UNIT - V

MOBILE COMMUNICATION

5.1. Cellular Telephone – Introduction

The cellular radio mobile telephone services is the latest development in modern communication systems. It plays an important role in providing safety measures and warnings to the traffic jams, road accidents, breakdown cases etc., for assistance to ambulance, police and fire - brigades for immediate help and assistance to the scene of occurance of disasters.

During second world war, the mobile radio transmitter were used by the Allied Forces from the front lines to give pre-warnings to the base stations for quick necessary actions. The first commercial mobile radio telephone services were developed by Messers Bell @ Co. in the USA in 1946 in six channels in 150 MHz band.

In celluer telephone system, the same channel frequency may be used several times in the same city for which the given area is divided in to a number of regions or cells. Each being served by a specific band of frequencies, and none of the cells surrounding a given cell, employing the same frequency.

The major objective of cellular system is shown below.

a) The system should provide service to hand-held portable phones as also to mobile phones, and should support a built-in tariff charging system.

b) Any mobile unit may call another mobile unit in the same specified area and the quality of service should be same as that of a wired telephone system.

c) As soon as a mobile station leaves the site of a cell to enter the site of another cell, the channel should automatically switch to the new cell to ensure unintercepted service.

5.2. Evolution of cellular Telephone

In the July 28 of 1945 E.K. Jett, then the commissioner of the FCC introduced a cellular scheme referred to as simply a small zone radio telephone system.

On June 17 of 1946 in St, Louis, Missouri, AT & T and South western Bell introduced the first American commercial mobile radio telephone service to private customers. In the same year similar services were offered to 25 major cities throughout the united states. Each city utilized one base station consisting of a high powered transmitter and a sensitive receiver that were centrally located on a hill top or tower that covered an area within a 30 to 50 mile radius of the base station.

In 1947, AT & T introduced a radio telephone service in between New York and Boston, called as highway service. This system operated in the band of 35MHz to 45 MHz.

PTT (push to talk) FM mobile telephone systems introduced the first half duplex system in 1940's with the frequency band of 35MHz to 45MHz. This system requires the channel bandwidth of 120 KHz.

In the early 1950's the FCC doubled the number of mobile telephone channels by reducing the bandwidth to 60KHz per channel. In 1960, AT & T introduced direct dialing, full duplex mobile telephone service with other performance enhancements.

In 1968, AT & T proposed an Improved Mobile Telephone system (IMTS) with the channel bandwidth of 30 KHz.

In 1974, the FCC allocated an additional 40 MHz bandwidth for cellular telephone service (825 MHz to 845 MHz and 870 MHz to 890 MHz). Actually these frequency bands were already allocated to UHF television channels of 70-83. In 1975, the FCC granted AT & T, the first licence to operate a developmental cellular telephone service in Chicago. By 1976, the Bell Mobile phone service for metropolitan New York city offered only 12 channels, that could serve a maximum of 543 subscribers. In 1976, the FCC granted authorization to the American Radio Telephone Service (ARTS) to install a second developmental system in the Baltimore Washington, D.C area. In 1983, the FCC allocated 666 numbers of 30 KHz bandwidth half duplex mobile telephone channels to AT & T to form the first U.S cellular telephone system called **Advanced Mobile Phone system** (AMPS).

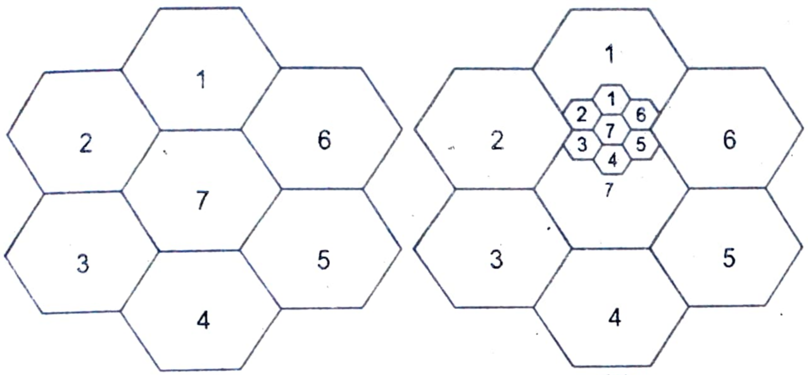
In 1991, the first digital cellular services were introduced in several major US cities. The calling capacity specified in the U.S. Digital Cellular (USDC) standard accommodates three times the user capacity of AMPS. This system uses frequency modulation (FM) and frequency division multiple accessing (FDMA). The USDC standard

specifies digital modulation, speech coding and time division multiple accessing (TDMA). Qualcomm developed the first cellular telephone system based on code division multiple accessing (CDMA). The Telecommunications Industry Association (TIA) standardized Qualcomm's system as Interim standard 95 (IS-95). In 1998, Motorola Corporation implemented Iridium, a satellite based wireless personal communications satellite system (PCSS).

5.3. Fundamental concepts of cellular telephone

With the cellular concept, each area is further divided into hexagonal-shaped cells that fit together to form a honey comb pattern as shown in the fig.5.1(a). The hexagon shape was chosen because it provides the most effective transmission by approximating a circular pattern while eliminating gaps inherently present between adjacent circles. A cell is defined by its physical size and more importantly, by the size of population and traffic patterns. The number of cells per system and size of the cells are not specified by FCC (Federal Communications Commission). It has been assigned in accordance with anticipated traffic patterns. Each geographical area is allocated a fixed number of cellular voice channels.

The physical size of a cell varies, depending on user density and calling patterns. For example, large cells (called macrocells) typically have a radius between 1 mile and 15 miles, with base station transmit power between 1W and 6W. The smallest cells (called microcells) typically have a radius of 1500 feet or less, with base station transmit powers between 0.1W and 1W. A cell configuration with two sizes of cell is shown in the fig.5.1(b).

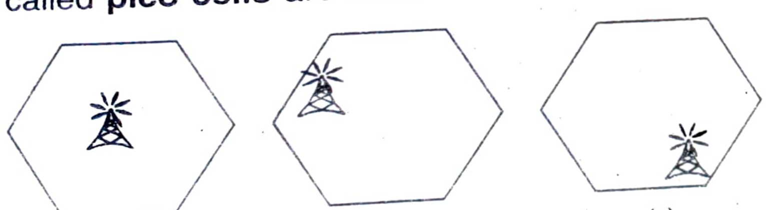


(a) (b)

Fig. 5.1 (a) Honeycomb cellpattern (b) Honeycomb pattern with two sizes of cells

Microcells are used most often in high-density areas such as found in large cities and inside buildings. Macrocells may overlay clusters of microcells with slow moving mobile units using the microcells and faster moving units using the macrocells. The mobile unit is able to identify itself as either fast or slow moving.

