LECTURE NOTES

On

CELLULAR COMMUNICATIONS

Unit-5

IV B. Tech II semester
Department of ECE
GIT,GITAM

by

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FREQUENCY MANAGEMENT AND CHANNEL ASSIGNMENT

1)Frequency management

-Numbering the channels

-Grouping the voice channels into subsets (done by each system according to its preference).

-Designating setup channel.

2)Channel assignment

-The allocation of specific channels to cell sites and mobile units.

-A fixed channel set consisting of one or more subsets is assigned to a cell site on a long-term basis.

-During a call, a particular channel is assigned to a mobile unit on a short- term basis.

-Ideally channel assignment should be based on causing the least interference in the system

1)Frequency management

i) NUMBERING THE RADIO CHANNELS:

-Most mobile units and systems are operating on 666 channels as shown in the following frequency management chart.

-A channel consists of two frequency channel bandwidths, one in the low band and one in the high band, with band width of 19.98MHz.
Low band 825MHz-844.98MHz
High band 870MHz-889.98MHz

-If expected band width of radio channel is 30kHz, then total number of radio channels either in low band or high band are
N= 19.98M/30k= 666 channels
Low band-666 Channels, High band-666 Channels

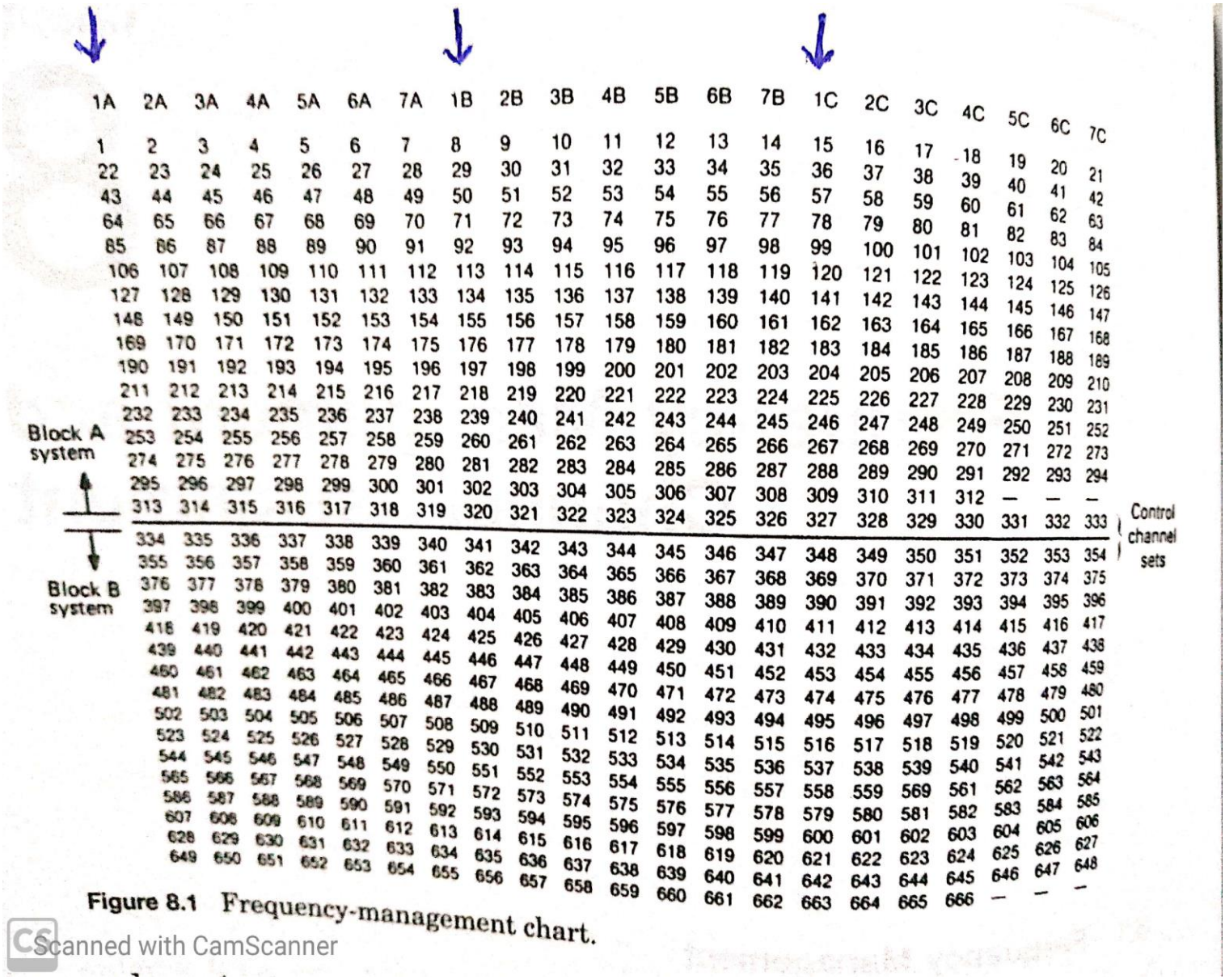
-When a call established between two subscribers two radio channels required between base station and mobile station at both ends for forward and reverse directions of transmission. In order to minimize interference one radio channel will be chosen from low band and another radio channel will be chosen from high band.

-The 666 channels are divided into two groups: block A system and block B system. Each market (i.e., each city) has two systems for a duopoly market policy. Each block has 333 channels.

Channels 1-333 block A

Channels 334-666 block B

	Total radio Channels		**Voice Channels**		**Setup Channels**	
	Total	Range	**Total**	Range	**Total**	Range
Block-A	**333**	1-333	**312**	1-312	**21**	313-333
Block-B	**333**	334-666	**312**	355-666	**21**	334-354



1A	2A	3A	4A	5A	6A	7A	1B	2B	3B	4B	5B	6B	7B	1C	2C	3C	4C	5C	6C	7C
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
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274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294
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313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333
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628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648
649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	—	—	—

Block A system

Block B system

Control channel sets

Figure 8.1 Frequency-management chart.

-These 42 set-up channels are assigned in the middle of all the assigned channels to facilitate scanning of those channels by frequency synthesizers.

-In the new **additional spectrum allocation of 10 MHz** (sec Fig. 5.2.), an additional 166 channels are assigned. Since a 1 MHz is assigned below 825 MHz (or 870 MHz) in the future, additional channels will be numbered up to 849 MHz (or 894 MHz) and will then circle back. The last channel number is 1023.

