UNIT-5
Cellular Communication

Cellular phone systems:

A mobile phone is an electronic device used for mobile telecommunications over a cellular network of specialized base stations known as cell sites. A cell phone offers full Duplex Communication and transfer the link when the user moves from one cell to another. As the phone user moves from one cell area to another, the system automatically commands the mobile phone and a cell site with a stronger signal, to switch on to a new frequency in order to keep the link.

Mobile phone is primarily designed for Voice communication. In addition to the standard voice function, new generation mobile phones support many additional services, and accessories, such as SMS for text messaging, email, packet switching for access to the Internet, gaming, Bluetooth, camera with video recorder and MMS for sending and receiving photos and video, MP3 player, radio and GPS.

A **mobile phone** (also known as a **cellular phone**, **cell phone**, **hand phone**, or simply a **phone**) is a phone that can make and receive telephone calls over a radio link while moving around a wide geographic area. It does so by connecting to a cellular network provided by a mobile phone operator, allowing access to the public telephone network. By contrast, a cordless telephone is used only within the short range of a single, private base station.

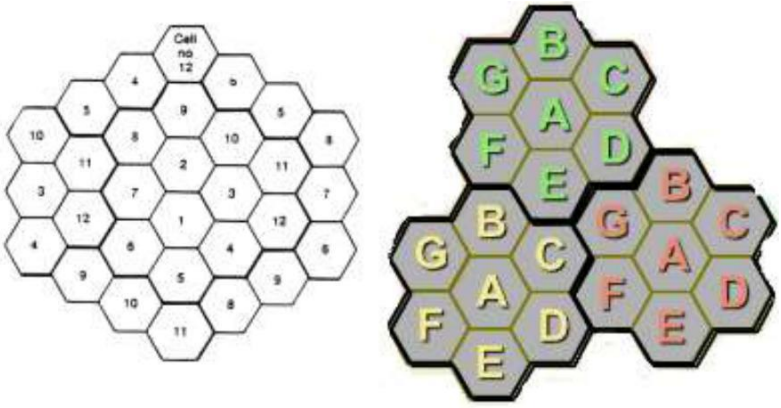
In addition to telephony, modern mobile phones also support a wide variety of other services such as text messaging, MMS, email, Internet access, short-range wireless communications (infrared, Bluetooth), business applications, gaming, and photography. Mobile phones that offer these and more general computing capabilities are referred to as smartphones.

A **cellular network** or **mobile network** is a wireless network distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. In a cellular network, each cell uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed bandwidth within each cell.

When joined together these cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.

In a cellular radio system, a land area to be supplied with radio service is divided into regular shaped cells, which can be hexagonal, square, circular or some other regular shapes, although hexagonal cells are conventional.

Each of these cells is assigned multiple frequencies ($f_1 - f_6$) which have corresponding radio base stations. The group of frequencies can be reused in other cells, provided that the same frequencies are not reused in adjacent neighboring cells.



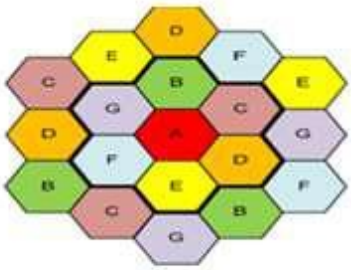
The cells which collectively use the complete set of available frequencies is called a cluster.

Cells with the same letter use the same set of frequencies.

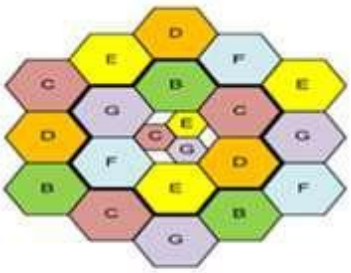
A cell *cluster* is outlined in bold, and replicated over the coverage area. In this example, the cluster size, *N*, is equal to 7; and the frequency reuse factor is 1/7, since each cell contains 1/7 of the total number of available channels.

