Wireless Communications

(SECTION A PART I)

INTRODUCTION TO WIRELESS COMMUNICATION SYSTEMS

Course Information

University Syllabus

MEEC-508 WIRELESS MOBILE COMMUNICATION

L	T	P		Marks	Credits
4	-	-	Exams :	100	4
			Sessionals :	50	2
			Total :	150	6
			Duration of Exam :	3 hrs.	

1. Introduction to mobile radio systems: Paging systems, cordless telephone system, Cellular telephone systems- Cellular concept, frequency reuse, channel assignment strategies, Interference and system capacity, trunking and grade of service, cell splitting, sectoring, microcell zone concept, HO strategies.

2. Mobile radio propagation: mechanism, free space path loss, log-distance path loss models, Okumara model, Hata model, PCS model, Wideband PCS microcell model, indoor propagation models, Jake's channel model, Multi path characteristics of radio waves, signal fading, Time dispersion, Doppler spread, coherence time LCR, fading statistics, diversity techniques

3. Introduction to spread spectrum communication, multiple access techniques used in mobile wireless communication: FDMA/TDMA/CDMA, Cellular CDMA, packet radio protocols, CSMA, reservation protocols, capacity of cellular CDMA, soft HO

4. Wireless systems and standards: GSM standards, signaling and call control, mobility management, location tracing, wireless data networking, packet error modeling on fading channels, Performance analysis of link and transport layer protocols over wireless channels, mobile data networking (mobile IP), wireless data services, IS-95, GPRS

Text Books:

1. Wireless Communications: Theodore S. Rappaport; Pearsons.
2. Mobile Cellular Telecommunication: W.C.Y.Lee; McGraw Hill

Reference Book:

1. Mobile Communications: Jochen Schiller; Pearson

Outline

- Introduction
  - What is Wireless Communication ?
  - Evolution of Mobile Radio Communications.
  - Classification of Wireless Communication.
  - Examples of Mobile Radio Systems.
  - Paging Systems.
  - Cordless Telephone Systems
  - Comparisons of Various Wireless Systems.

What is Wireless Communication?

Brief Introduction

Characteristics of Wireless Comm.

- Convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere
- Unreliable channel (attenuation, fading, shadowing, interference)
- Complicated design and management
- Device limitations (power supply, LCD)
- Limited bandwidth and expensive service

Why use wireless communication?

- Provides mobility
  - A user can send and receive messages no matter where he/she located
- Added convenience / reduced cost
  - Enables communications without adding expensive infrastructure
  - Can easily setup temporary wireless LANs (disaster situations)
- Developing nations use cellular telephony rather than laying wires to each home
- Use resources only when sending or receiving signal

Why is wireless different than wired?

- Noisy, time-varying channel
  - BER varies by orders of magnitude(Digital Communication)
  - Enviromental conditions affect transmission
- Shared medium
  - Other users create interference
  - Must develop ways to share the channel
- Bandwidth is limited
  - TÜK, FCC determines the frequency allocation
  - ISM band for unlicensed spectrum (902-928 MHz, 2.4-2.5 GHz, 5.725-5.875 GHz)
- Requires intelligent signal processing and communications to make efficient use of limited bandwidth in error-prone environment

Limitations and Difficulties of Wireless

- Mobility brings unique challenges of its own
- Limitations from political and technical difficulties may inhibit wireless technologies (but doubtful today)
- Lack of an industry-wide standard, which should be a concern to the global community (but the global economy will mandate a solution)
- Device limitations
  - e.g., small LCD on a mobile telephone can only display a few lines of text
  - e.g., browsers of most mobile wireless devices use wireless markup language (WML) instead of HTML
- Security – Achilles heel of the technology
- RF Effects – long term effects on humans? Environment?

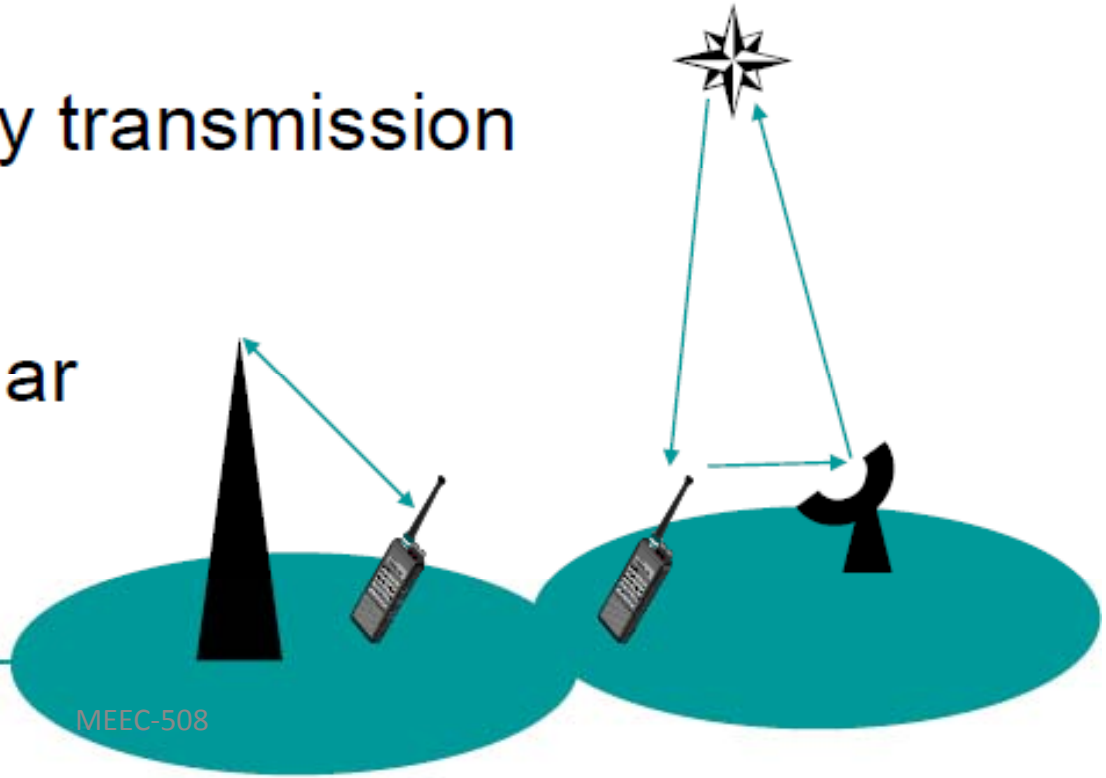
Paging systems

- Traditional paging is one-way ,personal wireless alerting /
- messaging system.
- The first paging system was developed by Charles F. Neergard,a radio engineer.
- Information delivered in paging system can be done in the following four types:

- **Alert tone**
- **Voice messages**
- **Digit string(Numeric pager)**
- **Text string (Alphanumeric pager)**

Paging Systems

- Broad coverage for short messaging
- Message broadcast from all base stations
- Simple terminals
- Optimized for 1-way transmission
- Answer-back hard
- Overtaken by cellular



FEATURES OF PAGING SYSTEM

FEATURE	MOBILE UNIT	BASE STATION
COVERAGE RANGE	HIGH	HIGH
REQUIRED INFRA-STRUCTURE	HIGH	HIGH
COMPLEXITY	LOW	HIGH`
HARDWARE COST	LOW	HIGH
CARRIER FREQUENCY	< 1 GHz	< 1 GHz
FUNCTIONALITY	RECEIVER	TRANSMITTER

Paging systems

- Paging systems are comm. Systems that can send brief alert/message to a subscriber.
- Depending on the type of service , the message can either be numeric message, an alphanumeric message, or a voice message.
- Paging systems are typically used to notify a subscriber of the need to call a particular telephone no. or travel to a known location to receive further instructions.

Paging systems

- In modern paging systems news headlines, stock quotations & faxes can be sent.
- A message can be sent to a paging subscriber via the paging system access number with a telephone keypad or modem. The issued message is called a page.
- The paging system then transmits the page throughout the service area using base stations which broadcast the page on a radio carrier.

Paging systems

- While a simple paging system can cover a limited range of 2km to 5km or may even be confined to within individual buildings, wide area paging systems can provide world wide coverage.

Paging systems

- Wide area paging systems consist of a network of telephone lines, many base stations transmitters and large radio towers that simultaneously broadcast a page from each base station(known as simulcasting)
- Simulcast transmitters may be located within the same service area or in different cities or countries.
- Paging systems are designed to provide reliable comm. to subscribers wherever they are; whether inside a building, driving on a highway, or flying in an airplane.

Paging systems

- This necessitates larger transmitter powers(kilowatts) & low data rates(a couple of thousand bits/sec) for max. coverage from each BS.

Wide area paging networks

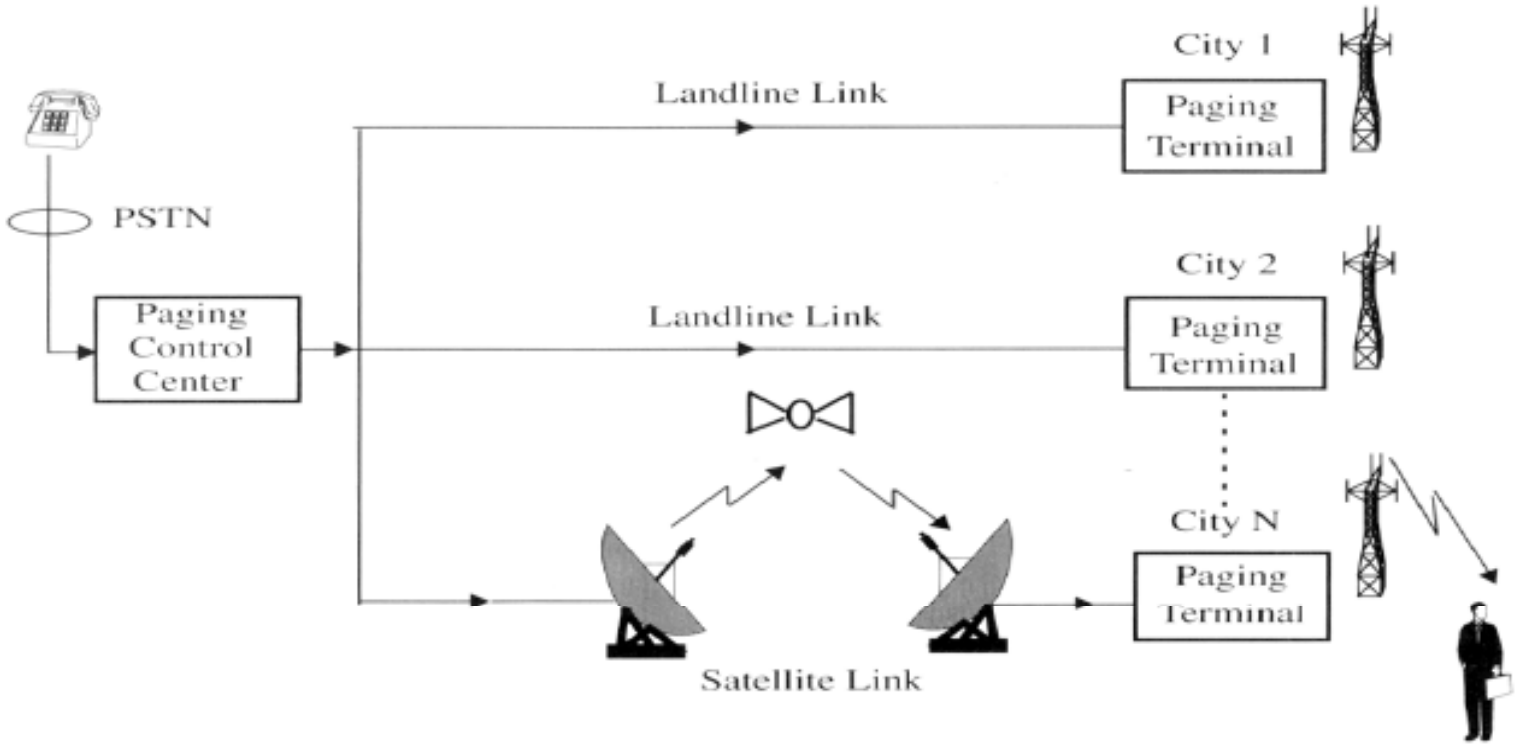
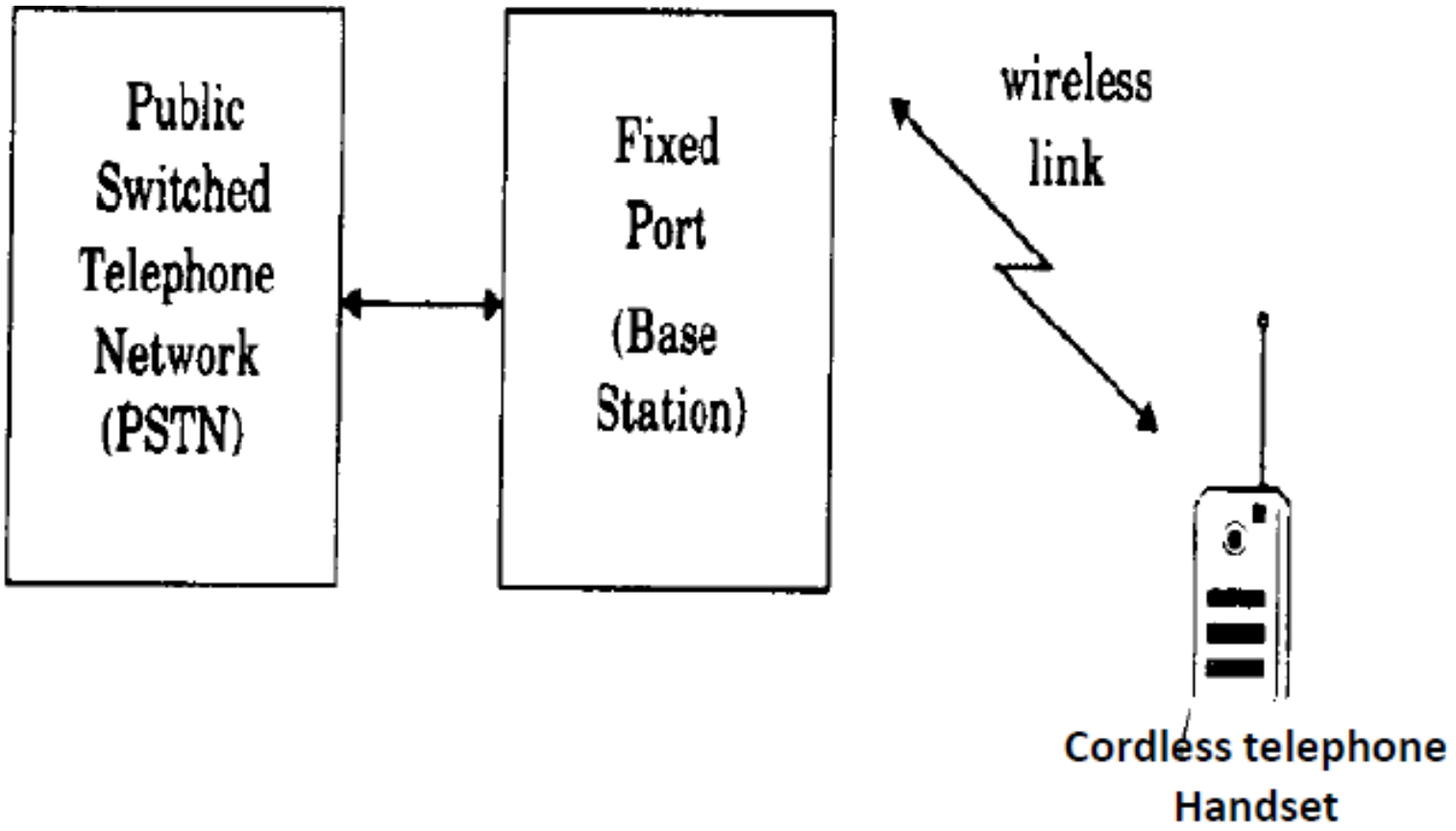


Figure 1.3 A wide area paging system. The paging control center dispatches pages received from the PSTN throughout several cities at the same time.