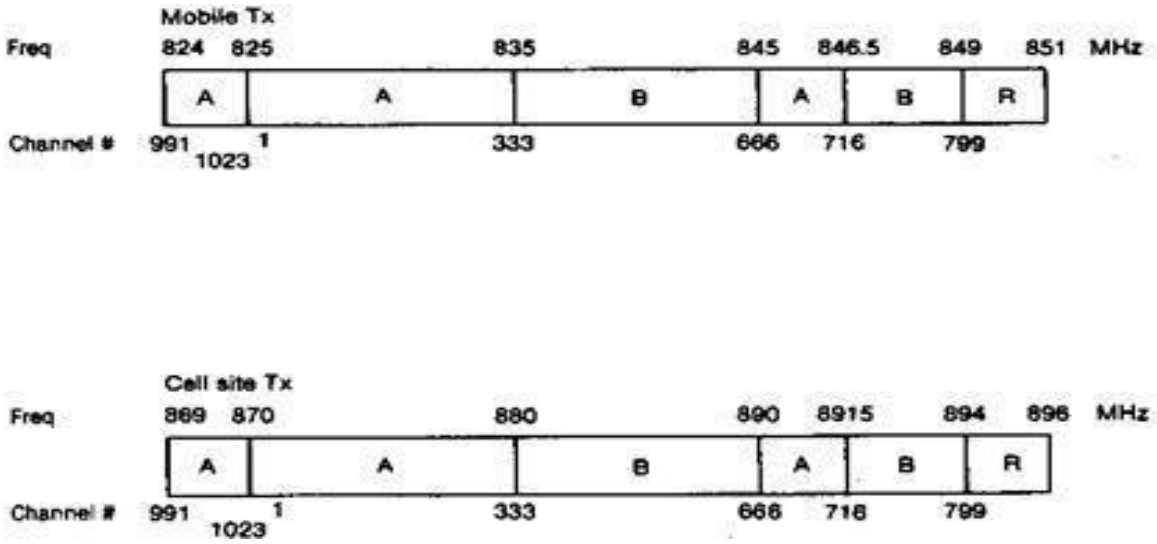


Fig.5.2. New additional spectrum allocation

ii) GROUPING INTO SUBSETS

-The number of voice channels for each system is 312. We can group these into any number of subsets.

-Since there are 21 set-up channels for each system, it is logical to group the 312 channels into 21 subsets. Each subset then consists of 16 channels.

-In each set, the closest adjacent channel is 21 channels away, as shown in Fig.5.1. The 16 channels in each subset can be mounted on a frame and connected to a channel combiner.

-Wide separation between adjacent channels is required for meeting the requirement of minimum isolation.

-In a **seven- cell frequency-reuse cell system** the size of cluster is 7, so because of 21 subsets each cell contains three subsets, iA+iB+iC, where i is an integer from 1 to 7. The total number of voice channels in a cell is about 45. The minimum separation between three subsets is 7 channels.

-If six subsets are equipped in an omnicell site, the minimum separation between two adjacent channels can be only three (21/6> 3) physical channel bandwidths.

For example,

1A+1B+1C+4A+4B+4C
or
1A+1B+1C+5A+5B+5C

iii) SET-UP CHANNELS

-Set-up channels also called control channels are the channels designated to setup calls.

-We should not be confused by fact that a call always needs a set-up channel. A system can be operated without set-up channels also. If we are choosing such a system all the 333 channels in each cellular system (block A or block B) can be voice channels; however each mobile unit must then scan 333 channels continuously and detect the signaling for its call. A customer who wants to initiate a call must scan all the channels and find an idle (unoccupied) one to use.

- Set-up channels can be classified by usage into two types:

a)Access channels

b)Paging channels

- An access channel is used for the mobile-originating calls and paging channels for the land originating calls

-The forward set-up channel functions as the paging channel for responding to the mobile-originating calls. The reverse set-up channel functions as the access channel for the responder to the paging call. The forward set-up channel is transmitted at the cell site, and the reverse set-up channel is transmitted at the mobile unit. All set-up channels carry data information only.

a)**Access channels**

- An access channel is used for the mobile-originating calls.

- In mobile-originating calls, the mobile unit scans its 21 set-up channels and chooses the strongest one.

- Because each set-up channel is associated with one cell, the strongest set-up channel indicates which cell is to serve the mobile-originating calls.

-The mobile unit monitors the Busy/Idle status bits over the desired forward setup channel. When the idle bits are received, the mobile unit can use the corresponding reverse set- up channel to initiate a call.

-Frequently only one system operates in a given city; for instance, block B system might be operating and the mobile unit could be set to –preferable A system.| When the mobile unit first scans the 21 set-up channels in block A, two conditions can occur.

1. If no set-up channels of block A are operational, the mobile unit automatically switches to block B.
2. If a strong set-up signal strength is received but no message can be detected, then the scanner chooses the second strongest set-up channel. If the message still cannot be detected, the mobile unit switches to block B and scans to block B set-up channels.

b)Paging channels:

-Paging channels are used for land originated calls

-Each cell site has been allocated its own setup channel (control channel). The assigned forward set-up channel (FOCC) of each cell site is used to page the mobile unit with the same mobile station control message.

-When the mobile unit responds to the page on the reverse set-up channel, the cell site which receives the response checks the signal reception level and makes a decision regarding the voice channel assignment based on least interference.

2)Channel assignment

-The allocation of specific channels to cell sites and mobile units.
-A fixed channel set consisting of one or more subsets is assigned to a cell site on a long-term basis.
-During a call, a particular channel is assigned to a mobile unit on a short- term basis.
-Ideally channel assignment should be based on causing the least interference in the system.

Channel assignment strategies

i) Fixed Channel assignment

ii) Non Fixed Channel assignment

i) Fixed Channel assignment schemes

a) Adjacent channel assignment

b) Channel sharing and Barrowing

c) Sectorization

d) Underlay-Overlay

a) Adjacent-Channel Assignment:

-Adjacent-channel assignment includes neighboring-channel assignment and next-channel assignment. The near-end–far-end (ratio) interference can occur among the neighboring channels.

-In an Omni-directional-cell system, if one channel is assigned to the middle cell of seven cells, next channels cannot be assigned in the same cell. Also, no next channel (preferably including neighboring channels) should be assigned in the six neighboring sites in the same cell system area (Fig. 5.3a).

-In a directional-antenna-cell system, if one channel is assigned to a face, next channels cannot be assigned to the same face or to the other two faces in the same cell. Also, next channels cannot be assigned to the other two faces at the same cell site (Fig. 5.3b).

