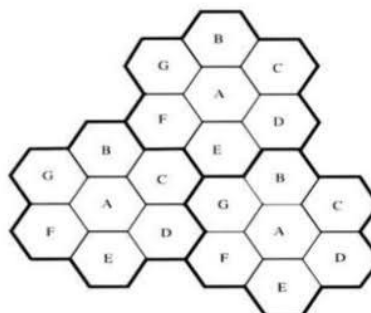
Frequency R

### Frequency Reuse

**Frequency  
Reuse**

Frequency Reuse

Figure 3.1  
same as  
in this or  
each cell



**Figure 3.1** Illustration of the cellular frequency reuse concept. Cells with the same letter use the same set of frequencies. A cell cluster is outlined in bold and replicated over the coverage area. In this example, the cluster size,  $N$ , is equal to seven, and the frequency reuse factor is  $1/7$  since each cell contains one-seventh of the total number of available channels.

- Each cellular base station allocated a group of radio channels within a small geographic area called a cell.

is

- Neighboring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning
- seven groups of channel from A to G
- footprint of a cell - actual radio coverage
- omni-directional antenna v.s. directional antenna
- Hexagonal geometry has
  - exactly six equidistance neighbors
  - the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees.
- Only certain cluster sizes and cell layout are possible.
- The number of cells per cluster,  $N$ , can only have values which satisfy
- Co-channel neighbors of a particular cell, ex,  $i=3$  and  $j=2$ .

## **Interference**

- Sources of interference

- Two major cellular interference
  - co-channel interference
  - adjacent channel interference

### **Co-channel Interference**

- Frequency reuse - there are several cells that use the same set of frequencies
  - co-channel cells
  - co-channel interference
- To reduce co-channel interference, co-channel cell must be separated

by a minimum distance When the size of the cell is approximately the same

- co-channel interference is independent of the transmitted power
- co-channel interference is a function of

R: Radius of the cell

D: distance to the center of the nearest co-channel cell

- Increasing the ratio  $Q=D/R$ , the interference is reduced.

Q is called the co-channel reuse ratio

For a hexagonal geometry

- A small value of Q provides large capacity

- A large value of  $Q$  improves the transmission quality - smaller level of

co-channel interference

- A tradeoff must be made between these two objectives

### Adjacent Channel Interference

Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent channel interference. Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the passband. The problem can be particularly serious if an adjacent channel user is transmitting in very close range to a subscriber's receiver, while the receiver attempts to receive a base station on the desired channel. This is referred to as the near-far effect, where a nearby transmitter (which may or may not be of the same type

that used by the cellular system) captures the receiver of the subscriber. Alternatively, the near-far effect occurs when a mobile close to a base station transmits on a channel close to one being used by a weak mobile. The base station may have difficulty in discriminating the desired mobile user from the "bleedover" caused by the close adjacent channel mobile. Adjacent channel interference can be minimized through careful filtering and channel assignments. Since each cell is given only a fraction of the available channels, a cell need not be assigned channels which are all adjacent in frequency. By keeping the frequency separation between each channel in a given cell as large as possible, the adjacent channel interference may be reduced considerably. Thus instead of assigning channels which form a contiguous band of frequencies within a particular cell, channels are allocated such that the frequency separation between channels in a given cell is maximized. By sequentially assigning successive channels in the frequency band to different cells, many channel allocation schemes are able to separate adjacent channels in a cell by as many as  $N$  channels.

### Power Control for Reducing Interference

In practical cellular radio and personal communication systems, the power levels transmitted by every subscriber unit are under constant control by the serving base stations. This is done to ensure that each mobile transmits the smallest power necessary to maintain a good quality link

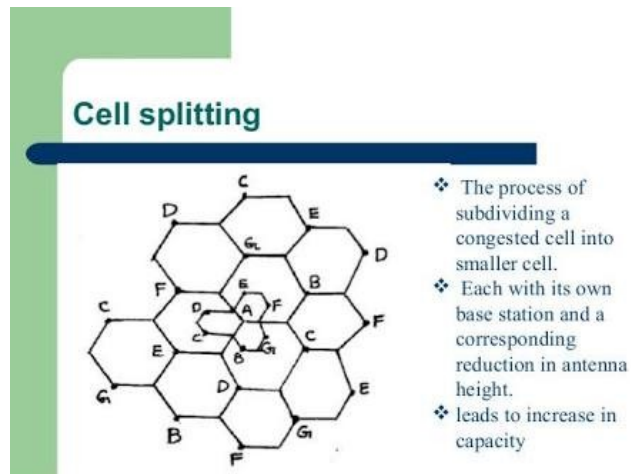
## Improving Coverage and Capacity in Cellular Systems

As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users. At this point, cellular design techniques are needed to provide more channels per unit coverage area. Techniques such as cell splitting, sectoring, and coverage zone approaches are used in practice to expand the capacity of cellular systems. Cell splitting allows an orderly growth of the cellular system. Sectoring uses directional antennas to further control the interference and frequency reuse of channels. The zone microcell concept distributes the coverage of a cell and extends the cell boundary to hard-to-reach places. While cell splitting increases the number of base stations in order to increase capacity, sectoring and zone microcells rely on base station antenna placements to improve capacity by reducing co-channel interference. Cell splitting and zone microcell techniques do not suffer the trunking inefficiencies experienced by sectored cells, and enable the base station to oversee all handoff chores related to the microcells, thus reducing the computational load at the MSC. These three popular capacity improvement techniques will be explained in detail.

### Cell Splitting

Cell splitting is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power. Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused. By defining new cells which have a smaller radius than the original cells and by installing these smaller cells (called microcells) between the existing cells, capacity increases due to the additional number of channels per unit area. Imagine if every cell in were reduced in such a way that the radius of every cell was cut in half. In order to cover the entire service area with smaller cells, approximately four times as many cells would be required. This can be easily shown by considering a circle with radius  $R$ . The area covered by such a circle is four times as large as the area covered by a circle with radius  $R/2$ . The increased number of cells would increase the number of clusters over the coverage region, which in turn would increase the number of channels, and thus capacity, in the coverage area. Cell splitting allows a system to grow by replacing large cells with smaller cells, while not upsetting the channel allocation scheme required to maintain the minimum co-channel reuse ratio  $Q$  between co-channel cells. An example of cell splitting is shown in Figure 3.8. In Figure 3.8, the base stations are placed at corners of the cells, and the area served by base station A is assumed to be saturated with traffic (i.e., the blocking of base station A exceeds acceptable rates). New base stations are therefore needed in the region to increase the number of channels in the area and to reduce the area served by the single base station. Note in the figure that the original base station A has been

surrounded by six new microcells. In the example shown in Figure 3.8, the smaller cells were added in such a way as to preserve the frequency reuse plan of the system. For example, the microcell base station labeled G was placed half way between two larger stations utilizing the same channel set G. This, cell splitting merely scales the geometry of the cluster. In this case, the radius of each new microcell is half that of the original cell.



## Sectoring

cell splitting achieves capacity improvement by essentially rescaling the system. By decreasing the cell radius  $R$  and keeping the co-channel reuse ratio  $D/R$  unchanged, cell splitting increases the number of channels per unit area. However, another way to increase capacity is to keep the cell radius unchanged and seek methods to decrease the  $D/R$  ratio. As we now show, sectoring increases SIR so that the cluster size may be reduced. In this approach, first the SIR is improved using directional antennas, then capacity improvement is achieved by reducing the number of cells in a cluster, thus increasing the frequency reuse. However, in order to do this successfully, it is necessary to reduce the relative interference without decreasing the transmit power. The co-channel interference in a cellular system may be decreased by replacing a single omnidirectional antenna at the base station by several directional antennas, each radiating within a specified sector. By using directional antennas, a given cell will receive interference and transmit with only a fraction of the available co-channel cells. The technique for decreasing co-channel interference and thus increasing system performance by using directional antennas is called sectoring. The factor by which the co-channel interference is reduced depends on the amount of sectoring used. A cell is normally partitioned into three  $120^\circ$  sectors or six  $60^\circ$  sectors

When sectoring is employed, the channels used in a particular cell are broken down into sectorized groups and are used only within a particular sector, as illustrated in Figure 3.10(a) and (b).