Cell Splitting:

Cell splitting is the process of dividing the radio coverage of a cell site in a wireless telephone system into two or more new cell sites. Cell splitting may be performed to provide additional capacity within the region of the original cell site.



Original Cell Distribution



Cell Distribution following the splitting of the cell labeled A in the upper figure

The new small cells are reassigned new frequencies that do not cause co-channel interference with adjacent cells as shown in the above figure.

The power transmitted in the small cells is reduced compared to the power transmitted in the large cells. It requires much less power to cover the cell compared to the large cells. Higher network capacity is obtained due to cell splitting. It increases the battery life of these mobile phones.

The main disadvantage of cell splitting is that it requires the construction of new towers, which is very costly.

Microcell: A microcell is a cell in a mobile phone network served by a low power cellular base station (tower), covering a limited area such as a mall, a hotel, or a transportation hub. A microcell uses power control to limit the radius of its coverage area.

Typically the range of a microcell is less than two kilometers wide

Microcells - smaller cells embedded within macrocells

- Cell radii are less than 1 km.
- Base stations are compact, low-cost, at heights of ~10 m.

Macrocell: A macrocell is a cell in a mobile phone network that provides radio coverage served by a high power cellular base station (tower). Generally, macrocells provide coverage larger than microcell. The antennas for macrocells are mounted on ground-based masts, rooftops and other existing structures, at a height that provides a clear view over the surrounding buildings and terrain. Macrocell base stations have power outputs of typically tens of watts. The term macrocell is used to describe the widest range of cell sizes. Macrocells are found in rural areas or along highways. Over a smaller cell area, a microcell is used in a densely populated urban area.

Macrocells - cells in the traditional cellular system

- Cell radii are 1 to 10 km.
- Base stations are costly, antenna tower heights ≥ 30 m.

Frequency Bands used in Cellular communication:

Frequency bands are groupings of radio frequencies that are used by mobile networks to communicate with mobile phones. The frequency bands that a phone supports determine to a large degree where and on which networks it can be used. For example, T-Mobile USA uses the 1900MHz band for its GSM network, while AT&T uses both 1900MHz and the newer 850MHz frequency bands. Europe and most of the rest of the world use the 900MHz and 1800MHz frequency bands for GSM. So for a device to work properly on T-Mobile USA as well as work in Europe, it would need to support the 1900MHz band and one or both of the 900MHz and 1800MHz bands used in Europe. A tri-band device supports 3 different bands, while a quad-band device supports 4.

System	Band	Uplink - Mobile To Base (MHz)	Downlink - Base To Mobile (MHz)	AFRCN	Equivalent UMTS/LTE band
T-GSM-380	380	380.2 – 389.8	390.2 – 399.8	dynamic	
T-GSM-410	410	410.2 – 419.8	420.2 – 429.8	dynamic	
GSM-450	450	450.6 – 457.6	460.6 – 467.6	259 – 293	31
GSM-480	480	479.0 – 486.0	489.0 – 496.0	306 – 340	
GSM-710	710	698.2 – 716.2	728.2 – 746.2	dynamic	12
GSM-750	750	777.2 – 792.2	747.2 – 762.2	438 – 511	
T-GSM-810	810	806.2 – 821.2	851.2 – 866.2	dynamic	27
GSM-850	850	824.2 – 849.2	869.2 – 893.8	128 – 251	5
P-GSM-900	900	890.0 – 915.0	935.0 – 960.0	1 – 124	

In GSM-850, the frequencies ranging from 824.2 MHz to 849 MHz are reserved for uplink transmission from the call phone to the base station. These channels are also called reverse channels. The frequencies ranging from 869.2 MHz to 893.8 MHz form the downlink bands from the base station to the cell phone. Both these 25 MHz segments of frequencies were originally divided into 832 channels each 30 KHz wide.

