LECTURE NOTES

ON

Principles of Cellular & Mobile Communications (20A04706)

IV B. Tech I Semester (R20)

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JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR

B.Tech IV- I Sem **L T P C**

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(20A04706) PRINCIPLES OF CELLULAR AND MOBILE COMMUNICATIONS

Course Objectives:

- To understand the concepts and operation of cellular systems.
- To apply the concepts of cellular systems to solve engineering problems.
- To analyse cellular systems for meaningful conclusions.
- To evaluate suitability of a cellular system in real time applications.
- To design cellular patterns based on frequency reuse factor.

Course Outcomes:

At the end of the course, the student should be able to

- Understand the concepts and operation of cellular systems (L1)
- Apply the concepts of cellular systems to solve engineering problems (L2).
- Analyse cellular systems for meaningful conclusions, Evaluate suitability of a cellular system in real time applications (L3).
- Design cellular patterns based on frequency reuse factor (L4).

UNIT I Introduction to Cellular Mobile Systems

Why cellular mobile communication systems? A basic cellular system, Evolution of mobile radio communications, Performance criteria, Characteristics of mobile radio environment, Operation of cellular systems. Examples for analog and digital cellular systems.

UNIT II Cellular Radio System Design

General description of the problem, Concept of frequency reuse channels, Cochannel interference reduction, Desired C/I ratio, Cell splitting and sectoring.

UNIT III Handoffs and Dropped Calls

Why handoffs and types of handoffs, Initiation of handoff, Delaying a handoff, Forced handoffs, Queuing of handoffs, Power-difference handoffs, Mobile assisted handoff and soft handoff, Cell-site handoff, Intersystem handoff. Introduction to dropped call rate.

UNIT IV Multiple Access Techniques for Wireless Communications

Introduction, Frequency Division Multiple Access, Time Division Multiple Access, Code Division Multiple Access and Space Division Multiple Access.

UNIT V Digital Cellular Systems

Global System for Mobile Systems, Time Division Multiple Access Systems, Code Division Multiple Access Systems. Examples for 2G, 3G and 4G systems. Introduction to 5G system.

Textbooks:

1. William C. Y. Lee, “Mobile Cellular Telecommunications”, 2ndEdition, McGraw-Hill International, 1995.
2. Theodore S. Rappaport, “Wireless Communications – Principles and Practice”, 2ndEdition, PHI, 2004.

References:

1. Aditya K. Jagannatham “Principles of Modern Wireless Communications Systems – Theory and Practice”, McGraw-Hill International, 2015.

CMC

Introduction:-

Communication is Nothing but transfer of information for telecasting / broadcasting information from One place to another place. The transmitting place we call it as Source and Receiving place is known as destination.

→ So, information transfering from One place to another place is known as "Communication."

→ It is done through electricity (or) Radiowaves. that means it is done in two forms.

→ Through electricity means it is a wired Communication.

→ Through Radiowaves means it is a wireless Communication.

→ So, the information has been transferred through One place to another place by means of electricity / Radio waves that means wired (or) wireless Communication.

→ Mobile is a device which is Communicating is in motion. The device is in a Moving State.

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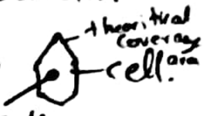
→ Communication which is done in while the device is in moving Condition.

→ The information has been transferring in One place to another place while the device is in moving Condition that's called "Mobile Communication" why it is

→ Cellular is nothing but this mobile Communication is based upon cellular Passage it's nothing but a cell. (hexagonal shape)



→ cellular Passage where we use the word "cell". that cell shape is "hexagonal." that "location" is called as "base transeiver station" (BTS). In local language it is known as "Cell Towers" (or) "Cell Point".

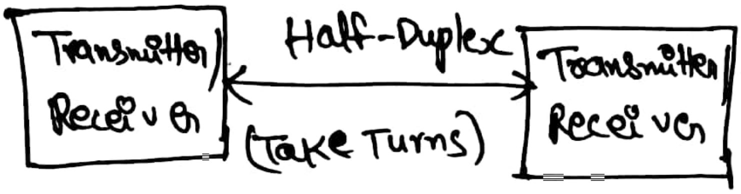
→ The Coverage area of a Cell Tower is known as "Cell."

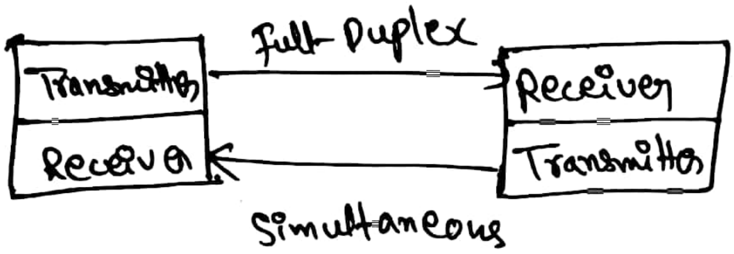
→ In Practical Shape of a Cell is "uneven."

whereas Coming to the basetransceiver Station the device is used for transmitting and receiving of information (Full-duplex Communication).

→ In Simplex Communication, transmission and Reception of information is done in Single -freq. Channel. There is no backward Communication.

→ Transmission and Receiving done in single frequency in half-duplex Communication





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Cellular and Mobile Communications

Unit-I

Introduction:-

Communication:- Exchange of information (or) transfer of information (or) Broadcasting of information is called as "communication".

Cellular communication:-

Consider a Geographical area and splitting the geographical area into small shapes and each shape treated as a cell and establishing the communication (Transmitting and Receiving the signal (or) exchange the information between the cells) among the cells is called as "cellular communication".

→ The shape of cell is "Hexagonal."

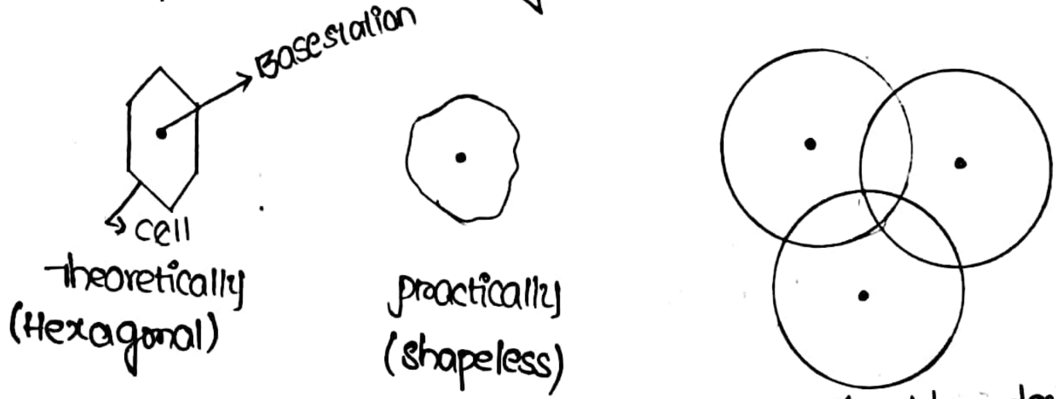


Fig: Cell shapes

→ The coverage area of cell tower is called "cell".

→ The group of cells is called as "cluster" with N=7 where N is Number of cells.

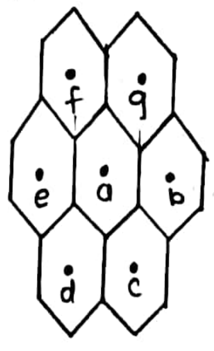


Fig: cluster

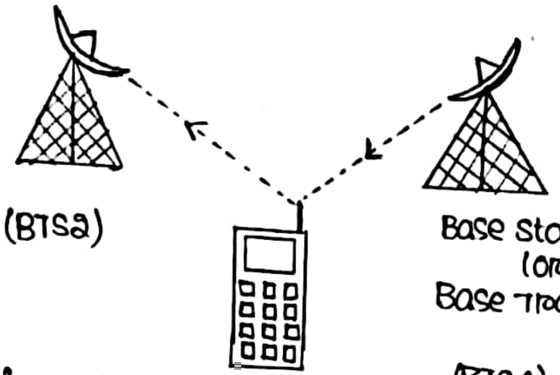
Cellular mobile communication:-

The communication between cells held with mobile is called as cellular mobile communication.

→ communication done in two forms. They are
(i) wired communication
(ii) wireless communication.

→ Cellular mobile communication done with "full duplex communication". i.e., transmitting and receiving both are done through single channel for single time slot.

→ The communication from one mobile to another mobile can be done using Base station.



→ The transfering of information from one BTS to another BTS is nothing but the transferring of information from one cell to another cell. using mobile. and this process continues.

Handoff process:-

Handing over the information from one cell to another cell without redialling (or) re-initiating the call is called as Hand off process.

→ When a person is moving from one BTS to another BTS, if there is a disconnection of call, then there is no handoff process.

→ If the distance is large, and the person is moving at very high speed, in that case we use cellular concept.

→ If a person is staying at one particular cell for long time then it is called "dual time (td)."

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Limitations of conventional telephone system:-

One of many reasons for developing a cellular mobile telephone system and developing it in many cities is the operational limitations of conventional mobile telephone systems: Limited service capability, Poor service performance and inefficient frequency spectrum.

(i) Limited service capability:-

The communications coverage area of each zone is normally planned to be as large as possible, which means that the transmitted power should be high as the federal specifications allows. The user who starts a call in one zone has to reinitiate the call when moving into a new zone. because the call will be dropped. This is an undesirable radio telephone system since there is no guarantee that a call can be completed without a handoff capability.

The handoff is a process of automatically changing frequencies as the mobile unit moves into a different frequency zone so that the conversation can be continued in a new frequency zone without dialing. Another disadvantage of the conventional system is that the number of active users is limited to the number of channels assigned to a particular frequency zone.

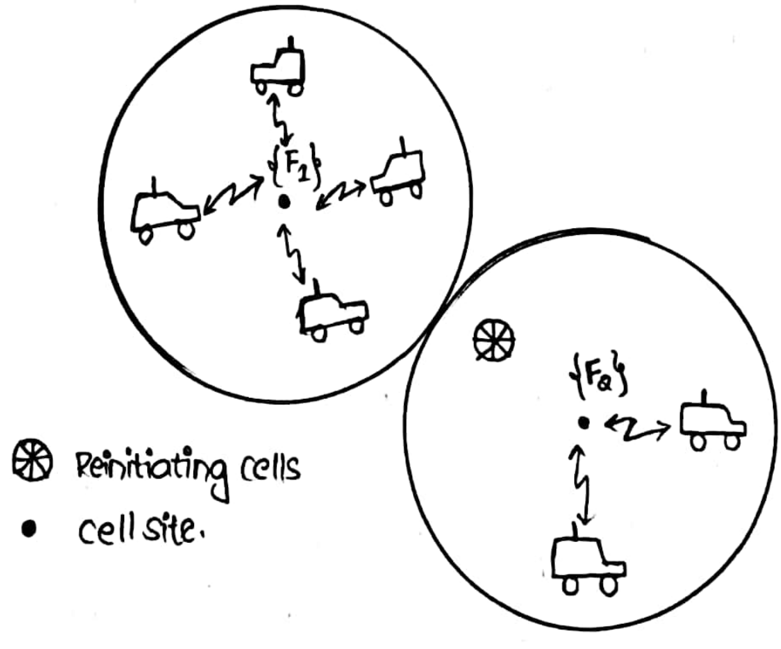

Fig: conventional Mobile system.

(ii) poor service performance :-

In the past, a total of 33 channels were allocated to three mobile telephone systems: Mobile Telephone Service (MTS), Improved Mobile Telephone Service (IMTS) MJ systems and Improved Mobile Telephone Service (IMTS) MK systems. MTS operates around 40 MHz and MJ operates at 150 MHz; both provide 11 channels; IMTS MK operates at 450 MHz and provides 12 channels. These 33 channels must cover an area 50mi in diameter.

In 1976, New York city had 6 channels of MJ serving 320 customers, with another 2400 customers on a waiting list. New York city also had 6 channels of MK serving 225 customers, with another 1300 customers on a waiting list. The large number of subscribers created a high blocking probability during busy hours. The actual number of blockings will be shown later. Although service performance was undesirable, the demand was still great. A high-capacity system for mobile telephones was needed.

(iii) Inefficient frequency spectrum utilization :-

In a conventional mobile telephone system, the frequency utilization measurement M_0 is defined as the maximum number of customers that could be served by one channel at the busy hour. equation-① gives the 1976 new york city data cited earlier.

$$M_0 = \frac{\text{No. of customers}}{\text{channel}} \quad (\text{conventional systems}) \longrightarrow ①$$

or

$$M_0 = \begin{cases} 53 \text{ customers/channel} & (\text{MJ system}) \\ 37 \text{ customers/channel} & (\text{MK system}) \end{cases}$$

Assume an average calling time of 1.76 min and apply the Erlang B model. calculate the blocking probability as follows. use 6 channels, with each channel serving the two different numbers of customers shown in eq①. The offered load can then be obtained by eq②,

$$A = \frac{\text{av calling time (minutes)} \times \text{total customers}}{60 \text{ min}} \text{ erlangs} \longrightarrow eq②.$$

$$A_1 = \frac{1.76 \times 53 \times 6}{60} = 9.33 \text{ erlangs} \quad \text{(MJ system)}$$

$$A_2 = \frac{1.76 \times 37 \times 6}{60} = 6.51 \text{ erlangs} \quad \text{(MK system)}.$$

Given that the number of channels is 6 and the offered loads are $A_1 = 9.33$ and $A_2 = 6.51$, read from the table to obtain the blocking probabilities $B_1 = 50$ percent (MJ system) and $B_2 = 30$ percent (MK system), respectively. It is likely that half the initiating calls will be blocked in the MJ system, a very high blocking probability.

If the actual average calling time is greater than 1.76 min, the blocking probability can be even higher. To reduce the blocking probability, we must decrease the value of the frequency spectrum utilization measurement M_0 as shown in equation ①.

A Basic cellular system :-

A basic cellular system consists of three parts: a mobile unit, a cell site, and a Mobile Telephone switching office (MTSO), as shown in below figure, with connections to link the three sub systems.

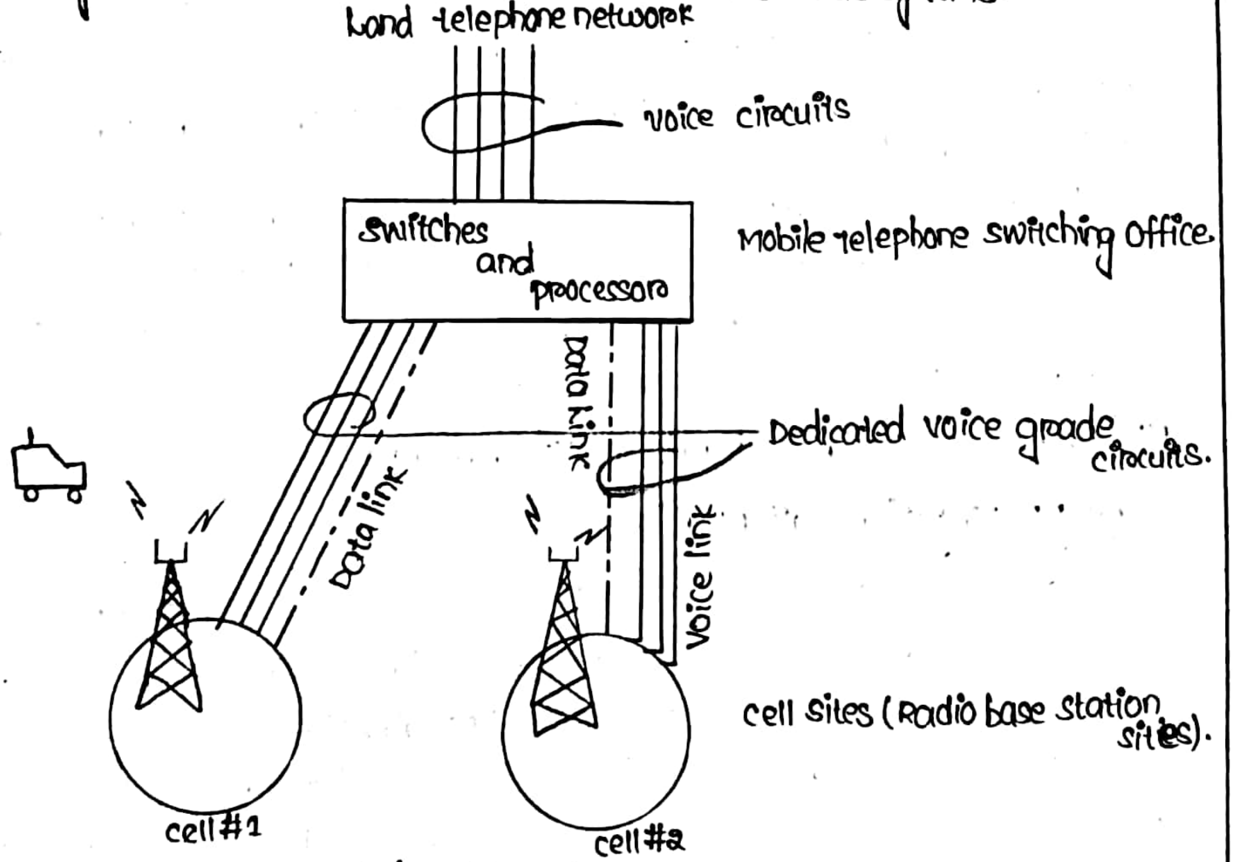

Fig: cellular system

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1, Mobile units :-

A mobile telephone unit contains a control unit, a transceiver and an antenna system.

2, cell site:-

The cell site provides interface between the MTSO and the mobile units. It has a control unit, radio cabinets, antennas and powerplant, data terminals.

3, MTSO:-

The switching office, the central coordinating element for all cell sites, contains the cellular processor and cellular switch. It interfaces with telephone company zone offices, controls call processing and handles billing activities.

4, connections:-

The radio and high-speed data links connect the three subsystems. Each mobile unit can only use one channel at a time for its communication link. But the channel is not fixed; it can be any one in the entire band assigned by the serving area, with each site having multichannel capabilities that can connect simultaneously to many mobile units.

The MTSO is the heart of the cellular mobile system. Its processor provides central coordination and cellular adminstration.

The cellular switch, which can be either analog or digital, switches calls to connect mobile subscribers to other mobile subscribers and to the nationwide telephone network.

The high-speed data links cannot be transmitted over the standard telephone trunks and therefore must use either microwave links or T-carriers. Microwave radio links or T-carriers carry both voice and data between the cellsite and MTSO.

Uniqueness of Mobile Radio environment:-

i, The propogation attenuation:-

The propogation path loss increases not only with frequency but also with distance. If the antenna height at the cellsite is 30 to 100m and at the mobile unit about 3m and the distance between the cellsite and mobile unit is usually 2km or more, then the incident angles of both the direct wave and the reflected wave are very small.

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Mobile Radio transmission medium:

*→ In signal propagation their exists path loss and the path loss represents signal attenuation measured in dB.

*→ The path loss in dB is defined as the difference between effective transmitted power and effective received power

$$\text{path loss (dB)} = 10 \log \frac{P_T}{P_R}$$

where,

$P_T = G_T G_R \lambda^2$

$P_R = 16\pi^2 d^2$

G_T – Transmitting antenna gain

G_R – Receiving antenna gain

d – distance b/w transmitting & receiving antennas

λ – wavelength of the carrier power $= c/f$

*→ It is important to note the mobile radio transmission medium.

*→ The value of propagation path loss increases with frequency and distance.

*→ The incident angle of the direct wave is θ_1 w.r.t the mobile unit & incident angle of the wave reflected is θ_2.

*→ The angle θ_1 measured w.r.t direct wave path is also known as "Elevation angle".

The propagation path loss would be 40dB/dec. where "dec" is an abbreviation of decade, i.e., a period of 10. This means that a 40-dB loss at a signal receiver will be observed by the mobile unit as it moves from 1 to 10 Km. Therefore C is inversely proportional to R^4.

$$C \propto R^{-4}$$

$$C = \alpha R^{-4} \longrightarrow (1)$$

where,

C = received carrier power

R = distance measured from the transmission to the receiver unit

α = Constant of proportionality.

The difference in power reception at two different distances R_1 and R_2 will result in

$$C_1 = \alpha R_1^{-4}$$

$$C_2 = \alpha R_2^{-4}$$

$$\frac{C_2}{C_1} = \frac{\alpha R_2^{-4}}{\alpha R_1^{-4}}$$

$$\frac{C_2}{C_1} = \frac{R_2^{-4}}{R_1^{-4}}$$

$$\left(\frac{C_2}{C_1}\right) = \left(\frac{R_2}{R_1}\right)^{-4} \longrightarrow (2)$$

↓

To change +ve then,

$$\left(\frac{C_2}{C_1}\right) = \left(\frac{R_1}{R_2}\right)^{+4}$$

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The decibel expression of eq – ② is

$$\Delta C \text{ (in dB)} = C_2 - C_1 \text{ (in dB)}$$

$$= \log (C_2 - C_1)$$

$$= \log C_2 - \log C_1$$

$$= 10 \log \left(\frac{C_2}{C_1}\right)$$

$$= 10 \log \left(\frac{R_1}{R_2}\right)^4$$

$$\Delta C \text{ (in dB)} = 40 \log \left(\frac{R_1}{R_2}\right) \longrightarrow ③$$

(a) The linear and decibel scale expression are

$$C \propto R^{-2} \text{ (free space)} \longrightarrow ④ \quad (\text{where } -2 = 20\text{db/dec})$$

$$\Delta C = C_2 \text{ (in dB)} - C_1 \text{ (in dB)}$$

$$= 20 \log \frac{R_1}{R_2} \text{ (free space)} \longrightarrow ⑤$$

(b) for real time mobile environments C will be $C = \alpha R^{-\gamma}$

γ – lies between 2 & 5.

(c) If 'γ' takes the value $\gamma \leq 2$ then it would be free space Condition.

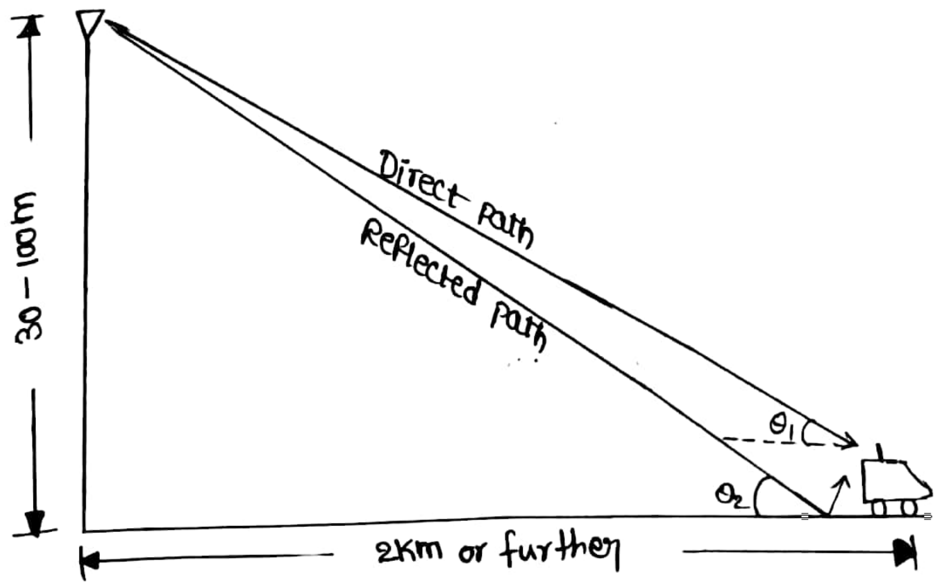

fig: mobile radio transmission model

Severe fading:-

The antenna height of the mobile unit is lower than its typical surroundings, and the carrier frequency wavelength is much less than the sizes of the surrounding structures, multipath waves causes a signal-fading phenomenon.