Assuming seven-cell reuse, for the case of  $120^\circ$  sectors, the number of interferers in the first tier is

reduced from six to two. This is because only two of the six co-channel cells receive interference with a particular sectorized channel group. Referring to Figure 3.11, consider the interference experienced by a mobile located in the right-most sector in the center cell labeled “5”. There are three cochannel cell sectors labeled “5” to the right of the center cell, and three to the left of the center cell. Out of these six co-channel cells, only two cells have sectors with antenna patterns which radiate

into the center cell, hence a mobile in cell will experience interference on forwardlink from two sectors. The S/I for this case found using (3.8) to be 24.2 is a significant improvement over omnidirectional. Section 3.5, worst case S/I

to be 17 dB. This S/I improvement allows the wireless engineer to then decrease the cluster size  $N$  in order to improve the frequency reuse, and thus the system capacity. In practical systems, further improvement in S/I is achieved by downtilting the sector antennas such that the radiation pattern in the vertical (elevation) plane has a notch at the nearest co-channel cell distance.

## Sectoring

A directional antenna transmits to and receives from only a fraction of total of the co-channel cells. Thus CCI is reduced

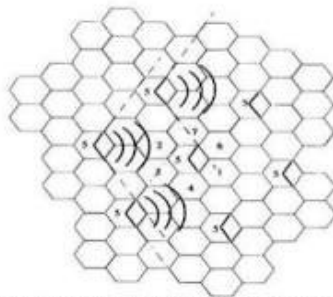


Figure 3.11 Illustration of how 120° sectoring reduces interference from co-channel cells. Out of the 6 co-channel cells in the first tier, only two of them interfere with the center cell. If omnidirectional antennas were used at each base station, all six co-channel cells would interfere with the center cell.

cell, and the center experience the only these resulting can be Equation dB, which

over the case in where the was shown



## Repeaters for Range Extension

Often a wireless operator needs to provide dedicated coverage for hard-to-reach areas, such as within buildings, or tunnels. Radio retransmitters, known as repeaters, are often used to provide such range extension capabilities. Repeaters are bidirectional in nature, and simultaneously send signals to and receive signals from a serving base station. Repeaters work using over-the-air signals, so they may be installed anywhere and are capable of repeating an entire cellular or PCS band. Upon receiving signals from a base station forward link, the repeater amplifies and reradiates the base station signals to the specific coverage region. Unfortunately, the received noise and interference is also reradiated by the repeater on both the forward and reverse link, so care must be taken to properly place the repeaters, and to adjust the various forward and reverse link amplifier levels and antenna patterns. Repeaters can be easily thought of as bidirectional “bent pipes” that retransmit what has been received. In practice, directional antennas or distributed antenna systems (DAS) are connected to the inputs or outputs of repeaters for localized spot coverage, particularly in tunnels or buildings. By modifying the coverage of a serving cell, an operator is able to dedicate a certain amount of the base station’s traffic for the areas covered by the repeater. However, the repeater does not add capacity to the system—it simply serves to reradiate the base station signal into specific locations. Repeaters are increasingly being used to provide coverage into and around buildings, where coverage has been traditionally weak [Rap96], [Mor00]. Many carriers have opted to provide in-building wireless penetration by installing microcells outside of large buildings, and

then installing many repeaters with DAS networks within the buildings. This approach provides immediate coverage into targeted areas, but does not accommodate the increases in capacity that will arise due to increased outdoor and indoor user traffic. Eventually, dedicated base stations within buildings will be needed to accommodate the large number of in-building cellular users. Determining the proper location for repeaters and distributed antenna systems within buildings requires careful planning, particularly due to the fact that interference levels are reradiated into the building from the base station and from the interior of the building back to the base station. Also, repeaters must be provisioned to match the available capacity from the serving base station. Fortunately, software products, such as SitePlanner [Wir01], allow engineers to rapidly determine the best placements for repeaters and the required DAS network while simultaneously computing the available traffic and associated cost of the installation. SitePlanner is protected by US Patent 6,317,599 and other patents. Using SitePlanner, engineers can very quickly determine the proper provisioning for a particular level of range extension

## CHAPTER 4 MULTIPLE ACCESS TECHNIQUES

### Introduction to multiple access

In case of mobile communication, which is a form of wireless communication, the only restraint on communication is the bandwidth restraint which means we have a limited frequency range that we can use for communication. Hence, we must somehow, allow multiple users communicate in the same frequency range.

Multiple Access Techniques are ways to access a single channel by multiple users. They provide multiple access to the channel. A “channel” refers to a system resource allocated to a given mobile user enabling the user to establish communication with the network (other users). Based on the type of channel, we can use a particular multiple access technique for communication.

The types of channel and the corresponding multiple access techniques are listed below:

- **Frequency Channels [FDMA – Frequency Division Multiple Access]** – Frequency band divided into small frequency channels and different channels are allocated to different users – like in FM radio. Multiple users can transmit at the same time but on different frequency channels.
- **Time-slot Within Frequency Bands [TDMA – Time Division Multiple Access]** – Each user is allowed to transmit only in specified time-slots with a common frequency band. Multiple users can transmit at the same frequency band at different times.
- **Distinct Codes [CDMA – Code Division Multiple Access]** – Users may transmit at the same time using the same frequency band but using different codes so that we can decode to identify a particular user.

### Frequency Division Multiple Access

Frequency Division Multiple Access (FDMA) is one of the most common analogue multiple access methods. The frequency band is divided into channels of equal bandwidth so that each conversation is carried on a different frequency (*as shown in the figure below*).

### FDMA Overview

In FDMA method, guard bands are used between the adjacent signal spectra to minimize crosstalk between the channels. A specific frequency band is given to one person, and it will be received by identifying each of the frequency on the receiving end. It is often used in the first generation of analog mobile phone.

### Advantages of FDMA

As FDMA systems use low bit rates (large symbol time) compared to average delay spread, it offers the following advantages –

- Reduces the bit rate information and the use of efficient numerical codes increases the capacity.
- It reduces the cost and lowers the inter symbol interference (ISI)
- Equalization is not necessary.
- An FDMA system can be easily implemented. A system can be configured so that the improvements in terms of speech encoder and bit rate reduction may be easily incorporated.
- Since the transmission is continuous, less number of bits are required for synchronization and framing.

### Disadvantages of FDMA

Although FDMA offers several advantages, it has a few drawbacks as well, which are listed below –

- It does not differ significantly from analog systems; improving the capacity depends on the signal-to-interference reduction, or a signal-to-noise ratio (SNR).
- The maximum flow rate per channel is fixed and small.
- Guard bands lead to a waste of capacity.
- Hardware implies narrowband filters, which cannot be realized in VLSI and therefore increases the cost.

### **Time Division Multiple Access**

Time Division Multiple Access (TDMA) is a digital cellular telephone communication technology. It facilitates many users to share the same frequency without interference. Its technology divides a signal into different timeslots, and increases the data carrying capacity.

#### TDMA Overview

Time Division Multiple Access (TDMA) is a complex technology, because it requires an accurate synchronization between the transmitter and the receiver. TDMA is used in digital mobile radio systems. The individual mobile stations cyclically assign a frequency for the exclusive use of a time interval.

In most of the cases, the entire system bandwidth for an interval of time is not assigned to a station. However, the frequency of the system is divided into sub-bands, and TDMA is used for the multiple access in each sub-band. Sub-bands are known as **carrier frequencies**. The mobile system that uses this technique is referred as the **multi-carrier systems**.

In the following example, the frequency band has been shared by three users. Each user is assigned definite **timeslots** to send and receive data. In this example, user '**B**' sends after user '**A**,' and user '**C**' sends thereafter. In this way, the peak power becomes a problem and larger by the burst communication.

#### FDMA and TDMA

This is a multi-carrier TDMA system. A 25 MHz frequency range holds 124 single chains (carrier frequencies 200) bandwidth of each kHz; each of these frequency channels contains 8 TDMA conversation channels. Thus, the sequence of timeslots and frequencies assigned to a mobile station is the physical channels of a TDMA system. In each timeslot, the mobile station transmits a data packet.

The period of time assigned to a timeslot for a mobile station also determines the number of TDMA channels on a carrier frequency. The period of timeslots are combined in a so-called TDMA frame. TDMA signal transmitted on a carrier frequency usually requires more bandwidth than FDMA signal. Due to the use of multiple times, the gross data rate should be even higher.

#### Advantages of TDMA

Here is a list of few notable advantages of TDMA –

- Permits flexible rates (i.e. several slots can be assigned to a user, for example, each time interval translates 32Kbps, a user is assigned two 64 Kbps slots per frame).
- Can withstand gusty or variable bit rate traffic. Number of slots allocated to a user can be changed frame by frame (for example, two slots in the frame 1, three slots in the frame 2, one slot in the frame 3, frame 0 of the notches 4, etc.).
- No guard band required for the wideband system.
- No narrowband filter required for the wideband system.

