Chapter 1
Introduction to Mobile Computing

1.1 Introduction to Mobile Computing-
Mobile Computing Functions, Mobile Computing Devices, Mobile Computing Architecture, Evolution of Wireless Technology.
1.2 Cellular Concepts- Frequency reuse, Channel assignment strategies, Handoff strategies.
Interference and system capacity- Co-channel Interference, Adjacent Channel Interference, Channel planning for wireless system, Power control for reducing Interference.
1.3 Improve coverage and capacity in cellular system- Cell splitting, Sectoring, Repeaters for range extension, A micro cell zone concept.

Mobile Computing Functions

Mobile computing can be defined as a computing environment over physical mobility. The user of the mobile computing environment will be able to access data, information or logical objects from any device in any network while on move.
A computing environment is defined as mobile if it supports one or more of these characteristics:

1. **User mobility**: User should be able to move from one physical location to another location and use same service
2. **Network mobility**: User should be able to move from one network to another network and use same service
3. **Device mobility:** User should be able to move from one device to another and use same service
4. **Session mobility:** A user session should be able to move from one user-agent environment to another.
5. **Service mobility:** User should be able to move from one service to another.

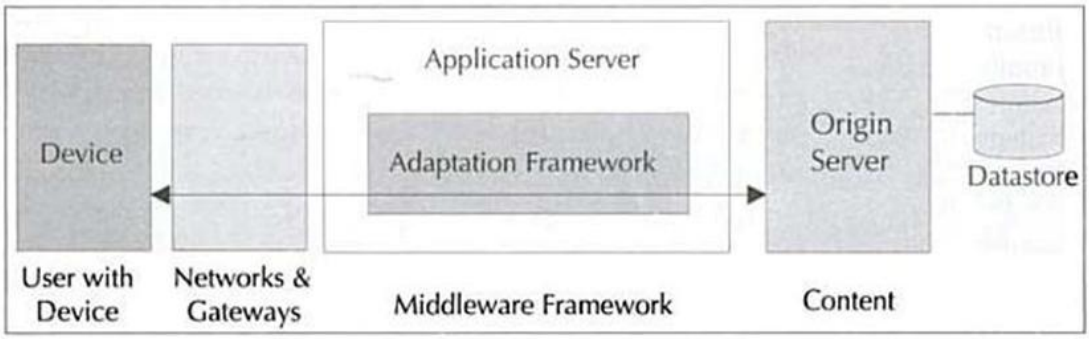
6. **Host mobility:** The user should be either a client or server.

The mobile computing functions can be logically divided into following major segments
1) **User with device**: The user device, this could be fixed device like desktop computer in office or a portable device like mobile phone. E.g Laptop Computers, Desktop Computers, Fixed Telephones, Mobile Phones, Digital TV with set top box, palmtop computers, pocket PCs, two way pagers, handheld terminals etc.
2) **Network**: Whenever a user is mobile, he will be using different networks at different places at different time eg GSM, CDMA, iMode, Ethernet, Wireless LAN, and Bluetooth etc.
3) **Gateways:** This is required to interface different transport bearers. These gateways convert one specific transport bearer. These gateways convert one specific transport bearer to

another transport bearer. Example: From a fixed phone (with voice interface) we access a service by pressing different keys on the telephone.

- These keys generate DTMF (Dual Tone Multi Frequency) signals.
- These analog signals are converted into digital data by Interactive Voice Response (IVR) gateway to interface with a computer application
- Other Examples will be WAP Gateway, SMS Gateway etc.