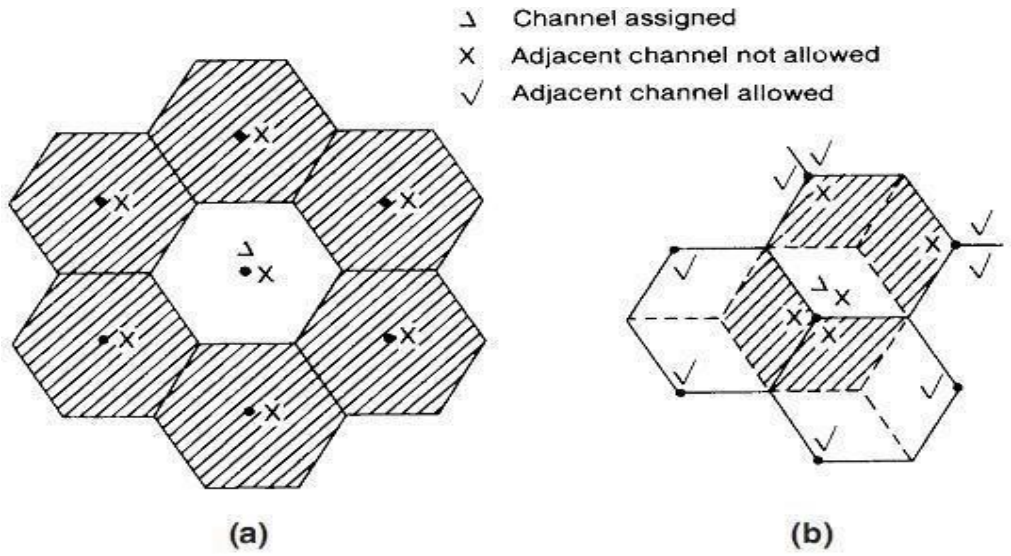


Fig.5.3 Adjacent channel assignment (a) Omni direction antenna cells;
(b) Directional antenna cells

b) CHANNEL SHARING

-Channel sharing is a short-term traffic-relief scheme.

-When a cell needs more channels, the channels of another face at the same cell site can be shared to handle the short-term overload.

-Since we cannot allow adjacent channels to share with the nominal channels in the same cell, channel sets 4 and 5 cannot both be shared with channel sets 12 and 18, as indicated by the grid mark. Many grid marks are indicated in Fig.5.4 for the same reason.

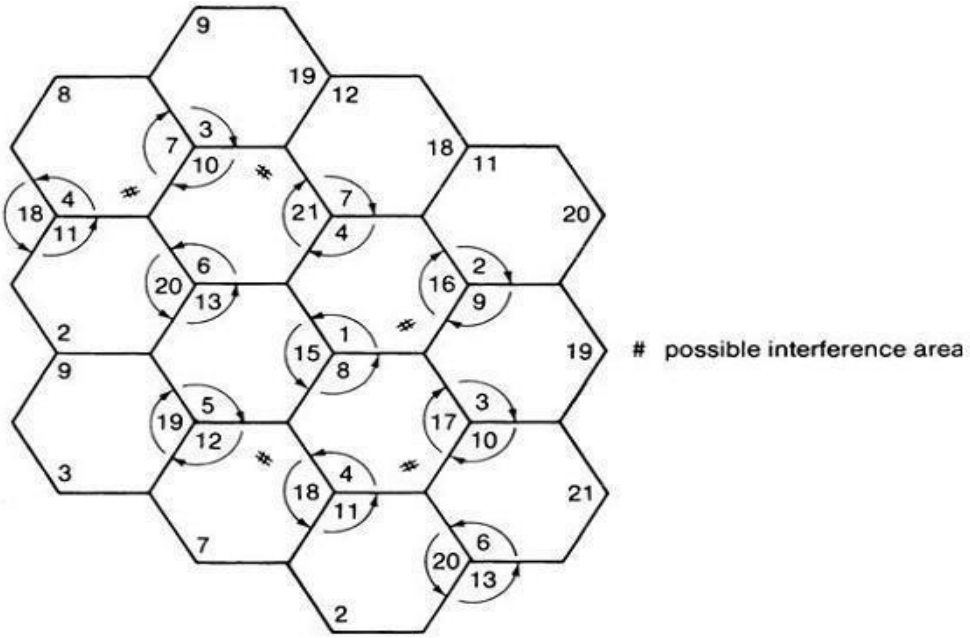


Fig.5.4. Channel sharing algorithm

CHANNEL BORROWING

-Channel borrowing is usually handled on a long-term basis.

-The extent of borrowing more available channels from other cells depends on the traffic density in the area.

-The channel-borrowing scheme is used primarily for slowly-growing systems. It is often helpful in delaying cell splitting in peak traffic areas. Since cell splitting is costly, it should be implemented only as a last resort.

c) Sectorization

-The total number of available channels can be divided into sets (subgroups) depending on the Sectorization of the cell configuration: the 120◦-sector system, the 60◦-sector system, and the 45◦-sector system.

Sectorized Cells: There are three basic types.

1. The 120◦-sector cell is used for both transmitting and receiving Sectorization. Each sector has an assigned a number of frequencies. Changing sectors during a call requires handoffs.

2. The 60◦-sector cell is used for both transmitting and receiving Sectorization. Changing sectors during a call requires handoffs. More handoffs are expected for a 60◦ sector than a 120◦ sector in areas close to cell sites (close-in areas).

3. The 120◦ or 60◦-sector cell is used for receiving Sectorization only. In this case, the transmitting antenna is Omni directional. The number of channels in this cell is not sub- divided for each sector. Therefore, no handoffs are required when changing sectors. This receiving-Sectorization-only configuration does not decrease interference or increase the D/R ratio; it only allows for a more accurate decision regarding handing off the calls to neighboring cells.

d) UNDERLAY-OVERLAY ARRANGEMENT

-The traffic capacity at cell can be increased by using Underlay-Overlay arrangement as shown in figure.

-The underlay is inner circle and the overlay is outer ring.

-The transmitted powers of voice channels at the site are adjusted for these two areas, then different voice frequencies are assigned to each area.

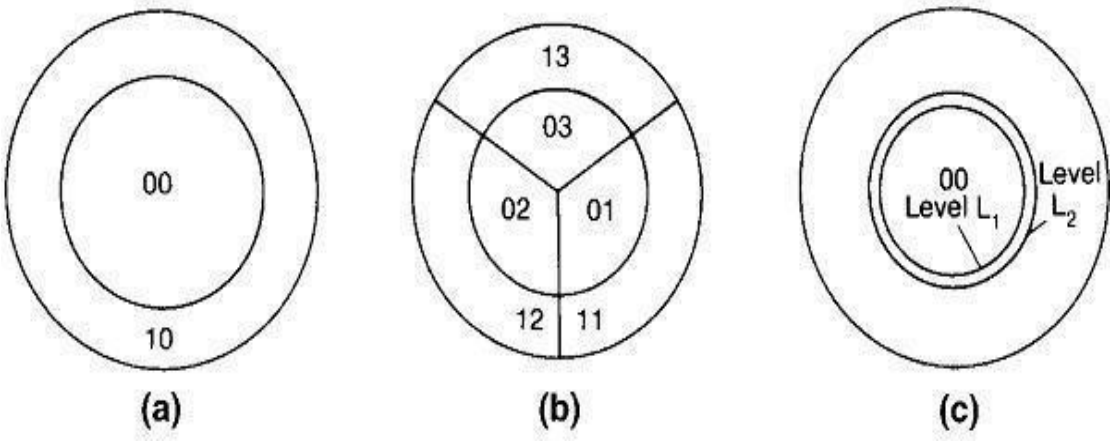


Fig.5.5. Under laid-overlaid cell arrangements. (a) Underlay-overlay in omnicell; (b) Underlay-overlay in Sectorized cell; (c) Two level handoff scheme

-The use of either an Omni directional antenna at one site to create two sub ring areas or three directional antennas to create six subareas is illustrated in Fig. 5.5 b.