In well shielded areas or areas with high levels of interference, cellular radio signals are too weak to provide reliable communications indoor. In these areas very small cells, called **pico cells** are used.



(a) (b) (c)

Fig. 5.2 (a) Center excited cell (b)Edge excited cell (c)Corner excited cell

In hexagonal shaped cells, the base station transmitter can be located in three places. They are

i) **Center excited cells** - Here the base station transmitter is located in the center of a cell, as shown in the fig.5.2(a).

ii) **Edge excited cells** - Here the base station transmitter is located in the vertices of a cell, as shown in the fig.5.2(b).

iii) **Corner excited cells** - Here the base station transmitter is located in the corner of a cell, as shown in the fig.5.2(c).

Omnidirectional antennas are normally used in center excited cells, and sectored directional antennas are used in edge and corner excited cells.

Cells are grouped in to cluster. Each cluster utilizes the entire available radio spectrum.

The reason for clustering is that adjacent cells cannot use the same frequency spectrum because of interference. So the frequency bands have to be split in to chunks and distributed among the cells of a cluster. The number of cells in a cluster is called cluster size or frequency reuse factor.

Two types of interference are important in a cellular system.

i) **Co-channel interference** - The interference due to using the same frequencies in cells of different clusters is referred to as co-channel interference.

The cells that use the same set of frequencies or channels are called co-channel cells.

(ii) **Adjacent channel interference** - The interference from different frequency channels used within a cluster whose side-lobes overlap is called adjacent channel interference.

The allocation of channels within the cluster and between clusters must be done so as to minimize both of these.

5.4. Importance of cellular topology

Suppose we want to provide a radio communication service to a city. We assume that the available total bandwidth is 25MHz, and each user requires 30KHz of bandwidth for voice communication. If we use one antenna to cover the entire city, we can only support 25MHz/30KHz = 833 simultaneous users.

Now by employing a cellular topology, where 20 lower power antennas are apportunistically located to minimize both kinds of interference. We divide our frequency bands in to four sets and assign one set to each cell. Each cell has a spectrum of 25MHz/4 = 6.25MHz allocated to it. Suppose we have a cluster of four cells, the number of simultaneous users supported per cell is 6.25MHz/30KHz = 208. The total number of users per cluster is 4 x 208 = 832. The total number of simultaneous users is now 832 x 5 = 4160, because we have five clusters of four cells each. The new capacity is roughly five times the capacity with a single antenna.

The number of simultaneous users, $n = \frac{M(W/N)}{B}$

where

M = number of cells required to cover an area

W = total available spectrum

N = frequency reuse factor

B = bandwidth needed per user

5.5. Simplified cellular telephone system

A cellular telephone system provides a wireless connection to the PSTN (Public switched telephone network) for any user location within the radio range of the system. Cellular system accommodate a large number of users over a large geographic area, within a limited frequency spectrum. Cellular system provide high quality service compared with landline telephone systems.

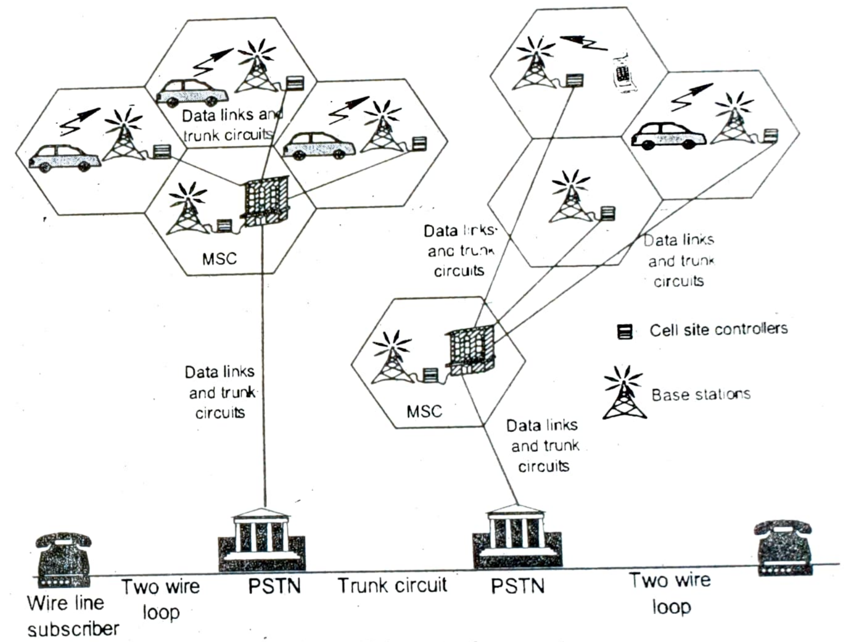


Fig. 5.3 Simplified cellular telephone system

Fig.5.3 shows a basic cellular system, which consists of mobile stations, base stations and a mobile switching center (MSC). The mobile switching center is sometimes called mobile telephone switching office (MTSO), since it is responsible for connecting all mobiles to the PSTN in a cellular system. Each mobile communicates via radio with one of the base stations and may be handed-off to any number of base stations throughout the duration of a cell.

The mobile station consists of a transceiver, an antenna, and control circuitry, and may be mounted in a vehicle or used as a portable handheld unit. The base station consists of several transmitters and receivers which simultaneously handle full duplex communications. The base station serves as a bridge between all mobile users in the cell and connects the simultaneous mobile calls via telephone lines or microwave lines to the MSC.

The MSC co-ordinates the activities of all of the base stations and connects the entire cellular system to the PSTN. A typical MSC handles 10000 cellular subscribers and 5000 simultaneous conversations at a time.

Communication between the base station and mobiles is defined by a standard common air interface (CAI) that specifies four different channels.

The channels used for voice transmission from the base station to mobiles are called **forward voice channels** (FVC).

The channels used for voice transmission from mobiles to the base station are called **reverse voice channels** (RVC). The two channels responsible for initiating mobile calls are the Forward control channels (FCC) and Reverse control channels (RCC). Control channels are often called set up channels because they are only involved in setting up a call and moving it to an unused voice channel.

When a cellular phone is turned ON, but it is not get engaged in a call, it first scans the group of forward control

channels to determine the one with the strongest signal and then monitors that control channel until the signal drops below a usable level. At this point it again scans the control channels in search of the strongest base station signal.

