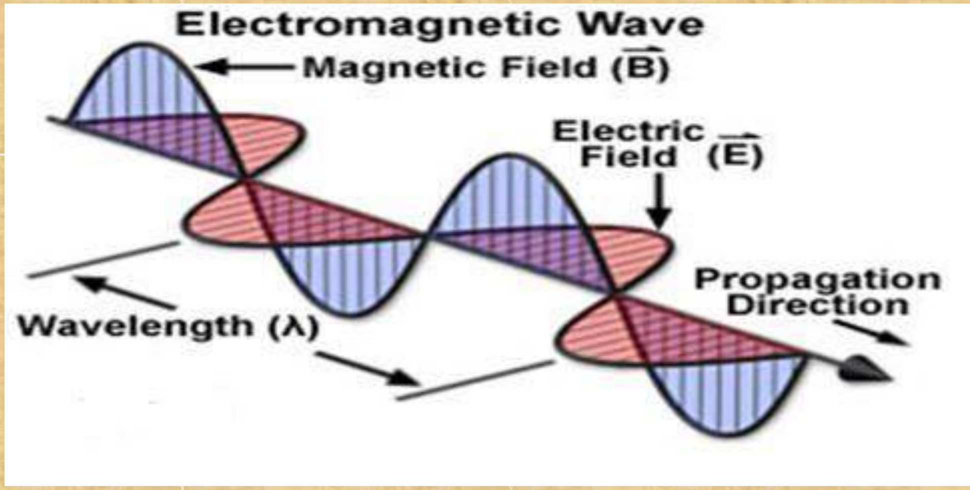
WIRELESS AND MOBILE COMMUNICATION

Wireless Communication

Wireless communication is transfer of information over a distance without using electrical conductors or wires.

Electromagnetic waves

The changing electric and magnetic fields propagate through space and form electromagnetic waves.



Cordless Telephone

It is a telephone with a wireless handset. It communicates via radio waves with a base station connected to fixed telephone line.

Cellular telephone system

Cellular telephone system provides a wireless connection to the PSTN.

Cell

High capacity is feasible by limiting the coverage area of each base station transmitter to a small geographical area called cell.

Cellular telephone system

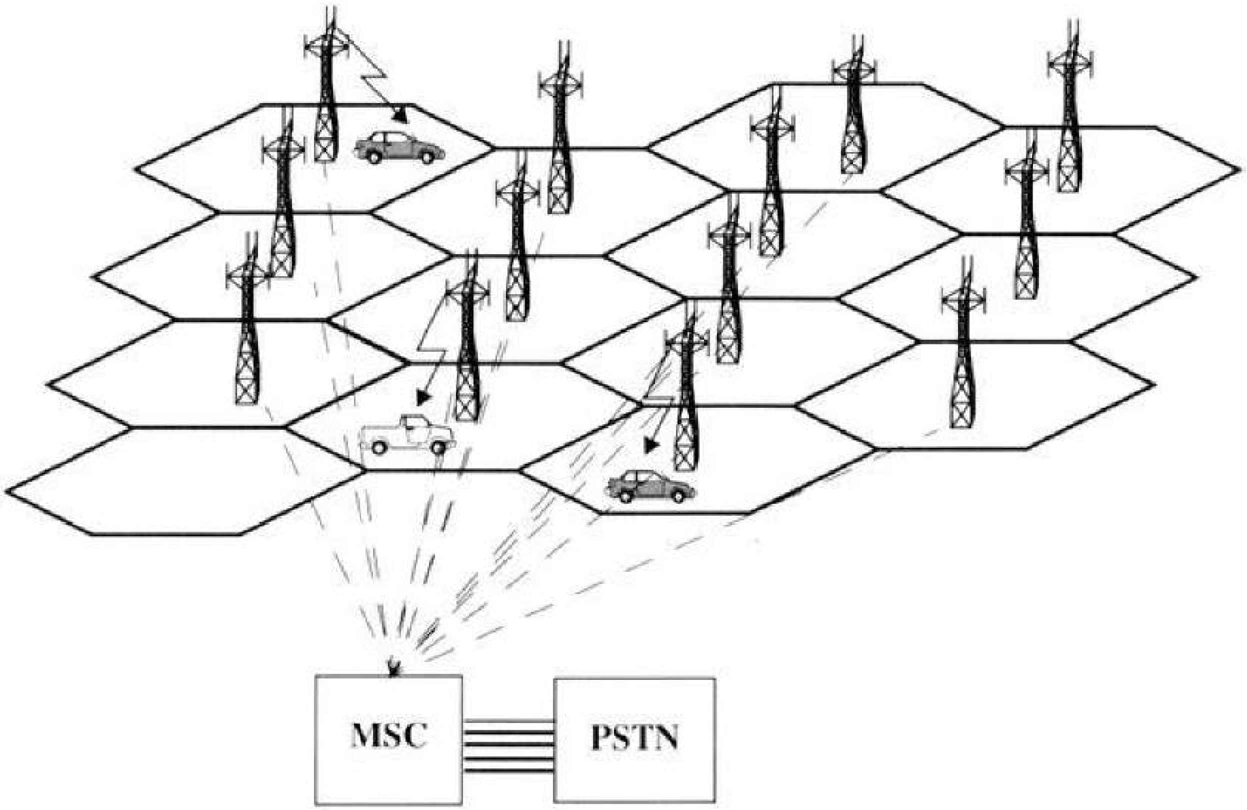


Figure 1.5 A cellular system. The towers represent base stations which provide radio access between mobile users and the mobile switching center (MSC).

CELLULAR TELEPHONE SYSTEM

Cellular Telephone System

First generation cellular system:

First generation is generally written as 1G.

<u>AMPS in America and Australia</u>

Advance Mobile Phone System.

It uses 25MHz band in uplink transmission from 824 to 849MHz.

It uses 25 MHz band in downlink transmission from 869 to 894MHz.

<u>ETACS</u>

European Total Access Communication System

<u>NTT</u>

Nippon Telephone and Telegraph in Japan

1G analog Cellular System

region	America	Europe	Japan
parameter	AMPS	ETACS	NTT
Multiple access	FDMA	FDMA	FDMA
duplexing	FDD	FDD	FDD
Forward channel	869-894 MHz	935-960 MHz	870-885MHz
Reverse channel	824-849 MHz	890-915 MHz	925-940 MHz
Channel spacing	30 KHz	25 kHz	25 kHz
Data Rate	10 kbps	8 kbps	0.3 kbps
Spectral efficiency	0.33 bps/Hz	0.33 bps/Hz	0.012 bps/Hz
Capacity	832 channels	1000 channels	600 channels

Second Generation Cellular System

S. No.	Region parameter	US IS-54	Europe GSM	Japan PDC	US IS-95
1	Multiple Access	TDMA/ FDD	TDMA/ FDD	TDMA/ FDD	CDMA
2	Modulation	Pi/4 DQPSK	GMSK	Pi/4 DQPSK	QPSK/ OQPSK
3	Forward Channel	869-894 MHz	935-960 MHz	810-826 MHz	869-894 MHz
4	Reverse Channel	824-849 MHz	890-915 MHz	940-956 MHz	824-849MHz
5	Channel Spacing	30kHz	200kHz	25kHz	1.250 kHz
6	Data Chip Rate	48.6 kbps	270.833 kbps	42kbps	1.2288 Mbps

7	Speech Code Rate	7.95 kbps	13.4 kbps	6.7 kbps	1.2/2.4/ 4.8/9.6 kbps

3G wireless Communications

3G systems provide fast communication services.

3G wireless communications include multimedia entertainment, infotainment and location based services.

2.5G networks such as GPRS (Global Packet Radio Service) are already available in some parts of Europe.

It supports 144 kbps bandwidth with vehicles, 384kbps in campus and 2Mbps in stationary such as building.

3G supports the following:

PLMNs(Public land mobile networks.

Mobile IP(Mobile Internet Protocol)

WATM networks(Wireless Asynchronous transfer Mode)

LEO(Low Earth Orbit) satellite networks.

4G systems

In July 2003, ITU made a requirement for 4G system and 4G supports to:

At a standstill condition, the transmission rate should be 1 Gbps.

At a moving condition transmission rate should be 100 Mbps.

It includes the following:

(i) Interactive multimedia services such as teleconferencing, wireless internet etc.

(ii) Wider bandwidths, higher bit rates.

(iii) Global mobility and service portability.

(iv) Low Cost.

(v) Scalability of mobile networks.

4G uses OFDM (Orthogonal Frequency Division Multiplexing).

CELLULAR CONCEPT

Cellular Concept

The cellular concept is a major improvement in solving the problem of spectral accumulation or obstructions related to signals traffic.

