What is Mobile Computing?

Mobile Computing consist of two terms Mobile & Computing. Mobile means not stationary and Computing is the activity of developing and using computer technology including hardware and software. Thus, mobile computing is a technology that allows anytime, anywhere & everywhere computing. Mobile computing can be defined as a computing environment over physical mobility such that user of a mobile computing environment will be able to access data, information or other logical objects from any device in a network while on move. Mobile computing system allows a user to perform a task from anywhere using a computing device. While on the move, the preferred device will be a mobile device, while back at the home the device acts as desktop computer. To make mobile computing environment existing, it is necessary that the communication is spread over both wired & wireless media.

Mobile computing is the process of computation on a mobile device. In such computing, a set of distributed computing systems, service providers or servers participate, connect and synchronize through mobile communication protocol. Mobile computing offers mobility. It provides decentralized computations on diversified devices, systems and networks which are mobile and they are interconnected by mobile communication standards and protocols. A mobile device does not restrict itself to one application. Mobile Computing facilitates a large number of applications on a single device.

Mobile computing is based in different contexts with different names. The most common names are :—

Anywhere, Anytime Information, Mobile Computing is a technology in which information is available anywhere, all the time.

Ubiquitous Computing, Ubiquitous Computing refers to the blending of computing devices with environmental objects. It is a term that describes integration of computers into all objects in our everyday environment.

Nomadic Computing, The computing environment is nomadic and moves alongwith the user.

Pervasive Computing, Pervasive means existing in all parts of a place or thing. Pervasive computing provides an environment in which information is used everywhere, by everyone and at all times. Mobile computing is called pervasive computing when a network have the characteristics of transparency & Adaptability.

Virtual Home Environment, VHE is defined as an environment in a foreign network such that the mobile user can experience the same computing experience as they have in their home or corporate computing environment.

Global Service Portability, Making a service portable and available in every environment. Any service of any environment will be available globally.

Definitions of Mobile Computing

⇒ Providing information at any time, any place, and in any form. Whether in office, at home or any place.

⇒ Mobile computing is associated with mobility of hardware, data and software in computer applications.

⇒ Mobile computing is the use of computers in a non-static environment

⇒ Mobile computing is using a computer while on move

Comparison between Wired & Mobile Networks

Wired Networks	Mobile Networks
1. High Bandwidth	1. Low Bandwidth
2 Low bandwidth Variability	2. High bandwidth variability
3 Low delay	3 Higher delay.
4 High power & resource machines	4. Low power & resource machines.

Why Mobile?

⇒ Enable Anywhere/Anytime Computing

⇒ Enable new applications.

⇒ Bring communications to areas without pre-existing infrastructure.

Applications of Mobile Computing

1) Transport

⇒ transmission of news, weather, conditions etc.
⇒ personal comunication using GSM
⇒ position and tracking via GPS.

2) Emergencies

⇒ Early transmission of patient data to hospital.
⇒ Provides current status.

3) Travelling salesperson

⇒ have direct access to customer files stored in central location.
⇒ consistent database for all agents

4) Entertainment, education

⇒ outdoor internet access
⇒ intelligent travel guide with upto date location dependent information

5) Mobile Cheque

An mcheque is a mobile based payment system used during a purchase. The service is activated through text message exchanges between the customer, retail outlet & the mobile service provider. Service provider authenticates the customer & activate the account to transfer money to retailer account.

6) Smartphones

A smartphone is a mobile phone with additional capacity and computing functions so as to enable multiple applications such as SMS & Bluetooth capability.

7) Enterprise Solution

Enterprise or large business networks have huge database & documentation environment. Enterprise solution refers to the solutions for corporations or networks. Now a days, mobile devices are increasingly used to provide enterprise solution.

Challenges in Mobile Computing

Mobile Computing faces number of challenges including more frequent disconnections, lower bandwidth, greater variation in available bandwidth, greater network heterogeneity and increased security risks.

1) Disconnection

Network failure is of greater concern to mobile computing designs than traditional designs because wireless communication is susceptible to disconnection.

2) High Bandwidth Variability

Mobile Computing designs have greater variation in network bandwidth. Bandwidth can shift one to four orders of magnitude. Traffic causes this much variation in a network.

3) Heterogeneous Networks

In contrast to stationary computers, which stay connected to a single network, mobile computers encounter more heterogeneous network connections. As they leave the range of one network and switch to another. In different places they experience different networks. In some situations, a mobile computer may have access to ~~mobile~~ several network connection at once where adjacent cells overlap or can be merged for wired access. Also, mobile computers may need to switch interfaces when going between indoors and outdoors. This heterogenity make mobile networking more complex.

4) Security Risks

Because connection to a wireless link is so easy, the security of wireless communication can be easily compromised than wired especially if transmission extends over a large area. This increases the pressure on mobile computing software designers to include the security concern. Secure communication over insecure channel is accomplished by encryption. Security depends on a secret encryption key only known to authorized party. Managing these keys securely is also difficult.

5) Low Bandwidth

Network bandwidth is divided among the users sharing a cell. The bandwidth per user is an important measure of network capacity. When available bandwidth does not satisfy the demand, user will be waiting and should be given a priority.

6) Mobile Elements are Resource Poor as Compared to Static.

For a given technology we require some resources such as processor speed, memory size & disk capacity. Mobile elements are resource-poor as compared to static

7) Technical Challenges of Mobile Computing

Main challenges against mobile computing is to cope up with the limited memory, battery life and processing abilities to provide high degree of portability and optimal wireless communication services.

Coping With Uncertainities

1) NETWORK DESIGN

If we design our network with following point, we may cop up with low bandwidth problem.

a) More number of cells for a given user area.

b) Use smaller wireless cells. All the mobile computers within a cell share the bandwidth.

c) Use of overlapping cells operating in different spectrum reduce the power requirements.

d) Transceivers covering less area achieve high bandwidth.

2) Software Techniques

We can't increase the available bandwidth but can be utilized efficiently by using following ways:-

a) Use compression technique at the two ends of wireless link.

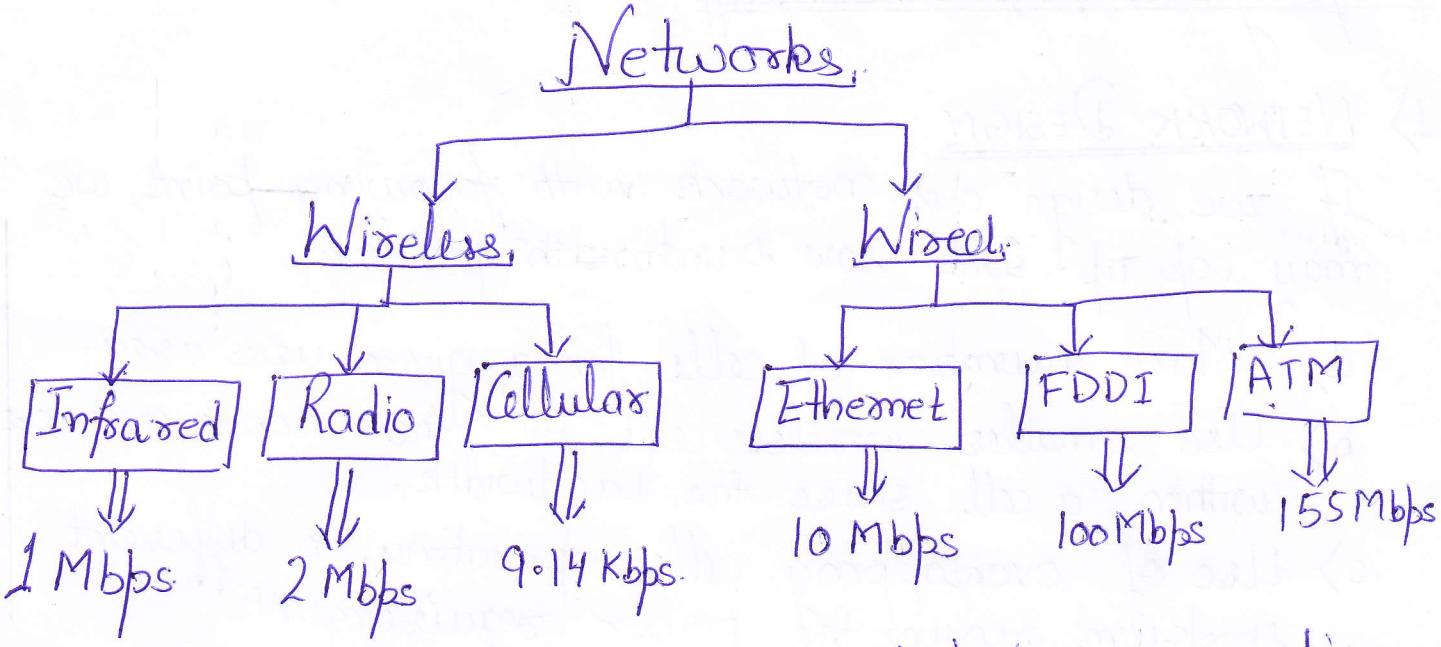
b) Use concept of Logging (Bulk usage is more efficient than multiple small usage).

c) Data communication is bursty. Bursty mean high-bandwidth transmission over short period of time

d) During a burst, if demand exceeds the capacity, then burst is like a short disconnection

These techniques doesnot increase the bandwidth but improves the utilization.

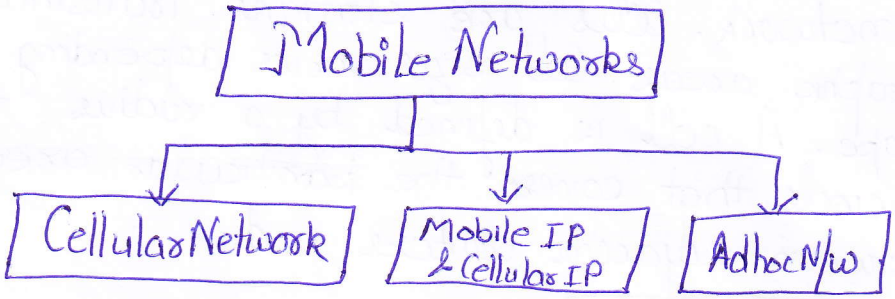
3) BANDWIDTH IMPROVEMENTS



By using proper technology & techniques according to the application, We can also solve the low bandwidth problem faced by mobile computing.

CELLULAR NETWORK

Mobile Networks are networks of mobile devices, servers and distributed computing systems. There are basic three type of networks used as mobile network.



CELLULAR NETWORK

A cellular network is a radio network distributed over land areas called cells, each served by atleast one fixed location transceiver known as cell site or base station. Thus, a cellular system is characterized as a high capacity mobile system in which available frequency spectrum is partitioned or divided into discrete channels which are assigned in groups to geographic cells covering a cellular Geographic Service Area (GSA). Cellular network offers a number of advantages such as:—

- ⇒ Increased Capacity
- ⇒ Reduced power use
- ⇒ Larger coverage area.
- ⇒ Reduced interferance from other signals.

Components & Terminology used in Cellular Network

1) **Cell** A cell is the basic geographic unit of cellular system. These are of hexagonal structures that form a shaped network. Cells are stations transmitting over small geographic areas. Cell sizes varies depending upon the landscape. A cell is defined by a radius that is a radius of circle that covers the particular area. The distance between adjacent centers is d.

$$\boxed{d = \sqrt{3}R}$$

where R is the cell radius.

Each cell has its own antenna which is a collection of transmitter, receiver and control unit. Adjacent cells are assigned with different frequencies to avoid the interferance. The cell size is 100 m in cities and 35 km on country side.

Base Station The covered area of a cellular network is divided into small areas called cells. Each cell has a base station which communicates simultaneously with all mobile cells and passes traffic to MSC. BS provides direct communication with the mobile phones. There may be a number of base stations that are linked to a Base Station Controller (BSC). This unit acts as a small centre to route cells to required BS and also decides which BS is best suited to particular cell.

MSC It is the heart of cellular network. It is responsible for routing and switching. It controls a number of cells (clusters), arrange BS and channels for mobiles and handle connections. It also contains HLR and VLR. It contain many backup and duplicate circuits to ensure that it doesn't fail. It is difficult to manage

a cell being responsible for setup, routing call and termination of call, management of inter MSC. Thus, MSC may be connected to the other MSC or PSTN.

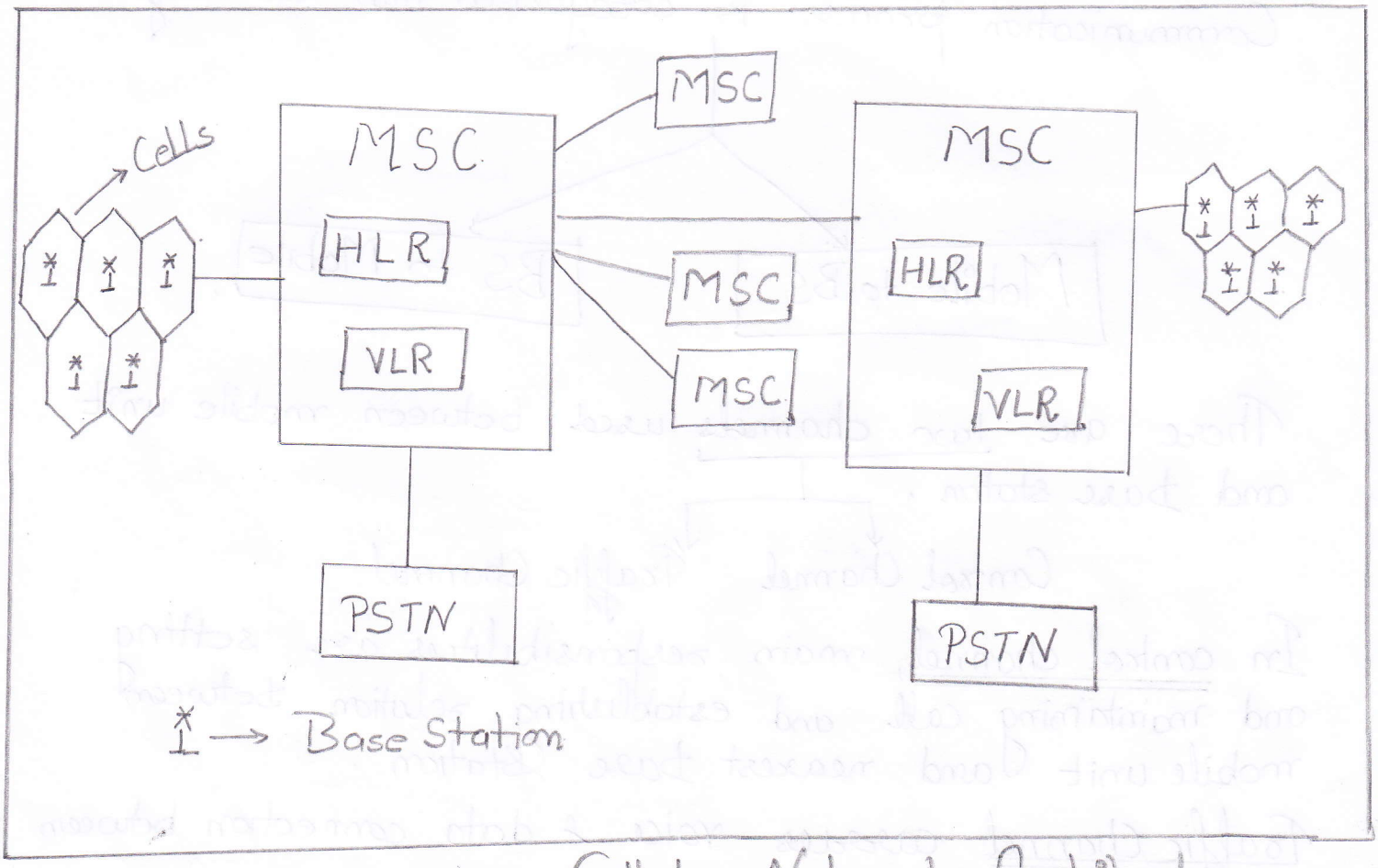
Home Location Register

HLR is a database that records the current location of each mobile that belongs to the MSC.

Visitor Location Register

VLR is a database that records the visting location of each mobile.

Cellular Network Architecture

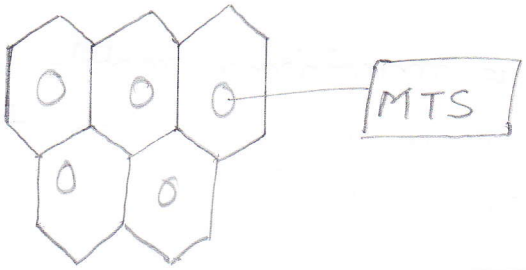


Cellular Network Architecture

The entire communication process can be described with the help of following steps :-

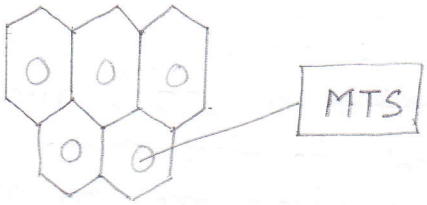
1) Monitoring for Strongest Signal.

When the mobile unit is turned ON it scan and select the strongest setup that are channels for the system. First it selects base station and then provide handshake between mobile unit and MTSO through base station in the cell. This handshake is used for identifying the users and register its location.



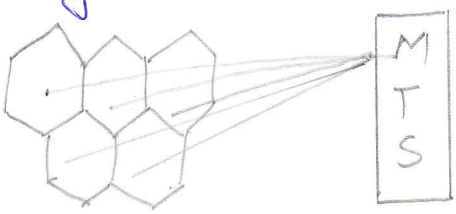
2) Request for Connection

The mobile unit originate a call by sending the number of called unit on preselected setup channels. These setup channel must be idle.



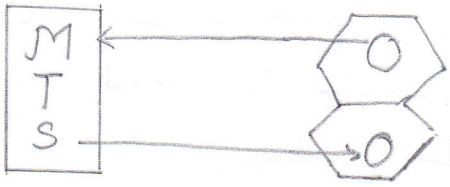
3) Paging

MTSO then attempt to complete the basic communication to called unit. The MTSO sends or paging message to certain base station depending on the called mobile no. Each base station signals transmit the paging signal in its own assigned setup channels.



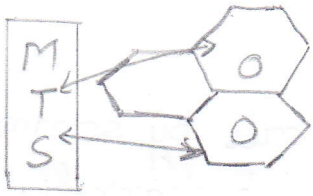
4) Call Accepted.

The called mobile unit recognised users, its number on the set of channels being monitored and respond to the base station. Base Station sends response to the MTSO and MTSO set up circuit between called and calling mobile unit.