The 5% of the total number of channels are control channels, and 95% are dedicated to voice and data traffic for the end users. The control channels are standardized over the entire geographic area.

When a telephone call is placed to a mobile user, the MSC dispatches the request to all base stations in the cellular system. The mobile identification number (MIN) which is the subscriber's telephone number, is then broadcast as a paging message over all of the forward control channels throughout the cellular system. The mobile receives the paying message sent by the base station which it monitors, and responds by identifying itself over the reverse control channel. The base station relays the acknowledgement sent by the mobile and informs the MSC of the handshake. Then the MSC instructs the base station to move the call to an unused voice channel within the cell. Typically, between 10 to 60 voice channels and just one control channel are used in each cell's base station. The base station signals the mobile to change frequencies to an unused forward and reverse voice channels to instruct the mobile telephone to ring, thereby instructing the mobile user to answer the phone.

Once a call is on progress, the MSC adjusts the transmitted power of the mobile and changes the channels of the mobile unit and base stations in order to maintain call quality as the subscriber moves in and out of range of each base station. This is called a **hand-off.**

When a mobile originates a call, a call initiation request is sent on the reverse control channel. With this request the mobile unit transmits its telephone number (MIN), electronic serial number (ESN), and the telephone number of the called party. The mobile also transmits a station class mark (SCM) which indicates what the maximum transmitter power level is for the particular user. The cell base station receives this data and sends it to the MSC. The MSC validates the request, makes connection to the called party through the PSTN, and instructs the base station and mobile user to move to an forward and reverse voice channel pair to allow the conversation to begin.

All cellular systems provide a service called roaming. This allows subcribers to operate in service areas other than the one from which service is subscribed.

Depending on the manufacturer and system configuration, the MSC is known by different names.

i) Mobile Telephone Switching Office (MTSO) - This name is given by Bell Telephone Laboratories.

ii) Electronic Mobile Xchange (EMX) : This name is given by Motorola.

iii) AEX - by Ericcson

iv) NEAX - by NEC

v) Switching Mobile Center (SMC) and Master Mobile Center (MMC) - by Novatel

5.6. Frequency reuse

The same spectrum can support multiple users separated by a distance is the primary approach for efficiently using the spectrum. The reusing of available spectrum is called **'frequency reuse'**.

Cellular radio systems rely on an intelligent allocation and reuse of channels throughout a coverage region. Each cellular base station is allocated a group of radio channels to be used within a small geographic area called cell. The base station antennas are designed to achieve the desired coverage within the particular cell by limiting the coverage area to within the boundaries of a cell. The same group of channels may be used to cover different cells that are separated from each other by distance large enough to keep interference levels within tolerable limits. The design process of selecting and allocating channel groups for all cellular base stations within a system is also called **frequency reuse** or **frequency planning.**

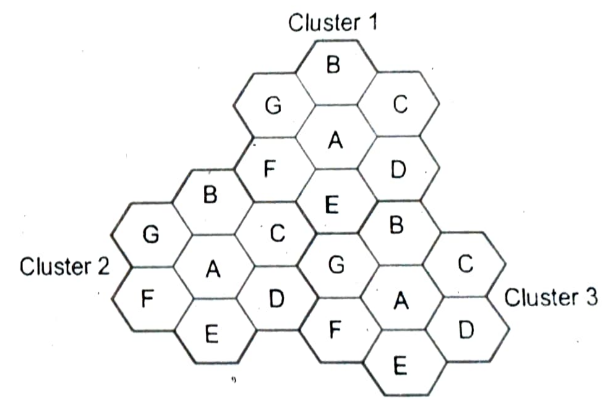


Fig. 5.4 Illustration of the cellular frequency reuse concept

Fig.5.4 illustrates the concept of cellular frequency reuse, where cells labeled with the same letter use the same group of channels. The hexagonal cell shape shown in the figure is a simple model of the radio coverage for each base station. The actual radio coverage of a cell is known as the **'footprint'**.

To understand the frequency reuse concept, consider a cellular system which has a total of S duplex channels available for use. If each cell is allocated a group of K channels (K < S), and if the S channels are divided among N cells in to unique and disjoint channel groups, which each have the same number of channels.

The total number of available radio channels can be expressed as

$$S = KN$$

The N cells which collectively use the complex set of available frequencies is called a **'cluster'.** If a cluster is replicated M times within the system, the total number of duplex channels C, can be used as a measure of capacity and is given by

$$C = MKN = MS$$

The capacity of a cellular system is directly proportional to the number of times a cluster is replicated in a fixed service area. The factor N is called the cluster size and is typically equal to 4, 7 or 12. If the cluster size N is reduced while the cell size is kept constant, more clusters are required to cover a given area, and hence more capacity (a larger value of C) is achieved.

A larger cluster size causes the ratio between the cell radius and the distance between co-channel cells to decrease, leading to weaker co-channel interference. Conversely, a smaller cluster size indicates that co-channel cells are located much closer together.

The value of N is a function of how much interference a mobile or base station can tolerate, while maintaining a sufficient quality of communications. The smallest possible value of N is desirable in order to maximize capacity over a given coverage area.

The frequency reuse factor of a cellular system is given by 1/N, since each cell within a cluster is only assigned 1/N of the toal available channels in the system.

5.7. Interference

Interference is the major limiting factor in the performance of cellular radio systems. The sources of interference includes the following factors.

i) Another mobile in the same cell

ii) A cell in progress in a neighbouring cell

iii) Other base stations operating in the same frequency band

iv) Any non cellular system which inadvertently leaks energy in to the cellular frequency band.

Interference on voice channels causes cross talk, where the subscriber hears interference in the background due to an undesired transmission. On control channels, interference leads to missed and blocked calls due to errors in the digital signaling. Interference is more severe in urban areas, due to greater RF noise floor and the large number of base stations and mobiles. The two major types of system generated cellular interference are co-channel interference and adjacent channel interference.

5.7.1 Co-channel interference

Frequency reuse implies that in a given coverage area there are several cells that use the same set of frequencies. These cells are called co-channel cells. The interference between signals from these cells is called co-channel interference. Co-channel interference can be produced by simply increasing the carrier power of the transmitter. This is because an increase in carrier transmit power increases the interference to neighbouring co-channel cells. To reduce co-channel interference, co-channel cells must be physically separated by a minimum distance to provide sufficient isolation due to propagation.