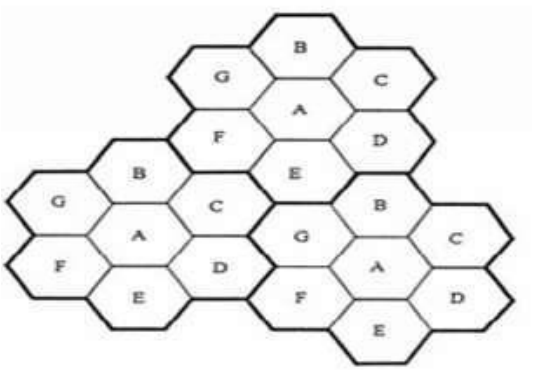
ARFCN (Absolute Radio Frequency Channel Number):

It is a channel numbering scheme. It is used to identify specific RF channels in GSM. *ARFCN* is a code that specifies a pair of physical carriers and channels. These are used for the transmission and reception one for uplink signal and the other for the downlink signal. The ARFCN can be used to calculate the exact frequency of the radio channel.

Refer the previous table for different AFRCN numbers

Frequency reuse:

It defines the procedure of a single carrier frequency being used repeatedly, within distinct geographical areas for maximum user facilitation and coverage. This procedure originated with the first-generation AMPS (advanced mobile phone service) cellular networks and was successfully adapted by second- and third-generation networks. Although the practical methods of reusing a single frequency vary in different networks, the original principles have remained the same.



Every cellular network is allotted with a band (group) of operating frequencies, over which its communication procedures take place. In this regard, allotting each cell with its own distinct career frequency and not reusing it again results in limited coverage of a cellular network, and for this reason, every frequency is to be reused in different cells after a significant distance spacing them from each other. This distance is usually obtained theoretically, with a standard formula of $D=R\sqrt{3N}$, where "D" is the distance required for frequency reuse, "R" is the approximate radius of each cell and "N" denotes number of cells per cluster.

Roaming:

In wireless telecommunications, **roaming** is a general term referring to the extension of connectivity service in a location that is different from the home location where the service was registered. Roaming ensures that the wireless device is kept connected to the network, without losing the connection. The term "roaming" originates from the GSM (Global System for Mobile Communications)sphere, the term "roaming" can also be applied to the CDMA technology.

GSM Roaming is defined as the ability for a cellular customer to automatically make and receive voice calls, send and receive data, or access other services, including home data services, when travelling outside the geographical coverage area of the home network, by means of using a visited network. This can be done by using a communication terminal or else just by using the subscriber identity in the visited network.

When a user turns on his cell phone in a roaming area the phone identifies itself to the switch. The switch then finds out it the phone is local one. If it is not so the switch will attempt to find switch based on the exchange. When the home switch is located it has to be found out if roaming is possible. If roaming is possible then the switch called the roaming switch sets up a visitor Location Register (VLR). The VLR is the database in a mobile services switching center. This store a copy of the data held in the home Location Register (HLR) on that switching center. The HLR is the data base in public land mobile network that stores details of each mobile. If switched ON, the VLR on which it is currently registered. The home switch also gets notified about the change so that it can route the user as at home. The incoming calls are routed from home switch to the roaming switch after sending a message. This whole process of registration of the phone and notification of the home takes about 2 Seconds.

Handoff in Wireless Mobile Networks:

Handoff is the process of changing the channel (frequency, time slot, spreading code, or combination of them) associated with the current connection while a call is in progress. It is often initiated either by crossing a cell boundary or by deterioration in quality of the signal in the current channel.

Handoff is divided into two broad categories— hard and soft handoffs. They are also characterized by “break before make” and “make before break.”

In hard handoffs, current resources are released before new resources are used;

in soft handoffs, both existing and new resources are used during the handoff process.

Poorly designed handoff schemes tend to generate very heavy signaling traffic and, thereby, a dramatic decrease in quality of service (QOS). The reason why handoffs are critical in cellular communication systems is that neighboring cells are always using a disjoint subset of frequency bands, so negotiations must take place between the mobile station (MS), the current serving base station (BS), and the next potential BS. Other related issues, such as decision making and priority strategies during overloading, might influence the overall performance.