-As seen in Fig.5.5, a set of frequencies used in an overlay area will differ from a set of frequencies used in an underlay area in order to avoid adjacent-channel and co-channel interference.

Implementation:

-The antenna of a set-up channel is usually Omni directional. When an incoming call is received by the set-up channel and its signal strength is higher than a level L, the under laid cell is assigned; otherwise, the overlaid cell is assigned.

-The handoffs are implemented between the under laid and overlaid cells. In order to avoid the unnecessary handoffs, we may choose two levels L1 and L2 and L1 > L2 as shown in Fig. 5.5 (c). When a mobile signal is higher than a level L1 the call is handed off to the under laid cell. When a signal is lower than a level L2 the call is handed off to the overlaid cell.

ii)NON FIXED CHANNEL ASSIGNMENT STRATEGY

a) **Dynamic Channel Assignment:** In dynamic channel assignment (DCA), no fixed channels are assigned to each cell. Therefore, any channel in a composite of N radio channels can be assigned to the mobile unit. This means that a channel is assigned directly to a mobile unit. On the basis of overall system performance, DCA can also be used during a call.

b) **Hybrid Channel Assignment:** Hybrid channel assignment (HCA) is a combination of FCA and DCA. A portion of the total frequency channels will use FCA and the rest will use DCA.

c) **Borrowing Channel Assignment:** Borrowing channel assignment (BCA) uses FCA as a normal assignment condition. When all the fixed channels are occupied, then the cell borrows channels from the neighboring cells.

d) **Forcible-Borrowing Channel Assignment:** In forcible-borrowing channel assignment (FBCA), if a channel is in operation and the situation warrants it, channels must be borrowed from the neighboring cells and at the same time, another voice channel will be assigned to continue the call in the neighboring cell.

Handoff Mechanism

Handoff

It is the process of transferring(handing over) an active call from one cell to another cell or one channel to another channel in same cell in a cellular network.

WHY HANDOFF IS NECESSARY

-The value of implementing handoffs is dependent on the size of the cell. For example, if the radius of the cell is 32 km (20 mi), the area is 3217 km^2(1256 mi^2). After a call is initiated in this area, there is little chance that it will be dropped before the call is terminated as a result of a weak signal at the coverage boundary.

-Then why bother to implement the handoff feature? Even for a 16-km radius, cell handoff may not be needed except in a fringe area.

-Today the size of cells becomes smaller in order to increase capacity. Also people talk longer. The handoffs are very essential.

-Handoff is needed in two situations where the cell site receives weak signals from the mobile unit:

(1) at the cell boundary, say, −100 dBm, which is the level for requesting a handoff in a noise-limited environment; and

(2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig.1.

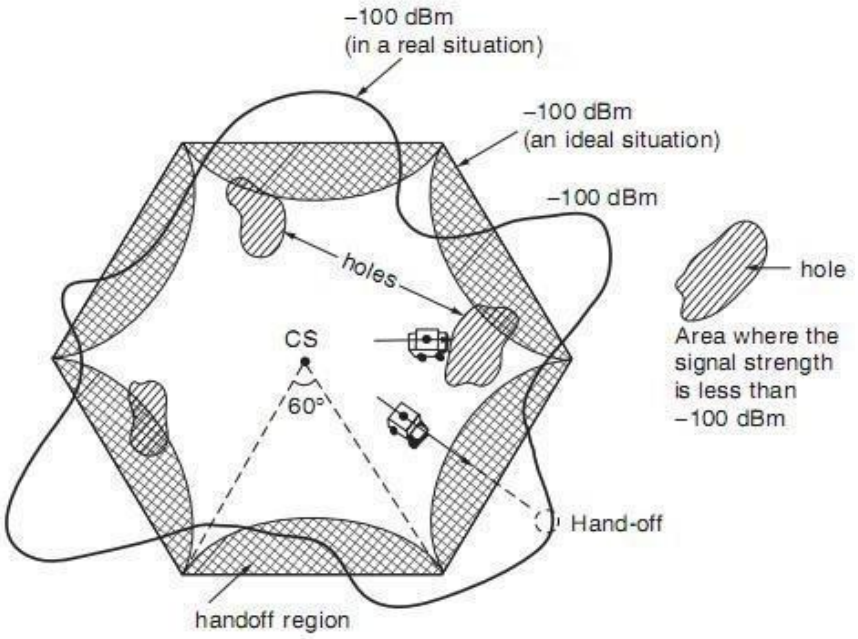


Fig.1. Occurrence of handoffs

WHAT ARE THE TWO DECISIONS MAKING PARAMETERS OF HANDOFF EXPLAIN

-There are two decision-making parameters of handoff:
(1) that based on signal strength and
(2) that based on carrier-to-interference ratio.

-The handoff criteria are different for these two types. In type 1, the signal-strength threshold level for handoff is −100 dBm in noise-limited systems and −95 dBm in interference-limited systems.

-In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

CONCEPT OF DELAYING A HANDOFF

-In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff.

-A handoff could be delayed if no available cell could take the call. A plot of signal strength with two request handoff levels and a threshold level is shown in Fig.3. The plot of average signal strength is recorded on the channel received

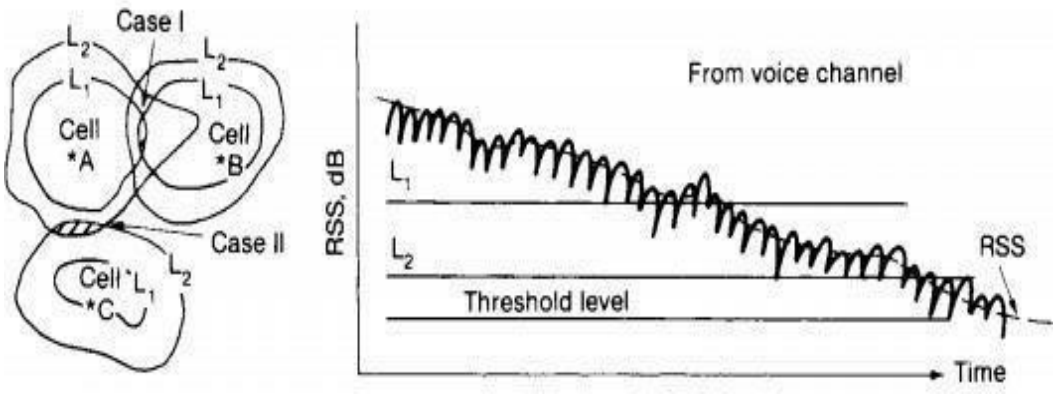


Fig.3. A two level handoff scheme

-Signal strength indicator (RSSI), which is installed at each channel receiver at the cell site.