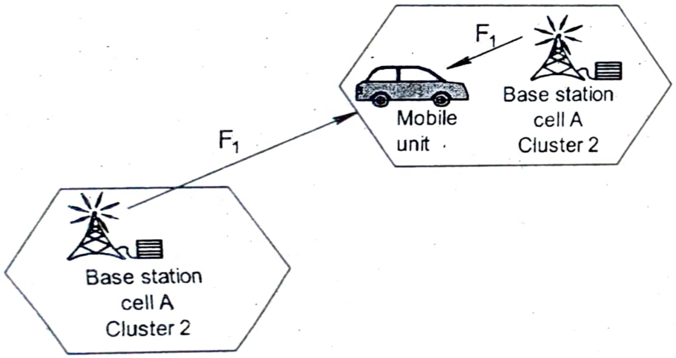


Fig. 5.5 Co-channel interference

Co-channel interference is illustrated in the fig.5.5. The base station in cell A of cluster 1 is transmitting on frequency F_1, and at the same time, the base station in cell A of cluster 2 is transmitting on the same frequency. Although the two cells are in different clusters, they both use the A group of frequencies. The mobile unit in cluster 2 is receiving the same frequency from two different base stations. Although the mobile unit is under the control of the

base station in cluster 2, the signal from cluster 1 is received at a lower power level as co-channel interference.

Interference between cells is proportional not to the distance between the two cells but rather to the ratio of the distance to the cell's radius. Since a cell's radius is proportional to transmit power, more radio channels can be added to a system by either (1) decreasing the transmit power per cell, (2) making cells smaller, or (3) fitting vocated coverage area with new cells.

When the size of each cell is approximately the same and the base stations transmit the same power, the co-channel interference ratio is independent of the transmitted power and becomes a function of the radius of the cell (R) and the distance between centres of the nearest co-channel cells (D).

By increasing the ratio of D/R, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased. The parameter Q, called the co-channel reuse ratio, is related to the cluster size.

For a hexagonal geometry, $Q = \frac{D}{R} = \sqrt{3N}$

A small value of Q provides larger capacity, since the cluster size N is small, whereas a large value of Q improves the transmission quality, due to a smaller level of co-channel interference.

5.7.2. 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 in to the pass band.

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 captures the receiver of the subscriber. Alternatively, the near-far effect occurs when a mobile close to a base station transmit on a channel close to one being used by a weak mobile.

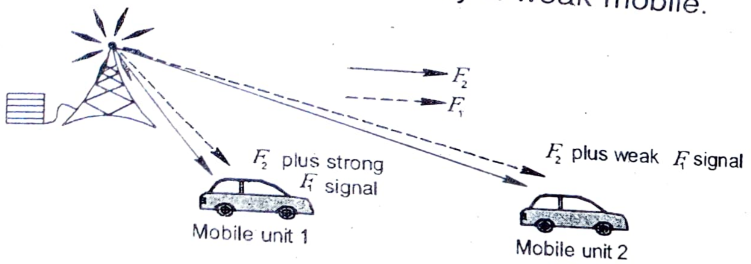


Fig. 5.6 Adjacent-channel interference

Adjacent channel interference is shown in the fig.5.6 Mobile unit 1 receiving frequency F_1 from base station A. At the same time, base station A is transmitting frequency F_2 to mobile unit 2. Because mobile unit 2 is much farther from the base station than mobile unit 1, F_2 is transmitted at a much higher power level than F_1.

Mobile unit 1 is located very close to the base station, and F_2 is located next to F_1 in the frequency spectrum (i.e., the adjacent channel). Therefore mobile unit 1 is receiving F_2 at a much higher power level than F_1. Because of the high power level, the filters in mobile unit 1 cannot block all the energy from F_2, and the signal intended for mobile unit 2 interferes with mobile unit 1's reception of F_1. The F_1 does not interfere with mobile unit 2's reception because F_1 is received at a much lower power level than F_2.

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. If the frequency reuse factor is large (eg. small N) the separation between adjacent channels at the base station may not be sufficient to keep the adjacent channel interference level within tolerable limits.

5.8. Improving coverage and capacity in cellular systems

As the demand for wireless service increases, the number of channels assigned to a cell 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. The techniques such as cell splitting, sectoring and coverage zone approaches are used to expand the capacity of cellular systems.

5.8.1. Cell splitting

Cell splitting is a 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. The new cells have a small radius than the original cells called microcells.

The purpose of cell splitting is to increase the channel capacity and improve the availability and reliability of a cellular telephone network. When a cell reaches maximum capacity, that means when the number of subscribers wishing to place a call at any given time equals the number of channels in the cell, this is called the maximum traffic load of the cell.

Splitting cell areas creates new cells, providing an increase in the degree of frequency reuse, thus increasing the channel capacity of a cellular network. Cell splitting provides for orderly growth in a cellular system. The major drawback of cell splitting is that it results in more base station transfers (hand offs) per call and a higher processing load per subscriber.

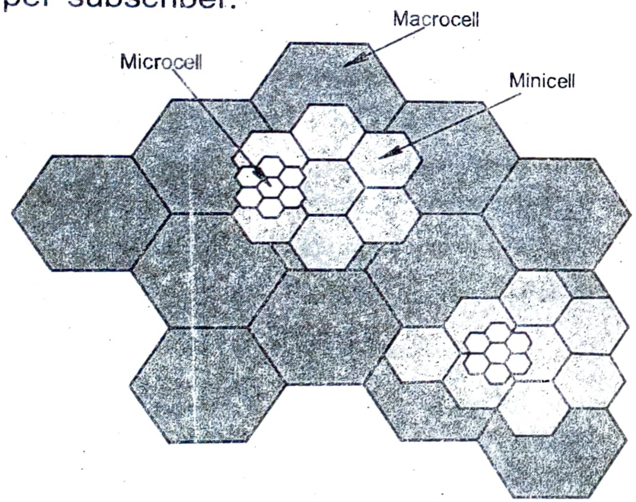


Fig. 5.7 Cell splitting

Cell splitting is the process of subdividing highly congested cells into smaller cells, each with their own base station and set of channel frequencies. If a new call is initiated in an area where all the channels are in use, a

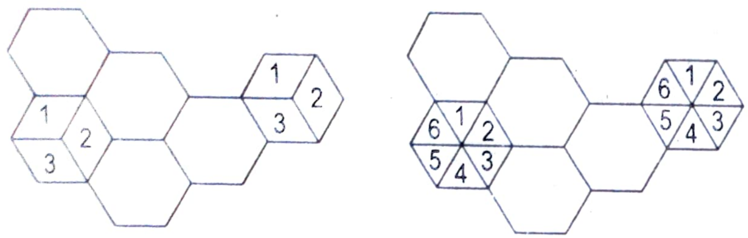
condition called blocking occurs. A high occurrence of blocking indicates that a system is overloaded.