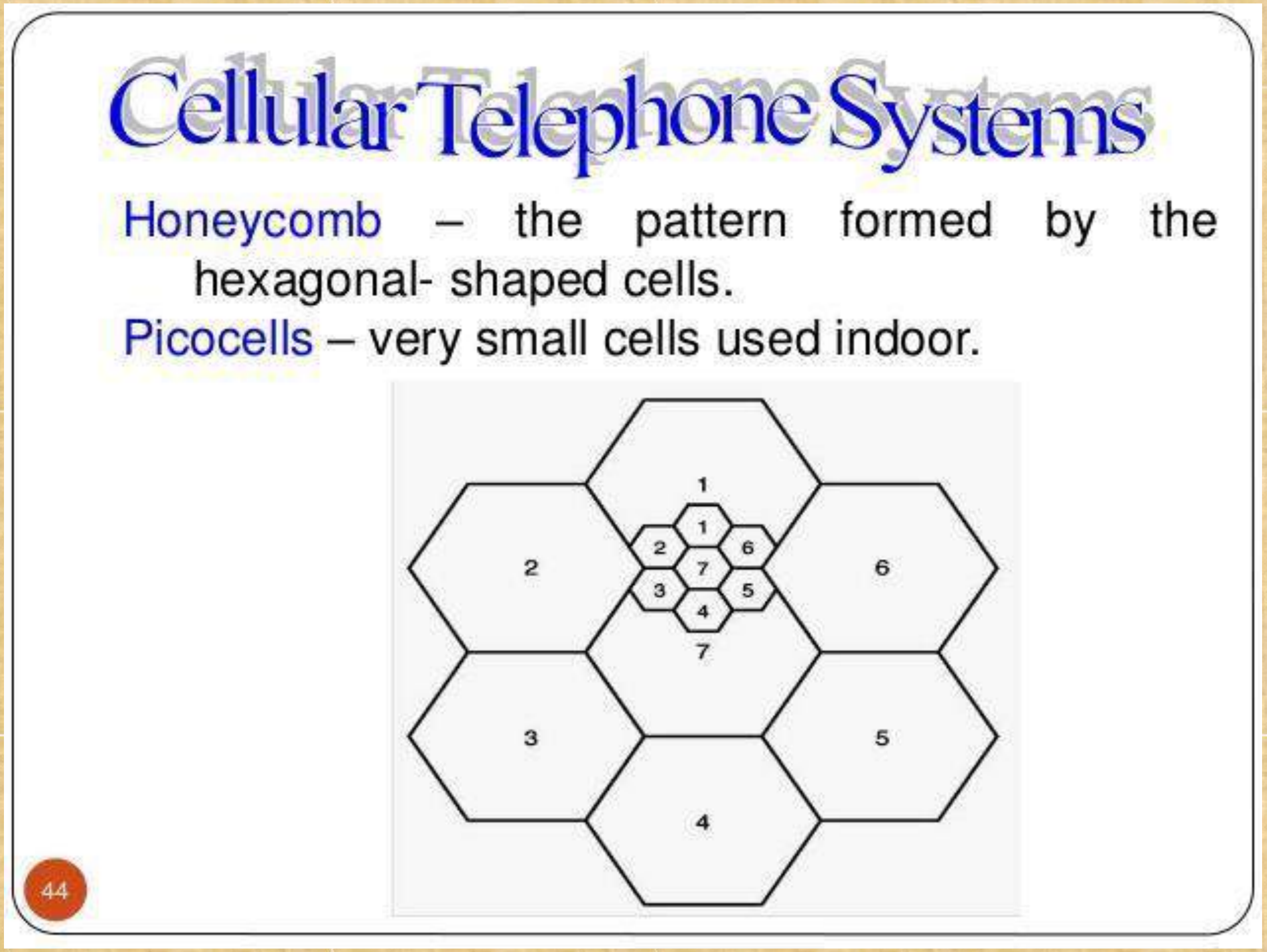
It also solves the problem of user capacity.

Cell Area

A cellular network is a radio network distributed over land (geographical area) is known as cell and this area is known as cell area.

Each cell station is served by at least one fixed location transceiver and this location is known as cell site or base station.

Honeycomb cell pattern



The hexagonal shape is chosen because it provides most effective transmission.

Hexagonal shaped cells are approximated to a circular shape and it eliminates inherently gaps present between adjacent cells.

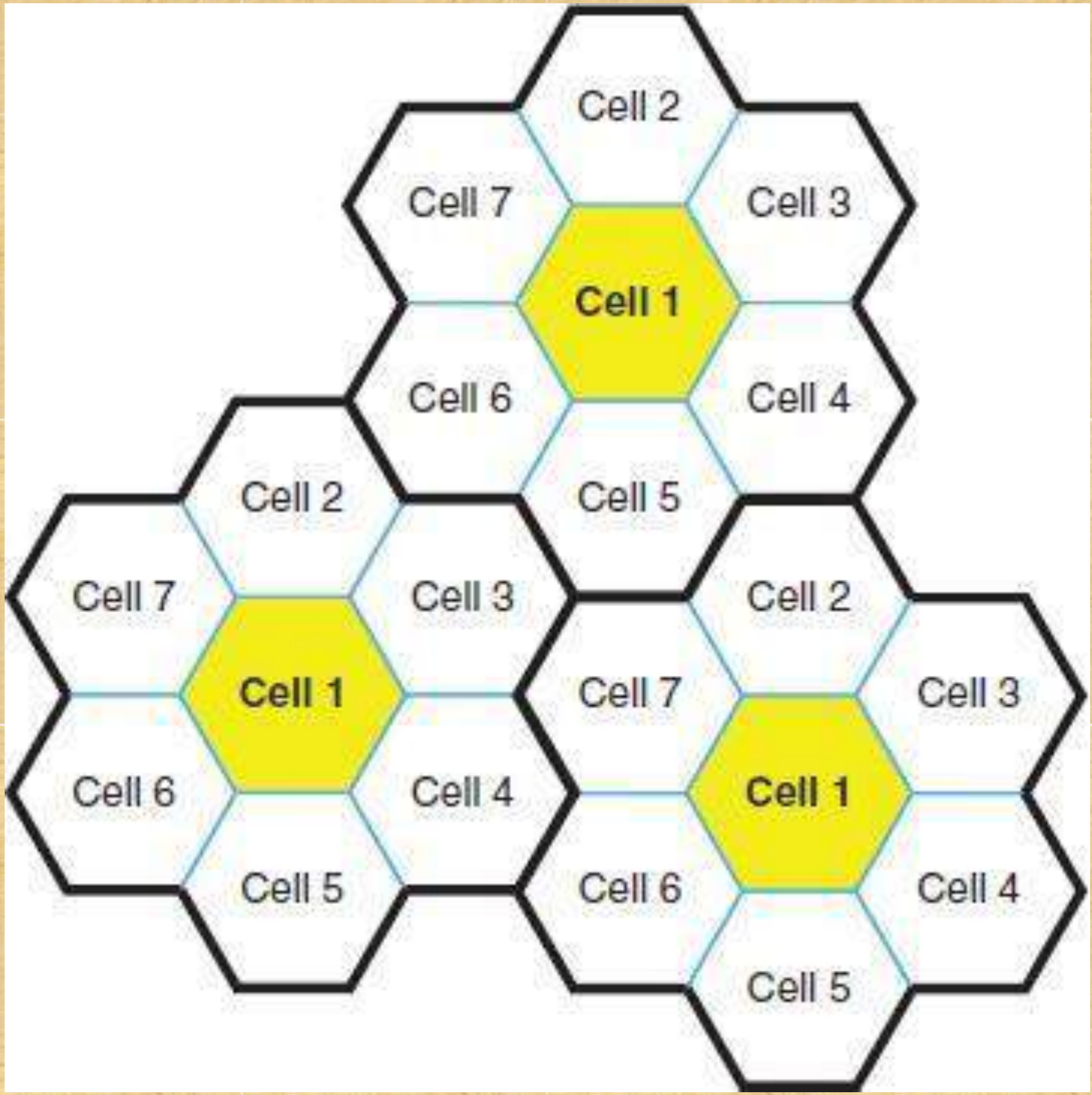
Macrocells

Radius between 1 mile and 15 miles.

Microcells

Radius upto 2 km.

Frequency Reuse



Frequency reuse is the process in which same set of frequencies can be allocated to more than one cell; provided cells are separated by sufficient distance.

The total no of channels available in a cluster can be expressed mathematically as

$$F=GN$$

F=no of full duplex cellular channels available in a cluster

G=no of channels in a cell

N=no of cells in a cluster

Mathematically, FRF is given as:

FRF=N/C

FRF=Frequency Reuse Factor

N=total no of full duplex channels in an area.

N=total no of full duplex channels in a cell.

FRF has no units

To connect cells without gap in between the geometry of hexagon is to satisfy the equation:

$N=i^2 + ij + j^2$

N = no of cells per cluster

i and j = non negative integer values

Interference

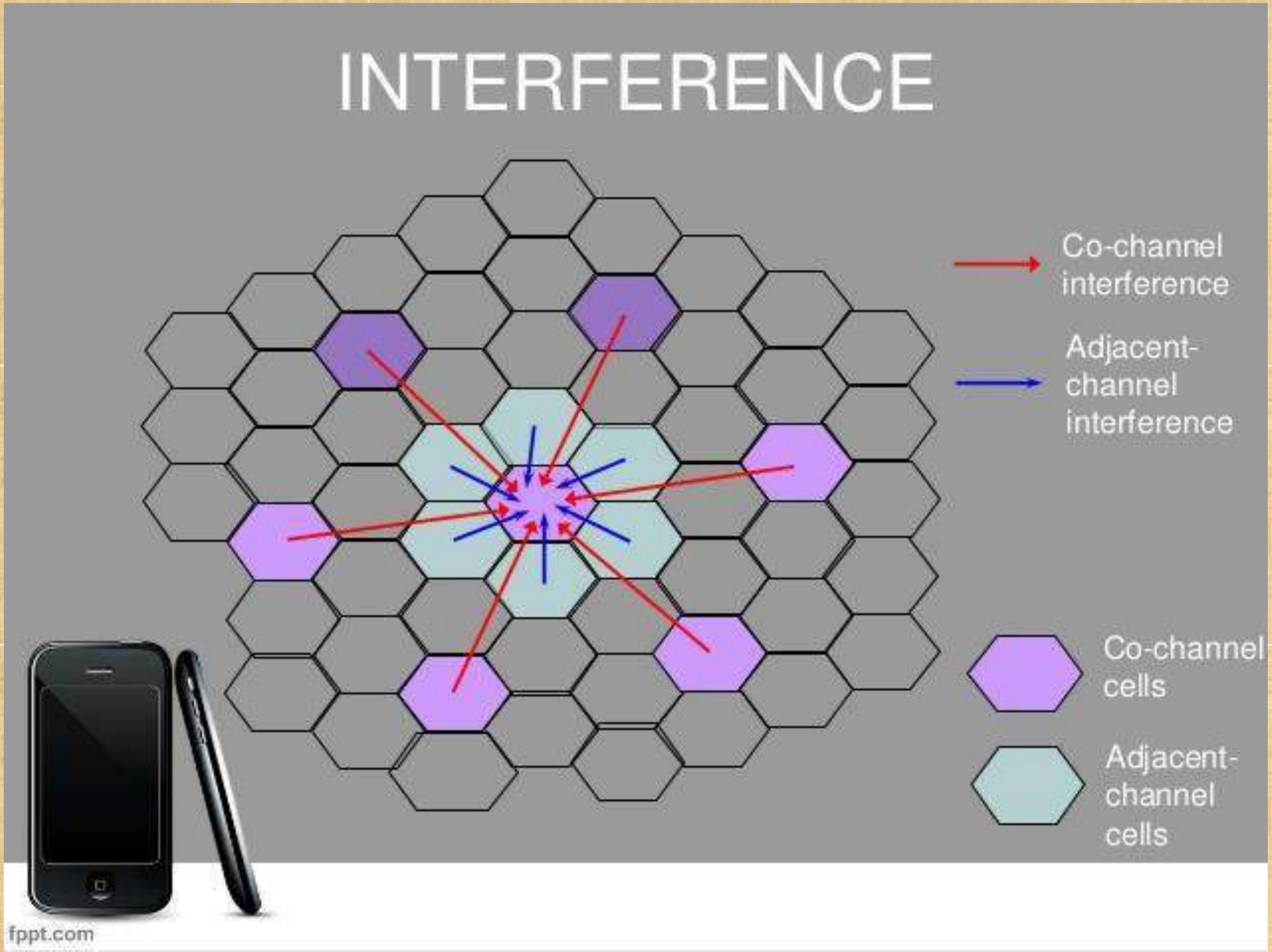
Interference is defined as a form of external noise.

There are two types of interferences produced within a cellular telephone system. These are:

(i) Co-channel Interference

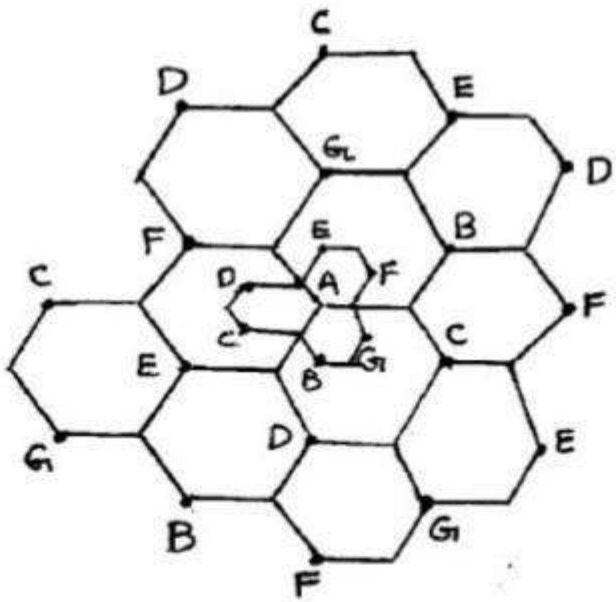
(ii) Adjacent channel interference.

Interference



Improving coverage and capacity in a cellular system

Cell splitting



- The process of subdividing a congested cell into smaller cell.
- Each with its own base station and a corresponding reduction in antenna height.
- leads to increase in capacity

Cell Sectoring

Sectoring methods

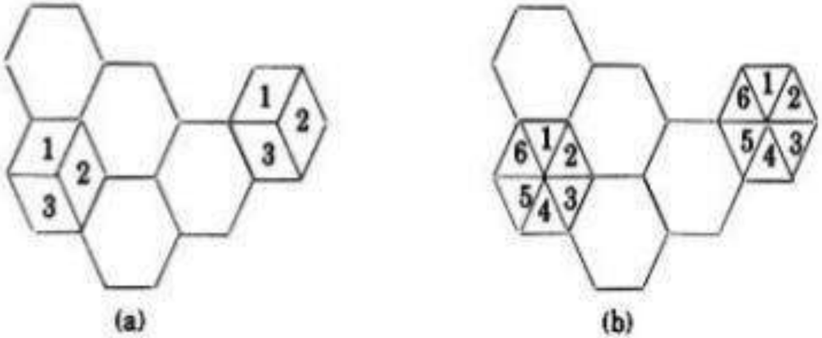
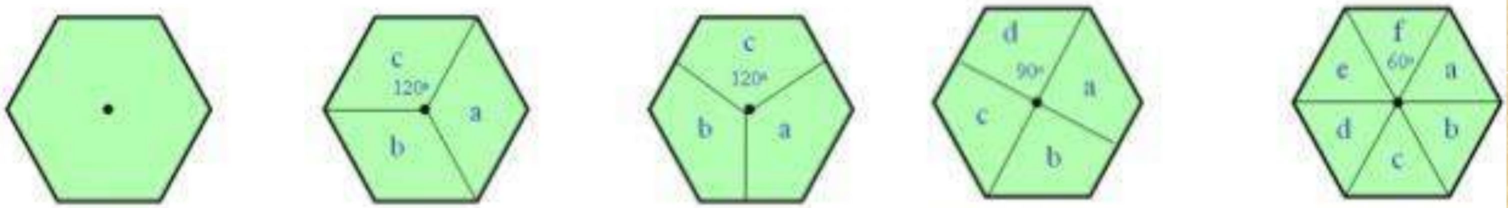


Figure 3.10 (a) 120° sectoring; (b) 60° sectoring.

Cell sectoring

Improving Capacity in Cellular Systems

- Aim: To provide more channels per unit coverage area
- Techniques: Three techniques are used to improve capacity
- SECTORING:
  - Use directional antennas to further control the interference and frequency reuse of channels.
  - Examples: Omni, 120^0, 60^0 and 90^0



(a). Omni (b). 120° sector (c). 120° sector (alternate) (d). 90° sector (e). 60° sector

Repeater for range extension

It is a must for a wireless operator to provide coverage for "hard to reach areas".

Hard to reach areas are such as buildings, valleys, or tunnels.

To provide effective services in cellular communication, Radio re transmitters known as repeaters are used.

Repeater amplifies the signal received from base station and radiates it further to the specific coverage region.

Chapter 3

Frequency Division Multiple Access (FDMA) Techniques

In Frequency-Division Multiple Access the channel bandwidth is subdivided into a variety of sub-channels. FDMA is used for voice and data transmission. During this method the general channel bandwidth is shared by multiple users, therefore a variety of users can transmit their data simultaneously. No code words and synchronization are required in FDMA. Power efficiency is reduced using FDMA, it's an old and proven system used for analog signals. In this article, we will discuss Frequency Division Multiple Access (FDMA) Techniques.

What is FDMA?

FDMA is a type of channelization protocol. This bandwidth is divided into various frequency bands. Each station is allocated a band to send data and that band is reserved for the particular station for all the time which is as follows:

Frequency Division Multiple Access (FDMA) Techniques

1. Multi-channel-per-carrier (MCPC) transmission
2. Single-channel per carrier (SCPC) transmission

Multi-Channel-Per-Carrier Transmission

- Analog multiplexing is used at earth station in the early stages of communication, this helps in combining large numbers of telephone channels into a single baseband signal and thus modulating into a single RF carrier.
- Using frequency division multiplexing (FDM) telephone signals can be combined in a group of channels, this is done by shifting the baseband frequency to a higher frequency.
- Upto 1800 telephone channels in a satellite are multiplexed using the FDM, thus making wide baseband that occupies bandwidth of 8 MHz.
- The wide baseband signals are then modulated onto the RF carrier using FM i.e. Frequency Modulation.
- Different RF carrier for each and every earth station is used for frequency modulations.
- A common transponder for transmission is been shared from various earth stations for the FDM-FM-RF. This technique is called as FDM-FM-FDMA.
- So has various different telephone channels are been multiplexed for transmission over a single RF carrier, it is known as Multi-channel-per carrier (MCPC) transmission.
- The below attached images show fixed assigned FDM-FM-FDMA scheme for the two C-band transponders.

Transponder 1

Single-Channel-Per Carrier Transmission

- When a single signal on a carrier is been send via the earth station, this FDMA access technique is called as "Single-channel-per carrier (SCPC) transmission".
- Hence if a system in which large number of small earth station are used, for example mobile telephones, which access via a single transponder using FDMA is called a Single-channel-per carrier Frequency division multiple access scheme (SCPC-FDMA).
- The SCPC systems can be reconfigurable, this depends on the traffic condition which is been accumulated to that particular system, thus making it compatible with the demand assignment systems.
- So when the link is been activated then only the carrier for SCPS channel is transmitted.
- This helps in reducing the transponder power consumption.

Advantages of FDMA

- FDMA uses simple hardware resources and is easy to set up.
- It efficiently handles smaller groups of users.
- The system isn't overly complicated.
- All stations can transmit continuously without waiting their turn.
- It lowers the amount of data transmitted, which can increase capacity.
- It reduces interference between symbols, improving communication quality.

Disadvantages of FDMA

- FDMA works only with analog signals.