-When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s.

-At the first handoff level, the handoff takes place if the new signal is stronger.

-However, when the second handoff level is reached, the call will be handed off with no condition.

-The MSO always handles the handoff call first and the originating calls second.

Advantages of Delayed Handoff

-Consider the advantage of having a two-handoff-level algorithm is that it makes the handoff occur at the proper location and eliminates possible interference in the system.

-In Figure 3, case I, shows the area where the first-level handoff occurs between cell A and cell B. If we only use the second-level handoff boundary of cell A, the area of handoff is too close to cell B. Figure 3, case II, also shows where the second-level handoff occurs between cell A and cell C. in is because the first-level handoff cannot be implemented.

Forced Handoff

A forced handoff is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

Controlling a Handoff:

-The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer
or
Assign a high handoff threshold to request a handoff earlier.

-The MSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

Queuing of handoff:

-Queuing of handoffs is more effective than two-threshold-level handoffs.

-The MSO will queue the requests of handoff calls instead of rejecting them if the new cell sites are busy. A queuing scheme becomes effective only when the requests for handoffs arrive at the MSO in batches or bundles. If handoff requests arrive at the MSO uniformly, then the queuing scheme is not needed.

INTERSYSTEM HANDOFF

-Occasionally, a call may be initiated in one cellular system (controlled by one MSO) and enter another system (controlled by another MSO) before terminating.

-In some instances, intersystem handoff can take place; this means that a call handoff can be transferred from one system to a second system so that the call is continued while the mobile unit enters the second system.

-Consider the simple diagram shown in Fig.7. The car travels on a highway and the driver originates a call in system A. Then the car leaves cell site A of system A and enters cell site B of system B. Cell sites A and B are controlled by two different MSOs. When the mobile unit signal becomes weak in cell site A, MSO A searches for a candidate cell site in its system and cannot find one.

-Then MSO A sends the handoff request to MSO B through a dedicated line between MSO A and MSO B, and MSO B makes a complete handoff during the call conversation.

-If two MSOs are manufactured by different companies, then compatibility must be determined before implementation of intersystem handoff can be considered.

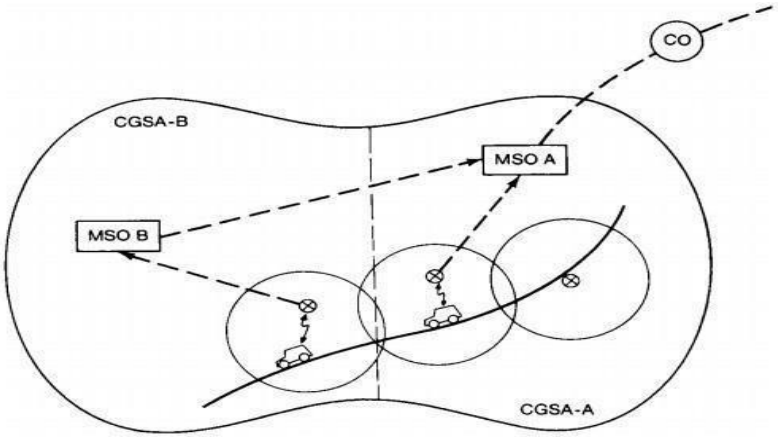


Fig.7. Intersystem handoffs

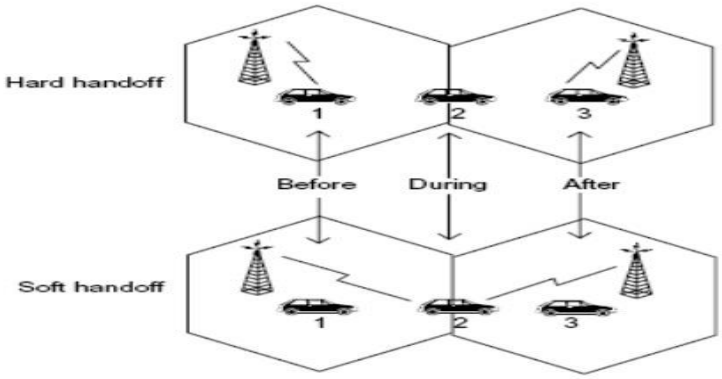
Hard handoff and Soft handoff

Hard handoff – "break before make" policy.

-In a hard handoff, an actual break in the connection occurs while switching from one cell to another.
-The radio links from the mobile station to the existing cell is broken before establishing a link with the next cell.
-It is generally an inter-frequency handoff.
-It is used in GSM.

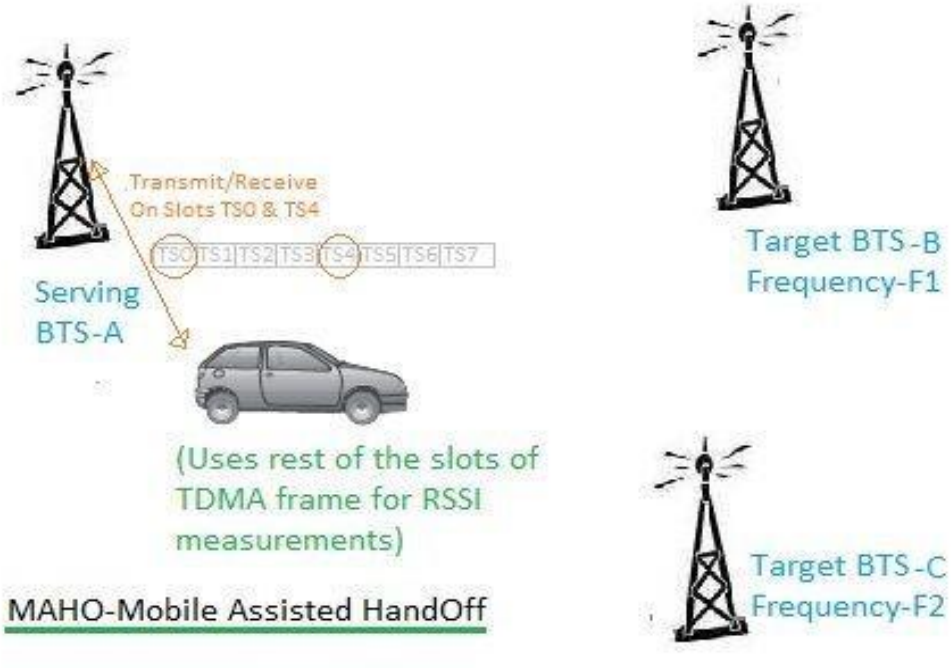
Soft handoff – "make before break" policy.