The concept of cell splitting is shown in the fig.5.7. Macrocells are divided into minicells, which are then further divided in to microcells as traffic density increases. Each time a cell is split, its transmit power is reduced. Cell splitting increases the channel capacity of a cellular telephone system by rescaling the system and increasing the number of channels per unit area (channel capacity). Hence cell splitting decreases the cell radius while maintaining the same co-channel reuse ratio (D/R).

The 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.

5.8.2. Sectoring

In cell splitting method the cell radius is decreased and keeping the co-channel reuse ratio D/R unchanged, which will increase the number of channels per unit area. In another way to increase capacity is to keep the cell radius unchanged and decrease the D/R ratio; called **sectoring**. The sectoring increases SIR (Signal to Interference ratio) so that the cluster size may be reduced. In this method, first the SIR is improved using directional antennas, then improve the capacity by reducing the number of cells in a cluster, thus increasing the frequency reuse. To do this method successfully, it is necessary to reduce the relative interference without decreasing the transmit power



(a) (b)

Fig. 5.8(a)120°sectoring (b)60°sectoring

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. The smaller areas are called sectors. By using directional antenna, 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 co-channel interference is reduced depends on the amount of sectoring used. A cell is normally partitioned in to three 120^0 sectors or six 60^0 sectors as shown in the fig.5.8.

5.9. Roaming and Handoff

When a mobile unit moves from its own service area to another service area is called **roaming**. This allows subscribers to operate in service areas other than the one which service is subscribed. When a mobile enters a city or geographic area that is different from its home service area, it is registered as a roamer in the new service area. This is accomplished over the FCC, since each roamer is camped on to an FCC at all times.

Every several minutes, the MSC issues a global command over each FCC in the system, asking for all mobiles which are previously unregistered to report their MIN and ESN over the RCC.

New unregistered mobiles in the system periodically report back their subscriber information upon receiving the registration request, and the MSC then uses the MIN/ESN data to request billing status authorization for billing purposes, the MSC registers the subscriber as a valid roamer. Once registered, roaming mobiles are allowed to receive and place calls from that area, and billing is routed automatically to the subscriber's home service provider.

One of the most important features of a cellular system is its ability to transfer calls that are already in progress from one site controller to another as the mobile unit moves from cell to cell within the cellular network. The base station includes converting the call to an available channel within new cell's allocated frequency subset. The transfer of a mobile unit from one base station's control to another base station's control is called a handoff (or handover). Handsoff should be performed as infrequently as possible and be completely transparent (seamless) to the subscriber. That means the subscriber cannot perceive that their facility has been switched from one base station to another base station.

A hand off consists of four stages. They are

i) **Initiation** - Either the mobile unit or the network determines the need for a hand-off and initiates the necessary procedures.

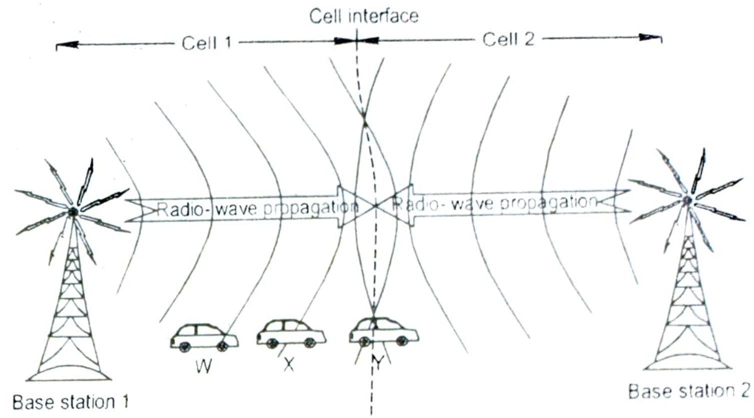
ii) Resource reservation - Appropriate network procedures reserve the resources needed to support the hand off (ie., a voice and a control channel)

iii) Execution - The actual transfer of control from one base station to another base station takes place.

iv) Completion - Unnecessary network resources are relinguished and made available to other mobile units.

A connection that is momentarily broken during cell-to-cell transfer is called a hard hand off. A hard hand off is a break-before-make-process. In hard hand off, the mobile unit breaks its connection with one base station before establishing connection with a new base station. Hard hand off generally occur when a mobile unit is passed between disjoined systems with different assignments, air interface characteristics or technologies.

A flowless hand off is called a soft hand off. It normally takes approximately 200ms. It is imperceptible to voice telephone users. With a soft hand off a mobile unit establishes contact with the new base station before giving up its current radio channel by transmitting coded speech signals to two base stations simultaneously. Both base stations send their received signals to the MTSO, which estimates the quality of two signals and determines when the transfer should occur. A soft hand off requires that the two base stations operate synchronously with one another.



Mobile unit travelling away from base station 1 and towards base station 2

Fig. 5.9 Hand off

Fig.5.9 shows how a base station transfer is accomplished when a mobile unit moves from one cell in to another. The mobile unit is moving away from base station 1 (ie., toward base station 2). When the mobile unit is at positions W and X, it is well within the range of base station 1 and very distant from base station 2. However when the mobile unit reaches position Y, it receives signals from base station 1 and base station 2 approximately at same power level, and the two base stations should be setting up for a hand-off. When the mobile unit crosses from cell 1 into cell 2, the hand off should be executed and completed.

The computers use hand off decision algorithms based on variations in signal strength and signal quality. When a call in progress, the switching center monitors the received signal strength of each user channel. Hand offs can be initiated when the signal strength measured by either the base station or the mobile units receiver falls below a predetermined threshold level. During hand off, information about the user stored in the first base station is transferred to the new base station.

5.10. Satellite multiple access technique

Multiple access is "the ability" of a large number of earth stations to simultaneously interconnect their respective voice, data, teletype, facsimile and television links through a satellite. The multiple-access problem is fundamental to satellite communications. Basically there are three multiple access techniques. They are

a) Frequency Division Multiple Access (FDMA)
b) Time Division Multiple Access (TDMA)
c) Code Division Multiple Access (CDMA)

a) Frequency division multiple access

In FDMA, all users share the satellite at the same time, but each transmits in its own unique frequency band. This is most commonly employed with analog modulation, where signals are present all the time. The available transponder bandwidth is divided among the users and all can transmit simultaneously, as illustrated in the fig.5.10.