- *It lacks flexibility, so existing traffic patterns must change gradually.*
- *Transponders need extensive bandwidth.*
- *It doesn't support high traffic capacity.*
- *RF filters must meet strict adjacent channel rejection standards, which can increase costs.*
- *The maximum bit rate per channel is small and remains fixed.*

Difference Between FDMA, CDMA and TDMA

FDMA	TDMA	CDMA
FDMA stands for Frequency Division Multiple Access.	TDMA stands for Time Division Multiple Access.	CDMA stands for Code Division Multiple Access.
In this, sharing of bandwidth among different stations takes place.	In this, only the sharing of time of satellite transponder takes place.	In this, there is sharing of both i.e. bandwidth and time among different stations takes place.
There is no need of any codeword.	There is no need of any codeword.	Codeword is necessary.
In this, there is only need of guard bands between the adjacent channels are necessary.	In this, guard time of the adjacent slots are necessary.	In this, both guard bands and guard time are necessary.
Synchronization is not required.	Synchronization is required.	Synchronization is not required.

FDMA	TDMA	CDMA
The rate of data is low.	The rate of data is medium.	The rate of data is high.
Mode of data transfer is continuous signal.	Mode of data transfer is signal in bursts.	Mode of data transfer is digital signal.
It is little flexible.	It is moderate flexible.	It is highly flexible.

What is TDMA?

Time Division Multiple Access (TDMA) : TDMA is the channelization protocol in which bandwidth of channel is divided into various stations on the time basis. There is a time slot given to each station, the station can transmit data during that time slot only which is as follows.

Figure – TDMA

Each station must aware of its beginning of time slot and the location of the time slot. TDMA requires synchronization between different stations. It is type of access method in the data link layer. At each station data link layer tells the station to use the allocated time slot.

Advantages of TDMA

- As cell sizes decrease, TDMA requires substantial investment in space, support, and base-station hardware.
- It can transmit data at speeds ranging from 64 kbps to 120 Mbps.
- TDMA separates users based on time, ensuring no interference from simultaneous transmissions.
- It supports services like fax, voiceband data, SMS, multimedia applications, and video conferencing.
- TDMA extends battery life by allowing devices to transmit only part of the time during conversations.
- It effectively handles both data transmission and voice communication needs.

Disadvantages of TDMA

- If all time slots in the current cell and the next cell are occupied, users allocated specific slots may not connect to a call.
- Frequency/slot allocation in TDMA can be complex.
- High data rates in TDMA require equalization.
- Network and spectrum planning in TDMA is complex and time-consuming, needing expertise and resources.
- TDMA focuses on organization and range planning.

What is CDMA?

Code Division Multiple Access (CDMA) : In CDMA, all the stations can transmit data simultaneously. It allows each station to transmit data over the entire frequency all the time. Multiple simultaneous transmissions are separated by unique code sequence. Each user is assigned with a unique code sequence.

Figure – CDMA

In the above figure, there are 4 stations marked as 1, 2, 3 and 4. Data assigned with respective stations as d_1, d_2, d_3 and d_4 and the code assigned with respective stations as c_1, c_2, c_3 and c_4.

Advantages of CDMA

- CDMA has a very high spectral capacity, supporting many users within a wide bandwidth.
- It doesn't require synchronization between users.
- CDMA channels are hard to decode, improving cellular communication security.
- It provides better secure transmission capabilities.
- Dropouts only occur when the user is twice the distance from the base station.

Disadvantages of CDMA

- CDMA faces channel pollution when a user's phone connects to multiple cell sites, but only one has strong signal.
- CDMA isn't as mature as GSM, since it's newer.
- CDMA requires time synchronization.

Wideband Code Division Multiple Access (WCDMA) is a type of cellular technology that was developed as a third-generation (3G) mobile communications standard. It is based on the Code Division Multiple Access (CDMA) technologies that were developed in the 1980s, but it uses a wider frequency band and provides higher data rates than previous versions of CDMA.

WCDMA

WCDMA was developed by the Third Generation Partnership Project (3GPP), a collaboration between several telecommunications standards organizations. The first version of the WCDMA standard was released in 1998, and it was later adopted by many mobile network operators around the world as a way to provide high-speed data services to their customers.

The development of WCDMA began in the late 1990s, and the first WCDMA networks were launched in Japan in 2001. There were 100s of WCDMA networks open and in total 150 operators were available with licenses for frequencies of WCDMA operations. Now WCDMA networks are deployed in Europe and Asia in the UMTS band of around 2 GHz. WCDMA is also known as **Universal Mobile Telecommunications System (UMTS)**, which is the third generation (3G) mobile telecommunications standard developed by the International Telecommunication Union (ITU). WCDMA was one of the two main 3G technologies that were standardized by the **International Telecommunication Union (ITU)**, along with TD-SCDMA.

WCDMA was widely adopted as the dominant 3G technology in many parts of the world, including Europe, Asia, and North America. It offered several benefits over the 2G (second generation) mobile networks that it replaced, including higher data rates, improved capacity, and better coverage.

WCDMA has evolved over time, and later versions of the standard (such as High-Speed Packet Access, or HSPA) have been developed to provide even higher data rates and more efficient use of the spectrum. Today, WCDMA and its successors are used by billions of people around the world as a means of accessing the internet and staying connected with others.

WCDMA was eventually superseded by more advanced 4G (fourth generation) technologies, such as **LTE (Long-Term Evolution) and WiMAX (Worldwide Interoperability for Microwave Access)**, which offer even higher data rates and improved performance. However, WCDMA is still used in many parts of the world, especially in areas where 4G networks are not yet available or are not yet widely adopted.

Advantage:

One major advantage of WCDMA is its ability to handle large amounts of data, making it well-suited for applications such as mobile internet browsing and streaming video. It also has good coverage and reliability, as it is able to transmit signals over long distances and through physical barriers such as walls and buildings.

Disadvantage:

However, there are also some disadvantages to WCDMA. One drawback is that it requires a more complex and expensive infrastructure to support its wideband frequency bands. It is also more susceptible to interference from other sources, such as other wireless devices or electrical equipment. Additionally, WCDMA has been superseded by newer, faster mobile technologies such as 4G and 5G.

Overall, WCDMA has played an important role in the evolution of mobile telecommunications, but it has been replaced by newer technologies that offer improved performance and capacity.

OFDMA

OFDMA (**orthogonal frequency-division multiple access**), a technology in Wi-Fi 6, improves wireless network performance by establishing independently modulating subcarriers within frequencies. This approach allows simultaneous transmissions to and from multiple clients.

OFDMA (Orthogonal Frequency Division Multiple Access) is a wireless technology that works by:

1. Taking a WiFi channel and dividing it into multiple sub-channels (sub-carriers).
2. Assigning these sub-channels to specific devices, allowing simultaneous communication with the router
3. Enhancing throughput, reducing latency, and improving quality of service, especially in dense, high-traffic environments
4. Dividing a Wi-Fi channel into smaller frequency allocations (resource units) to communicate with multiple clients.
5. Assigning subsets of subcarriers to individual users for simultaneous low-data-rate transmission

What is OFDMA (orthogonal frequency-division multiple access)?

Orthogonal frequency-division multiple access (OFDMA) is a technology of Wi-Fi 6 (802.11ax) that lets access points serve multiple clients at the same time. OFDMA follows a set of rules created for the transmission of data between multiple terminals or clients over a transmission medium. The terminal could be any device at the end of a transmission channel, such as a computer or phone, and the medium could be a wireless network.

Orthogonal frequency-division multiplexing is a signal modulation technique that uses multiple subcarriers within the same communications channel. These subcarriers are closely spaced, transmit in parallel and carry low-bit rate data. The use of multiple subcarriers makes the technique resilient to selective fading and interference as well as provides fairly high spectral efficiency.

OFDM is itself based on frequency-division multiplexing and was commonly used in the past for cellular networking, broadcast media and older Wi-Fi standards like IEEE 802.11ac (Wi-Fi 5). OFDMA is a variant of the OFDM scheme. Specifically, it is a multi-user variant of OFDM, meaning it allows for multiple access and simultaneous data access for different users. This form of communication is an upgrade to both FDM and OFDM.

The differences between OFDM, FDM and a single wideband channel frequency wireless data transmission scheme. OFDMA is a variant of the OFDM scheme.

How OFDMA works

Traditional multiplexing technologies used analog modulation. In contrast, OFDMA uses carrier signal waves, called subcarriers, to move small bits of information in a more streamlined fashion. These subcarriers may be data subcarriers, reference-signal subcarriers or null subcarriers. Only the data subcarriers are used for data transmission. The channel is split into smaller frequencies known as resource units (RUs), so wireless carriers can efficiently occupy and use the frequency bands they are licensed to use.

By assigning subsets of time-frequency RUs to multiple users (e.g., access points), OFDMA allows users to communicate with multiple clients and simultaneously transmit data. The RUs are assigned depending on the bandwidth needed by the user as well as other factors, such as quality of service requirements, packet size and device constraints. Users may also have varying usage patterns or data loads but they are all accommodated in OFDMA because of the use of multiple closely-spaced subcarriers and flexible RU allocation.

An example of how OFDMA works is when two phones send data over the same phone line. A time-interval may be assigned to each phone so that they will take turns sending their signal over the line at their assigned intervals. However, these time frames are imperceptibly small, making it seem that the data transfers by both phones are happening simultaneously and seamlessly.