SIM card:

A Subscriber Identity Module (SIM) card is a portable memory chip used mostly in cell phones that operate on the Global System for Mobile Communications (GSM) network. These cards hold the personal information of the account holder, including his or her phone number, address book, text messages, and other data. When a user wants to change phones, he or she can usually easily remove the card from one handset and insert it into another. SIM cards are convenient and popular with many users, and are a key part of developing cell phone technology.

One of the biggest advantages of SIM cards is that they can easily be removed from one mobile phone and used in any other compatible phone to make a call. This means that, if the user wants to buy a new handset, he or she can activate it quickly by inserting his or her old SIM card. The user's phone number and personal information is carried on the card, so there's no need to do anything else to transfer this information.

A SIM card offers security for both the user's data and his or her calls. The cards can be locked, meaning that only someone who has the correct personal identification number (PIN) can use the card. If the phone is stolen, the thief cannot use a locked SIM or get any information off of it without the PIN.

Functionality of the SIM card:

1) Identification of a subscriber: The IMSI (International Mobile Subscriber Identity) programmed on the SIM card, is the identity of a subscriber. Each IMSI is mapped to a mobile number and provisioned on the HLR to allow a subscriber to be identified.

2) Authentication of a subscriber: This is a process, where, using the authentication algorithm on the SIM card, a unique response is provided by each subscriber based on IMSI, Ki (stored on SIM) and local network. By matching this response with values computed on the network a legal subscriber is logged on to the network and he or she can now make use the services of the mobile service provider.

3) Storage: To store phone numbers and SMS.

4) Applications: The SIM Tool Kit or GSM 11.14 standard allows creating applications on the SIM to provide basic information on demand and other applications for m-commerce, chatting, cell broadcast, phonebook backup, location based services etc.

IMEI number:

An IMEI is a serial number that uniquely identifies a GSM mobile phone. Typically 15 digits long, the IMEI code is broken into sections that provide information about a phone, such as its manufacturer, to the mobile network that the phone is connected to. IMEI numbers of stolen devices are blacklisted in some countries so that the phone cannot easily be used by a thief. CDMA's new MEID identifier system is compatible with the existing IMEI structure. Also known as: "International Mobile Equipment Identity"

Data encryption:

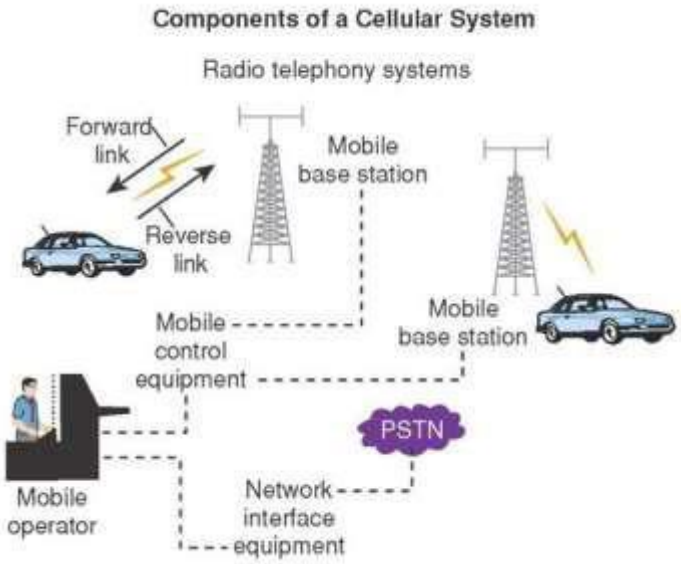
Encryption is a mechanism that protects your valuable information, such as your documents, pictures, or online transactions, from unwanted people accessing or changing it.