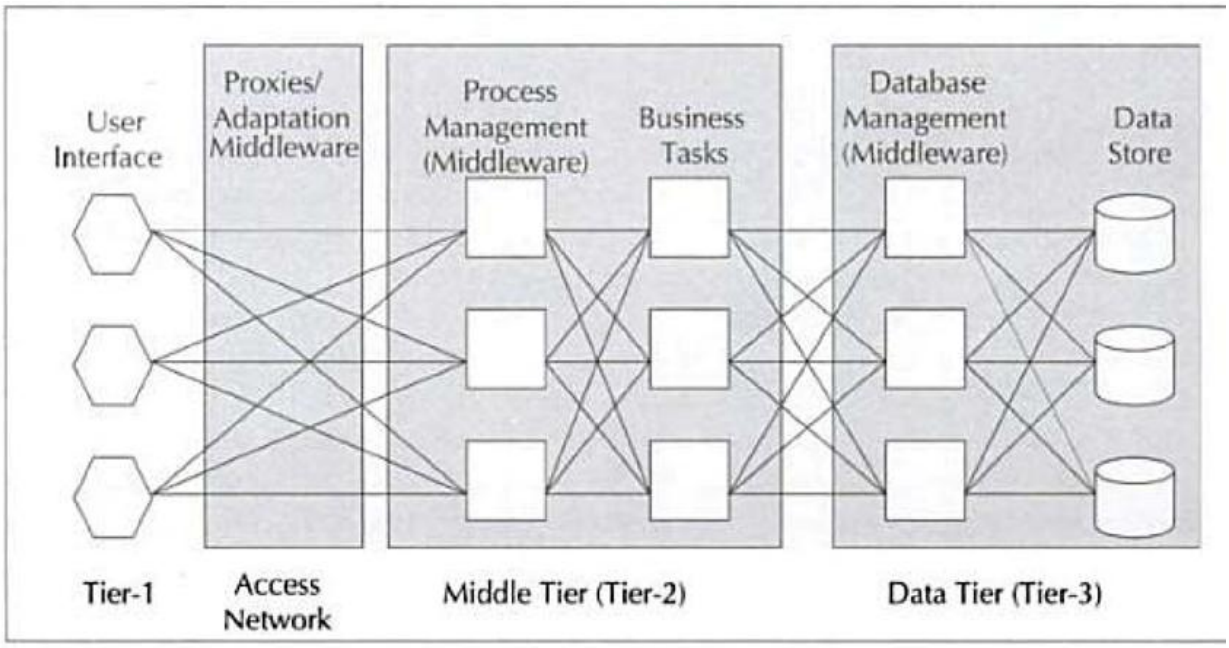
4) **MiddleWare**: This is more of a function rather than a separate visible node. In the present context middleware handles the presentation and rendering of the context on a particular device. It will also handle the security and personalization for different users.
5) **Content**: This is the domain where the origin server and content is This could be an application, system or even an aggregation of systems. The content can be mass market, personal or corporate content. Origin Server will have some means to accessing the database and the storage devices.



Mobile Computing Devices:

- The device for mobile computing can be either a computing device or a communication device.
- In computing device category it can be a desktop computer, laptop computer or a palmtop computer.
- On the communication device side it can be a fixed line telephones, a mobile telephone or a digital TV.
- When computing technology is embedded into equipments, Human Computer Interaction (HCI) plays a critical role in effectiveness, efficiency and user experience.
- The desktop computer uses Keyboard and Mouse.
- Palmtop or Tablet PC uses Pen
- Mobile phone uses Microphone and Speakers.
- Digital TV uses Remote Control for interaction.

Mobile Computing Architecture



Three-tier Architecture for Mobile

In the three-tier architecture, the first layer is the
User Interface or Presentation Tier:

- This layer deals with user facing device handling and rendering.
- This tier includes a user system interface where user services (such as session, text input, dialog and display management) reside.

The second tier is the **Process Management or Application Tier:**

- This layer is for application programs or process management where business logic and rules are executed.
- This layer is capable of accommodating hundreds of users.
- It controls transactions and asynchronous queuing to ensure reliable completion of transactions.
- It performs the business logic of processing user input, obtaining data and making decisions.
- Application Tier may include technology like CGI, Java, JSP, .Net services, PHP or ColdFusion deployed in products like Apache, WebSphere, WebLogic, iPlanet, JBOSS.

The third and final tier is the **Database Management or Data Tier:**

- This layer is for database access and management.
- This tier architecture provides increased performance, flexibility, maintainability, reusability and scalability while hiding complexity of distributed processing from the user.
- Data Tier is used to store data needed by the application and acts as a repository for both temporary and permanent data.

The data could be stored in any form of datastore or database (Relational Databases, Simple Text files or legacy Hierarchical Database), XML format for Interoperability.

Evolution of Mobile Communciations

- **First Generation (1G)**
  - Launched in the mid 1980
  - Analog Systems
  - Voice Traffics Only
  - FDMA/FDD Multiple Access
  - Confined to National Boundaries
  - E.g AMPS (Advanced Mobile Phone Services) in US
- **Second Generation (2G)**
  - Developed for Voice Communications
  - Digital Systems, Digital Modulation
  - Provides data rated of the order of 9.6 Kbps
  - E.g GSM Global System for Mobile Communication – TDMA/FDMA
  - 900 Mhz and 1800 Mhz Band
  - Personal Digital Communications(PDC) (Popular in Japan)
  - IS-95
    - CDMA Based
    - US/South Korea
- **Limitations of Second Generation (2G)**
  - Developed for Voice Communications (unsuitable for data traffic)
  - Avg rate of the order of tens of kbps
  - Not suitable for Internet (Packet Switched Services) Circuit Switched
  - Multiple standards (no true global coverage)

2.5 G

- The effort to remove the impediments of 2G systems resulted in 2.5G
- Digital Systems
- Voice +Low Data Rate
- Internet Access through GPRS(General Packet Radio Services)
- Enhanced Data Rated for Global Evolution (EDGE) : Uses better Modulation Techniques)