-In soft handoff, at least one of the links is kept when radio links are added and removed to the mobile station.
-This ensures that during the handoff, no break occurs.
-This is generally adopted in co-located sites.
- It is used in CDMA



Mobile Assisted Handoff

-Mobile Assisted Handoff (MAHO) is a technique in which the mobile devices assist the Base Station Controller (BSC) to transfer a call to another BSC.
-It is used in GSM cellular networks.
-In other systems, like AMPS, a handoff is solely the job of the BSC and the Mobile Switching Centre (MSC), without any participation of the mobile device.
-However, in GSM, when a mobile station is not using its time slots for communicating, it measures signal quality to nearby BSC and sends this information to the BSC. The BSC performs handoff according to this information.



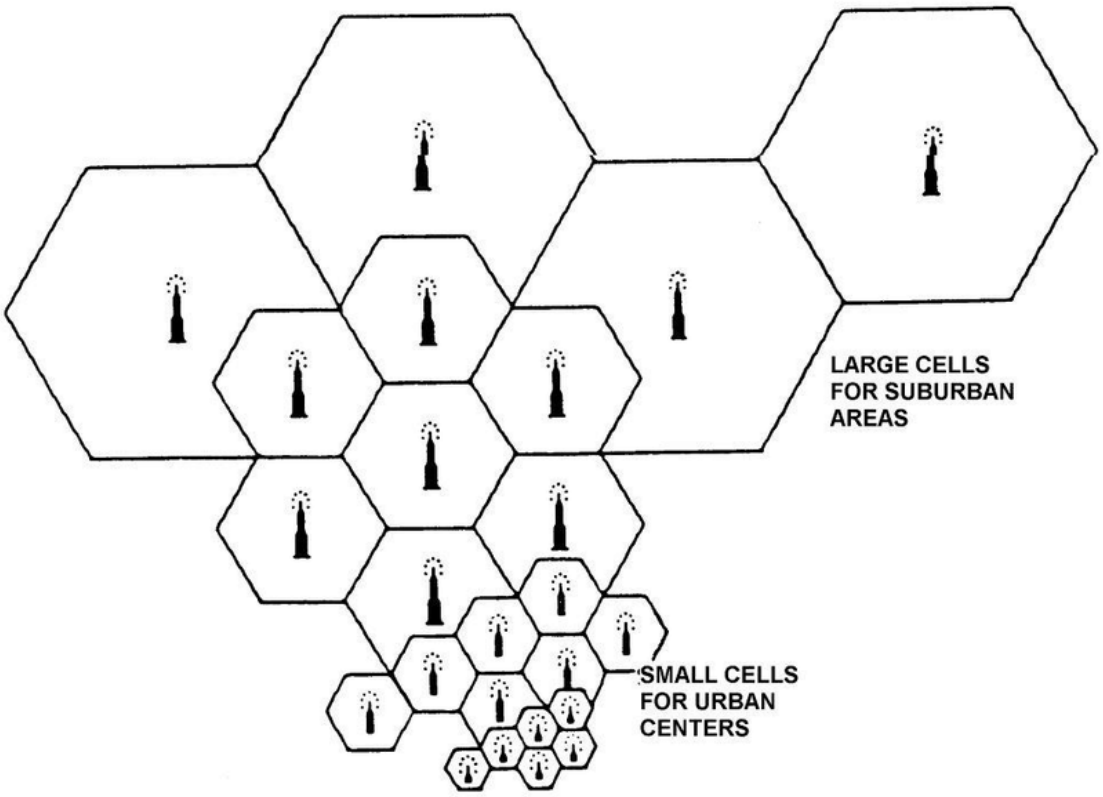
Cell splitting

-Cell splitting is the process of subdividing a congested cell into smaller cells such that each smaller cell has its own base station with Reduced antenna height and Reduced transmitter power.
-It increases the capacity of a cellular system since number of times channels are reused increases.

There are two kinds of cell-splitting techniques:

a. Permanent splitting:
   - Each new split cell is planned ahead of time with consideration of the number of channels, transmitted power, assigned frequencies, selection of the cell-site and traffic load consideration.
   -When the installation is ready the actual service cut-over is set at the lowest traffic point, usually at midnight on a weekend.

b. Dynamic splitting:
   -This scheme is based on utilizing the allocated spectrum efficiency in real time.
   - Cell splitting proceeds gradually over a cellular operating system to prevent dropped calls.


LARGE CELLS
FOR SUBURBAN
AREAS
SMALL CELLS
FOR URBAN
CENTERS

DEFINITION OF DROPPED CALL RATE

-The definition of a dropped call is after the call is established but before it is properly terminated.
-The definition of "the call is established" means that the call is setup completely by the setup channel.
-If there is a possibility of a call drop due to no available voice channels, this is counted as a blocked call not a dropped call.
-If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered a dropped call.
-This case can happen when the mobile or portable units are at a standstill and the radio carrier is changed from a strong setup channel to a weak voice channel due to the selective frequency fading phenomenon.

The perception of dropped call rate by the subscribers can be higher due to:

1. The subscriber unit not functioning properly (needs repair).
2. The user operating the portable unit in a vehicle (misused).
3. The user not knowing how to get the best reception from a portable unit (needs education).

<u>Dropped call rate and voice quality</u>

-In principle, dropped call rate can be set very low if we do not need to maintain the voice quality.
-The dropped call rate and the specified voice quality level are inversely proportional.
-In designing a commercial system, the specified voice quality level is given relating to how much C/I (or C/N) the speech coder can tolerate.

Digital Cellular Systems

Different digital cellular systems are

1) GSM
2) TDMA(IS-54)
3) CDMA(IS-95)

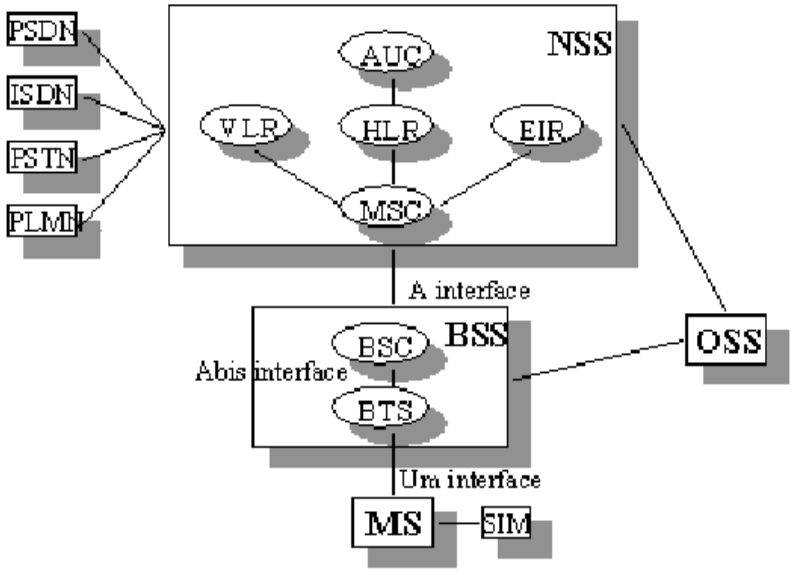
1) GSM (Global system for Mobile Communication)

