Listen Learn Lead

Engineering Excellence for Empowerment

Nadar Saraswathi College of Engineering & Technology

NSCET E-LEARNING PRESENTATION

LISTEN … LEARN… LEAD…

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

III YEAR / VI SEMESTER

EC8652– WIRELESS COMMUNICATION

Dr.R.ATHILINGAM
Associate professor & Head (i/c)
Nadar Saraswathi College of & Technology,
Vadapudupatti, Annanji (po), Theni – 625531.

MULTIPLE ACCESS TECHNIQUES

UNIT 02 – CELLULAR ARCHITECTURE– LECTURE 01

MULTIPLE ACCESS TECHNIQUES

- Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.
- The sharing of spectrum is required to achieve high capacity by simultaneously allocating the available bandwidth (or the available amount of channels) to multiple users.
- For high quality communications, this must be done without severe degradation in the performance of the system. In wireless communications systems, it is often desirable to allow the subscriber to send simultaneously information to the base station while receiving information from the base station.
- For example, in conventional telephone systems, it is possible to talk and listen simultaneously, and this effect, called duplexing, is generally required in wireless telephone 53 stems. Duplexing may be done using frequency or time domain techniques.

DUPLEXING

- Frequency division duplexing (FDD) provides two distinct bands of frequencies for every user.
- The forward band provides traffic from the base station to the mobile, and the reverse band provides traffic from the mobile to the base.

- Time division duplexing (TDD) uses time instead of frequency to provide both a forward and reverse link.
- If the time split between the forward and reverse time slot is small, then the transmission and reception of data appears simultaneous to the user.

Frequency Division Multiple Access (FDMA)

- Frequency division multiple access (FDMA) assigns individual channels to individual users.
- Each user is allocated a unique frequency band or channel.
- These channels are assigned on demand to users who request service.
- During the period of the call, no other user can share the same frequency band.
- In FDD systems, the users are assigned a channel as a pair of frequencies; one frequency is used for the forward channel, while the other frequency is used for the reverse channel.

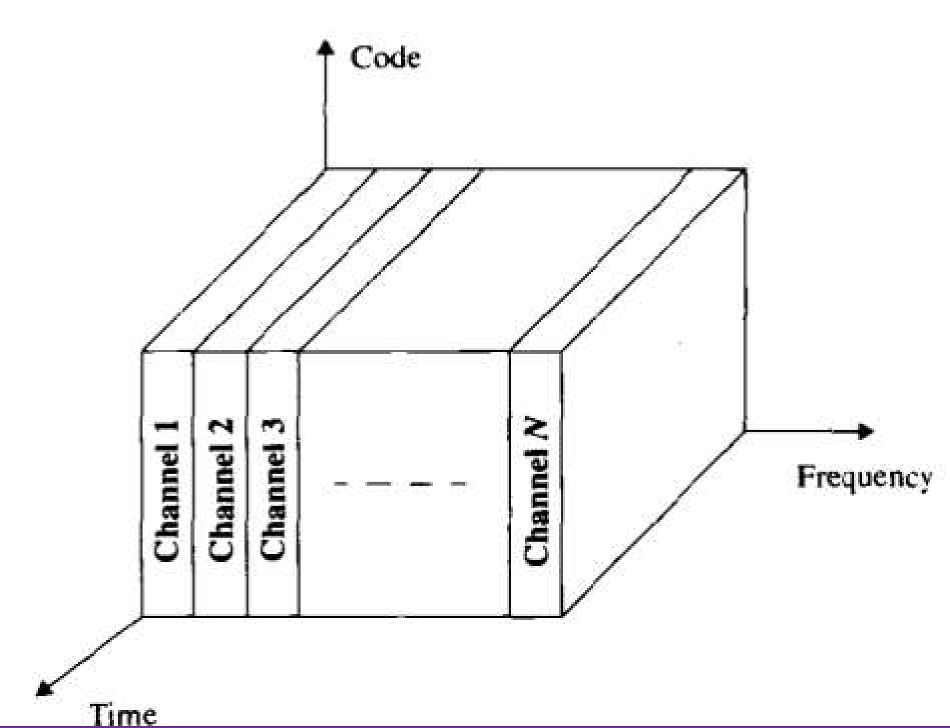
The features of FDMA are as follows:

1. The FDMA channel carries only one phone circuit at a time.
2. If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity. It is essentially a wasted resource.
3. After the assignment of a voice channel, the base station and the mobile transmit simultaneously and continuously.

4. The bandwidths of FDMA channels are relatively narrow (30 kHz) as each channel supports only one circuit per carrier
5. The symbol time is large as compared to the average delay spread. This implies that the amount of intersymbol interference is low and, thus, little or no equalization is required in FDMA narrowband systems.
6. The complexity of FDMA mobile systems is lower when compared to TDMA systems, though this is changing as digital signal processing methods improve for TDMA.
7. Since FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes (such as synchronization and framing bits) as compared to TDMA.
8. FDMA systems have higher cell site system costs as compared to TDMA systems, because of the single channel per carrier design, and the need to use costly bandpass filters to eliminate spurious radiation at the base station.
9. The FDMA mobile unit uses duplexers since both the transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units and base stations.

- AMPS, analog narrowband frequency modulation (NBFM) is used to modulate the carrier.
- The number of channels that can be simultaneously supported in a FDMA system is given by

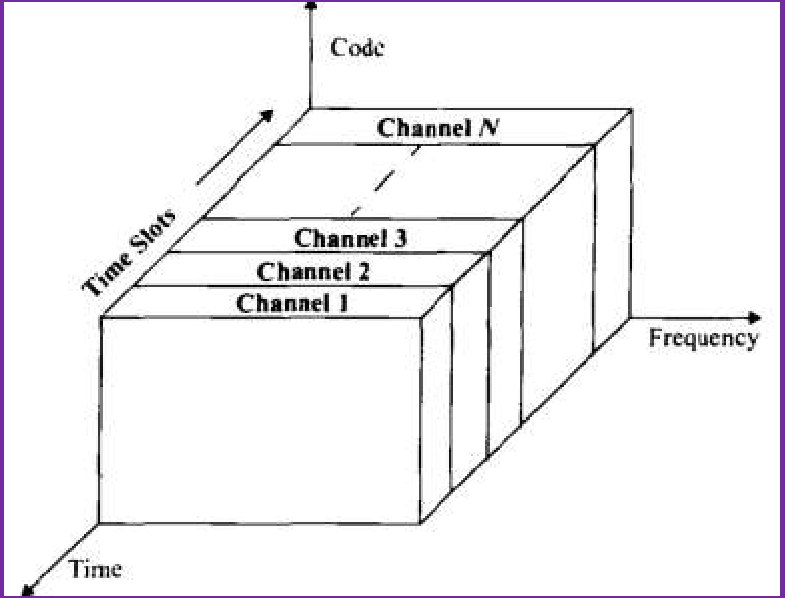
$$N = \frac{B_t - 2B_{guard}}{B_c}$$



Time Division Multiple Access (TDMA)