CORDLESS TELEPHONE SYSTEMS

- Cordless telephone systems are full duplex comm. systems that use radio to connect a portable handset to a dedicated BS,which is then connected to a dedicated telephone line with a specific telephone no on the PSTN.
- In first generation cordless telephone systems(manufactured in 1980s) ,the portable unit communicates only to the dedicated base unit and only over distances of a few tens of meters.
- Early cordless telephones operate solely as extension telephones to a transceiver connected to subscriber line on the PSTN & are primarily for in-home use.

Diagram of Cordless Telephone System



CORDLESS TELEPHONE SYSTEMS…..

- Second generation cordless telephone have introduced which allow subscribers to use their handsets at many outdoor locations within urban centers such as London or Hong Kong.
- Modern cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged & then respond to the page using the cordless telephone.
- Cordless telephone system provide the user with limited range of mobility, as it is usually not possible to maintain a call if the user travels outside the range of the BS.
- Typical second generation base stations provide coverage ranges up to a few hundred meters.

FEATURES OF CORDLESS PHONE SYSTEM

FEATURE	MOBILE UNIT	BASE STATION
COVERAGE RANGE	LOW	LOW
REQUIRED INFRA-STRUCTURE	LOW	LOW
COMPLEXITY	MODERATE	`LOW
HARDWARE COST	LOW	MODERATE
CARRIER FREQUENCY	1-3 GHz	1-3 GHz
FUNCTIONALITY	TRANS-RECEIVER	TRANS-RECEIVER

Cordless Telephones

- Characterized by
  - Low mobility (in terms of range and speed)
  - Low power consumption
  - Two-way tetherless (wireless) voice communication
  - High circuit quality
  - Low cost equipment, small form factor and long talk-time
  - No handoffs between base units
- Appeared as analog devices
- Digital devices appeared later with CT2, DECT standards in Europe and ISM band technologies in USA

Cordless Telephones

- Usage
  - At homes
  - At public places where cordless phone base units are available
- Design Choices
  - Few users per MHz
  - Few users per base unit
    - Many base units are connected to only one handset
  - Large number of base units per usage area
  - Short transmission range

Cordless Phone

- Some more features
  - 32 Kb/s adaptive differential pulse code modulation (ADPCM) digital speech encoding
  - Tx power <= 10 mW
  - Low-complexity radio signal processing
    - No forward error correction (FEC) or whatsoever.
  - Low transmission delay < 50ms
  - Simple Frequency Shift Modulation (FSK)
  - Time Division Duplex (TDD)

Comparison of Various WirelessSystems

Table 1.5 Comparison of Mobile Communication Systems—Mobile Station

Service	Coverage Range	Required Infra-structure	Complexity	Hardware Cost	Carrier Frequency	Functionality
TV Remote Control	Low	Low	Low	Low	Infrared	Transmitter
Garage Door Opener	Low	Low	Low	Low	< 100 MHz	Transmitter
Paging System	High	High	Low	Low	< 1 GHz	Receiver
Cordless Phone	Low	Low	Moderate	Low	< 1 GHz	Transceiver
Cellular Phone	High	High	High	Moderate	< 2 GHz	Transceiver

Comparison of Various Wireless Systems

Table 1.6 Comparison of Mobile Communication Systems—Base Station

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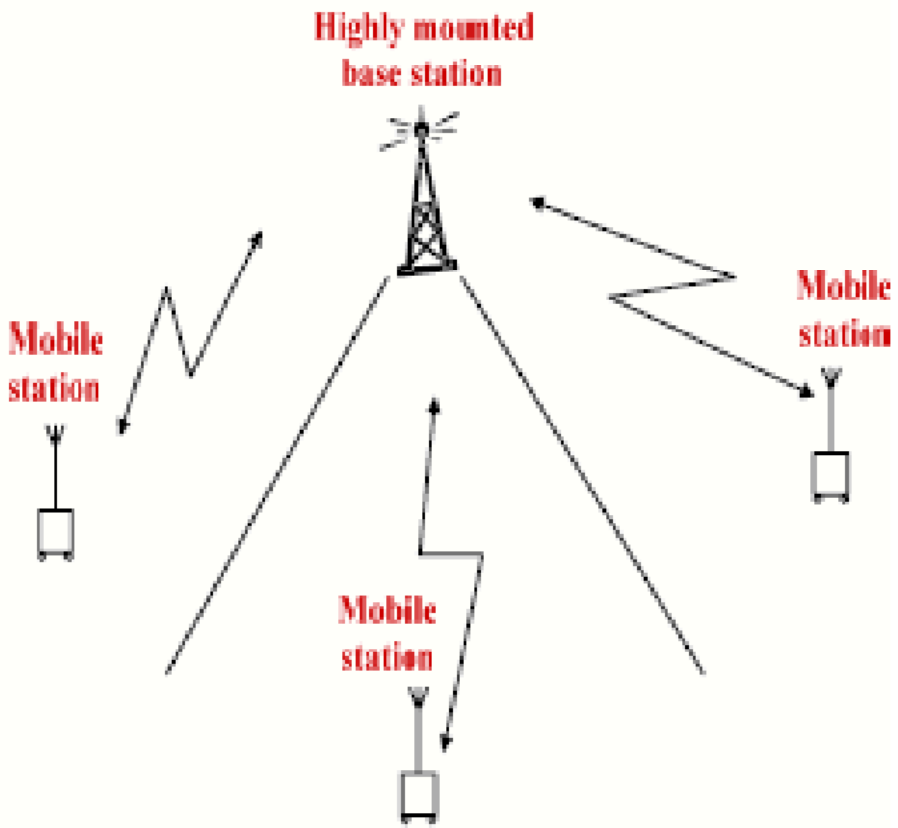
Cellular System Engineering

- Early-day mobile radio communications:
  - **Objective:** achieve a large coverage by using a single, high powered transmitter
  - **Macro-cell system:** one central base station served all mobiles
  - **Advantage:**
    large coverage:
    a thousand square miles
  - **Disadvantages:**
    small number of supported users (capacity)
    impossible to reuse frequency
    high transmit power



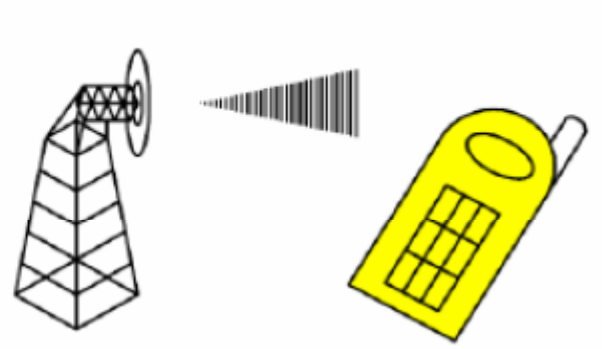
Cellular System Engineering

Wireless

The first commercially available radio and telephone system, known as improved mobile telephone service (IMTS), was put into service in 1946.

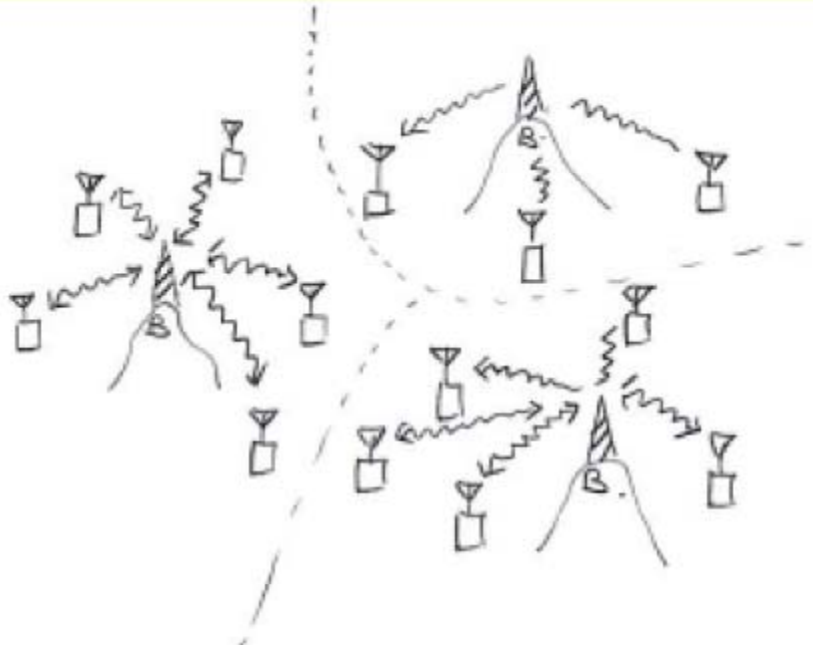
With IMTS, a tall transmitter tower was erected near the center of a metropolitan area with several assigned channels. Any vehicle within range could attempt to seize one of those channels and complete a call. Unfortunately, the number of channels did not come even close to satisfying the need.

Worse, as the metropolitan area grew, higher power were applied at the transceivers, the reach was made greater, but more subscribers were unable to get dial tone.



Cellular System Engineering

- Cellular Mobile Systems: Introduced by AT&T during 1960's.
- Made use of signal attenuation after traveling a certain distance; so that the same carrier frequency can be reused after a certain distance.
- Capacity is greatly increased.



Cellular Systems

The Cellular Concept – System Design Fundamentals

- The cellular concept was a major breakthrough in solving the problem of *spectral congestion* and *user capacity*.
- Replaces 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.

Cellular Systems

Cellular Concept

- areas divided into cells
- developed by Bell Labs 1960's-70's
- a system approach, no major technological changes
- few hundred meters in some cities, 10s km at country side
- each served by base station with lower power transmitter
- each gets portion of total number of channels
- neighboring cells assigned different groups of channels, interference minimized

CELLULAR CONCEPT

- It is an implementation of Space Division Multiplexing.
- To divide the coverage area into a no. of contiguous smaller areas (called CELL) which are each served by its own base station

Cellular Concepts

- Each Base Station is allocated a portion of total no. of channels available to the entire system.
- Neighboring base stations are assigned different groups of channels so as to reduce interference.
- A Cluster is a group of cells. No channels are reused within a cluster.

CELL AND A CLUSTER

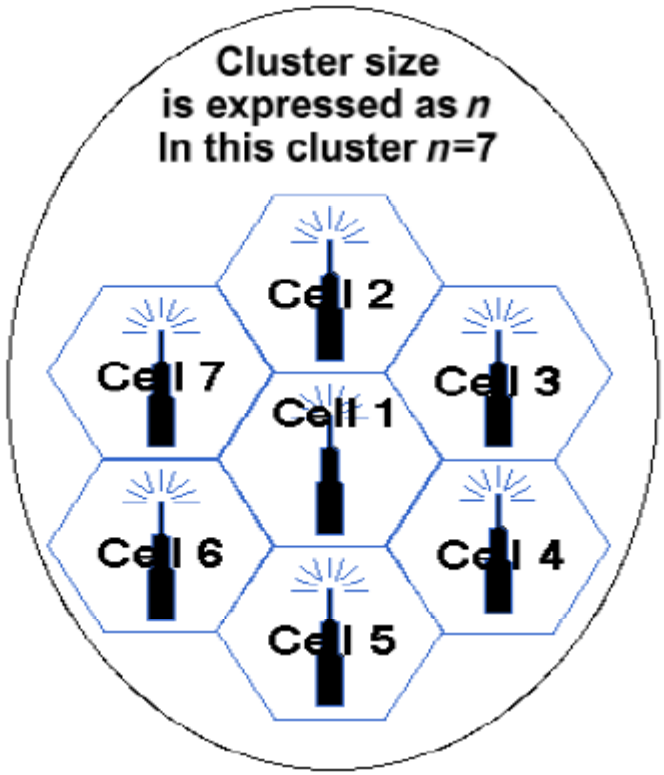
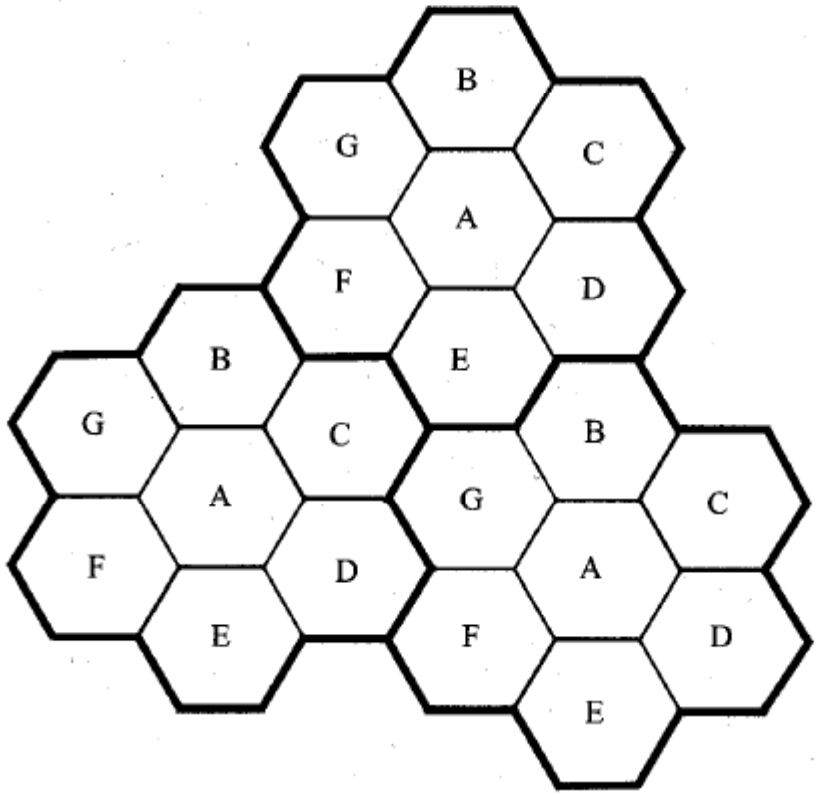


DIAGRAM VIEW OF CELLULAR CONCEPT



Cellular Systems(Advantages)

- Solves the problem of spectral congestion and user capacity.
- Offer very high capacity in a limited spectrum without major technological changes.
- Reuse of radio channel in different cells.
- Enable a fix number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.