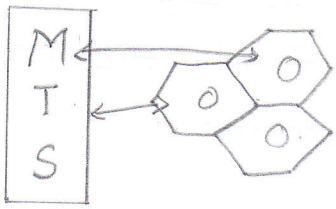
5) Ongoing Call

When the connection is maintained, mobile unit exchange their voice or data signals going through their respective base station and MTSO.



6) Hand-off

When a mobile user travels from one area of coverage or cell to another cell within a call duration, the call should be transferred to the new cell's base station. This ability for transferrence in mobile cellular system design is called handoff.



Why Cell is of Hexagonal Shape?

In cellular system a land area is divided into a regular shaped cells, which can be hexagonal, square, circular or some other shapes, although hexagonal cells are convential. There are some criteria for cell shape as given below:—

i) Geometric Shape
ii) Area without overlap
iii) Area of cell covered is maximum.

Geometric shape and area without overlap is satisfied by a hexagon, square and triangle as they can be fitted in a manner where there is no area of overlap. The circle on the other hand would overlap or leave gap.

Overlapping of cells causes interference and ~~leave~~ gap between cells means loss of coverage in these areas.

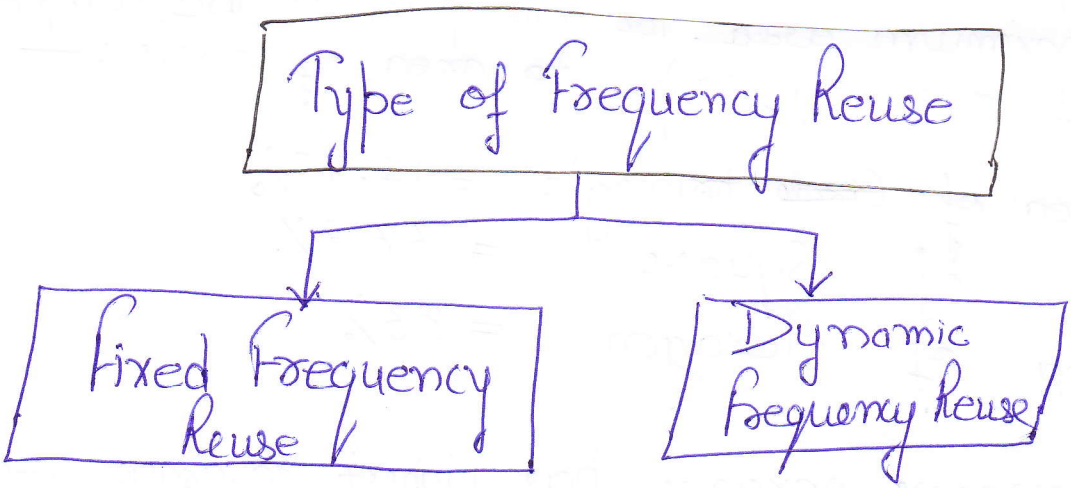
When area factor is considered circle has highest area however it doesnot satisfy second criteria of overlap. Therefore, we consider a shape which fits correctly and has maximum area. For this purpose, we compare area of remaining shape to area of circle:—

Area of ~~Circle~~ triangle = 17.77%
Area of Square = 63.7%
Area of Hexagon = 83%

which means hexagon has highest coverage area. Thus hexagon shape satisfy all criteria.

FREQUENCY RE-USE

If a given set of frequencies or radio channels, can be reused without increasing antenna then the large geographical area as covered by a single high power transmitter and geographical area can be divided into number of small areas each allocated a subset of frequencies. Provided that the seperation of two cells is sufficiently wide so that same subset of frequencies can be use. This concept of reusing the set of frequencies is known as frequency reuse. The ability of reuse the frequency means to expand the total system capacity without need to employ high power antenna. The key characteristic of cellular network is the ability to reuse the frequency to increase coverage or capacity. In a cellular system, frequency reuse is achieved by assigning a subset of total number of channels available to BS and controlling power output. In this way, cellular network increases the capacity (i.e, total number of available channels to users).



Fixed Frequency Reuse

Each cell has predetermined number of channels and if all channels used then cell is blocked and no service is provided. In this case, cells can borrow channels from another ~~etha~~ cell, this is called frequency borrowing.

Dynamic Frequency Reuse

There is no permanent allocation of frequency channels to the cells and frequency band are requested from MSC which assigns the band channels to cell using re-used distance.

Calculating Frequence-Reuse Factor

Let us assume that,

N = frequency reuse factor

R = Radius of cell.

d = Distance between centres of adjacent cells.

D_{min} = Minimum distance between centres of cells that use same frequencies.

S = Total number of channels allocated for the systems

For a hexagonal, cell pattern,

$$\boxed{d = \sqrt{3}\, R.}$$

$$\boxed{D_{min} = \sqrt{3}\, N_{Reuse} * R}$$

If each cell is assigned equal number of channels, then number of channels per cell is:-

$$\boxed{N_{cpc} = K/S}$$

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

$K \rightarrow$ no. of cells which can't use same frequency.

example

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

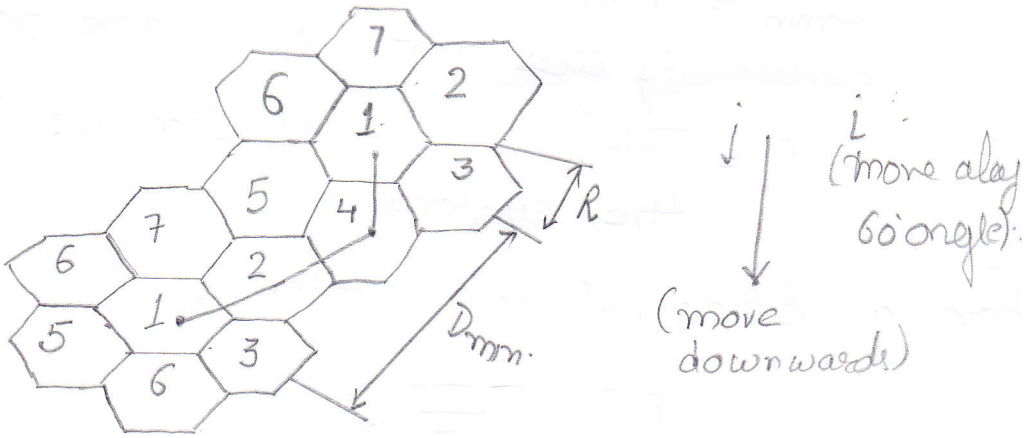
Let assume, $i = 2$

$j = 1$

then,

$$K = (2)^2 + 2 \cdot 1 + (1)^2$$
$$= 4 + 2 + 1$$
$$= 7$$

$$D_{min} = \sqrt{3K} * R$$
$$= \sqrt{3(7)} * R$$
$$= \sqrt{21} * R$$
$$\boxed{D_{min} = 4.58 R}$$

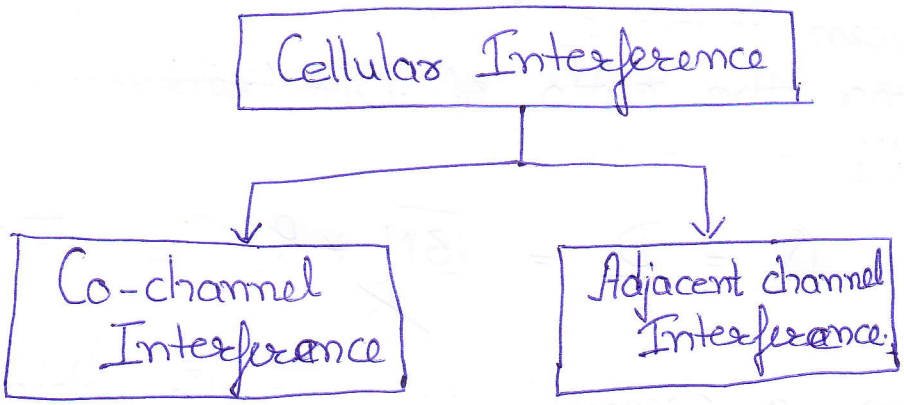


INTERFERENCE

Interference is the major drawback in the performance of cellular radio systems. Sources of interference are :—

⇒ Another mobile in the same cell.
⇒ Call in progress in a neighbouring cell.
⇒ Other base stations operating in the same frequency band.

We have two type of channels, i.e voice channels and control channels. Interferance on Voice channels causes cross talk where the subscriber hears interferance in the background due to undesired transmission. On control channels, interference leads to missed and blocked calls due to errors in digital signaling. Intereferance is a major bottleneck in increasing capacity & responsible for dropped Calls. There are two types of channel interference.



Co-channel Interferance

Frequency reuse implies that in a given coverage area, there are several cells that use the same set of frequencies. These cells are called co-channel cells, and interferance from these cells is called co-channel interferance. Thus, Co-channel interference is crosstalk from two different radio transmitters using same frequency channel.

There are several reasons for co-channel Interference such as :-

⇒ Adverse Weather Conditions
⇒ Poor frequency Planning
⇒ Overly Crowded Radio Spectrum.

Thermal noise can be overcome by ~~reducing~~ increasing signal-to-noise ratio, but co-channel interference can't reduced by increasing power of transmitter because an increase in carrier transmitter power increases interference to neighbouring co-channel cells. To reduce, co-channel interference, cells must be physically seperated by a minimum distance to provide isolation. When the size of each cell is approximately same and the base stations transmit the same power, then co-channel interference ratio is independent of transmitted power and becomes a function of radius of cell (R) and distance between centres of nearest co-channel cells (D). By increasing the ratio of D/R, seperation between co channel cells is increased.

$$Q = \frac{D}{R} = \frac{\sqrt{3N} * R}{R} = \sqrt{3N}.$$

Q ⟶ Co-channel Reuse Ratio which is related to cluster size.

	Cluster Size (N)	Reuse Ratio (Q)
i=1, j=1	3	3.
i=1 j j=2	7	4.58
i=2, j=2	12	6
i=1, j=3	13	6.24

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

small value of Q	⟹ Larger Capacity.
Large value of Q	⟹ small interference

Adjacent Interference

Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent interference. Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak into the passband. Also known as near-far effect where nearby transmitter which may or may not be of same type as used by cellular system captures the receiver of the subscriber. Near-far effect occurs when a mobile close to a base station transmits on a channel close to one being used by a weak mobile. The base station have difficulty in discriminating the desired mobile user from number of users caused by adjacent interference.

Adjacent interference can be minimized by careful filtering & channel assignments. By keeping frequency seperation between each channel in a given cell as large as possible, adjacent channel interference may be reduced.

Capacity Increasing Methods.

There are various methods used to increase the capacity of system such as :—

i) By adding new channels
ii) Frequency Borrowing
iii) Cell Splitting
iv) Cell Sectoring

Cell Splitting

Cell splitting is a process of subdividing a cell into smaller cell each have its own base station. It increases the capacity of cellular system since it increases the number of times the channels are reused by defining new cells which have smaller radius than the original cell. By introducing the smaller cells between the existing cells, capacity increases due to additional number of channels per unit area. Smaller cells are added in such a way that it preserve the frequency plan of the system. Thus cell splitting process increase the capacity of system by using following way :-

⇒ By defining new cells which has smaller radius than original.

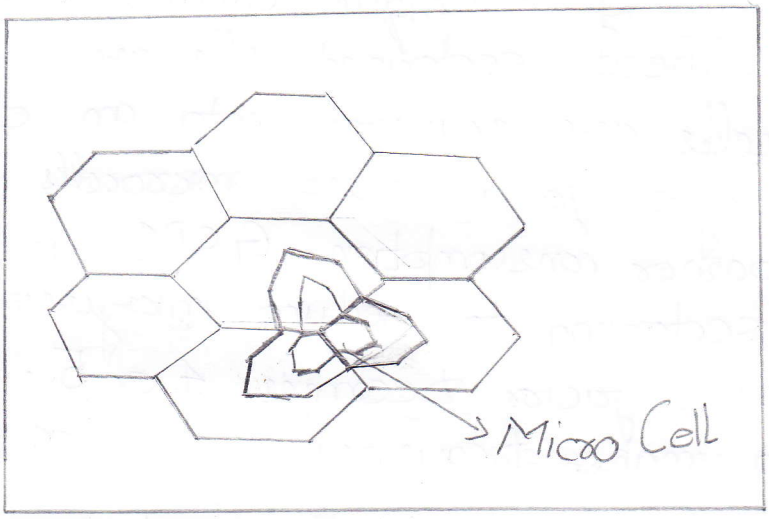
⇒ By installing smaller cells between existing cells.

⇒ Number of channels are increased.

The splitting process involves not only splitting the cells to smaller unit but also ⟹

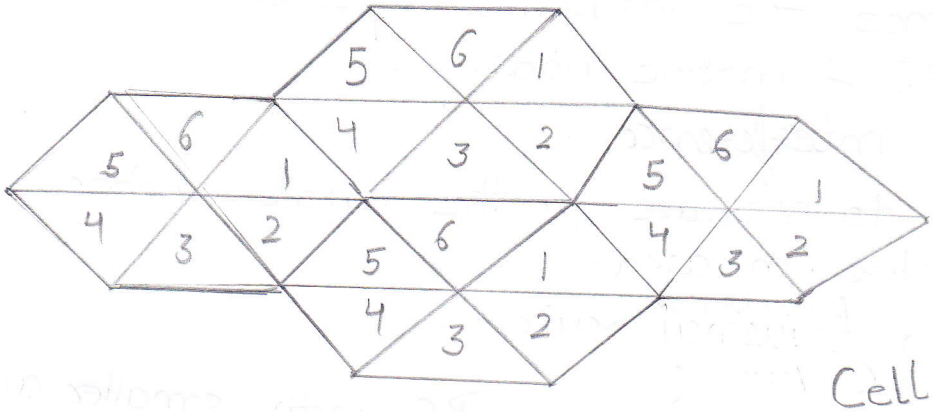
→ decrease the transmission power in BS & mobile node.
→ avoid interference
→ leads to increase in the total number of clusters in area.
→ allow frequency reuse.

Each split cell has its own BS with smaller antenna. Smaller cells are termed as micro cells.



Cell Sectoring

Cell sectoring is a technique that involves the division of cells into number of wedge-shaped sectors, each of which has its own set of channels. This technique can be implemented by installing directional antenna that subdivides cells into three or six sectors. Thus, the sectoring may leads to an increase in the overall cell capacity by a factor of 3 to 6. Sectoring also increases the frequency reuse factor which provides a high degree of frequency reuse.



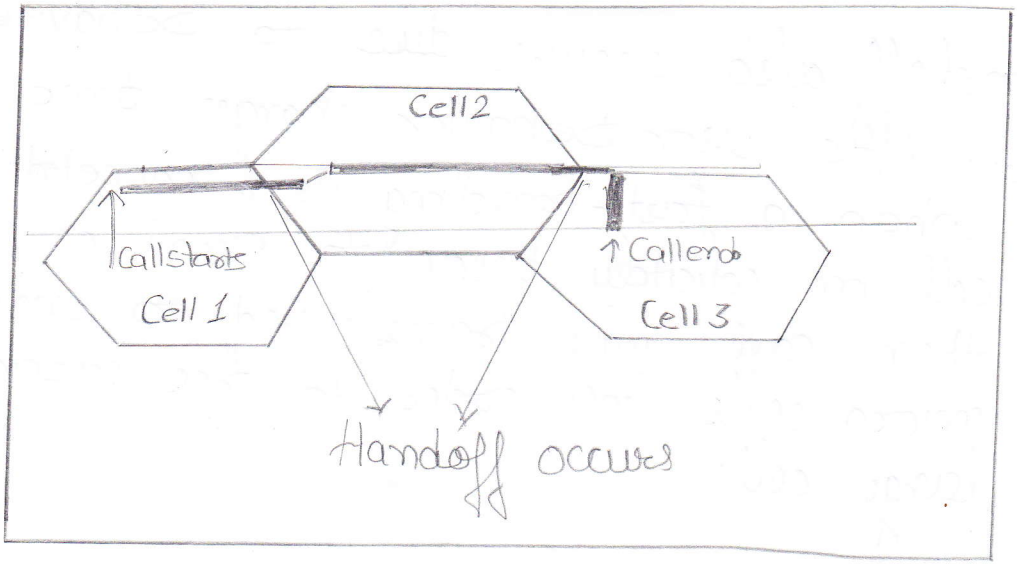
Cell Sectoring

The cell sectoring technique creates a subsets of a given cell. These sectorised cells are called microcells. These microcells are adjusted into an existing cell structure. Benfits from these microcells is that it reduce power consumption. GSM use the concept of sectoring to reduce interference and frequency reuse factor becomes 4 or 5. CDMA uses sectoring to make frequency reuse factor as 1.

This sectoring technique increases the capacity of system and also reduces the interferences caused by cell neighbours.

HANDOFF

When a mobile user travels from one area of coverage or cell to another cell within a call duration, then call should be transferred to the new cell's base station otherwise call will be dropped because link with current base station becomes two weak. This ability for transference in mobile cellular system design is called handoff. Thus, Handoff refers to the process of transferring an ongoing call from one channel connected to network to another. During a call, BS (Base Station) monitors the signal quality / strength (C/I) ratio from mobile. If the signal quality / strength ratio falls below a predesignated threshold, the network requests the neighbouring base station. If another BS indicating better C/I ratio then the current BS, a signaling message is sent to mobile on speech channel from current BS to inform the mobile to retune to a free channel in neighbouring cells. The mobile retunes to new channel and simultaneously the network switches the call to new BS.



Why Handoff Occurs ?

1. When the phone is moving away from area covered by one cell and entering the area covered by another cell, then call is transferred to second cell to avoid call termination.

2. When capacity for connecting new calls for a given cell is used up or existing call is overlapped by another cell, then it is transferred to that cell to free-up some capacity in first cell for other users.

3. In non-CDMA networks when channel used by phone becomes interfered by another phone using same channel in different cell, then it is needed to transfer a call to different channel in same cell or to different channel in another cell to avoid interference.

4. In CDMA network, handoff occurs to reduce the interference to a smaller neighbouring cells due to near-far effect even when mobile still has an excellent connection to existing cell.

5. Handoff also occurs due to behaviour of user. As user behavior changes time to time.
   eg ⇒ when a fast-travelling user conneted to large cell immediately belong to small covering area then call may transferred to small micro cells in order to free capacity on large cell.

Types of Handoff

The most basic form of handoff is when a phone call in progress is redirected from its current cell (source) and its used channel in that cell to new cell (target) and a new channel. The source and target cells may be served from two different cell sites or from one and the same cell site.

1) Inter-Cell Handoff

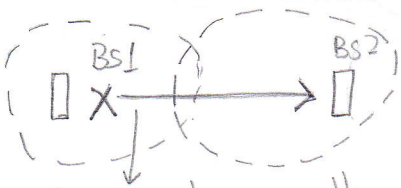
A type of handoff in which the source and the target are different cells. The purpose of inter-cell handoff is to maintain the call as subscriber is moving out of the area covered by source cell and entering the area of target cell.