- TDMA uses time slots, and in each slot only one user is allowed to either transmit or receive.
- Each user occupies a cyclically repeating time slot, so a channel may be thought of as particular time slot that reoccurs every frame, where N time slots comprise a frame.
- TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non continuous.
- The transmission from various users is interlaced into a repeating frame structure.
- It can be seen that a frame consists of a number of slots.
- Each frame is made up of a preamble, an information message, and tail bits.
- In TDMAITDD, half of the time slots in the frame information message would be used for the forward link channels and half would be used for reverse link channels.
- In TDMAIFDD systems, an identical or similar frame structure would be used solely for either forward or reverse transmission, but the carrier frequencies would be different for the forward and reverse links.
- In general, TDMAJFDD systems intentionally induce several time slots of delay between the forward and reverse time slots of a particular user, so that duplexers are not required in the subscriber unit.

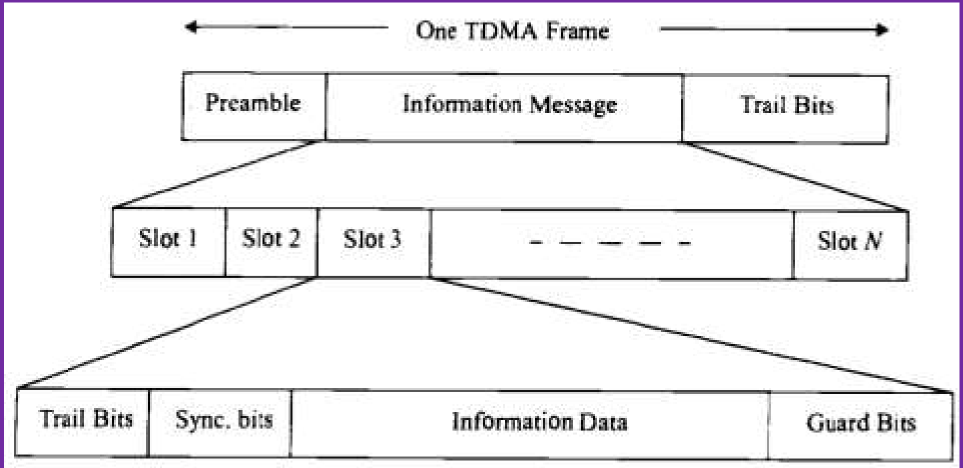
- In a TDMA frame, the preamble contains the address and synchronization information that both the base station and the subscribers use to identify each other.
- Guard times are utilized to allow synchronization of the receivers between different slots and frames.



1. TDMA shares a single carrier frequency with several users, where each user makes use of non overlapping time slots. The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth, etc.
2. Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).
3. Because of discontinuous transmissions in TDMA, the handoff process is much simpler for a subscriber unit, since it is able to listen for other base stations during idle time slots. An enhanced link control, such as that provided by mobile assisted handoff (MAHO) can be carried out by a subscriber by listening on an idle slot in the TDMA frame.
4. TDMA uses different time slots for transmission and reception, thus duplexers are not required. Even if FDD is used, a switch rather than a duplexer inside the subscriber unit is all that is required to switch between transmitter and receiver using TDMA.
5. Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.
6. In TDMA, the guard time should be minimized. If the transmitted signal at the edges of a time slot are suppressed sharply in order to shorten the guard time, the transmitted spectrum will expand and cause interference to adjacent channels.

The number of TDMA channel slots that can be provided in a TDMA system is found by multiplying the number of TDMA slots per channel by the number of channels available and is given by

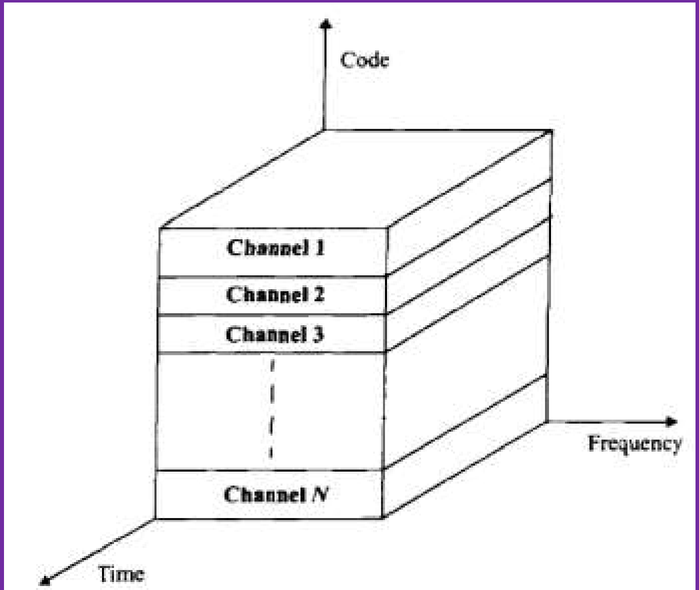
$$N = \frac{m(B_{tot} - 2B_{guard})}{B_c}$$



Code Division Multiple Access (CDMA)

- In code division multiple access (CDMA) systems, the narrowband message signal is multiplied by a very large bandwidth signal called the spreading signal.
- The spreading signal is a pseudo-noise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message.
- All users in a CDMA system use the same carrier frequency and may transmit simultaneously.
- Each user has its own pseudorandom codeword which is approximately orthogonal to all other code words.
- The receiver performs a time correlation operation to detect only the specific desired codeword.
- All other code words appear as noise due to decorrelation.
- For detection of the message signal, the receiver needs to know the codeword used by the transmitter.
- Each user operates independently with prior knowledge of the other users.

- In CDMA, the power of multiple users at a receiver determines the noise floor after decorrelation.
- If the power of each user within a cell is not controlled such that they do not appear equal at the base station receiver, then the near-far problem occurs.