- **Cellular concept:**
  - Each base station is allocated a portion of the total number of frequency channels available to the entire system, and nearby base stations are assigned different groups of channels.
  - Neighboring base stations are assigned different groups of channels so that the interference between base stations (and the mobile users under their control) is minimized.
  - The available channels may be reused as many times as necessary, so long as the interference is kept below acceptable levels

    →provide higher capacity
- **Cell:**
  - Is a small geographic area in which a group of radio channels is allocated to be used.
- **Footprint:**
  - Is the actual radio coverage of a cell and is determined from field measurements or propagation prediction models.

- **Hexagonal cells:** for convenience in handling performance analysis and system modeling.
  - **centre-excited cell**: the cell having the base station at the cell centre
  - **edge-excited cell**: the cell having base stations on the three of the six cell vertices
- **Cluster:**
  - Is the number of cells that collectively use the complete set of available frequency channels.
  - Cluster size *N* usually equal to 4, 7, 9 or 12.
  - For a given area (constant cell size), *smaller cluster size, higher capacity*
  - *N* is a function of how much interference a mobile or base station can tolerate while maintaining a sufficient quality of communications
- **Frequency reuse factor:**
  - Is the reciprocal of the cluster size
  - A higher frequency reuse factor implies a higher number of frequency channels is available for each cell.

Choices of Hexagonal Cell

Factors:

- Equal area
- No overlap between cells

Choices:

CHOICE OF CELL SHAPE

- CELL SHAPE should be chosen as a **regular polygon** shape so as to obtain an easier insight to the system.
- Three Possible Choices are:
- 1.Equilateral Triangle
- 2.Square
- 3.Regular Hexagon

For a given S

A3 > A1

A3 > A2

Here, A3 provides maximum coverage area for a given value of S.

Actual cellular footprint is determined by the contour of a given transmitting antenna.

By using hexagon geometry, the fewest number of cells covers a given geographic region.

Choice of Hexagonal Shape

- **REASON : For a given radius i.e. largest possible distance b/w the polygon centre and its edge Hexagon has the largest area.**
- **CIRCLE CAN'T BE A CHOICE BECAUSE OF THE PROBLEM OF NON OVERLAPPING OF ADJACENT AREAS.(Although it is best approximation concerned with radiation pattern of antenna at Base Station)**

Frequency Reuse

Each cellular base station is allocated a group of radio channels.

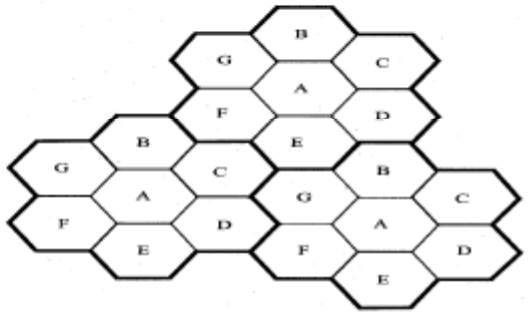
Base stations in adjacent cells are assigned channel groups which contain different channels than neighboring cells.

Frequency Reuse

- Each cellular base station is allocated a group of radio channels within a small geographic area called a *cell*.
- Neighboring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning

•seven groups of channel from A to G

•footprint of a cell - actual radio coverage



Frequency Reuse

Frequency reuse is the process in which same set of frequencies (channels)Can be provided to more than one cells provided that cells are separated by sufficient distance.

Frequency Reuse

Cellular Frequency Reuse Concept

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

A cell *cluster* is outlined in bold, and replicated over the coverage area.

In this example, the cluster size, *N*, is equal to 7; and the frequency reuse factor is 1/7, since each cell contains 1/7 of the total number of available channels.

Example

- FREQUENCY REUSE increases the capacity of the system.
- EXAMPLE:

Consider following parameters with a single high power Transmitter:

COVERAGE AREA: 50 Square Km

NO OF VOICE CHANNELS: 40

EXAMPLE (CONTD.)

- REPLACING IT WITH 9 LOW POWER TRANSMITTERS (supporting 40% of channels)
- Parameters are:

COVERAGE AREA:=50/9=5.5 Square Km each

NO OF VOICE CHANNELS: (40% of 40)* 9=144

CONCLUSIONS DRAWN FROM EXAMPLE

- **IMPROVEMENT OVER NO. OF CHANNELS**
- **MORE NO. OF CUSTOMERS CAN BE SERVED.**
- **INCREASED CELLULAR SYSTEM CAPACITY.**

Channel Capacity

- Consider a cellular system which has a total of *S* duplex channels.
- Each cell is allocated a group of *k* channels, $k < S$.
- The *S* channels are divided among *N* cells.
- The total number of available radio channels

$$S = KN$$

- The *N* cells which use the complete set of channels is called *cluste*
- The cluster can be repeated *M* times within the system. The total number of channels, *C*, is used as a measure of capacity

$$C = MKN = MS$$

- The capacity is directly proportional to the number of replication *M*.
- The cluster size, *N*, is typically equal to 4, 7, or 12.
- Small *N* is desirable to maximize capacity.
- The frequency reuse factor is given by $1/N$

CHOICE OF 'N'

- If **Cluster Size N is reduced** while cell size remains constant, more clusters are required to cover a given area & hence **more capacity** is achieved.
- So From design point of view smallest possible value of N is desirable to maximize capacity over a given coverage area.
- Also small N causes distance b/w co-channel cells to decrease hence **increased co-channel interference.**

CHOICE OF 'N'

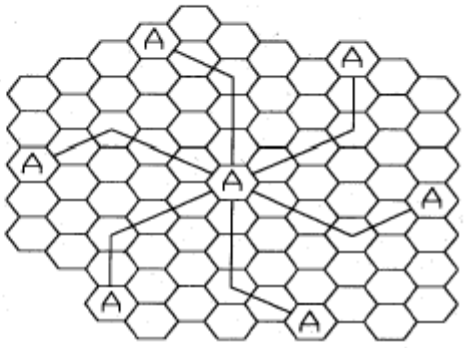
- If **Cluster size N is large**, distance between co-channel cells increases so **weaker co-channel interference.**
- THE VALUE OF N IS A FUNCTION OF HOW MUCH INTERFERENCE A MOBILE OR BASE STATION CAN TOLERATE WHILE MAINTAINING A SUFFICIENT QUALITY OF COMMUNICATION

Design of Cluster Size N

- Hexagonal geometry has
  - exactly six equidistance neighbors
  - the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees.
- Only certain cluster sizes and cell layout are possible.
- The number of cells per cluster, *N*, can only have values which satisfy

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

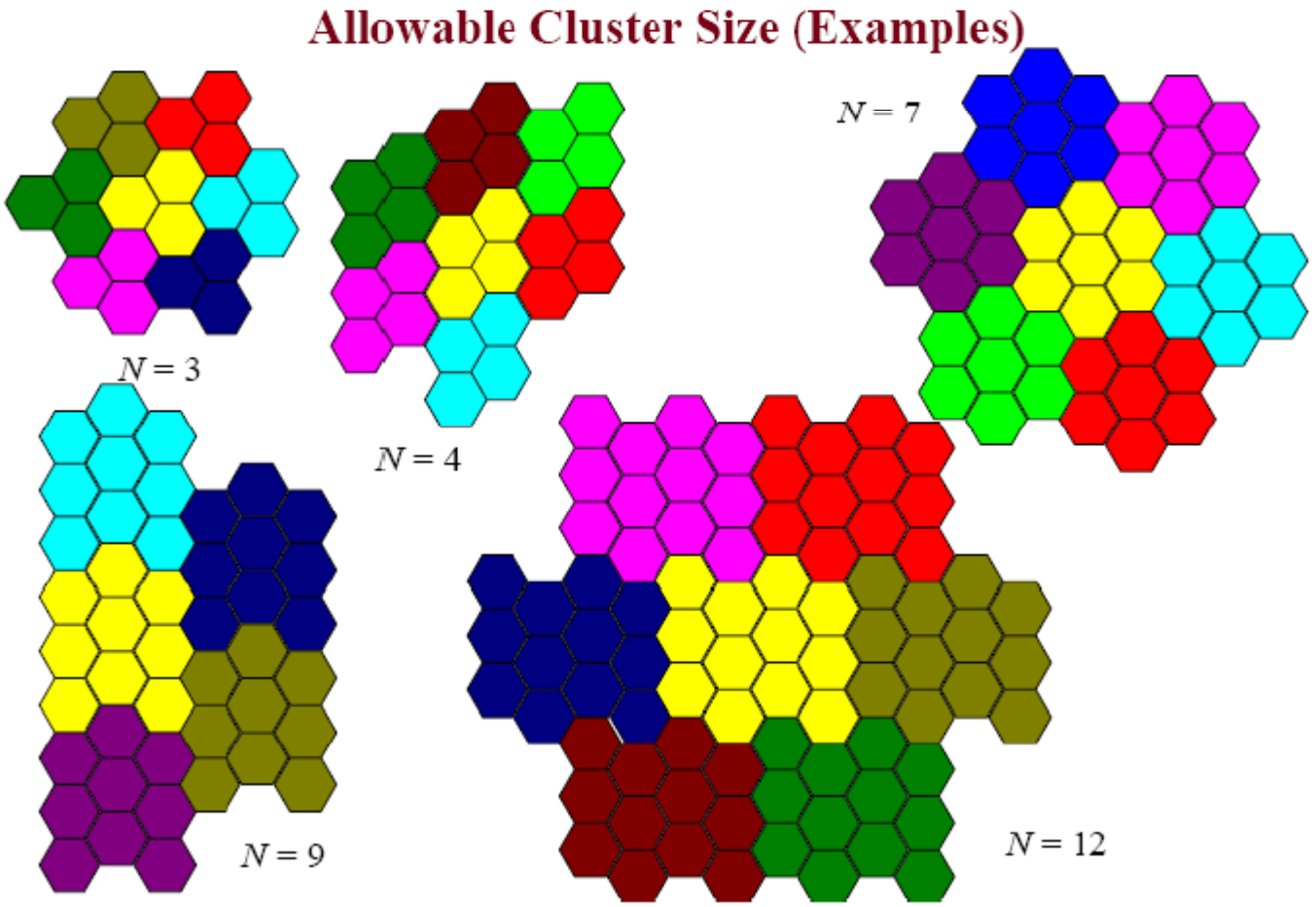
- Co-channel neighbors of a particular cell, ex, ***i=3*** and ***j=2***.



STEPS TO FIND NEAREST CO-CHANNEL NEIGHBORS OF A PARTICULAR CELL

- (1)Move i cells along any chain of hexagons and then
- (2)Turn 60 degrees counter clockwise and move j cells

Design of Cluster Size N



Design of Cluster Size N

Allowable Cluster Size

- Because the hexagonal cells are required to be connected without gaps between adjacent cells in a cellular system, the geometry of hexagons is such that the allowable cluster size N is not arbitrary and is given by

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

- where i and j are non-negative numbers. Some values of N are:

	$j = 0$	$j = 1$	$j = 2$	$j = 3$
$i = 0$	0	1	4	9
$i = 1$	1	3	7	13
$i = 2$	4	7	12	19
$i = 3$	9	13	19	27

Channel Assignment Strategies

- **Frequency reuse scheme**
  - **Objectives: increases capacity while minimizing interference**
    The design process of selecting and allocating channel groups for all of the cellular base stations within a system --**Channel assignment scheme**
- **Channel assignment strategy**
  - **Fixed channel assignment**
  - **Dynamic channel assignment**

Channel Assignment Strategies

- **Fixed channel assignment**
  - each cell is allocated a predetermined set of voice channel.
  - any new call attempt can only be served by the unused channels.
  - the call will be *blocked* if all channels in that cell are occupied.
  - **Variations: borrowing strategy, etc.**
  - MSC supervises the borrowing.

Channel Assignment Strategies

BORROWING STRATEGY: A variation of fixed assignment strategy :

- A cell is allowed to borrow channels from a neighboring cell if all its own channels are occupied.
- MSC supervises such borrowing procedures & ensures that borrowing does not disrupt or interfere with any of the calls in progress in the donor cell.

Channel Assignment Strategies

- **Dynamic channel assignment**
  - No pre-determined assignment of frequency channels(Voice Channels) is made.
  - When a call arrives, the base station ask the mobile switching centre (MSC) to allocate a channel.
  - MSC must take into account the co-channel interference ,reuse distance, cost function in channel allocation to requested call based on algorithm.

Channel Assignment Strategies

-Heavy storage and computational load, lower blocking probability and increased channel utilization.