2) Intra-Cell Handoff

Handoff in which the source and target are one and same ~~channel~~ cell and only used channel is changed during handoff. Purpose of intra-cell handoff is to change one channel which may be interfered.

3) Hard Handoff

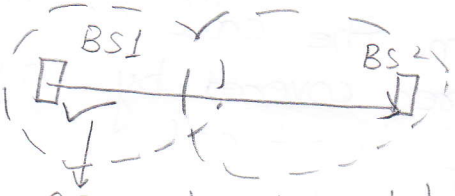
Also known as break before make. It is a type of handoff in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus, the connection to the source is broken before the connection to the target is made. Hard handoff minimize the disruption to the call.



Connection with current base station is breaked before making new connection.

4) Soft Handoff

Also known as make before break. Handoff in which the channel in the source cell is retained and used for a while in parallel with channel in the target cell. The connection to the target is established before connection to the source is broken. The interval during which two connections are used in parallel is very short. When a call is in a state of soft handoff the signal of best of all used channels can be utilizeat at given moment.



Connection is not broken, first make connection with target.

5) Vertical Handoff

Vertical handoff refer to the automatic failure from one technology to another in order to maintain communication. For example, a laptop might be able to use both high speed wireless LAN & cellular technology. Wireless LAN connections provide higher speeds while cellular technologies provide ubiquitous coverag. Thus laptop users want to use wireless LAN when connection is avaulable and use cellular technology when wireless LAN is unavailable.

6) Horizontal Handoff

Horizontal handoff refer to the technique of changing access point belonging to same technology.

Types of Handoff

The most basic form of handoff is when a phone call in progress is redirected from its current cell (source) and its used channel in that cell to new cell (target) and a new channel. The source and target cells may be served from two different cell sites or from one and the same cell site.

1) Inter-Cell Handoff

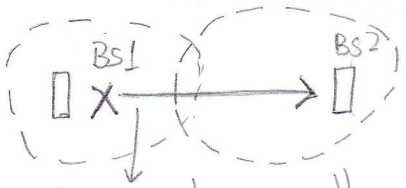
A type of handoff in which the source and the target are different cells. The purpose of inter-cell handoff is to maintain the call as subscriber is moving out of the area covered by source cell and entering the area of target cell.

2) Intra-Cell Handoff

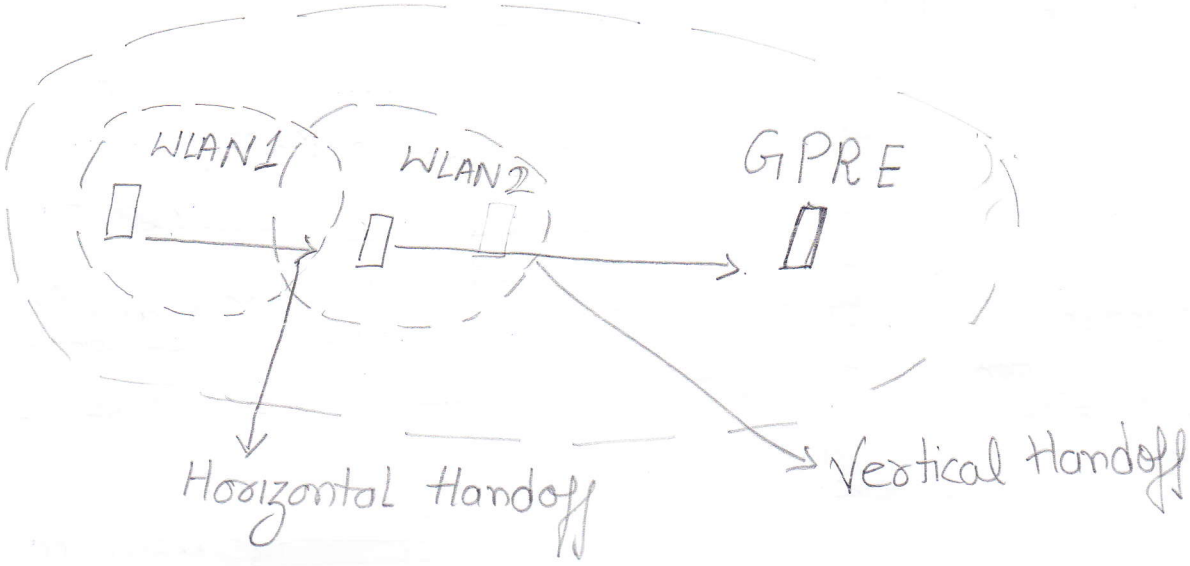
Handoff in which the source and target are one and same ~~channel~~ cell and only used channel is changed during handoff. Purpose of intra-cell handoff is to change one channel which may be interfered.

3) Hard Handoff

Also known as break before make. It is a type of handoff in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus, the connection to the source is broken before the connection to the target is made. Hard handoff minimize the disruption to the call.



Connection with current base station is breaked before making new connection



Handoff Strategies

When mobile moves into a different cell, MSC automatically transfers the call to new channel belonging to new base station. This handoff not only involves the identification of new base station, but also requires that voice & control signals be allocated to channels associated with new base station. Processing handoffs is an important task in any cellular radio system. Handoffs must be performed successfully and as infrequently as possible. To meet these requirements, system designers must specify an optimal signal level to initiate a handoff. When a particular signal level is specified as minimum usable signal for acceptance voice quality at base station receiver, then slightly stronger signal level is used as a threshold at which handoff is made.

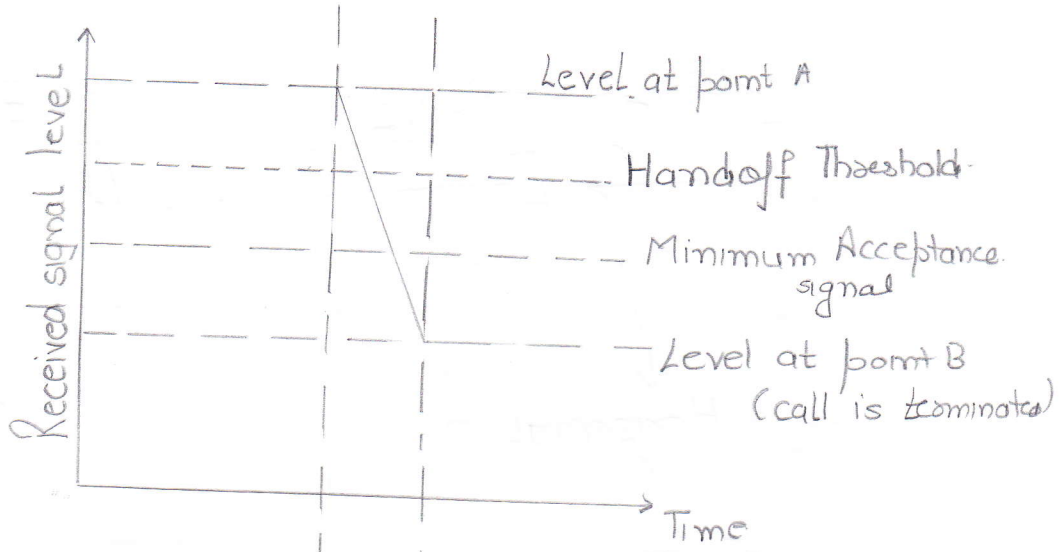
$$\boxed{\Delta = P_{handoff} - P_{minimum\ usage}}$$

$\Delta \longrightarrow$ large, then unnecessary handoffs occur.

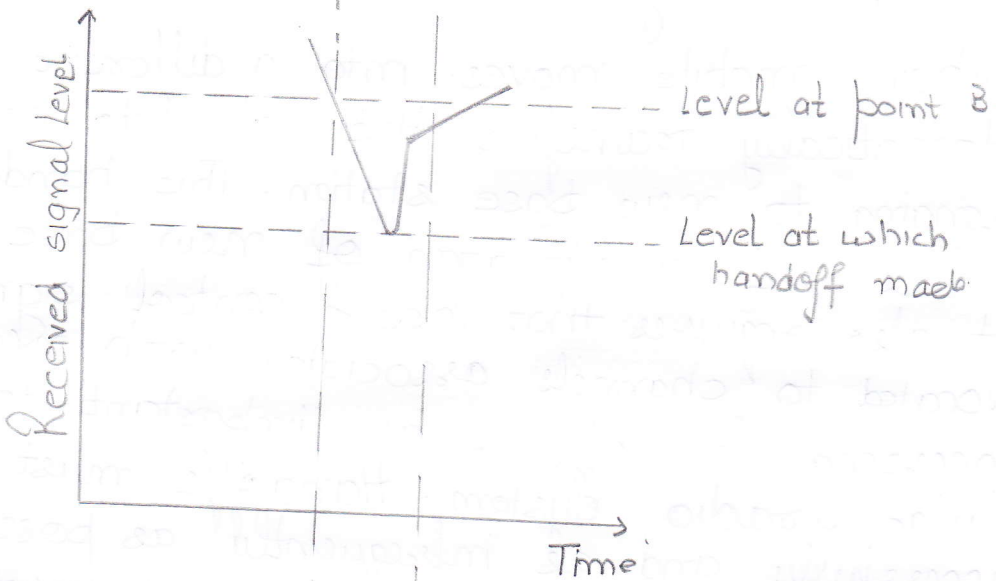
$\Delta \longrightarrow$ small, there may be insufficient time to complete handoff.

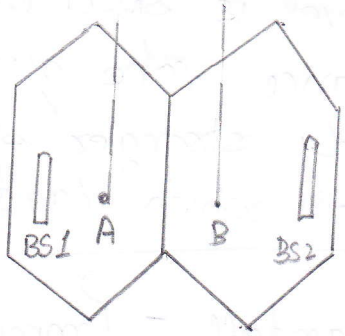
Therefore, Δ must be choosen carefully to meet the requirements.

a) Improper handoff situation when Δ is too small.



b) Proper Handoff.





In first generation analog cellular system, signal strength measurements are made by base stations and supervised by MSC. Each base station constantly monitors the signal of all mobiles ~~users~~ to determine relative location. In addition to measuring the signal of calls in progress with in cell, a seperate receiver in each base station called locator receiver is used to scan and determine the strength of mobile users which are in neighbouring cells. Based on the locator receiver signal strength information from each BS, MSC decides if a handoff is necessary or not.

In digital technology, handoff decisions are mobile assisted. The handoff strategy used is called Mobile Assisted Handoff Operation (MAHO).

<u>MAHO</u> operates as :—

1. Every mobile measures the received power from surroundings BSs.
2. Mobile continually reports the results to the serving BS.
3. A handoff occurs when power received from another BS exceed the power received from current base station.
4. Thus, MSC does not need to monitor the complete process.

<u>MAHO</u> method enables the call to be handled over between base stations at much faster rate than in first generation analog system since handoff measurements are made by mobile not by MSC. This method is best suited for microcellular environments, where handoffs are more frequent

Prioritizing Handoff.

Two methods are used to give a priority to handoff.

- Guard Channel concept
- Queuing of Handoff

In Guard channel concept, a fraction of the total available channels in a cell is reserved for handoff requests.

Advantage → Efficient spectrum utilization

Disadvantage → Reduce the total carried traffic.

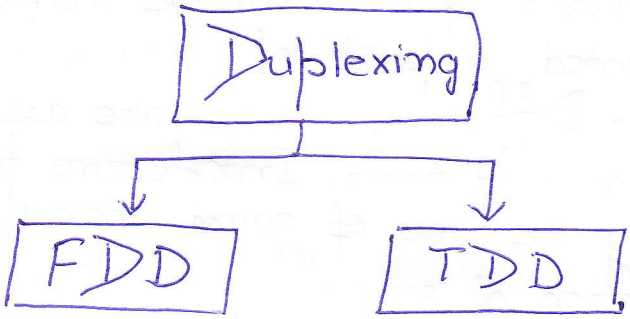
Queuing of handoff method is used to decrease the probability of call termination due to lack of available channels.

Advantages

1) Advantage of hard handoff is that at any moment in time one call uses only one channel.
2) Phones hardware does not capable of receiving one or more channels in parallel.
3) Reliability of the connection becomes higher.
4) Probability of interference can be reduced.

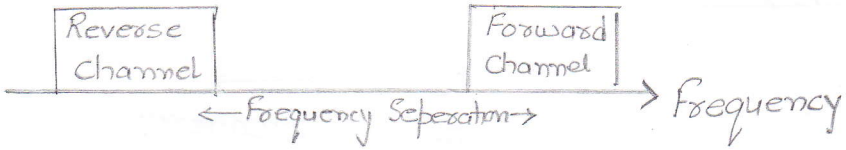
Multiple Access Techniques

Multiple access schemes are used to allow many mobile users to share simultaneously a finite amount of radio spectrum. The sharing of spectrum is required to achieve high capacity by allocating the available bandwidth to multiple users. In wireless communication systems, it is desirable to allow the subscribers to send simultaneously information to base station while receiving information from base station. This process is known as duplexing. Duplexing may be done using frequency or time domain techniques.



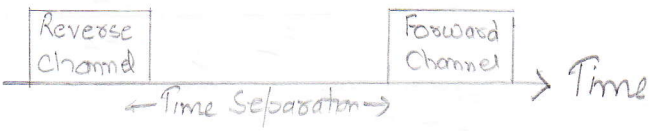
FDD → Frequency Domain Duplexing

FDD provides two distinct bands of frequencies for every user. The forward band provides traffic from the base station to the mobile and reverse band provide traffic from mobile to base station. The frequency seperation between each forward and reverse station or channel is constant.

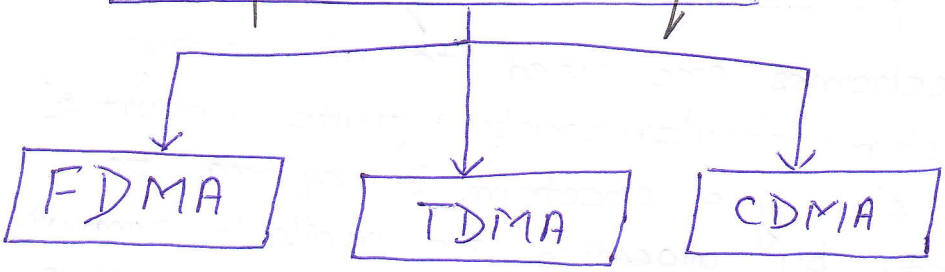


TDD ⇒ Time Division Multiplexing

TDD uses time instead of frequency to provide both a forward & reverse link. In TDD, multiple users share a single radio channel by taking turns in time domain

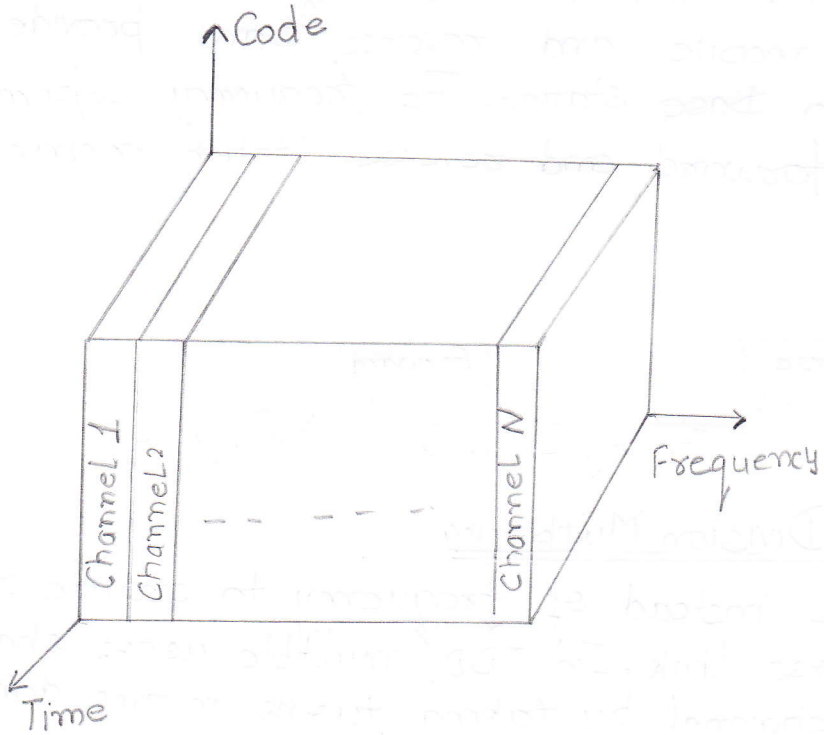


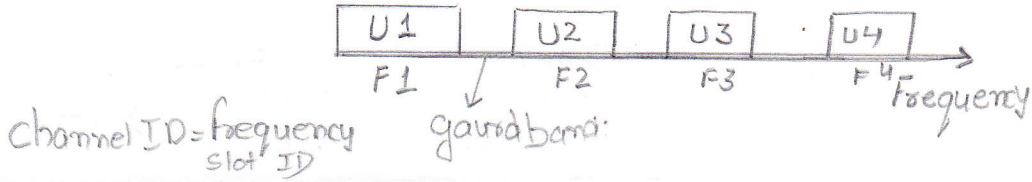
Multiple Access Techniques



Frequency Division Multiple Access

FDMA assigns individual ~~users~~ channels to individual users. Users share the available spectrum in the frequency domain and a user is allocated a part of frequency band called traffic channel. Different users are assigned different traffic channels on demand basis. Interference from adjacent channels is limited by the use of gaurd channels or bands that maintain seperation of signals associated with different users. In FDMA, each user is allocated a unique frequency band or channel. These channels are assigned on demand to users who request service. During the period of call, no other user can share same channel.





Features of FDMA

1) The FDMA channel carries only one phone circuit at a time.
2) If an FDMA channel is not used, then it sits idle and cannot be used by other users to increase or share capacity.
3) After assignment of a voice channel, base station & mobile transmit simultaneously.
4) FDMA technique reduce interference but limits the number of users.
5) FDMA mobile unit use duplexers since both transmitter & receiver operate at the same time.
6) FDMA systems have higher cell site system costs as compared to other technologies, because of single channel per carrier design & need to use band pass filters.
7) Complexity of FDMA mobile systems is lower when compared to TDMA systems.

Example

The first US analog cellular system, the Advanced Mobile Phone System (AMPS) is based on FDMA/FDD. A single user occupies a single channel while call is in progress. Multiple or simultaneous users are accomodated in AMPS by giving each user a unique channel.

Number of channels that can be simultaneously supported by FDMA system is given as:-

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

$B_t \rightarrow$ total spectrum allocation.