#### Disadvantages of TDMA

The disadvantages of TDMA are as follow –

- High data rates of broadband systems require complex equalization.
- Due to the burst mode, a large number of additional bits are required for synchronization and supervision.
- Call time is needed in each slot to accommodate time to inaccuracies (due to clock instability).
- Electronics operating at high bit rates increase energy consumption.
- Complex signal processing is required to synchronize within short slots.

#### **Code Division Multiple Access**

Code Division Multiple Access (CDMA) is a sort of multiplexing that facilitates various signals to occupy a single transmission channel. It optimizes the use of available bandwidth. The technology is commonly used in ultra-high-frequency (UHF) cellular telephone systems, bands ranging between the 800-MHz and 1.9-GHz.

#### CDMA Overview

Code Division Multiple Access system is very different from time and frequency multiplexing. In this system, a user has access to the whole bandwidth for the entire duration. The basic principle is that different CDMA codes are used to distinguish among the different users.

Techniques generally used are direct sequence spread spectrum modulation (DS-CDMA), frequency hopping or mixed CDMA detection (JDCDMA). Here, a signal is generated which

extends over a wide bandwidth. A code called **spreading code** is used to perform this action. Using a group of codes, which are orthogonal to each other, it is possible to select a signal with a given code in the presence of many other signals with different orthogonal codes.

#### How Does CDMA Work?

CDMA allows up to 61 concurrent users in a 1.2288 MHz channel by processing each voice packet with two PN codes. There are 64 Walsh codes available to differentiate between calls and theoretical limits. Operational limits and quality issues will reduce the maximum number of calls somewhat lower than this value.

In fact, many different "signals" baseband with different spreading codes can be modulated on the same carrier to allow many different users to be supported. Using different orthogonal codes, interference between the signals is minimal. Conversely, when signals are received from several mobile stations, the base station is capable of isolating each as they have different orthogonal spreading codes.

The following figure shows the technicality of the CDMA system. During the propagation, we mixed the signals of all users, but by that you use the same code as the code that was used at the time of sending the receiving side. You can take out only the signal of each user.

#### CDMA Capacity

The factors deciding the CDMA capacity are –

- Processing Gain
- Signal to Noise Ratio
- Voice Activity Factor
- Frequency Reuse Efficiency

Capacity in CDMA is soft, CDMA has all users on each frequency and users are separated by code. This means, CDMA operates in the presence of noise and interference.

In addition, neighbouring cells use the same frequencies, which means no re-use. So, CDMA capacity calculations should be very simple. No code channel in a cell, multiplied by no cell.

But it is not that simple. Although not available code channels are 64, it may not be possible to use a single time, since the CDMA frequency is the same.

#### Centralized Methods

- The band used in CDMA is 824 MHz to 894 MHz (50 MHz + 20 MHz separation).
- Frequency channel is divided into code channels.
- 1.25 MHz of FDMA channel is divided into 64 code channels.

#### Advantages of CDMA

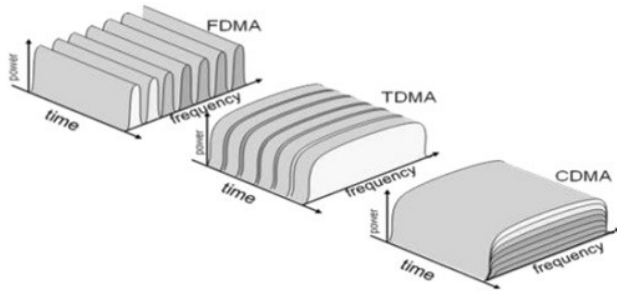
CDMA has a soft capacity. The greater the number of codes, the more the number of users. It has the following advantages –

- CDMA requires a tight power control, as it suffers from near-far effect. In other words, a user near the base station transmitting with the same power will drown the signal latter. All signals must have more or less equal power at the receiver
- Rake receivers can be used to improve signal reception. Delayed versions of time (a chip or later) of the signal (multipath signals) can be collected and used to make decisions at the bit level.
- Flexible transfer may be used. Mobile base stations can switch without changing operator. Two base stations receive mobile signal and the mobile receives signals from the two base stations.
- Transmission Burst – reduces interference.

#### Disadvantages of CDMA

The disadvantages of using CDMA are as follows –

- The code length must be carefully selected. A large code length can induce delay or may cause interference.
- Time synchronization is required.
- Gradual transfer increases the use of radio resources and may reduce capacity.
- As the sum of the power received and transmitted from a base station needs constant tight power control. This can result in several handovers.



## **Spread Spectrum Multiple Access**

The multiple access technique in spread spectrum networks usually refers to the ability of certain kinds of signals to coexist in the same frequency and time space with an acceptable level of mutual interference. The use of pseudorandom or pseudo noise (PN) waveforms in a wireless network is motivated largely by the desire to achieve good performance in fading multipath channels and the ability to operate multiple links with pseudo-orthogonal waveforms using spread spectrum multiple access. Typically, a RAKE receiver achieves multipath diversity by exploiting the large bandwidth inherent in spread spectrum systems. Unlike FDMA and TDMA, every user in a SSMA system is allocated the full bandwidth all the time.

## **SPREAD SPECTRUM COMMUNICATIONS**

Spread spectrum has been used in many military applications including ant jamming, ranging and secure communications. It refers to signalling schemes which are based on some form of coding (that is not a function of the transmitted information) and which use a bandwidth that is several orders of magnitude greater than the information rate. The bandwidth expansion is achieved using a pseudo noise (PN) code that converts a narrowband signal into a noise-like signal before transmission. The PN code is a special sequence of bits which are called chips because they represent small sections of a data bit. The sequence repeats itself after a finite amount of time. This sequence possesses desirable correlation properties (i.e., strong autocorrelation compared with itself and low cross correlation when compared with other codes) that enable a spread spectrum receiver to recover the intended information signal even when other users are transmitting using the same bandwidth at the same time.

Spread spectrum is more resistant to multipath effects and more tolerant of interference. They are primarily interference (or power) limited rather than bandwidth limited. Since spread spectrum spreads the energy over a large bandwidth, the energy per unit frequency is correspondingly reduced by the same factor. Hence, the interference produced is significantly smaller as compared to narrowband systems. There is a fundamental difference between the bandwidth expansion due to coding and that due to spectrum spreading. Spectrum spreading plays no role in



increasing channel capacity but can perform other useful roles such as providing low probability of interception of the signal, good electromagnetic capability, and a multiple access capability.

There are generally two types of SSMA techniques:

- frequency-hopped spread spectrum (FHSS)
- direct-sequence spread spectrum (DSSS).

### **Frequency hopping Spread Spectrum**

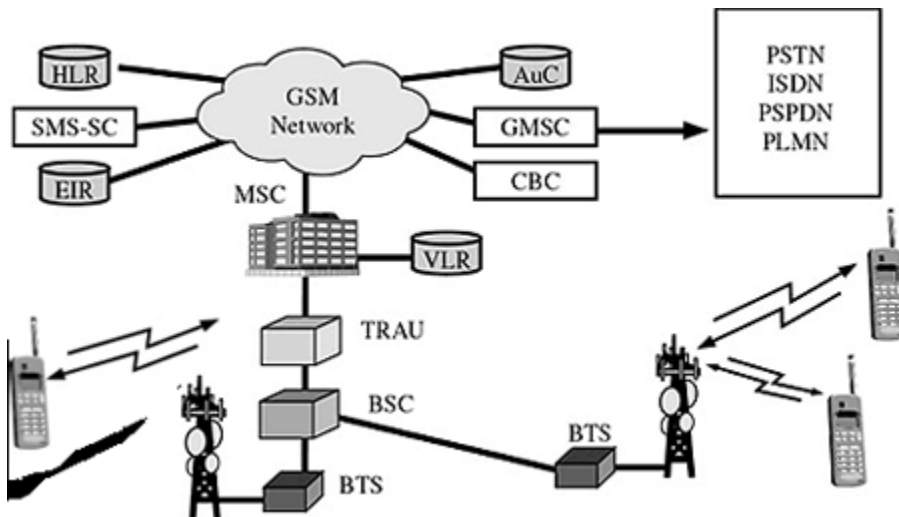
**Frequency-hopping spread spectrum (FHSS)** is a method of transmitting radio signals by rapidly switching a [carrier](#) among many [frequency channels](#), using a [pseudorandom](#) sequence known to both [transmitter](#) and [receiver](#). It is used as a [multiple access method](#) in the [code division multiple access](#) (CDMA) scheme **frequency-hopping code division multiple access (FH-CDMA)**.