-Dynamic Channel allocation is complex (In Real environment)

Advantages of Dynamic Channel Assignment Strategy

- Reduces likelihood of blocking
- Increases Trunking Capacity of System

Handoff Strategies

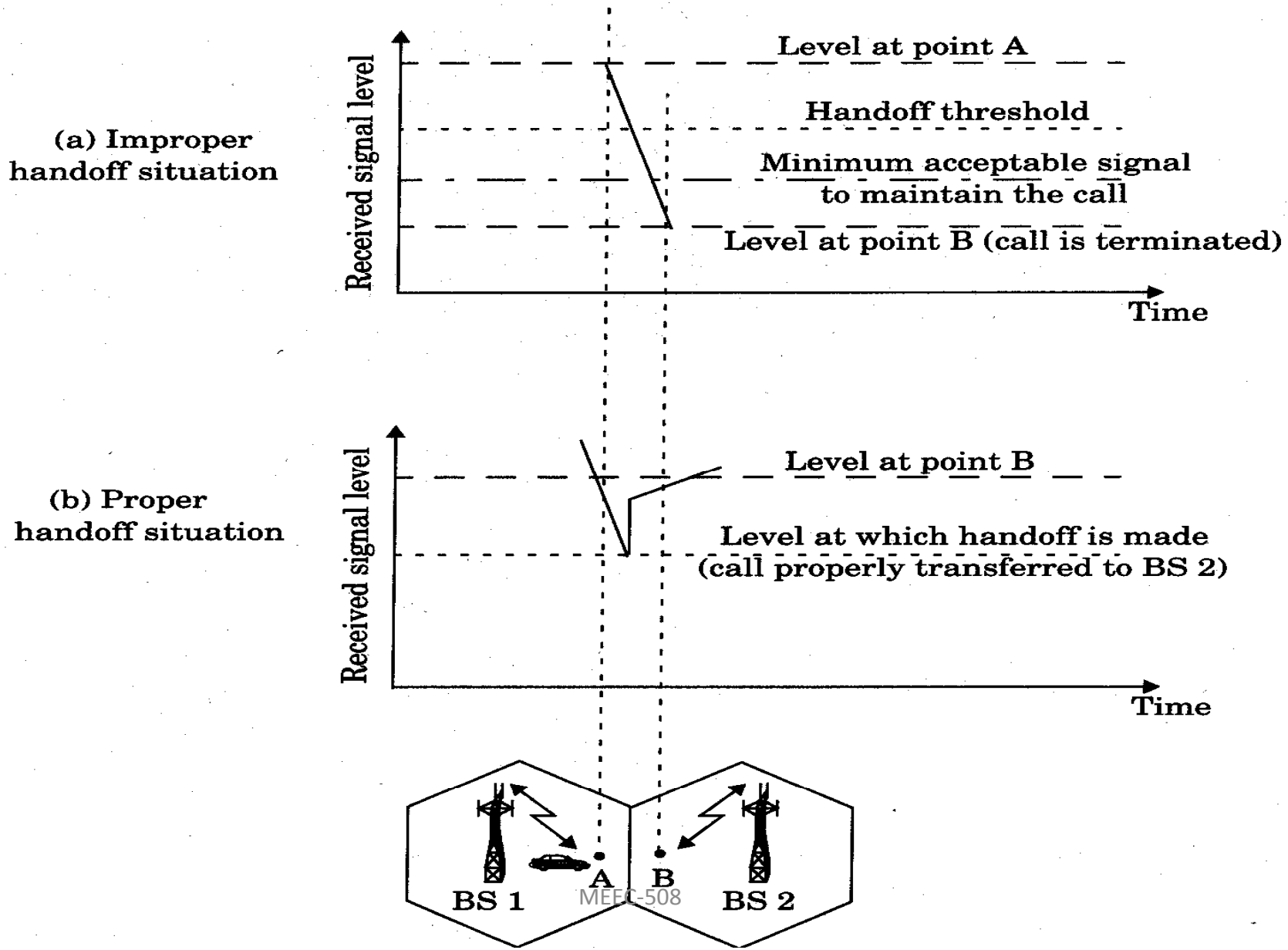
- When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.
- Handoff operation
  - identifying a new base station
  - re-allocating the voice and control channels with the new base station.
- Handoff Threshold
  - Minimum usable signal for acceptable voice quality (-90dBm to -100dBm)
  - Handoff margin cannot be too large or too small.
  - If is too large, unnecessary handoffs burden the MSC
  - If is too small, there may be insufficient time to complete handoff before a call is lost.

$$\Delta = P_{\text{handoff}} - P_{\text{minimum usable}}$$

Δ

Δ

Handoff Strategies



Handoff Strategies

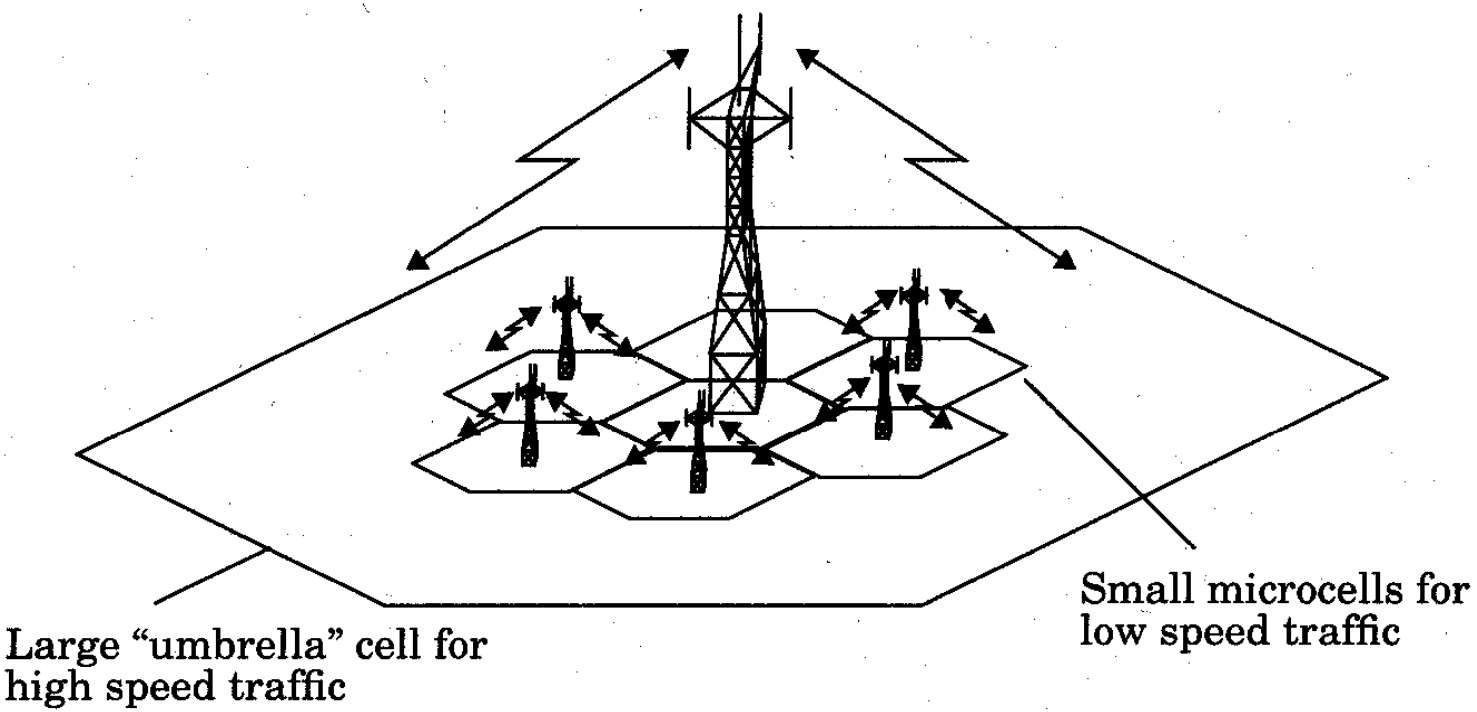
- Handoff must ensure that the drop in the measured signal is not due to momentary fading and that the mobile is actually moving away from the serving base station.

- Dwell time: the time over which a call may be maintained within a cell without handoff.

- Dwell time depends on
  - propagation
  - interference
  - distance
  - speed

Practical Handoff Consideration

- Different type of users
  - High speed users need frequent handoff during a call.
  - Low speed users may never need a handoff during a call.
- Microcells to provide capacity, the MSC can become burdened if high speed users are constantly being passed between very small cells.
- Minimize handoff intervention
  - handle the simultaneous traffic of high speed and low speed users.
- Large and small cells can be located at a single location (umbrella cell)
  - different antenna height
  - different power level
- Cell dragging problem: pedestrian users provide a very strong signal to the base station
  - The user may travel deep within a neighboring cell


Small microcells for
low speed traffic
Large "umbrella" cell for
high speed traffic

COVERAGE &CAPACITY EXPANSION TECHNIQUES

1. To obtain additional spectrum for new subscribers but this is expensive approach.
2. Change the cellular architecture.
3. Change the frequency allocation methodology.
4. Change the Modem and Access technology.

Cell splitting

- **Need of Cell Splitting:**

As no. of subscribers increase within a given area, the no. of channels allocated to a cell is no longer sufficient for supporting the subscriber demand. It becomes necessary to allocate more channels to the area that is being covered by this cell. This can be done by **CELL SPLITTING.**

MAXIMUM TRAFFIC LOAD

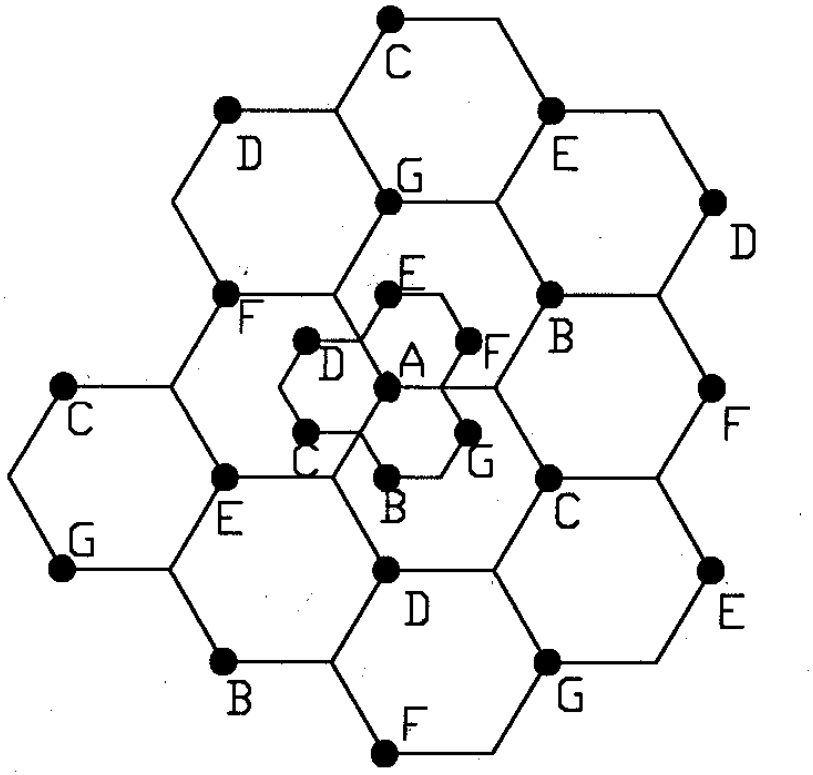
- **MAXIMUM TRAFFIC LOAD:**

  The point when a cell reaches maximum capacity occurs when the no. of subscribers wishing to place a call at any given time equals no. of channels in the cell.

CELL SPLITTING

- Cell Splitting is the process of subdividing a congested cell into smaller cells each with its own base station and corresponding reduction antenna height and transmitter power.
- It increases the capacity of the system since it increases the no. of times the channels are reused

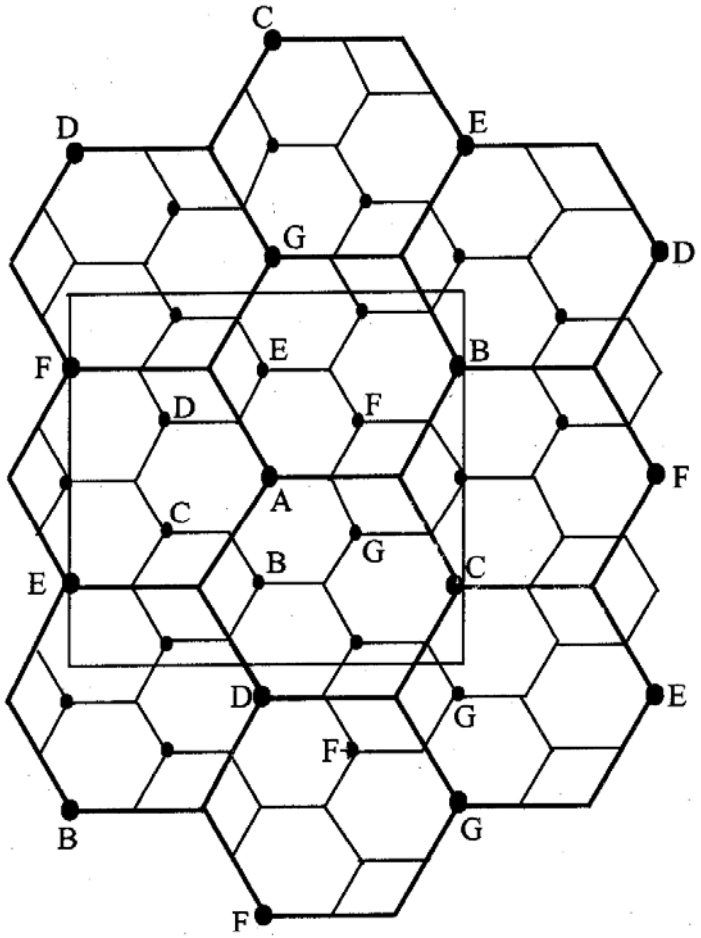
Cell splitting



Cell splitting

- Smaller cells are added in such a way to preserve the frequency reuse plan of the system for e.g Microcell base station labeled G is placed exactly half way b/w two large stations using the same channel set G

Illustration of cell splitting



Cell splitting

- New cell radius=Old cell radius/2
- New cell area=Old cell radius/4
- If each new cell carries the same maximum traffic load of the old cell then
- New Traffic Load /Unit Area=4(Old Traffic Load /Unit Area)

Problems Arising

- Let transmit power of BS of smaller cell is same as that of larger cells.
- Radius of new cell=R/2.
- Maximum distance the mobile can be from BS of this cell is R/2.
- FOR SMALLER CELL:Although the distance b/w this cell and any co-channel larger cell is reduced by half the value of Signal to Noise ratio remains the same.

Cell splitting

- FOR LARGER CELL: Signal to Noise ratio is not maintained because co-channel reuse ratio for these cells is now D/2R with respect to smaller cell.
- In order to maintain the same level of interferences the transmit power of the BS in the smaller cell should be reduced but these will increase the interference observed by the mobiles in the smaller cell.

D/R is the co- channel ratio

- Transmission power reduction from P_{t1} to P_{t2}
- Examining the receiving power at the new and old cell boundary

$$P_r[\text{at old cell boundary}] \propto P_{t1} R^{-n}$$

$$P_r[\text{at new cell boundary}] \propto P_{t2} (R/2)^{-n}$$

- If we take *n = 4* and set the received power equal to each other

$$P_{t2} = \frac{P_{t1}}{16}$$

- The transmit power must be reduced by 12 dB in order to fill in the original coverage area.