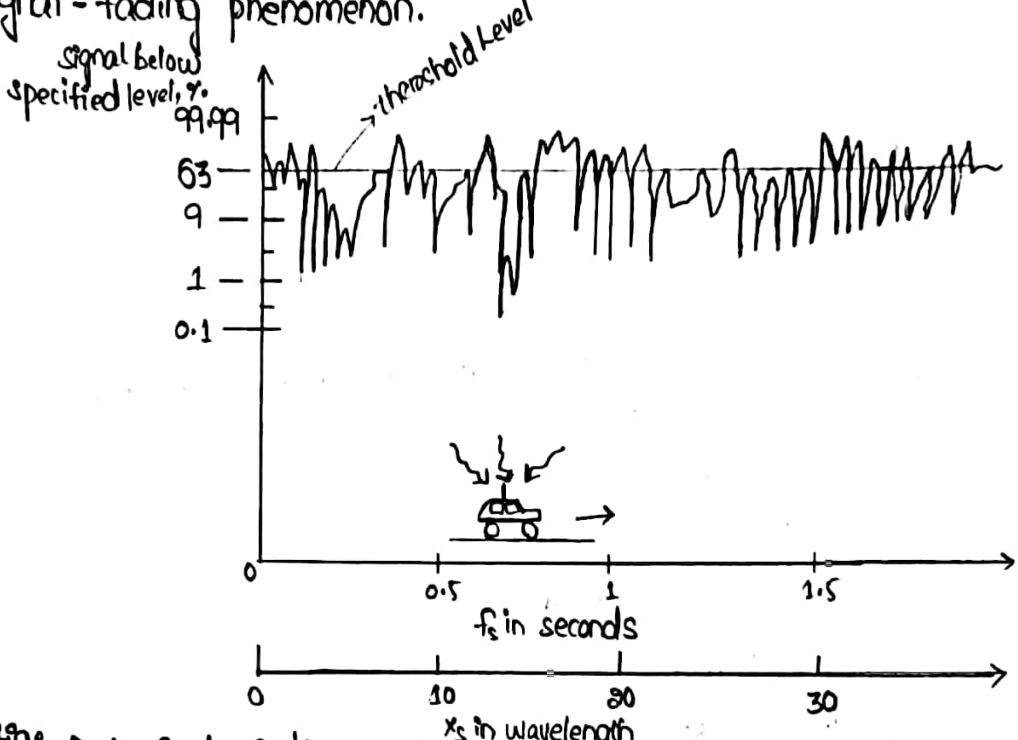

Fig: A typical fading signal received while the mobile unit is moving.

Model of transmission medium:-

A mobile radio signal $r(t)$, illustrated in figure below, can be artificially characterized by two components $m(t)$ and $r_0(t)$ based on natural physical phenomena.

$$r(t) = m(t)\, r_0(t)$$

The component $m(t)$ is called *Local mean, Long-term fading, or log normal fading* and its variation is due to the terrain contour between the base station and the mobile unit. The factor r_0 is called *multipath fading, short-term fading, or Rayleigh fading* and its variation is due to the waves reflected from the surrounding buildings and other structures.

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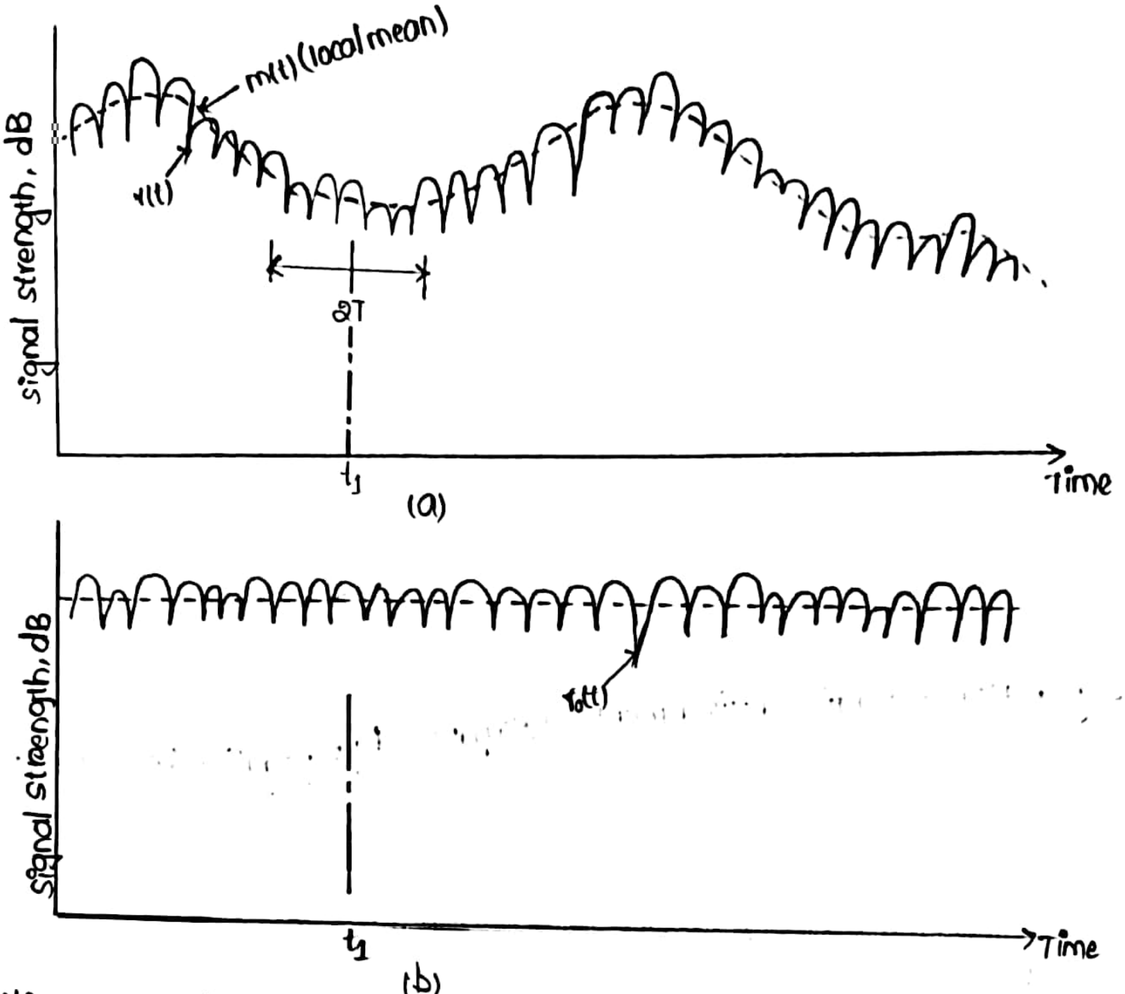

Fig: A mobile radio signal fading representation. (a) A mobile signal fading. (b) A short-term signal fading.

Mobile fading characteristics:-

Rayleigh fading is also called multipath fading in the mobile ratio environment. When these multipath waves bounce back and forth due to the buildings and houses, they form many standing-wave pairs in space as shown in below figure.

Those standing-wave pairs are summed together and become an irregular wave-fading structure. When a mobile unit is standing still, its receiver only receives a signal strength at that spot, so a constant signal is observed. When the mobile unit is moving, the fading structure of the wave in the space is received. It is a multipath fading.

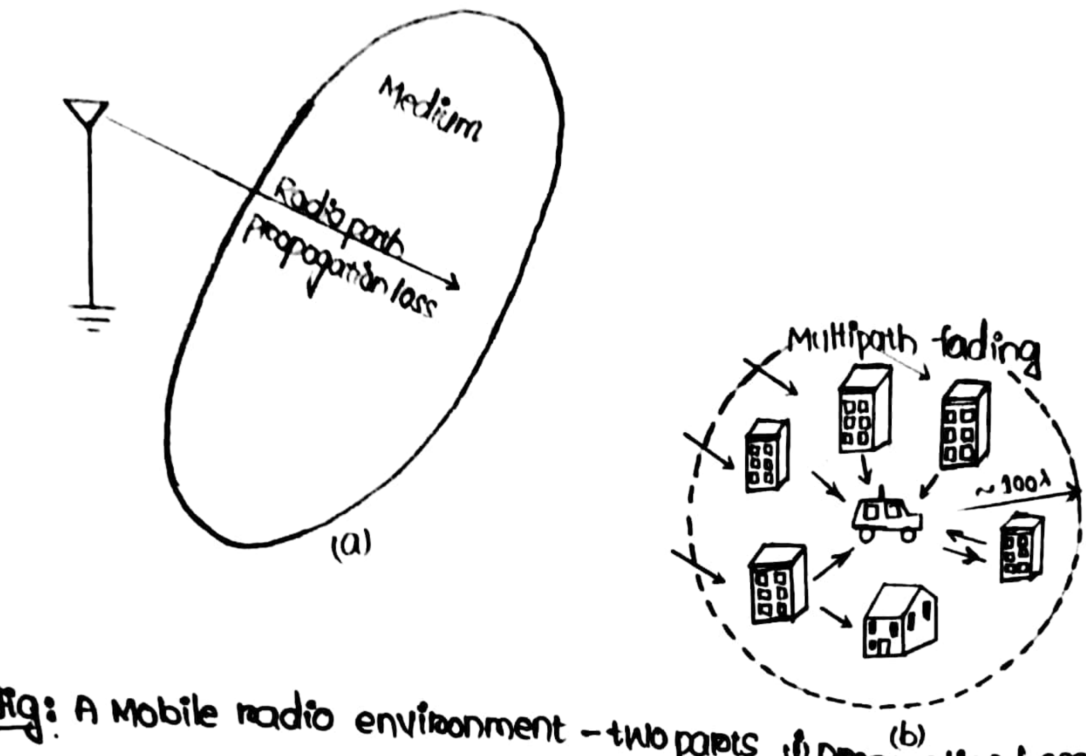

Fig: A Mobile radio environment – two parts (1) Propogation loss ; (2) Multipath fading.

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Performance criteria :-

There are three categories for specifying performance criteria.

1. Voice quality :-

⇒ Voice quality is very hard to judge without subjective tests from user's opinions.

⇒ In this technical area engineers cannot decide how to build a system without knowing ~~the voice~~ the voice quality that will satisfy the users.

⇒ In military communications, the situation differs : armed forces personnel must use the assigned equipment.

For any given commercial communications system, the voice quality will be based upon the following criterion :

a set value x at which y percent of customers rate the system voice quality (from transmitter to receiver) as good or excellent, the top two circuit merits (CM of the five listed below).

CM	Score	Quality scale
CM5	5	Excellent (speech perfectly understandable)
CM4	4	Good (speech easily understandable, some noise)
CM3	3	Fair (speech understandable with a slight effort, occasional repetitions needed).
CM2	2	poor (speech understandable only with considerable effort, frequent repetitions needed
CM1	1	unsatisfactory (speech not understandable

As the percentage of customers choosing CM4 and CM5 increases, the cost of building the system rises.

The average of the CM scores obtained from all the listeners is called mean opinion score (MOS). Usually the toll-quality voice is around MOS ≥ 4.

2. Service Quality:

Three items are required for service quality.

(i) coverage: The system should serve an area as large as possible. with radio coverage, however, because of irregular terrain configurations, it is usually not practical to cover 100% of the area for two reasons.

(a) The transmitted power would have to be very high to illuminate weak spots with sufficient reception, a significant added cost factor.

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(b) The higher the transmitted power, the harder it becomes to ~~continue~~ control interference. However

⟹ Therefore, systems usually try to cover 90% of an area in flat terrain & 75% of an area in hilly terrain.

⟹ The combined voice quality and coverage criteria in Amps cellular systems state that 75% of users rate the voice quality between good and excellent in 90% of the served area, which is generally flat terrain.

⟹ The voice quality and coverage criteria would be adjusted as per decided various terrain conditions.

⟹ In hilly terrain, 90% of users must rate voice quality good or excellent in 75% of the served area.

⟹ A system operator can lower the percentage values stated above for a low-performance and low-cost system.

ii) Required grade of service :- for a normal start-up system the grade of service is specified for a blocking probability (delay) of 0.02 for initiating calls at the busy hour. This is an average value.

However, the blocking probability at each cell site will be different. At the busy hour, near freeways, automobile traffic is usually heavy, so the blocking probability at certain cell sites may be higher than 2%, especially when car accidents occur.

⟹ To decrease the blocking probability requires good system plan and a sufficient number of radio channels.

same capacity but no. of customers are less in cell 1 more in cell 2

(iii) Number of dropped calls:- During a calls in an hour, if a call is dropped and a-1 calls are completed, then the call drop rate is 1/a. This drop rate must be kept low.

⟹ A high drop rate could be caused by either coverage problems or handoff problems related to inadequate channel availability.

3. Special features:- push-to talk (PTT)

A system would like to provide as many special features as possible, such as call forwarding, call waiting, voice stored (VSR) box, automatic roaming, (or) navigation services, short message service (sms) However, sometimes the customers may not be willing to pay extra charges for these special services. multimedia service (mms)

Operations of cellular systems:

The operation can be divided into ~~five~~ 4 parts and a hand off procedure. They are:-

①

① Mobile unit Initialization:

* when a user sitting in a car turns on the receiver of the mobile unit, then the receiver scans all the channels, selects the strongest channel and locks it.
* Locking the strongest channel means selecting the nearest cell site.
* This process of selecting and locking the strongest channel is called "self-location scheme", which is user independent and used in the ideal state of mobile unit.
* when the call initiates from the landline to a mobile unit. The paging process in longer. The large percentage of calls originates at the mobile unit. when the land line originated calls increase a feature called "registration" can be used.

Advantage:

It reduces the load on the cell site

Disadvantage:

It doesnot give the location information of ideal mobile unit to cell site.

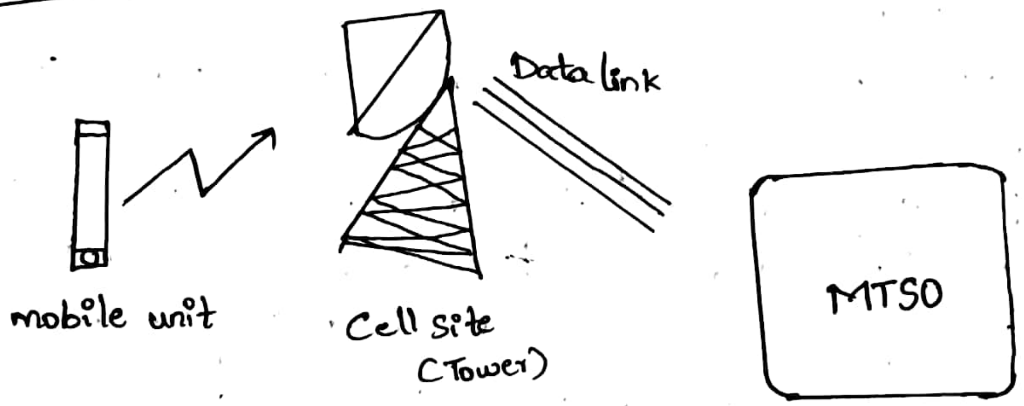
② Mobile originated cell:

* The user dials (calls) the called number, which is stored in the register of the mobile unit to check whether the number is correct or not, by pushing the "send" button.
* This is the request for the service by the mobile unit to the cell site.
* After receiving the request for service, the cell site provides by the best directional antenna

for voice channel and at the same time cell site sends the request to MTSO [Mobile Telephone Switching Office] via (through) high speed data link.

* Then MTSO will provide the best voice channel for call and the cell site acts on it through the best directive antenna to link the mobile unit.
* Thus mobile unit connects to the MTSO
* Then MTSO will ~~provide~~ connects the wire line party through the telephone company zone office.

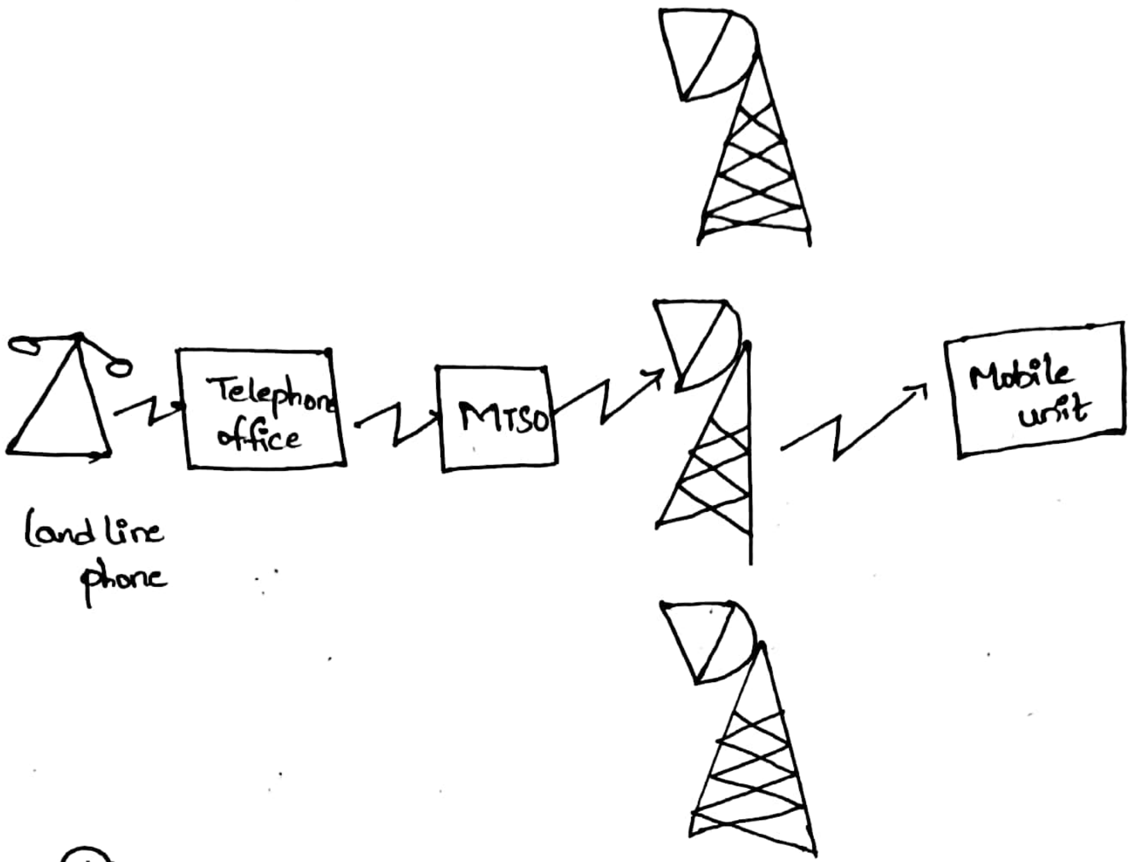
Diagram for explanation of mobile originated cell operation:



③ Network Originated call:

* when a land-line (user) party dials a mobile unit number, then the telephone office identifies, that the number is of Mobile i.e wireless, so the Telephone office recognizes the call to MTSO
* MTSO sends the paging (short) message consisting of mobile number to some cell sites depending on the mobile number and searching algorithm.
* Then each cell site will send the page to the Mobile unit
* The Mobile unit also follows the instruction to

tune to all assigned voice channel and initiate ②
user alert.



④ Call termination:

when the mobile unit user turns off the transmitter, then a particular signal i.e. Signalling tone is send to the cell site and both sides (sender and receiver) makes the voice channel free i.e disconnects the call between two parties

(or)

when the mobile user turns off the transmitter, a particular signal transmits to the cell site, and both sides free the voice channel. The mobile unit resumes monitoring pages through the strongest set up channel.

5. Handoff Procedure:

* During a call, two parties are on the voice channel.

* when the mobile unit moves out of the coverage area of its cell site, the reception of signal becomes weak. Then the present cell will request for "Handoff".

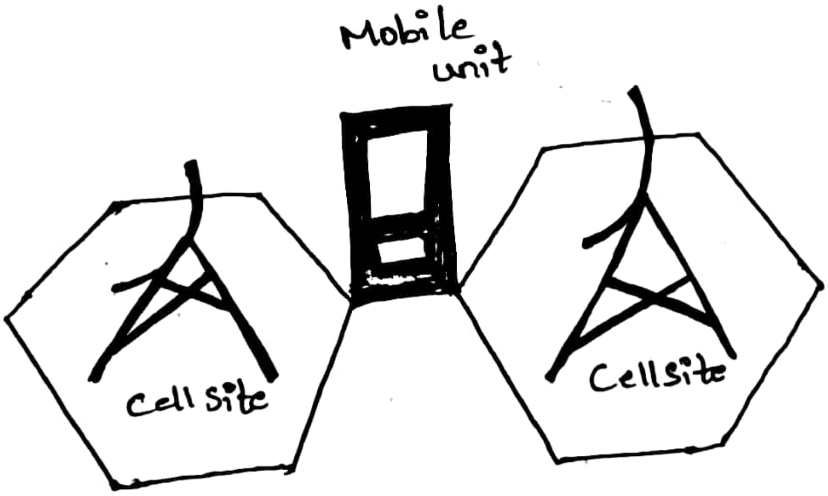
* The cellular system switches the call to new channel of the new cell site without either interrupting (stopping) or alerting the user.

* The call continues as long as the user is talking

Thus the user doesnot notice the Handoff process.

* Handoff was first used by AMPS system then it was renamed as Handover by the European systems.

Handoff procedure:



Evolution of Cellular systems :-

→ In the year of 1920 first conventional mobile s/m was launched for military & emergency services.

→ In 1940 public mobile radio (automatic) s/ms was launched.

→ Later, (MTS) mobile telephone s/m and improved mobile telephone s/m (IMTS) were introduced to support larger number of mobile stations.

→ In 1979, the first 1G cellular n/w was launched in japan.

→ In 1981, the first international cellular n/w, Nordic mobie telephone (NMT) s/m's came operation in Nordic countries.

→ In 1983, two other 1G s/m's ① Advanced mobile phone s/m (AMPS)
② Total Access communicati s/m (TACs)

were introduced in the US and other European countries.

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INTRODUCTION

- The term 'mobile' has completely revolutionized the communication by opening up innovative applications that are limited to one's imagination. Today, mobile communication has become the backbone of the society. All the mobile system technologies have improved the way of living. Its main plus point is that it has privileged a common mass of society.

EVOLUTION

- The first wire line telephone system was introduced in the year 1877. Mobile communication systems as early as 1934 were based on Amplitude Modulation (AM) schemes and only certain public organizations maintained such systems.
- However, during its initial three and a half decades it found very less market penetration owing to high costs and numerous technological drawbacks. But with the development of the cellular concept in the 1960s at the Bell Laboratories, mobile communications began to be a promising field of expanse which could serve wider populations.

Evolution of cellular systems :-

1G wireless Technology

* This started with the Advanced Mobile phone service that was invented at Bell Labs and first installed in 1982
* using Analog signals.
* It's speed was upto 2.4Kbps.
* frequency typically 150MHz & above

Drawbacks of 1G

- poor battery.
- poor voice quality
- Large in size
- No security
- frequency call drop

2G wireless Technology

* It enables services such as text messages, picture messages and MMS.
* It provides better quality and capacity
* widely used in 90's - 2000
* allows multiple users on a single channel
* supports voice as well as data.
* radio signals on 2G networks are digital which can be compressed and multiplexed easily.
* 2G technologies can be divided into TDMA based and CDMA - based standards depending on the type of multiplexing used.

* Speed 9.6 kbps.
* carrier frequency is of 200KHZ

Drawbacks of 2G

* weaker digital signal
* These systems are unable to handle complex data such as videos

2.5G wireless Technology :-

* 2.5G is a technology between the second [2G] and third [3G] generation of mobile telephony.
* 2.5G is sometimes described as 2G cellular Techno-logy combined with GPRS
* used in 2001-2004
* In addition to circuit switched data, packet switched data was also implemented.
* Enhanced multimedia and streaming video are possi-ble.
* supports web browsing
* 2.5G is General packet Radio service which is Evolution from GSM
* It can be used for services such as wireless application protocol [WAP] access, Multimedia Messaging service [MMS], and for Internet communication services such as email and world wide web acess.
* carrier frequency is same as that of 2G.

Features Include in 2.5 G

- phone calls
- Send / Receive E-mail Messages
- Web Browsing
- Speed : 64-144 Kbps
- Camera phones

3G Wireless Technology:

- Data transmission speed increased from 144kbps-2Mbps.
- providing faster communication
- send / Receive large Email Messages
- High speed web / More security
- TV streaming / Mobile TV / phone calls came into picture during 2004-2005
- carrier frequency is 5MHz.
- 3G networks offer greater security than their 2G predecessors because 3G networks permit validation measures when communicating with other devices.
- Applications of 3G: Mobile TV, Video on Demand, video conferencing, Location-based services and Global positioning system [GPS]

Drawbacks of 3G

- High Bandwidth Requirement
- expensive 3G phones
- Large cell phones

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4G Wireless Technology :

- capable of providing 100Mbps - 1Gbps speed.
- More security
- High capacity
- Low cost per-bit
- Improves the capacity and coverage, and ensures user fairness
- Also introduces multicarrier to be able to use ultra wide bandwidth up to 100MHZ of spectrum supporting very high data rates.
- LTE is a standard for wireless communication of high-speed data for mobile phones and data terminals.
- supports at least 200 active data clients in every 5MHz cell.
- It is based on the GSM/EDGE and network technologies, increasing the capacity and speed using new modulation techniques
- Ability to manage fast moving mobiles and supports MBSFN
- EDGE - Enhanced Data Rates for GSM communication
- UMTS - universal Mobile Telecommunications system
- HSPA - High speed packet Access

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Drawbacks of 4G:

- Battery uses is more
- Hard to implement
- Need complicated hardware
- Expensive equipment required to implement next generation network.