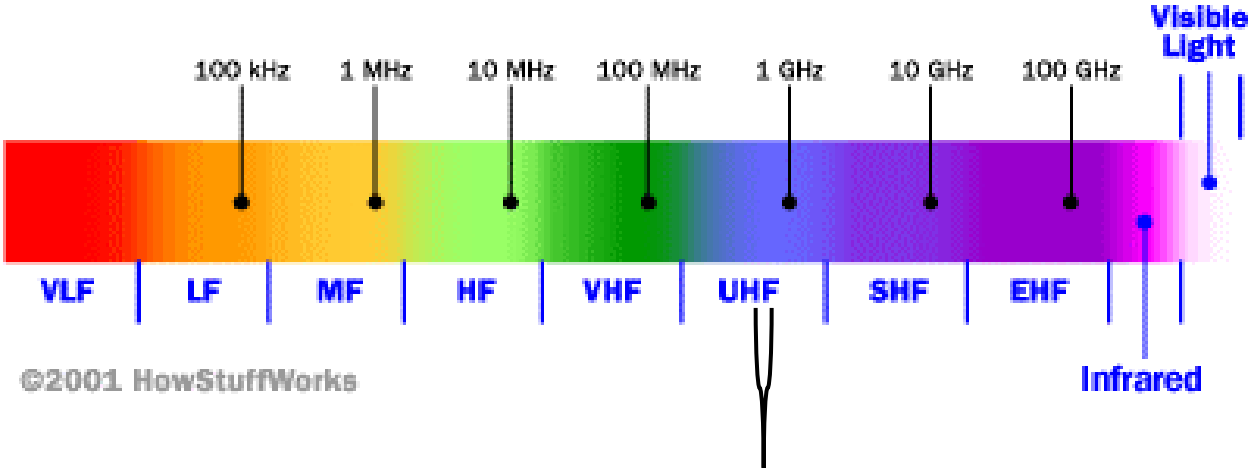
- **Third Generation (3G)**
- Digital Modulation
- Simultaneous Voice + High Speed Data
- Multi-Megabit Internet Access
- Voice activated Calls
- Multimedia Transmission
- CDMA-2000 International Standard for 3G

Need for 4G

- Present communication systems are primarily designed for one specific application such as speech on a mobile telephone or high rate data in a wireless local area Network(WLAN).
- 4G will integrate various networks, functions and applications
- 4G will create the global information multimedia village
- Will support a variety of data rates from 2G to 3G to 3G+ WLAN systems to pico and small microcellular connectivity and fixed line systems.

Cellular Network Basics

- There are many types of cellular services;
- Cellular network/telephony is a *radio*-based technology; radio waves are electromagnetic waves that *antennas* propagate
- Most signals are in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands



Cell phones operate in this frequency range

What is CELL?

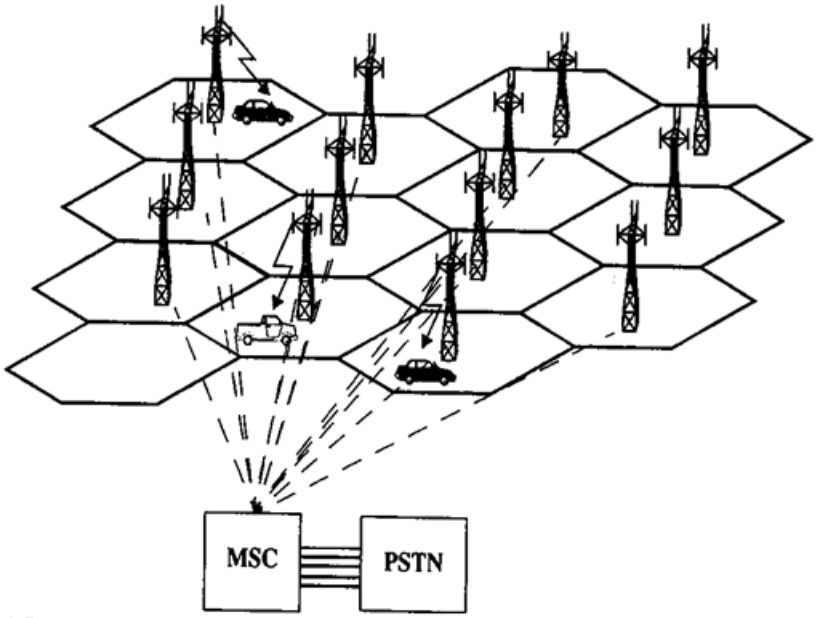
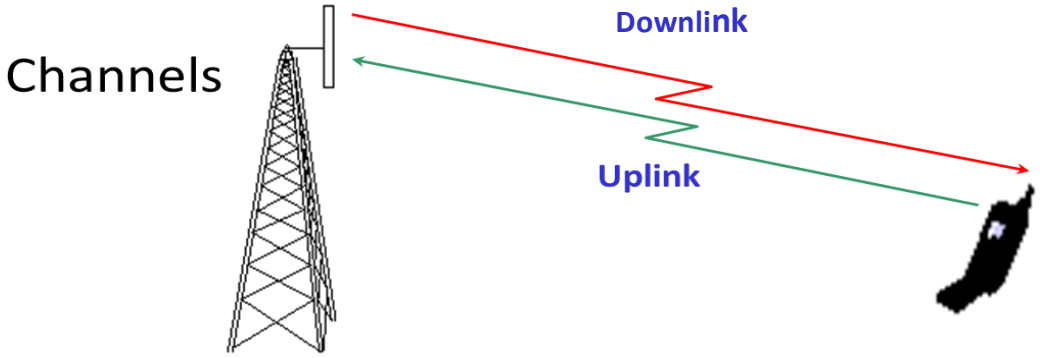


Figure 1.5
An illustration of a cellular system. The towers represent base stations which provide radio acc between mobile users and the Mobile Switching Center (MSC).