1. Many users of a CDMA system share the same frequency. Either TDD or FDD may be used. Unlike TDMA or FDMA, CDMA has a soft capacity limit.
2. Increasing the number of users in a CIJMA system raises the noise floor in a linear manner. Thus, there is no absolute limit on the number of users in CDMA. Rather, the system performance gradually degrades for all users as the number of users is increased, and improves as the number of users is decreased.
3. Multipath fading may be substantially reduced because the signal is spread over a large spectrum. If the spread spectrum bandwidth is greater than the coherence bandwidth of the channel, the inherent frequency diversity will mitigate the effects of small-scale fading.
4. Channel data rates are very high in CDMA systems. Consequently, the symbol (chip) duration is very short and usually much less than the channel delay spread.
5. Since PN sequences have low autocorrelation, multipath which is delayed by more than a chip will appear as noise. A RAKE receiver can be used to improve reception by collecting time delayed versions of the required signal.

6. Since CDMA uses co-channel cells, it can use macroscopic spatial diversity to provide soft handoff. Soft handoff is performed by the MSC, which can simultaneously monitor a particular user from two or more base stations. The MSC may chose the best version of the signal at any time without switching frequencies.
7. Self-jamming is a problem in CDMA system. Self-jamming arises from the fact that the spreading sequences of different users are not exactly orthogonal, hence in the despreading of a particular PN code, non-zero contributions to the receiver decision statistic for a desired user arise from the transmissions of other users in the system.
8. The near-far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.

CELLULAR CONCEPT

UNIT 02 – CELLULAR ARCHITECTURE– LECTURE 02

INTRODUCTION

- The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity.
- It offered very high capacity in a limited spectrum allocation without any major technological changes.
- The cellular concept is a system level idea which calls for replacing a single, high power transmitter (large cell) with many low power transmitters (small cells), each providing coverage to only a small portion of the service area.
- Each base station is allocated a portion of the total number of channels available to the entire system, and nearby base stations are assigned different groups of channels so that all the available channels are assigned to a relatively small number of neighboring base stations.
- Neighboring base stations are assigned different groups of channels so that the interference between base stations is minimized. By systematically spacing base stations and their channel groups throughout a market, the available channels are distributed throughout the geographic region and may be reused as many times as necessary, so long as the interference between co-channel stations is kept below acceptable levels.

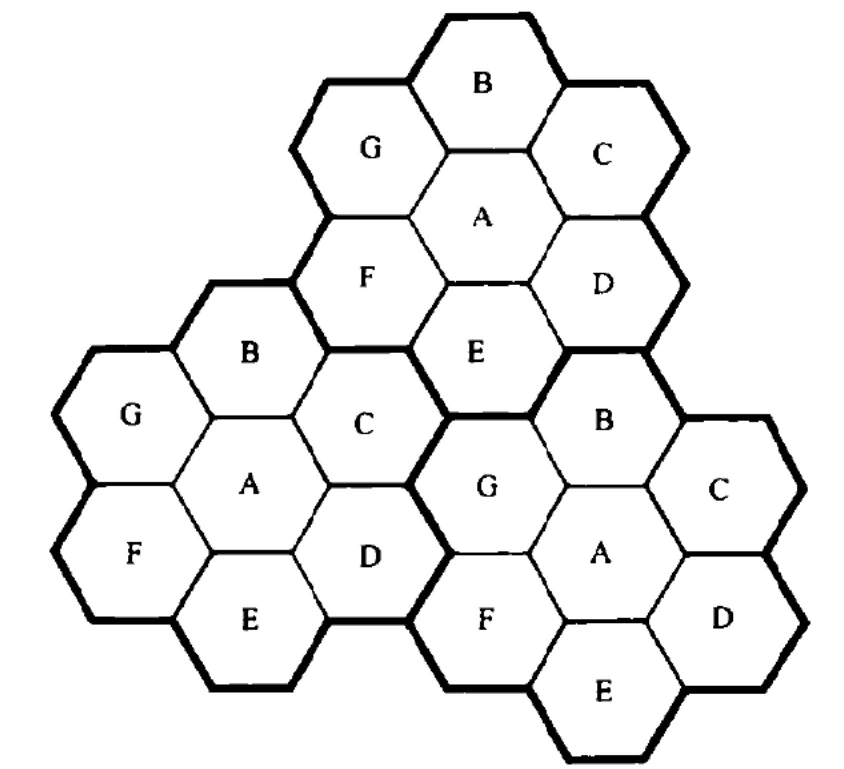
Frequency Reuse

- 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 a cell.
- Base stations in adjacent cells are assigned channel groups which contain completely different channels than neighboring cells.
- 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 one another by distances large enough to keep interference levels within tolerable limits.
- The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called frequency reuse or frequency planning

Factors Influencing Small-Scale Fading

- In the concept of frequency reuse, cells labeled with the same letter use the same group of channels.
- The frequency reuse plan is overlaid upon a map to indicate where different frequency channels are used.
- The hexagonal cell shape is conceptual and is a simplistic model of the radio coverage for each base station, but it has been universally adopted since the hexagon permits easy and manageable analysis of a cellular system.
- The actual radio coverage of a cell is known as the footprint and is determined from field measurements or propagation prediction models.
- Thus, when considering geometric shapes which cover an entire region without overlap and with equal area, there are three sensible choices: a square; an equilateral triangle; and a hexagon.
- A cell must be designed to serve the weakest mobiles within the footprint, and these are typically located at the edge of the cell. For a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of the three.