OFDMA and FDM

FDM is a communications technology in which multiple signals are combined and then transmitted over a single channel. The total available bandwidth is divided into multiple non-overlapping frequency bands. Overlapping is prevented due to the presence of guard bands, which refer to unused frequencies that separate the assigned bands. At the sending end, the modulated signals are combined with a multiplexer. The individual signals are then extracted from the combined signal at the receiving end using a demultiplexer.

OFDMA is an updated version of FDM that parallels internet carriers' switch to Wi-Fi 6 wireless as well as the upgrade of phone carriers upgrading to 4G and 5G LTE. Instead of the traditional analog modulation used in multiplexing, OFDMA uses carrier signal waves as subcarriers to move small bits of information in a more streamlined fashion.

OFDMA in Wi-Fi 6

OFDMA is one of the technology enhancements introduced in Wi-Fi 6. Wi-Fi 6 offers speeds of up to 9.6 Gbps, a sharp improvement over the 3.5 Gbps available in Wi-Fi 5. The higher speed can be split across multiple devices, so each device can benefit from potentially higher speeds.

With the introduction of OFDMA, Wi-Fi 6 increases network capacity to mitigate the access issues that are common when multiple Wi-Fi devices are active on a single network. Regardless of how many devices are added to the network or their data demands, OFDMA ensures strong connections and uninterrupted access over Wi-Fi 6, as well as lower latency for real-time applications like audio/video conferencing and online gaming. OFDMA can also increase the maximum throughput of a Wi-Fi network and improve the power efficiency of Wi-Fi-enabled mobile devices.

Advantages and disadvantages of OFDMA

One of the biggest advantages of OFDMA transmission is that it doesn't suffer from intracell interference. That said, OFDMA is somewhat prone to intercell interference, which can lead to degradation of signal quality. However, it is possible to mitigate intercell interference using techniques such as packet scheduling, frequency reuse and interference coordination.

Apart from low intracell interference, other advantages of ODFMA include the following:

- Higher diversity frequency.

- More efficiently packed subcarriers in the frequency spectrum, ensuring optimal spectral efficiency.
- More flexibility, as channels and subchannels can be toggled on and off.
- Provision for multiple independent channels.
- Better coverage over networks.

Owing to these advantages, OFDMA is frequently used in wireless LAN (Wi-Fi), long-term evolution (LTE or 4G) and WiMAX systems.

Potential disadvantages of OFDMA include the following:

- The diversity of frequencies is conditional on how subcarriers are assigned to users, which can become complex.
- It requires extra power because it is always on and ready to send a transmission.
- It has a higher sensitivity than other channel types to frequency offset.

CHAPTER 4

GSM

GSM (Global System for Mobile Communication) is a digital mobile network commonly utilized by mobile phone users in Europe and around the world. GSM, the most popular of the three digital wireless telephony systems (TDMA, GSM, and CDMA), is a version of time division multiple access (TDMA). GSM converts and compresses data before sending it along a channel with two other streams of user data, each with its time slot.

What is GSM?

GSM stands for Global System for Mobile Communication. GSM is an open and digital cellular technology used for mobile communication. It uses 4 different frequency bands 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz. It uses the combination of FDMA and TDMA.

GSM is having 4 different sizes of cells

- **Macro**: In this size of the cell, a Base Station antenna is installed.
- **Micro**: In this size of cell, antenna height is less than the average roof level.
- **Pico**: Small cells' diameter of a few meters.
- **Umbrella**: It covers the shadowed (Fills the gaps between cells) regions.

Features of GSM

- Supports international roaming
- Clear voice clarity
- Ability to support multiple handheld devices.
- Spectral / frequency efficiency
- Low powered handheld devices.
- Ease of accessing network
- International ISDN compatibility.
- Low service cost.
- New features and services.

The Architecture of GSM

- **BSS** : BSS stands for Base Station Subsystem. BSS handles traffic and signaling between a mobile phone and the network switching subsystem. BSS having two components **BTS** and **BSC.**
- **NSS** : NSS stands for Network and Switching Subsystem. NSS is the core network of GSM. That carried out call and mobility management functions for mobile phone present in network. NSS have different components like **VLR, HLR** and **EIR.**

- **OSS** : OSS stands for Operating Subsystem. OSS is a functional entity which the network operator monitor and control the system. **OMC** is the part of OSS. Purpose of OSS is to offer the customer cost-effective support for all GSM related maintenance services.

Suppose there are 3 Mobile stations which are connected with the tower and that tower is connected to BTS through TRX, then further connected to BSC and MSC. Let's understand the functionality of different components.

- **MS** : MS stands for Mobile System. MS comprises user equipment and software needed for communication with a mobile network. Mobile Station (MS) = Mobile Equipment(ME) + Subscriber Identity Module (SIM). Now, these mobile stations are connected to tower and that tower connected with BTS through TRX. TRX is a transceiver which comprises transmitter and receiver. Transceiver has two performance of sending and receiving.
- **BTS** : BTS stands for Base Transceiver Station which facilitates wireless communication between user equipment and a network. Every tower has BTS.
- **BSC** : BSC stands for Base Station Controller. BSC has multiple BTS. You can consider the BSC as a local exchange of your area which has multiple towers and multiple towers have BTS.
- **MSC** : MSC stands for Mobile Switching Center. MSC is associated with communication switching functions such as call setup, call release and routing. Call tracing, call forwarding

all functions are performed at the MSC level. MSC is having further components like VLR, HLR, AUC, EIR and PSTN.

- **VLR** : VLR stands for Visitor Location Register. VLR is a database which contains the exact location of all mobile subscribers currently present in the service area of MSC. If you are going from one state to another state then your entry is marked into the database of VLR.
- **HLR** : HLR stands for Home Location Register. HLR is a database containing pertinent data regarding subscribers authorized to use a GSM network. If you purchase SIM card from in the HLR. HLR is like a home which contains all data like your ID proof, which plan you are taking, which caller tune you are using etc.
- **AUC** : AUC stands for Authentication Center. AUC authenticates the mobile subscriber that wants to connect in the network.
- **EIR** : EIR stands for Equipment Identity Register. EIR is a database that keeps the record of all allowed or banned in the network. If you are banned in the network then you can't enter the network, and you can't make the calls.
- **PSTN** : PSTN stands for Public Switched Telephone Network. PSTN connects with MSC. PSTN originally a network of fixed line analog telephone systems. Now almost entirely digital in its core network and includes mobile and other networks as well as

fixed telephones. The earlier landline phones which places at our home is nothing but PSTN.

- **OMC** : OMC stands for Operation Maintenance Center. OMC monitor and maintain the performance of each MS, BSC and MSC within a GSM system.

Three subsystem BSS, NSS and OSS are connected with each other via some interfaces. Total three interfaces are there:

- **Air Interface** : Air interface is also known as UM interface. Interface between MS and BTS is called as UM interface because it is mobile analog to the U interface of ISDN.
- **Abis Interface** : It is a BSS internal interface linking with BTS and BSC.
- **A interface** : It provides communication between BSS and MSC.

How Does GSM Work?

GSM is a globally recognised digital cellular communication protocol. The GSM standard was developed by the European Telecommunications Standards Institute to describe the procedures for second-generation digital mobile networks, such as those used by mobile phones. It is a broad-area communications technology programme that uses digital radio channelling to provide audio, information, and multimedia communication systems. Every GSM radio channel is 200 kHz broad and is further divided into frames of eight time slots. The GSM system consists of mobile stations, base stations, and interweaving switching systems.

The GSM programme allows 8 to 16 audio users to share a single radio channel, and each radio transmission station can have numerous radio channels. Because of its simplicity, cost, and accessibility, GSM is now the most often utilised network technology in the Internet of Things (IoT).

Services of GSM

- **Bearer services/ data services:** GSM specifies different mechanism for data transmission, The original GSM allowing for data rates of up to 9600 bits/s. Bearer services permit transparent or non transparent data transmission.
    - **Transparent bearer services:** Transparent bearer services only use the physical layer to transmit data. Data transmission has a constant delay at throughput if no transmission error occurs.

Difference between GSM and CDMA

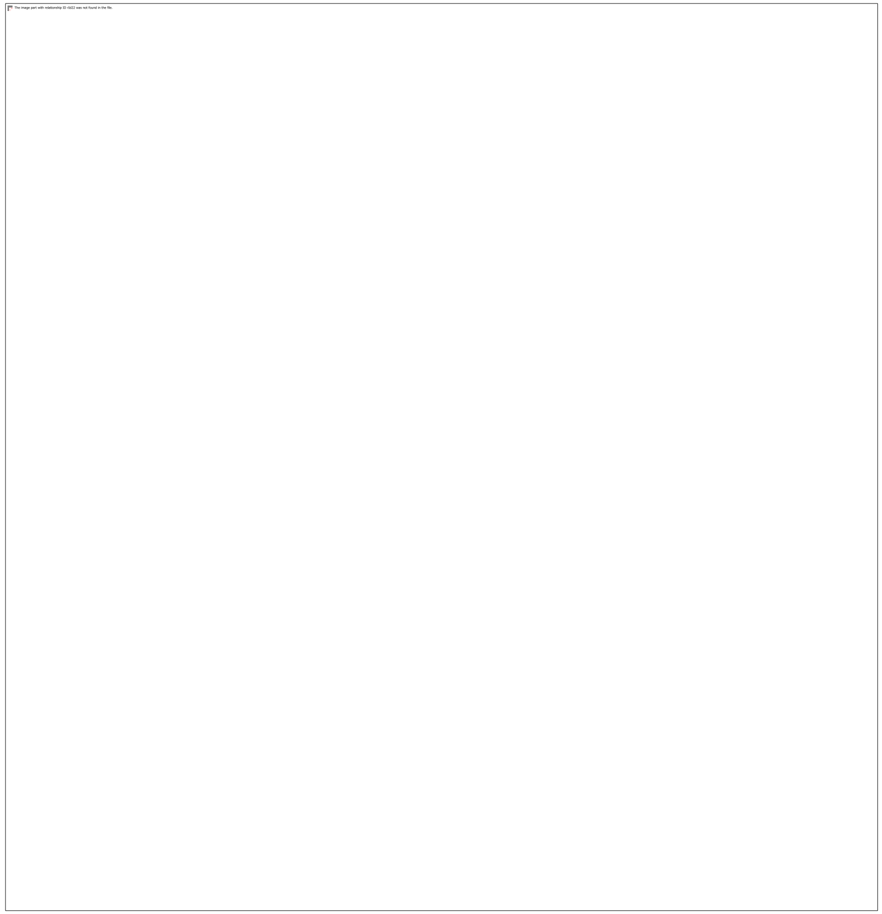
Last Updated : 11 Feb, 2024

GSM stands for **Global System for Mobile Communication** Voices, while **CDMA** stands for **Code Division Multiple Access.** GSM uses **FDMA (Frequency division multiple access)** and **TDMA (Time division multiple access)**. GSM supports transmitting data and voices both at once, but CDMA does have not this feature. In contrast, only mobile phones from a set of whitelisted companies can be used with a CDMA network.