5G wireless Technology:

- The router (or) switch we are going to use in 5G network would provide high connectivity with wireless device
- It is 10 times more faster than 4G.
- It has a expected speed of 1gbps.
- Lower cost than the previous version

Features:

- uploading & Downloading speed of 5G touching the peak
- Better & fast solution
- It is highly supportable to WWWW
- Large phone Memory, Dialing speed, clarity in Audio, video.
- 5G technology is going to give tough competition to computers and laptops.

Analog and Digital cellular systems:

* cellular telephone systems can be "Analog" (or) "Digital".
* older cellular systems [AMPS, TACS, NMT]; are analog and newer systems [GMS, CDMA, PCS] are "Digital".
* TACS - Total Access Communication system
* NMT - Nordic Mobile, Telephone
* PCS - personal communication system.
* The major difference between the two system is how the voice signal is transmitted between the phone and basestation.
* with analog system the audio is directly modula--ted on to a carrier. This a very much like FM radio where the signal is translated to the RF signal
* with digital systems, the audio is converted to digitized samples
* with analog transmissions, interference gets translated directly in to the recovered signal and there is no check that the received signal is authentic
* The neat thing about the digital is that the 1's and 0's cannot be easily confused (or) distored during transmission plus extra data is typically included in the transmission to help, detect and correct any errors.

Analog and Digital cellular systems:-

cellular systems in the united states:-

There are 150 major market areas in the united states where licenses for cellular systems can be granted by the FCC (Fedaral communication commission).

They have been classified by their populations into five groups. Each group has 30 cities.

1. Top 30 markets – very large cities.
2. Top 31 to 60 markets – large-sized cities
3. Top 61 to 90. markets – medium-sized cities
4. Top 91 to 120 markets – below medium-sized cities
5. Top 121 to 150 markets – small-sized cities.

Each market area is planned to have two systems.

⟹ The status of each system in each area of groups 1 to 3 as of December 1985 appears.

There are 305 MSAs (metropolitan statistical areas) and 482 RSAs (rural statistical areas).

Cellular systems outside the united states :- 34.

Japan :- Nippon Telegraph and Telephone corporation (NTT) developed an 800-MHz land mobile telephone system and put it into service in the Tokyo area in 1979. The general system operation is similar to the Amps system.

⟹ It accesses ≈ 40,000 subscribers in 500 cities.

⟹ It covers 75% of all Japanese cities, 25% of inhabitable areas, and 60% of the population.

⟹ In Japan, 9 automobile switching centers (ASCs), 51 mobile control stations (MCSs), 465 mobile base stations (MBSs) and 39,000 mobile subscriber stations (MSSs) were in operation as of Feb 1985.

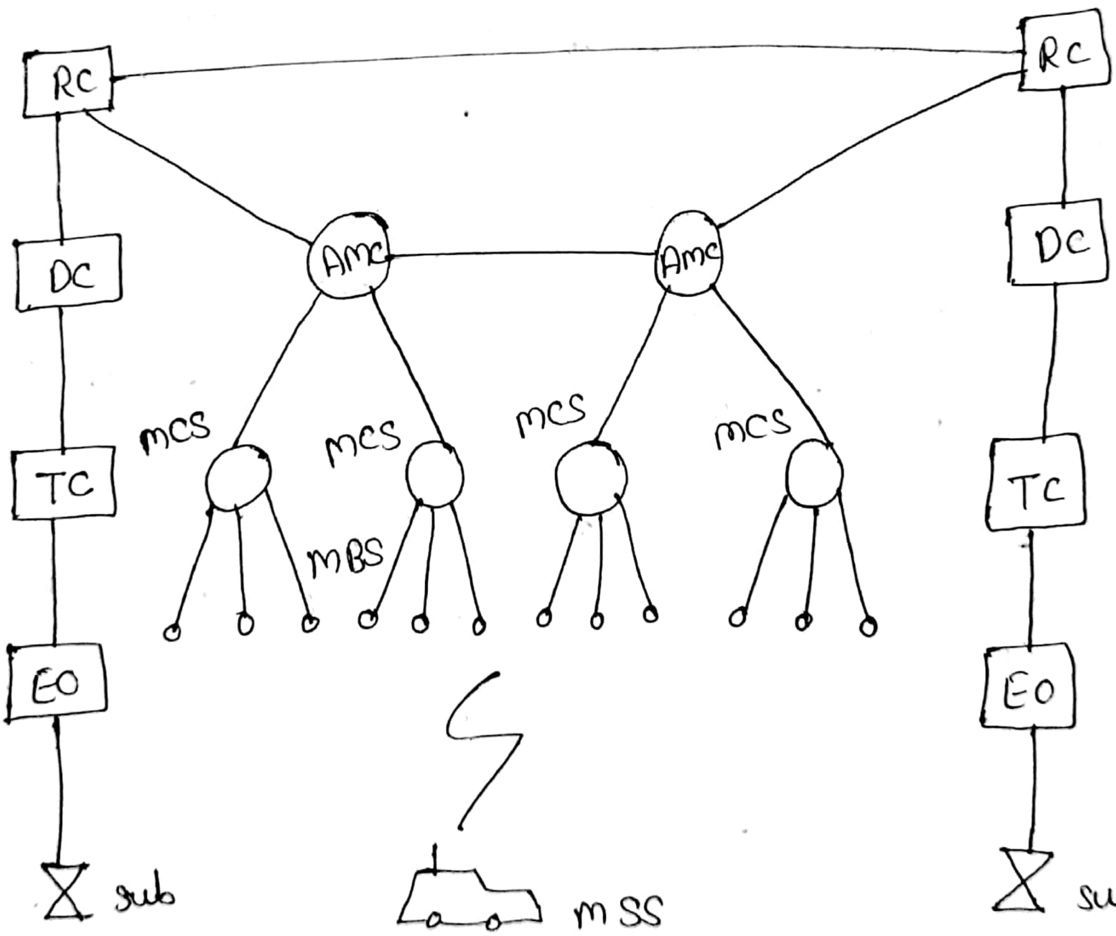
⟹ The Japanese mobile telephone service n/w configuration is shown in fig. below. In the metropolitan Tokyo area, about 30,000 subscribers are being served.

⟹ In 1985 operated over a spectrum of 30MHz. The total number of channels was 600, and the channel bandwidth was 25KHz.

⟹ This system comprised an automobile switching center (ASC), a mobile control station (MCS), a mobile base station (MBS), and a mobile subscriber station (MSS).

→ At present there is no competitive situation set up by the government.

→ However, the Japanese ministry of post and Telecommunication (MFT) is considering providing a dual competitive situation similar to that in the united states.



RC – Regional center

DC – District center

TC – Toll center

EO – End office.

AMC – Automobile switching center

MCS – mobile control station

MBS – mobile Base station

MSS – mobile subscriber station.

United Kingdom: In June 1982 the government of the United Kingdom announced two competing national cellular radio networks. The UK system is called TACS (Total Access Communications system).

→ The total number of channels was 1000, with a channel bandwidth of 25KHZ per channel.

→ Among them, 600 channels are assigned and 400 are reserved.

→ Two competing cellular network operators, cellnet and vodafone, are operating in the united kingdom.

→ Each network system has only 300 spectoral channels.

→ The cellnet system started operating in January 1985.

→ cellnet has over 200 cell sites, covering 82% of the united kingdom.

→ vodaphone, though, which started operations late, has served the same areas as cellnet.

Canadian system :- In 1978, a system called AURORA was designed for the Alberta government telephone (AGT). The system provides provincewide mobile telephone service at 400MHZ. ongoing developmental work on the AURORA is underway at 800MHz.

AURORA 400 system : It is aimed at 40,000 subscribers living in an area ≈ 1920Km x 960Km.

→ The AURORA 400 system initially has 40 channels and is expected to add an additional 20 channels with frequency reuse and a seven-cell cluster plan.

→ A fully implemented system has 120 cells.

→ The 400-MHz system doesnot have a handoff capability.

AURORA 800 system :- The AURORA 800 system is truly frequency transparent.

→ By repackaging the radio frequency (RF) sections on the cell site, the mobile unit can be operated on any mobile RF band up to 800 MHz.

→ The handoff capability will be implemented in this system.

Nordic system :- This system was built mostly by Scandinavian countries (Denmark, Norway, sweden & finland) in corporation with saudi Arabia and spain and is called the NMT network.

→ It is currently a 450-MHz system, but an 800-MHz system will be implemented soon since the frequency-transparent concept as the AURORA 800 system is used to convert the 450-MHz system to the 800-MHz system.

→ The total bandwidth is 10MHz, which has 200 channels with a bandwidth of 25KHz per channel.

→ This system does have handoff and roaming capability

→ It also uses repeators to increase the coverage in a low traffic area.

→ The total number of subscribers is around 100,000.

European cellular systems :-

⇒ All the present generation of European cellular networks is totally lacking in cross-border compatibility.

⇒ Besides the united Kingdom and NMT networks, the others include the following.

Benelux-country network :- The netherlands served on their ATF2 network (the same as the NMT 450 network) at the begining of 1985.

It has a nation wide coverage using 50 cell sites with two different cell sizes, 20- and 5Km radii. The capacity of the present system is 15,000 to 20,000 subscribers.

Dutch PT&T is using a single Ericsson AXE10 switch.

Luxembourg came on air in August 1985.

In 1986, Belgium joined the network. The network is It operates at 450MHz.

compatible among the 3 countries.

France: A direct-dial car telephone operating at 160 MHz can access the system in 10 regional areas. The network serves 10,000 subscribers.

By the end of 1984, 450 MHz was in operation. In the mean time Radicom 2000 (digital signaling) was introduced; operating at 200 MHz but with no handoff feature.

Spain: It uses an NMT 450 MHz cellular network introduced in 1982. It was the first cellular system in Europe. The number of cells in service is 13. There are 3 separate networks operating 104 channels. Each channel bandwidth is 25 KHz

Austria: A new NMT cellular network called Autotelefonnetz C has two mobile switching exchanges and has enough capacity for 30,000 subscribers.

The Austrian PT&T has allocated 222 duplex duplex channels in ranges 451.3 to 455.7 MHz and 461.3 to 465.7 MHz, with a channel bandwidth of 20 KHz.

Although both Austria and Spain are using NMT 450 systems, their systems are not compatible because of different frequency allocations, channels spacings (B.W), and protocols by different PT&Ts.

Germany: A full national coverage, including west Berlin, using a C-450 cellular system was installed in september 1985 with 100 cell sites.

⟹ Another 75 cell sites were completed in mid-1986.

⟹ Also, Germany and France are working on cross-border compatibility in cellular radio systems and have proposed a CD-900 digital system.

Switzerland: Swiss PT&T decided to install an NMT 900-MHz cellular network that had a capacity of 12,000 subscribers. A pilot scheme with 20 transmitters (cell sites) was installed in the zurich area in late 1986.

cellular systems in the rest of the world:-

Australia is installing a system using Ericsson's AXE-10 switching network and will operate at 800 MHz with 12 sites concentrated in three big cities.

Kuwait's cellular system uses NEC's

switches and provides 12 sites.

It operates at 800 MHz.

Hong Kong has three systems. The united kingdom's TACS system is installed with motorola switches. The united states' AMPS system and Japanese NEC systems were also installed in Hong Kong. It is a very competitive market.

⟹ All systems are penetrating the markets of both portable sets and car sets.

Digital cellular systems:-

⟹ In 1992 the first digital cellular system, GSM (special mobile Group), was deployed in Germany. GSM is a European standard system.

⟹ In the united states, an NA-TDMA system (IS-54) and a CDMA system (IS-95) have been developed.

⟹ NA-TDMA was deployed in 1993 and CDMA is planned for deployment in 1995.

⟹ A Japanese system, PDC (personal Digital cellular), was deployed in osaka in June 1994.

total number of channels in K cells is divided as K increases, trunking inefficiency results.

The smallest value of K is K=3, obtained by setting i = 1, j=1 in the equation $K = i^2 + ij + j^2$

Number of customers in the system:-

When we design a system, the traffic conditions in the area during a busy hour are some of the parameters that will help determine both the sizes of different cells and the number of channels in them.

Now, take the maximum number of calls per hour in each cell Q_i and sum them over all cells. Assume that 60 percent of the car phones will be used during the busy hour, on average, one call per phone ($\eta_c = 0.6$) if that phone is used. The total allowed subscriber traffic M_t can be obtained.

Cochannel Interference Reduction Factor:-

Reusing an identical frequency channel in different cells is limited by cochannel interference between cells, and the cochannel Interference can become a major problem. Here we would like to find the minimum frequency reuse distance in order to reduce this cochannel Interference.

$$q = \frac{D}{R}$$

q = Cochannel Interference Reduction factor

D = Distance between the cells

R = Radius of each cell from centre.

It means that the received threshold level at the mobile unit is adjusted to the size of the cell. Actually, cochannel Interference is a function of a parameter q defined.

$$D = (K_I , C/I)$$

K_I = No. of cells

C/I = Carrier to Interference Ratio

$$\frac{C}{I} = \frac{C}{\sum_{K=1}^{K_t} I_K}$$

In a fully equipped hexagonal-shaped cellular system, there are always six cochannel interfering cells in the first tier as shown in Fig (a) that is, $K_I = 6$

Cochannel Interference can be experienced both at the cell site and at mobile units in the center cell.

The local noise is much less than the interference level and can be neglected.

Then C/I can be expressed as

$$C/I = \frac{R^{-r}}{\sum_{K=1}^{K_t} D_k^{-r}}$$

γ = propogation path loss.

where γ is a propagation path loss slope[5] determined by the actual terrain environment.

The six cochannel interfering cells in the second tier of cause weaker interference than those in the first tier.

∴ The cochannel interference from the second tier of interfering cells is negligible

$$C/I = \frac{1}{\sum_{K=1}^{K_t} \left(\frac{D_K}{R}\right)^{-r}}$$

$$= \frac{1}{\sum_{K=1}^{K_t} (q_K)^{-r}}$$

where q_K is the cochannel interference reduction factor with K^{th} cochannel interfering cell

$$q_K = \frac{D_K}{R}$$

Desired C/I from a Normal case in an omnidirectional Antenna System:-

There are two cases to be considered: (1) the signal and cochannel interference received by the mobile unit and (2) the signal and cochannel interference received by the cell site. N_m and N_b are the local noises at the mobile unit and the cell site, respectively. Usually N_m and N_b are small and can be neglected as compared with the interference level.

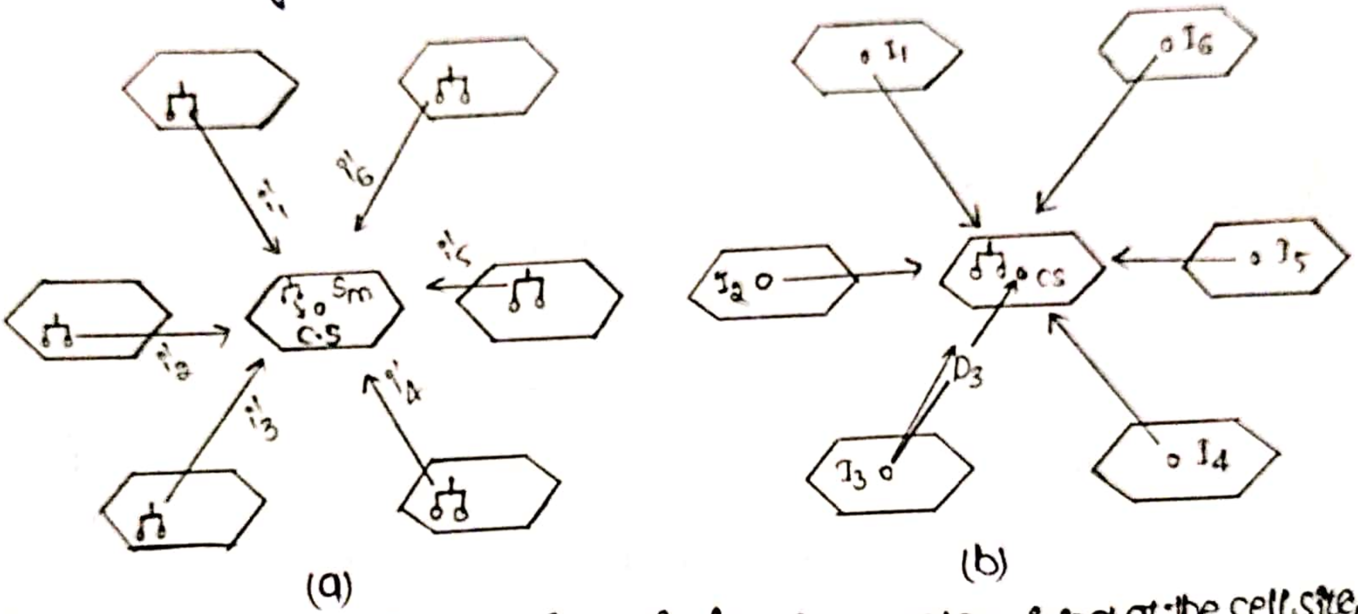


fig: cochannel interference from six interferers. (a) Receiving at the cell site, (b) Receiving at the mobile unit.

→ As long as the received carrier-to-interference ratios at both the mobile unit and the cell site are the same, the system is called a balanced system.

→ In a balanced system, we can choose either one of the two cases to analyze the system requirement; the results from one case are the same for the others.

Assume that all D_K are the same for simplicity, as shown in fig a, then $D = D_K$, and $q = q_K$, and

$$\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^{\gamma}}{6}$$

Thus,

$$q^{\gamma} = 6\left(\frac{C}{I}\right)$$

$$q = \left(6\frac{C}{I}\right)^{1/\gamma}$$

where

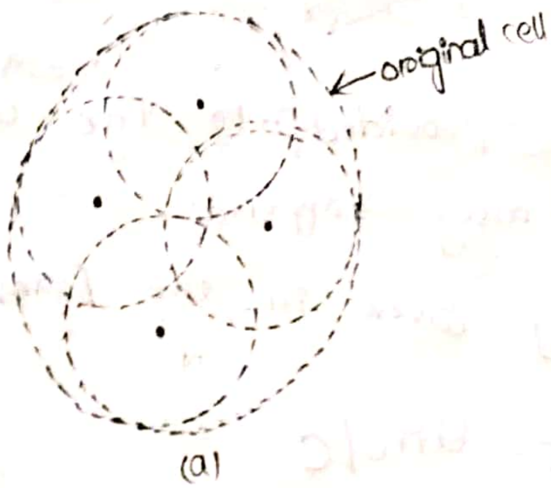
q = cochannel interference reduction factor

C/I = carrier to interference ratio.

γ = propogation path loss.

and $q = D/R$.

→ the greater the value of q, the lower the co-channel interference.



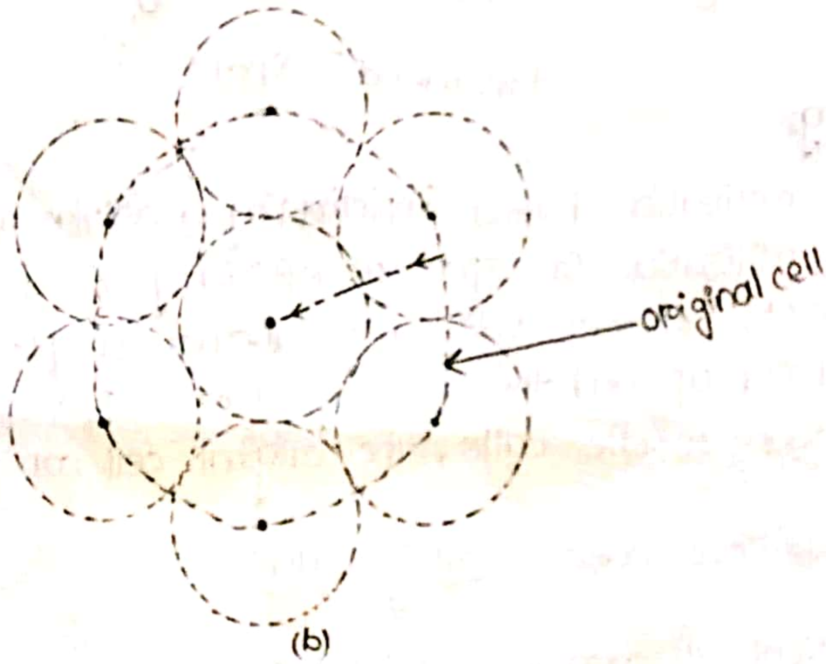


Fig: cell splitting

2) Dynamic splitting:-

→ This scheme is based on utilizing the allocated spectrum efficiency in real time.

→ The algorithm for dynamically splitting cell sites is a tedious job. Since we cannot afford to have one single cell unused during cell splitting at heavy-traffic hours.

UNIT-II

① **General Description of the problem:-** Based on the concept of efficient spectrum utilization, the cellular mobile radio System design Can be broken into many elements. They are

(i) The frequency reuse channels

(ii) The Co-channel interference reduction factor

(iii) The desired Carrier-to-interference ratio

(iv) the hand off mechanism

(v) Cell Splitting.

- **Maximum number of Calls per hour per cell:-** To Calculate the predicted number of Calls per hour per Cell a in each cell, we have to Know the Size of the cell and the traffic Conditions in the Cell.
- **Maximum number of frequency Channels per cell:-** The maximum number of frequency Channels per cell N is Closely related to an average Calling time in the System.

→ If an average Calling time T is 1.76 min and the maximum calls per hour per cell Q_i is

$$A = \frac{Q_i T}{60} \text{ erlangs.}$$

Concept of Frequency Reuse channels:

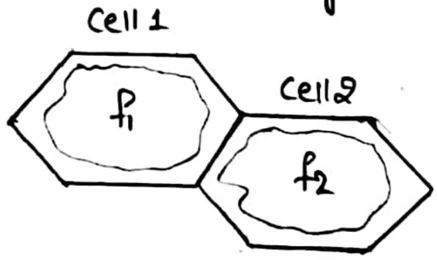
Frequency Reuse:- Frequency reuse is the basic core concept of the cellular Mobile radio system. In this Frequency reuse system, users in different geographic Locations (different cells) may simultaneously use the same Frequeky channel.

The Frequency reuse system can drastically increase the spectrum efficiency, but if the system is not properly designed, serious Interference may occur. Interference due to the common use of the same channel is called Cochannel Interference and is our major concern in the concept of frequency reuse.

Cochannel Interference:-

cochannel Interference is nothing but Interference due to common use of the Same channel

Let us consider 2 cell sites having coverage area frequencies at borders of a 2 cells are f_1 and f_2 respectively. when a person moves from one cellsite to another cellsite the signals may combined and it becomes clumsy.



→ To avoid co-channel Interference, we use frequency Reuse concept.

Example:-

A Radio channel consists of a pair of frequencies, one for each direction of transmission that is used for full-duplex operation. A particular C, Radio system channel, say F_1, used in one geographic zone to call a cell, say C_1, with a coverage radius R can be used in another cell with the same coverage radius at a distance D away.

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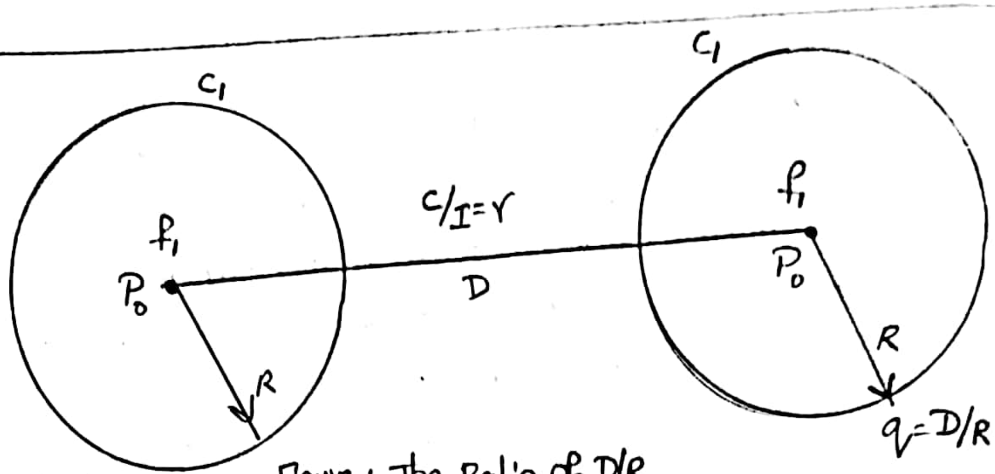


Figure : The Ratio of D/R

Increasing the spectrum efficiency without changing the bandwidth is called as frequency reuse.