Encryption works by using a mathematical formula called a cipher and a key to convert readable data (plain text) into a form that others cannot understand (cipher text). The cipher is the general recipe for encryption, and your key makes your encrypted data unique. Only people with your unique key and the same cipher can unscramble it. Keys are usually a long sequence of numbers protected by common authentication mechanisms, such as passwords, tokens, or biometrics (like your fingerprint)

Encryption tools (usually in the form of computer programs or software) are widely available and can be used to secure:

• Stored data, from single files to entire hard disks;
• Computer code such as computer operating systems;
• Information transmitted over the Internet, including emails and internet telephony (Voice over Internet Protocol or VoIP);
• Entire communications infrastructures, such as wireless networks (including mobile telephony).

Architecture of Cellular mobile communication network:

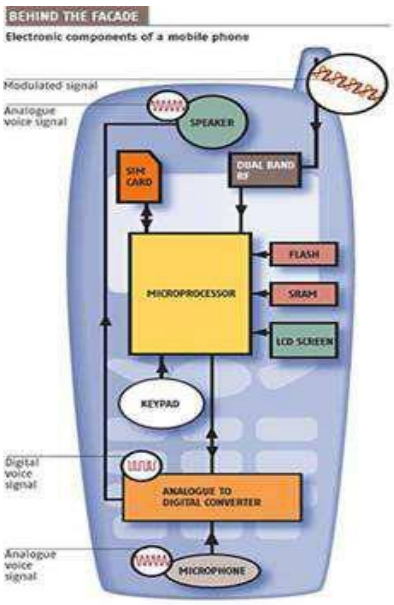


Block diagram of Cellular phone hand set:

A mobile phone is an electronic device used for mobile telecommunications over a cellular network of specialized base stations known as cell sites. A cell phone offers full Duplex Communication and transfer the link when the user moves from one cell to another. As the phone user moves from one cell area to another, the system automatically commands the mobile phone and a cell site with a stronger signal, to switch on to a new frequency in order to keep the link.

Mobile phone is primarily designed for Voice communication. In addition to the standard voice function, new generation mobile phones support many additional services, and accessories, such as SMS for text messaging, email, packet switching for access to the Internet, gaming, Bluetooth, camera with video recorder and MMS for sending and receiving photos and video, MP3 player, radio and GPS.

Mobile phone is a sophisticated device using SMD components, Microprocessor, Flash memory etc. In addition to the Circuit board, Mobile phone also has Antenna, Liquid Crystal Display (LCD) , Keyboard, Microphone, Speaker and Battery. Below is the Block diagram of Mobile phone



The circuit board is the heart of the Mobile phone. It has chips like Analog-to-Digital and Digital-to-Analog conversion chips that translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog.

Following are the **Chips** present in Mobile phone.

1. *Digital signal processor*

It is generally rated as having 40 MIPS (millions of instructions per second) to conduct calculations of signal manipulation at high speed. This chip deals with both compression and decompression of the signals.

It handles all the housekeeping tasks for the keyboard and display. It also deals with command and control signaling with the base station, and coordinates the rest of the functions on the board.

3. The Flash memory and ROM Chips of the Mobile phone act as a storage location for the phone. These chips store the customizable options of the cell phone, as well as the entire operating system. The power and radio frequency sections of the phone, phone recharging and power management etc are controlled by this chip. It also controls several hundred FM channels. The RF amplifiers focus on signals that go in and out of the phone's antennae.

Qualitative study of GSM and CDMA:

Features	***GSM***	***CDMA***
Operating Frequency	900 and 1800-MHz	800-MHz and 1900 MHz
Phone calls	Easily tampered.	More secured because of the spread spectrum.
Technology	TDMA and FDMA	CDMA
Encoding	Digital	Digital
Roaming	Worldwide, all countries except Japan and South Korea	Limited
Signal quality/coverage area	Good coverage indoors on 850/900 MHz Repeaters possible. 35 km hard limit.	Unlimited cell size, low transmitter power permits large cells
Handoff	Hard	Soft
Power consumption	Less	More

****