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



$$S = kN$$

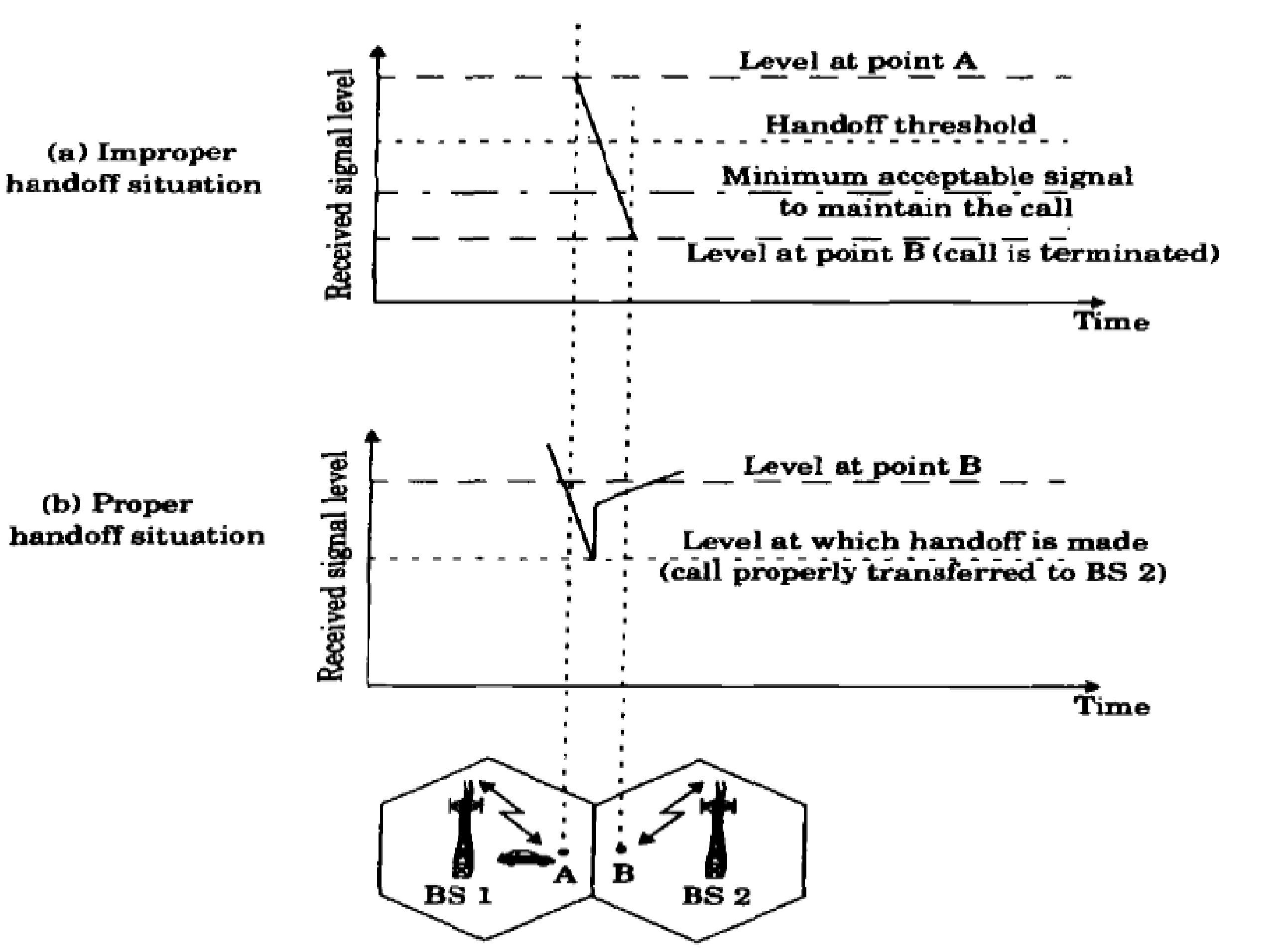
$$C = MkN = MS$$

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

Channel Assignment Strategies

- For efficient utilization of the radio spectrum, a frequency reuse scheme that is consistent with the objectives of increasing capacity and minimizing interference is required.
- The choice of channel assignment strategy impacts the performance of the system, particularly as to how calls are managed when a mobile user is handed off from one cell to another
- In a fixed channel assignment strategy; each cell is allocated a predetermined set of voice channels.
- Any call attempt within the cell can only be served by the unused channels in that particular cell.
- If all the channels in that cell are occupied, the call is blocked and the subscriber does not receive service.
- In one approach, called the borrowing strategy, a cell is allowed to borrow channels from a neighboring cell if all of its own channels are already occupied.
- The mobile switching center (MSC) supervises such borrowing procedures and ensures that the borrowing of a channel does not disrupt or interfere with any of the calls in progress in the donor cell.

- In a dynamic channel assignment strategy, voice channels are not allocated to different cells permanently.
- Instead, each time a call request is made, the serving base station requests a channel from the MSC.
- The switch then allocates a channel to the requested cell following an algorithm that takes into account the likelihood of fixture blocking within the cell, the frequency of use of the candidate channel, the reuse distance of the channel, and other cost functions.
- Accordingly, the MSC only allocates a given frequency if that frequency is not presently in use in the cell or any other cell which falls within the minimum restricted distance of frequency reuse to avoid co-channel interference.


(a) Improper handoff situation
Received signal level
Level at point A
Handoff threshold
Minimum acceptable signal to maintain the call
Level at point B (call is terminated)
Time
(b) Proper handoff situation
Received signal level
Level at point B
Level at which handoff is made (call properly transferred to BS 2)
Time
BS 1
A
B
BS 2

Handoff Strategies

- When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.
- This handoff operation not only involves a new base station, but also requires that the voice and control signals be allocated to channels associated with the new base station.
- Processing handoffs is an important task in any cellular radio system.
- Many handoff strategies prioritize handoff requests over call initiation requests when allocating unused channels in a cell site.
- In deciding when to handoff, it is important to ensure that the drop in the measured signal level is not due to momentary fading and that the mobile is actually moving away from the serving base station.
- The time over which a call may be maintained within a cell, without handoff, is called *the dwell time*

Prioritizing Handoffs

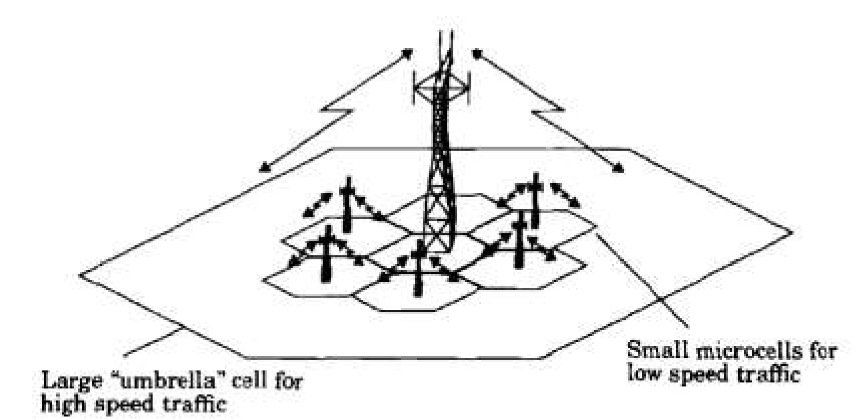
- One method for giving priority to handoffs is called the guard channel concept, whereby a fraction of the total available channels in a cell is reserved exclusively for handoff requests from ongoing calls which may be handed off into the cell.
- This method has the disadvantage of reducing the total carried traffic, as fewer channels are allocated to originating calls.
- Guard channels, however, offer efficient spectrum utilization when dynamic channel assignment strategies, which minimize the number of required guard channels by efficient demand based allocation, are used.
- Queuing of handoff requests is another method to decrease the probability of forced termination of a call due to lack of available channels.
- Queuing of handoffs is possible due to the fact that there is a finite time interval between the time the received signal level drops below the handoff threshold and the time the call is terminated due to insufficient signal level.
- The delay time and size of the queue is determined from the traffic pattern of the particular service area.