FDMA is the simplest form of multiple accessing. In it an earth station is permanently assigned a carrier frequency (or several carrier frequencies for a busy station) and a bandwidth around that carrier frequency. The station frequency modulates all of its outgoing traffic-whatever the destination- on that carrier.

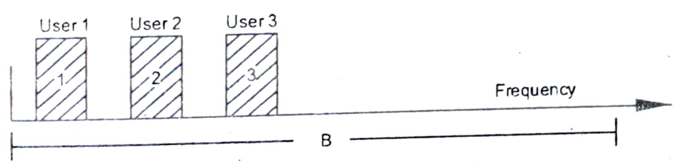


Fig. 5.10 Frequency Division (FDMA)

In fixed frequency operation each carrier is assigned a dedicated frequency band for the uplink and other carrier

utilizes that band. In demand multiple access (DMA) frequency bands are shared by several carrier, with a particular band assigned at the time of need, depending on availability.

Individual carrier spectra in a FDMA system must be sufficiently separated from each other and to prevent carrier cross talk. A high power carrier will affect the adjacent low power carriers. However, excessive separation causes needless waste of satellite bandwidth. FDMA involves relatively simple frequency tuning for accessing and providing essentially independent channel on-off operation.

The carrier frequencies and bandwidth assigned to all the earth stations constitute a satellite's frequency plan. Every station that operates in FDMA network must be able to receive atleast one carrier from all the stations in the network.

b) Time division multiple access (TDMA)

In TDMA, only one user transits at any time and that user can use the entire available bandwidth, so the instantaneous data rate is proportional to the available bandwidth. This TDMA concept is illustrated in the fig.5.11.

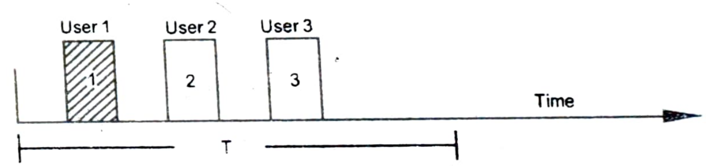


Fig. 5.11 Time Division (TDMA)

The intermittent nature of TDMA transmissions makes it particularly attractive for digital modulation. TDMA is easy to reconfigure for changing traffic demands, resist noise and interference, mixes voice, video and data traffic and so on. One advantage of TDMA is that it permits a transponder's amplifier to operate at or near saturation, and it maximizes downlink (C/N). Since only one carrier is at a time, there are no intermodulation products. The main problem that the amplifier non-linearity can cause is increased intersymbol interference, and this can be reduced by filtering and equalization.

A receiving station must first recover the transmitter carrier frequency, then recover the transmitting station clock pulses, and then identify the start of each frame so that it can recover each transmitted channel and route it on to its destination. Each TDMA station has to know when to transmit the signals.

The TDMA bursts (users) are separated by empty time slots called guard times. Those prevent overlaps and make it easier for receiving stations to separate incoming bursts.

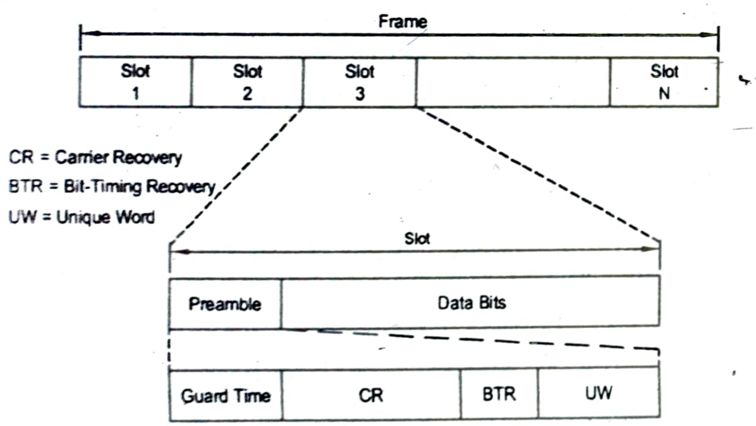


Fig. 5.12 Frame Formatting in TDMA

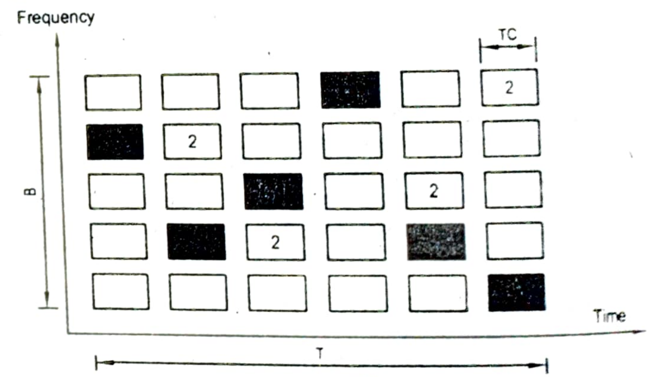
A typical format of TDMA frame is shown in the fig.5.12. The frame is divided into slots, each assigned to an uplink station. Each slot interval is then divided into a preamble time and a data transmission time. The preamble

time is used to send synchronization bits so that a receiving station gated to the slot can lock up its receiver decoder.

The preamble generally contains the following parts; (i) guard time to allow for some error in slot timing, (ii) a phase referencing (CR) and bit-timing interval (BTR) to allow a phase coherent decoder to establish carrier and bit synchronization, and (iii) a unique code word to estabilish word synchronization.

c) Code division multiple access (CDMA)

In CDMA, many earth stations simultaneously transmit orthogonally coded spread-spectrum signals that occupy the same frequency band. Decoding systems receive the combined transmissions from many stations and recover one of them. That is in CDMA scheme, users can transmit simultaneously and also share the frequency allocation. The frequency hopping with CDMA is illustrated in the fig.5.13.



Code Division (CDMA)

Fig. 5.13 CDMA

In this system, a number of users occupy all of a transponder bandwidth all of the time. The signals from different users are encoded, so that information from an individual transmitter can be detected and recovered only by properly synchronized receiving station that knows the code eing used. That is each receiving station has its own code, alled its address and a transmitting station simply odulates its transmission with the address of the intended ceiver whenever it wishes to send a message to that ceiver.