In frequency reuse concept handover process occur with same frequencies.

Frequency Reuse schemes :-

The Frequency reuse concept can be used in the time domain and space domain.

1. Time Domain: occupation of same frequency in different time slots called as Time Division Multiplexing (TDM).
2. Space Domain:

   occupation of same frequency in different geographical area

   ex:- FM & AM

   occupation of same frequency Repeatedly in same geographical area

   ex:- Basic cellular system.

Frequency reuse distance :-

The minimum distance which allows the same frequency to be reused will depend on many factors, such as the number of cochannel cells in the vicinity of the center cell, the type of geographic terrain occur, the antenna height, and the transmitted power at each cell site.

The Frequency reuse distance D can be determined from

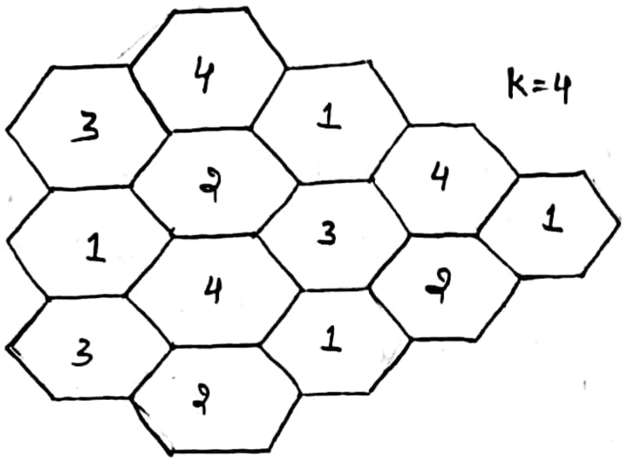
$$D = \sqrt{3K}\,R$$

The total Spectrum allocation is divided into K frequency reuse pattern

K = Cluster size

Available in 4, 7, 12, 19

$$D = \begin{cases} 3.46R & K=4 \\ 4.6R & K=7 \\ 6R & K=12 \\ 7.55R & K=19 \end{cases}$$



$K = i^2 + ij + j^2 = 19$

Shift parameters $i=3,\ j=2$

K=19

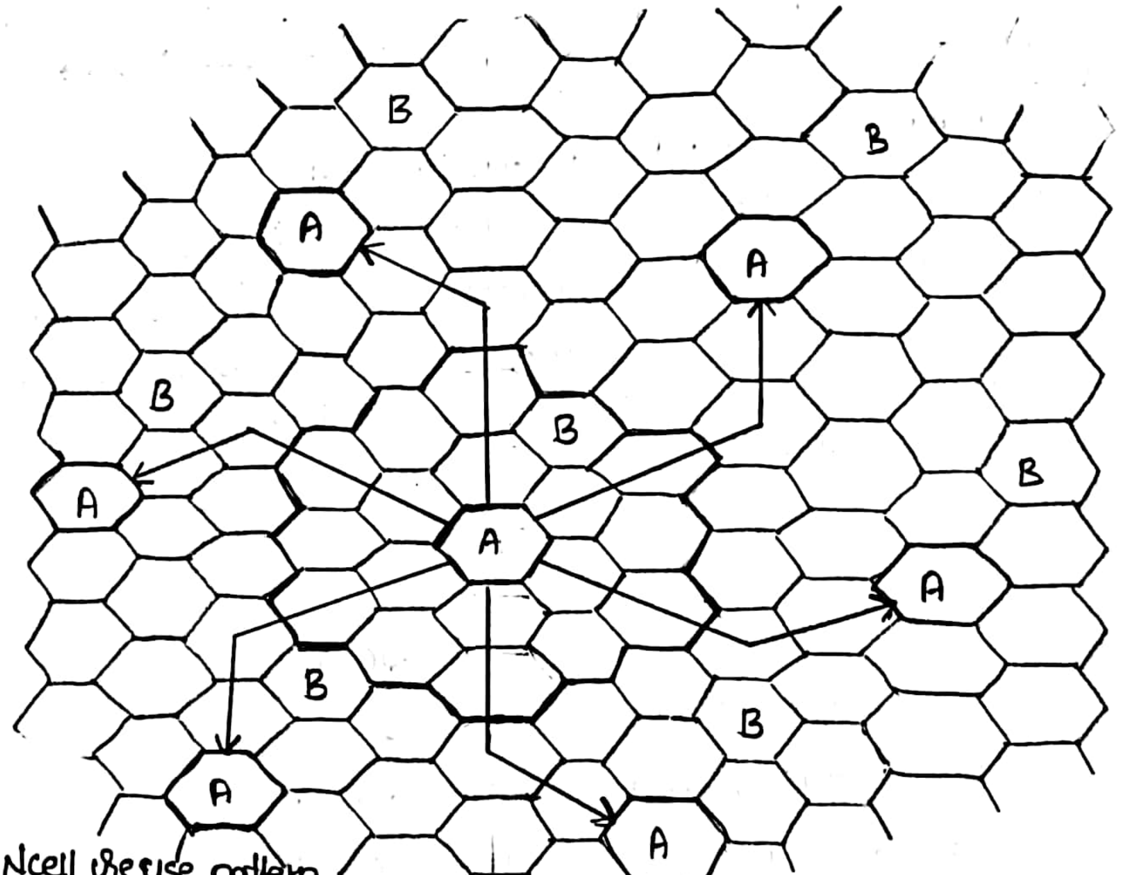


Figure: Ncell reuse pattern

If all the cell sites transmit the same power, then K increases and the frequency Reuse distance D increases. This increased D reduces the chance that cochannel Interference may occur.

When K is too Large, the number of channels assigned to each of K cells becomes small. It is always true that if the

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Cochannel Interference Reduction Factor:-

Reusing an identical frequency channel in different cells is limited by co channel interference between cells, and the Cochannel Interference can become a major problem. Here we would like to find the minimum frequency reuse distance in order to reduce this cochannel Interference.

$$\therefore q = \frac{D}{R} \longrightarrow (1)$$

when the ratio "q" increases co-channel interference decreases.

q = co-channel Interference Reduction factor

D = Distance between the cells

R = Radius of each cell from centre.

It means that the received threshold level at the mobile unit is adjusted to the size of the cell. Actually, co-channel Interference is a function of a parameter q defined.

$$D = f(k_I, C/I) \longrightarrow (2)$$

k_I = No. of cells

C/I = carrier to Interference Ratio

$$\frac{C}{I} = \frac{C}{\sum_{k=1}^{k_I} I_k} \longrightarrow (3)$$

* In a fully equipped hexagonal shaped cellular System, there are always six co-channel interfering cells in the first tier as shown in Fig (a) that is, $k_I = 6$.

* Co-channel Interference can be experienced both at the cell site and at mobile units in the center cell.

* If the interference is much greater, then the carrier to interference ratio (C/I) at the mobile units caused by the six interfering sites is the same as the C/I received at the center cell site caused by interfacing mobile units in the six cells.

* Assume the local noise is much less than the interference level and can be neglected.

Then C/I can be expressed as

$$C/I = \frac{R^{-\gamma}}{\sum_{k=1}^{K_t} D_k^{-\gamma}} \longrightarrow (4)$$

γ = propogation path loss

where γ is a propogation path loss slope determined by the actual terrain environment.

The six co-channel Interfering cells in the second tier of cause weaker interference than those in the first tier.

∴ The co-channel interference from the second tier of interfering cells is negligible.

$$C/I = \frac{1}{\sum_{k=1}^{K_t} \left(\frac{D_k}{R}\right)^{-\gamma}}$$

$$= \frac{1}{\sum_{k=1}^{K_t} (q_k)^{-\gamma}}$$

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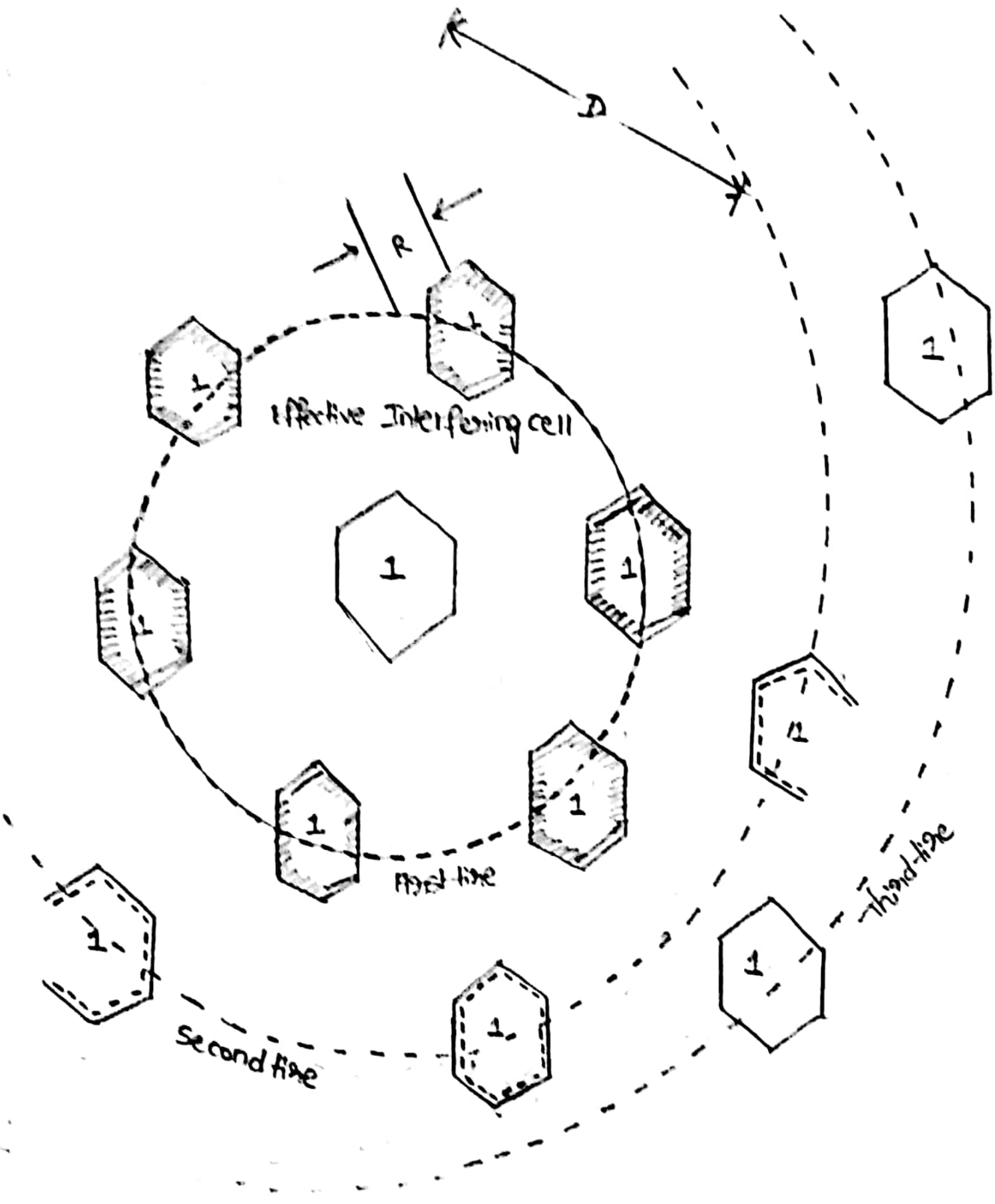

Figure (a) : Six effective interfering cells of cell 1

Desired C/I from a Normal case in an Omnidirectional Antenna System:

There are two cases to be considered:

(i) the Signal and co-channel interference received by the mobile unit.

(ii) the Signal and co-channel interference received by the cell site.

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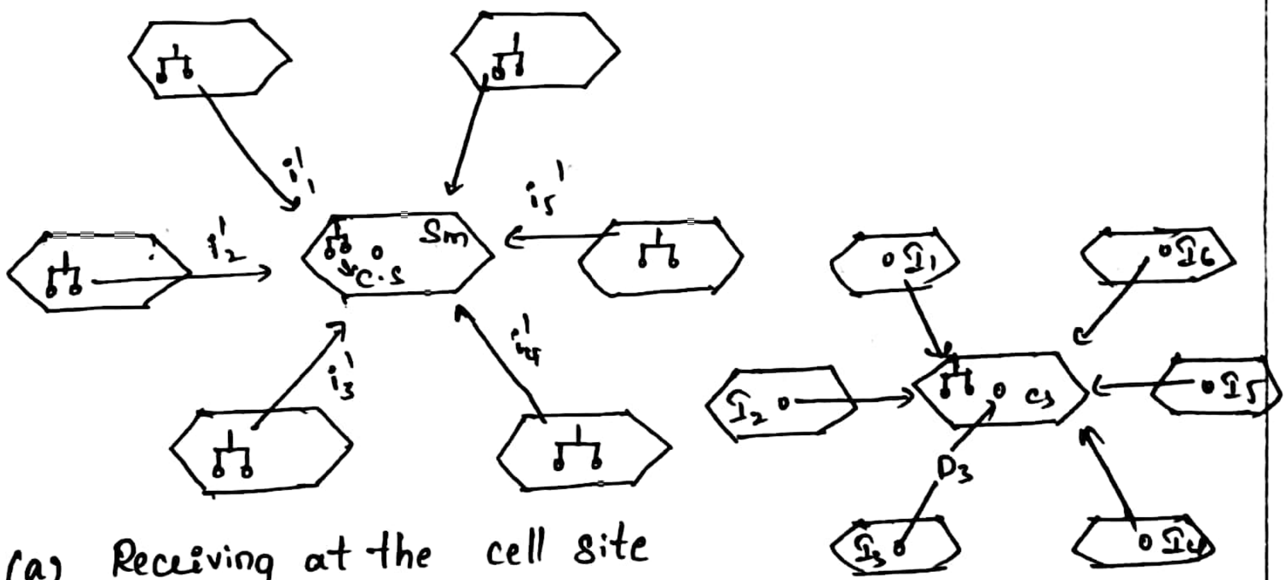
* Usually N_m and N_b are small and can be neglected as compared with the interference level.

Fig: co-channel interference from six interference



(a) Receiving at the cell site

(b) Receiving at the mobile unit

* As long as the received carrier to interference ratios at both the mobile unit and the cell site are the same, the system is called a balanced System.

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* Assume that all D_k are the same for simplicity as shown in Fig a, then $D = D_k$ and $q = q_k$

$$\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^{\gamma}}{6}$$

Thus, $q^{\gamma} = 6\left(\frac{C}{I}\right)$

$$q = \left(6\frac{C}{I}\right)^{1/\gamma}$$

where

q = co-channel interference reduction factor

C/I = carrier to interference ratio

γ = propogation path loss

and $q = D/R$

* The greater the value of q, the lower the co-channel interference.

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→ System Capacity :-

(or)

Number of channels in a cellular system :-

→ In order to compute the capacity in a wireless cellular system we first make a few definations

let

S = no. of channels (or) frequencies available per cluster

K = no. of channels per cell.

N = no. of cells per cluster.

observe $\boxed{S = KN}$ (channel per cluster

Now, let

M = no. of cluster per entire s/m (system)

C = total no. of channels available per s/m

→ the number 'C' which is a measure of the capacity of the s/m.

→ It is very important to the service provides since it determines the maximum traffic capacity that can be sold by the service provider.

→ The higher the capacity the higher the potential revenue to the service provider.

$$C = MS$$

$$\boxed{C = MKN}$$

→ A Large cluster Size (N) indicates that the ratio between the cell radius and the distance between co-channel cells is Large.

→ Conversely, a Small cluster Size (N) indicates that co-channel cells are located much closer together.

→ The value for N is a function of how much interference a mobile or base station can tolerate while maintaining a sufficient quality of communications.

→ The Frequency reuse factor of a cellular system is given by 1/N, since each cell within a cluster is only assigned 1/N of the total avaliable channels in the system.

Hexagonal shaped cells :-

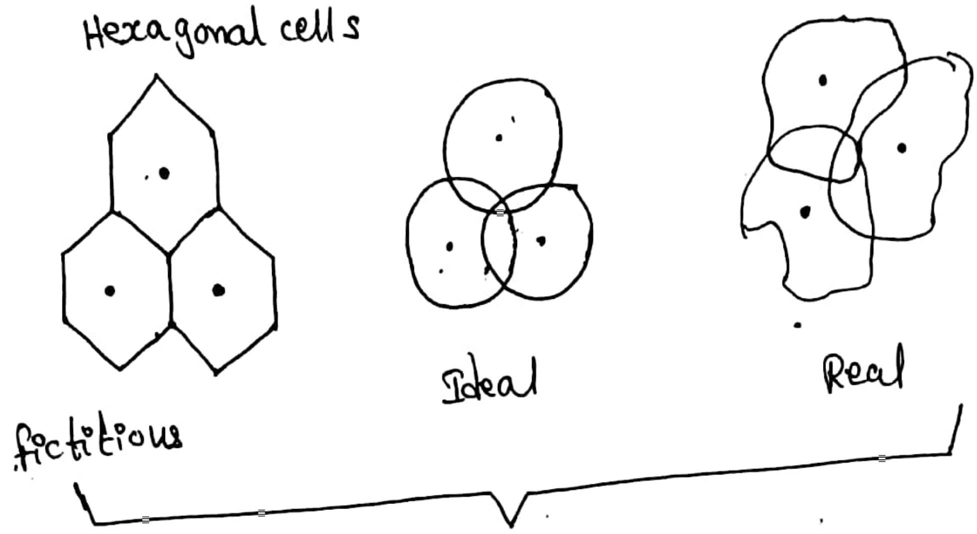

fig: Hexagonal cells and the real shapes of their coverages.

⟹ Hexagonal - shaped communication cells are artificial and that such a shape cannot be generated in the real world.

⟹ Engineers draw hexagonal- shaped cells on a layout to simplify the planning and design of a cellular system because it approaches a circular shape that is the ideal power coverage area.

⟹ The circular shapes have overlapped areas which make the drawing unclear.

⟹ The hexagonal-shaped cells fit the planned area nicely with no gap and no overlap between the hexagonal cells.

Problem

① If the Maximum number of calls per hour Q_i in one cell be 5000 and an average calling time T be 1.76 Minutes. The blocking Probability is 2%. Find the offered load, if Q_i is 3000. Find the offered load. Compare this with no of channels by using Erlang B Model charts.

Sol: Given that,

Max. no of calls per hour Q_i = 5000/hr

Avg calling time T = 1.76 min

Blocking Probability B = 2%.

If Q_i = 30000, offered load A = ?

Then the Expression for offered load is given by

$$A = \frac{Q_i(\text{per hour})\,T(\text{min})}{60}$$

$$= \frac{5000 \times 1.76}{60}$$

$$= 146.67 \text{ Erlangs.}$$

∴ A = 146.67 Erlangs

If the Maximum number of calls per hour Q_i = 30000

Then the respective offered load is obtained as

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$$A = \frac{Q_i \text{ (per hour)} \cdot T \text{ (min)}}{60}$$

$$= \frac{30000 \times 1.76}{60}$$

$$= 880 \text{ Erlangs.}$$

$$\therefore A = 880 \text{ Erlangs}$$

For A = 46.67 Erlangs and B = 2%. The respective No of channels can be obtained using Erlang B Model Chart, are

$$N = 160$$

For A = 880 Erlangs and B = 2% the respective No of channels can be obtained by using Erlang B Model chart are

$$N \cong 900$$

Thus, from the above result it is evident that, if the value of offered load increases, the No of channels also increases.

→ As users increases channel capacity decreases some Techniques are needed to provide extra channels.

→ frequency reuse

→ cell splitting.

(20)

Need for cell splitting :-

cell splitting is one of the concept which can be used to improve the utilization of spectrum efficiency in a cellular mobile system.

Usually, the original cell can be split into smaller cells when,

1. Traffic density starts to build up.
2. The frequency channels in each cell cannot provide enough mobile calls.
3. To make more voice channels available to accommodate traffic growth in the area covered by the original cell.

cell splitting :-

cell splitting.

when the traffic density is more in the system then the frequency channel present in a cell must provide enough mobile calls hence the original cell can be split into smaller cells, which is known as cell splitting. (21)

If the radius of a cell is reduced from R to $\frac{R}{2}$. The area of the cell is reduced from area to $\frac{Area}{4}$. However, the number of available channels is also increased.

i.e. If radius of new cell $= \frac{\text{Radius of old cell}}{2}$ → (1)

Then,

Area of new cell $= \frac{\text{Area of old cell}}{4}$ → (2)

Assume that, the maximum traffic load carried by the new cell is same as that of old cell. Then,

$$\frac{\text{New traffic load}}{\text{Unit area}} = 4 \times \frac{\text{traffic load}}{\text{Unit area}} \rightarrow (3)$$

Fig (1) shows the two different ways of splitting. The original cell site is not used in the earlier case, whereas it is used in the former case. Cell splitting is usually done on demand. When in a certain cell there is too much traffic which causes too much blocking of calls. The cell is split into smaller micro cells

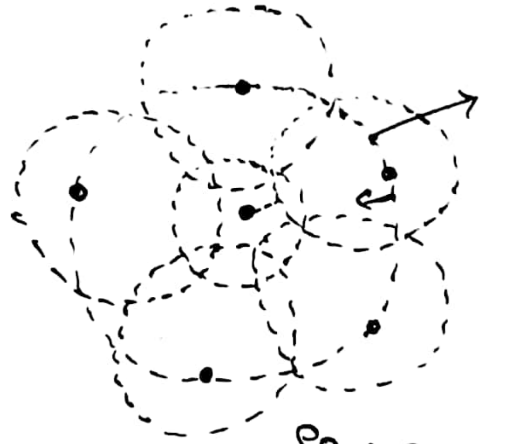

fig (a)

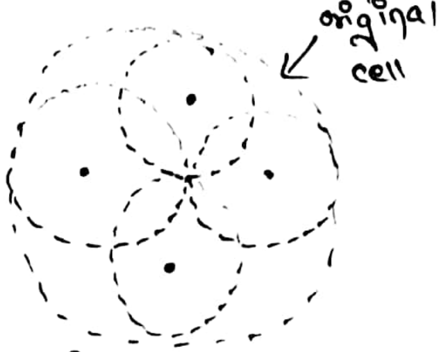

fig (b)

Basically, the cell splitting techniques are of two types. They are

(1) Permanent splitting :-

In this technique we need to plan the Installation of every new split cell ahead of time. The parameters which are to be considered in this splitting are,

(i) No of channels
(ii) Txed Power
(iii) Assigned frequencies
(iv) choosing of the cell site selection
(v) Traffic load consideration.

As long as the cut over from large cells to small cells takes place during a low traffic period, handling of these splitting can be very easy. Because of this cut over only a few calls will be dropped. The downtime of the system assumed should be within 2 hrs. The rule which is to be followed by the frequency assignment is based on the frequency reuse distance ratio 'q' with the power adjustment

2. Dynamic splitting:-

⇒ This technique is also referred as real time splitting. In this technique, the splitting is based on utilizing the allocated spectrum efficiency in real time. The algorithm for dynamically splitting cell sites is a tedious job, since we cannot afford to have one single cell unused during cell splitting procedure handling made easy by using a software algorithm programs.

The two consideration which are to be made in the maintenance of frequency reuse distance ratio 'q' by the cell splitting process in a system are,

(i) Cell splitting affects the neighbouring cells.

(ii) Particular channels should be used as barriers.

Drawback of cell splitting:-

(1) In practice not all cells are split simultaneously therefore we may have cells of different sizes.

(2) Also the Hand-off b/w the cells and micro cells has to be taken care off so that, high speed & low speed mobiles are equally served.

(3) Decreasing cell size results in more hand-off per call and higher processing load per subscriber. Thus, the hand-off rate will increase approximately.

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* Cellular structure:-

→ Macro cells:-

* These cells are the base stations that provide Coverage to a Large area With Inter Site Distance (ISD) from hundreds of meters to several Kilometers.

* They fulfill the baseline Coverage for any LTE Network, Providing Connectivity and up all the time.

* The Power Consumption varies from 100W to 450W. they have Sectored antennas normal Covering 120 degrees per Seconds.