FHSS is a wireless technology that spreads its signal over rapidly changing frequencies. Each available frequency band is divided into sub-frequencies. Signals rapidly change ("hop") among these in a pre-determined order. Interference at a specific frequency will only affect the signal during that short interval. FHSS can, however, cause interference with adjacent [direct-sequence spread spectrum](#) (DSSS) systems. A sub-type of FHSS used in [Bluetooth](#) wireless data transfer is adaptive frequency hopping spread spectrum (AFH).

## CHAPTER 5 MOBILE COMMUNICATION SYSTEM

### **GSM (Global System for Mobile Communications, originally Groupe Spécial Mobile)**

GSM (Global System for Mobile Communications, originally Groupe Spécial Mobile) is a standard developed by the European Telecommunications Standards Institute (ETSI) to describe the protocols for second-generation digital cellular networks used by mobile devices such as tablets, first deployed in Finland in December 1991.[2] As of 2014, it has become the global standard for mobile communications – with over 90% market share, operating in over 193 countries and territories.



2G networks developed as a replacement for first generation (1G) analog cellular networks, and the GSM standard originally described as a digital, circuit-switched network optimized for full duplex voice telephony. This expanded over time to include data communications, first by circuit-switched transport, then by packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution, or EGPRS).

Subsequently, the 3GPP developed third-generation (3G) UMTS standards, followed by fourth-generation (4G) LTE Advanced standards, which do not form part of the ETSI GSM standard.

"GSM" is a trademark owned by the GSM Association. It may also refer to the (initially) most common voice codec used, Full Rate.

### **Global System for Mobile Communications (GSM) services**

are a standard collection of applications and features available to mobile phone subscribers all over the world. The GSM standards are defined by the 3GPP collaboration and implemented in hardware and software by equipment manufacturers and mobile phone operators. The common standard makes it possible to use the same phones with different companies' services, or even roam into different countries. GSM is the world's most dominant mobile phone standard.

The design of the service is moderately complex because it must be able to locate a moving phone anywhere in the world, and accommodate the relatively small battery capacity, limited input/output capabilities, and weak radio transmitters on mobile devices.

### **BTS (Base Transceiver Station)**

A list of cell broadcast messages (cell IDs) received on an Android smartphone.

**Cell Broadcast/Cell Information (CB)** messaging is a mobile technology feature defined by the ETSI's GSM committee and is part of the GSM standard. It is also known as Short Message Service-Cell Broadcast. (SMS-CB).

Cell Broadcast is designed for simultaneous delivery to multiple users in a specified area. Whereas the Short Message Service-Point to Point (SMS-PP) is a one-to-one and one-to-a-few service (requires multiple SMS messages, as each message can only carry one phone number), Cell Broadcast is a one-to-many geographically focused messaging service. Cell Broadcast messaging is also supported by UMTS.

Cell Broadcast messaging was technologically demonstrated in Paris for the first time in 1997. Some mobile operators use Cell Broadcast for communicating the area code of the antenna cell to the mobile user (via channel 050), for nationwide or citywide alerting, weather reports, mass messaging, location-based news, etc. Not all operators have the Cell Broadcast messaging function activated in their network yet, and many handsets do not have the capability to support cell broadcast.

Cell Broadcast is a technology that allows a text or binary message to be defined and distributed to all mobile terminals connected to a set of cells.

Thus, one Cell Broadcast message can reach a large number of terminals[a] at once. In other words, Cell Broadcast messages are directed to radio cells, rather than to a specific terminal. A Cell Broadcast message is an unconfirmed push service, meaning that the originator of the message does not know who has received the message, allowing for services based on anonymity. Mobile telephone user manuals describe how the user can switch the receiving of Cell Broadcast messages on or off, to eliminate unwanted messages or extend battery life.

**Mobile phone tracking** is the ascertaining of the position or location of a mobile phone, whether stationary or moving. Localization may occur either via multilateration of radio signals between (several) cell towers of the network and the phone, or simply via GPS. To locate a mobile phone using multilateration of radio signals, it must emit at least the roaming signal to contact the next nearby antenna tower, but the process does not require an active call. The Global System for Mobile Communications (GSM) is based on the phone's signal strength to nearby antenna masts. [1]

**Mobile positioning may include location-based** services that disclose the actual coordinates of a mobile phone, which is a technology used by telecommunication companies to approximate the location of a mobile phone, and thereby also its user

**Multimedia Messaging Service (MMS)** is a standard way to send messages that include multimedia content to and from a mobile phone over a cellular network. Users and providers may refer to such a message as a PXT, a picture message, or a multimedia message.[1] The MMS standard extends the core SMS (Short Message Service) capability, allowing the exchange of text messages greater than 160 characters in length. Unlike text-only SMS, MMS can deliver a

variety of media, including up to forty seconds of video, one image, a slideshow[2] of multiple images, or audio.

The most common use involves sending photographs from camera-equipped handsets.[citation needed] Media companies have utilized MMS on a commercial basis as a method of delivering news and entertainment content, and retailers have deployed it as a tool for delivering scannable coupon codes, product images, videos, and other information.

The 3GPP and WAP groups fostered the development of the MMS standard, which is now continued by the Open Mobile Alliance (OMA).

**Wireless Application Protocol (WAP)** is a technical standard for accessing information over a mobile wireless network. A WAP browser is a web browser for mobile devices such as mobile phones that uses the protocol. Introduced with much hype in 1999,[1] WAP achieved some popularity in the early 2000s, but by the 2010s it had been largely superseded by more modern standards. Most modern handset internet browsers now fully support HTML, so they do not need to use WAP markup for web page compatibility, and therefore, most are no longer able to render and display pages written in WAP.[2]

Before the introduction of WAP, mobile service providers had limited opportunities to offer interactive data services, but needed interactivity to support Internet and Web applications such as email, stock prices, news and sports headlines. The Japanese i-mode system offered another major competing wireless data protocol.

### **GSM – Architecture, Features & Working**

GSM is a mobile communication modem; it stands for global system for mobile communication (GSM). The idea of GSM was developed at Bell Laboratories in 1970. It is widely used mobile communication system in the world. GSM is an open and digital cellular technology used for transmitting mobile voice and data services operates at the 850MHz, 900MHz, 1800MHz and 1900MHz frequency bands.

GSM system was developed as a digital system using time division multiple access (TDMA) technique for communication purpose. A GSM digitizes and reduces the data, then sends it down

through a channel with two different streams of client data, each in its own particular time slot. The digital system has an ability to carry 64 kbps to 120 Mbps of data rates.

## **GMS Modem**

### **GSM Modem**

There are various cell sizes in a GSM system such as macro, micro, pico and umbrella cells. Each cell varies as per the implementation domain. There are five different cell sizes in a GSM network macro, micro, pico and umbrella cells. The coverage area of each cell varies according to the implementation environment.

## **Time Division Multiple Access**

TDMA technique relies on assigning different time slots to each user on the same frequency. It can easily adapt to data transmission and voice communication and can carry 64kbps to 120Mbps of data rate.

## **GSM Architecture**

A GSM network consists of the following components:

**A Mobile Station:** It is the mobile phone which consists of the transceiver, the display and the processor and is controlled by a SIM card operating over the network.

**Base Station Subsystem:** It acts as an interface between the mobile station and the network subsystem. It consists of the Base Transceiver Station which contains the radio transceivers and handles the protocols for communication with mobiles. It also consists of the Base Station Controller which controls the Base Transceiver station and acts as a interface between the mobile station and mobile switching centre.

**Network Subsystem:** It provides the basic network connection to the mobile stations. The basic part of the Network Subsystem is the Mobile Service Switching Centre which provides access to different networks like ISDN, PSTN etc. It also consists of the Home Location Register and the Visitor Location Register which provides the call routing and roaming capabilities of GSM. It also contains the Equipment Identity Register which maintains an account of all the mobile equipments wherein each mobile is identified by its own IMEI number. IMEI stands for International Mobile Equipment Identity.

**Features of GSM Module:**

Improved spectrum efficiency

International roaming

Compatibility with integrated services digital network (ISDN)

Support for new services.

SIM phonebook management

Fixed dialing number (FDN)

Real time clock with alarm management

High-quality speech

Uses encryption to make phone calls more secure

Short message service (SMS)

The security strategies standardized for the GSM system make it the most secure telecommunications standard currently accessible. Although the confidentiality of a call and secrecy of the GSM subscriber is just ensured on the radio channel, this is a major step in achieving end-to-end security.