$B_c \rightarrow$ Channel bandwidth

example If US AMPS cellular operator is allocated 12.5 MHz for each simplex band and if B_t is 12.5 MHz and B_{gaurd} is 10 KHz and B_c is 30 KHz. Find number of channels available?

solution

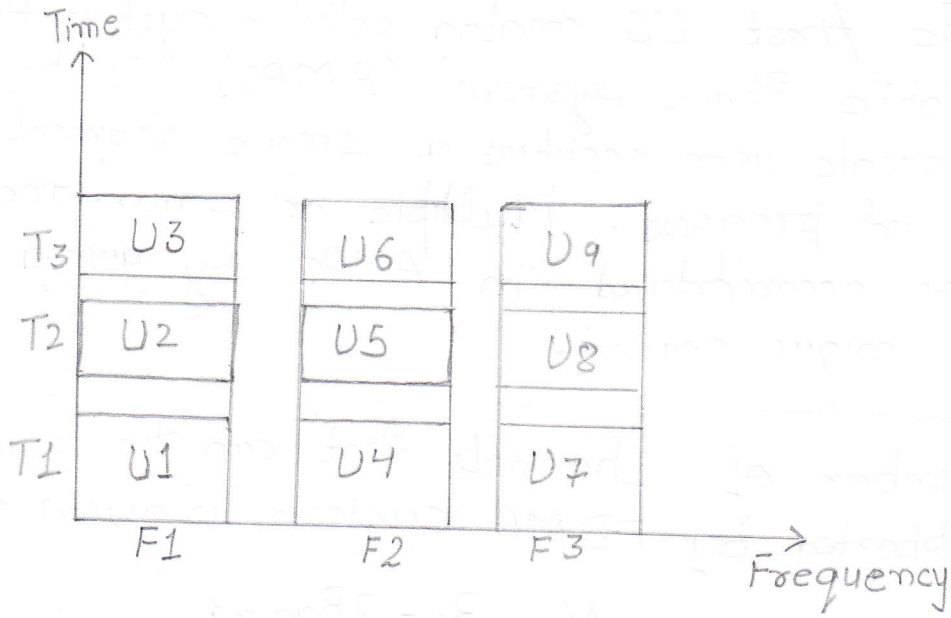
$$N = \frac{B_t - 2B_{gaurd}}{B_c}$$

$$= \frac{12.5 \times 10^6 - 2(10 \times 10^3)}{30 \times 10^3}$$

$$= 416$$

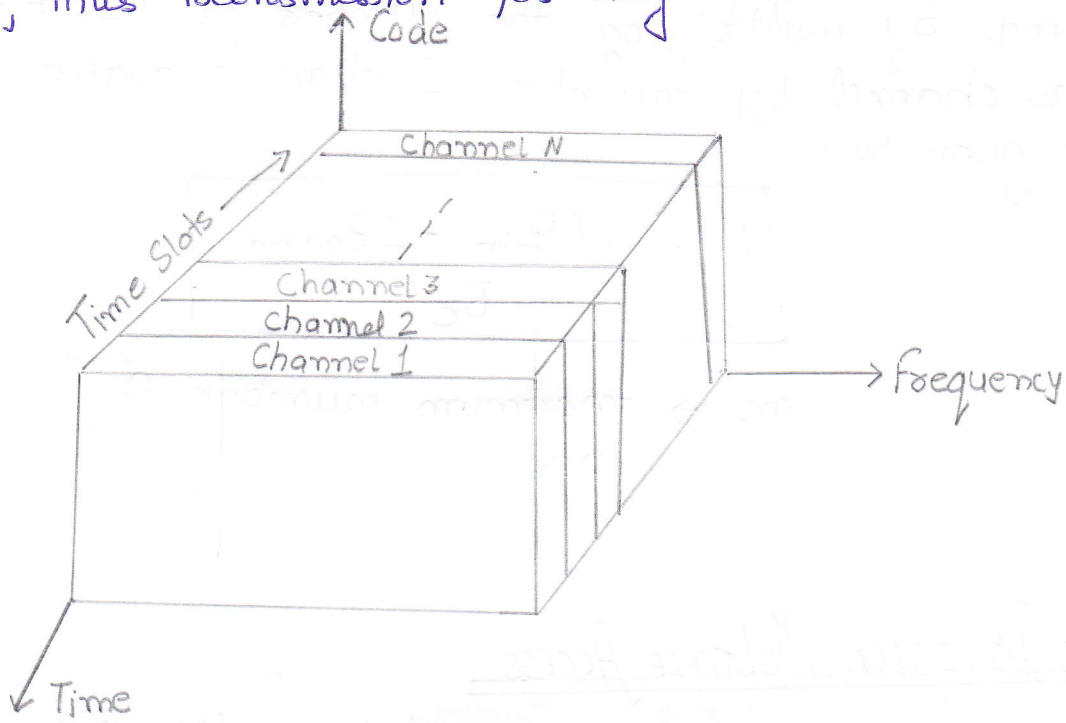
Time Division Multiple Access

In TDMA techniques that are utilized in many digital cellular systems, the available spectrum is partitioned into narrow frequency bands or channels which in turn are divided into a number of time slots. An individual user is assigned a time slot that permits access to frequency channel for duration of time slot. Thus, TDMA systems divide the radio spectrum in time slots.



Channel ID = Frequency Slot ID + time slot ID

TDMA divides the radio spectrum into time slots and in each slot only one user is allowed to either transmit or receive. TDMA transmit data in buffer and burst method, thus transmission for any user is noncontinous.



Features of TDMA

1) TDMA shares a single carrier frequency with several users, where each user make use of nonoverlapping time slots.
2) Data transmission is not continous but occurs in bursts. This results in low battery consumption.
3) Because of discontinous transmission of TDMA, the handoff process is much simpler, since it is able to listen for other base stations during idle time slots.
4) TDMA use different time slots for receiver and transmitter, thus duplexers are not required.
5) Transmission rates are very high as compared to FDMA channels.
6) High synchronization is required in TDMA systems. because of burst transmission. TDMA transmissions are slotted, requires that receiver must be synchronized for each data burst

Number of channels in TDMA system.

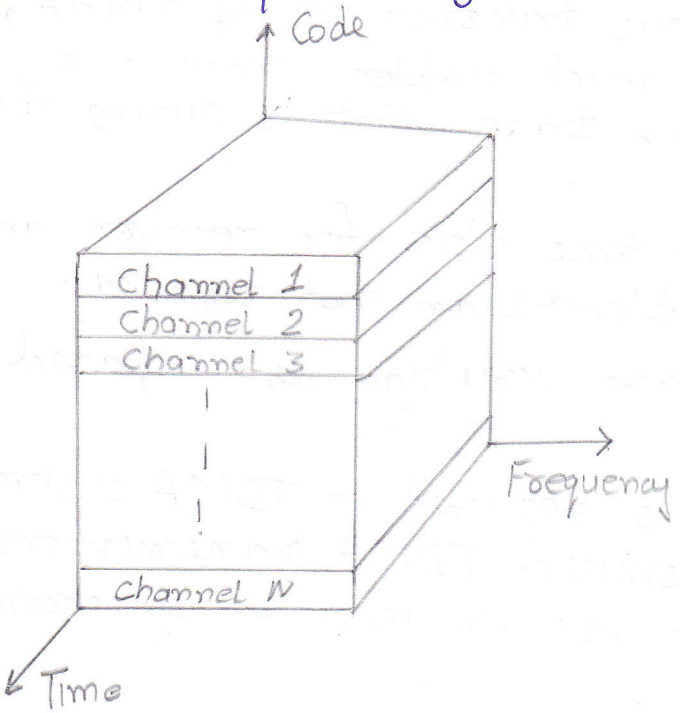
The number of TDMA channel slots can be found by multiplying the number of TDMA slots per channel by number of channels available and is given by :-

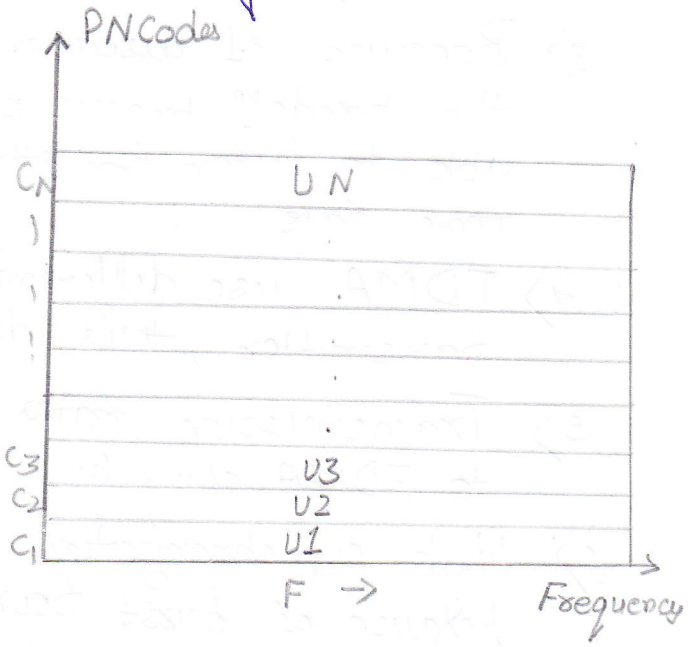
$$N = \frac{m(B_{tot} - 2B_{guard})}{B_c}$$

$m \rightarrow$ maximum number of TDMA users.

CODE DIVISION MULTIPLE ACCESS

In CDMA, the message signal is multiplied by a very large bandwidth signal called spreading signal. The spreading signal ~~called~~ is a pseudo noise code sequence that has a chip rate of magnitudes greater than the data rate of the message. All users in a CDMA systems use the same carrier frequency and may transmit simultaneously. Each user has its PN code. Each user operates independently with no knowledge of other users.





Chanel ID = PN Code ID

Since the signals in the case of CDMA utilize the entire allocated block of spectrum, no guard bands of any kind are necessary.

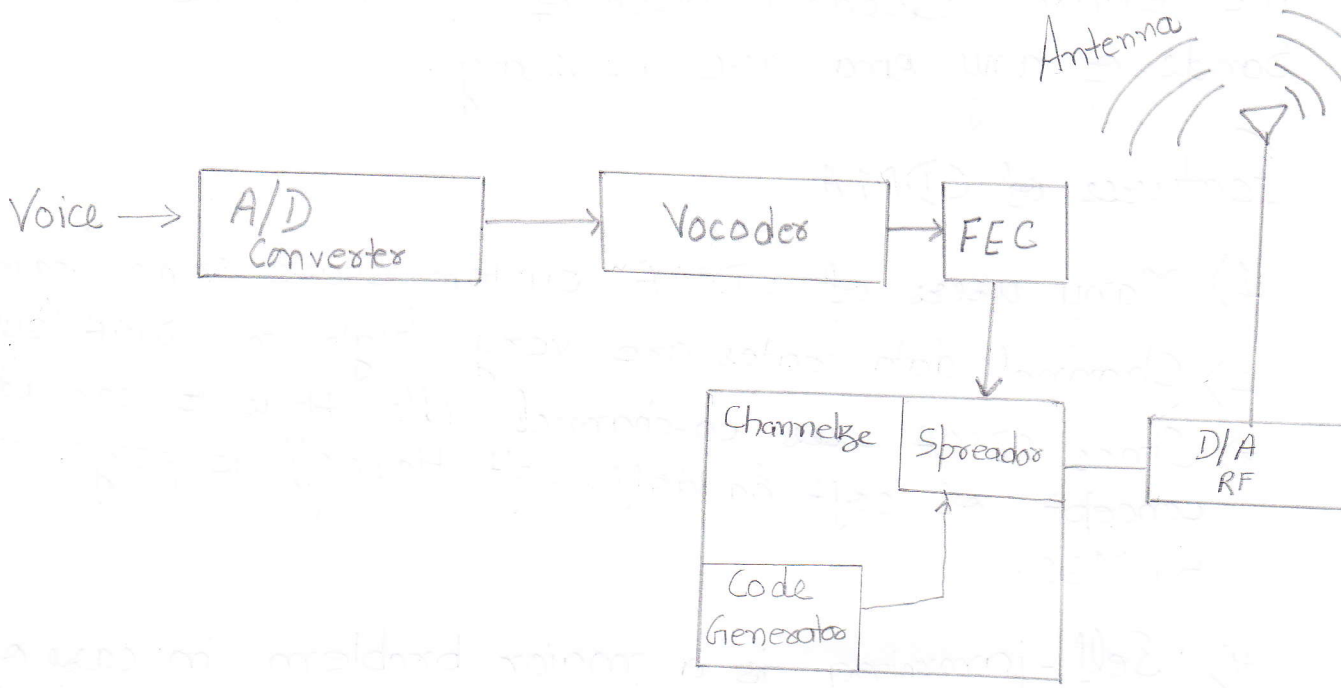
Features of CDMA

1) Many users of CDMA system share same frequency.
2) Channel data rates are very high in CDMA system.
3) Since CDMA uses co-channel cells, thus it can use concept of soft handoff. Soft Handoff is performed by MSC.
4) Self-jamming is a major problem in case of CDMA system. Self-jamming arises from the fact that spreading sequences of different users are not orthogonal.
5) Near-far problem occurs at a CDMA receiver if an undesired user as high detected power as compared to the desired user.
6) CDMA provides better facilities such as voice quality, system capacity, privacy and flexibility
7) CDMA uses codes to convert between analog voice signals and digital signals.

CDMA working

CDMA uses codes to convert between voice and digital signals. The generation of CDMA signals can be classified into five steps:-

1 ⇒ Analog to Digital Conversion 2 ⇒ Vocoding
3 ⇒ Encoding and Interleaving.
4 ⇒ Channelizing the signals.
5 ⇒ Conversion of digital signal to RF signal



First step of CDMA signal generation is analog to digital conversion called A/D conversion. CDMA uses Pulse Code Modulation (PCM) to accomplish A/D Conversion. The second step of CDMA signal generation is voice compression. CDMA uses a device called vocoder to accomplish voice compression.

Encoders and interleavers are built into the BTS and the phones. The purpose of the encoding and interleaving is to build redundancy into the signal so that information lost in transmission can be recovered. Interleaving is a process of method of reducing the effects of burst errors and recovering lost bits. The encoded voice data is further encoded to seperate it from other encoded voice data. The encoded symbols are then spread over the entire bandwidth of the CDMA channel. This process is called channelization. The receiver knows the code and uses it to recover the voice data.

CDMA codes

- Walsh Codes
- PN Codes

Walsh Codes

Walsh codes channelize users on the forward link (BTS to mobile). Walsh codes provide a unique identity for each user. In other words, Walsh codes are unique enough that voice data can only recovered by a receiver applying the same Walsh code. All other signals are discarded as they are noise.

PN Codes

PN codes channelize users on the reverse link. A PN code is one that appears to be random, but not. PN code used in CDMA is a combination of codes. Thats why CDMA is so secure.

Advantages of CDMA

1) Coverage

CDMA's features result in coverage that is 1.7 and 3 times that of TDMA. Power control helps the network to dynamically expand coverage area.

2) Capacity

CDMA capacity is ten to twenty times that of analog system & four times that of TDMA. Reasons for this high capacity include.

1.) CDMA's universal frequency reuse
2.) CDMA users are seperated by codes, not frequencies
3) Power control minimizes interference.
4) CDMA use soft handoff which also increase capacity because soft handoff requires less power.

3) Clarity

CDMA system can achieve clarity because of CDMA's strong digital processing.

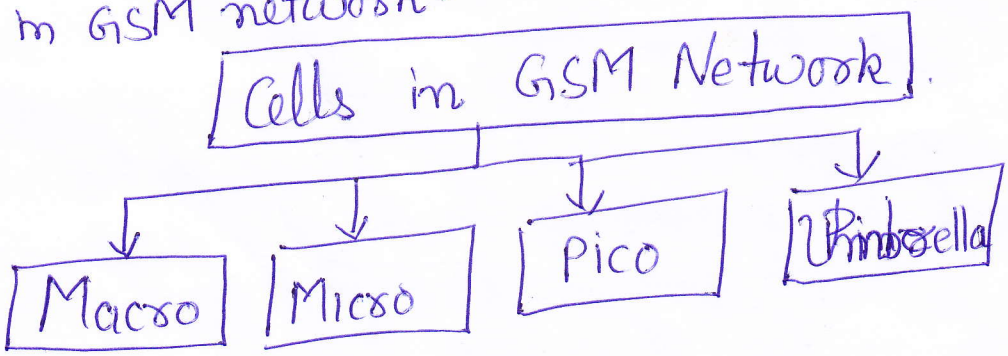
Approach	TDMA	FDMA	CDMA
1) Idea	Segment the time into disjoint time slots, demand driven or fixed pattern.	Segment the frequency band into disjoint sub-bands.	Spread the spectrum using codes.
2) Terminals	All terminals are active for short periods of the time on same frequency.	Every terminal has its own frequency, uninterrupted.	All the terminals can be active at same place at same time, uninterrupted
3) Technique	Time is divided into slots, each user transmit or receive in its own time slot only.	Instead of time, channel bandwidth is divided into subbands, each user assigned subband, All users work at same time.	All users work in time & frequency band but each user assiging a code.
4) Technology	TDMA is digital technology & used in GSM.	FDMA is analog technology & oldest one.	CDMA is latest technology.

GSM Global System for Mobile Communication

GSM is the most popular standard for mobile phone in the world. According to the estimation, GSM service is used by over 2 billion people across more than 212 countries and territories. GSM cover 71% of all the digital wireless market. Thus, GSM is a technology that is rapidly growing and constantly evolving with wireless, satellite and cordless systems offering greatly expanded services. These services include multimedia data services, high speed, inbuilt support for side by side use of these services and provide the facilities.

Technical Details

GSM is a cellular network which means that mobile phones connect to it by searching for cells. GSM operates in four different frequency ranges. Most GSM networks operate in the 900 MHz or 1800 MHz bands. GSM uses combination of FDMA and TDMA. Using FDMA, the band is divided into 124 channels each with a carrier bandwidth of 200 KHz. Using TDMA, each of these channels is then further divided into 8 time slots. There are four different cell sizes in GSM network.



⇒ Macro Cells. can be regarded as cells where the base station antenna is installed on a building above average roof top level.

⇒ Micro Cells are the cells whose antenna height is under average roof top level.

⇒ Pico cells are small cells whose coverage diameter is a few dozen meters, they are mainly used indoors.

⇒ Umbrella Cells are used to cover shadowed regions of smaller cells & fill in gaps in coverage between those cells.

GSM features

⇒ Support for international roaming.

⇒ Good Speech quality.

⇒ Ability to support handheld terminals.

⇒ Low terminal and service cost.