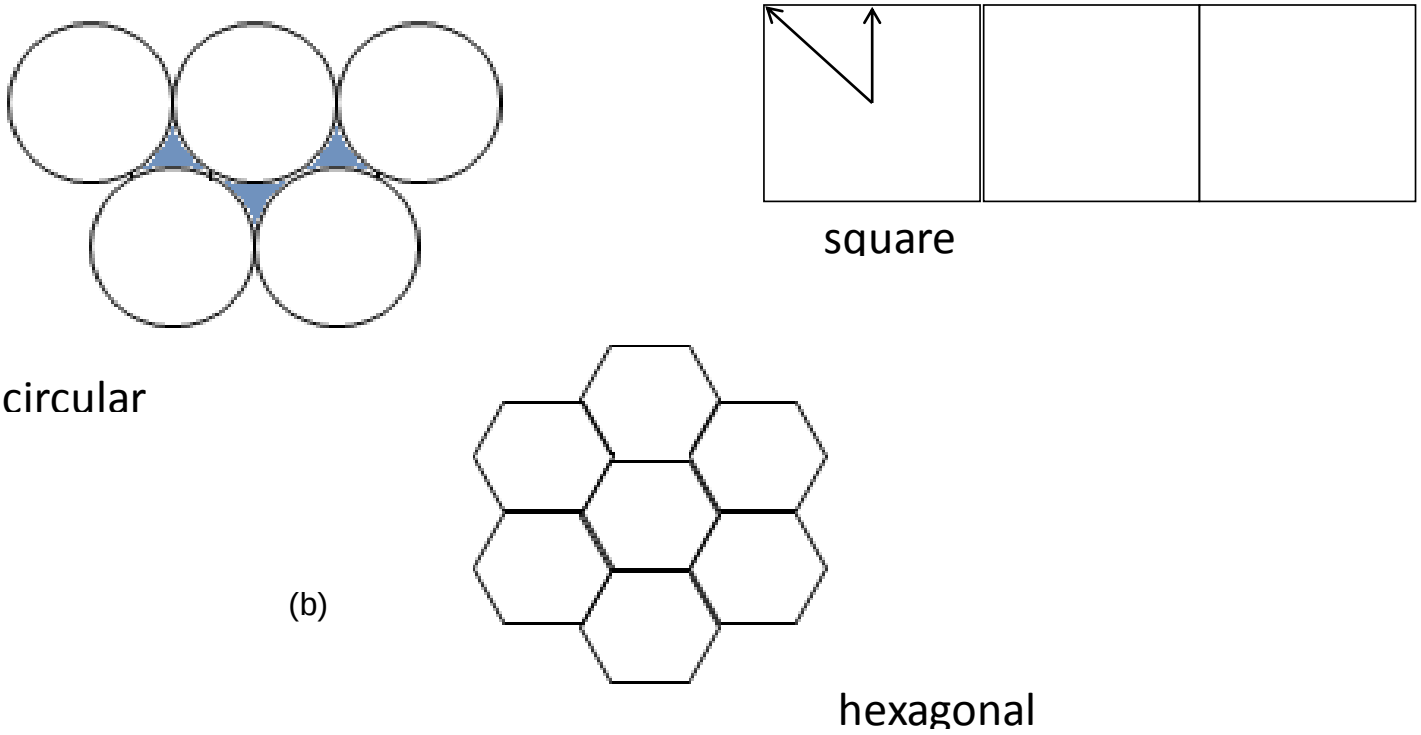
- Larger area divided into small no. Of areas
- Shape is Hexagonal
- Each with its own base station and set of frequencies.
- High Capacity us achieved by limiting the coverage of each base station to a small geographic region called a cell.
- Same frequencies/ timeslots/codes are reused by spatially separated base stations.
- A switching technique called Handoff enables a call to proceed uninterrupted when one user moves from one cell to another.

GSM



Base Station (BTS –Base Transceiver Station)
A fixed station in a mobile radio system used for radio communication with mobile stations. Base stations are located at the center or on the edge of a coverage region and consist of radio channels and transmitter and receiver antennas mounted on a tower.

Why hexagonal cell ?