→ Microcells:-

* Micro cells have lower transmit Power than macro BSs. they are Smaller base stations with full features that are used to Cover both indoor and Outdoor Crowded areas.

* It can typically Cover a range of few meter to One or two Kilometers.

* The power Consumption ranges from 50W to 150W

* They are generally used for indoor purposes as Well as outdoor Such as hot-spots.

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Pico cells:-

* Pico cells have lower transmit Power than macro BSs, they have Omnidirectional antennas unlike macro BSs which are Sectored
* The transmits Power Ranges from 250mW to 2W They are generally used for indoor Purposes around hot-spots like officers, railway Stations etc.

* Femto cell:-

* Femto cells are also known as HeNBs (H e NodeB) are deployment for Small rooms and home requirements generally for a very Small range Coverage less than 30m.
* They have Omnidirectional antennas, transmit Power in around 100mV.
* They Could be plugged is using a DSL Line or Modern Cable.

problems

*An antenna has $D = 4$, $P_{rad} = 40\Omega$, $R_{div} = 10\Omega$ find antenna efficiency and Maximum Power gain?

A Given that

For an antenna,

Directivity $D = 4$

Radiation resistance, $R_{rad} = 40\Omega$

dissipation resistance, $R_{rad} = 10\Omega$

Antenna Efficiency $\eta = ?$

Max Power gain, $G_{P(max)} = ?$

Then, the expression for efficiency of an antenna is given by.

$$\text{Efficiency } \eta = \frac{R_{rad}}{R_{rad} + R_{div}}$$

$$\eta = \frac{40}{40+10} = \frac{40}{50} = 0.8$$

$$= 0.8 \times 100\%$$

$$= 80\%$$

$$\eta = 80\%$$

Then, the Expression for Max Power gain in term of directivity and Efficiency of antenna is given by..

$$G_{P(max)} = \eta D$$

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0.8×4

$= 3.2$

And $G_{pmax}(dB) = 10\log_{10} 3.2$

$= 5.05 dB$

$G_{p(max)} = 5.05 dB$

2.) During busy hour, the number of calls per hour Q_i for each 10 cells is 2000, 1500, 3000 1000, 1200, 1800, 3200, 2600 & 800 Assume that 60 of the car phones will be used during this period and that one call is made per car phone find the no. of customer in the system?

A) Given that

In a cellular system during a busy hour, the Number of call per hour for each to cell is,

$Q_1 = 2000$; $Q_2 = 1500$; $Q_3 = 3000$, $Q_4 = 500$

$Q_5 = 1000$, $Q_6 = 1200$, $Q_7 = 1800$

$Q_9 = 2600$, $Q_{10} = 800$

The Percentage of car phones used during the busy period $\eta = 60\%$.

Total no. of customers in the s/m M_t = ?

Then, the total no. of calls per hour per hour per car phone is given.

$$Q_t = \sum_{i=1}^{10} Q_i$$

$Q_i = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9 + Q_{10}$

$1000 + 500 + 3000 + 500 + 1000 + 1200 + 2600 + 800$

$= 17600$

$Q_t = 17600$ calls per hour.

The total no. of customers in the system is given bus

$$M_t = \frac{Q_t}{\eta}$$

$$= \frac{17600}{0.6}$$

$= 29333.33$

$M_t \simeq 29334.$

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* Cell Sectoring: * Decrease Interference.
* Increase channel capacity

→ Cell are divided into a number of Wedge -Sharped Sectors, each with their own Set of channels.

→ Sectoring:- Sectoring is another way to increase capacity. In Sectoring, a cell has the Same Coverage Space but instead of using a Single Omni-directional antenna that transmits in all directions, either three or Six directional antennas are used and each with beamwidth of about 120° or 60° ~~as~~ Shown in

→ Each Sector Causes interferences to the cells that are in its transmission angle only.

→ Unlike the Case of no Sectoring Where Six interfering Co-channel cells from the first-tier Co-channels cells Cause interference, With 120° Sectoring, two or three Co-channel cells Cause interfacing and With 60° Sectoring One or two Co-channel cells Cause interference.

→ Figure 2.25 Shows the Case of cluster Size of N=4 in Which only two of the Six Co-chann

Cells cause interference to the middle cell for the sector labelled S_2 in the case of 120° cell sectoring.

→ The other four cells, although they are radiating at the same frequencies cause no interferences because the middle cell is not in their radiation angles.

→ For the case of 60° cell sectoring, only one cell causes interference. The number co-channel interfering cell depends on the cluster shape and size.

→ The CIR must now be modified from

$$\frac{C}{I} = \frac{1}{6(q)} = \frac{q}{6}$$ (due to six interfering cells)

$$\frac{C}{I} = \frac{1}{2(q)} = \frac{q}{2}$$ (due to two interfering cell).

→ Where q is the co-channel interference reduction factor and g = is the path loss exponential constant

→ The denominator has been reduced from 6 to 2 to account for the reduced number of interference sources

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fig: Normall cell.

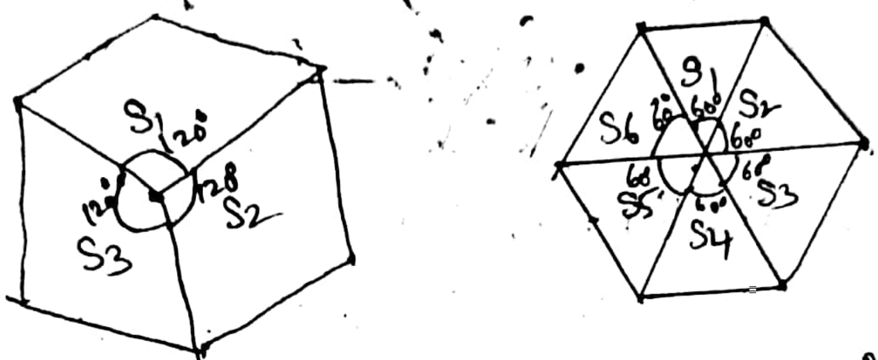

fig: 2.23: A cell divided into (a) 120° and (b) 60°

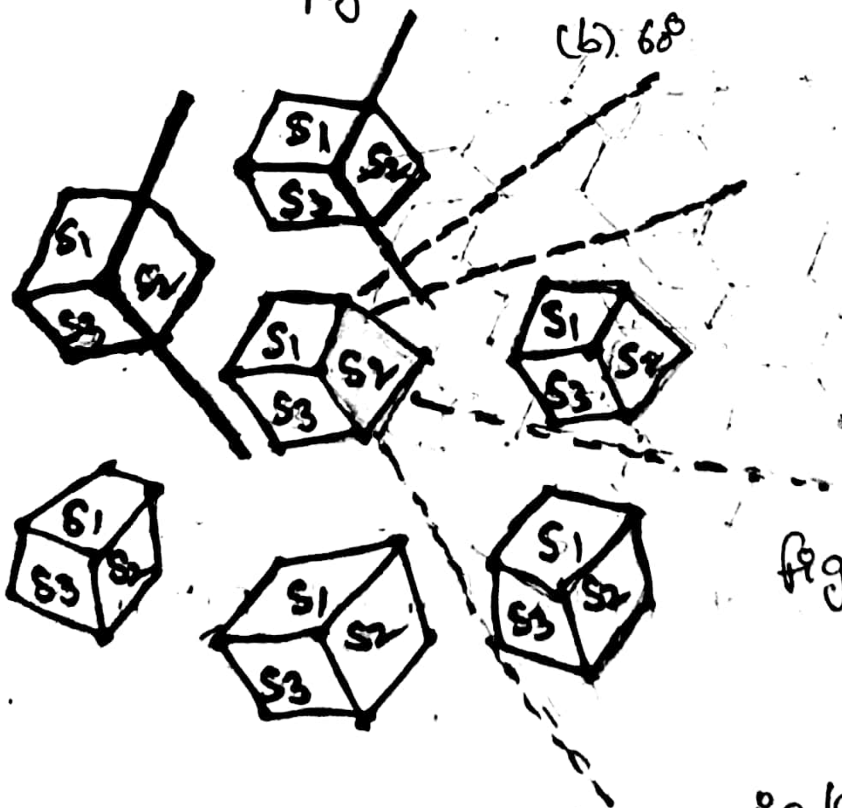

fig (a)

fig:- 2.25 Interference in (a) 120° and (b) 60° cell sectoring.

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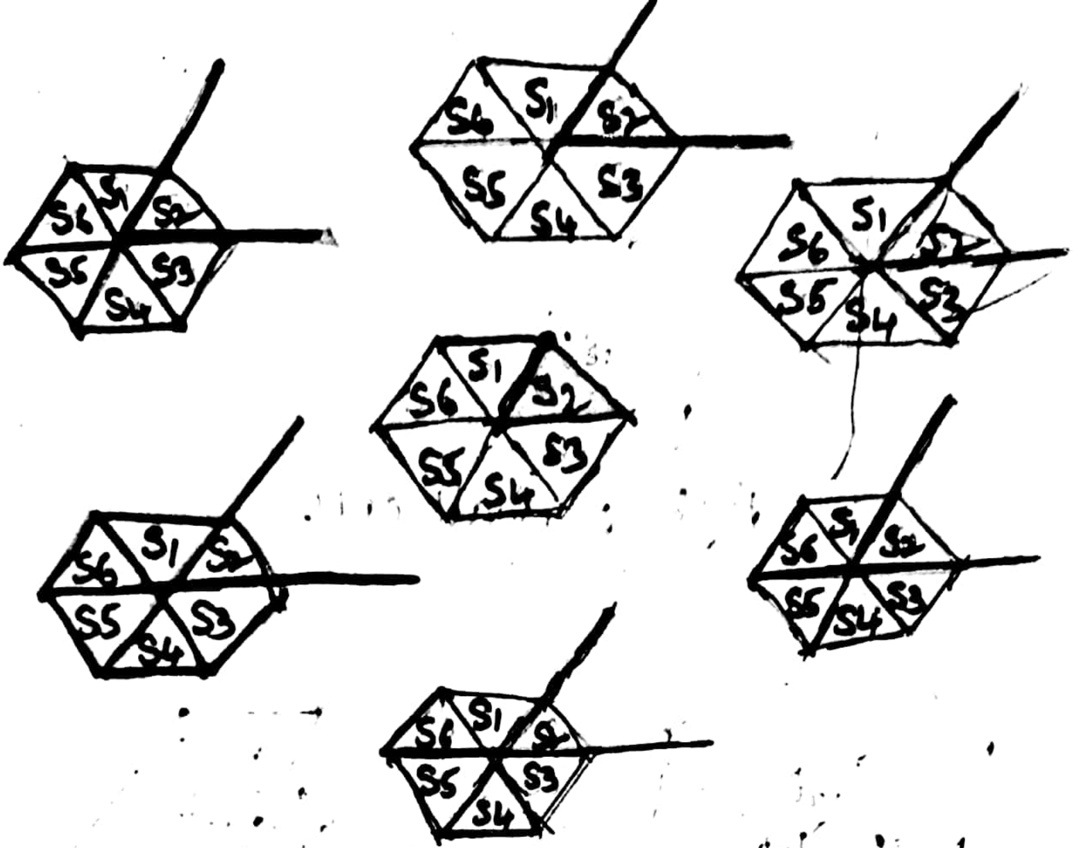

fig: (b) 2.25 Interference in (b) 60° cell sectoring.

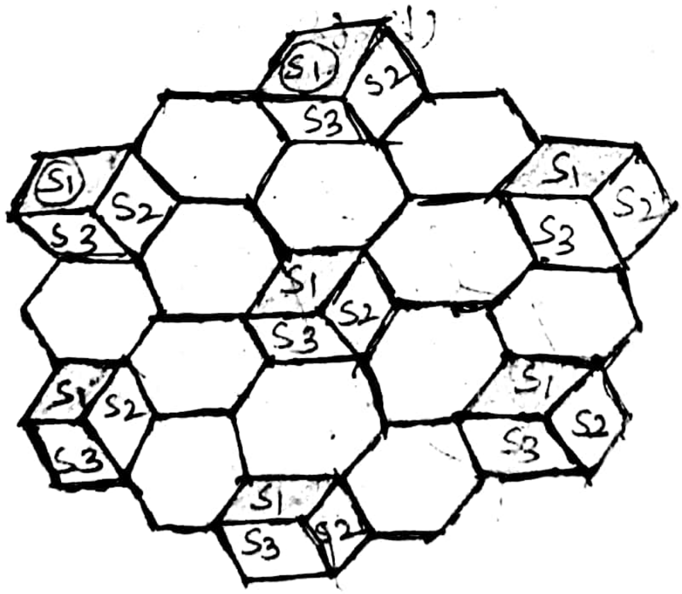

fig:- 2.24 Sectoring for four cell pattern

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→ In addition to the reduced number of interfacing towers that Sectoring Produces, the SIR is increased for the Same cluster size.

→ And another Problem With Sectoring is that dividing a cell into Sectors requires that a call in Progress will have to be handed off when a mobile unit travels into new Sector.

→ Although the need of hand offs between Sector as well as between cells does not directly reduce the number of Customers that Can be Supported, it does increase the complexity of the system needed to support them.

Handoff:-

- The handoff is an important cellular concept that is implemented on voice channels.
- To maintain a call in progress inspite of movement of subscriber from one cell to another cell handoff is applied.
- Handoff is required in two main situations.
  1) At a cell boundary (signal strength - 100dB)
  2) whenever the mobile reaches a hole/gap within the cell.

Types of handoff:-

There are two main types of handoff available.

a) Handoffs based on the signal strength (SS)

b) Handoff based on the carrier-to-interference (C/I).

- In Type(a), the signal-strength threshold level for handoff is -100dBm in noise-limited systems and -95dBm in interference limited systems.
- In Type(b), the value of C/I at the cell boundary for handoff should be 18dB in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

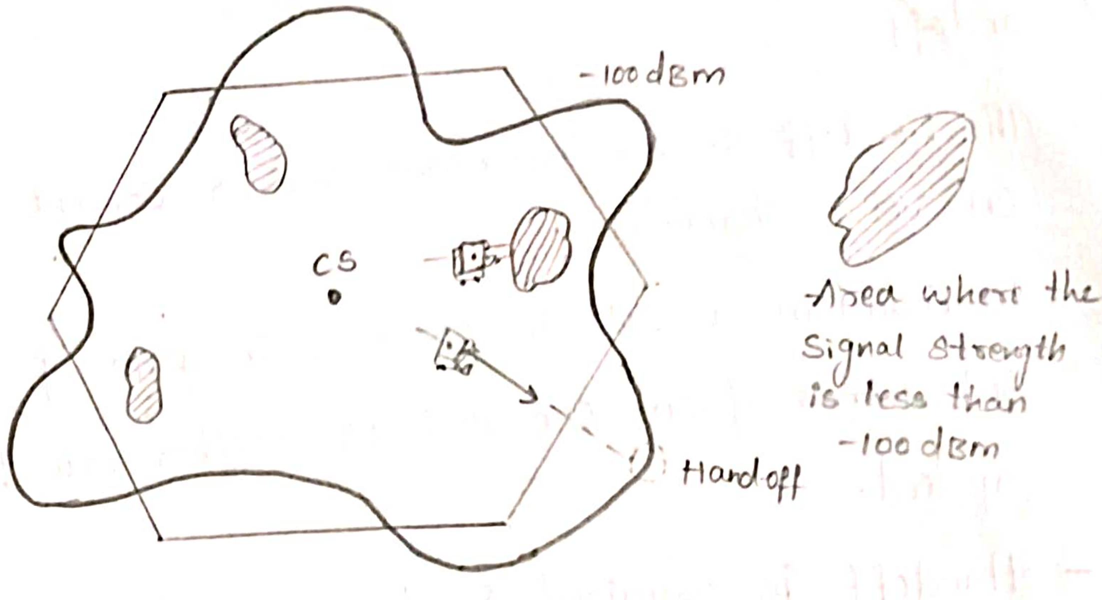


Fig: Occurrence of handoff.

- Received signal strength (RSS) = C+I ⟶ ①

  Where C ⟶ carrier signal power

  I ⟶ Interference level

- If C/I drops in a cell and if the occurance of handoffs is dependent on C/I then in this case as a response to drop C/I either the propagation distance or interference will increase.

Handoffs can be controlled by using the carrier-to-interference ratio C/I

$$\frac{C+I}{I} \approx \frac{C}{I} \longrightarrow ②$$

In eq ②, we can set a level based on C/I, so C drops as a function of distance but I is dependent on the location.

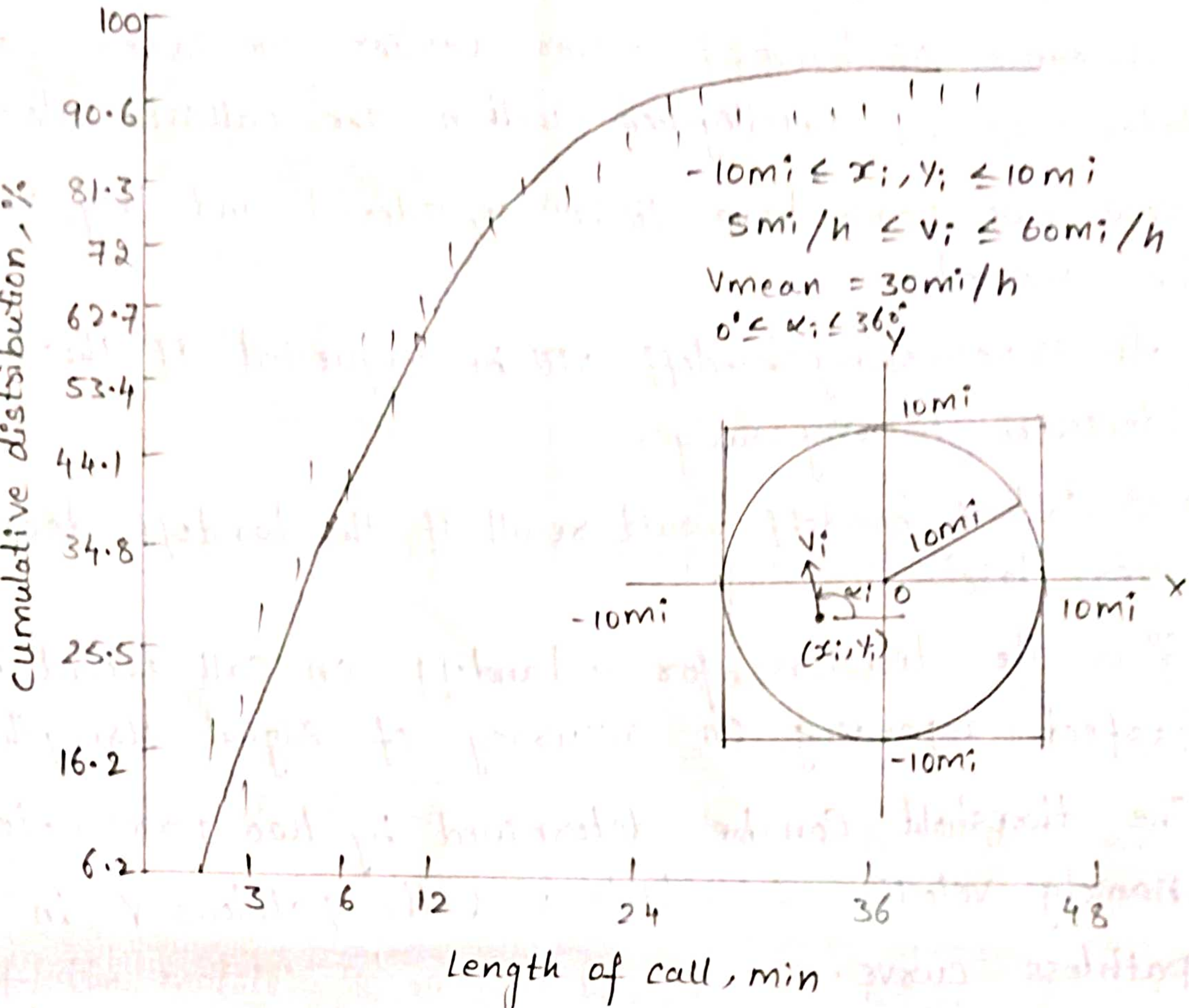


fig:- The probability of requiring handoff

0.2 handoff per call in a 16- to 24-km cell

1-2 handoff per call in a 3.2- to 8-km cell

3-4 handoff per call in a 1.6- to 3.2-km cell.

Initiation of a Handoff :-

- In the cell site the signal strength is continously monitored using a reverse voice channel. Depending on the strength the decision for handoff is made.
- If the signal strength reaches a level that is higher than the threshold level set for minimum voice quality, cellsite will request the switching office (MTSO) for handoff to

continue the call.

- Occurance of handoff either earlier or later can be determined by intelligence within the cellsite also

- Now two points have to be considered and they should be avoided.

1) An unneccessary handoff will be requested if the handoff decision is very early.

2) A failure handoff would result if the handoff decision is very late.

- Thus the decision for a handoff on call should be perfect depending on accuracy of signal strength measured

- The threshold can be determined by two parameters namely velocity of vehicle 'v' & the pathloss γ in the pathloss curve.

- Assume the threshold level is -100dBm at cell boundary. To have a handoff here the signal strength level should be higher than -100dBm (Δ).

- If signal strength is = -100dBm + ΔdB then a request for handoff will be initiated. The value of Δ should not be too large or too small so that proper handoff initiation at right time will be made.

- We can calculate the velocity v of the mobile unit based on the predicted level-crossing rate (LCR) at a -10dB level with respect to the root-mean-square (rms) level, which is at -90dBm; thus.

$$V = \begin{cases} \dfrac{n\lambda}{\sqrt{2\pi}\,(0.27)} & ft/s \\ n\lambda & mi/h \end{cases} \quad \text{at } -10\text{-dB level.}$$

where n is the LCR (crossing per second) counting positive slopes and λ is the wavelength in feet.

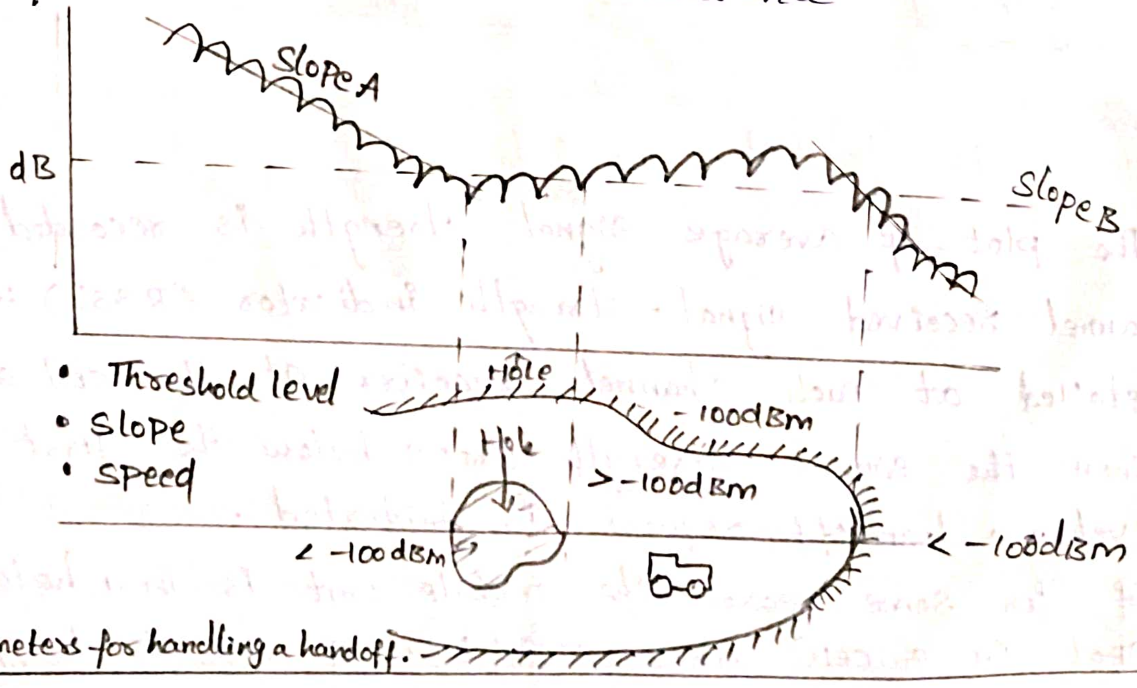
V(mi/h) ≈ n (crossings/s) at 850 MHz and a −10-dB level

- Handoff may be necessary but can't be done at following cases.

1) mobile is at signal strength hole & not at cell boundary.