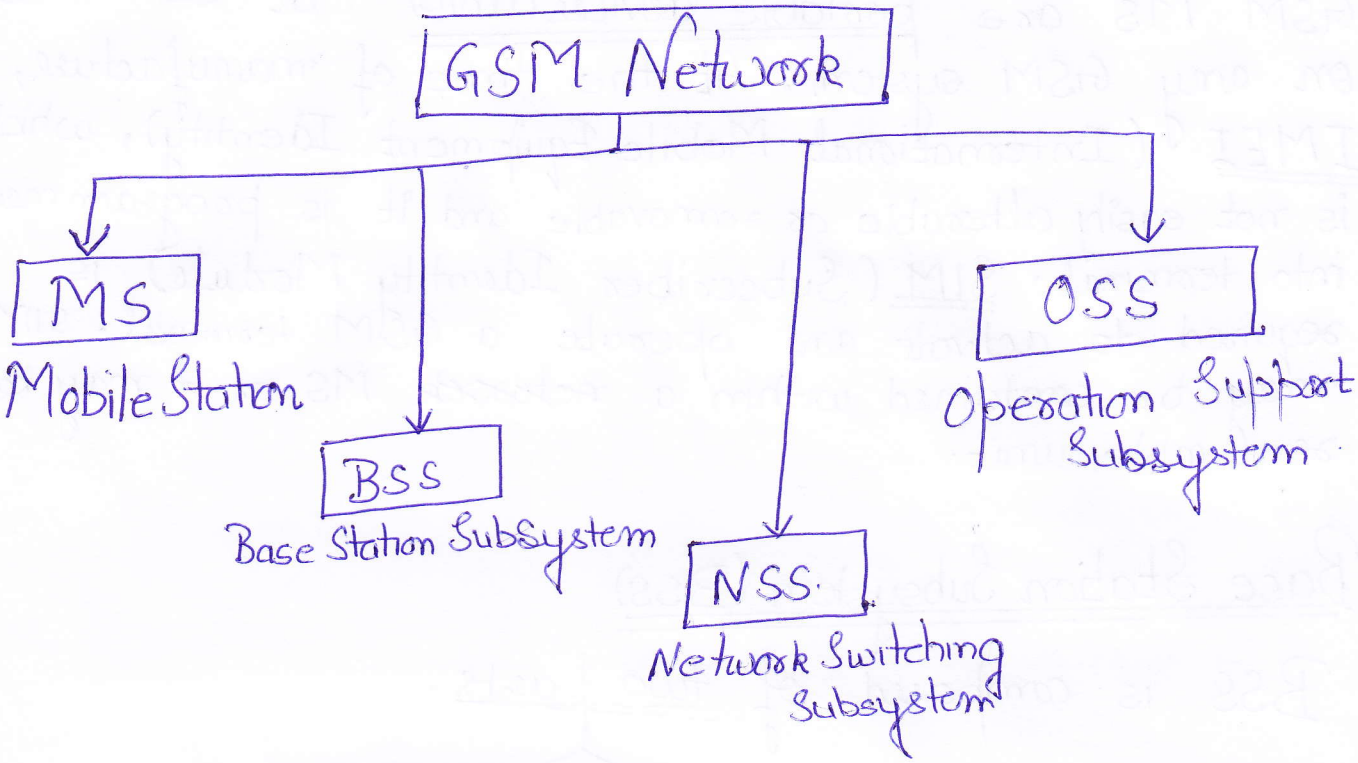
⇒ Support for a new services and facilities.

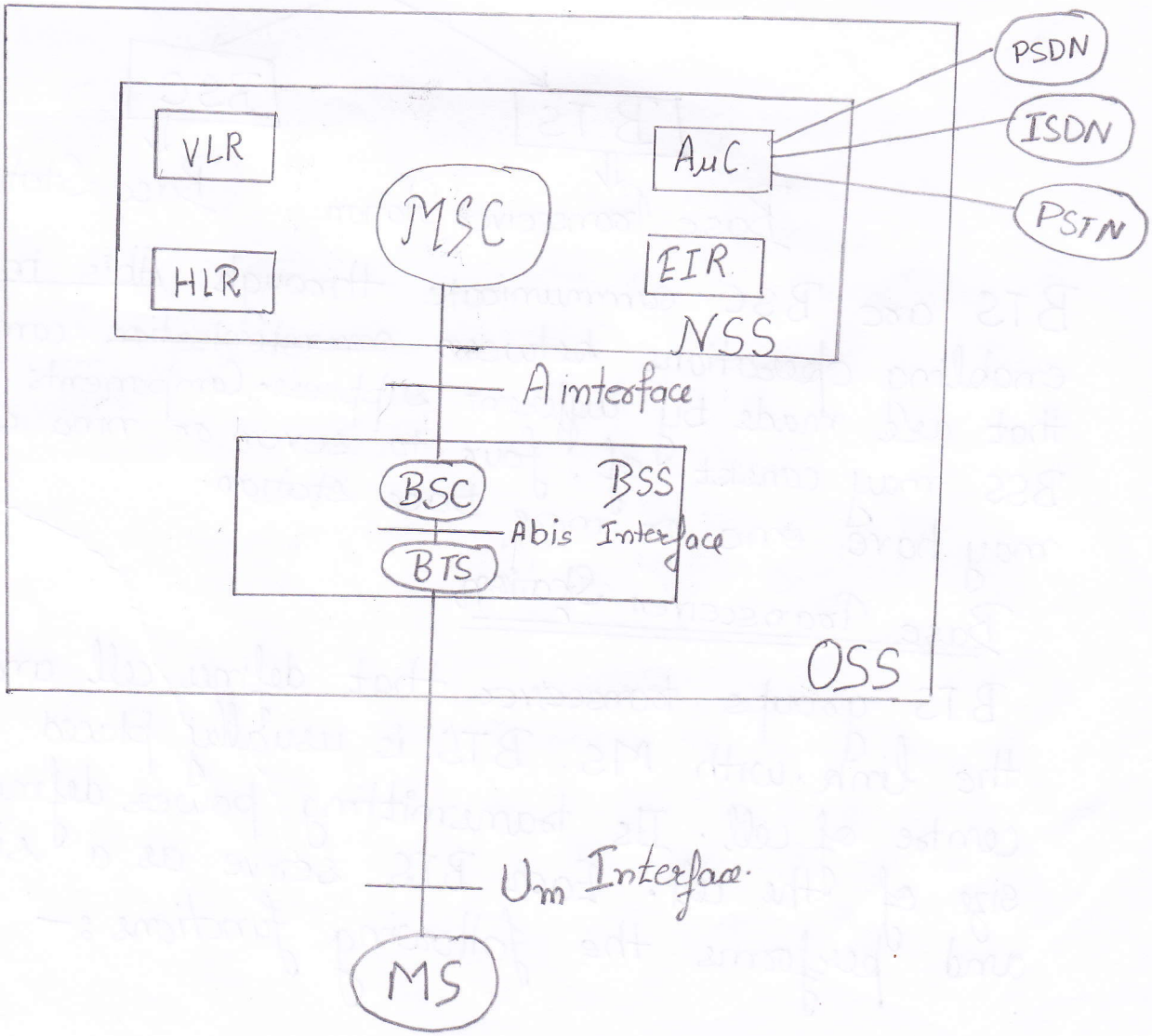
⇒ ISDN compatability.

⇒ International Roaming.

GSM Architecture

GSM network follow and structured in hierarchic fashion consisting of MS, BSS, NSS and OSS.





Mobile Station MS consist of the physical equipment, such as transceiver, display, processors, SIM cards etc. It provides the air interface to the user in GSM network. GSM MS are portable devices (units) that can be used on any GSM system. At the time of manufacture, IMEI (International Mobile Equipment Identity), which is not easily alterable or removable and it is programmed into terminal. SIM (Subscriber Identity Module) is required to activate and operate a GSM terminal. SIM may be contained within a ~~network~~ MS or it may be removable unit.

Base Station Subsystem (BSS)

BSS is composed of two parts.

- BTS ⇓ Base Transceiver Station
- BSC ⇓ Base Station Controller

BTS are BSC communicate through Abis interface, enabling operations between ~~communication~~ components that are made by different suppliers. Components of a BSS may consist of four to seven or nine cells. BSS may have one or more base station.

Base Transceiver Station

BTS groups transceiver that defines cell and handle the link with MS. BTS is usually placed in the centre of cell. Its transmitting power defines the size of the cell. Each BTS serve as a single cell and performs the following functions :-

⇒ Encoding, encrypting, multiplexing, modulating and feeding RF signals to antenna.
⇒ Decoding, decrypting and equalizing received signals.
⇒ Transcoding
⇒ Random Access Detection

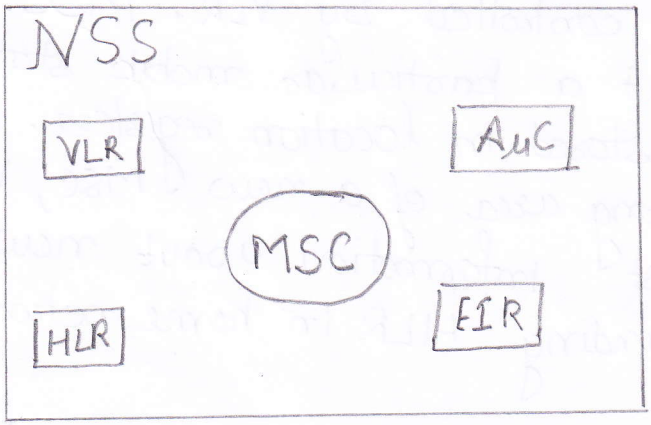
Base Station Controller (BSC)

BSC manages radio resources for one or more BTSs. It handles radio channel setup, frequency hoping & handovers. BSC is the connection between mobile & MSC. It assigns and releases frequencies & timeslots for the MS. BSC also handles intercell handover. It controls the power transmission of BSS and MS in its area. It is a switching device that handles the radio resources. Additional functions includes -

⇒ Control of frequency hoping
⇒ Traffic management, reduces the number of lines from MSC
⇒ Providing an interface
⇒ Power Management
⇒ Time & Frequency Synchronization
⇒ Handoff management.

Network Switching Subsystem

This component of GSM consist of many parts such as VLR, HLR, MSC, EIR & AuC



Mobile Switching Center

The central component of Network Subsystem is MSC which perform following functions :—

⇒ It acts like a normal switching node for mobile subscribers.

⇒ It provides all functionality such as registration, authentication, location updating, handovers & call routing.

⇒ It includes databases needed to store information to manage the mobility.

⇒ Call setup, supervision & release.

⇒ Management of resources during a call.

Home Location Register (HLR)

MSC with HLR and VLR provide the call routing and roaming capabilities of GSM. The HLR is considered a database that stores information of subscribers belonging to the covering area of a MSC. HLR may be implemented as a distributed database, there is only one HLR per GSM network. HLR contains all administrative information of each subscriber registered in GSM network.

Visitor Location Register

VLR can be considered as tempory copy of some information stored in HLR. VLR is similar to cache. VLR contain selected information borrowed from HLR which are necessary for call routing & control. Mobile current location is also controlled by VLR. MSC contains no information about a particular mobile station, this information is stored in location registers. When subscriber enters the covering area of a new MSC, VLR associated with MSC request information about new subscriber from its corresponding HLR in home network.

Equipment Identity Register

EIR is a database that contains a list of all valid mobile equipment within the network, where each mobile station is identified by IMEI. An IMEI is marked as invalid if it has been reported stolen or not approved.

Authentication Center

AuC is responsible for authentication of a subscriber. This is a protected database and stores a copy of the secret key stored in each subscriber's SIM card. These data help to verify the user's identity.

Operation and Support Subsystem

OSS controls and monitors the GSM systems. The OSS is connected to different components of NSS and provide to the BSC. It also controls the traffic load of the BSS. Increasing number of base stations due to development of cellular radio networks resulted in maintenance tasks which is transferred to BTS. All the information regarding maintenance of different services managed in this layer. Thus, OSS is a functional unit that monitors and controls the system.

The purpose of OSS is to offer the customer cost-effective support for centralized, regional & maintainance activities that are required for a GSM network. Thus, the main function of OSS is to provide a network overview and support for maintenance activities of different operation and maintenance organization.

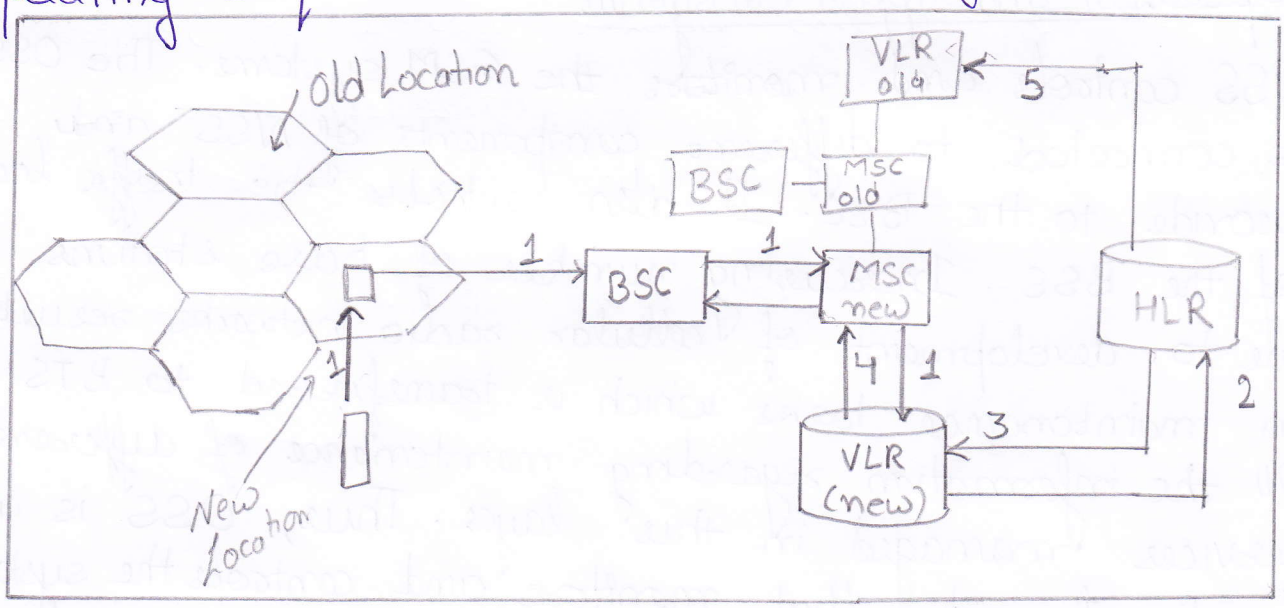
Call Flow Sequence in GSM

GSM call flow sequence involve following steps :—

1) Location Updating
2) Mobile Call origination
3) Mobile Call termination
4) Authentication.
5) inter-MSC cell handoff

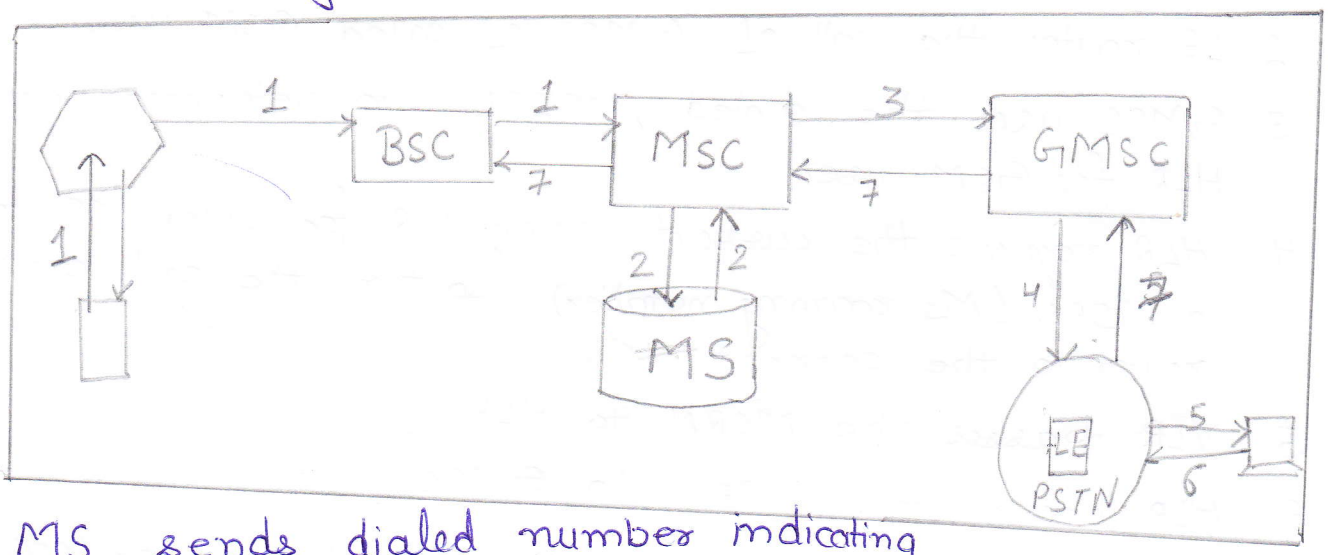
Location Updating

Location updating feature is invoked when an active MS moves from one location area to another. Location updating sequence is shown in following figure.



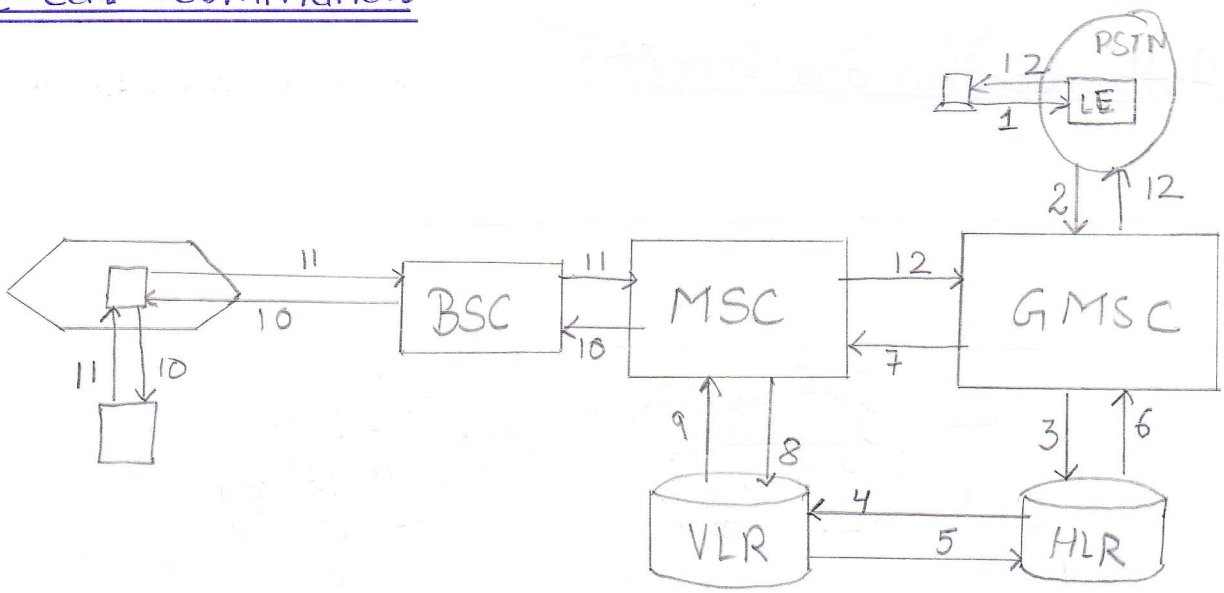
1) MSC sends a Location update Request to VLR (new) via BSS & MSC.
2) VLR sends location update message to HLR servig MS which includes address of new VLR & IMSI of MS.
3) Service and security related data for MS is sent back to VLR.
4) VLR sent acknowledgment of successful update.
5) HLR request old VLR to delete data related to MS.