What is CDMA?

CDMA is an acronym for **Code Division Multiple Access,** which is also a radio telecommunication standard similar to GSM. It is based on the **spread spectrum technology** and makes optimal use of the available bandwidth.

In a CDMA system, each user's signal is combined with a unique broadcast code, which transmits the signal in a wider bandwidth than the original data signal. CDMA technology offers many advantages, such as increased capacity, improved call quality, better security due to unique codes used for each user, increased resistance to interference and fading, and CDMA is widely used in wireless networks, including 2G, 3G, . some are 4G cellular networks. However, in many parts of the world, it has largely been replaced by other technologies such as GSM and LTE.



CDMA

Advantages of CDMA

- It makes effective use of a fixed frequency spectrum.
- The quantity of Users is unrestricted.

- It offers an adaptable distribution of resources.
- Because it works with other cellular technologies, roaming across the country is possible.

Disadvantages of CDMA

- Time synchronisation is necessary.
- It is unable to provide international roaming, a significant GSM benefit.
- The more users there are, the worse the CDMA system performs.
- Since CDMA networks are relatively new compared to GSM networks, they are not mature.
- When utilising CDMA, code length should be carefully chosen as it may cause a delay.
- The general quality of the service declines as the user base grows.

What is GSM?

A digital mobile communication standard called GSM, or Global System for Mobile Communication, is used to send and receive speech and data signals over a network. It uses a wedge spectrum and is also referred to as the second-generation standard for telecommunication or mobile networks. Other wireless services including UMTS (Universal Mobile Radio System), EDGE (Enhanced Data

Rates for GSM Evolution), and GPRS (General Packet Radio Service) have developed as a result of the GSM standard.

GSM

Advantages of GSM

- We can have inexpensive base stations and mobile sets thanks to GSM technology.
- Enhancement of spectrum efficiency is achieved.
- In GSM, the speech or data signals are of excellent quality.
- The GSM and ISDN (Integrated Services Digital Network) work together.

Disadvantages of GSM

- Multiple users sharing the same bandwidth can generate bandwidth delays and interface issues for the transmission.

- It may cause interference with some gadgets, including those that use pulse transmission technology, such hearing aids. As a result, many places have policies requiring cell phones to be turned off, including hospitals, airports and gas stations.
- Installing repeaters is necessary to improve coverage.
- Because of its low data rate capacity, sophisticated GSM devices are utilised when high data rates are required.
- Since Qualcomm owns many patents on GSM technology, a licence from them is required.
- Because there isn't a large enough market for manufacturers to release IS-95 devices, IS-95 is often deployed in tiny towers.

Differences Between GSM and CDMA

Parameters	GSM	CDMA
Full form global	Global System for Mobile communication.	Code Division Multiple Access.

Parameters	GSM	CDMA
Technology used	FDMA(Frequency Division Multiple Access) & TDMA (Time Division Multiple Access).	CDMA(Code Division Multiple Access).
Availability	GSM is globally widely used and available.	CDMA is available in fewer countries and carriers.
Data speed rate	42Mbps in HSPA (3G).	3.6Mbps in CDMA.
Features	GSM supports transmitting data and voice both at once.	CDMA does not support this feature.
Customer Information	Stored in a SIM card.	Stored in a headset or phone.

Parameters	GSM	CDMA
Encryption	GSM does not provide built-in encryption is available.	CDMA provides built-in encryption.
Secure	GSM offers less secure communication.	CDMS offers secure communication.
Roaming	GSM enables worldwide roaming.	CDMA enables limited roaming.
Signal Detection	GSM signals can be detected since they are focused in a narrow bandwidth.	CDMA transmissions are difficult to detect.
SIM Card	There is always a requirement of SIM card for a GSM device to function.	There are no such

BLUE TOOTH

1. What is Bluetooth?

Bluetooth is a short-range wireless communication technology used to exchange data between devices over short distances (typically up to 100 meters or 328 feet). It is commonly used for connecting peripheral devices such as headphones, keyboards, mice, and smartphones.

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2. Key Features of Bluetooth

- **Short-range communication**: Typically operates within 10 meters, though some versions support up to 100 meters.
- **Low power consumption**: Ideal for battery-powered devices.

- **Secure communication**: Supports encryption and authentication to prevent unauthorized access.

EDGE

EDGE (Enhanced Data rates for GSM Evolution), a wireless communication system. EDGE is a 3G technology used in mobile networks that provides higher data transmission rates compared to the earlier GSM (Global System for Mobile Communications) standards.

Here are some key notes on EDGE in wireless communication systems:

1. Overview of EDGE

- **Definition**: EDGE is a 2.75G technology that enhances the capabilities of GSM networks by providing faster data transfer rates.

It is considered an enhancement of GPRS (General Packet Radio Service) and is sometimes called "Enhanced GPRS" or "EGPRS."

- **Data Rates**: EDGE can deliver data rates of up to 384 kbps (kilobits per second) under optimal conditions, which is faster than GPRS's 56-114 kbps but slower than full 3G technologies like UMTS (Universal Mobile Telecommunications System).
- **Backward Compatibility**: EDGE operates over existing GSM and GPRS infrastructures, making it an attractive upgrade for mobile operators.

2. Technology Components

- **Modulation Scheme**: EDGE uses **8PSK (8 Phase Shift Keying)** instead of the standard GMSK (Gaussian Minimum Shift Keying) used in GSM. This allows EDGE to transmit three bits per symbol rather than just one, thus increasing data rates.

WI-FI

Wi-Fi (short for *Wireless Fidelity*) is a technology that allows devices to connect to the internet or communicate with one another wirelessly using radio waves. It plays a critical role in wireless communication, particularly in home, office, and public networks, as it offers high-speed internet access without the need for physical cables.

How Wi-Fi Works in Wireless Communication

Wi-Fi operates based on the IEEE 802.11 family of standards, which define the protocols for wireless local area networks (WLANs). Here's a simplified explanation of the key components and how Wi-Fi works:

- **Radio Waves**: Wi-Fi uses radio frequency (RF) waves to transmit data between devices, typically at frequencies of 2.4 GHz or 5 GHz (with newer standards also using 6 GHz). These waves travel through the air, and devices equipped with Wi-Fi adapters can send and receive data by modulating the RF signals.

Access Points (APs): An access point is a device that connects to a wired router or switch and allows wireless devices to connect to the local network. It essentially broadcasts Wi-Fi signals that devices like smartphones, laptops, and tablets can detect and connect to. The AP acts as an intermediary, enabling data transfer between the devices and the internet.

Wi-Fi Standards: The performance and features of Wi-Fi networks are defined by different IEEE 802.11 standards. For example:

1. **802.11b/g/n**: Older standards, commonly used in many Wi-Fi networks.

2. **802.11ac**: Offers faster speeds and improved range, commonly used in modern networks.
3. **802.11ax (Wi-Fi 6)**: The latest standard, providing even faster speeds, improved efficiency, and better performance in congested environments (e.g., densely populated areas with many connected devices).

Wireless Router: A wireless router combines a traditional router and an access point. It connects to a modem (which provides internet access) and transmits Wi-Fi signals to allow devices to connect wirelessly. The router directs the traffic between devices in the local network and the wider internet.

Security: Wi-Fi networks are secured using encryption methods such as WPA2 (Wi-Fi Protected Access 2) or WPA3 (the newer, more secure standard). Encryption ensures that data transmitted over the network remains private and protected from unauthorized access.

Interference and Range: Wi-Fi signals can be affected by physical obstructions, interference from other wireless devices, and the distance from the access point. The range of a Wi-Fi network depends on the router's power, the environment, and the specific Wi-Fi standard in use.

2.

Applications of Wi-Fi in Wireless Communication

- **Home Networking**: Wi-Fi enables the interconnectivity of devices like smartphones, laptops, smart TVs, IoT devices (e.g., thermostats, lights, cameras), and gaming consoles within a home without needing cables.

- **Enterprise Networks**: In business settings, Wi-Fi allows employees to access the internet, internal networks, and cloud-based resources wirelessly, providing flexibility and reducing the need for physical networking cables.
- **Public Wi-Fi**: Many public spaces such as cafes, airports, hotels, and libraries offer free or paid Wi-Fi access, enabling users to stay connected while on the go.
- **Internet of Things (IoT)**: Many IoT devices rely on Wi-Fi to communicate with other devices or cloud services. This includes smart home appliances, wearable devices, and sensors used in various industries.