**GSM Modem**

A GSM modem is a device which can be either a mobile phone or a modem device which can be used to make a computer or any other processor communicate over a network. A GSM modem requires a SIM card to be operated and operates over a network range subscribed by the network operator. It can be connected to a computer through serial, USB or Bluetooth connection.

A GSM modem can also be a standard GSM mobile phone with the appropriate cable and software driver to connect to a serial port or USB port on your computer. GSM modem is usually preferable to a GSM mobile phone. The GSM modem has wide range of applications in transaction terminals, supply chain management, security applications, weather stations and GPRS mode remote data logging.

### **Working of GSM Module:**

From the below circuit, a GSM modem duly interfaced to the MC through the level shifter IC Max232. The SIM card mounted GSM modem upon receiving digit command by SMS from any cell phone send that data to the MC through serial communication. While the program is executed, the GSM modem receives command 'STOP' to develop an output at the MC, the contact point of which are used to disable the ignition switch. The command so sent by the user is based on an intimation received by him through the GSM modem 'ALERT' a programmed message only if the input is driven low. The complete operation is displayed over 16×2 LCD display.

### **CDMA:**

Code Division Multiple Access (CDMA) is a digital cellular technology used for mobile communication. CDMA is the base on which access methods such as cdmaOne, CDMA2000, and WCDMA are built. CDMA cellular systems are deemed superior to FDMA and TDMA, which is why CDMA plays a critical role in building efficient, robust, and secure radio communication systems.

### **A Simple Analogy**

Let's take a simple analogy to understand the concept of CDMA. Assume we have a few students gathered in a classroom who would like to talk to each other simultaneously. Nothing would be audible if everyone starts speaking at the same time. Either they must take turns to speak or use different languages to communicate.

**The second option is quite similar to CDMA** — students speaking the same language can understand each other, while other languages are perceived as noise and rejected. Similarly, in radio CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only those users associated with a particular code can communicate.

### **Salient Features of CDMA**

CDMA, which is based on the spread spectrum technique has following salient features –

In CDMA, every channel uses the full available spectrum.



Individual conversations are encoded with a pseudo-random digital sequence and then transmitted using a wide frequency range.

**CDMA** consistently provides better capacity for voice and data communications, allowing more subscribers to connect at any given time.

CDMA is the common platform on which 3G technologies are built. For 3G, CDMA uses 1x EV-DO and EV-DV.

### **Difference Between GSM and CDMA**

GSM (Global System for Mobile Communication) and CDMA (Code Division Multiple Access) are two dominant technologies for mobile communication. These two technologies differ in the way calls and data travel over the mobile phone networks take place. On comparing both the technologies GSM has some limitation when the call quality is concerned but still has more flexibility and an easy implementation relative to the CDMA technology. The major difference between the two lies in terms of the technology they use, security factors, their global reach and the data transfer speeds.

#### **1. Technology**

The CDMA is based on spread spectrum technology which makes the optimal use of available bandwidth. It allows each user to transmit over the entire frequency spectrum all the time. On the other hand GSM operates on the wedge spectrum called a carrier. This carrier is divided into a number of time slots and each user is assigned a different time slot so that until the ongoing call is finished, no other subscriber can have access to this. GSM uses both Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) for user and cell separation. TDMA provides multiuser access by chopping up the channel into different time slices and FDMA provides multiuser access by separating the used frequencies.

#### **2. Security**

More security is provided in CDMA technology as compared with the GSM technology as encryption is inbuilt in the CDMA. A unique code is provided to every user and all the conversation between two users are encoded ensuring a greater level of security for CDMA

users. The signal cannot be detected easily in CDMA as compared to the signals of GSM, which are concentrated in the narrow bandwidth. Therefore, the CDMA phone calls are more secure than the GSM calls. In terms of encryption the GSM technology has to be upgraded so as to make it operate more securely.

### **3. Spectrum Frequencies**

The CDMA network operates in the frequency spectrum of CDMA 850 MHz and 1900 MHz while the GSM network operates in the frequency spectrum of GSM 850 MHz and 1900 MHz.

### **4. Global Reach**

GSM is in use over 80% of the world's mobile networks in over 210 countries as compared to CDMA. CDMA is almost exclusively used in United States and some parts of Canada and Japan. As the European Union permissions GSM use, so CDMA is not supported in Europe. In North America, especially in rural areas, more coverage is offered by CDMA as compared to GSM. As GSM is an international standard, so it's better to use GSM in international roaming. GSM is in use by 76% of users as compared to CDMA which is in use by 24% users.

### **5. Data Transfer Rate**

CDMA has faster data rate as compared to GSM as EVDO data transfer technology is used in CDMA which offers a maximum download speed of 2 mbps. EVDO ready mobile phones are required to use this technology. GSM uses EDGE data transfer technology that has a maximum download speed of 384 kbps which is slower as compared to CDMA. For browsing the web, to watch videos and to download music, CDMA is better choice as compared to GSM. So CDMA is known to cover more area with fewer towers.

### **6. Radiation Exposure**

GSM phones emit continuous wave pulses, so there is a large need to reduce the exposures to electromagnetic fields focused on cell phones with “continuous wave pulses”. On the other hand CDMA cell phones do not produce these pulses. GSM phones emit about 28 times more radiation on average as compared to CDMA phones. Moreover, GSM phones are more biologically reactive as compared to CDMA.

### **Introduction to General Packet Radio Service (GPRS)**

The General Packet Radio Service (GPRS) is a new nonvoice value added service that allows information to be sent and received across a mobile telephone network. It supplements today's Circuit Switched Data and Short Message Service. GPRS is NOT related to GPS (the Global Positioning System), a similar acronym that is often used in mobile contexts.

### **Key User Features of GPRS**

Theoretical maximum speeds of up to 171.2 kilobits per second (kbps) are achievable with GPRS using all eight timeslots at the same time. This is about three times as fast as the data transmission speeds possible over today's fixed telecommunications networks and ten times as fast as current Circuit Switched Data services on GSM networks. By allowing information to be transmitted more quickly, immediately and efficiently across the mobile network, GPRS may well be a relatively less costly mobile data service compared to SMS and Circuit Switched Data.

**GPRS facilitates** instant connections whereby information can be sent or received immediately as the need arises, subject to radio coverage. No dial-up modem connection is necessary. This is why GPRS users are sometimes referred to be as being "always connected". Immediacy is one of the advantages of GPRS (and SMS) when compared to Circuit Switched Data. High immediacy is a very important feature for time critical applications such as remote credit card authorization where it would be unacceptable to keep the customer waiting for even thirty extra seconds.

GPRS facilitates several new applications that have not previously been available over GSM networks due to the limitations in speed of Circuit Switched Data (9.6 kbps) and message length of the Short Message Service (160 characters). GPRS will fully enable the Internet applications you are used to on your desktop from web browsing to chat over the mobile network. Other new applications for GPRS, profiled later, include file transfer and home automation - the ability to remotely access and control in-house appliances and machines.

## **Introduction to Global Positioning Systems GPS**

This page provides an introduction to Geographic Positioning System (GPS). Please click on the links below or scroll down the page for more information.

### **Introduction to GPS**

The Global Positioning System (GPS) is a satellite-based navigation system that consists of 24 orbiting satellites, each of which makes two circuits around the Earth every 24 hours. These satellites transmit three bits of information – the satellite's number, its position in space, and the time the information is sent. These signals are picked up by the GPS receiver, which uses this information to calculate the distance between it and the GPS satellites.

With signals from three or more satellites, a GPS receiver can triangulate its location on the ground (i.e., longitude and latitude) from the known position of the satellites. With four or more satellites, a GPS receiver can determine a 3D position (i.e., latitude, longitude, and elevation). In addition, a GPS receiver can provide data on your speed and direction of travel. Anyone with a GPS receiver can access the system. Because GPS provides real-time, three-dimensional positioning, navigation, and timing 24 hours a day, 7 days a week, all over the world, it is used in numerous applications, including GIS data collection, surveying, and mapping.

### **Global Positioning System (GPS)**

The Global Positioning System (GPS), originally Navstar GPS,[1] is a satellite-based radionavigation system owned by the United States government and operated by the United States Air Force.[2] It is a global navigation satellite system that provides geolocation and time information to a GPS receiver anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. Obstacles such as mountains and buildings block the relatively weak GPS signals.

The GPS does not require the user to transmit any data, and it operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. The GPS provides critical positioning capabilities to military, civil, and commercial users around the world. The United States government created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.