2) If the mobile is at cell boundary but no channel in the new cell is available to make handoffs.

- In these cases MTSO has to take step to make handoff faster before a dropped call occurance.



- Threshold level
- slope
- speed

fig:- parameters for handling a handoff.

⇒ Delaying a handoff :-

- when a base station wants to handover the call to the base station of new cell where the subscriber enters, the new base station will accept it & takes call control.
- This smooth handoff is possible only if the new cell is free to take it. If there the cell not available (free) then the handoff will be delayed. This is known as delayed handoff.

Two-handoff-level algorithm.

- The purpose of creating two request handoff level is to provide more opportunity for a successful handoff.

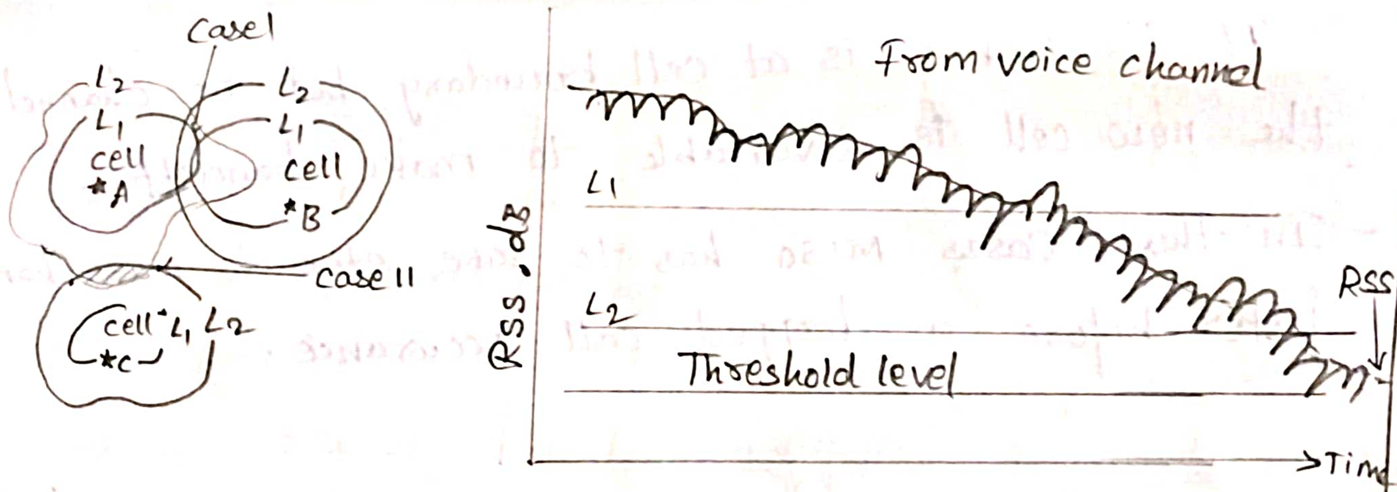


fig:- A two-level handoff scheme.

- The plot of average signal strength is recorded on the channel received signal-strength indicator (RSSI) which is installed at each channel receiver at the cell site.
- When the signal strength drops below the first handoff level, a handoff request is initiated.
- If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighbouring cell is busy, then

handoff will be requested periodically every 5s.

- At the first handoff level, the handoff takes place if the new signal is stronger. However when the second handoff level is reached, the call will be handed off with no condition.

- The MTSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below, the threshold level, then call is dropped. If the supervisory Audio tone (SAT) is not sent back to the cell site by the mobile unit within 5s the cell site ~~turns~~ turns off the transmitter.

<u>Advantages of Delayed handoff</u>

1) If the neighbouring cells are busy delayed handoff helps to continue the call in progress smoothly till the new cell gets free.

2) In two-handoff-level algorithm only after the second handoff the call will be dropped. Thus probability of call blocking is very less.

3) This algorithm also makes handoff to take make at correct location.

4) The algorithm minimizes interference in the system.

⇒ Forced Handoffs:-

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

Controlling a handoff:

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer or assign a high handoff threshold level to request a handoff earlier. The MTSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

Creating a handoff:

In this case, the cell site does not request a handoff but the MTSO finds that some cells are too congested while others are not. Then the MTSO can request cell sites to create early handoffs for those congested cells. In other words, a cell site has to follow the MTSO's order & increase the handoff threshold to push the mobile units at the new boundary and to hand off earlier.

Cell-site hand-off :-

* If the mobile unit is moving from one cell site to the other a new voice channels is assigned to that mobile unit by removing the existing channel
* Usually hand-off is given to the mobile unit by following the procedure
* If the mobile unit is, leaving the host cell site and entering into adjacent cell site if the mobile unit is accepted by the adjacent cell sites with same channel then it is considered as cell site hand-off.

Queuing of hand-off :-

* Thousands of cell sites and a large numbers of mobile units are associated to the cellular systems
* Therefore huge number of hand-off requests are placed at MTSO for execution per second
* Queuing of hand-off is the most effective technique for execution of hand-off based on loading in the adjacent cell site
* If hand-off requests are reaching to MTSO in large number then queuing is required.
* If queuing is implemented and hand-offs are executed properly by the MTSO then no blocking and number of dropped calls in the system.
* Based on queuing of hand-offs the following '3' conditions are considered in cellular system.

i) No queuing on either the originating cells or the hand-off calls

* Non-availability of channels leads to blocking of originating calls
* It is given by

$$B_0 = \frac{A^N}{N!} P(0) \quad \text{—— (1)}$$

where,

$$P(0)_{oq} = \left[\sum_{n=0}^{N} \frac{A^N}{n!} \right]^{-1} \quad \text{—— (2)}$$

where, A = Total number of calls

N = number of voice calls

$$A = \frac{\lambda_1 + \lambda_2}{\mu}$$

here, $\frac{1}{\mu}$ = Average calling time (sec)

λ_1 = Arrival rate for originating calls

λ_2 = Arrival rate for hand-off calls

ii) Queuing the originating calls but not hand-off calls :-

* Blocking reduces if originated calls are queued.
* The blocking probability for originating calls is given by,

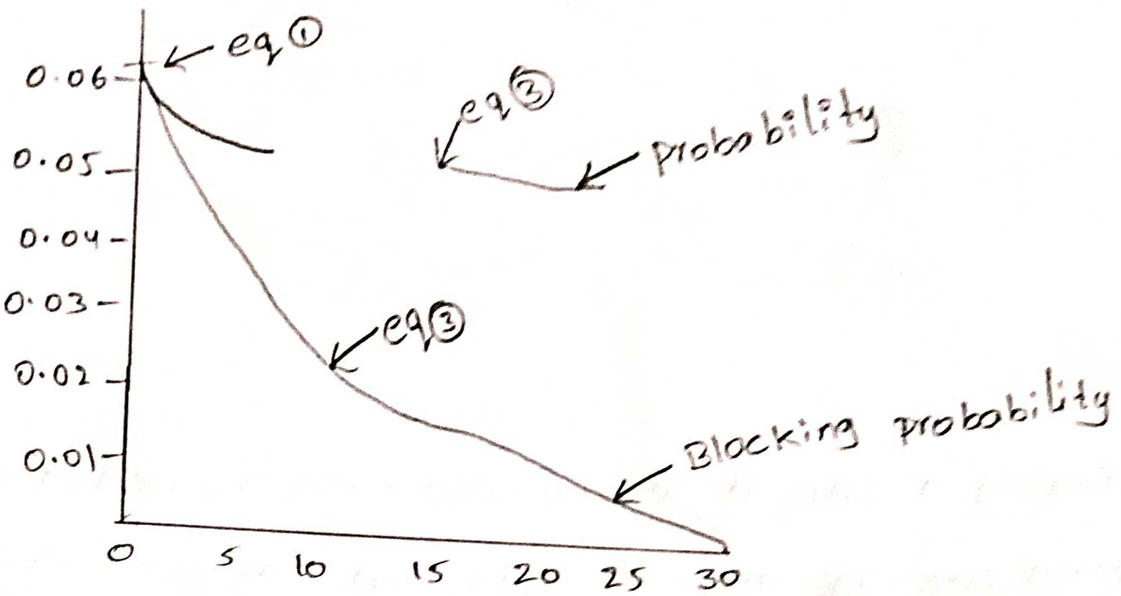
$$B_{eq} = \left[\frac{b_1}{N}\right]^{M_1} P_q(0) \quad \text{—— (3)}$$

where, b_1 = Total number of originating calls

$$= \frac{\lambda_1}{\mu}$$

$$P_q(0) = \left[N! \sum_{n=0}^{N} \frac{A^N}{N!} + \frac{1 - (b_1/N)^{M_1+1}}{1 - (b_1/N)} \right]^{-1} \quad \text{—— (4)}$$

→ fig-1 shows the plot for blocking probability of originate call



(figure-1)

→ As handoff calls are not queued

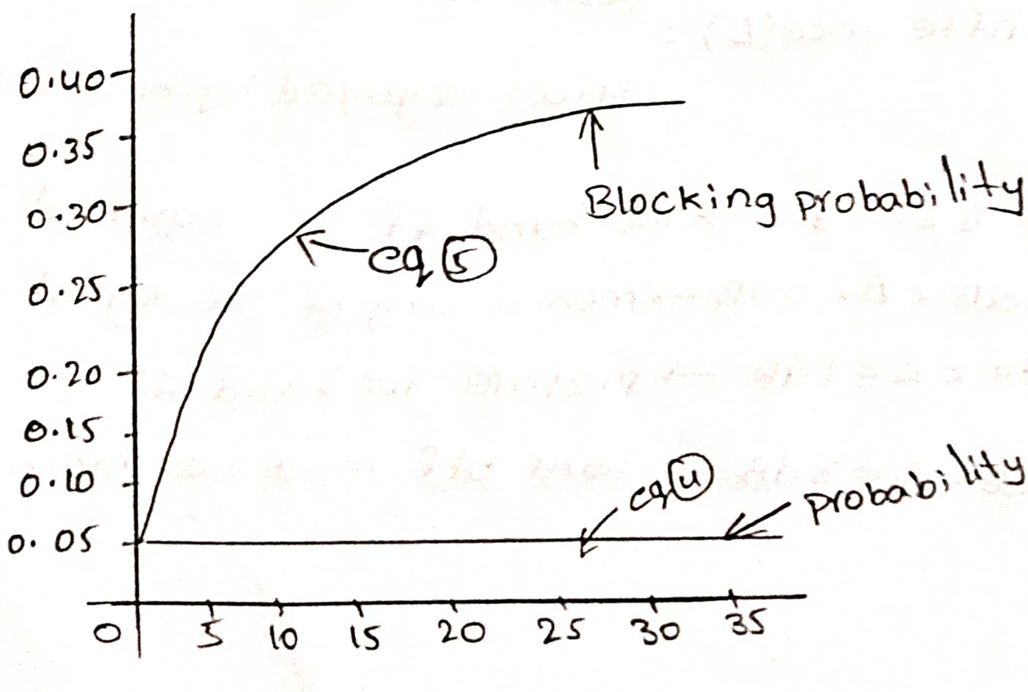
→ The blocking probability for handoff calls is given by

$$B_{oh} = \frac{1-(b_1/N)^{M+1}}{1-(b_1/N)} P_q(0) \rightarrow ⑤$$

where,

M_1 = size of queue for originating calls

→ fig-2 show the plot for blocking probability of handoff calls



iii) Queing the hand-off calls but not the originating calls

* If hand-off cells are queued then the blocking reduces when compared to case ii)
* The blocking probability for the hand-off calls is given by,

$$B_{hq} = \left(\frac{b_2}{N}\right)^{M_2} P_q(0) \qquad (6)$$

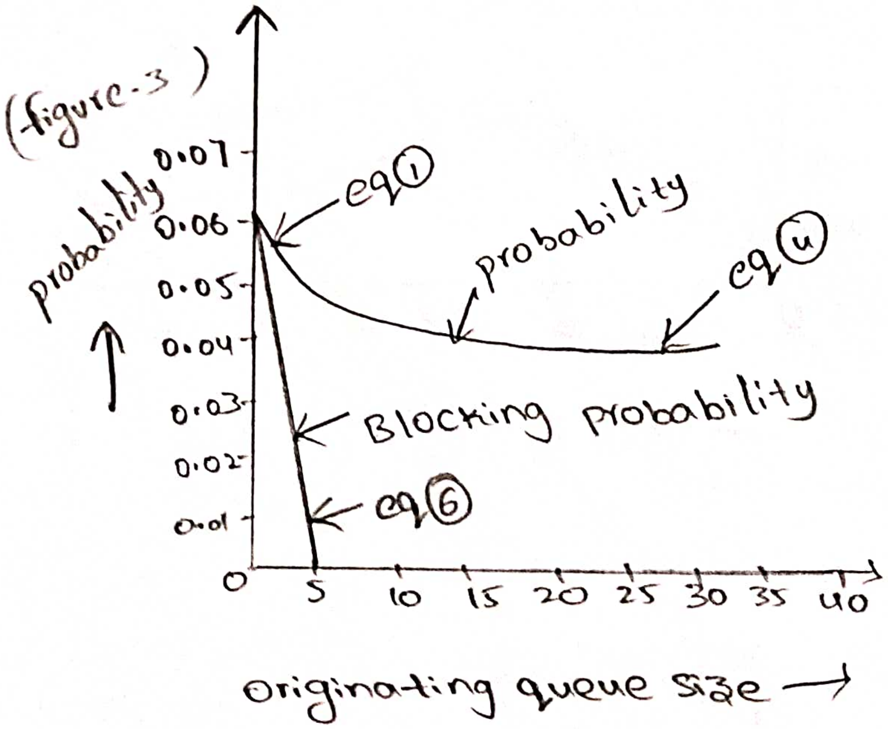
where,

M_2 = Sizes of queue for hand-off calls

b_2 = Total number of hand-off calls.

$$b_2 = \frac{\lambda_2}{\mu}$$

→ figure-3, shows that the plot for blocking probability of hand-off calls.

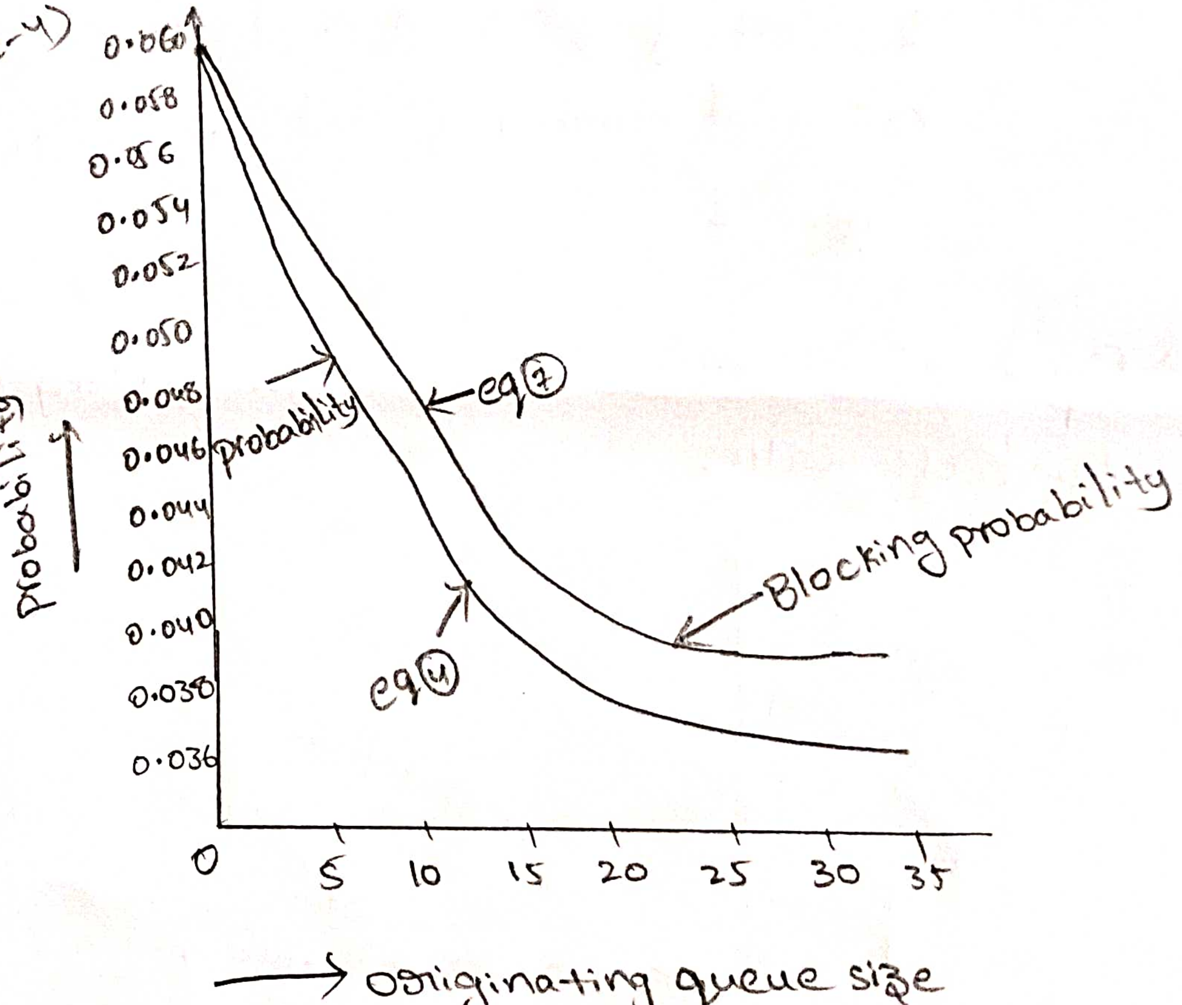


* The blocking probability for originating calls is given by

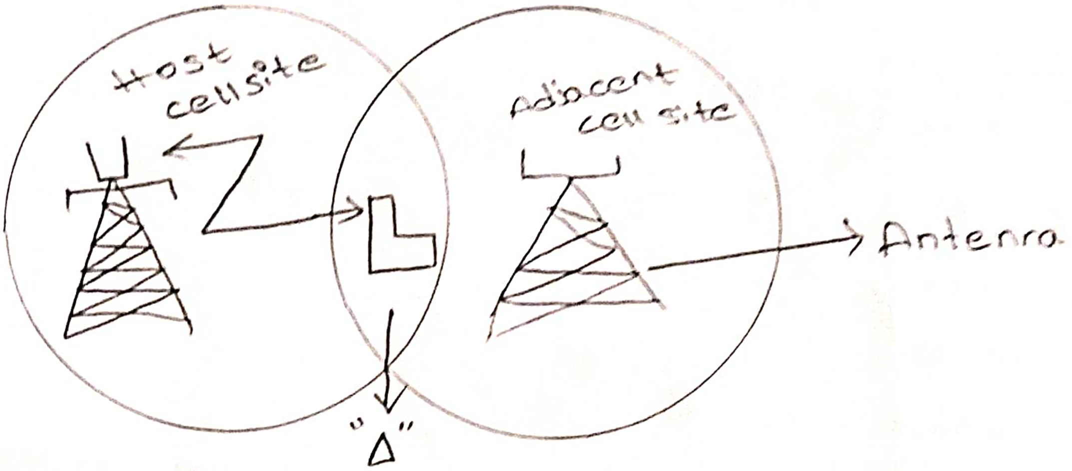
$$B_{ho} = \frac{1-(b_2/N)^{M_2+1}}{1-(b_2/N)} P_q(0) \qquad (7)$$

→ Figure-4, shows the plot for blocking probability of originating calls.

(figure-4)



Power difference hand off :-



→ During a call, if the mobile unit is entering into common coverage area of host and adjacent cellsite Then the signal transmitted by mobile unit is received by both cellsites.

→ Based on this, a better algorithm can be derived to execute handoff process by means of power difference.

→ Host cellsite is used to execute various steps of handoff process, it is called as "Power difference hand off".

$$\text{Power difference}(\Delta) = \frac{\text{power received adjacent cell site}}{\text{power required by host cellsite}}$$

→ (i) If $\Delta < -3\,dB$ → No hand off is required

ii) $-3\,dB < \Delta < 0\,dB$ → monitoring of the signal strength

iii) $0\,dB < \Delta < 1\,dB$ → prepare for hand off.

iv) $1\,dB < \Delta < 3\,dB$ → hand off must be given

⇒ Mobile Assisted Handoff (MAHO) and soft Handoff

- In a normal handoff procedure, the request for a handoff is based on the signal strength or the SAT range of a mobile signal received at the cell site from the reverse link.

In the digital cellular system, the mobile receiver is capable of monitoring the signal strength of the setup channels of the neighboring cells while serving a call.

- For instance, in a TDMA system, one time slot is used for serving a call, the rest of the time slots can be used to monitor the signal strengths of setup channels.
- When the signal strength of its voice channel is weak, the mobile unit can request a handoff and indicate to the switching office which neighboring cell can be a candidate for handoff.
- Now the switching office has two peices of information, the signal strengths of both forward & reverse setup channels, of a neighboring cell or two different neighboring cells.
- The switching office, therefore, has more intelligent information to choose the proper neighboring cell to handoff to.

Soft Handoff.

- The soft handoff is applied to one kind of digital cellular system named CDMA.
- In CDMA systems, all cells can use the same radio carrier.
- Therefore, the frequency reuse factor K approaches one.
- Since the operating radio carriers of all cells are the Same, no need to change from one frequency to another frequency but change from one code to another code.

we call this kind

- Thus there is no hard handoff. we call this kind handoff a soft handoff.
- If sometimes there are more than one CDMA radio carrier operating in a cell, and if the soft handoff from one cell to another is not possible for some reason the intra-cell hard handoff may take place first, then go to the inter-cell soft handoff.

⇒ Inter System Handoff :-

- when a call handoff can be transferred from one system to another system to continue a call in progress it is called as intersystem handoff.
- The MTSO maintains a software to take care of this handoff situation linking two different systems.
- Consider the following example. A subscriber in a vehicle moves from one system(m) to another (N).
- A MTSO m is linked to the current base station & call is initiated.
- But as the system enters another system before termination the handoff is transferred to the new system & new MTSO.

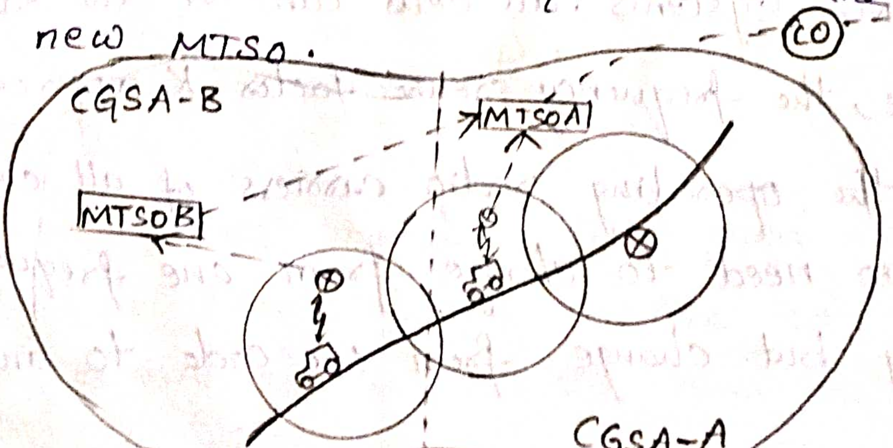


fig:- Intersystem handoffs.

⇒ Dropped call Rate:-

- If the no. of dropped calls are more in a system it expresses a less efficient cellular system. Thus the cellular system should try to avoid dropped calls & it should serves all the call communications.
- The dropped call rate deals with the number of dropped call in a time 't' in the cellsite. It is a parameter to measure system efficiency.
- The dropped call rate increases due to anyone of the following reasons.

(i) The mobile unit is not functioning correctly.
(ii) If the subscriber doesn't know how to operate
(iii) If the subscriber operates the unit in a moving vehicle.

- The voice quality of the speech signal is inversely proportional to the dropped call rate. The dropped call rate has to be designed for having desired voice quality. Some of the factors to be dealt in thin connection are listed below.

a) Percentage of signal coverage.
b) Calculation of adjacent channel interference & co-channel interference in worst case of interference during busy hour.
c) Response time of handoff in the system.
d) Handoff signalling & MAHO measurements.