Advantages of Wi-Fi in Wireless Communication

- **Convenience**: Wi-Fi allows devices to connect without the need for cables, making it ideal for mobile devices and reducing clutter.

- **High Speed**: Wi-Fi can support high-speed internet access, with newer standards like Wi-Fi 6 offering speeds of up to 9.6 Gbps.
- **Wide Adoption**: Wi-Fi is widely available in homes, businesses, and public spaces, making it one of the most popular methods for wireless internet access.
- **Scalability**: Wi-Fi networks can be easily expanded by adding additional access points or range extenders to cover larger areas or handle more devices.

Limitations of Wi-Fi

- **Range**: Wi-Fi signals can be weakened by physical obstacles (walls, floors, etc.) and can experience interference from other devices (microwaves, Bluetooth, etc.).

- **Security Concerns**: Open or poorly secured Wi-Fi networks can be vulnerable to unauthorized access and cyberattacks if not properly encrypted.
- **Congestion**: In areas with many Wi-Fi networks (e.g., apartment buildings), networks can experience interference and congestion, slowing down the connection speeds.

Future of Wi-Fi in Wireless Communication

As more devices become connected through the Internet of Things (IoT) and data consumption continues to increase, Wi-Fi technology is evolving. Newer standards, like **Wi-Fi 6E** (which operates in the 6 GHz band), promise better performance and lower latency. The development of **Wi-Fi 7** is also underway, expected to provide even faster speeds, lower latency, and enhanced support for high-bandwidth applications such as AR/VR, 4K/8K streaming, and online gaming.

Summary

Wi-Fi is a cornerstone of modern wireless communication, enabling fast, flexible, and reliable internet access across homes, businesses, and public spaces. It relies on radio waves, standards defined by IEEE 802.11, and secure access points to transmit data wirelessly. While it offers numerous advantages, including ease of use, mobility, and widespread availability, challenges such as interference, range limitations, and security must be managed to ensure optimal performance. As the technology continues to evolve, Wi-Fi will remain central to the development of new applications in wireless communication.

CHAPTER 5

3G System (Third-Generation Mobile Networks)

Overview of 3G System

- **3G** refers to the third generation of mobile telecommunications technology, designed to provide faster data transfer rates, improved voice quality, and a more efficient use of spectrum compared to previous generations (2G).
- 3G systems are based on **WCDMA (Wideband Code Division Multiple Access)**, though other 3G technologies like **CDMA2000** and **TD-SCDMA** exist.
- 3G networks enable services like video calling, mobile internet access, and higher-quality voice communication.

Key Features of 3G Networks

1. **Higher Data Transfer Rates**:

2.
    - 3G networks offer download speeds of up to 2 Mbps (theoretical max), though real-world speeds may vary.
    - They can support applications such as video streaming, web browsing, and mobile gaming.

3. **Global Roaming**:

4.

- 3G supports international roaming and provides seamless voice and data connectivity when traveling abroad.

5.

Enhanced Voice Quality:

6.

- Voice calls are clearer and more reliable compared to 2G, due to improved coding techniques and more efficient spectrum usage.

7.

Always-On Connectivity:

8.

- Users can remain connected to the internet without needing to reconnect every time they access a new service.

9.

Multimedia Services:

10.

- Supports multimedia services, such as video calling, mobile TV, and advanced messaging.

3G Network Architecture

3G systems are divided into three major components:

User Equipment (UE):

- This includes mobile phones, tablets, and other wireless devices that connect to the 3G network.

Radio Access Network (RAN):

- The RAN consists of:
  - **Node B (Base Station)**: Responsible for radio communication with the User Equipment (UE).
  - **RNC (Radio Network Controller)**: Controls the Node Bs and manages resources like handovers between cell towers and power levels.

Core Network (CN):

- **Serving GPRS Support Node (SGSN)**: Handles packet-switched data services, including routing of user data to/from the internet.
- **Gateway GPRS Support Node (GGSN)**: Provides interconnection to external packet-switched networks, such as the internet.
- **Mobile Switching Center (MSC)**: Handles circuit-switched voice calls and manages mobility.

3G Technology Standards

- **WCDMA (Wideband Code Division Multiple Access)**: The most widely used 3G technology, it operates in frequency bands ranging from 1.92 GHz to 2.2 GHz.

- **CDMA2000**: An alternative to WCDMA, based on the CDMA standard used in 2G networks.
- **TD-SCDMA (Time Division Synchronous Code Division Multiple Access)**: A 3G standard developed primarily by China for use in their domestic market.

3G Radio Interface

1. **Frequency Division Duplex (FDD)**:
    - FDD separates uplink (transmission from UE to network) and downlink (transmission from network to UE) frequencies.
    - WCDMA uses FDD for most deployments.
2. **Time Division Duplex (TDD)**:

    - TDD uses the same frequency band for both uplink and downlink, with the direction of transmission changing at regular intervals.
    - TD-SCDMA uses TDD.

3G Data Services

- **Circuit-Switched Data (CSD)**: For traditional voice calls, also used for low-speed data transfer.
- **Packet-Switched Data**: Used for internet access, email, MMS, and other data services.
- **High-Speed Downlink Packet Access (HSDPA)**: An enhancement to 3G that increases downlink speeds (can achieve speeds up to 14.4 Mbps in some cases).

- **High-Speed Uplink Packet Access (HSUPA)**: Enhances uplink speeds, enabling faster uploads (up to 5.8 Mbps).

3G vs 2G and 4G

-

  Compared to 2G:

-

  - 3G provides much faster data rates (up to 2 Mbps for 3G, compared to 56 kbps to 384 kbps for 2G).
  - 3G also supports multimedia services, such as video calling and mobile TV, which 2G cannot.

-

Compared to 4G:

-
    - 4G provides significantly faster speeds (up to 1 Gbps), lower latency, and better overall performance for streaming, gaming, and large-scale data applications.
    - 3G is slower and has higher latency than 4G, but still offers substantial improvements over 2G.

3G Evolution and 3.5G/3.75G

-

3.5G (HSPA): High-Speed Packet Access is a set of protocols designed to enhance the 3G network by increasing the data transfer rates. It includes HSDPA (downlink) and HSUPA (uplink).

-
-

3.75G (HSPA+): An advanced version of HSPA that further improves speeds (up to 42 Mbps) and introduces better spectrum efficiency.

-

Challenges of 3G Networks

Spectrum Constraints:

- 3G requires significant bandwidth, and in some regions, there is limited spectrum available for 3G deployment.

Infrastructure Costs:

- Building and maintaining 3G infrastructure is costly, requiring substantial investments in base stations, backhaul, and core network equipment.

Competition with 4G:

- As 4G technology became more widely available, many users migrated to faster, more efficient LTE networks, which offer better speed, lower latency, and improved support for data-heavy applications.

Conclusion

3G marked a major leap forward in mobile communication, bringing fast data services and multimedia capabilities to mobile phones and devices. While it has been largely superseded by 4G and 5G technologies, 3G still serves as a critical bridge in many parts of the world, providing essential connectivity and a reliable backup network. Understanding 3G provides a foundational knowledge for grasping the evolution of mobile network technologies leading to modern 5G systems.

4G

1. Overview of 4G

- 4G stands for the *fourth generation* of mobile telecommunications technology.

- Provides faster data transfer speeds and better reliability compared to 3G.
- Enables high-speed internet access, supports HD streaming, video calls, online gaming, and IoT connectivity.

2. Core Technologies

- **LTE (Long Term Evolution):** The most widely used 4G technology, offering high-speed data and low latency.
- **WiMAX (Worldwide Interoperability for Microwave Access):** Alternative 4G standard, primarily used in some areas but less common than LTE.

3. Speed and Performance

- Average speed: **5–12 Mbps** download, **2–5 Mbps** upload, with peak rates reaching 100 Mbps.

- Significantly improved latency compared to 3G, typically around 50-100 ms.

4. Network Architecture

- **Evolved Packet Core (EPC):** Simplified all-IP network architecture for efficient data transfer.
- **OFDM (Orthogonal Frequency-Division Multiplexing):** Reduces interference, improving data speed and quality.
- **MIMO (Multiple Input, Multiple Output):** Uses multiple antennas for increased data throughput.

5. Key Features

- **Higher Bandwidth:** Allows more data to be transferred, supporting a higher number of users and services.

- **Improved Mobility:** Supports faster movement without losing connectivity, ideal for mobile users in transit.
- **Better Spectrum Efficiency:** Efficient use of available spectrum resources, supporting more users on the same network.

6. Applications

- **Mobile Broadband:** Fast internet access on mobile devices for streaming, gaming, etc.
- **IoT (Internet of Things):** Supports numerous connected devices, including smart home products and wearables.
- **HD Voice and Video Calls:** Enhanced quality for calls and video interactions over IP.

7. Challenges and Limitations

- **Battery Consumption:** Faster data rates often mean higher power usage.
- **Coverage Issues:** While widespread, some rural or remote areas may have limited 4G connectivity.
- **Compatibility**: Older devices may not support 4G, requiring upgrades.

8. Transition to 5G

- 4G will coexist with 5G for years to come, with 4G serving as the backbone for 5G networks in many areas.
- While 5G brings much higher speeds, 4G is expected to remain essential for coverage and fallback.

These notes cover the essentials of 4G, including its technical basis, capabilities, applications, and limitations.

UMTS

UMTS (Universal Mobile Telecommunications System):

1. Overview of UMTS

- UMTS is a *3G mobile communication technology* developed to provide higher data speeds than 2G systems like GSM.
- Part of the IMT-2000 family, standardized by the 3GPP (3rd Generation Partnership Project).
- Designed for enhanced voice, data, and multimedia capabilities with global interoperability.