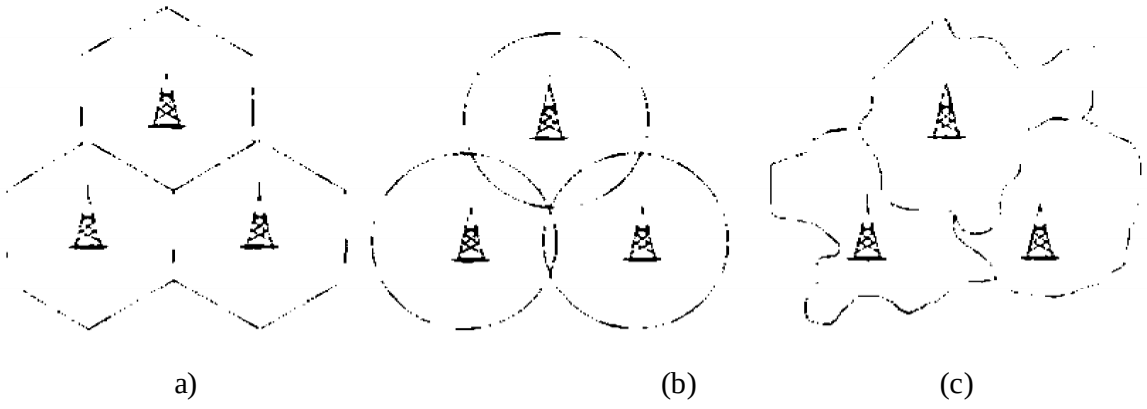


Fig. A.3. 1 (a) Theoretical Coverage (b) Ideal Coverage (c) Real Coverage

Frequency reuse

- Frequency reuse is a technique of reusing frequencies and channels within a communication system to improve capacity and spectral efficiency. Frequency reuse is one of the fundamental concepts on which commercial wireless systems are based that involve the partitioning of an RF radiating area into cells. The increased capacity in a commercial wireless network, compared with a network with a single transmitter, comes from the fact that the same radio frequency can be reused in a different area for a completely different transmission.
- Frequency reuse in mobile cellular systems means that frequencies allocated to the service are reused in a regular pattern of cells, each covered by one base station. The repeating regular pattern of cells is called cluster. Since each cell is designed to use radio frequencies only within its boundaries, the same frequencies can be reused in other cells not far away without interference, in another cluster. Such cells are called „co-channel" cells. The reuse of frequencies enables a cellular system to handle a huge number of calls with a limited number of channels.
- Figure shows a frequency planning with cluster size of 7, showing the co-channels cells in different clusters by the same letter. The closest distance between the co-channel cells (in different clusters) is determined by the choice of the cluster size and the layout of the cell cluster.

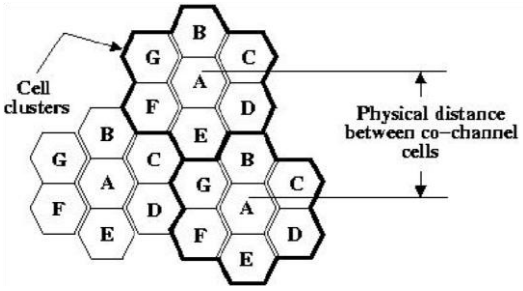


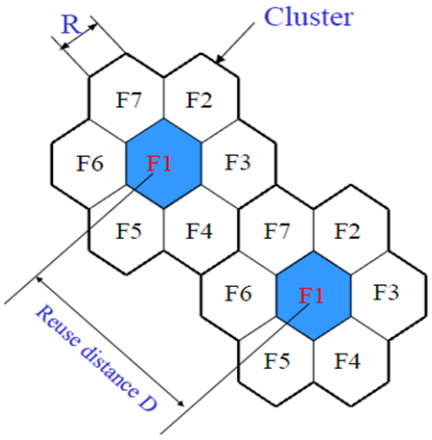
Figure: Frequency reuses technique of a cellular system.

❖For hexagonal cells reuse distance---

D= R.√3N

❖Reuse factor---

q= D/R= √3N



Reuse Distance
Channel capacity (Cell Capacity and Reuse)
1) S=kN
2) C = MKN = MS

where
S=Channels
N= no of cells in a cluster.
C= capacity
M= number of clusters(N cells replicated)
K= allotted channel to a cell

- Consider a cellular system with S duplex channels available for use and let N be the number of cells in a cluster.
  If each cell is allotted K duplex channels with all being allotted unique and disjoint channel groups
  we have S = KN under normal circumstances.
  Now, if the cluster are repeated M times within the total area, the total number of duplex channels, or,
  the total number of users in the system (Capacity) would be
  C = MS = KMN.
- Hence the capacity gain achieved is directly proportional to the number of times a cluster is repeated.
  For a fixed cell size, small N decreases the size of the cluster with in turn results in the increase of the number of clusters and hence the capacity.
  However for small N, co-channel cells are located much closer and hence more interference.
  The value of N is determined by calculating the amount of interference that can be tolerated for a sufficient quality communication. However, the cluster size N cannot take on any value and is given only by the following equation.