The GPS project was launched by the U.S. Department of Defense in 1973 for use by the United States military and became fully operational in 1995. It was allowed for civilian use in the 1980s. Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS and implement the next generation of GPS Block IIIA satellites and Next Generation Operational Control System (OCX). Announcements from Vice President Al Gore and the White House in 1998 initiated these changes. In 2000, the U.S. Congress authorized the modernization effort, GPS III. During the 1990s, GPS quality was degraded by the United States government in a program called "Selective Availability", however, this is no longer the case, and was discontinued in May 2000 by law signed by former President Bill Clinton. New GPS receiver devices using the L5 frequency to begin release in 2018 are expected to have a much higher accuracy and pinpoint a device to within 30 centimeters or just under one foot.

The GPS system is provided by the United States government, which can selectively deny access to the system, as happened to the Indian military in 1999 during the Kargil War, or degrade the service at any time. As a result, a number of countries have developed or are in the process of setting up other global or regional navigation systems. The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s. GLONASS can be added to GPS devices, making more satellites available and enabling positions to be fixed more quickly and accurately, to within two meters. China's BeiDou Navigation Satellite System is due achieve global reach in 2020. There are also the European Union Galileo positioning system, and India's NAVIC. Japan's Quasi-Zenith Satellite System (scheduled to commence in November 2018) will be a GPS satellite-based augmentation system to enhance GPS's accuracy.

**Bluetooth:** is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz[3]) from fixed and mobile devices, and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994,[4] it was originally conceived as a wireless alternative to RS-232 data cables.

Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 30,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics.[5] The IEEE standardized Bluetooth as IEEE 802.15.1, but no longer maintains the standard. The Bluetooth SIG oversees development of the specification, manages the qualification program, and protects the trademarks.[6] A manufacturer must meet Bluetooth SIG standards to market it as a Bluetooth device.[7] A network of patents apply to the technology, which are licensed to individual qualifying devices.

**Wi-Fi** or WiFi (/ˈwaɪfaɪ/) is a technology for wireless local area networking with devices based on the IEEE 802.11 standards. Wi-Fi is a trademark of the Wi-Fi Alliance, which restricts the use of the term Wi-Fi Certified to products that successfully complete interoperability certification testing. Devices that can use Wi-Fi technology include personal computers, video-game consoles, phones and tablets, digital cameras, smart TVs, digital audio players and modern printers. Wi-Fi compatible devices can connect to the Internet via a WLAN and a wireless access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometres achieved by using multiple overlapping access points.

## CHAPTER 6. DIGITAL AND DATA COMMUNICATION

### 6.0 Introduction to Digital Communication

In the design of large and complex digital systems, it is often necessary to have one device communicate digital information to and from other devices. One advantage of digital information is that it tends to be far more resistant to transmitted and interpreted errors than information symbolized in an analog medium. This accounts for the clarity of digitally encoded telephone connections, compact audio disks, and for much of the enthusiasm in the engineering community for digital communications technology. However, digital communication has its own unique pitfalls, and there are multitudes of different and incompatible ways in which it can be sent. Hopefully, this chapter will enlighten you as to the basics of digital communication, its advantages, disadvantages, and practical considerations

- [Digital](#) communication needs synchronization in synchronous modulation.
- High [power](#) consumption.
- It required more bandwidth as compared to [analog](#) systems.
- It has sampling error.
- Complex circuit, more sophisticated device making is also disadvantage of digital system.

There is lots of talk nowadays about buzzwords such as "Analog" and "Digital". Certainly, engineers who are interested in creating a new communication system should understand the difference. Which is better, analog or digital? What is the difference? What are the pros and cons of each? This chapter will look at the answers to some of these questions.

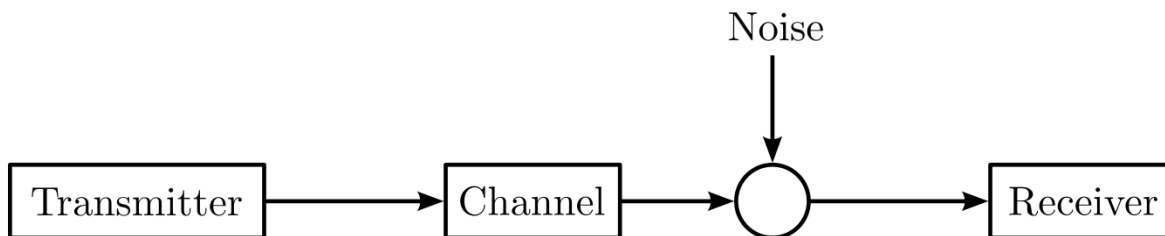


Fig. 6.1 Basic Block Diagram of Electronic Communication System

What exactly is an analog signal, and what is a digital signal ?

#### 6.1.1 Analog Communication system

Analog signals are continuous in both time and value. Analog signals are used in many systems, although the use of analog signals has declined with the advent of cheap digital signals. All natural signals are Analog in nature or analog signal is that signal which amplitude on Y axis change with time on X axis...

### 6.1.2 Digital Communication system

Digital signals are discrete in time and value. Digital signals are signals that are represented by binary numbers, "1" or "0". The 1 and 0 values can correspond to different discrete voltage values, and any signal that *doesn't quite fit* into the scheme just gets rounded off.

or digital signal is that signal which have certain or fixed value on Y axis change with time on X axis...

Digital signals are sampled, quantized & encoded version of continuous time signals which they represent. In addition, some techniques also make the signal undergo encryption to make the system more tolerant to the channel.

## 6.2 BLOCK DIAGRAM OF DIGITAL COMMUNICATION SYSTEM

Up to this point we have described an electrical communication system in rather broad terms based on the implicit assumption that the message signal is a continuous time-varying waveform. We refer to such continuous-time signal waveforms as analog signals and to the corresponding information sources that produce such signals as analog sources. Analog signals can be transmitted directly via carrier modulation over the communication channel and demodulated accordingly at the receiver. We call such a communication system an analog communication system.

Alternatively, an analog source output may be converted into a digital form and the message can be transmitted via digital modulation and demodulated as a digital signal at the receiver. There are some potential advantages to transmitting an analog signal by means of digital modulation. The most important reason is that signal fidelity is better controlled through digital transmission than analog transmission. In particular, digital transmission allows us to regenerate the digital signal in long-distance transmission, thus eliminating effects of noise at each regeneration point. In contrast, the noise added in analog transmission is amplified along with the signal when amplifiers are used periodically to boost the signal level in long-distance transmission. Another reason for choosing digital transmission over analog is that the analog message signal may be highly redundant. With digital processing, redundancy may be removed prior to modulation, thus conserving channel bandwidth. Yet a third reason may be that digital communication systems are often cheaper to implement.

In some applications, the information to be transmitted is inherently digital; e.g., in the form of English text, computer data, etc. In such cases, the information source that generates the data is called a discrete (digital) source.

In a digital communication system, the functional operations performed at the transmitter and receiver must be expanded to include message signal discretization at the transmitter and message signal synthesis or interpolation at the receiver. Additional functions include redundancy removal, and channel coding and decoding.



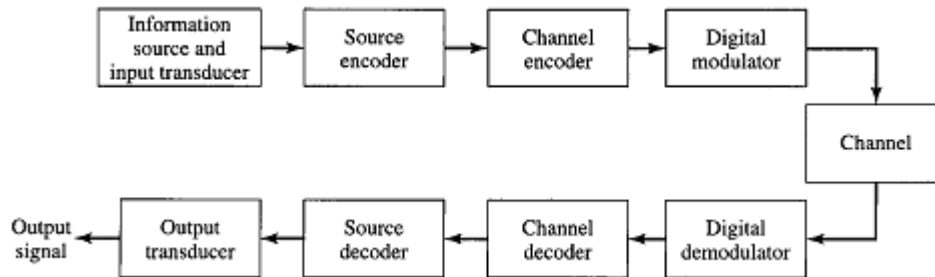


Fig. 6.2 Block Diagram of Digital Communication System

### 6.3 ADVANTAGES OF DIGITAL COMMUNICATION

There are some important advantages of digital communication are given below,

- Digital communication can be done over large distances through internet and other things.
- Digital communication gives facilities like video conferencing which save a lot of time, money and effort.
- It is easy to mix signals and data using digital techniques.
- The digital communication is fast, easier and cheaper.
- It can be tolerated the noise interference.
- It can be detect and correct error easily because of channel coding.
- Used in military application.
- It has excellent processing techniques are available for digital signals such as data compression, image processing, channel coding and equalization etc.

### 6.4 DISADVANTAGES OF DIGITAL COMMUNICATION

- Digital communication needs synchronization in synchronous modulation.
- High Power consumption.
- It required more bandwidth as compared to Analog systems.
- It has sampling error.
- Complex circuit, more sophisticated device making is also disadvantage of digital system.