2. Core Technologies

- **WCDMA (Wideband Code Division Multiple Access):** The primary access technology for UMTS, using a wide radio channel to allow multiple users.
- **HSPA (High-Speed Packet Access):** An upgrade to UMTS, HSPA includes HSDPA (downlink) and HSUPA (uplink) for faster data speeds.

3. Speed and Performance

- Original UMTS speeds: up to **384 Kbps** for mobile devices, **2 Mbps** for stationary use.
- HSPA improves speeds, reaching **14.4 Mbps** download (HSDPA) and up to **5.76 Mbps** upload (HSUPA).
- Latency generally around **100-200 ms**, which is acceptable for web browsing and standard apps.

4. Network Architecture

- **Core Network:** Divided into Circuit-Switched (for voice) and Packet-Switched (for data) domains.
- **UTRAN (UMTS Terrestrial Radio Access Network):** Connects mobile devices to the core network via Node Bs (base stations) and Radio Network Controllers (RNCs).
- **All-IP Network Evolution:** Later versions moved toward an IP-based core network, improving data performance.

5. Key Features

- **Global Roaming:** Seamless international roaming across countries due to global standardization.
- **Higher Capacity:** Supports more users per cell site compared to GSM, improving network efficiency.

- **Dual-Transfer Mode:** Allows simultaneous voice and data use, an advantage over 2G.

6. Applications

- **Mobile Internet:** Enables faster browsing and basic video streaming on mobile devices.
- **Multimedia Messaging (MMS):** Allows sending multimedia files like images and videos.
- **Video Calls:** Supports video calling, though with limited quality due to network speeds.
- **Location-Based Services:** Supports GPS and location-based applications.

7. Challenges and Limitations

- **Limited Data Rates:** Speeds are significantly lower compared to 4G and 5G, especially in high-usage areas.
- **Battery Drain:** Power consumption can be high due to WCDMA and HSPA's processing requirements.
- **Coverage:** Some rural or remote areas may lack strong UMTS coverage, relying on GSM (2G) fallback.

8. Transition to 4G and Beyond

- While UMTS provides solid 3G connectivity, it's increasingly replaced by 4G LTE for higher speeds and efficiency.
- UMTS infrastructure still supports many devices globally and acts as a fallback in 4G and early 5G networks.

These notes provide an overview of UMTS, covering its underlying technologies, network structure, applications, and limitations as a 3G standard.

LTE

LTE (Long Term Evolution):

1. Overview of LTE

- LTE is a 4G mobile communication standard aimed at providing high-speed data, low latency, and improved user experience.
- Developed by the 3GPP as a major enhancement over 3G UMTS, designed to meet the growing demand for mobile data and internet services.

2. Core Technologies

- **OFDMA (Orthogonal Frequency-Division Multiple Access)**: Splits bandwidth into smaller sub-carriers, improving efficiency and allowing simultaneous data transmissions.
- **MIMO (Multiple Input, Multiple Output)**: Utilizes multiple antennas at both the transmitter and receiver to increase data rates and reliability.

- **All-IP Network:** LTE abandons the circuit-switched architecture, using an IP-based system for both voice and data, allowing for better efficiency and integration with the internet.

3. Speed and Performance

- LTE provides download speeds of up to **100 Mbps** and upload speeds of up to **50 Mbps** in ideal conditions.
- Average speeds: **5-12 Mbps** download and **2-5 Mbps** upload, depending on network conditions and device compatibility.
- **Latency:** Typically 10-50 ms, enabling smoother browsing, gaming, and real-time applications.

5G

5G technology:

1. Overview of 5G

- 5G is the *fifth generation* of mobile network technology, developed to support massive connectivity, ultra-fast data speeds, and low latency for new and existing applications.
- Provides faster, more reliable, and higher capacity networks compared to 4G LTE, enabling transformative applications like augmented reality (AR), virtual reality (VR), and autonomous vehicles.

2. Core Technologies

- **mmWave (Millimeter Wave):** Uses high-frequency bands (24 GHz and above) for ultra-fast data speeds over shorter distances.

- **Sub-6 GHz:** Utilizes mid and low-frequency bands (below 6 GHz), offering a balance between speed and range, improving coverage in urban and rural areas.
- **Massive MIMO (Multiple Input, Multiple Output):** Deploys a large number of antennas on base stations to enhance capacity and efficiency.
- **Network Slicing:** Allows operators to create multiple virtual networks on a single physical 5G infrastructure, customized for different applications.

3. Speed and Performance

- Potential peak speeds: up to **10 Gbps**, with average speeds ranging from **50 Mbps to 3 Gbps**, depending on conditions.

- **Latency:** Ultra-low latency of **1-10 ms**, ideal for real-time applications like autonomous driving, remote surgery, and cloud gaming.
- Improved **capacity** allows 5G networks to support a significantly higher number of connected devices simultaneously.

4. Network Architecture

- **5G Core (5GC):** Built on an all-IP architecture, 5G core supports diverse applications and services with advanced capabilities like network slicing.
- **Edge Computing:** Data processing closer to the user, reducing latency by avoiding central network processing for some applications.
- **Distributed Network Design:** Multiple small cells and base stations work together for reliable high-speed coverage, especially in urban areas.

5. Key Features

- **Enhanced Mobile Broadband (eMBB):** Supports high-speed internet for mobile devices, providing smooth HD streaming and immersive media experiences.
- **Ultra-Reliable Low Latency Communications (URLLC):** Designed for mission-critical applications that require stable, near-instantaneous data transfer.
- **Massive Machine Type Communications (mMTC):** Connects a large number of IoT devices efficiently, ideal for smart cities, industrial IoT, and smart agriculture.

6. Applications

- **Autonomous Vehicles**: Ultra-low latency and high reliability are essential for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication.
- **AR/VR and Immersive Media:** High bandwidth and low latency enable seamless virtual reality and augmented reality experiences.
- **Smart Cities**: Supports infrastructure for connected services like traffic management, surveillance, waste management, and environmental monitoring.
- **Industrial Automation:** Enables real-time monitoring and control in manufacturing, logistics, and supply chain sectors.

7. Challenges and Limitations

- **Infrastructure Costs**: Implementing 5G requires extensive infrastructure, including a dense network of small cells, especially for mmWave.

- **Limited Range of mmWave:** High-frequency mmWave signals have limited range and can be obstructed by buildings, foliage, or rain.
- **Device Compatibility**: 5G-capable devices are needed to access 5G networks, and not all areas have coverage yet.
- **Energy Demand:** The power requirements for 5G base stations and network components are higher than for 4G, impacting operational costs.

8. Coexistence with 4G

- **5G Non-Standalone (NSA):** Early 5G networks are built on 4G infrastructure, utilizing existing LTE core while adding 5G capabilities.
- **5G Standalone (SA):** Pure 5G networks with a dedicated 5G core provide full performance benefits and support advanced features like network slicing.

9. Future Development

- **Beyond 5G (B5G) and 6G:** Research into new standards and technologies is ongoing to address limitations of 5G and support even more advanced applications, focusing on higher efficiency, speed, and global connectivity.

These notes cover the essentials of 5G, including its technical foundation, performance, key applications, challenges, and its evolving relationship with earlier networks.

4. Network Architecture

- **Evolved Packet Core (EPC):** A simplified, all-IP core network that improves data handling and latency.

- **eNodeB (evolved Node B):** The LTE equivalent of a base station, which manages the radio interface, allocates bandwidth, and handles user mobility.
- **Simplified Handover:** Supports seamless transitions between cells, even at high speeds, providing better connectivity for mobile users.

5. Key Features

- **High Spectral Efficiency:** Optimizes use of available spectrum, supporting more users per cell with high data speeds.
- **Low Latency:** Improved response time enhances real-time applications like video calls and gaming.
- **Voice over LTE (VoLTE):** Allows high-quality voice calls over the LTE network using IP, providing clearer audio and faster call setup times.

6. Applications

- **Mobile Broadband:** LTE supports high-speed internet for smartphones, tablets, and mobile routers, enabling HD video streaming, gaming, and web browsing.
- **IoT (Internet of Things):** With LTE-M and NB-IoT, LTE supports connected devices such as smart home systems, wearables, and industrial IoT applications.
- **Public Safety and Emergency Services:** Provides reliable connectivity for first responders and emergency services.

7. Challenges and Limitations

- **Battery Usage:** The high data rates and active usage patterns can lead to increased battery drain on devices.
- **Coverage Variation:** LTE coverage may vary, especially in rural areas or locations with challenging geography.

- **Compatibility**: Older devices, designed for 3G, require upgrading to be compatible with LTE networks.

8. Evolution to LTE-Advanced and 5G

- **LTE-Advanced (LTE-A):** Enhances LTE with higher speeds (up to 1 Gbps) and improved features like carrier aggregation, which combines multiple channels for faster data.
- **Transition to 5G**: LTE remains a vital part of mobile networks, often used as a fallback for 5G. LTE's infrastructure also helps support and complement 5G deployments.

These notes cover LTE's essential aspects, including its technical structure, speed advantages, key applications, and role in evolving mobile networks.

DIFFERENCE BETWEEN 4G AND 5G

1. **Speed and Data Rates**

- **4G**: Typical download speeds range from **5–12 Mbps**, with peak speeds around **100 Mbps**.
- **5G**: Averages around **50 Mbps to 3 Gbps**, with potential peak speeds reaching **10 Gbps** in ideal conditions, making 5G up to **100 times faster than 4G