Mobile Call Origination



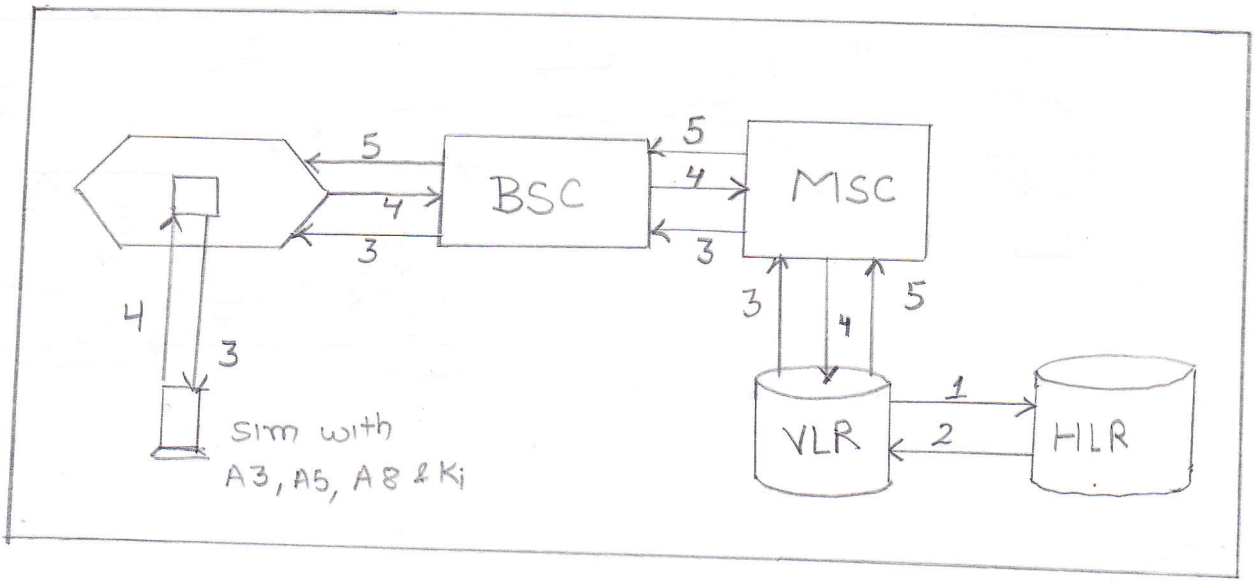
1. MS sends dialed number indicating service requested to MSC.
2. MSC checks from VLR if MS is allowed the request service.
3. If call is allowed, MSC routes call to GMSC
4. GMSC routes call to Local exchange of called user.
5. LE alerts (applies ringing) the called terminal.
6. Answer back (ring back tone) from called terminal to LE.
7. Answer back signal is routed back to MS.

Mobile Call Termination



1 PSTN user dials MSISDN of called user in GSM
2 LE routes the call of GMSC of called GSM user
3 GMSC uses the dialed MSISDN to determine serving HLR for GSM user
4 HLR requests the current serving VLR for called MS for a MSRN (Ms roaming number) so that the call can be routed to the correct MSC.
5 VLR passes the MSRN to HLR
6 HLR passes the MSRN to GMSC.
7 Using MSRN, GMSC routes the call to serving MSC.
8 MSC check the VLR for current location Area Identity for MS.
9 VLR provides current location for MS.
10 MSC pages the MS via appropriate BSS. The MS responds to the page and sets up the necessary signaling links.
11. When BSS has established the necessary radio links, MSC is informed and call is delivered to MS.
12. When MS answers the call, connection is completed to calling PSTN user.

Authentication and Encryption



1 At terminal location update, VLR sends IMSI to HLR

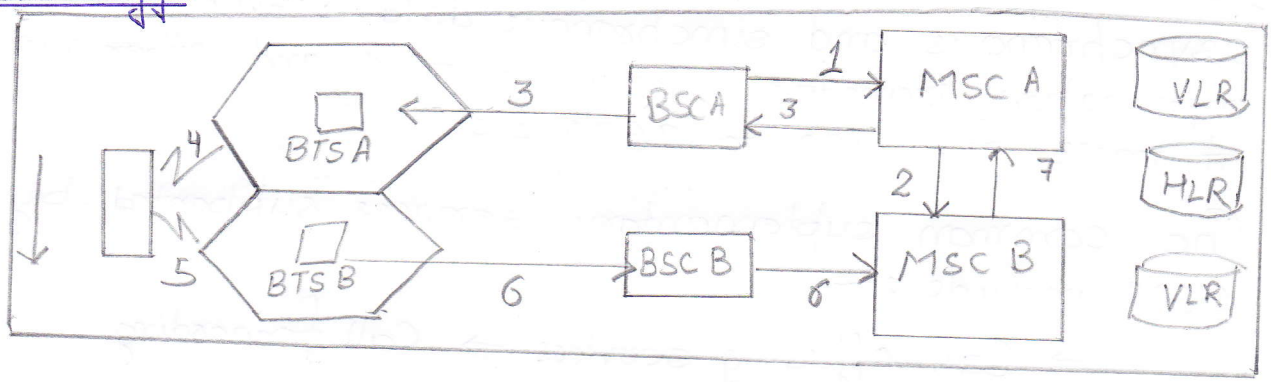
2 HLR returns security triplets to the VLR.

3 For authentication & ciphering the VLR sends symmetric key to MS.

4 Using stored cryptography algorithm (A3) & key provided by VLR MS calculate secure key returns it to VLR. MS also calculate cipher key Kc.

5 If key returned by MS matches with stored key in VLR then VLR sends cipher key Kc to BTS.

Handoff



1 BSC A informs MSC A that MS needs handover from BTS A to BTS B.

2 MSC A informs MSC B that handover from BTS A to BTS B.

3 MSC A commands BSC A/BTS A to proceed with the handover to BTS B.

4 BTS A commands MS to changes to a specified channel on BTS B.

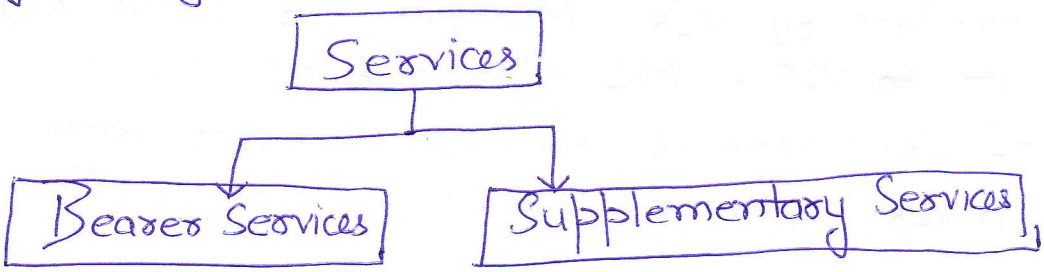
5 MS informs BTS B that it is on specified channel on BTS B.

6 BTS B informs BSC B & MSC B that handover is complete.

7 MSC B informs MSC A that handover to BTS B is complete.

GSM Services

GSM supports a range of basic services. The most important services supported by GSM is telephony. Other services provided by GSM specification are emergency calling and voice messaging.



Bearer Services supported in GSM include various asynchronous and synchronous data services for information transfer between GSM and other networks at rates from 300 to 9600 b/s.

The common suplementary services supported by GSM include :-

- ⇒ Call offering services → Call forwarding
- ⇒ Call restriction services → call barring
- ⇒ Call waiting services
- ⇒ tele conferencing
- ⇒ Closed user group services.

Location Management

Location management is one of the major function of mobile computing network. The main aim of location management is to track the location. Location tracking consist of two concepts i.e, terminal mobility and personal mobility.

Terminal Mobility → Require a unique terminal id & allows the terminal to move around. (GSM phones, laptops equipped with IP address & software).

Personal Mobility → Allows particular identified users to make and receive calls independtly of the terminal in use.

Location Management operations

- Paging
- Updating

Paging ⇒ MSC performs a search operation to track the mobile. Paging is performed by MSC. MSC broadcast the message on the network. The target then replies in the reverse channel.

Updating ⇒ MSC set up an upper bound that decides when particular location become uncertain. Mobile sends the location update message to the MSC.

Location Management Level.

Level 0 No Location Management

In early wireless systems, human operators had to process the calls and user's locations can not be managed by system. User can generate a call through any BS and paging messages addressed to called mobile. Main characterstic of these systems were very large cells and low population.

This level 0 method does not track the mobiles, A search for called user must be done over complete radio coverage within a limited time. This method is also referred as flooding. Main advantage of this method is its simplicity because it does not require to implement special database. But it does not fit with large networks.

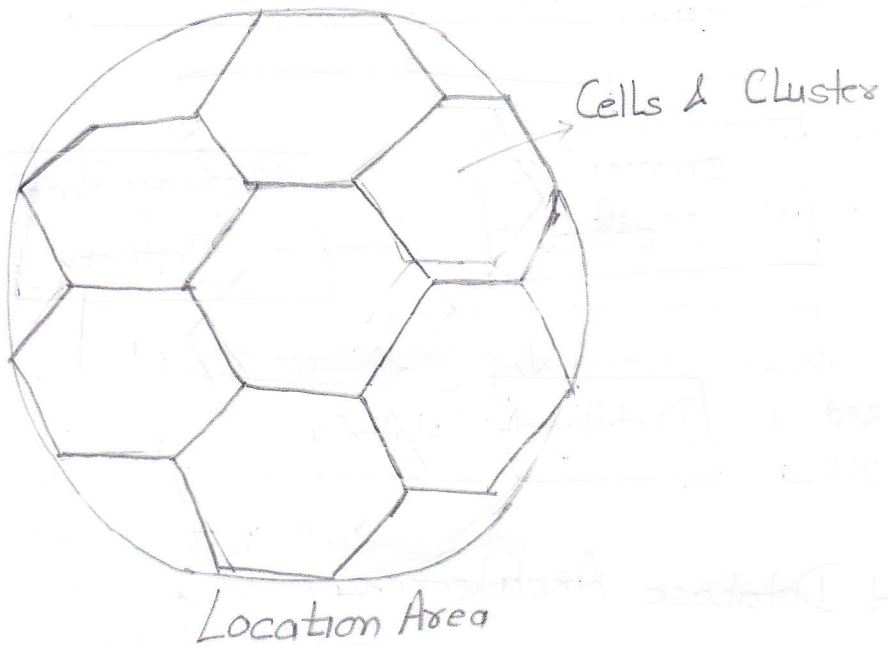
Level 1 Manual Registration

This method requires that the user must locate himself to receive his incoming calls. This method is simple to manage because it only requires the management of indicator which stores the current location of user. When a user moves to new area, it is necessary to register himself. Main drawback of this method is constraint for a user to register each time he moves. This method is economic because of low equipment used.

Level 2 Automatic Management

Location method used in cellular system use the concept of location area. Location area allow the ~~user~~ system to track the mobiles during their roaming in the network. The subscriber location

is known if the system knows the LA in which subscriber is located. When system establish communication with mobile, paging only occur in current LA. Thus, resource consumption is limited to this LA.



Automatic location management method

- Periodic updating
- Updating on LA crossing
- Hybrid Method.

Periodic Updating Method.

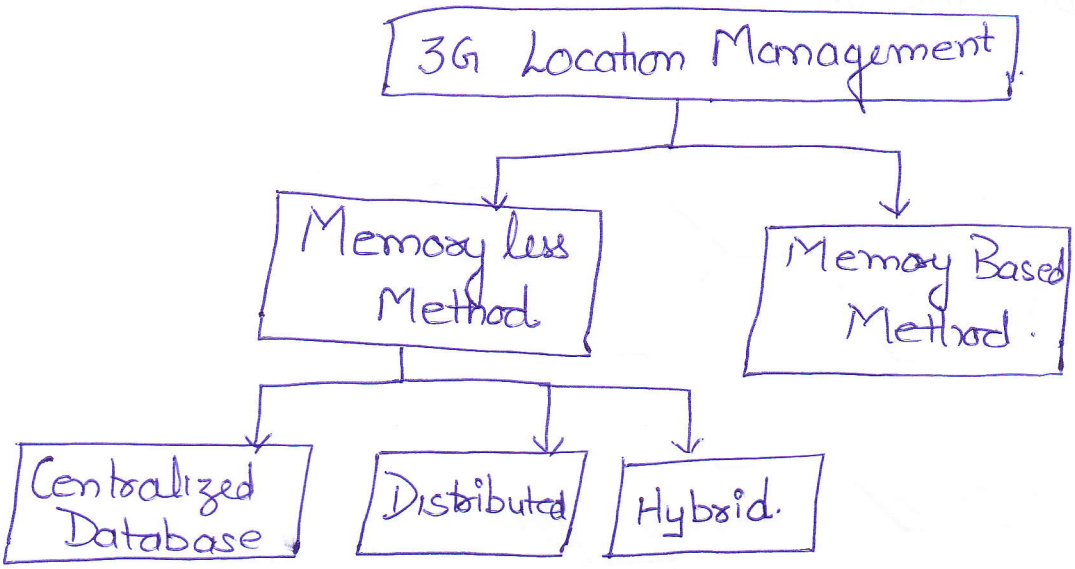
This method requires that mobile periodically transmit its identity to the network. Main drawback of this method is resource consumption.

Location updating on LA crossing

This method requires that each BS periodically broadcast the identity of LA. Mobile is required to permanently listen to network broadcast information and store current LA identity. If received LA number differ from stored one, then location update procedure is automatically triggered by mobile.

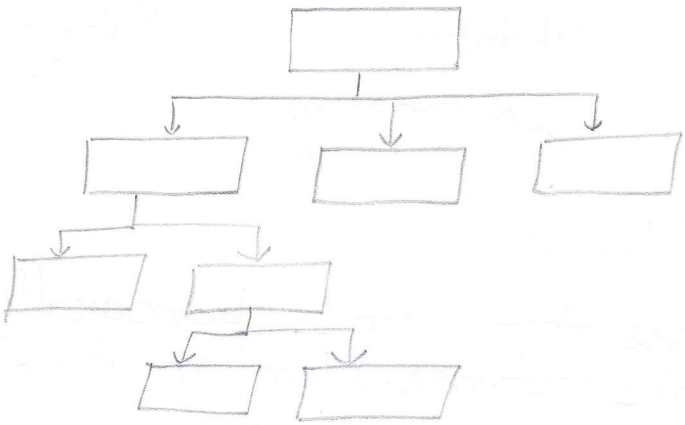
Level 3 Location Databases & Memories.

Also known as 3G location management.
It is of mainly two type.



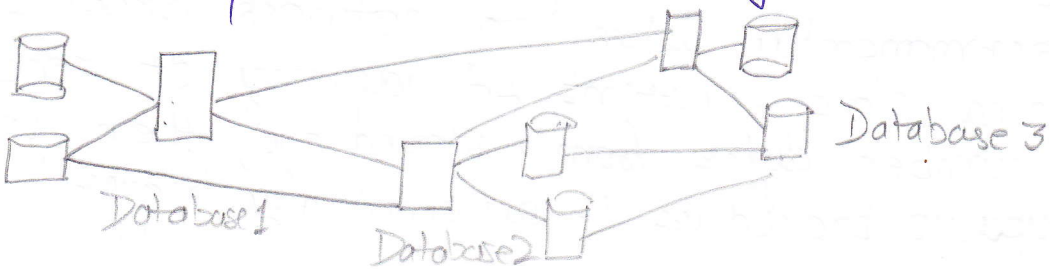
Centralized Database Architecture

This method is based on centralized database and well suited for small & medium networks. Typically based on star topology.



Distributed Database Architecture

It uses the several independent databases. Best suited to large networks. Main problem with this method is its implementation & management



Hybrid database Architecture.

It combines the centralized and decentralized architectures. A central database is used to store all users information. Other small databases are distributed all over the network.

Memory-Based Method.

Memory based location management method is required because systems do lot of repetitive actions which can be avoided if predicted. System acts as memory less processes. Short term and long term memory processes help the system to avoid the repetitive actions.

Location Management Implementations

Location management can be achieved by various methods. Mostly used schemes are :-

⇒ HLR-VLR scheme
⇒ Hierarchical scheme
⇒ Predictive Location Management

HLR-VLR scheme

HLR-VLR scheme mainly implemented in GSM architectures. The MSC maintains a home database called Home Location Register (HLR) that is associated with each mobile user and a visitor database "Visitor Location Register" VLR is maintained at each zone.

HLR ⟹ maintain database about home agents

VLR ⟹ maintain database about visitors

Features of HLR

⇒ It is located at pre-specified zone for each user
⇒ It maintains current location of the user.
⇒ To locate a user 'x', the HLR for 'x' is identified and queried.
⇒ When 'x' moves, it contacts HLR and updates it to "New Current Location".

Features of VLR.

⇒ It stores profile of users not at home location but currently located inside operating area of MSC.
⇒ When call is placed from zone 'i' to x then MSC queries for x in i's VLR.
⇒ If not found then HLR of 'x' is contacted.
⇒ When x moves from i to j then location management system delete entry x from i's VLR.
⇒ New entry of x is made to j's VLR. x's HLR is updated.

Location Updating in HLR-VLR scheme:

1) When mobile phone is ON, it perform updating indicating its IMSI (Internation Mobile Subscriber Identity) to MSC which authenticates the device.
2) When mobile moves to new location area or different network. Mobile device sends update message to new MSC/VLR. If MS is authorized to operate in MSC/VLR then
   a) Subscriber's HLR update current location.
   b) MSC sends a message to old MSC/VLR to cancel its VLR entry.

3) Mobile user employs the periodic location update. The mobile has to register itself with the serving MSC after a pre specified updating time period. If after updating time period mobile station has not registered, it is then deregistered.

4) When MS is powered off, it performs IMSI detach procedure.

Hierarchical Scheme.

Hierarchical location management is carried out by extending the two-tier scheme of maintaining a hierarchy of location database. The location database at higher level contains location information for users located at levels below it. The management can be done by two ways,

- Static
- Adaptive.