### 6.5 DIFFERENCE BETWEEN DIGITAL AND TRANSMISSION

**Analog** and **digital** signals are used to transmit information, usually through electric signals. In both these technologies, the information, such as any audio or video, is transformed into electric signals. The **difference between analog and digital** technologies is that in analog technology, information is translated into electric pulses of varying amplitude. In digital technology, translation of information is into binary format (zero or one) where each bit is representative of two distinct amplitudes.

## Comparison chart

### Definitions of Analog vs. Digital signals

An **Analog signal** is any continuous signal for which the time varying feature (variable) of the signal is a representation of some other time varying quantity, i.e., analogous to another time varying signal. It differs from a digital signal in terms of small fluctuations in the signal which are meaningful.

A **digital signal** uses discrete (discontinuous) values. By contrast, non-digital (or analog) systems use a continuous range of values to represent information. Although digital representations are discrete, the information represented can be either discrete, such as numbers or letters, or continuous, such as sounds, images, and other measurements of continuous systems.

### Differences in Applications

Digital technology has been most efficient in cellular phone industry. Analog phones have become redundant even though sound clarity and quality was good.

Analog technology comprises of natural signals like human speech. With digital technology this human speech can be saved and stored in a computer. Thus digital technology opens up the horizon for endless possible uses.

## 6.6 DATA COMMUNICATION

### Definition - What does **Data Communications (DC)** mean?

Data communications (DC) is the process of using computing and communication technologies to transfer data from one place to another, and vice versa. It enables the movement of electronic or digital data between two or more nodes, regardless of geographical location, technological medium or data contents.

### Techopedia explains **Data Communications (DC)**

Data communications incorporates several techniques and technologies with the primary objective of enabling any form of electronic communication. These technologies include telecommunications, computer networking and radio/satellite communication. Data communication usually requires existence of a transportation or communication medium between the nodes wanting to communicate with each other, such as copper wire, fiber optic cables or wireless signals.

For example, a common example of data communications is a computer connected to the Internet via a Wi-Fi connection, which uses a wireless medium to send and receive data from one or more remote servers.

Some devices/technologies used in data communications are known as data communication equipment (DCE) and data terminal equipment (DTE). DCE is used at the sending node, and DTE is used at the receiving node.

## 6.7 DATA COMMUNICATION MODEL

To discuss computer networking, it is necessary to use terms that have special meaning. Even other computer professionals may not be familiar with all the terms in the networking alphabet soup. As is always the case, English and computer-speak are not equivalent (or even necessarily compatible) languages. Although descriptions and examples should make the meaning of the networking jargon more apparent, sometimes terms are ambiguous. A common frame of reference is necessary for understanding data communications terminology.

An architectural model developed by the International Standards Organization (ISO) is frequently used to describe the structure and function of data communications protocols. This architectural model, called the *Open Systems Interconnect (OSI) Reference Model*, provides a common reference for discussing communications. The terms defined by this model are well understood and widely used in the data communications community—so widely used, in fact, that it is difficult to discuss data communications without using OSI's terminology.

The OSI Reference Model contains seven *layers* that define the functions of data communications protocols. Each layer of the OSI model represents a function performed when data is transferred between cooperating applications across an intervening network. Figure 1-1 identifies each layer by name and provides a short functional description for it. Looking at this figure, the protocols are like a pile of building blocks stacked one upon another. Because of this appearance, the structure is often called a *stack* or *protocol stack*.

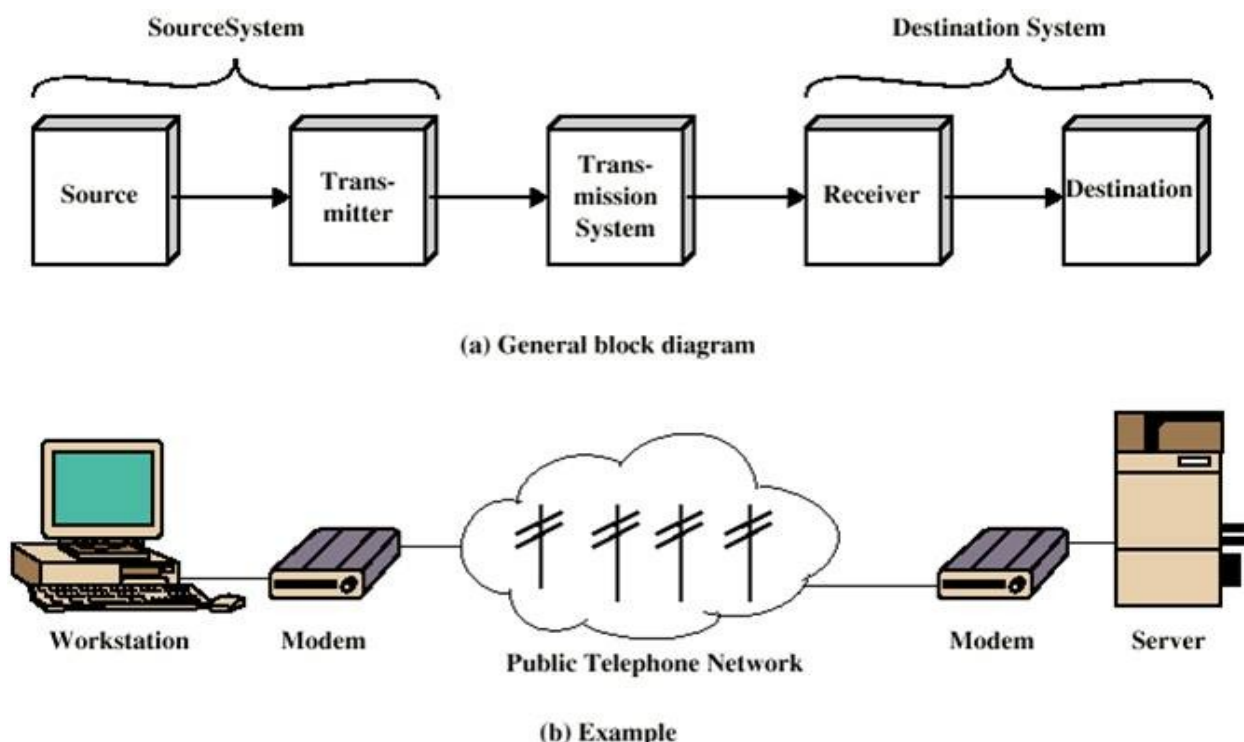


Fig.6.5 Block diagram of data communication System

## 6.8 DATA COMMUNICATION PRINCIPLES

This course provides an introduction to the field of data communications and computer networks. The course covers the principles of data communications, the fundamentals of signaling, basic transmission concepts, transmission media, circuit control, line sharing techniques, physical and data link layer protocols, error detection and correction, data compression, common carrier services and data networks, and the mathematical techniques used for network design and performance analysis. Potential topics include analog and digital signaling; data encoding and modulation; Shannon channel capacity; synchronous and asynchronously transmission; RS232 physical layer interface standards; FDM, TDM, and STDM multiplexing techniques; inverse multiplexing; analog and digital transmission; V series modem standards; PCM encoding and T1 transmission circuits; LRC, VRC, and CRC error detection techniques; Hamming and Viterbi forward error correction techniques; BSC and HDLC data link layer protocols; Huffman, MNP5, and V.42bis data compression algorithms; circuit, message, packet, and cell switching techniques; public key and symmetric encryption algorithms, authentication, digital signature, and message digest techniques, secure e-mail, PGP, and TLS/SSL security algorithms; Ethernet, Wi-Fi, Optical, and IP networks; reliability and availability; and queuing analysis network performance techniques.

### 6.8.1 Digital Data Transmission

Data transfer" redirects here. For sharing data between different programs or schemas, see [Data exchange](#).

**Data transmission** also **data communication** or **digital communications** is the transfer of [data](#) (a [digital bitstream](#) or a [digitized](#) analog signal<sup>[1]</sup>) over a [point-to-point](#) or [point-to-multipoint communication channel](#). Examples of such channels are [copper wires](#), [optical fibers](#), [wireless](#) communication channels, [storage media](#) and [computer buses](#). The data are represented as an [electromagnetic signal](#), such as an [electrical voltage](#), [radiowave](#), [microwave](#), or [infrared](#) signal.