Carrier separation is achieved at an earth station by entifying the carrier with the proper address. These dresses are usually in the form of periodic binary quences that either modulate the carrier directly or change frequency state of the carrier. Address identification is omplished by carrier correlation operation. Digital resses are obtained for code generators.

A station address generator continually cycles through address sequences, which are superimposed on the ier along with the data.

CDMA is more suited for military tactical munications environment where many small groups of le stations are briefly at irregular intervals.

Digital cellular system

Cellular systems which use digital modulation ique are called digital cellular systems. Digital systems s large improvement in capacity and system mance. In the late 1980's the United States Digital ar system (USDC) was developed to support more in a fixed spectrum allocation. USDC is a time division e access (TDMA) system. USDC offers as much as es the capacity of AMPS.

The USDC standard uses the same 45MHz FDD e as AMPS. The dual mode USDC/AMPS system was

standaraized as Interim standard 54 (IS-54) by the Electronic Industries Association and Telecommunication Industry Association (EIA/TIA) in 1990. USDC is also known as North American Digital Cellular (NADC), as it had been installed in Canada and Mexico. The USDC system was designed to share the same frequencies reuse plan, and base stations as AMPS, so that base stations and subscriber units could be equipped with both AMPS and USDC channels, within the same piece of equipment. To maintain compatibility with AMPS phones, USDC forward and reverse control channels use exactly the same signalling technique as AMPS.

5.12. Global system for mobile communications (GSM)

Global system for mobile (GSM) is a second generation cellular system standard. It was developed to solve the fragmentation problems of the first cellular system in Europe. GSM was the world's first cellular system to specify digital modulation and network level architecture and services. It is the world's most popular 2G (second generation) technology.

GSM was originally developed to serve as the pan European cellular service and promised a wide range of network services through the use of ISDN. Now GSM is the world's most popular standard for new cellular radio and personal communications equipment throughout the world. As of 2001, there were over 350 millions GSM subscribers worldwide.

GSM was first introduced in to European market in 1991. In 1992, GSM changed its name to the Global system for Mobile communications for marketing reasons. By the end of 1993 several non-European countries in South

America, Asia and Australia had Adopted GSM, which supports Personal Communication Services (PCS) in the 1.8GHz to 2.0GHz radio bands recently created by governments throughout the world.

5.13. GSM services

GSM services follow ISDN guidelines and are classified as either tele services or data services. Tele services include standard mobile telephony and mobile originated or base originated traffic. Data services include computer-to-computer communication and packet switched traffic.

User services may be divided in to three categories.

i) **Telephone services** - This service includes emergency calling and fascimite. GSM also supports Videotex and Teletex, though they are not integral parts of the GSM standard.

ii) **Bearer services or data services** - This service includes packet switched protocols and data rates from 300 bps to 9.6 kbps. Data may be transmitted using either a transparent mode (where GSM provides standard channel coding for the user data) or non transparent mode (where GSM offers special coding efficiencies based on the particular data service).

iii) **Supplementary ISDN services** - This services are digital in nature, and include all diversion, closed user groups, and caller identification. These services are not available in analog mobile networks. Supplementary services also include the short messaging service (SMS), which allows GSM subscribers and base stations to transmit alphanumeric pages of limited length.

- SMS may be used for safety and advisory applications, such as the broadcast of highway or weather information to all GSM subscribers within reception range.

Subscriber Identify Module (SIM) is one of the most remarkable feature of GSM. SIM is a memory device that stores information such as the subscriber's identification number, the networks and countries where the subscriber is entitled to service, privacy keys and other user specific informations. A subscriber uses the SIM with a four digit personal ID number to activate service from any GSM phone.

SMS are available as smart cards (credit card sized cards that may be inserted into any GSM phone) or plug-in modules. Without a SIM installed, all GSM mobiles are identical and non operational.

Subscriber may plug their SIM into any suitable terminal such as hotel phone, public phone or any portable or mobile phone and then able to have all incoming GSM calls routed to that terminal and have all outgoing calls billed to their home phones, no matter where they are in the world.

A second remarkable feature of GSM is the air privacy which is provided by the system. Unlike analog FM cellular phone systems which can be readily monitored, it is virtually impossible to eavesdrop on a GSM radio transmission. The privacy is made possible by encrypting the digital bit stream sent by a GSM transmitter, according to a specific secret cryptographic key that is known only the cellular carrier. This key changes with time for each user.

Every carrier and GSM equipment manufacturer must sign the Memorandum of Understanding (MoU) before developing GSM equipment or developing a GSM system.

The MoU is an international agreement which allows the sharing of cryptographic algorithms and other proprietary information between countries and carriers.

5.14. GSM architecture

The GSM system architecture consists of three major interconnected subsystems. They are (i) Base station subsystem (BSS), (ii) Network and switching subsystem, and (iii) Operation support subsystem (OSS). The subsystems interact between themselves and with the users through certain network interfaces.

The mobile station (MS) is also a subsystem, but is usually considered to be part of the BSS for architecture purposes.

The BSS, also known as the radio subsystem, provides and manages radio transmission paths between the mobile stations and the mobile switching center (MSC). The BSS also manages the radio interface between the mobile stations and all other subsystems of GSM. Each BSS consists of many base station controllers (BSCs) which connects the MS to the NSS via MSCs.

The NSS manages the switching functions of the system and allows the MSCs to communicate with other networks such as PSTN and ISDN.

The OSS supports the operation and maintenance of GSM and allows system engineers to monitor, diagnose and trouble shoot all aspects of the GSM system. This subsystem interacts with the other GSM subsystems.