Practical Handoff Considerations

- In practical cellular systems, several problems arise when attempting to design for a wide range of mobile velocities.
- High speed vehicles pass through the coverage region of a cell within a matter of seconds, whereas pedestrian users may never need a handoff during a call.
- Particularly with the addition of microcells to provide capacity, the MSC can quickly become burdened if high speed users are constantly being passed between very small cells.
- Several schemes have been devised to handle the simultaneous traffic of high speed and low speed users while minimizing the handoff intervention from the MSC.
- Another practical limitation is the ability to obtain new cell sites.

UMBRELLA CELL

- By using different antenna heights and different power levels, it is possible to provide "large" and "small" cells which are co-located at a single location.
- This technique is called the umbrella cell approach and is used to provide large area coverage to high speed users while providing small area coverage to users traveling at low speeds.
- The umbrella cell approach ensures that the number of handoffs is minimized for high speed users and provides additional microcell channels for pedestrian users.
- The speed of each user may be estimated by the base station or MSC by evaluating how rapidly the short term average signal strength on the RVC changes over time, or more sophisticated algorithms may be used to evaluate and partition users



CELL DRAGGING

- Another practical handoff problem in microcell systems is known as cell dragging.
- Cell dragging results from pedestrian users that provide a very strong signal to the base station.
- Such a situation occurs in an urban environment when there is a line-of-sight (LOS) radio path between the subscriber and the base station.
- As the user travels away from the base station at a very slow speed, the average signal strength does not decay rapidly. Even when the user has traveled well beyond the designed range of the cell, the received signal at the base station may be above the handoff threshold, thus a handoff may not be made.
- This creates a potential interference and traffic management problem, since the user has meanwhile traveled deep within a neighboring cell.

SOFT AND HARD HANDOFF

- Code division multiple access (CDMA) provides a unique handoff capability that cannot be provided with other wireless systems.
- Unlike channelized wireless systems that assign different radio channels during a handoff (called a hard handoff), spread spectrum mobiles share the same channel in every cell.
- Thus, the term handoff does not mean a physical change in the assigned channel, but rather that a different base station handles the radio communication task.
- By simultaneously evaluating the received signals from a single subscriber at several neighboring base stations, the MSC may actually decide which version of the user's signal is best at any moment in time.
- This technique exploits macroscopic space diversity provided by the different physical locations of the base stations and allows the MSC to make a "soft" decision as to which version of the user's signal to pass along to the PSTN at any instance
- The ability to select between the instantaneous received signals from a variety of base stations is called soft handoff

INTERFERENCE AND SYSTEM CAPACITY

- Interference is the major limiting factor in the performance of cellular radio systems.
- Sources of interference include another mobile in the same cell, a call in progress in a neighboring cell, other base stations operating in the same frequency band, or any non cellular system which inadvertently leaks energy into 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 the greater HF noise floor and the large number of base stations and mobiles. Interference has been recognized as a major bottleneck in increasing capacity and is often responsible for dropped calls.
- The two major types of system- generated cellular interference are co-channel interference and adjacent channel interference.

Co-channel Interference and System Capacity

- 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, and the interference between signals from these cells is called co-channel interference.
- Unlike thermal noise which can be overcome by increasing the signal-to noise ration (SNR), co-channel interference cannot be combated by simply increasing the carrier power of a transmitter
- This is because an increase in carrier transmit power increases the interference to neighboring 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.
- 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 (B) and the distance between centers of the nearest co-channel cells (D).
- By increasing the ratio of DIR, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased.

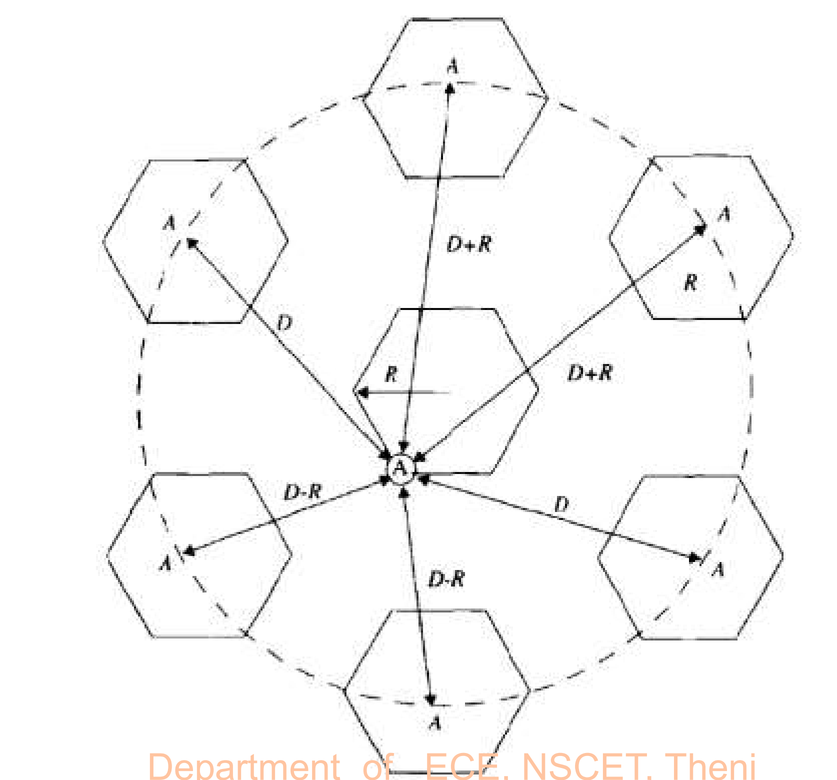
A small value of Q provides larger capacity since the cluster size N is small, whereas a large value of Q improves the transmission quality, due to a smaller level of co-channel interference. A trade-off must be made between these two objectives in actual cellular design

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i}$$

$$P_r = P_0\left(\frac{d}{d_0}\right)^{-n}$$

	Cluster Size (*N*)	Co-channel Reuse Ratio(*Q*)
$i = 1, j = 1$	3	3
$i = 1, j = 2$	7	4.58
$i = 2, j = 2$	12	6
$i = 1, j = 3$	13	6.24

Illustration of the first tier of co-channel cells for a cluster size of $N=7$. When the mobile is at the cell boundary (point A), it experiences worst case co-channel interference on the forward channel. The marked distances between the mobile and different co-channel cells are based on approximations made for easy analysis.