$N = i^2 + ij + j^2, \quad i \geq 0, j \geq 0,$ where i and j are integer numbers.

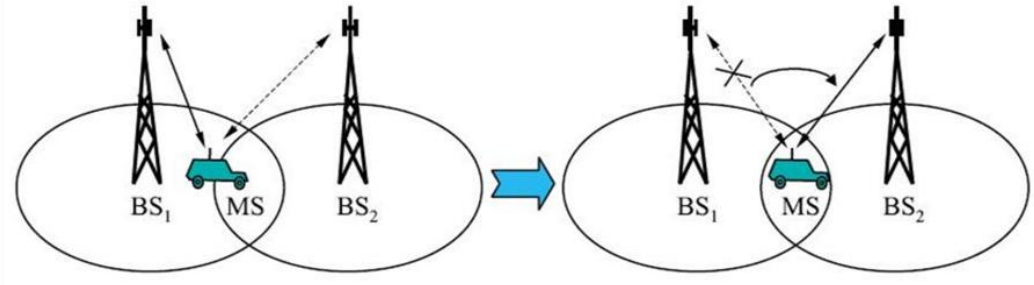
Channel assignment strategies
- **Channel Assignment strategies**:
- Types
  - Fixed channel assignment
  - Dynamic channel assignment

- **Fixed channel assignment**
- Each cell is allocated a predetermined set of voice channel
- Any new call attempt can only be served by the unused channels in the cell.
- The call will be *blocked* if all channels in that cell are occupied
- Borrowing strategy is a type of fixed channel assignment strategy.

- In this the cell is allowed to borrow channels from neighboring cell if all of its own channel are already occupied.
- The MSC (Mobile switching centre) supervises such borrowing procedures and ensures that borrowing of a channel does not disrupt or interfere with any of the calls in progress in the donor cell
- **Dynamic channel assignment**
- Channels are not allocated to cells permanently.
- Mobile Switching centre (MSC) allocate channels based on request.
- Reduce the likelihood of blocking, increase capacity.
- This requires the MSC to collect real time data on channel occupancy, traffic distribution & Radio Signal strength Indications (RSSI) of all channels on a continuous basis

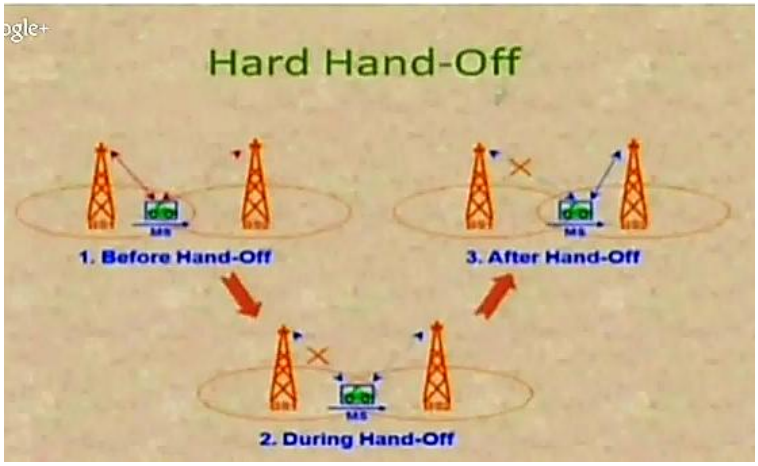
Hand-Off

- Handoff: A handoff refers to the process of transferring an active call or data session from one cell in a cellular network to another or from one channel in a cell to another. A well-implemented handoff is important for delivering uninterrupted service to a caller or data session user.