Static Location Management

It involves :—

⇒ Updates
⇒ Searches
⇒ Search_updates

Cost of location management includes number, size and distance message needs to travel.

Adaptive Location Management

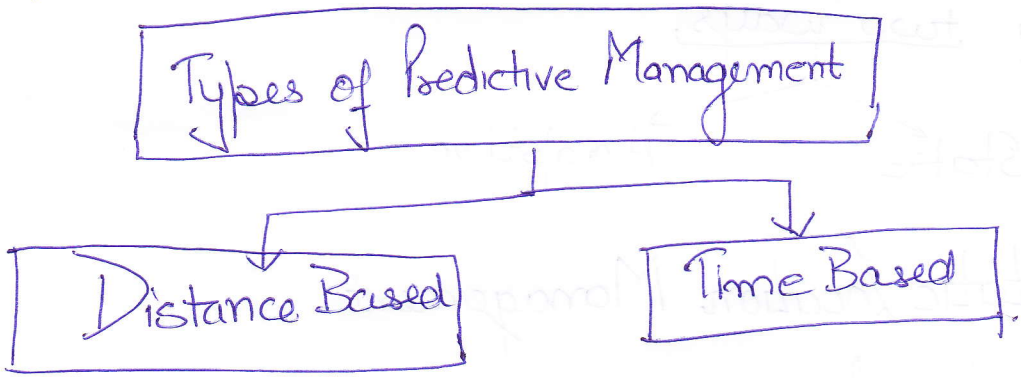
It is carried out in cases where the system designers have a prior knowledge of call mobility patterns for a particular host. Adaptive location management is helpful in situations where cost for storing & updating the information is high.

This method of location management allow preconnection and pre-assignment of data or service at the location before the user moves into it, so can immediately receive service or data. This method is based on user's movement history pattern. MMP (Mobile Motion Prediction) allows the system to predict the future location of the user. It is based on two models :-

Movement Circle is based on a closed model of user movement behavior.

Movement Track is used to predict routine movement.

There is no division of network into static areas, but the terminals report location to the nearest point of attachments.



Advantage of predictive management is that it requires least amount of effort to track the mobile. This method have optimal paging strategy or update scheme.

Mobile IP

First of all we discuss about Mobile. The term Mobile have different meanings as described below:-

1) Mobile means that user's physical location is not fixed. Users can access the network from multiple places.

2) Being mobile means that a user can also "roam". To roam is the ability to stay connected to the network as user moves. This application is based on the network infrastructure which require multiple base station or maintain one high capacity base station for all users in coverage area.

3) If a user moves into area where there is no coverage, then network connection will be lost. Mobility tries to make a network connection live.

All these definations have problems and they can be solved by using the concept of IP addressing. IP addressing was based on the assumption that a host is stationary & attached to one network. Router uses an IP address to route an IP datagram. IP address contain two parts.

$$\boxed{\text{IP address} = \text{Prefix} + \text{Suffix}}$$

Prefix → Associate with a host network.

eg ⇒ IP address 10.3.4.24/8 defines a host attached to network 10.0.0.0/8.

which means that host in the Internet does not have an address that it can carry with itself from one place to another. This address is valid only when host is attached to the network. If network changes, address is not valid. But, due to mobility host must move from one network to another. Thus, it is necessary to modify the IP addressing scheme. Simplest solution is that mobile host must change its address as it moves to

new network. Host can use DHCP [Dynamic Host Configuration Protocol] to obtain new address to associate it with new network. But this solution have many problems as described below.

a) Configuration files would need to be changed.

b) When host moves from one network to another, it must be rebooted.

c) DNS tables need to be revised.

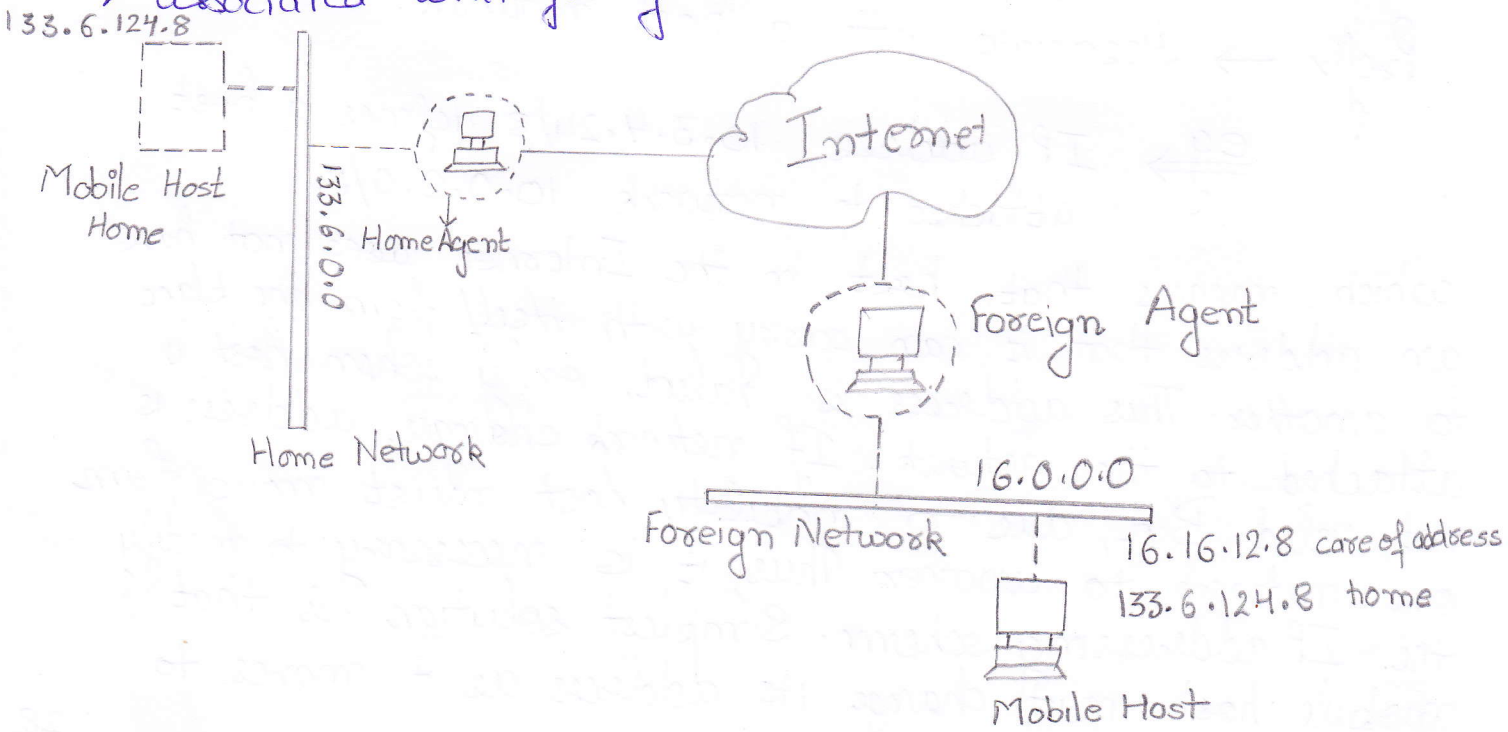
d) If host moves from one network to other during transmission, data exchange will be interrupted.

Another approach is used which is more reliable. This approach consist of two addresses.

- Home Address ⇒ Original Address
- Care-of-Address ⇒ Temporary Address

⇒ Home Address is permanent and it associates the host to its home network.

⇒ The care-of-Address is temporary, when a host moves from one network to another, the care-of address changes & associated with foreign network to which host moves.



Home Agent

Home agent is a forwarding mechanism which keep track of where the mobile host currently resides in the network. It acts on behalf of the mobile host when a remote host sends a packet to the mobile host. The home agent receives the packet and sends it to the foreign agent.

Foreign Agent

The foreign agent is assigned to the mobile host when it is away from its home base. It is a router attached to the foreign network. The foreign agent receives and delivers packets sent by the home agent to the mobile host. Foreign agent maintains a care-of address. Packets for the mobile host's home address are intercepted by the home agent and then tunneled to the foreign agent. Then foreign agent forwards the packets to the mobile host for which it is providing services.

Mobile IP Working

IP routes packets from a source to destination by using the concept of routing table. Routing table maintains the next-hop information for each destination IP address according to the number of networks to which that IP address is connected. In Mobile IP, the home agent redirects packets from the home network to the care of address by constructing a new IP header that contains the mobile host's care-of address as the destination IP address. This new header encapsulates the original packets, ensuring that mobile host's home address have no effect on encapsulated packet's routing until it arrives at care-of-address. Such encapsulation is known as tunneling.

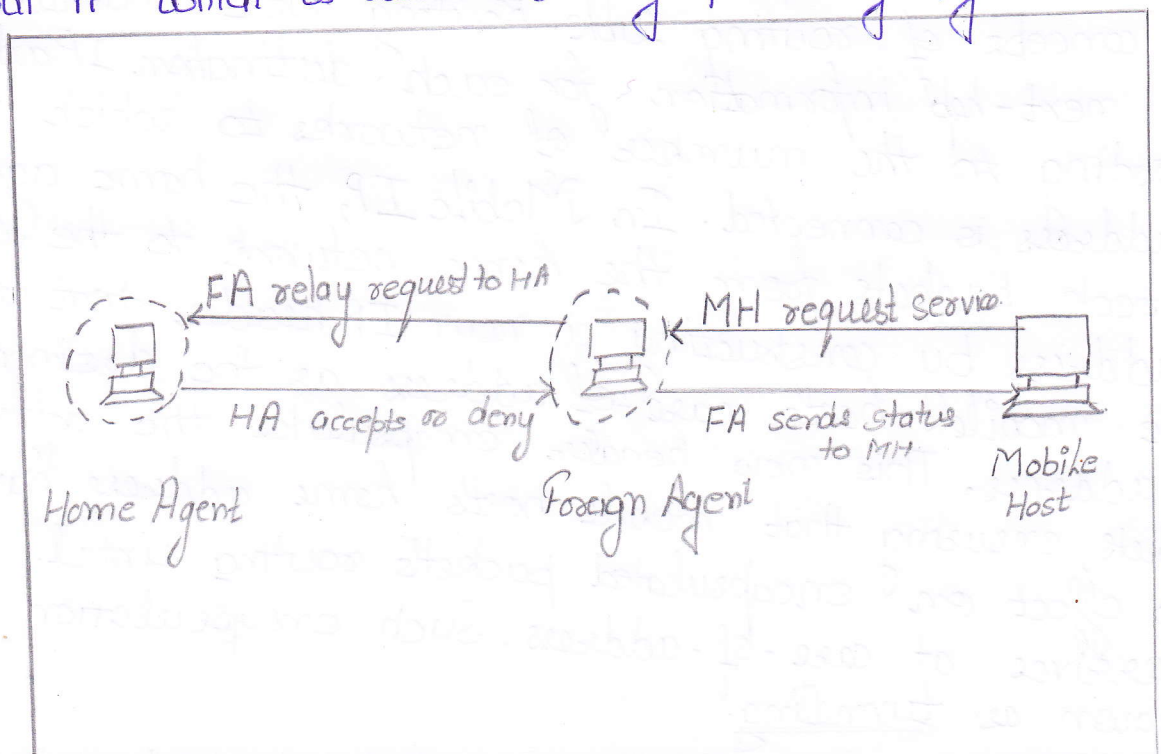
Mobile IP based on three mechanisms:-

⇒ Discovering the care-of-address
⇒ Registering the care-of-address
⇒ Tunneling to the care-of-address

Discovering the Care-of-Address

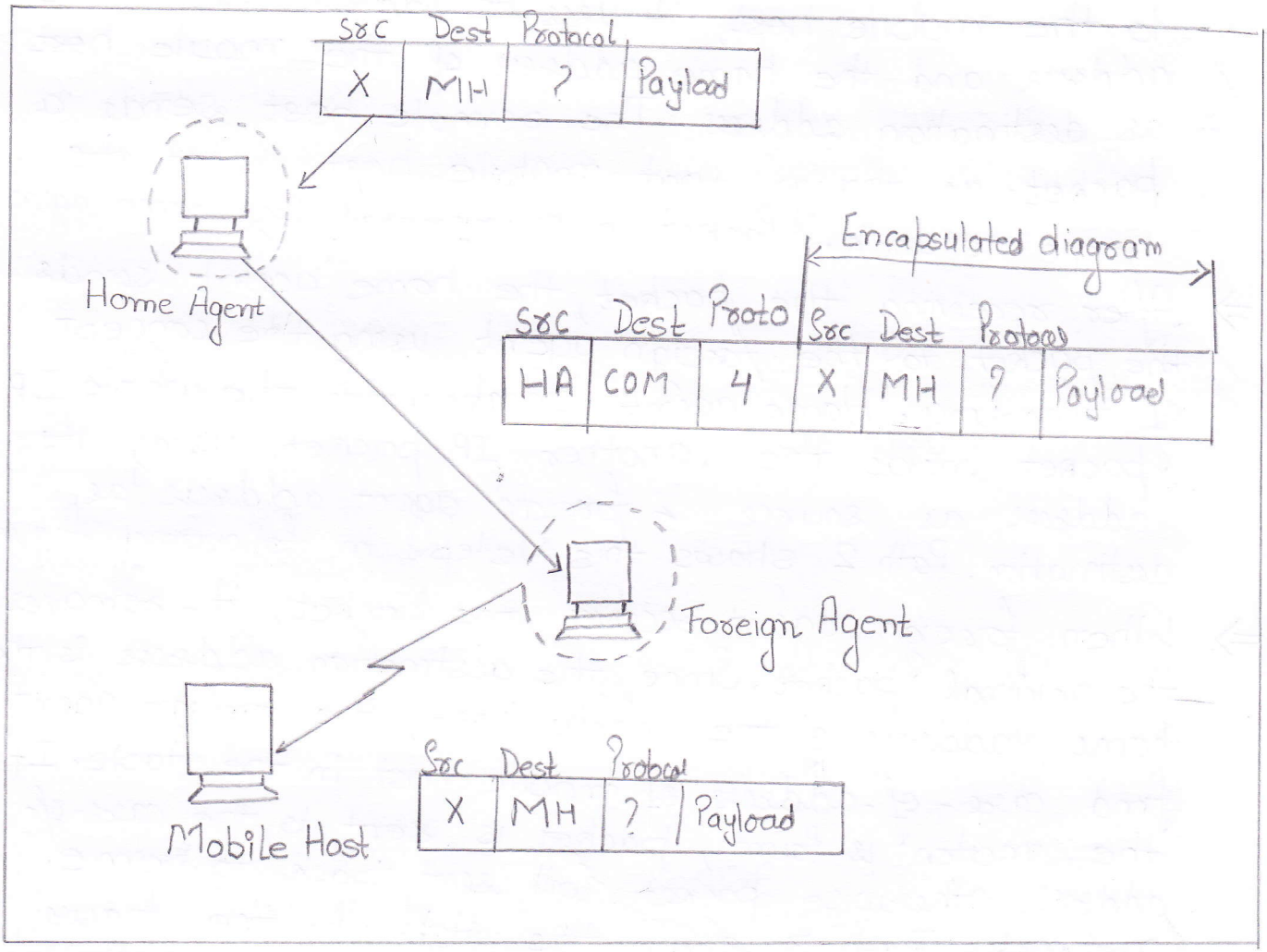
Discovery process use the concept of Router Advertisement. Mobile IP discovery does not modify the original fields of existing router advertisements but extends them to associate mobility functions. When router advertisement extended to contain the needed care-of-address, then they are known as Agent Advertisement. Home agents and Foreign agents regularly broadcast agent advertisement at regular intervals. If a mobile host needs to get a care-of-address & does not wait for periodic advertisement, then mobile host can broadcast or multicast that can be answered by home agent or foreign agent that receives it.

Registering the Care-of-Address When a mobile host has a care-of address then home agent must find about it which is described by following figure:—



Registration process begins when mobile host sends a registration request with care-of-address information. When the home agent receives this request, then it adds the necessary information to its routing table, approves the request and sends a registration reply back to the mobile host.

Tunneling to the Care-of-Address



All mobility hosts using Mobile IP is based on the concept of IP-within-IP. Using IP-within-IP, home agent [tunnel source] inserts a new IP header or tunnel header in front of any datagram IP header addressed to mobile host's home address. The new tunnel header uses the mobile host's care-of-address as the destination IP address. The tunnel source IP address is the home agent, tunned header uses 4 as higher level protocol to indicate that next protocol header is again IP header.

In IP within IP, original IP header is preserved. Therefore to recover the original packet, foreign agent has to eliminate tunnel header & deliever rest to the mobile host.

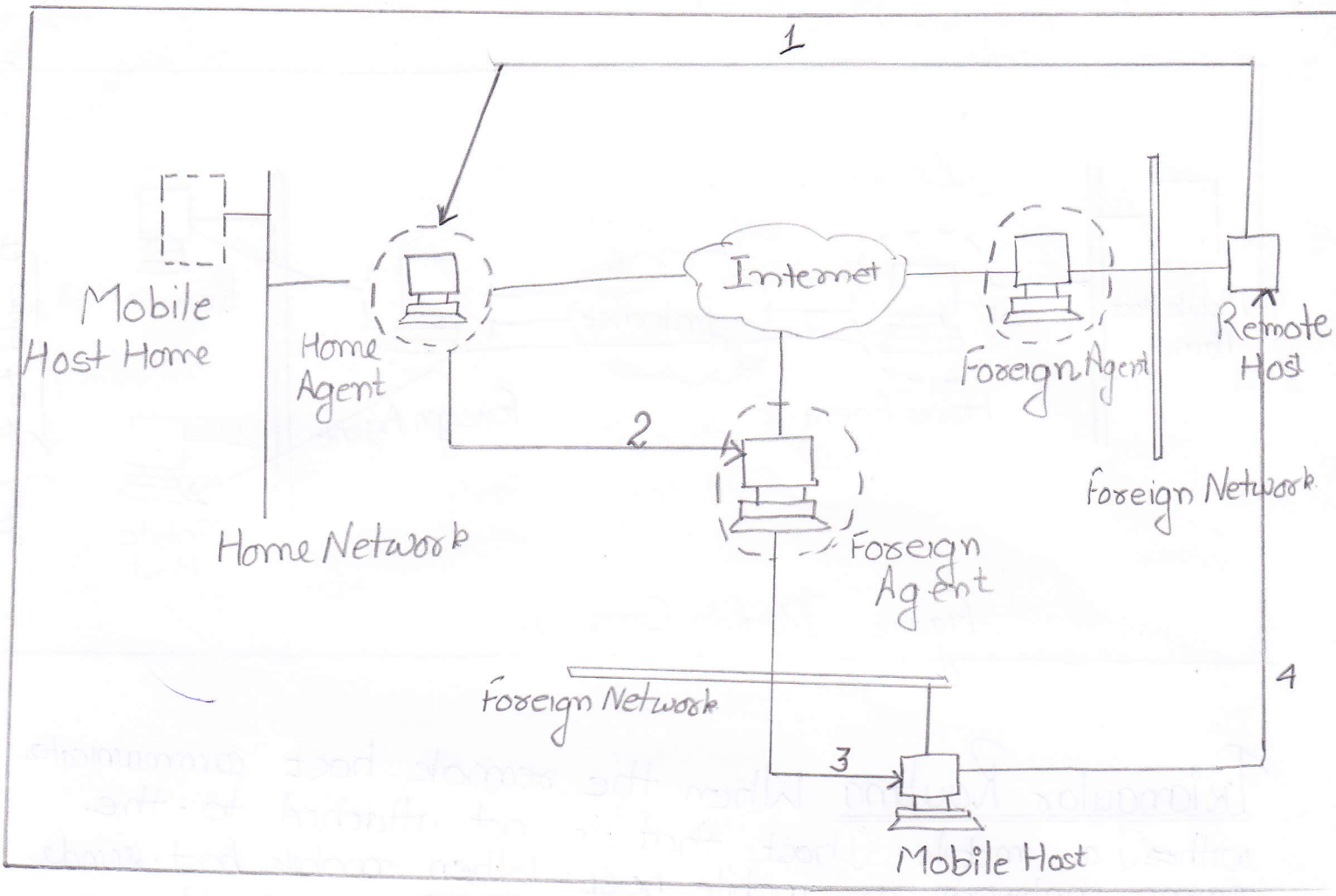
Data Transfer

⇒ When a remote host wants to send a packet to the mobile host, it uses its address as source address and the home address of the mobile host as destination address. The remote host sends a packet as though that mobile host is at its home network. Packet is interpreted by home agent

⇒ After receiving the packet, the home agent sends the packet to the foreign agent using the concept of tunneling. Home agent encapsulates the whole IP packet inside the another IP packet using its address as source & foreign agent address as destination. Path 2 shows this step in following figure.