Adjacent Channel Interference

- Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent channel interference.
- Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the passband.
- The problem can be particularly serious if an adjacent channel user is transmitting in very close range to a subscriber's receiver, while the receiver attempts to receive a base station on the desired channel.
- This is referred to as the near-far effect, where a nearby transmitter not be of the same type as that used by the cellular system) captures the receiver of the subscriber.
- Alternatively, the near-far effect occurs when a mobile close to a base station transmits on a channel close to one being used by a weak mobile.
- The base station may have difficulty in discriminating the desired mobile user from the "bleedover" caused by the close adjacent channel mobile.

Trunking and Grade of Service

- Cellular radio systems rely on trunking to accommodate a large number of users in a limited radio spectrum.
- The concept of trunking allows a large number of users to share the relatively small number of channels in a cell by providing access to each user, on demand, from a pool of available channels.
- In a trunked radio system, each user is allocated a channel on a per call basis, and upon termination of the call, the previously occupied channel is immediately returned to the pool of available channels.
- Trunking exploits the statistical behavior of users so that a fixed number of channels or circuits may accommodate a large, random user community.
- The telephone company uses trunking theory to determine the number of telephone circuits that need to be allocated for office buildings with hundreds of telephones, and this same principle is used in designing cellular radio systems.
- There is a trade-off between the number of available telephone circuits and the likelihood of a particular user finding that no circuits are available during the peak calling time.

- To design trunk radio systems that can handle a specific capacity at a specific "grade of service", it is essential to understand trunking theory and queuing theory
- One Erlang represents the amount of traffic intensity carried by a channel that is completely occupied (i.e. 1 call-hour per hour or 1 call-minute per minute).
- For example, a radio channel that is occupied for thirty minutes during an hour carries 0.5 Erlangs of traffic.
- The grade of service (GOS) is a measure of the ability of a user to access a trunked system during the busiest hour.
- The busy hour is based upon customer demand at the busiest hour during a week, month, or year.
- The busy hours for cellular radio systems typically occur during rush hours, between 4 p.m. and 6 p.m. on a Thursday or Friday evening.
- The grade of service is a benchmark used to define the desired performance of a particular trunked system by specifying a desired likelihood of a user obtaining channel access given a specific number of channels available in the system.
- It is the wireless designer's job to estimate the maximum required capacity and to allocate the proper number of channels.
- GOS is typically given as the likelihood that a call is blocked, or the likelihood of a call experiencing a delay greater than a certain queuing time.

Set-up Time: The time required to allocate a trunked radio channel to a requesting user.

Blocked Call: Call which cannot be completed at time of request, due to congestion. Also referred to as a *lost call*.

Holding Time: Average duration of a typical call. Denoted by H (in seconds).

Traffic Intensity: Measure of channel time utilization, which is the average channel occupancy measured in Erlangs. This is a dimensionless quantity and may be used to measure the time utilization of single or multiple channels. Denoted by A.

Load: Traffic intensity across the entire trunked radio system, measured in Erlangs.

Grade of Service (GOS): A measure of congestion which is specified as the probability of a call being blocked (for Erlang B), or the probability of a call being delayed beyond a certain amount of time (for Erlang C).

Request Rate: The average number of call requests per unit time. Denoted by λ seconds^{-1}.

- The second kind of trunked system is one in which a queue is provided to hold calls which are blocked.
- If a channel is not available immediately, the call request may be delayed until a channel becomes available.
- This type of trunking is called Blocked Calls Delayed, and its measure of GOS is defined as the probability that a call is blocked after waiting a specific length of time in the queue.
- To find the GOS, it is first necessary to find the likelihood that a call is initially denied access to the system.

$$Pr[blocking] = \frac{\frac{A^C}{C!}}{\sum_{k=0}^{C} \frac{A^k}{k!}} = GOS$$

$$Pr[delay > 0] = \frac{A^C}{A^C + C!\left(1 - \frac{A}{C}\right)\sum_{k=0}^{C-1} \frac{A^k}{k!}}$$

An urban area has a population of 2 million residents. Three competing trunked mobile networks (systems A, B, and C) provide cellular service in this area. System A has 394 cells with 19 channels each, system B has 98 cells with 57 channels each, and system C has 49 cells, each with 100 channels. Find the number of users that can be supported at 2% blocking if each user averages 2 calls per hour at an average call duration of 3 minutes. Assuming that all three trunked systems are operated at maximum capacity, compute the percentage market penetration of each cellular provider.

System A

Given:

Probability of blocking = 2% = 0.02

Number of channels per cell used in the system, $C = 19$

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ Erlangs

For $GOS = 0.02$ and $C = 19$, from the Erlang B chart, the total carried traffic, A, is obtained as 12 Erlangs.

Therefore, the number of users that can be supported per cell is

$$U = A/A_u = 12/0.1 = 120.$$

Since there are 394 cells, the total number of subscribers that can be supported by System A is equal to $120 \times 394 = 47280$.

System B

Given:

Probability of blocking = 2% = 0.02

Number of channels per cell used in the system, $C = 57$

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ Erlangs

For $GOS = 0.02$ and $C = 57$, from the Erlang B chart, the total carried traffic, A, is obtained as 45 Erlangs.

Therefore, the number of users that can be supported per cell is

$$U = A/A_u = 45/0.1 = 450.$$

Since there are 98 cells, the total number of subscribers that can be supported by System B is equal to $450 \times 98 = 44100$.