GSM Architecture

A GSM network consists of the following components mainly

- **Mobile Station(MS)**
- **Base Station Subsystem(BSS)**
- **Operation Subsystem(OSS)**
- **Network Subsystem(NSS)**

- **Mobile Station(MS):**
  -It includes mobile equipment(**ME**) which consists of the transceiver, the display and the processor and is controlled by a subscriber identity module(**SIM)** card which stores all the subscriber related information.
- **Base Station Subsystem(BSS):**
  -It acts as an interface between the mobile station and the network subsystem.
  -It consists of the Base Transceiver Station(**BTS**) which contains the radio transceivers and handles the protocols for communication with mobiles.
  -It also consists of the Base Station Controller(**BSC**) which controls several Base Transceiver station and acts as a interface between the BTS and mobile switching centre.



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

- **Operation Subsystem(OSS):**
  There are three functions of OSS
  i)Network operation and maintenance functions
  ii)Subscription management including charging and billing
  iii)Mobile equipment management

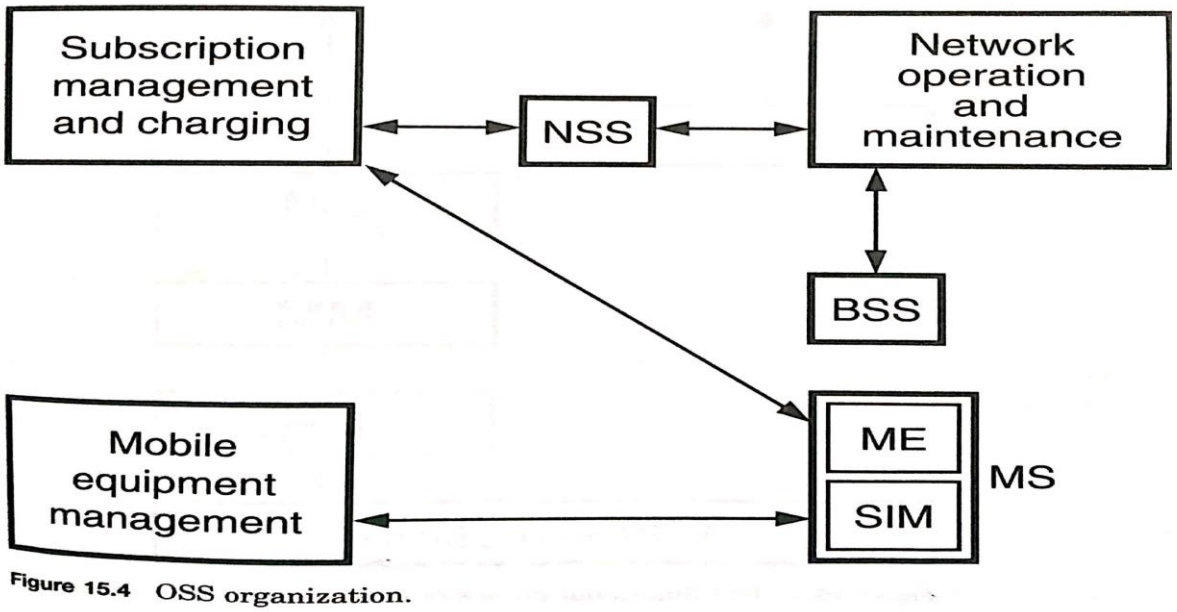


Figure 15.4 OSS organization.

Features of GSM Module:

- Improved spectrum efficiency
- International roaming
- Compatibility with integrated services digital network (ISDN)
- Support for new services.
- SIM phonebook management
- High-quality speech
- Uses encryption to make phone calls more secure
- Short message service (SMS)

TDMA

Time **D**ivision **M**ultiple **A**ccess (TDMA) :
-A digital wireless telephony transmission technique.
-TDMA allocates each user a different time slot on a given frequency.
-TDMA divides each cellular channel into three time slots in order to increase the amount of data that can be carried.
-TDMA technology was more popular in Europe, Japan and Asian countries, where as CDMA is widely used in North and South America. out of the world. Sometimes it is called as IS-54 system

Arcitecture of TDMA
The architecture is just like GSM but there is only one interface existing in TDMA, which is between MS and BTS called as common radio interface.