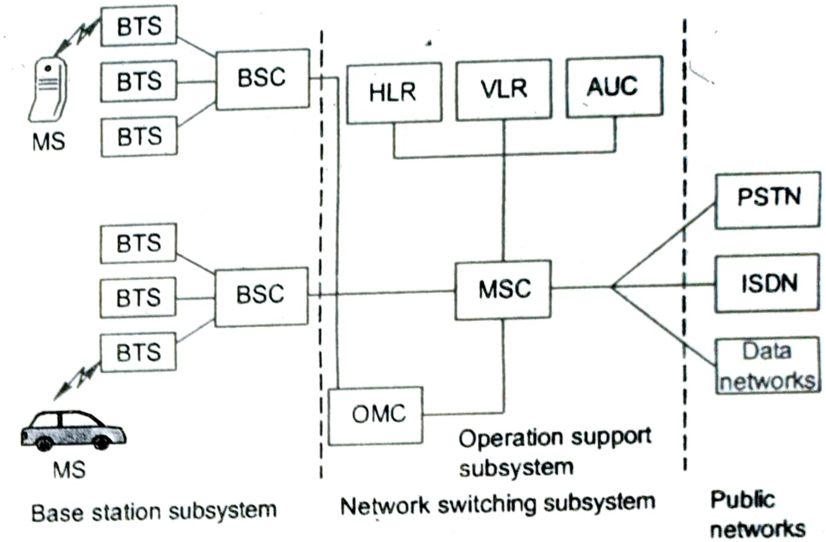


Fig 5.14 GSM system architecture

The block diagram of GSM architecture is shown in the fig.5.14. The mobile stations (MSs) communicate with the base station subsystem (BSS) over the radio air interface. The BSS consists of many BSCs which connects to a single MSC. Each BSC can controls upto several hundred Base Transceiver stations (BTSs). Some of the BTSs may be co-located at the BSC, and others may be remotely distributed and physically connected to the BSC by microwave link or dedicated leased lines.

The various interfaces used in GSM are illustrated in the fig.5.15. The interface which connects a BTS to a BSC is called **Abis interface.** The Abis interface carries traffic and maintenance data, and is specified by GSM to be standarized for all manufactures. Practically same manufacturer BTS and BCS equipments may be used for avoiding subtle differences.

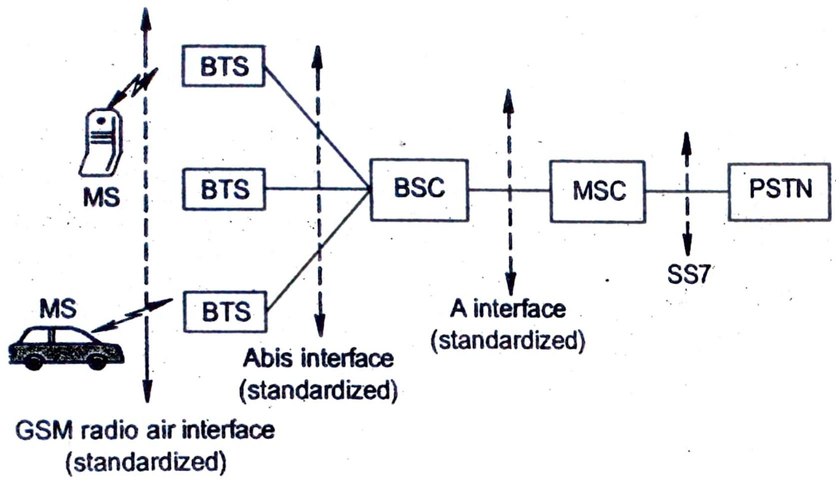


Fig 5.15 The various interfaces used in GSM

The BSCs are physically connected to the MSC through dedicated/leased lines or microwave link. The interface between a BSC and a MSC is called the **A interface,** which is standarized within GSM. The A interface uses an SS7 protocol called the signalling correction control part (SCCP). It supports communication between the MSC and the BSS, as well as network messages between the individual subscribers and the MSC. The A interface allows a service provider to use base stations and switching equipment made by different manufactures.

The NSS handles the switching of GSM call between external networks and the BSCs in the radio subsystem. The MSC is the central unit in the NSS and controls the traffic among all of the BSCs.

There are three different data bases in NSS. They are (i) Home location register (HLR), (ii) Visitor location register (VLR), and (iii) Authentication center (AUC). The HLR is a database which contains subscriber information and location information for each user who resides in the same

city as the MSC. Each subscriber in a particular GSM market is assigned a unique International Mobile Subcriber Identify (IMSI). This number is used to identify each home user.

The VLR is a database which temporarily stores the IMSI and customer information for each roaming subscriber who is visiting the coverage area of a particular MSC. The VLR is linked between several adjoining MSCs in a particular region and contains subscription information of every visiting user in the area.

Once a roaming mobile is logged in the VLR, the MSC sends the necessary information to the visiting subscriber's HLR, so that calls to the roaming mobile can be appropriately routed over the PSTN by the roaming user's HLR.

The Authentication center is a strongly protected data base which handles the authentication and encryption keys for every single subscriber in the HLR and VLR. The Authentication center contains a register called the Equipment Identify Register (EIR) which identifies stolen or fraudulently altered phones that transmit identify data that does not match with information contained in either the HLR or VLR.

The OSS supports one or several Operation Maintenance Centers (OMC), which are used to monitor and maintain the performance of each MS, BS, BSC and MSC within a GSM system.

The OSS has three functions. They are (i) to maintain all telecommunications hardware and network operations with a particular market, (ii) manage all charging and billing procedures, and (iii) manage all mobile equipment in the system.

5.15. GSM Radio subsystem

GSM was originally designed for 200 full duplex channels per cell with transmission frequencies in the 900MHz band. A second system called DSC - 1800 was established that closely resembles GSM. GSM uses two 25MHz requency bands.

i) The 890 - 915MHz frequency band is used for mobile unit-to-base station transmissions (reverse link transmissions)

ii) The 935 - 960MHz frequency band is used for base station - to - mobile unit transmission (forward link transmissions)

GSM uses frequency - division duplexing and a combination of TDMA and FDMA techniques to provide base stations simultaneous access to multiple mobile units.

The available forward and reverse frequency bands are subdivided into 200KHz wide voice channels called absolute radio frequency channel numbers (ARFCN). The ARFCN denotes a forward and reverse channel pair, which is separated in frequency by 45MHz. Each voice channel is time shared among as many as eight subscribers using TDMA.

Each of ARFCN channel subscribers occupies a unique time slot within the TDMA frame. Radio transmission in both directions is at a 270.833 kbps rate using binary Gaussian minimum shift keying (GMSK) modulation with an effective channel transmission rate of 33.833 kbps per user.

The basic parameters of GSM are the following.

i) GMSK modulation (Gaussian MSK)

ii) 50MHz bandwidth

  a) 890 - 915MHz mobile transmit band (reverse channel)

  b) 935 - 960MHz base station transmit band (forward channel)

iii) FDMA/TDMA

iv) Eight 25KHz channels within each 200KHz traffic channel.

v) 200KHz traffic channel

vi) 992 full duplex channels

vii) Supplementary ISDN services, such as call diversion, closed user groups, caller identification and short messaging service (SMS), which restricts GSM users and base stations to transmitting alphanumeric pages limited to a maximum of 160 seven-bit ASCII characters while simultaneously carrying normal voice messages.