System C

Given:

Probability of blocking = 2% = 0.02

Number of channels per cell used in the system, $C = 100$

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ Erlangs

For $GOS = 0.02$ and $C = 100$, from the Erlang B chart, the total carried traffic, A, is obtained as 88 Erlangs.

Therefore, the number of users that can be supported per cell is

$$U = A/A_u = 88/0.1 = 880.$$

Since there are 49 cells, the total number of subscribers that can be supported by System C is equal to $880 \times 49 = 43120$

Therefore, total number of cellular subscribers that can be supported by these three systems are $47280 + 44100 + 43120 = 134500$ users.

Since there are 2 million residents in the given urban area and the total number of cellular subscribers in System A is equal to 47280 , the percentage market penetration is equal to

$$47280/2000000 = 2.36\ \%$$

Similarly, market penetration of System B is equal to

$$44100/2000000 = 2.205\ \%$$

and the market penetration of System C is equal to

$$43120/2000000 = 2.156\ \%$$

The market penetration of the three systems combined is equal to

$$134500/2000000 = 6.725\ \%$$

A certain city has an area of 1,300 square miles and is covered by a cellular system using a 7-cell reuse pattern. Each cell has a radius of 4 miles and the city is allocated 40 MHz of spectrum with a full duplex channel bandwidth of 60 kHz. Assume a GOS of 2% for an Erlang B system is specified. If the offered traffic per user is 0.03 Erlangs, compute (a) the number of cells in the service area, (b) the number of channels per cell, (c) traffic intensity of each cell, (d) the maximum carried traffic, (e) the total number of users that can be served for 2% GOS, (f) the number of mobiles per channel, and (g) the theoretical maximum number of users that could be served at one time by the system.

(a) Given:

Total coverage area = 1300 miles

Cell radius = 4 miles

The area of a cell (hexagon) can be shown to be $2.5981R^2$, thus each cell covers

$$2.5981 \times (4)^2 = 41.57 \text{ sq mi.}$$

Hence, the total number of cells are $N_c = 1300/41.57 = 31$ cells.

(b) The total number of channels per cell (C)

$= \text{allocated spectrum} / (\text{channel width} \times \text{frequency reuse factor})$

$= 40,000,000 / (60,000 \times 7) = 95$ channels/cell

(c) Given:

$C = 95$, and $GOS = 0.02$

From the Erlang B chart, we have

traffic intensity per cell $A = 84$ Erlangs/cell

(d) Maximum carried traffic = number of cells × traffic intensity per cell

$= 31 \times 84 = 2604$ Erlangs.

(e) Given traffic per user = 0.03 Erlangs

Total number of users = Total traffic / traffic per user

$= 2604 / 0.03 = 86,800$ users.

(f) Number of mobiles per channel = number of users/number of channels

$= 86,800 / 666 = 130$ mobiles/channel.

(g) The theoretical maximum number of served mobiles is the number of available channels in the system (all channels occupied)

$= C \times N_C = 95 \times 31 = 2945$ users, which is 3.4% of the customer base.

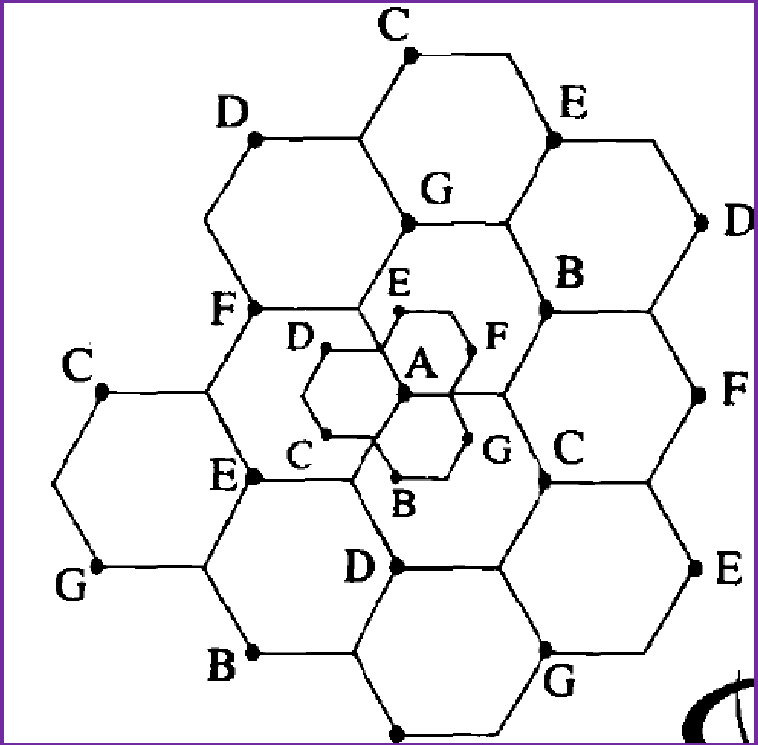
Improving Capacity In Cellular Systems

- As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users.
- At this point, cellular design techniques are needed to provide more channels per unit coverage area.
- Techniques such as cell splitting, sectoring, and coverage zone approaches are used in practice to expand the capacity of cellular systems.
- Cell splitting allows an orderly growth of the cellular system.
- Sectoring uses directional antennas to further control the interference and frequency reuse of channels.
- The zone microcell concept distributes the coverage of a cell and extends the cell boundary to hard-to-reach places.
- While cell splitting increases the number of base stations in order to increase capacity, sectoring and zone microcells rely on base station antenna placements to improve capacity by reducing co-channel interference.

Cell Splitting

- Cell splitting is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power.
- Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused.
- By defining cells which have a smaller radius than the original cells and by installing these smaller cells (called microcells) between the existing cells, capacity increases due to the additional number of channels per unit area.
- Imagine if every cell in were reduced in such a way that the radius of every cell was cut in half. In order to cover the entire service area with smaller cells, approximately four times as many cells would be required.
- This can be easily shown by considering a circle with radius R.
- The area covered by such a circle is four times as large as the area covered by a circle with radius R/2.
- The increased number of cells would increase the number of clusters over the coverage region, which in turn would increase the number of channels, and thus capacity, in the coverage area.