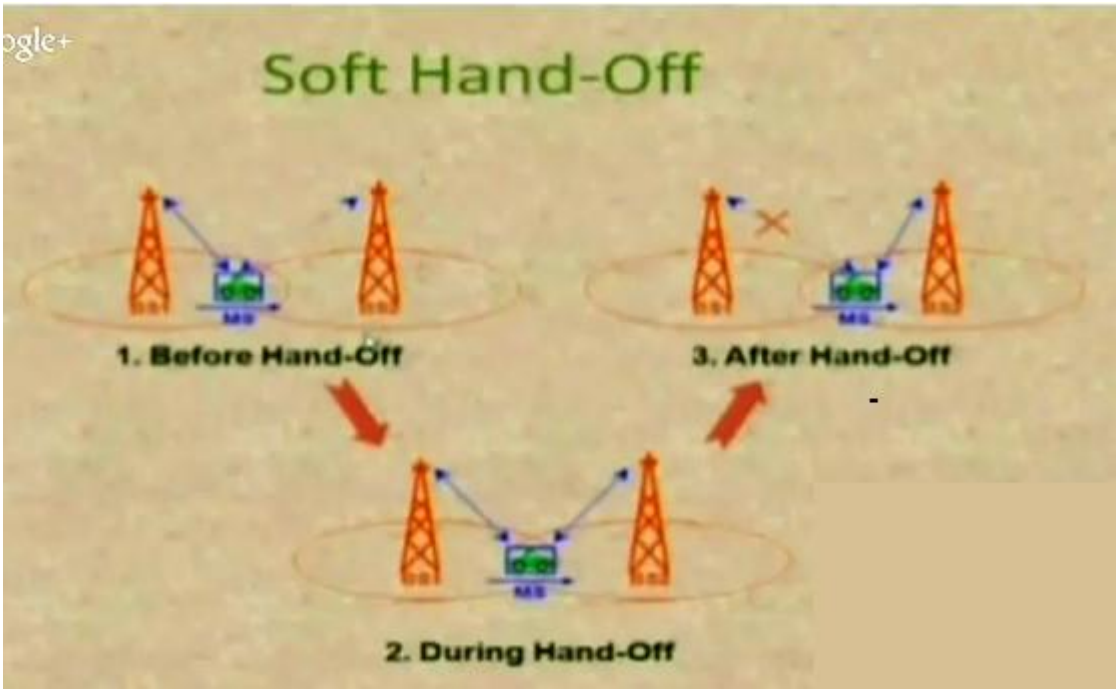


Hand-Off

- Handoffs may be classified into two types:
- **Hard-Off:** Characterized by an actual break in the connection while switching from one cell or base station to another. The switch takes place so quickly that it can hardly be noticed by the user.
- Because only one channel is needed to serve a system designed for hard handoffs, it is the more affordable option. It is also sufficient for services that can allow slight delays, such as mobile broadband Internet.



- **Soft Handoff:**
- Entails two connections to the cell phone from two different base stations.
- This ensures that no break ensues during the handoff. Naturally, it is more costly than a hard handoff.



Interference and System capacity

There are two major types of interferences:

- Co-channel Interference(CCI)
- Adjacent Channel Interference (ACI)

CCI is caused due to the cells that reuse the same frequency set. These cells using the same frequency set are called cochannel cells.
ACI is caused due to the signals that are adjacent in frequency.

Due to frequency reuse, several cells in a same coverage area use same frequency. These cells are known as co-channel cell.
The interference between signals from these co-channel cells is called co-channel interference. Co-channel interference is the cross talk between two different radio transmitters using the same radio frequency as is the case with the co-channel cells. The reasons of CCI can be because of either adverse weather conditions or poor frequency planning or overlycrowded radio spectrum.

If the cell size and the power transmitted at the base stations are same then CCI will become independent of the transmitted power and will depend on radius of the cell (R) and the distance between the interfering co-channel cells (D). If D/R ratio is increased, then the effective distance between the co-channel cells will increase and interference will decrease. The parameter Q is called the frequency reuse ratio and is related to the cluster size.

For hexagonal geometry.

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

From the above equation, small of 'Q' means small value of cluster size 'N' and increase in cellular capacity. But large 'Q' leads to decrease in system capacity but increase in transmission quality
Co-channel interference cannot be reduced by simply increasing the carrier power of transmitter. If we increase transmit power of carrier, it will increase interference to neighbouring channel cell.

How to avoid:
To reduce co-channel interference, co-channel cell can be physically be separated by minimum distance.

Adjacent Channel Interference (ACI)

- This is a different type of interference which is caused by adjacent channels i.e. channels in adjacent cells.
- It is the signal impairment which occurs to one frequency due to presence of another signal on a nearby frequency.
- This occurs when imperfect receiver filters allow nearby frequencies to leak into the passband.
- This problem is enhanced if the adjacent channel user is transmitting in a close range compared to the subscriber's receiver while the receiver attempts to receive a base station on the channel. This is called near-far effect.
- This effect can also occur if a mobile close to a base station transmits on a channel close to one being used by a weak mobile. This problem might occur if the base station has problem in discriminating the mobile user from the "bleed over" caused by the close adjacent channel mobile.
- Adjacent channel interference occurs more frequently in small cell clusters and heavily used cells. If the frequency separation between the channels is kept large this interference can be reduced to some extent.
- Thus assignment of channels is given such that they do not form a contiguous band of frequencies within a particular cell and frequency separation is maximized. Efficient assignment strategies are very much important in making the interference as less as possible. If the frequency factor is small then distance between the adjacent channels cannot put the interference level within tolerance limits.

Power Control for Reducing Interference

- In practical systems, the power level of every subscriber is under constant control by the serving BS
- Power control not only reduces interference levels but also prolongs battery life.

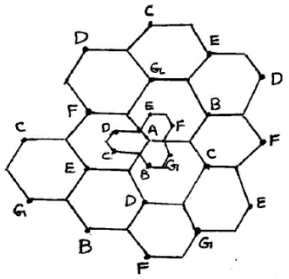
- In CDMA spread spectrum systems, power control is a key feature to ensure maximal utilization of the system capacity.
- Reduced interference leads to higher capacity.

Why cell splitting and sectoring?