- The other method is to divide the channel allocated to cells labeled A into two parts those used by ‘a’ and those not used by ‘a’.
- The channels used by ‘a’ will be used in the larger cells only within the radius of R/2 from the centre of the cell so that cochannel reuse ratio is maintained as far as these channels are concerned. This is called OVERLAID CELL CONCEPT where a larger macrocell coexists with a smaller microcell

SECTORING

We know For a hexagonal geometry

- $D/R=(3N)^{1/2}$ & S/N is inversely proportional to D/R
- In Cell Splitting capacity or no. of channels per unit area is increased by decreasing the cell radius & keeping cochannel reuse ratio D/R unchanged

SECTORING

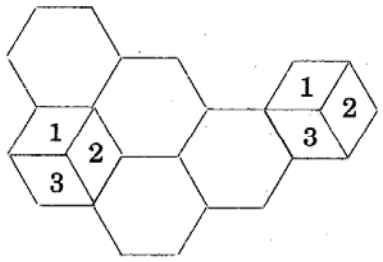
- Another way to increase the capacity is to keep cell radius unchanged and decrease D/R ratio.
- So Sectoring is the means to increase the channel capacity of a cellular telephone system by decreasing the D/R ratio while maintaining the same cell radius
- Channels allocated to a cell are further divided into three parts(120 degree sectors) each used in one sector of a cell.

SECTORING

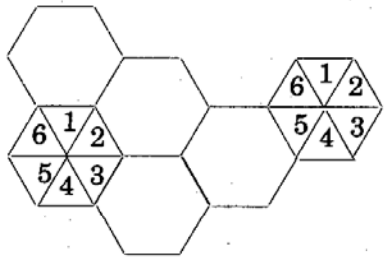
- In this approach first the S/I is improved by using directional antennas, then capacity improvement is achieved by reducing the no. of cells in a cluster.
- However Relative Interference is reduced without decreasing the transmit power.

Sectoring

- Decrease the *co-channel interference* and keep the cell radius *R* unchanged
  - Replacing single omni-directional antenna by several directional antennas
  - Radiating within a specified sector

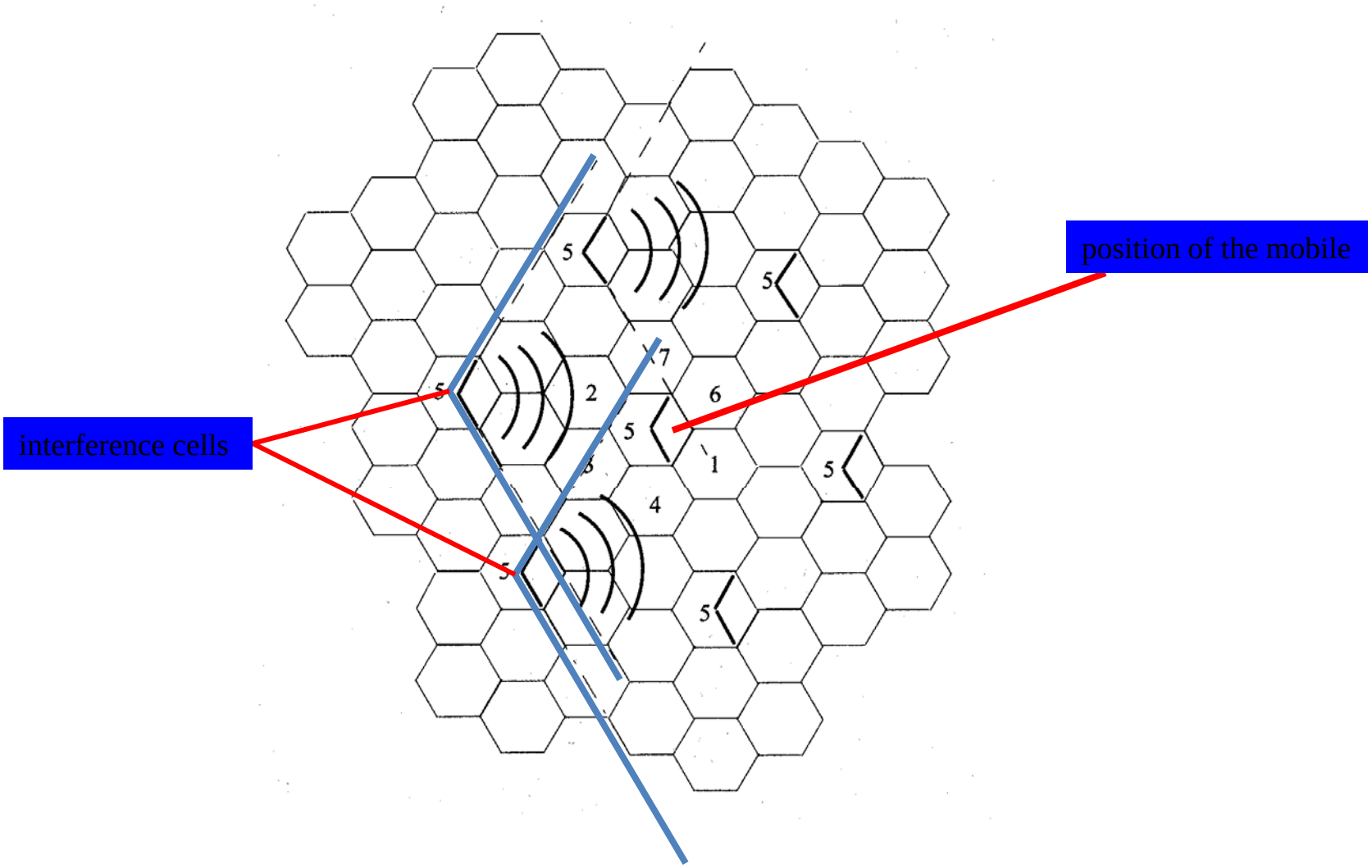


(a)



(b)

- Interference Reduction



Sectoring

- By using directional antennas a given cell will receive and transmit with only a fraction of available co-channel cells.
- In the example shown Consider the interference experienced by a mobile located in the rightmost sector in the center cell labeled ‘5’

.

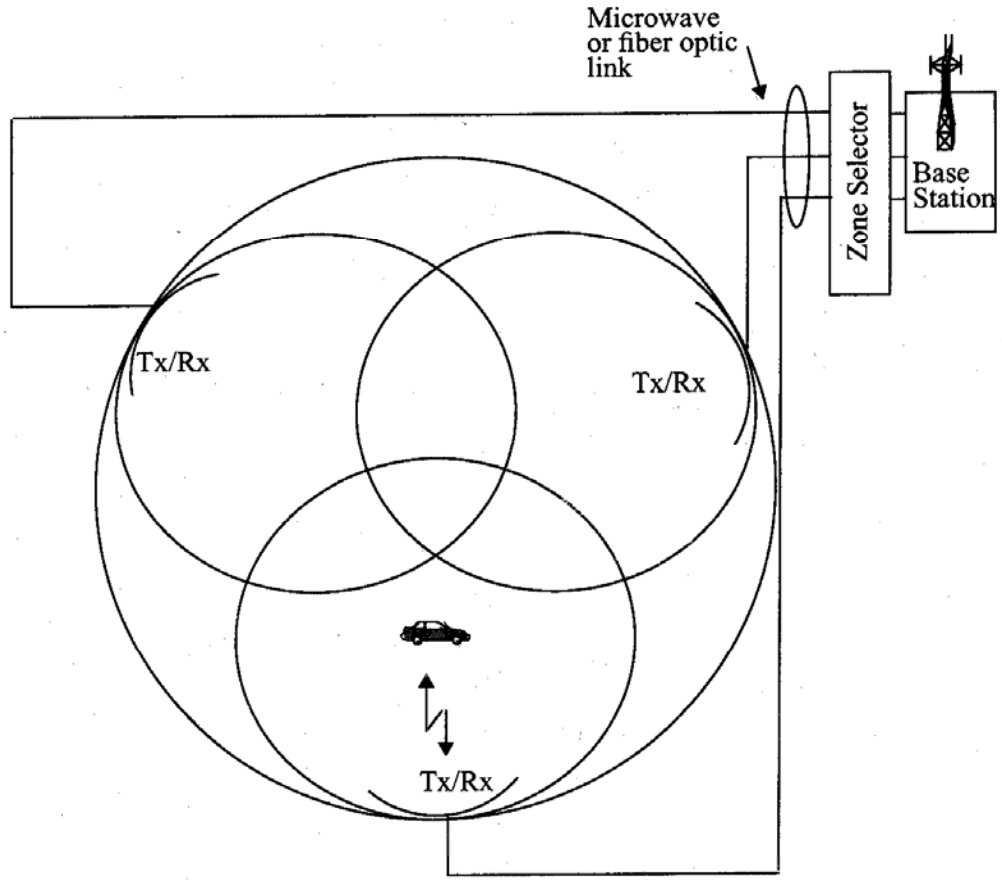
Sectoring

- There are six co-channel cell sectors labeled ‘5’ three to its right & three to its left. Out of these six only two cells have sectors with antenna patterns which radiate into the centre cell.Hence a mobile will experience interference on the forward link from these two sectors only.
- Hence Signal to Interference ratio is improved.
- By using 60 degree directional antennas no. of interfering cochannel cells reduces to one

LEE's MICROCELL ZONE CONCEPT

- In sectoring concept, Handoff is increased which increases the load on the switching &control link elements of the mobile system.
- In this concept there is only one BS per cell but there are three zone-sites located at the corners of a cell.
- All the three zone sites act as receivers for signal transmitted by mobile terminal and connected to a single BS and share the same radio equipment.

LEE's MICROCELL ZONE CONCEPT



LEE's MICROCELL ZONE CONCEPT

- The BS determines which of the zone-sites has the best reception from the mobile and uses that zone-site to transmit the signal on the downlink.
- As the mobile user travels within the cell it is served by the zone with the strongest signal retaining the same channel.
- Thus like in sectoring, a handoff is not required at MSC when mobile travels b/w zones within the cell. The BS simply switches the channel to a different zone site.

PERFORMANCE CRITERIA

- There are three basic criteria to specify a cellular system

VOICE QUALITY:-

- Voice quality is complicated parameter for design engineers. Because it depends person to person and also all mobile users not uses a common equipment, so in this area designer cannot decide that how to build a system without knowing the voice quality that will satisfied the users.

- In Military, Air force communication, this is not a problem, Armed forces must use the assigned equipment.
- In general the voice quality depend upon the criteria, a set value x at which y percent of customer rate the system voice quality is good or excellent(from transmitter to receiver).

PERFORMANCE CRITERIA

- Generally following scaled used for circuit merits in respect of voice quality.

CIRCUIT MERIT	SCORE	QUALITY SCALE
CM1	1	NOTUNDERSTANDABLE(UNSATISFACTORY)
CM2	2	POOR (UNDERSTANDABLE BUT REPETITONS REQUD)
CM3	3	FAIR
CM4	4	GOOD
CM5	5	EXCELLENT

- If percentage of customers choosing CM4,CM5, the cost of system increases.
- The average circuit merits obtained from all the listeners is called mean opinion score usually MOS greater than equal to 4

PERFORMANCE CRITERIA

SERVICE QUALITY

- Following parameter are required to judge the service quality

1) **COVERAGE AREA:-** If a system serve as for as possible large area it is good, but it is not possible to serve 100 percent due to irregular geographical structure.

- Due to following regions, also full coverage of area is not possible.

a)The transmitted power must be very high to illuminate weak spots, which increases the cost.

PERFORMANCE CRITERIA

b)The higher the transmitted power, higher the interference.

Hence, a system that usually cover 90 percent area in flat parts, while 60 to 70 percent in hill parts is considered as good.

2)GRADE OF SERVICES:- The grade of service is very good or rather very good if number of block calls out of 100 is two or less than two in peak hour. However, the blocking probability at each cell site is different. To decrease the block calls or blocking probability requires a good system plan and sufficient number of radio channel as well as number of cell site.

PERFORMANCE CRITERIA

3) **DROPED CALLS:-** To measure the dropped calls, there is a parameter named call drop rate. If during **Q** calls ,Q-1 calls are completed than call drop rate is 1/Q, if Q-2 calls are completed than call drop rate is 2/Q.

As for as possible call drop rate must be low.

A high drop rate can be caused either

1. coverage problems or
2. handoff problems related to channel availability.

PERFORMANCE CRITERIA

SPECIAL FEATURES

A system may provide some extra features like:

voice mail service

automatic roaming

call waiting

live news

rail reservation facilities and navigation services.

But some time customer may not ready to pay the extra charges for such services.

Cellular Systems

Control channels are used for initiating mobile calls.

Control channels are often called setup channels because they are involved for setting up call and moving it to an unused voice channel.

Control channels transmits and receive data messages that carry call initiation and service request s and monitored by mobile phones when they do not have a call in progress.

Forward channels act as beacons which continually broadcast all the traffic requests for all mobile systems.