- In Figure, the base stations are placed at corners of the cells, and the area served by base station A is assumed to be saturated with traffic (i.e., the blocking of base station A exceeds acceptable rates).
- New base stations are therefore needed in the region to increase the number of channels in the area and to reduce the area served by the single base station.
- The smaller cells were added in such a way as to preserve the frequency reuse plan of the system
- For example, the microcell base station labeled G was placed half way between two larger stations utilizing the same channel set G.
- This is also the case for the other microcells in the figure.
- As can be seen from Figure cell splitting merely scales the geometry of the cluster.
- In this case, the radius of each new microcell is half that of the original cell.



Sectoring

- By decreasing the cell radius R and keeping the co-channel reuse ratio D/R unchanged, cell splitting increases the number of' channels per unit area.
- However, another way to increase capacity is to keep the cell radius unchanged and seek methods to decrease the D/R ratio.
- In this approach, capacity improvement is achieved by reducing the number of cells in a cluster and thus increasing the frequency reuse.
- However, in order to do this, it is necessary to reduce the relative interference without decreasing the transmit power.
- The co-channel interference in a cellular system may be decreased by replacing a single omni-directional antenna at the base station by several directional antennas, each radiating within a specified sector.
- By using directional antennas, a given cell will receive interference and transmit with only a fraction of the available co-channel cells.

• The technique for decreasing co-channel interference and thus increasing system capacity by using directional antennas is called sectoring.

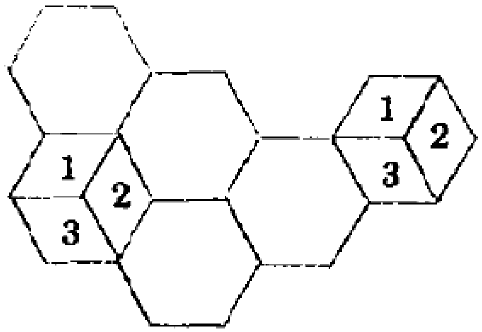
•The factor by which the co-channel interference is reduced depends on the amount of sectoring used.

•A cell is normally partitioned into three 1200 sectors or six 60° sectors as shown in Figure (a) and (b).

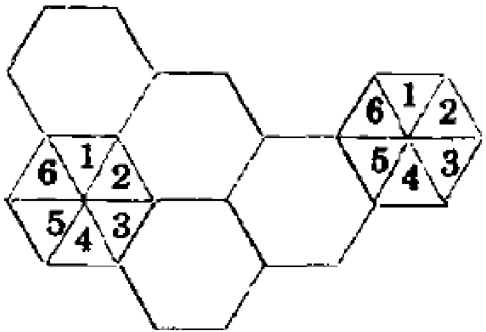
• When sectoring is employed, the channels used in a particular cell are broken down into sectored groups and are used only within a particular sector, as illustrated in Figure (a) and (b).

• Assuming 7-cell reuse, for the case of 120° sectors, the number of interferers in the first tier is reduced from 6 to 2.

•This is because only 2 of the 6 co-channel cells receive interference with a particular sectored channel group



(a)

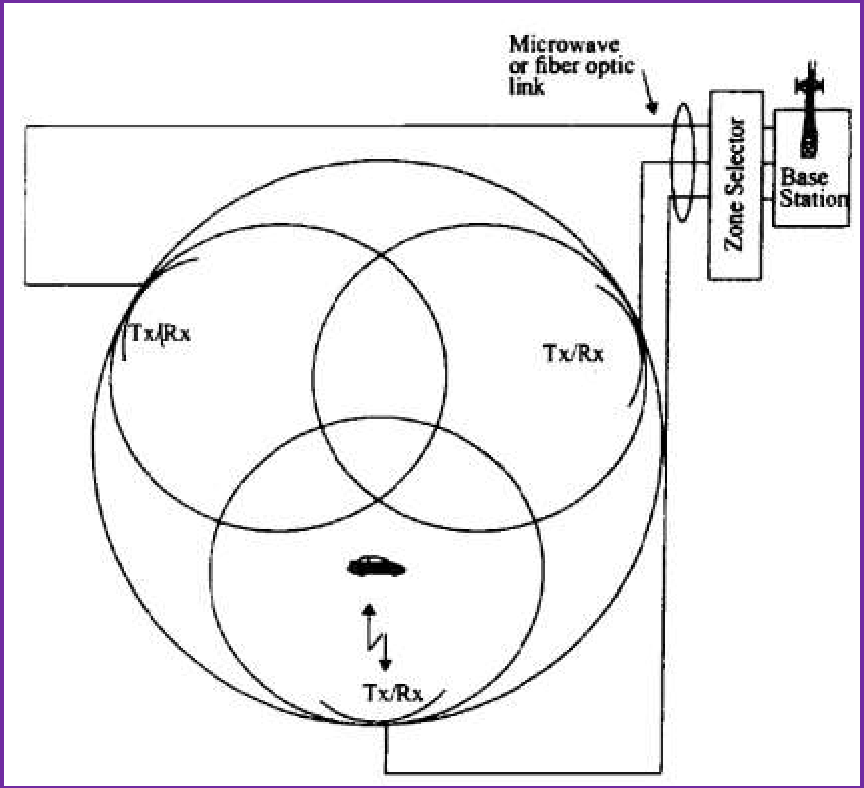


(b)

Microcell Zone Concept

- The increased number of handoffs required when sectoring is employed results in an increased load on the switching and control link elements of the mobile system.
- In this scheme, each of the three (or possibly more) zone sites (are connected to a single base station and share the same radio equipment.
- The zones are connected by coaxial cable, fiberoptic cable, or microwave link to the base station. Multiple zones and a single base station make up a cell.
- As a mobile travels within the cell, it is served by the zone with the strongest signal.
- This approach is superior to sectoring since antennas are placed at the outer edges of the cell, and any base station channel may be assigned to any zone by the base station.
- As a mobile travels from one zone to another within the cell, it retains the same channel.
- Thus, unlike in sectoring, a handoff is not required at the MSC when the mobile travels between zones within the cell.

- The base station simply switches the channel to a different zone site.
- The channels are distributed in time and space by all three zones and are also reused in co-channel cells in the normal fashion.
- The advantage of the zone cell technique is that while the cell maintains a particular coverage radius, the co-channel interference in the cellular system is reduced since a large central base station is replaced by several lower powered transmitters (zone transmitters) on the edges of the cell.
- Decreased co-channel interference improves the signal quality and also leads to an increase in capacity, without the degradation in trunking efficiency caused by sectoring.



THANKS!

Does anyone have any questions?

Rama.athilingam@gmail.com
9095100240