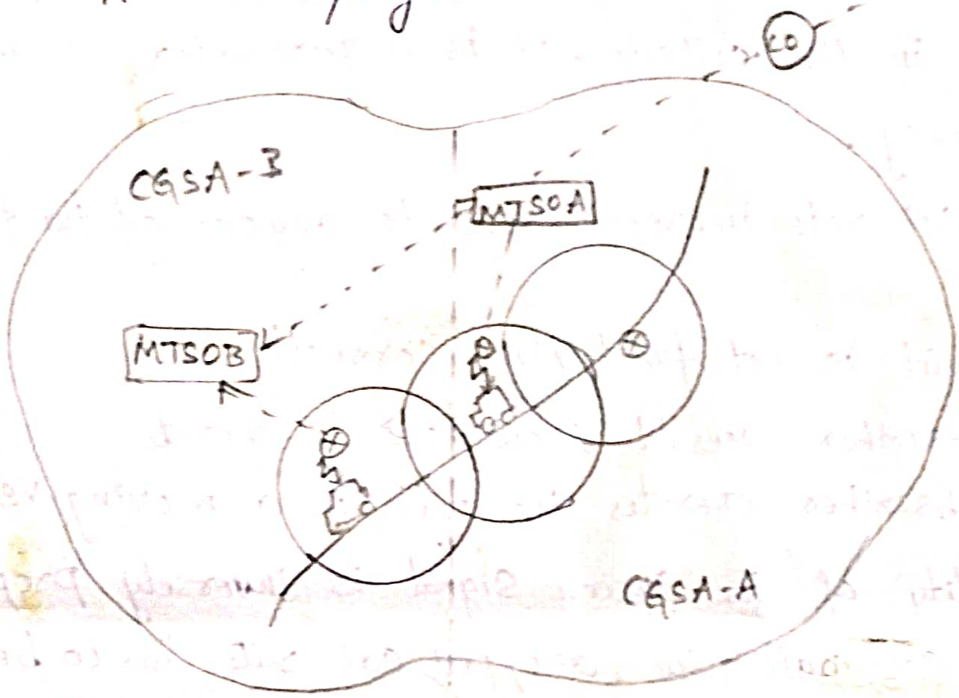
Analysis:-

- Let radio capacity be 'r'

It is given as
$$r = \frac{B_T/B_c}{\sqrt{2/3\left(\frac{C}{I}\right)_s}} \quad \text{(for six co-channel interferers)}$$

where B_T/B_c is total no. of the voice channels N receives the handoff control from MTSO m.

- Thus handoff is transferred from cellsite m to cellsite N.
- For doing this operation first the MTSO m searches for the right cellsite and makes a handoff request to it, now MTSO N provides a dedicated line for the handoff and helps to complete the handoff successfully.



- Thus before implementing inter-system handoff the compatibility of the MTSO's has to be checked in the design level itself.

Dropped call

- It is after the call is established but before it is smoothly terminated.
- That is a completely established call by set-up channel is dropped out before the smooth termination.
- When their is no voice channel availability, a call ait progress, such a condition is known as blocked call since it has not received a free channel. But dropped call is different from blocked call. Ocurrance of dropped call is an undesirable cellular situation which we donot want in a system.

UNIT - II

CELLULAR ARCHITECTURE

Multiple Access Techniques for Wireless Communication

- Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.
- In conversional telephone systems, it is possible to talk and listen simultaneously and this is called as Duplexing.
- The Duplexing may be done in time or frequency domain techniques.

FDD (Frequency Division Duplexing)

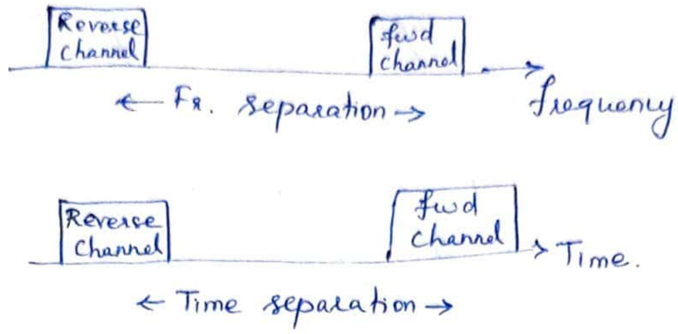
- It provides two distinct bands of frequencies for every user.
- The forward band provides traffic from base station to the mobile
- Reverse band provides traffic from mobile to the base station.
- In FDD any Duplex channel actually consist of two Simplex channels (a fwd & reverse) and a device is called Duplexer is used inside each subscriber unit and base station to allow simultaneous bidirectional radio Tx & Rx for both subscriber and base station on the Duplex channel pair.

TDD (Time Division Duplexing)

- It provides both forward and reverse link.

Multiple users share a single radio channel by taking turns in the time domain.

- The channel is assigned with time slots each time slot facilitates bidirectional communications. (Forward time slot & reverse time slots)



→ FDD provides two simplex channels at the same time.

→ TDD provides two simplex channels at the same frequency.

Types of Multiple Access Techniques.

- The several multiple access techniques are generally used, where the multiple users can send information thro' the communication channel to the receiver.

Multiple Access Techniques.

- Time Division Multiple Access (TDMA)
- Frequency Division Multiple Access (FDMA)
- Code Division Multiple Access (CDMA)
- Space Division Multiple Access (SDMA)

- FDMA, TDMA & CDMA are three major access techniques used to share the available bandwidth in wireless communication systems.
- These techniques can be grouped as narrowband and wideband systems depending upon how the available bandwidth is allocated to the users.

Narrowband System.

- In Narrowband system, the available radio spectrum (bandwidth) is divided into a large no. of narrow band channels.
- The channels are usually operated using FDD.
- In narrowband FDMA, a user is assigned a particular channel which is not shard by other users in the vicinity. and if FDD is used then the system is called FDMA/FDD.

Cable TV

- To minimize interference b/w forward and reverse links, the frequency separation is made within the frequency spectrum and common transceiver antenna to be used in each subscriber unit.

GSM Telephone system

- In narrowband TDMA, users to share the same radio channel but allocates a unique time slot to each user in a cyclical fashion on the channel, thus separating a small number of users in time on a single channel. TDMA generally a large no of radio channels alloted using FDD / TDD. Such system are called TDMA / FDD or TDMA / TDD.

SONET, Synch. optical N/W

Wideband System

Wifi → faster Commn.

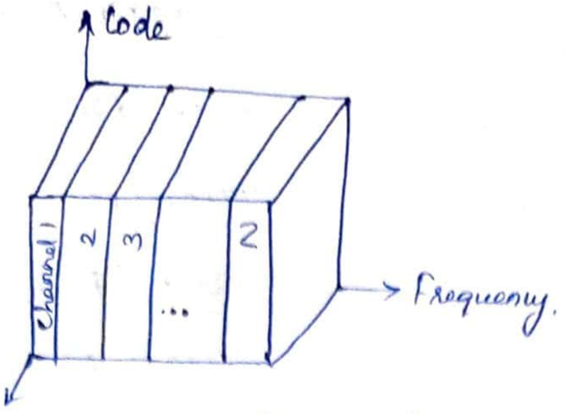
- In wide band system each user uses entire frequency spectrum.
- The Tx bandwidth of a single channel is much larger than the coherence bandwidth of the channel.
- In this system large no. of Tx are allowed to transmit on the same channel.
- But spread spectrum CDMA allows all the tx to access the channel at the same time.

Cellular System	Multiple Access Techniques.
1. Advanced Mobile phone System	FDMA / FDD
2. Global System for Mobile (GSM)	TDMA / FDD
3. US Digital Cellular	TDMA / FDD
4. Pacific Digital cellular	TDMA / FDD
5. Cordless Telephone	FDMA / TDD
6. Digital European Cordless Telephone	FDMA / TDD
7. US Narrowband Spread Spectrum	CDMA / FDD & CDMA / TDD.
8. W - CDMA	CDMA/FDD & CDMA/TDD
9. CDMA - 2000	CDMA / FDD & CDMA / TDD.

- In addition to FDMA, TDMA and CDMA two other multiple access schemes will be used in wireless communications. These are packet radio (PR) and Space Division Multiple Access (SDMA).

⊗ Frequency Division Multiple Access. (FDMA).

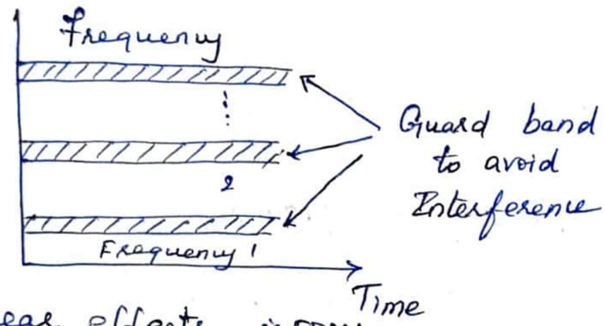
- FDMA assigns individual channels to individual users.
- Each user is alloted a unique frequency band or channel.
- One of the simplest analog multiple access method is FDMA. and it is commonly used for the voice and data transmission.
- Here the total system bandwidth is divided into non-overlapping frequency sub bands.
- During the period of call no. other user can share the same channel.
- In FDD System, the users are assigned a channel as pair of frequencies
  - ✓ (1) one frequency for forward channel
  - ✓ (2) other frequency for reverse channel.



FDMA scheme.

1. Need of Guard Bands.

- The adjacent frequeny bands in FDMA spectrum are likely interface with each other.
- Therefore to avoid interference it is necessary include the guard bands b/w the adjacent fr. bands.



2. Non-linear effects in FDMA.

- In this system, many channels share the same antenna at the base station.
- The power amplifiers, the power combiners when operated at or near for max. efficieny are creates non linear.
- The non-linearities causes signal spreading in the frequeny domain and creates intermodulation frequencies.
- This IM is undesired signal it creates RF radiation which can interfere with other channels in
- FDMA system. & even service also interfered.
- To minimize these effects RF filters are provided but these are heavy, costly...

3. No. of Channels in FDMA.

- The voice channels are sent on forward channel from base station to mobile unit and reverse channel from the mobile unit to base station
- The no. of channels that can be simultaneously supported in FDMA system.

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

- N_S - No. of subscribed channels.

Band widths:
- B_t - Total spectrum allocations.
- B_{guard} - Guard band allocated in spectrum band.
- B_c - Channel bandwidth.

B_t & B_c - Specified interms of simplex Bandwidths.

Problem: 1

- In US AMPS, 416 channels are allocated to various cellular operators. The channel b/w them is 30KHz. with the guard band of 10KHz. Calculate the spectrum allocation given to each operator.
- Spectrum allocated to each cellular operator is

$$B_t = N B_c + 2\,B_{guard}$$

$$= 416 \times 30 \times 10^3 + 2\,(10 \times 10^3)$$

$$= 12.5\ MHz$$

12.5 MHz allocated to each simplex band.

4. Features or characteristics of FDMA.

Advantages

1. Relatively simple to implement.
2. It carries only one phone circuit at a time.

Scanned with CamScanner

3. The base station and mobile transmit simultaneously and continuously

4. It usually implemented in narrow band system

5. The amount of inter symbol interference is low, so little or no equalization is required for narrow band system

6. Complexity is low compared ~~to TDMA~~ to TDMA

7. Absense of synchronization

8. To reduce interference-free Tx b/w uplink and downlink Channels, the fr. allocations have to be separated by sufficient amount.

9. FDMA is continuous Transmission where fewer bits are needed for overhead purposes such as Synchronisation and framing bits compared to TDMA.

Disadvantages.

1. It supports narrow band and is not suitable for multimedia Communications. (Audio & Video)

2. If channel is not in use, then it is idle & cannot be used for sharing the capacity by other user.

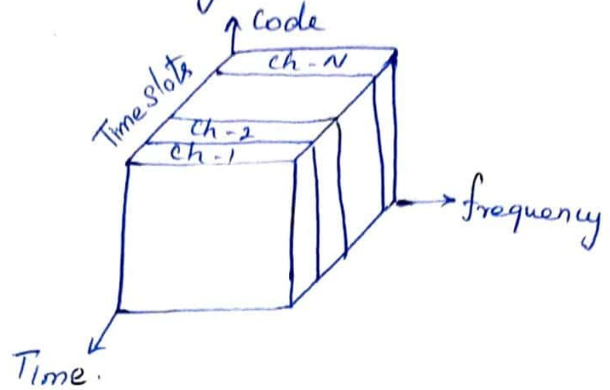
3. To minimize the intermodulation & adjacent channel interference RF filter is required.

4. FDMA system have higher cell site system costs are ~~high~~ compared to TDMA,

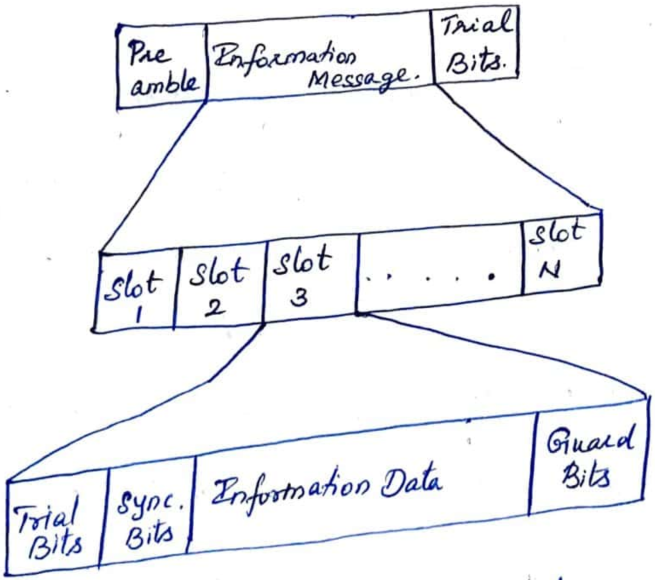
5. Lack of flexibility in case of reconfiguration.

(x) Time Division Multiple Access (TDMA)

- TDMA systems divide the radio spectrum into time slots and in each slot only one user is allowed to either Tx or Rx.



- Each user occupies a cyclically repeating time slot, so a channel may be thought of as a particular time slot that requires every frame, where N time slots in a frames.
- It transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous.
- This implies that digital data and digital modulation must be used with TDMA.



TDMA frame structure. The frame is cyclically repeated over time.

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 TDMA/TDD, 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 TDMA/FDD systems intentionally induce several time slots of delay b/w forward & reverse time slots for particular user, so that duplexers are not required in the subscriber unit.
- In TDMA frame, the preamble contains the address and synchronization information that base station and the subscribers, use to identify each other.
- Guard times are utilized to allow synchronization of the receiver b/w different slots and frames.

Features of TDMA.

- TDMA shares a single carrier frequency with several users, each user make use of nonoverlapping time slots.
- No. of slots/frame depends on modulation techniques, BW etc
- Data Tx of TDMA is not continious, but occurs in bursts.
- This results low battery consumption when not in use
- Adaptive equalization is required in TDMA System.
- In TDMA, the guard time should be minimized. If the transmitted signal at the edge of a time slots are suppressed sharply in order to shorten the guard time, the Tx spectrum will expand and cause interference to adjacent Channel.

- High synchronization overhead is required in TDMA systems because of burst transmissions.
- It is possible to allocate different numbers of time slots per frame to different users. Thus based on priority the bandwidth can be supplied.

Efficiency of TDMA.

- It is a measure of percentage of transmitted data that contains information as opposed to providing overhead for the access scheme.

η_f is percentage of bits per frame which contains Tx data.

$$b_{OH} = N_r b_r + N_t b_p + N_t b_g + N_r b_g$$

N_r - No. of reference bursts per frame
N_t - " traffic bursts per frame.
b_r - " overhead bits per reference bursts.
b_p - " " " per preamble in each slot.
b_g - " of equivalent bits in each guard time interval.
b_{OH} - " overhead bits per frame.

Then total no. of bits per frame b_T

$$b_T = T_f R.$$

T_f - Frame duration
R - Channel bit rate

Then
$$\eta_f = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100\%$$

No. of channels.

$$N = \frac{m\,(B_{tot} - 2B_g)}{B_c}$$
← Expression for no. of channels in TDMA.

m - Max. no. of TDMA users supported on each radio channel
B_{tot} - Total system bandwidth.
B_g - Guard Bandwidth

Ⓡ **Problem: 1**

Consider Global System for mobile which is TDMA/FDD System that uses 25 MHz for the forward link, which is broken into radio channels of 200 KHz. If 8 speech Channels are supported on a single radio channel. and if no guard band is assumed, find the number of simultaneous users that can be accomodated in GSM.

The no. of simultaneous users that can be accomodated in GSM is

$$N = \frac{25\,(\text{MHz})}{\left(\frac{200\ \text{KHz}}{8}\right)} = 1000 \text{ simultaneous users.}$$

Ⓡ **Problem: 2.**

If GSM uses a frame structure where each frame Consists of eight time slots, and each time slot contains 156.25 bits, and data transmitted at 270.833 kpbs in the channel, find (a) the time duration of a bit (b) The time duration of a slot (c) The time duration of a frame, and (d) how long must a user occupying a single time slot b/w two successive transmissions.

(a) The time duration of a bit $T_b = \frac{1}{270.833 \text{ kbps}} = \underline{3.692\ \mu s}$

(b) The time duration of a slot $T_{slot} = 156.25 \times T_b = 0.577\text{ ms}$

(c) The time duration of frame $T_f = 8 \times T_{slot} = 4.615\text{ms}$

(d) A user has to wait 4.615 ms, the arrival time of a new frame for its next transmission.

Problem: 3

A normal GSM has 3 start bits, 3 stop bits (also called as trailling bits) 26 training bits for allowing adaptive equalization, 8.25 guard bits and 2 bursts of 58 bits of encrypted data which is transmitted at 270.833 kbps in the channel. find

(a) No. of overhead bits per frame, b_{oh}

(b) Total no. of bits/frame

(c) frame rate

(d) Time duration of a slot

(e) frame efficiency

A time slot has $6 + 8.25 + 26 + 2(58) = 156.25$ bits

(a) No. of overhead bits, $b_{oh} = 8(6) + 8(8.25) + 8(26) = 322$ bits

(b) No. of bits/frame $= 8 \times 156.25 = 1250$ bits/frame

(c) Frame rate : 270.833 kbps / 1250 bits/frame = 216.66 frame/sec

(d) Time duration of a slot $= 156.25 \times 1/270.833\,\text{kbps} = 576.92\,\mu s$

(e) frame efficiency $= \eta = \left[1 - \frac{322}{1250}\right] = 74.24\%$

Multiple Access schemes:

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum.

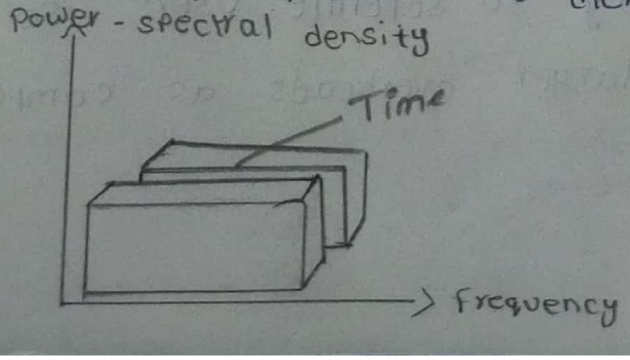
Various multiple access schemes are:

- FREQUENCY DIVISION MULTIPLE ACCESS: Different frequencies are assigned to different users.
- Time Division multiple Access: Different timeslots are assigned to different users.
- Code Division multiple Access: Each user is assigned a different code.

The goal of all multiple access methods is to maximize spectral efficiency i,e., to maximize the number of users per unit bandwidth.

Time Division multiple Access [TDMA]:

- Time division multiple access (TDMA) systems divide the radio spectrum into time slots, and in each slot only one user is allowed to either transmit or receive.
- A time unit is subdivided into N timeslots, the user can transmit with a high data rate. Then, it remains silent for the next N-1 timeslots, when other users take their turn. This process is then repeated Periodically.



• TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous. So, unlike in FDMA system which accommodate analog FM, digital data and digital modulation must be used with TDMA.

Features of TDMA:

• TDMA shares a single carrier frequency with several users, where each user makes use of non-overlapping time slots.

• Data transmission for users of a TDMA system is not continous, but occurs in bursts. This results in low battery consumption.

• Because of discontinous transmissions in TDMA, the handoff Process is much simpler for a subscriber unit.

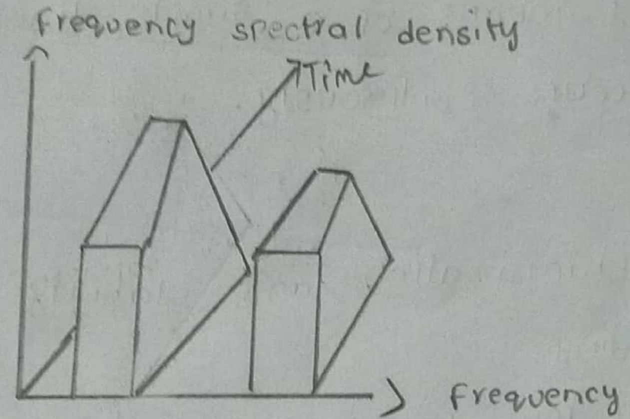
• TDMA uses different time slots for transmission and reception, thus duplexes are not required.

• Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.

• High synchronization overhead is required in TDMA systems because of burst transmissions. TDMA transmissions are slotted, and this requires the receivers to be synchronized for each data burst. In addition, guard slots are necessary to seperate users. So the TDMA systems having larger overheads as compared to FDMA.

Frequency Division multiple Access [AFDMA]:

- Frequency division multiple access [FDMA] assigns individual channels to individual users.
- The 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.



Features of FDMA:

- The FDMA channel carries only one phone circuit at a time.
- If an FDMA channel is not in use, then it cannot be used by other users to increase capacity.
- After the assignment of a channel, the BS and the mobile transmit simultaneously and continously.
- since FDMA is a continous transmission scheme, fewer bits are needed for overhead purpose.
- FDMA is usually implemented in narrowband systems.
- The amount of inter-symbol interference is low. so little or no equalization is required in FDMA narrowband systems.
- The FDMA mobile unit uses duplexers.

- FDMA requires tight RF filtering to minimize adjacent channel interference.

Advantages:

- The transmitter [Tx] and receiver [Rx] require little digital signal processing.
- (Temporal) synchronization is simple. Once synchronization has been established during the call setup, it is easy to maintain it by means of a simple tracking algorithm, as transmission occurs continously.

Disadvantages:

- Frequency synchronization and stability are difficult.
- Sensitivity of fading
- Sensitivity to random frequency modulation [FM].
- Intermodulation.

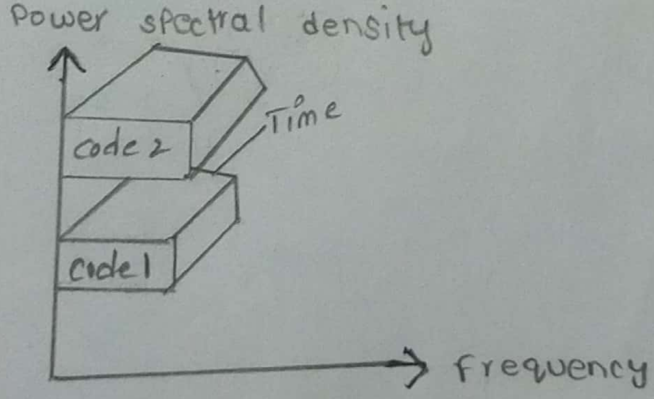
Nonlinear effects in FDMA:

- In a FDMA system, many channels share the same antenna at the base station. The Power amplifiers or the Power combiners are nonlinear. The nonlinearities cause signal spreading in the frequency domain and generate interr-modulation [IM] frequencies, IM is undesired RF radiation which can interfere with other channels in the FDMA system. Spreading of the spectrum results in adjacent-channel interference.

Intermodulation is the generation of undesirable harmonics.

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 ~~the~~ has a chip rate which is orders of magnitudes greater than the data rate of the message. each user has its own pseudorandom code word which is approximately orthogonal to all other code words.
- The receiver performs a time correlation operation to detect only the specific desired code word. All other code words appear as noise due to decorrelation. For detection of the message signal, the receiver needs to know the code word used by the transmitter.



Features of CDMA:

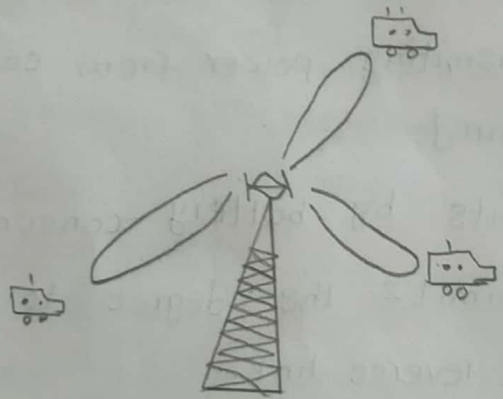
- Many users of a CDMA system share the same frequency. Either TDD or FDD may be used.
- Unlike TDMA or FDMA, CDMA has a soft capacity limit. The system performance gradually degrades for all users as the number of users is increased and improves as the number of users ~~in~~ is decreased.