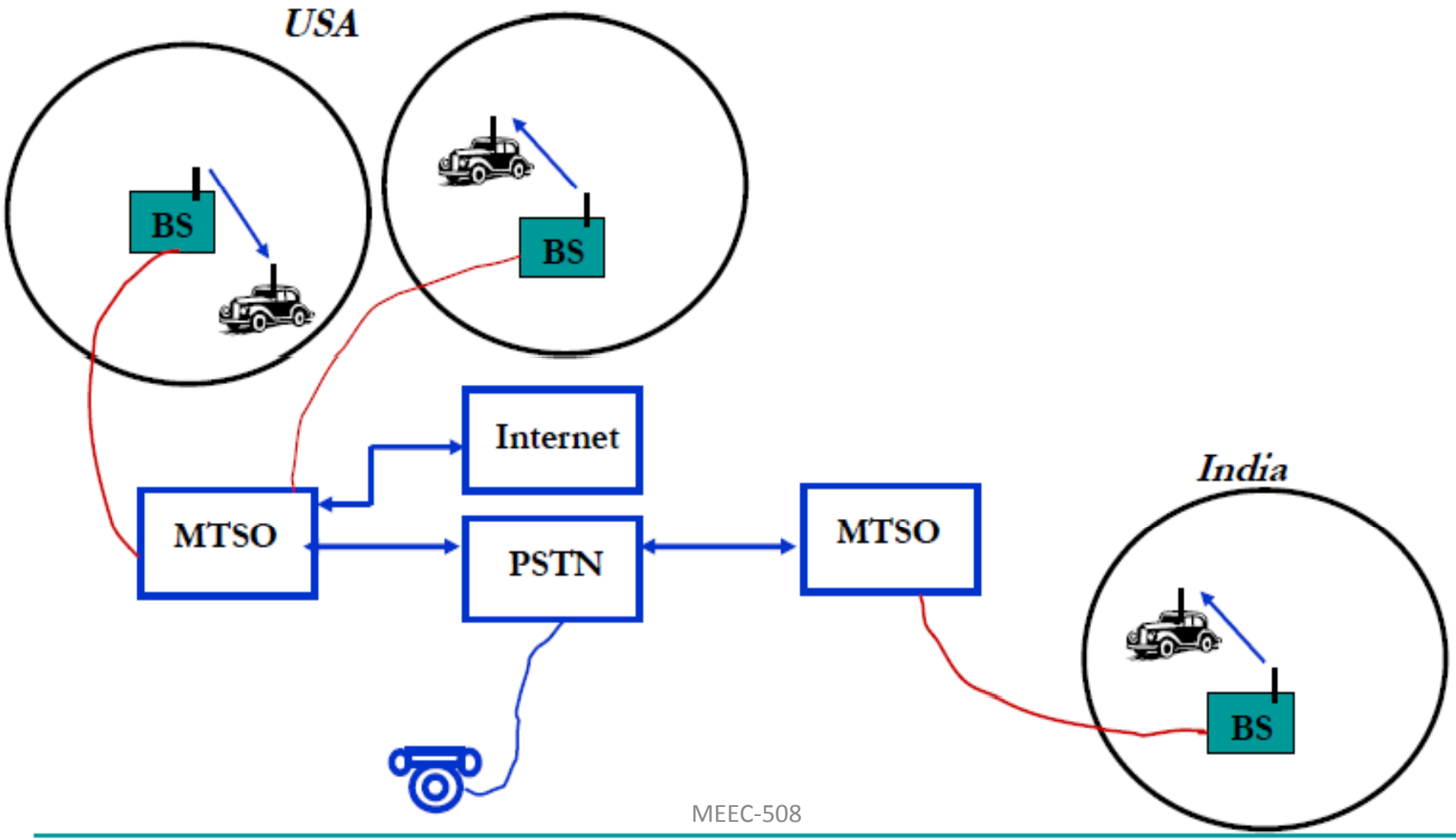
Cellular Topology

- Cellular network:
  - Series of overlapping hexagonal cells in a honeycomb pattern
- Cellular network components
  - Base Station: Transmitter, Receiver, Controller, Antenna
  - Cell: Base station's span of coverage
  - Mobile Switching Center: Contains all of the control and switching elements to connect the caller to the receiver, even as the receiver moves from one cell to another

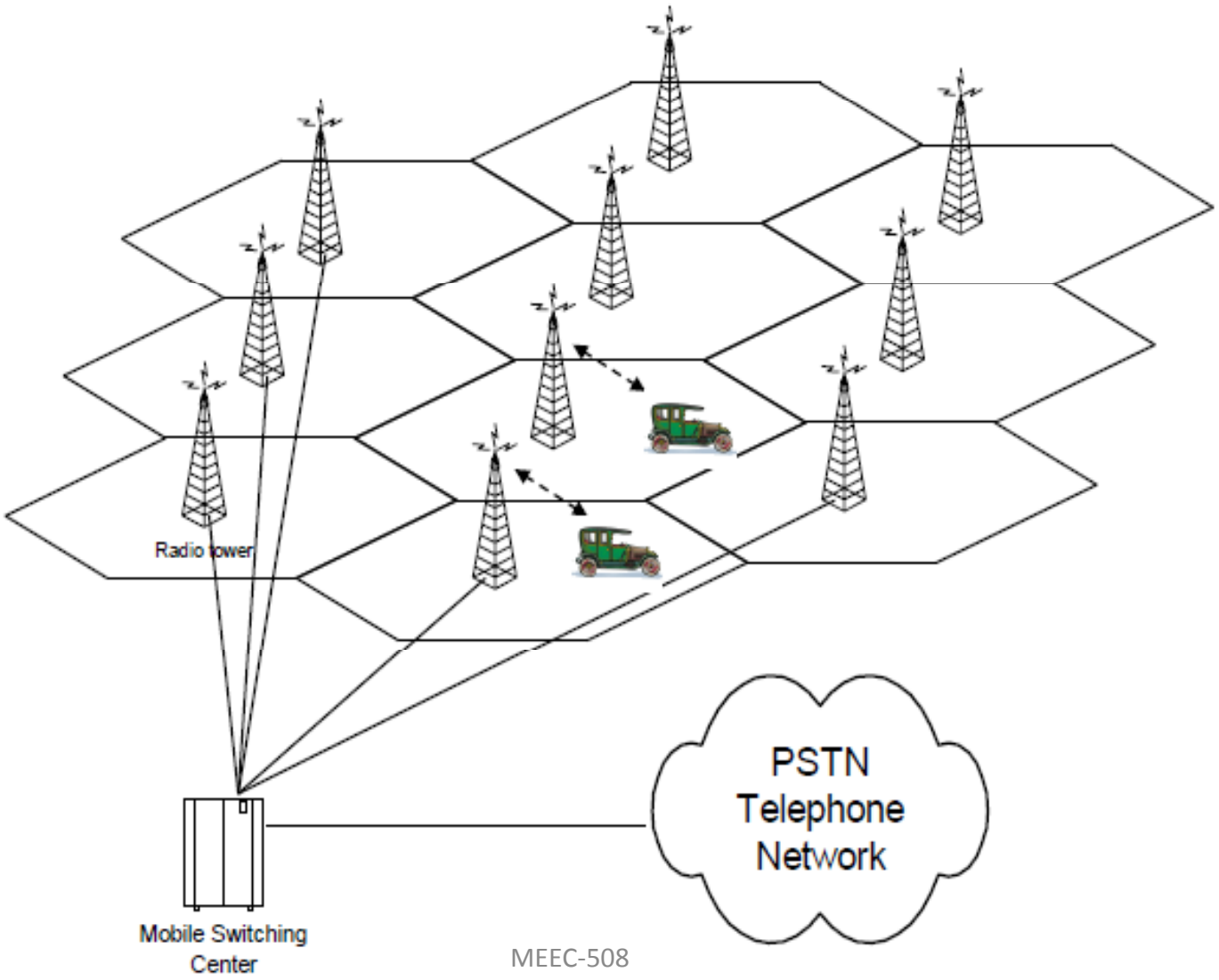
Cellular Telephone Systems

- Fig. shows a basic cellular system which consists of mobile stations ,base stations & a 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 & may be handed off to any no of base stations throughout the duration of call .
- The MS contains a transceiver, an antenna & control circuitry & may be mounted in a vehicle or used as a portable handheld unit.
- The BS consist of several transmitters & receivers which simultaneously handles full duplex comm. & generally have towers which support several transmitting & receiving antennas.
- The BS serves as a bridge between all mobile users in the cell & connects the simultaneous mobile calls via telephone lines or microwave links to the MSC.

Cellular Phone Networks



Cellular Telephony - Architecture



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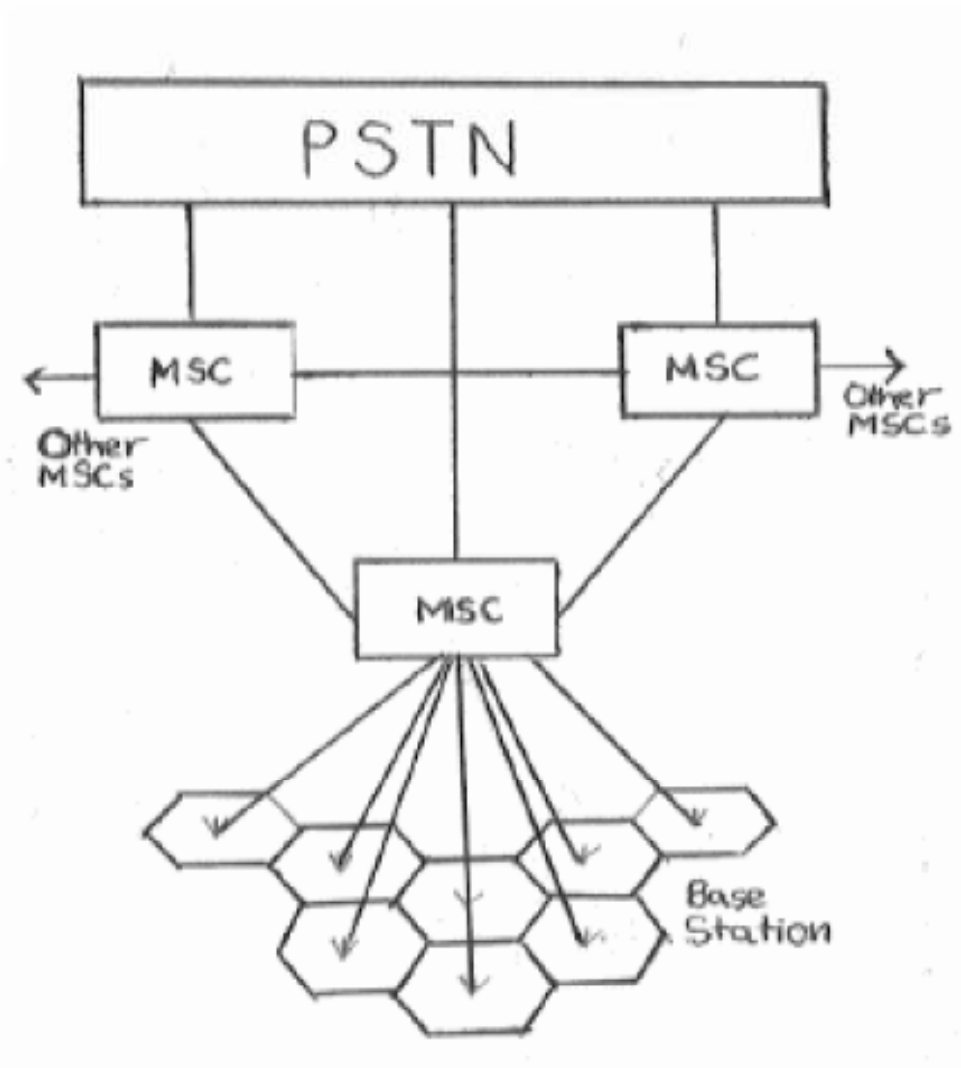

MTSO Controlled Call between Mobile Users

Steps:-

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

Functions:-

- **Call blocking**
- **Call termination**
- **Call dropping**
- **Calls to/from fixed and remote mobile subscriber**

Making a Call

Scan Control Channels: Your cell phone needs to use the "closest" base station because that's the one with the strongest signal and the one that will give the best connection. To *find* the closest base station, your phone checks all the control channels and determines which has the strongest signal.(Depending upon the threshold power level),At this point it again scans the control channels in search of strongest base station signal.

The control channels are defined and standardized over the entire geographical area covered and typically make up of 5% of the total number of channels available in the system.

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Get Channel Assignment: After the cellular service provider verifies that you are a valid, paying customer (based on the MIN and ESN your phone sent), the base station sends a Channel Assignment message to your phone (also a short 1/4-second burst). This message tells your phone where (that is, on which channel) the conversation will take place.

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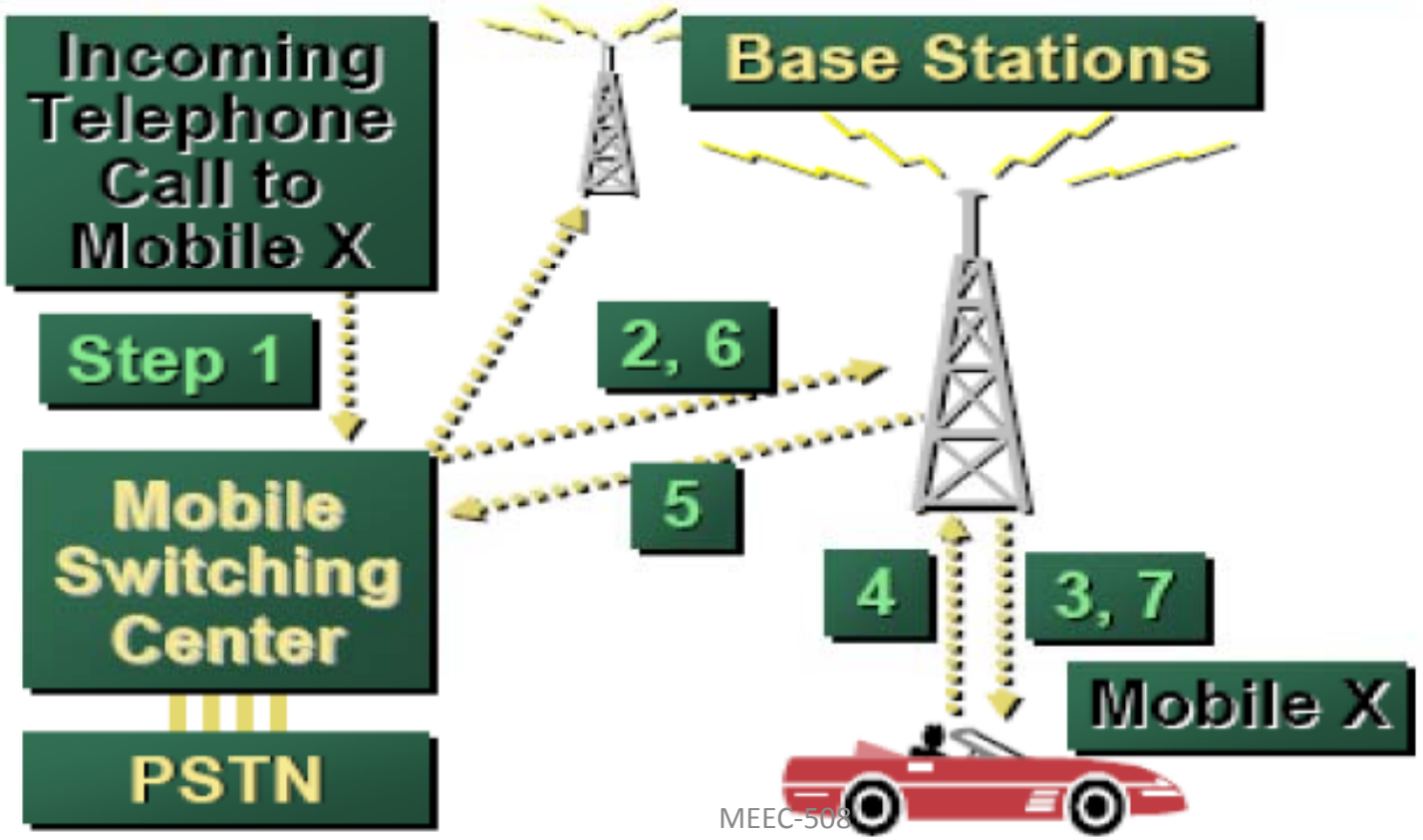

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Step 4 – The mobile receives the paging message sent by the base station it monitors and responds by identifying itself over the reverse control channel.

Step 5 – The base station relays the acknowledgement sent by the mobile and informs the MSC of the handshake.