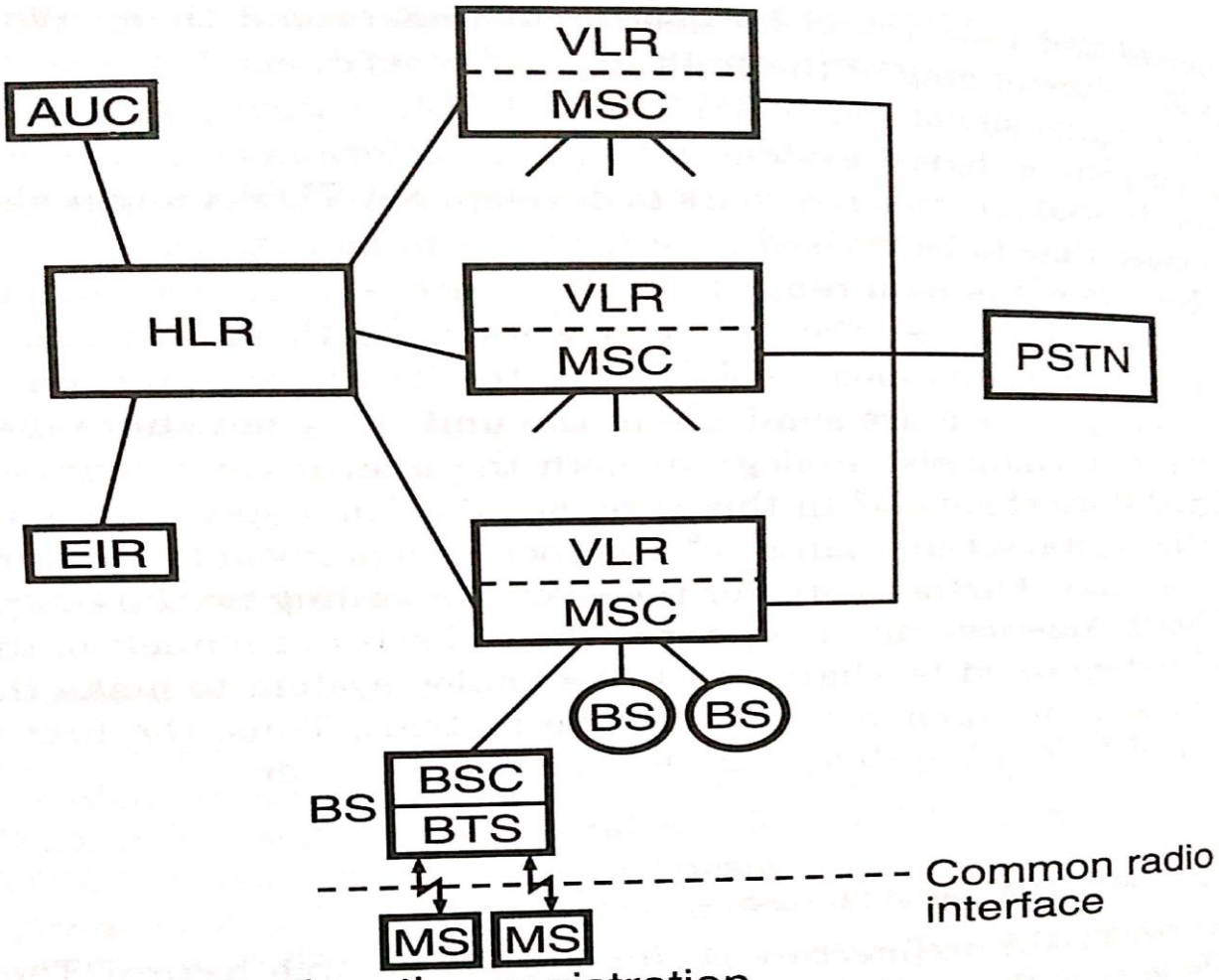


Figure 15.16 NA-TDMA system architecture.

TDMA Frame Structure

-One digital channel contains 25 frames per second.
-Each frame is 40ms long and totally 6 time slots existing. So each time slot is 6.66ms.
-One frame contains 1944 bits or 972 symbols. So each slot contains 324 bits or 162 symbols
-The duration of each bit is T_b=6.66m/324=20.57us
-So the data rate in radio channel is 48.6kbps.

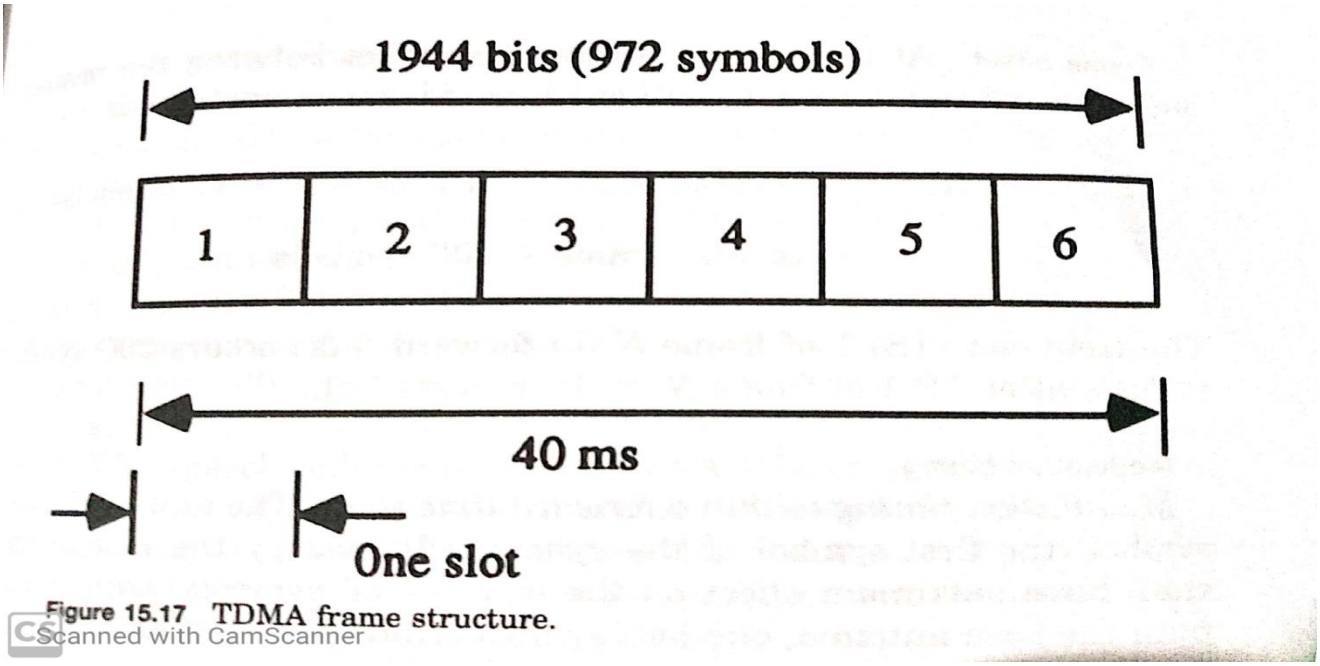


Figure 15.17 TDMA frame structure.

Advantages of TDMA:

- TDMA can easily adapt to transmission of data as well as voice communication.
- TDMA has an ability to carry data rates around 40kbps.
- TDMA allows the operator to do services like fax, voice band data, and SMS as well as bandwidth-intensive application such as multimedia and video conferencing.
- Since TDMA technology separates users according to time, it ensures that there will be no interference from simultaneous transmissions.
- TDMA provides users with an extended battery life, since it transmits only portion of the time during conversations.
- TDMA is the most cost effective technology to convert an analog system to digital.

Disadvantages of TDMA

- Disadvantage using TDMA technology is that the users has a predefined time slot. When moving from one cell site to other, if all the time slots in this cell are full the user might be disconnected.
- Another problem in TDMA is that it is subjected to multipath distortion. To overcome this distortion, a time limit can be used on the system. Once the time limit is expired the signal is ignored.

What is CDMA (IS-95)

Code **D**ivision **M**ultiple **A**ccess (CDMA: a digital wireless technology that uses spread-spectrum techniques. CDMA does not assign a specific frequency to each user. Instead, every channel uses the full available spectrum. Individual conversations are encoded with a pseudo-random digital sequence. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time, and it is the common platform on which 3G technologies are built.

Advantages of CDMA

- One of the main advantages of CDMA is that dropouts occur only when the phone is at least twice as far from the base station. Thus, it is used in the rural areas where GSM cannot cover.
- Another advantage is its capacity; it has a very high spectral capacity that it can accommodate more users per MHz of bandwidth.

Disadvantages of CDMA

- Channel pollution, where signals from too many cell sites are present in the subscriber. s phone but none of them is dominant. When this situation arises, the quality of the audio degrades.
- When compared to GSM is the lack of international roaming capabilities.
- The ability to upgrade or change to another handset is not easy with this technology because the network service information for the phone is put in the actual phone unlike GSM which uses SIM card for this.
- Limited variety of the handset, because at present the major mobile companies use GSM technology