- Frequency dependent transmission impairments [such as noise bursts and selective fading] have less effect on the signal.
- Multipath fading may be substantially reduced because the signal is spread over a large spectrum.
- Channel data rates are very high in CDMA systems.
- Since CDMA uses co-channel cells, it can use macroscopic spatial diversity to provide soft handoff.
- The near-far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.

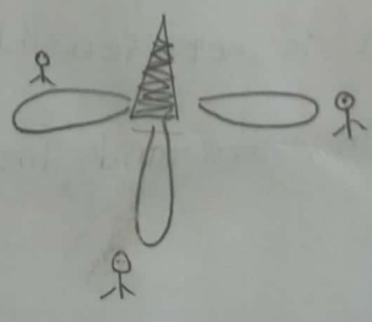
Scanned with CamScanner

Space Division multiple Access :-

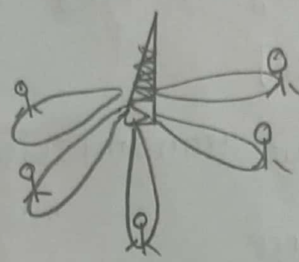
- Reuses the same set of frequency in given area.
- Two cells use same frequency if they are separated by certain distance [reuse distance].
- Focuses the signal in narrow transmission bands.
- It is free from Interference.
- Uses smart Antennas
- It prevents redundant signal transmission
- SDMA is used for allocating a separated space to users in wireless networks.



- A typical application involves assigning an optimal base station to a mobile phone user.
- Sectorized antennas considered as a primitive application of SDMA.



- In future adaptive antennas simultaneously steer energy in the direction of many users at once



- Typically SDMA is never used in isolation but always in combination with one or more other schems such as FDMA, TDMA or CDMA.
- Reverse link presents the difficulty in cellular system.
- Different propagation path exists from user to the base station
- Dynamic control of transmiting power from each user to the base station is required.
- Transmitted power limits by battery consumption of subscriber units which limits the degree to which power may be control in the reverse link.
- Possible solution is that the Base station [BS] should use a spatial filter for each user for that Adaptive antennas promise to mitigate reverse link Problems.

<u>Disadvantages:</u>

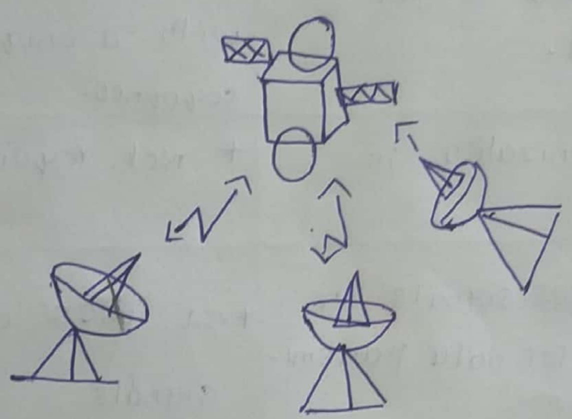
- Infinitely large antenna needed.
- Perfect Adaptive antenna is not feasible
- compromise needed (gain, size and directivity).

Comparison of multiple Access Techniques:

[FDMA , TDMA & CDMA]

* multiple Access:-

- Two (or) more earth stations, simultaneously access in the satellite transponder.
- Transponder is loaded with a large number of carriers from different ESs at different locations.



Types of multiple Access Techniques:-

i) FDMA - Frequency Division multiple Access (FDMA)

ii) TDMA - Time Division multiple Access

iii) CDMA - code Division multiple Access

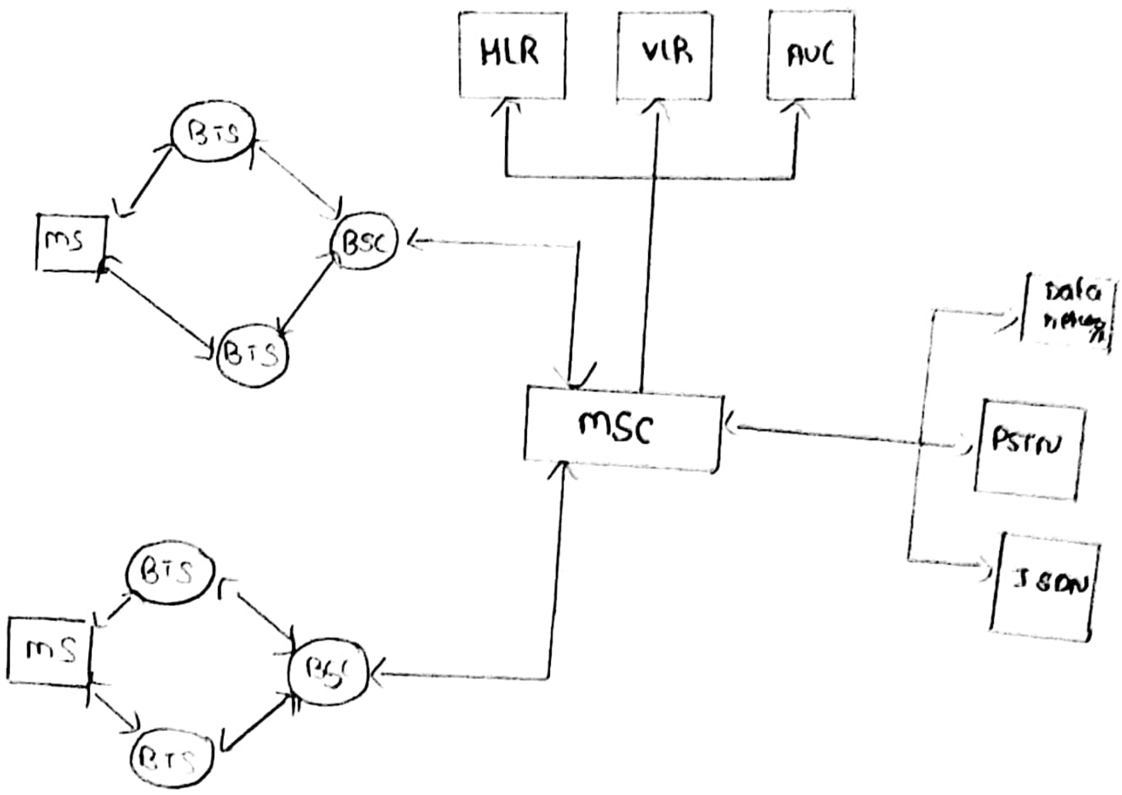
FDMA	TDMA	CDMA
* FDMA shares a single BW among multiple stations by dividing it into sub-channels	* It shares the time slot & transmission through satellite.	* CDMA shares both BW and time among multiple sations with separate unique code
* Each station is allocated with frequency band for all the time to send data.	* There is a time slot given each station to transmit data.	* It allows each station to transmit data over the entire frequency all the time.
* codeword is not required.	* codeword is not required.	* Each user is assigned with a unique code sequence.
* synchronization is not required	* synchronization is required.	* Not required
* It uses continously signals for data transmission	* It uses signals in bursts for data transmission.	* It uses digital signals
* It requires guard bands between adjacent bands	* It requires the guard time of the adjacent bands	* CDMA requires both guardband and guard time.
* Low data rate	* medium data rate	* High data rate
* Limited cell capacity	* Restricted cell capacity	* no capacity
* High cost	* low cost	* High installation cost & low operation cost
* less flexible	* moderate flexible	* Highly flexible.

FDMA	TDMA	CDMA
Advantages: -> simple, reliable	-> flexible -> entirely digital	Highly flexible soft signal handoff.r • Highly secured transmission
Disadvantages: -> Inflexible -> Fixed frequancies	-> It requires guard space synchronization problem.	-> complex receivers.
Applications:- -> Telephone systems -> radio systems -> cable TV GSM uses ~~as~~ FDMA is combination with TDMA	-> Digital cellular communication -> satellite system -> GSM, IS-136, iDEN	-> cellular system -> GPS -> personal communication service -> subscriber access control.

* Global system for mobile systems [GSM]

- The Global system for mobile communications [GSM] is a standard developed by the European Telecommunications standards institute [ETSI] to digital cellular networks used by mobile devices such as mobile phones and tablets to describe the protocols for second-generation (2G)

Block diagram:



MS - mobile station

BTS - Base station controller subsystem

BSC - Base station controller

HLR - Home location registor

VLR - visitor location register

AUC - Authentication centre

Mobile station [MS]:-

- Mobile station includes mobile equipment [ME] and subscriber identify module [SIM].
- Mobile equipment [ME] does not need to be personally assigned to one subscriber.
- The mobile equipment is not associated with a called number, it is linked to the SIM.

Base station system controller [BTS]:

-> The BSS consists of a base tranceiver sation [BTS] located at the antena site to the mobile equipment [ME] in an mobile station [MS]

-> As a subpart of the BTS, the TRAU may be sited away from the BTS, usually at the MSC.

Home location register [HLR]:

-> It contains the subscriber intercontion related to subscribers current locations.

-> A subdivision of HLR is the mobile communication of core network.

Visitor location register [VLR]:

-> It contains the information of naming subscribers.

-> Here, the information is stored temporarily.

Authentication center:-

It manages the security data for subscribers authentication. It contain equipment identify register which stores the data of mobile equipment [ME].

Base station controller:-

-> It is in control of and supervises a number of base transceiver stations.

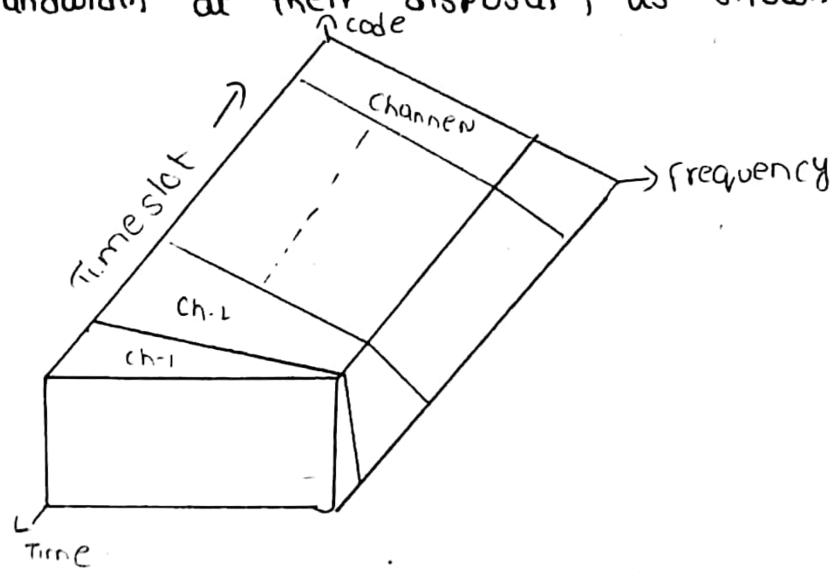
-> The BSC is responsible for the allocation of radio resource to a mobile call and for the hand overs.

Applications:

- It demonstrates the use of AT commands
- It making and receiving calls, sms, mms etc...
- These are mainly employed for computer-based sms and mms services.

* Time Division multiple Access systems :

- In digital systems, continous transmission is not required because users do not use the allotted bandwidth all the time.
- In such cases, TDMA is complimentary access technique to FDMA. Global systems for mobile commution (GSM) uses the TDMA technique.
- In TDMA, the entire bandwidth is divided into fewer channels compared to FDMA.
- The users are allotted time slots during which they have the entire channel bandwidth at their disposal, as shown in figure



→ TDMA requires careful time synchronization since users share the bandwidth in the frequency domain.

→ The number of channels are less, inter channel interference is almost neligible.

→ TDMA uses different time slots for transmission and reception.

→ This type of duplexing is referred to as Time Division duplexing [TDD].

• The features of TDMA:

a) TDMA shares a single carrier frequency with several users where each users makes use of non overlapping time slots.

b) The number of time slots per frame depends on several factors such as modulation technique, available bandwith etc..,

c) Data transmission in TDMA is not continous but occurs in bursts.

d) TDMA uses different time slots for transmission and reception thus duplexers are not required.

→ TDMA has as advantage that is possible to allocate different users by concatenating or reassigning time slot based on priority.

TDMA / FDD in GSM :.

→ GSM is widely used in Europe and other parts of the world. GSM uses a variation of TDMA along with FDD.

→ GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its.

* Code Division multiple Access system:-

→ In CDMA, the same bandwidth is occupied by all users, however they are all assigned separate codes, which differentiates them from each other.

→ CDMA is a 3G network

→ CDMA channel has a frequency of 1.25 MHZ

→ The CDMA methods enable multiple users to work on the same freq and time.

→ It offers more security.

→ Information stored in a headset or phone.

Direct sequence spread spectrum (DS-SS)

-> This is the most commonly used technology for CDMA. In DS-SS, the message signal is multiplied by a Pseudo Random noise code.

-> each user is given his own codeword which is orthogonal to the codes of other users and in order to detect the user, the receiver must know the codeword used by the transmitter.

-> There are, two problems in such systems which are discussed in the sequel.

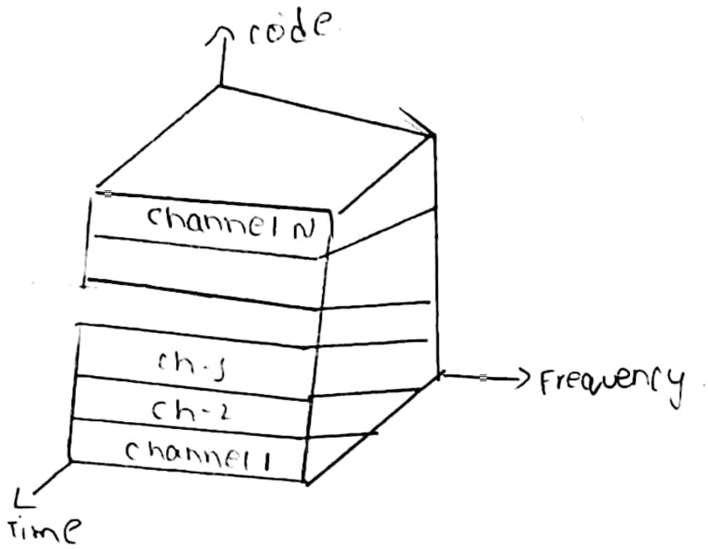


fig:- The basic concept of CDMA system.

- CDMA and self interference Problem
- CDMA and near - far problem

Applications:-

- cellulars system
- GPS
- Personal communication service
- subscriber access control.

1G Vs. 2G Vs. 3G Vs. 4G Vs. 5G:

Simply, the "G" stands for "**GENERATION**" . While you connected to internet, the speed of your internet is depends upon the signal strength that has been shown in alphabets like 2G, 3G, 4G etc. right next to the signal bar on your home screen. Each Generation is defined as a set of telephone **network standards** , which detail the technological implementation of a particular mobile phone system. The speed increases and the technology used to achieve that speed also changes. For eg, 1G offers 2.4 kbps, 2G offers 64 Kbps and is based on GSM, 3G offers 144 kbps-2 mbps whereas 4G offers 100 Mbps - 1 Gbps and is based on **LTE technology** .

Features	1G	2G	3G	4G	5G
Start/Devlopment	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
AccessSystem	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA
Core Network	PSTN	PSTN	Packet Network	Internet	Internet

The aim of wireless communication is to provide high quality, reliable communication just like wired communication(optical fibre) and each **new generation** of services represents a big step(a leap rather) in that direction. This evolution journey was started in **1979** from 1G and it is still continuing to 5G. Each of the Generations has standards that must be met to officially use the G terminology. There are institutions in charge of standardizing each generation of mobile technology. Each generation has requirements that specify things like throughput, delay, etc. that need to be met to be considered part of that generation. Each generation built upon the research and development which happened since the last generation. 1G was not used to identify **wireless technology** until 2G, or the second generation, was released. That was a major jump in the technology when the wireless networks went from **analog to digital** .

1G - First Generation

This was the first generation of **cell phone technology** . The very first generation of commercial cellular network was introduced in the late 70's with fully implemented standards being established throughout the 80's. It was introduced in 1987 by Telecom (known today as Telstra), Australia received its first cellular mobile phone network utilising a 1G analog system. 1G is an analog technology and the phones generally had poor battery life and voice quality was large without much security, and would sometimes experience **dropped calls** . These are the analog telecommunications standards that were introduced in the 1980s and continued until being replaced by 2G digital telecommunications. The maximum speed of 1G is **2.4 Kbps** .

2G - Second Generation

Cell phones experienced a significant advancement when they transitioned from 1G to 2G. The primary distinction between these two mobile telephone systems lies in the nature of their radio signals, with 1G utilizing analog signals and 2G employing digital signals. The primary objective of this transition was to establish secure and reliable communication channels, which necessitated the adoption of CDMA and GSM concepts. Notably, 2G networks introduced crucial features, including SMS and MMS services, elevating data communication capabilities alongside voice communication.

The commercial launch of 2G cellular telecom networks on the GSM standard occurred in Finland by Radiolinja (now part of Elisa Oyj) in 1991. To achieve the capabilities of 2G, multiplexing was utilized, allowing multiple users on a single channel. This enabled the integration of voice and data services on cellular phones. Noteworthy advancements from 1G to 2G encompassed essential services such as SMS, internal roaming, conference calls, call hold, and billing based on services like charges for long-distance calls and real-time billing.

In terms of data transfer speeds, 2G offered maximum speeds of 50 Kbps with General Packet Radio Service (GPRS) and up to 1 Mbps with Enhanced Data Rates for GSM Evolution (EDGE). It is essential to acknowledge that before the significant leap from 2G to 3G wireless networks, there were intermediary standards, namely 2.5G and 2.75G, which bridged the technological gap and paved the way for more advanced wireless technologies.

3G - Third Generation

This generation set the standards for most of the wireless technology we have come to know and love. Web browsing, email, video downloading, picture sharing and other **Smartphone technology** were introduced in the third generation. Introduced commercially in 2001, the goals set out for third generation mobile communication were to facilitate greater voice and data capacity, support a wider range of applications, and increase data transmission at a **lower cost** .

The 3G standard utilises a new technology called **UMTS** as its core network architecture - Universal Mobile Telecommunications System. This network combines aspects of the 2G network with some new technology and protocols to deliver a significantly faster data rate. Based on a set of standards used for mobile devices and mobile telecommunications use services and networks that comply with the International Mobile Telecommunications-2000 (**IMT-2000**) specifications by the International Telecommunication Union. One of requirements set by IMT-2000 was that speed should be at least 200Kbps to call it as 3G service.

3G has Multimedia services support along with **streaming** are more popular. In 3G, Universal access and portability across different device types are made possible (Telephones, PDA's, etc.). 3G increased the efficiency of frequency spectrum by improving how audio is **compressed** during a call, so more simultaneous calls can happen in the same frequency range. The UN's International Telecommunications

Union **IMT-2000** standard requires stationary speeds of 2Mbps and mobile speeds of 384kbps for a "true" 3G. The theoretical max speed for **HSPA+** is 21.6 Mbps.

Like 2G, 3G evolved into 3.5G and 3.75G as more features were introduced in order to bring about 4G. A 3G phone cannot communicate through a **4G network** , but newer generations of phones are practically always designed to be backward compatible, so a 4G phone can communicate through a 3G or even **2G network** .

4G - Fourth Generation

4G represents a significant **technological leap from its predecessor, 3G,** and owes its feasibility largely to remarkable advancements achieved in the past decade. Its primary objective is to offer users high-speed, top-notch, and extensive connectivity while simultaneously enhancing security measures and reducing the expenses associated with voice, data, multimedia, and **internet services delivered over IP.** This cutting-edge technology opens doors to a wide range of potential and existing applications, including improved mobile web access, IP telephony, immersive gaming experiences, high-definition mobile TV, seamless video conferencing, captivating 3D television, and efficient cloud computing solutions.

The advancements that have made 4G possible are primarily attributed to two key technologies, namely **MIMO (Multiple Input Multiple Output)** and OFDM (Orthogonal Frequency Division Multiplexing). Among the notable 4G standards, WiMAX has diminished in prominence, while **LTE (Long Term Evolution)** has gained widespread adoption with deployments across various networks. LTE, a series of enhancements to UMTS technology, is being implemented on Telstra's existing 1800MHz frequency band.

4G networks offer impressive speeds, **reaching up to 100 Mbps** while in motion and up to 1 Gbps for stationary or walking scenarios. Latency has been significantly reduced from approximately 300ms to below

100ms, resulting in a marked improvement in network congestion. Initially, 4G merely provided a modest speed boost over 3G. It is important to note that **4G and 4G LTE are not identical;** however, 4G LTE comes remarkably close to meeting the defined standards.

With the advent of 4G, tasks like downloading a new game or **streaming HD TV shows** can be accomplished seamlessly, without buffering interruptions, ensuring a smooth and enjoyable user experience.

Newer generations of mobile phones are designed with backward compatibility in mind, allowing a 4G device to function on 3G or even 2G networks. The consensus among carriers is that the inclusion of **OFDM (Orthogonal Frequency Division Multiplexing)** is a crucial factor for a service to be legitimately marketed as 4G. OFDM is a digital modulation technique that divides a signal into multiple narrowband channels at different frequencies.

To support the transition to LTE (Long Term Evolution), significant infrastructure changes are required from service providers. This is because voice calls in **GSM, UMTS, and CDMA2000** networks operate through circuit switching, and with the adoption of LTE, carriers must re-engineer their voice call networks.

Furthermore, there are intermediary designations such as 4.5G and 4.9G, representing the evolutionary stages of LTE-Advanced Pro, which incorporate additional features like increased MIMO (Multiple Input Multiple Output) and **Device-to-Device (D2D) communication.** These advancements pave the way towards the IMT-2020 standard and the requirements set for 5G technology.

5G - Fifth Generation

5G, or the **Fifth Generation,** refers to the latest advancement in wireless communication technology that offers significantly faster speeds, lower latency, increased capacity, and the ability to connect a massive number of devices simultaneously, enabling transformative applications and services such as autonomous vehicles, **Internet of Things (IoT)**, augmented reality (AR), and more. It is the fifth generation of cellular network technology, succeeding 4G LTE. 5G offers a number of improvements over 4G, including:

- **Faster speeds:** 5G can theoretically offer download speeds of up to 20 gigabits per second (Gbps), which is significantly faster than 4G's maximum of 1 Gbps.
- **Lower latency:** Latency is the time it takes for data to travel from one point to another. 5G has significantly lower latency than 4G, which can make it ideal for applications that require real-time communication, such as online gaming and autonomous vehicles.
- **More capacity:** 5G can support more devices on the network than 4G, which is important as the number of connected devices continues to grow.
- **New features:** 5G also supports a number of new features that were not possible with 4G, such as network slicing and massive machine-type communications (mMTC). Network slicing allows operators to create separate virtual networks within the same physical network, which can be used for different purposes, such as providing high-speed mobile broadband or supporting industrial applications. mMTC allows for the connection of millions of low-power devices, such as sensors and actuators, which can be used to monitor and control the environment or track assets.

Here are some of the **potential benefits** of 5G:

- **Faster downloads and streaming:** 5G can deliver ultra-fast speeds, which will allow users to download large files and stream high-definition video much faster than ever before.

- **Improved gaming and virtual reality:** 5G's low latency will make it possible for gamers to experience a more immersive experience, while virtual reality (VR) users will be able to enjoy smoother and more realistic visuals.
- **More reliable connections:** 5G's wider bandwidth and lower latency will make it possible for users to stay connected even in crowded areas or while moving quickly.
- **New possibilities for businesses:** 5G's high speeds and low latency will enable businesses to develop new applications and services that were not possible with previous generations of cellular networks.

5G is still a **developing technology,** but it has the potential to revolutionize the way we live and work. It is already being used in some countries, and it is expected to become more widespread in the coming years.

Conclusion

1G introduced the **first generation of mobile communication,** enabling analog voice calls. 2G brought digital technology, allowing for more efficient voice calls and basic data services. 3G expanded data capabilities, enabling internet access and multimedia applications. 4G further enhanced data speeds, supporting high-quality video streaming and mobile broadband. Finally, **5G represents the latest generation,** delivering ultra-fast speeds, low latency, and massive device connectivity, paving the way for advanced technologies like IoT, AR, and autonomous vehicles.