Analog or analogue transmission is a transmission 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. The messages are either represented by a sequence of pulses by means of a [line code](#) (*baseband transmission*), or by a limited set of continuously varying wave forms (*passband transmission*), using a digital [modulation](#) method. The passband modulation and corresponding demodulation (also known as detection) is carried out by [modem](#) equipment. According to the most common definition of [digital signal](#), both baseband and passband signals representing bit-streams are considered as digital transmission, while an alternative definition only considers the baseband signal as digital, and passband transmission of digital data as a form of [digital-to-analog conversion](#).

Data transmitted may be digital messages originating from a data source, for example a computer or a keyboard. It may also be an analog signal such as a phone call or a video signal, [digitized](#) into a bit-stream for example using [pulse-code modulation](#) (PCM) or more advanced [source coding](#) ([analog-to-digital conversion](#) and [data compression](#)) schemes. This source coding and decoding is carried out by [codec](#) equipment.

### **Distinction between related subjects**

---

Courses and textbooks in the field of *data transmission* as well as *digital transmission* and *digital communications* have similar content.

Digital transmission or data transmission traditionally belongs to [telecommunications](#) and [electrical engineering](#). Basic principles of data transmission may also be covered within the [computer science/computer engineering](#) topic of [data communications](#), which also includes [computer networking](#) or [computer communication](#) applications and networking protocols, for example routing, switching and [inter-process communication](#). Although the [Transmission control protocol](#) (TCP) involves the term "transmission", TCP and other transport layer protocols are typically *not* discussed in a textbook or course about data transmission, but in computer networking.

The term [tele transmission](#) involves the analog as well as digital communication. In most textbooks, the term [analog transmission](#) only refers to the transmission of an analog message signal (without digitization) by means of an analog signal, either as a non-modulated baseband signal, or as a passband signal using an [analog modulation method](#) such as [AM](#) or [FM](#). It may also include analog-over-analog [pulse modulated](#) baseband signals such as pulse-width modulation. In a few books within the computer networking tradition, "analog transmission" also refers to passband transmission of bit-streams using [digital modulation](#) methods such as [FSK](#), [PSK](#) and [ASK](#). Note that these methods are covered in textbooks named digital transmission or data transmission, for example.

## Applications and history

---

Data (mainly but not exclusively [informational](#)) has been sent via non-electronic (e.g. [optical](#), [acoustic](#), [mechanical](#)) means since the advent of [communication](#). [Analog signal](#) data has been sent electronically since the [advent of the telephone](#). However, the first data electromagnetic transmission applications in modern time were [telegraphy](#) (1809) and [teletypewriters](#) (1906), which are both [digital signals](#). The fundamental theoretical work in data transmission and information theory by [Harry Nyquist](#), [Ralph Hartley](#), [Claude Shannon](#) and others during the early 20th century, was done with these applications in mind.

Data transmission is utilized in [computers](#) in [computer buses](#) and for communication with [peripheral equipment](#) via [parallel ports](#) and [serial ports](#) such as [RS-232](#) (1969), [Firewire](#) (1995) and [USB](#) (1996). The principles of data transmission are also utilized in storage media for [Error detection and correction](#) since 1951.

Data transmission is utilized in [computer networking](#) equipment such as [modems](#) (1940), [local area networks](#) (LAN) adapters (1964), [repeaters](#), [repeater hubs](#), [microwave links](#), [wireless network access points](#) (1997), etc.

In telephone networks, digital communication is utilized for transferring many phone calls over the same copper cable or fiber cable by means of [Pulse code modulation](#) (PCM), i.e. sampling and digitization, in combination with [Time division multiplexing](#) (TDM) (1962). [Telephone exchanges](#) have become digital and software controlled, facilitating many value added services. For example, the first [AXE telephone exchange](#) was presented in 1976. Since the late 1980s, digital communication to the end user has been possible using [Integrated Services Digital Network](#) (ISDN) services. Since the end of the 1990s, broadband access techniques such as [ADSL](#), [Cable modems](#), [fiber-to-the-building](#) (FTTB) and [fiber-to-the-home](#) (FTTH) have become widespread to small offices and homes. The current tendency is to replace traditional telecommunication services by packet mode communication such as [IP telephony](#) and [IPTV](#).

Transmitting analog signals digitally allows for greater [signal processing](#) capability. The ability to process a communications signal means that errors caused by random processes can be detected and corrected. Digital signals can also be [sampled](#) instead of continuously monitored. The [multiplexing](#) of multiple digital signals is much simpler to the multiplexing of analog signals.

Because of all these advantages, and because recent advances in [wideband communication channels](#) and [solid-state electronics](#) have allowed scientists to fully realize these advantages, digital communications has grown quickly. Digital communications is quickly edging out analog communication because of the vast demand to transmit computer data and the ability of digital communications to do so.

The digital revolution has also resulted in many digital [telecommunication](#) applications where the principles of data transmission are applied. Examples are [second-generation](#) (1991) and later [cellular telephony](#), [video conferencing](#), [digital TV](#) (1998), [digital radio](#) (1999), [telemetry](#), etc.

Data transmission, digital transmission or digital communications is the physical transfer of data (a digital bit stream or a digitized analog signal[1]) over a point-to-point or point-to-multipoint communication channel. Examples of such channels are copper wires, optical fibers, wireless

communication channels, storage media and computer buses. The data are represented as an electromagnetic signal, such as an electrical voltage, radiowave, microwave, or infrared signal.

While analog transmission is the transfer of a continuously varying analog signal over an analog channel, digital communications is the transfer of discrete messages over a digital or an analog channel. The messages are either represented by a sequence of pulses by means of a line code (baseband transmission), or by a limited set of continuously varying wave forms (passband transmission), using a digital modulation method. The passband modulation and corresponding demodulation (also known as detection) is carried out by modem equipment. According to the most common definition of digital signal, both baseband and passband signals representing bit-streams are considered as digital transmission, while an alternative definition only considers the baseband signal as digital, and passband transmission of digital data as a form of digital-to-analog conversion.

Data transmitted may be digital messages originating from a data source, for example a computer or a keyboard. It may also be an analog signal such as a phone call or a video signal, digitized into a bit-stream for example using pulse-code modulation (PCM) or more advanced source coding (analog-to-digital conversion and data compression) schemes. This source coding and decoding is carried out by codec equipment.

### **Serial and parallel transmission**

---

In telecommunications, [serial transmission](#) is the sequential [transmission](#) of [signal elements](#) of a group representing a [character](#) or other entity of [data](#). Digital serial transmissions are bits sent over a single wire, frequency or optical path sequentially. Because it requires less [signal processing](#) and less chances for error than parallel transmission, the transfer rate of each individual path may be faster. This can be used over longer distances as a check digit or [parity bit](#) can be sent along it easily.

In telecommunications, [parallel transmission](#) is the simultaneous transmission of the [signal](#) elements of a character or other entity of data. In [digital](#) communications, parallel transmission is the simultaneous transmission of related signal elements over two or more separate paths. Multiple electrical wires are used which can transmit multiple bits simultaneously, which allows for higher data transfer rates than can be achieved with serial transmission. This method is used internally within the computer, for example the internal buses, and sometimes externally for such things as printers, The major issue with this is "skewing" because the wires in parallel data transmission have slightly different properties (not intentionally) so some bits may arrive before others, which may corrupt the message. A parity bit can help to reduce this. However, electrical wire parallel data transmission is therefore less reliable for long distances because corrupt transmissions are far more likely.

### **Asynchronous and synchronous data transmission**

---

**Asynchronous start-stop transmission** uses start and stop bits to signify the beginning bit [ASCII](#) character would actually be transmitted using 10 bits. For example, "0100 0001" would become "**1** 0100 0001 **0**". The extra one (or zero, depending on [parity bit](#)) at the start and end of the transmission tells the receiver first that a character is coming and secondly that the character has ended. This method of transmission is used when data are sent intermittently as opposed to in a solid stream. In the previous example the start and stop bits are in bold. The start



and stop bits must be of opposite polarity.<sup>[citation needed]</sup> This allows the receiver to recognize when the second packet of information is being sent.

**Synchronous transmission** uses no start and stop bits, but instead synchronizes transmission speeds at both the receiving and sending end of the transmission using [clock](#) signal(s) built into each component.<sup>[vague]</sup> A continual stream of [data](#) is then sent between the two nodes. Due to there being no start and stop [bits](#) the data transfer rate is quicker although more errors will occur, as the clocks will eventually get out of sync, and the receiving device would have the wrong time that had been agreed in the protocol for sending/receiving data. so some [bytes](#) could become corrupted (by losing [bits](#)). Ways to get around this problem include re-synchronization of the clocks and use of [check digits](#) to ensure the [byte](#) is correctly interpreted and received