⇒ When foreign agent receives the packet, it removes the original packet. Since, the destination address is the home address of the mobile host, the foreign agent find care-of-address of mobile host in the table. If the match is found, packet is sent to the care-of-address, otherwise packet will sent back to home network. Path 3 show this step in the figure

⇒ When mobile host send packet to remote, it sends it normally. Mobile host prepares a packet with its home address as source and the address of remote host as destination. Path 4 shows this step in the following figure.



Disadvantages of Mobile IP Main disadvantages of Mobile IP are double crossing and triangle routing

Double Crossing The double crossing occurs when a remote host communicates with a mobile host that has moved to the same network or site as remote host. When mobile host sends a packet to the remote host, the communication is local. However, when remote host sends a packet to the mobile host, the packet crosses the Internet twice as shown in the figure. Since a host communicates with number of hosts, then double crossing is inefficient.

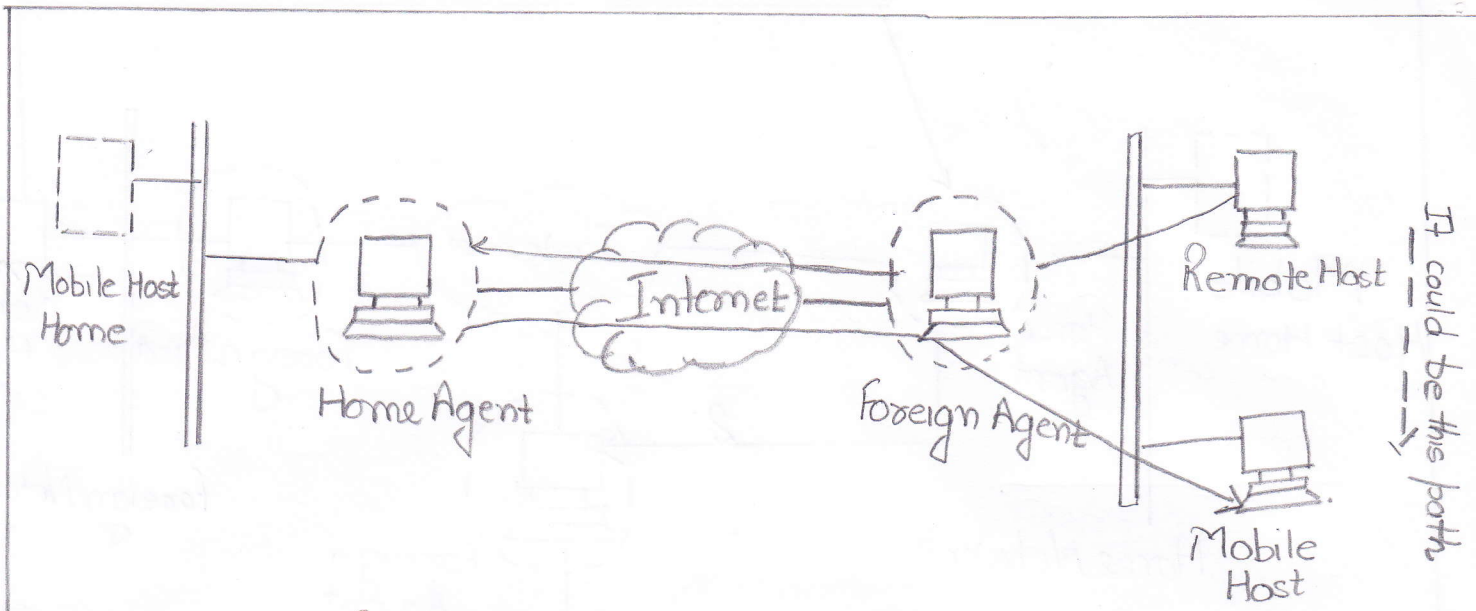
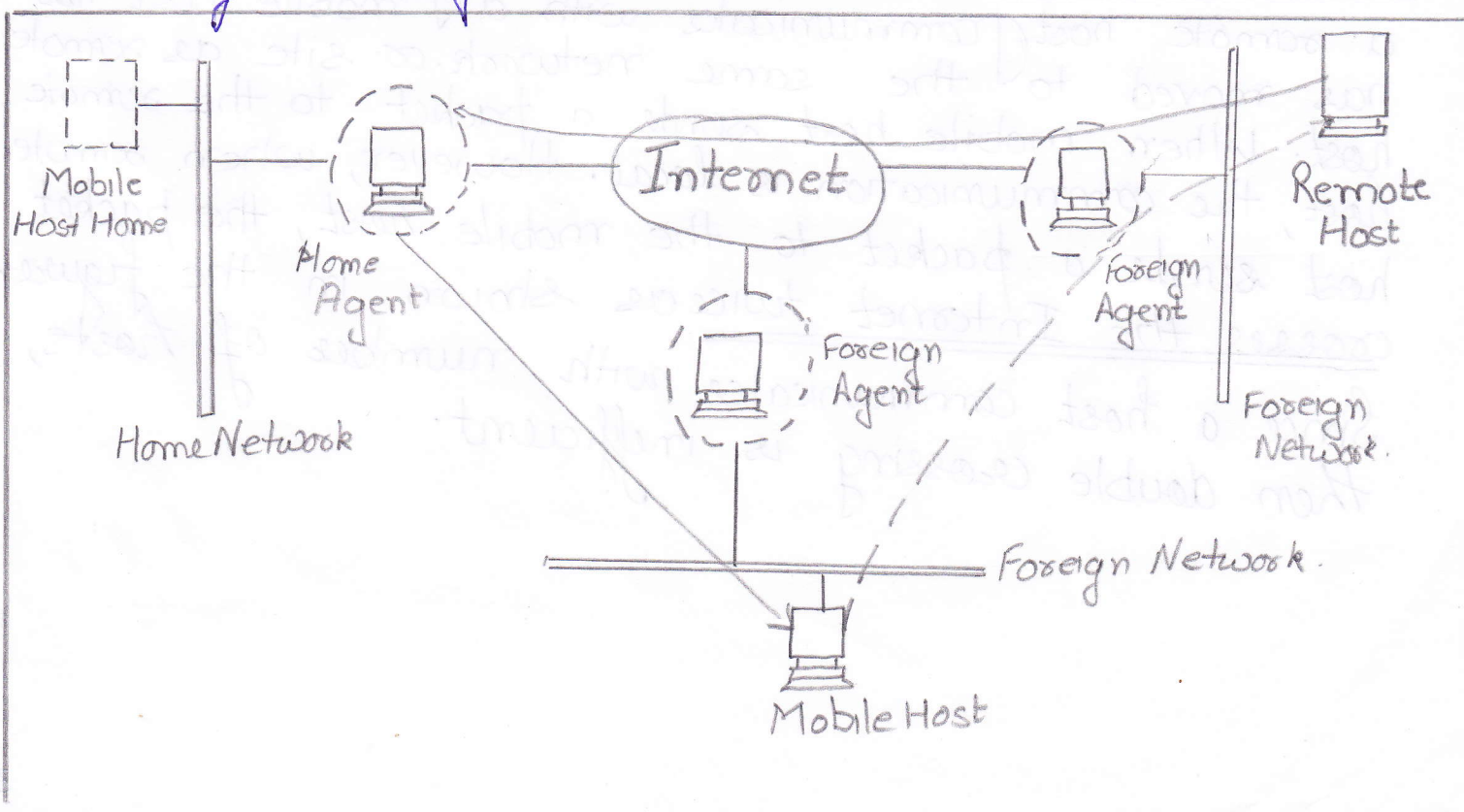


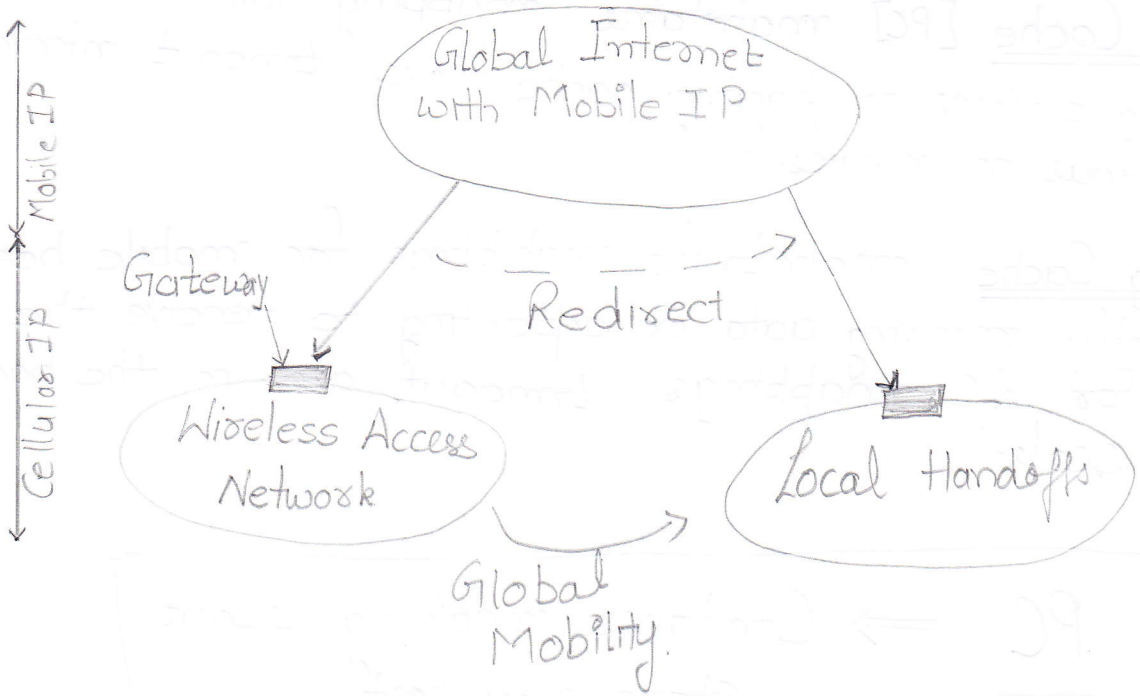
Figure Double Crossing

<u>Triangular Routing</u> When the remote host communicates within a mobile host that is not attached to the same network as mobile host. When mobile host sends a packet to the remote host, there is no inefficiency. When the remote host sends a packet to the mobile host, the packet goes from remote host to home agent & then to mobile host. Packet travels two sides of a triangle instead of just one side.

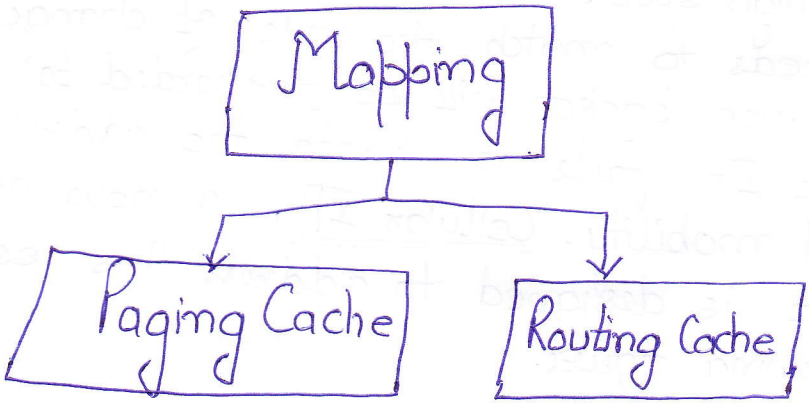


CELLULAR IP

The primary design goal for mobile IP protocol is to allow a host to change its point of access during data transfer without being disconnecting or needing to be reconfigured. Whenever the mobile host moves to a new subnet managed by a different foreign agent, then dynamic care-of address will change. This changed care-of-address needs to be communicated to the home agent. This process works for slowly moving hosts. For a high speed mobile host, the rate of update of address needs to match the rate of change of address. Otherwise, packet will be forwarded to old address. Mobile IP fails to update the address properly for high speed mobility. Cellular IP, a new host mobility protocol that is designed to address this issue and shown in following figure.



In a Cellular IP, none of the nodes know the exact location of a mobile host. Packets addressed to a mobile host are routed to its current base station on a hop by hop basis where each node only needs to know on which of its outgoing ports to forward packets. This limited routing information (also known as mapping) is local to the node and does not assume that nodes have any knowledge of a wireless network topology. Mapping are created and updated based on the packets transmitted by mobile hosts. Cellular IP uses two mechanism to implement mapping.

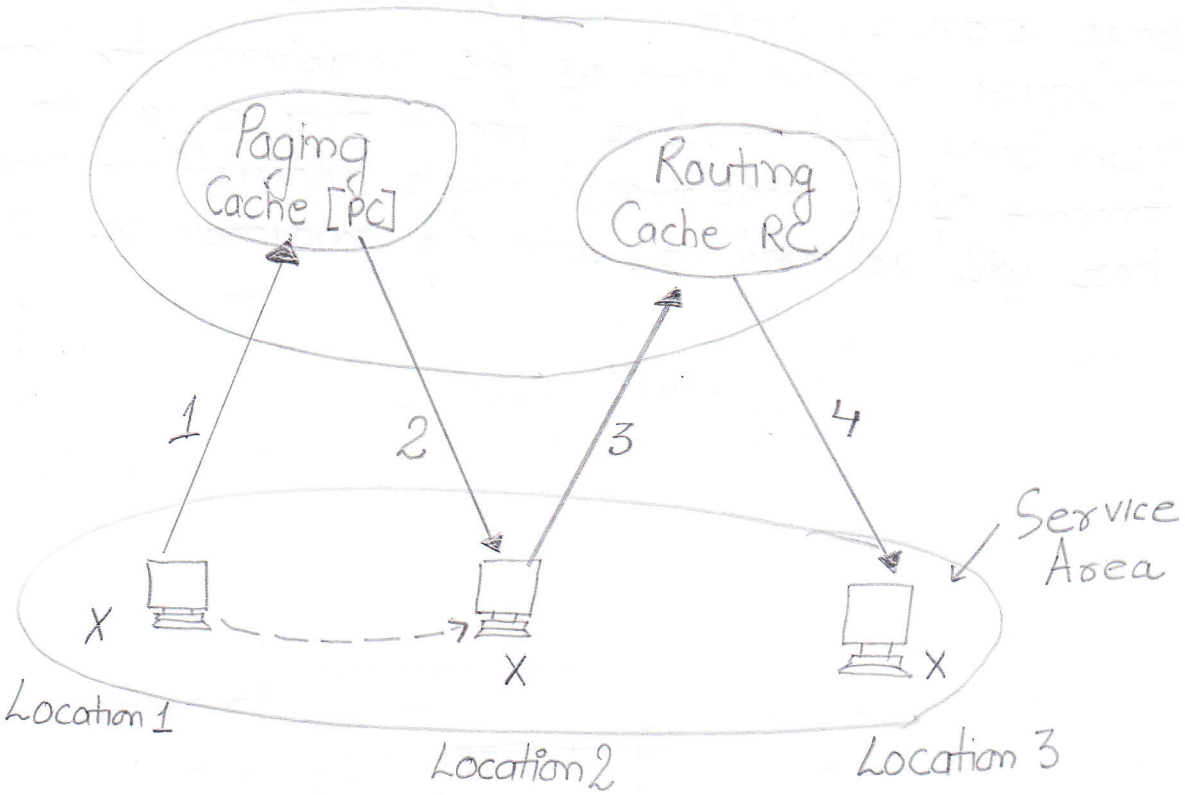


<u>Paging Cache</u> [PC] maintains mapping for ~~mobile~~ stationary hosts. Mapping entries in paging cache have timeout intervals in seconds or minutes.

<u>Routing Cache</u> maintains mappings for mobile hosts currently receiving data or expecting to receive the data. For RC mappings timeout are in the packet time scale.

PC	⟹	Contains mapping about stationary host
RC	⇒	contains mapping about mobile host

Cellular IP paging and Routing



While idle at location 1, the mobile host sends dummy packets at low frequency as shown in step 1. or keeps paging cache up to date by transmitting Let assume that the host is mobile and moved to location 2 without loss of any data. Paging cache mapping for X now points to location 2. While at location 2, there are data packets to be routed to mobile host X, PC mappings are used to find host (step 2). As there is data transmission, mapping database to be used will be Routing Cache. As long as data packets keep arriving, host maintains RC mappings, either by its outgoing data packets or through transmission of data packets (step 3).

Idle mobile hosts periodically generate short control packets called paging-update packets. These are sent to the nearest available base stations. The paging-update packets travel in the access network from base station to the gateway router on Hop-by-Hop basis.

Handoff in Cellular IP is always initiated by mobile host. As host approaches a new base station, it redirects its data packets from old to the new base station. Redirected packets will automatically configure a new path of RC mappings for host to new base station but for a time equal to the timeout of RC mappings, packets addressed to mobile host will delivered at both old and new base stations.