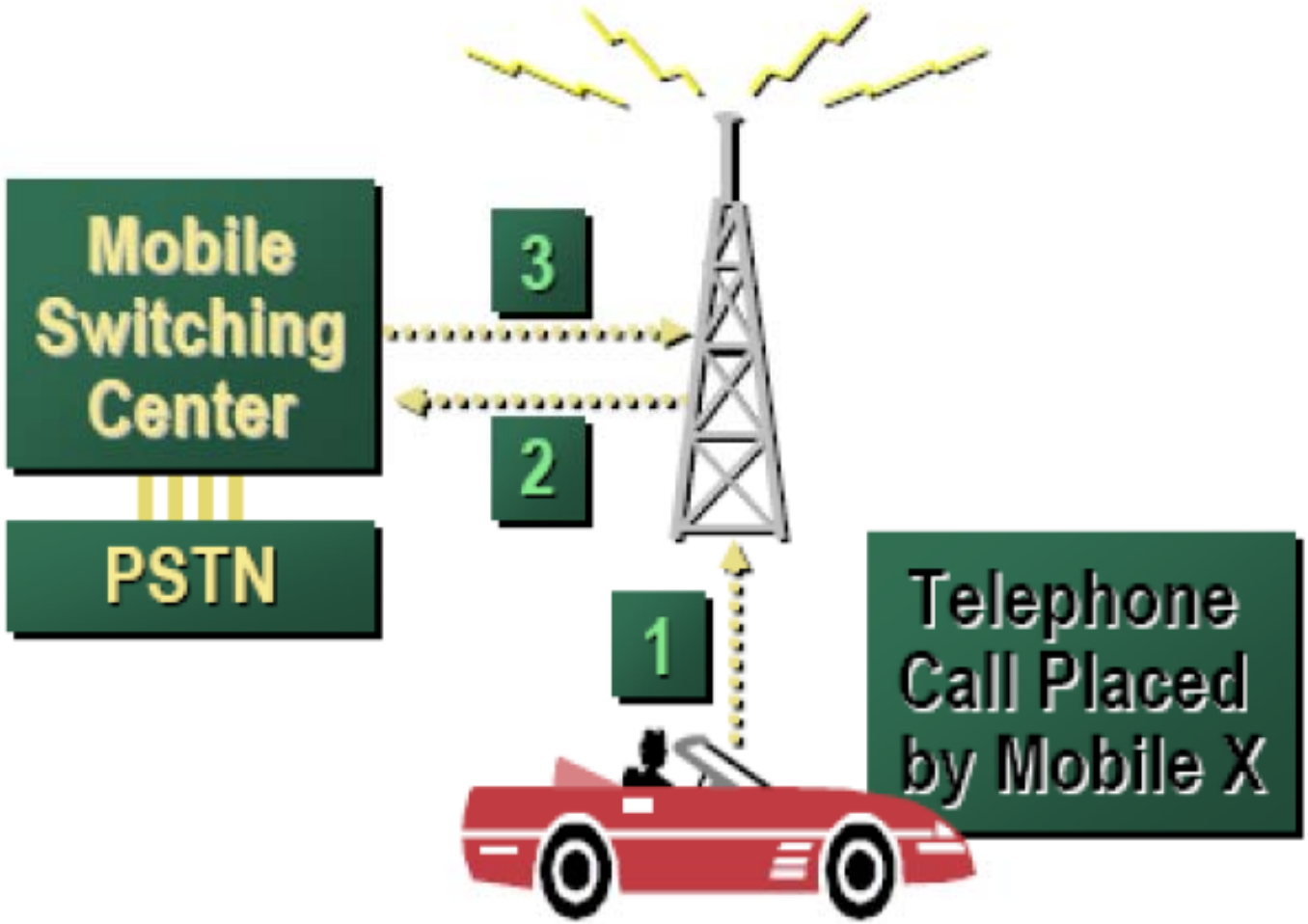
Step 6 – The MSC instructs the base station to move the call to an issued voice channel within in the cell.

Telephone call to mobile user

Step 7 – The base station signals the mobile to change frequencies to an unused forward and reverse voice channel pair.
At the point another data message (alert) is transmitted over the forward voice channel to instruct the mobile to ring.

Now the call is in progress. The MSC adjusts the transmitted power of the mobile and changes the channel of the mobile end and base stations in order to maintain call quality. This is called *handoff.*

Telephone Call Placed by Mobile



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Hand-over

- During a call, the base station would monitor the signal level from the mobile phone. When the mobile phone is moving into a new cell, the signal level will fall to a critical value causing the base station to inform the Mobile Switching Center(MSC) about this event. The MSC would instruct all the surrounding base stations to measure the mobile phone's signal level and transfer control to the base station receiving the strongest signal level. This is known as **hand-over** and occurs within **400ms**, so the phone user is hardly aware of a break.
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Other Events

Call Blocking:

During the mobile initiated if all the traffic channels assigned to the nearest BS are busy then a Busy tone is returned to the user.

Call Transmission:

When one of the two users hangs up or terminate the cell or switch off the mobile phone, the MTSO is informed and the traffic channels at the two BS are released. Generally it is choice of user, when he/she wants to terminate the call.

Call Drop:

During a connection due to interference or weak signal if BS cannot maintain the minimum required signal call will drop and informed to the MTSO.

Call to/from Fixed and Remote Subscriber:

The MSTO connects to the PSTN so MTSO can setup a connection between a mobile user in the area and a fixed subscriber via the telephone network.

Advanced Mobile Phone System (AMPS) (Analog Cellular System)

- **Used in North America**; **First -generation** analog cellular system, available since 1983; Developed by Bell Labs.
- **Adopts FDMA**
  - Voice channels are carried by different radio frequencies.
  - A total 50 MHz in 824-849 MHz & 869-894 MHz
  - Divided into 832 frequency channels: 416 downlinks and 416 uplinks(5% Control Channels)
  - Frequency Reuse: A frequency may be reused by cells in different clusters

AMPS (Advanced Mobile Phone System)

- Analog cell phone standard, established in 1983
- First used in Chicago
- Uses range of frequencies between 824Mhz and 894 MHz
- Pair of frequencies, one for transmit and one for receive create one channel
- Standard analog voice channel - 30kHz, comparable to a wired telephone

AMPS

- The scope of AMPS specification is limited to the air interface between subscriber equipment and base station radios. Signaling systems that link base stations to switches and switches to other switches are proprietary in North America
- A signaling standard for communications between mobile switches: IS-41, for roaming management

Digital Cellular- What it offers from Analog

- Better Quality
- Improved Bandwidth Efficiency
- Use of Micro Cellular Technology to accommodate smaller cells
- Improved Frequency Reuse
- Error Detection and Correction Techniques

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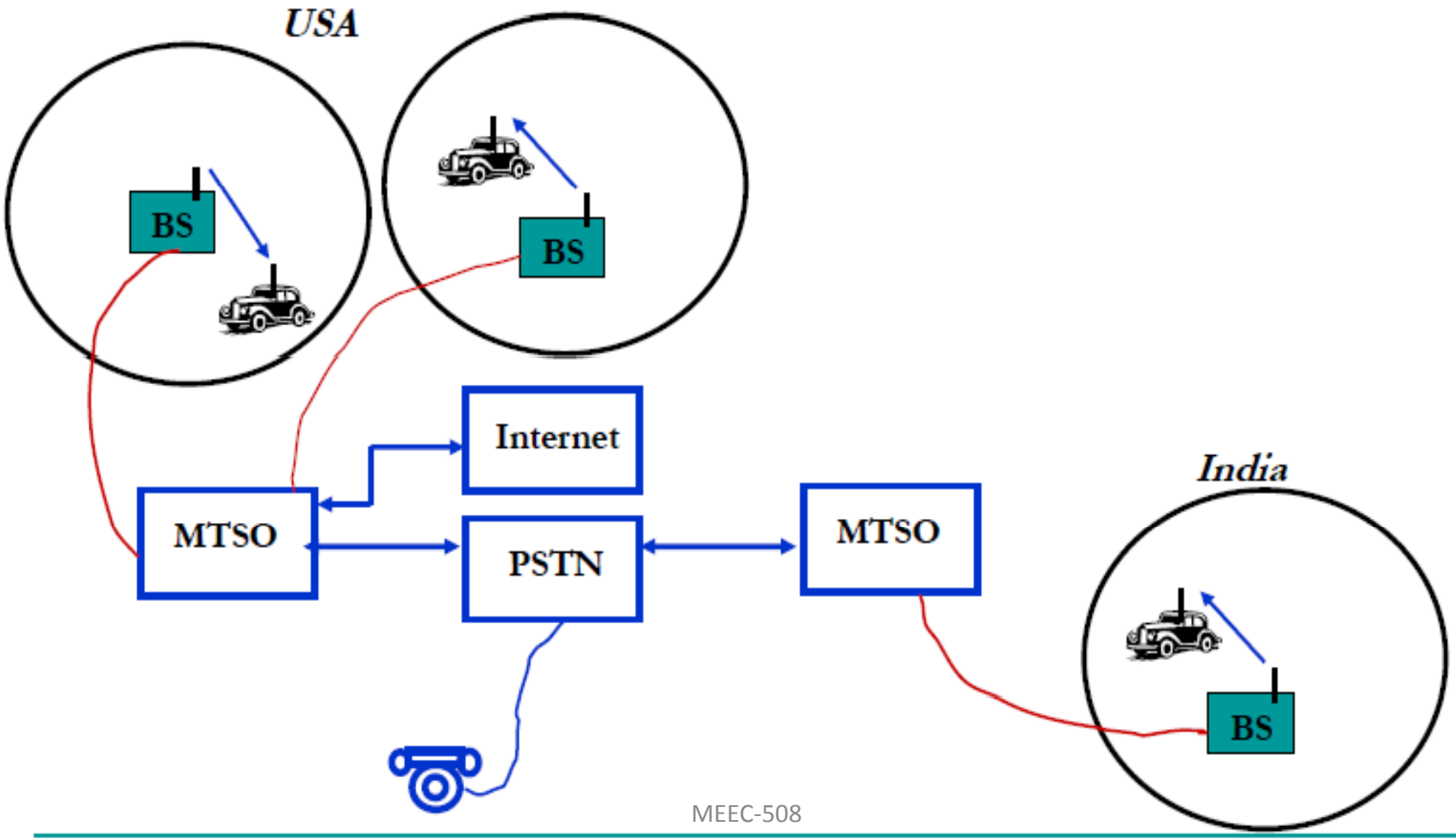

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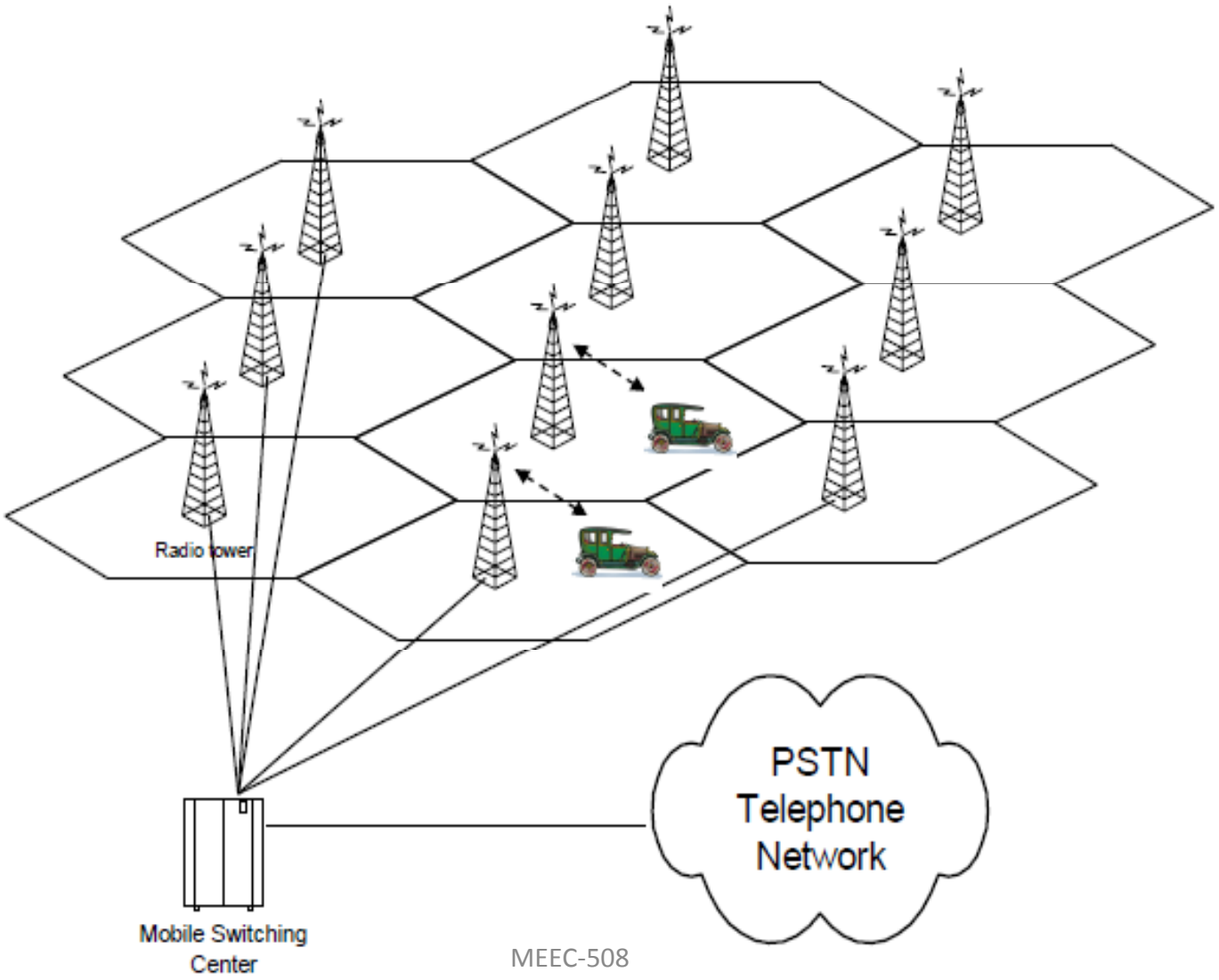

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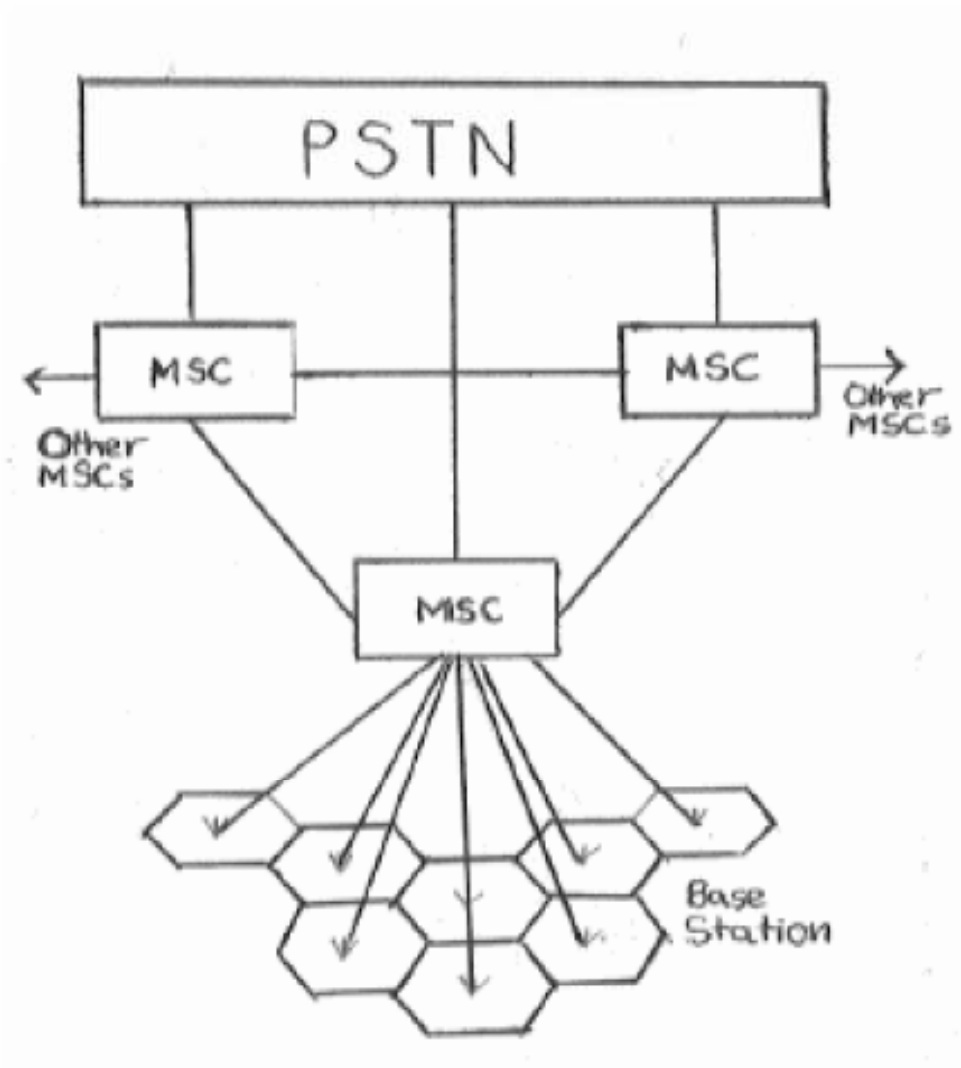

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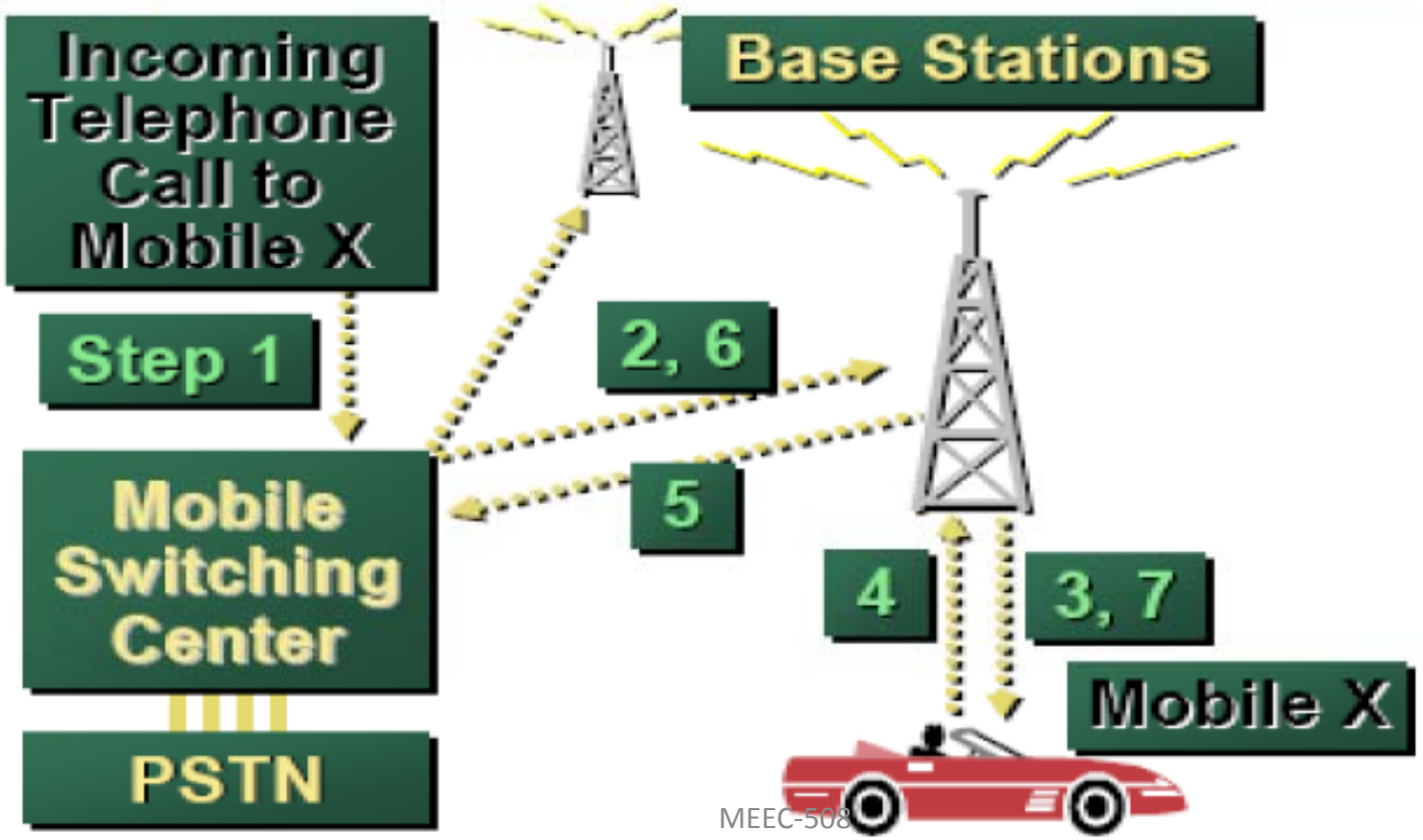

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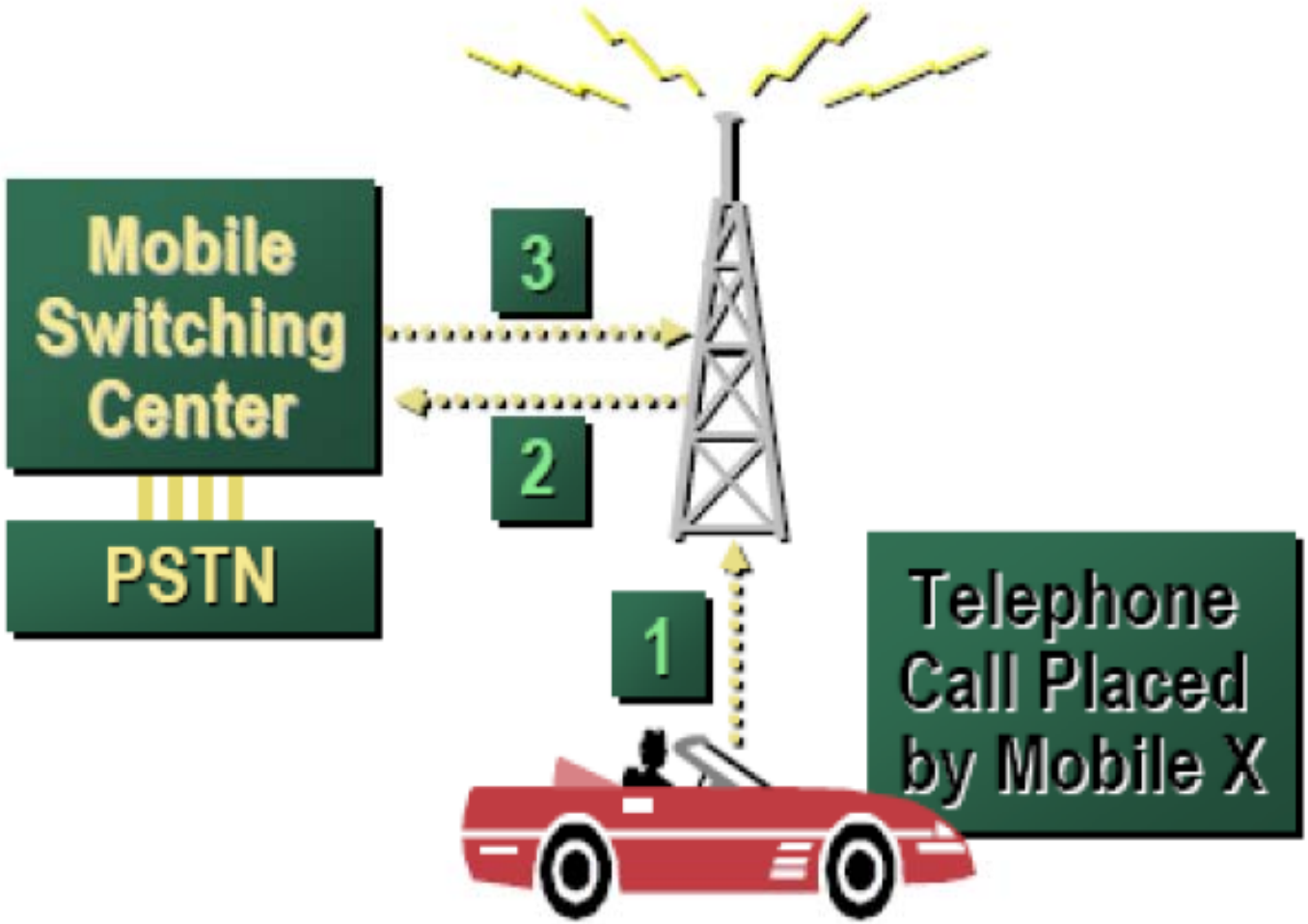

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Roaming

- All cellular systems provide a service called roaming. This allows subscribers to operate in service areas other than the one from 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.

- Registration
  - MSC polls for unregistered mobiles
  - Mobiles respond with MINs
  - MSC queries mobile's home for billing info

- Calls
  - MSC controls call, bills mobile's home

Roaming

- A wireless roaming network has five components that make it work:
  - A database for storing customer profile information such as features, dialing capabilities, and the home serving area identification. This is called the home location register (HLR).
  - A database of mobile numbers used by each switch on the network.
  - A signaling network for transmitting data messages between switches.
  - Routing specifications that direct the data messages to the appropriate destination.
  - Public long-distance connections for call delivery

Roaming

- A registration cycle keeps track of a phone as it travels around the network. It begins when a wireless user powers on their phone. The general steps for this process are:
- When the phone is powered on, it sends a data message to the cellsite. This data message contains the Mobile Identification Number (MIN or phone number) and the Electronic Serial Number (ESN). The cellsite forwards this information to the switch.
- The switch compares the MIN with a table of all MINs in the network. It will determine if the MIN belongs to a home customer, or to a visiting customer. In either case, the switch will request the subscriber's feature profile from the Home Location Register (HLR). The HLR for home customers may be integrated into the same switch or stored on a separate platform.

Roaming

- If the HLR is a separate platform, or if the customer is visiting from another system, the switch then sends a data message to the HLR across the signaling network. Routing specifications stored at Signaling Transfer Points (STPs) provide the necessary information to direct the message to the home location register.
- When the Home Location Register (HLR) receives the message, it checks the MIN & the ESN. If the numbers are valid, the HLR records the location of the phone and returns a message containing the subscriber's feature list and calling restrictions to the visited switch.
- Once the visited switch receives the return message, it creates a Visitor Location Register (VLR) to store information about the roamer, including the MIN, ESN, features, etc... This register will be used by the roamer as long as they are registered in the visited system.

Hand-over

- During a call, the base station would monitor the signal level from the mobile phone. When the mobile phone is moving into a new cell, the signal level will fall to a critical value causing the base station to inform the Mobile Switching Center(MSC) about this event. The MSC would instruct all the surrounding base stations to measure the mobile phone's signal level and transfer control to the base station receiving the strongest signal level. This is known as **hand-over** and occurs within **400ms**, so the phone user is hardly aware of a break.
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During the mobile initiated if all the traffic channels assigned to the nearest BS are busy then a Busy tone is returned to the user.

Call Transmission:

When one of the two users hangs up or terminate the cell or switch off the mobile phone, the MTSO is informed and the traffic channels at the two BS are released. Generally it is choice of user, when he/she wants to terminate the call.

Call Drop:

During a connection due to interference or weak signal if BS cannot maintain the minimum required signal call will drop and informed to the MTSO.

Call to/from Fixed and Remote Subscriber:

The MSTO connects to the PSTN so MTSO can setup a connection between a mobile user in the area and a fixed subscriber via the telephone network.

Advanced Mobile Phone System (AMPS) (Analog Cellular System)

- **Used in North America**; **First -generation** analog cellular system, available since 1983; Developed by Bell Labs.
- **Adopts FDMA**
  - Voice channels are carried by different radio frequencies.
  - A total 50 MHz in 824-849 MHz & 869-894 MHz
  - Divided into 832 frequency channels: 416 downlinks and 416 uplinks(5% Control Channels)
  - Frequency Reuse: A frequency may be reused by cells in different clusters

AMPS (Advanced Mobile Phone System)

- Analog cell phone standard, established in 1983
- First used in Chicago
- Uses range of frequencies between 824Mhz and 894 MHz
- Pair of frequencies, one for transmit and one for receive create one channel
- Standard analog voice channel - 30kHz, comparable to a wired telephone

AMPS

- The scope of AMPS specification is limited to the air interface between subscriber equipment and base station radios. Signaling systems that link base stations to switches and switches to other switches are proprietary in North America
- A signaling standard for communications between mobile switches: IS-41, for roaming management

Digital Cellular- What it offers from Analog

- Better Quality
- Improved Bandwidth Efficiency
- Use of Micro Cellular Technology to accommodate smaller cells
- Improved Frequency Reuse
- Error Detection and Correction Techniques