- As users increases channel capacity decreases.
- Techniques are needed to provide extra channels.
- Cell splitting and sectoring increases capacity.

Cell splitting

- It is the process of subdividing a congested cell into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power.
- Cell splitting increase the capacity of the cellular system since it increases the number of times that channels are reused.
- By defining new cells which have a smaller radius than the original cells and by installing these smaller cells (microcells) between the existing cell, capacity increases due to additional channels/unit area.
- An example of cell splitting is shown below the base station are placed in corners of the cells, and area served by base station A is assumed to be saturated with traffic. New base stations are therefore needed in the region to increases the number of channels in the area and to reduce the area served by the single base station.



Limitations:

- Handoffs are more frequent.
- Channel assignments become difficult.
- All cells are not split simultaneously so special care have to be taken for proper allocation of problem.

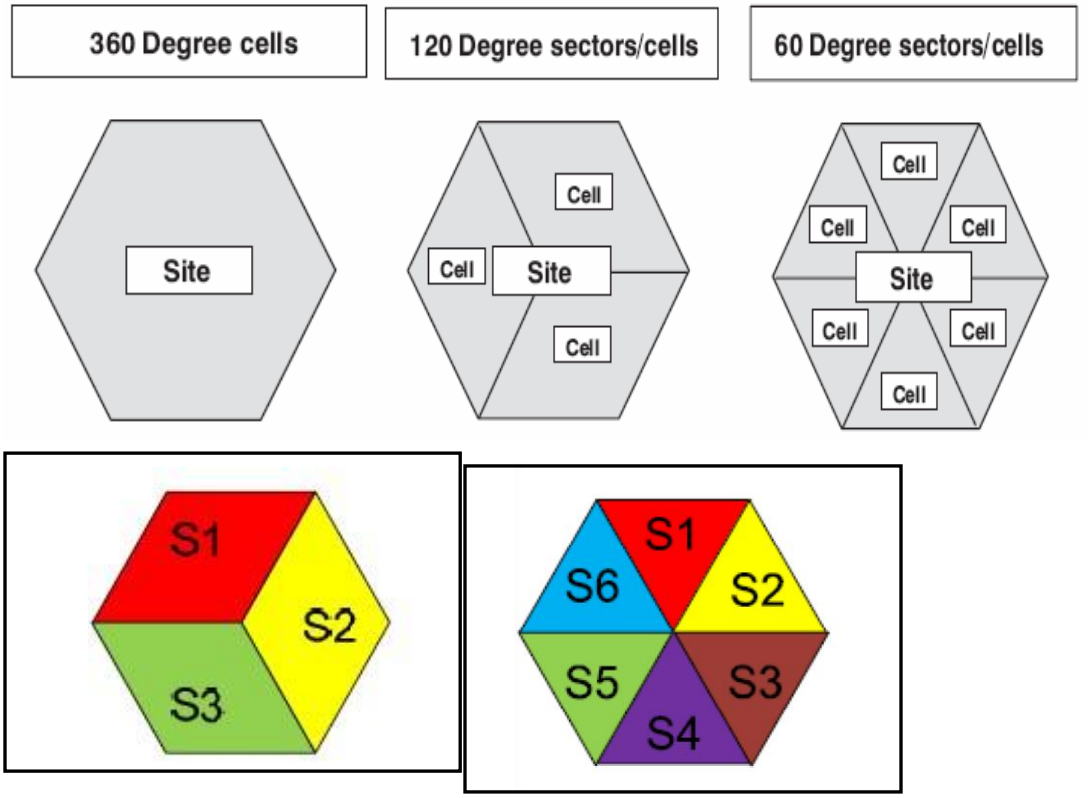
Cell sectoring:

- In cellular telephone system, co-channel interference can be decreased by replacing a single omnidirectional antenna with several directional antennas, each radiating within a smaller area. It is a method to increase capacity is to keep the cell radius unchanged and seek methods to decrease D/R ratio. Sectoring increases SIR, so that the cluster size may be reduced. First the SIR is improved using directional antennas, then capacity improvement is achieved by reducing the number of cell in the cluster; thus increasing the frequency reuse. To achieve this, it is necessary to reduce the relative interference without decreasing the transmit power.
- In sectoring a cell has the same coverage space but instead of using a single Omnidirectional antenna that transmits in all directions, either 3 or 6 directional antennas are used these antennas provide coverage to a sector of the hexagon.

- There are two types of sectoring in a cell
  - 3 directional antennas, 120° sectoring (each antenna covers 120°)
  - 2 6 directional antennas, 60° sectoring (each antenna covers 60°).

Advantages:
- It improves S/I ratio.
- It reduces interference which increases capacity.
- It enables to reduce the cluster size and provides an additional freedom in assigning channels.

Limitations:
- Increased number of antennas at each base station.
- Loss of traffic.
- Since sectoring reduces the coverage area of a particular group of channels, the number of handoffs increases as well.



120^0 Sectoring

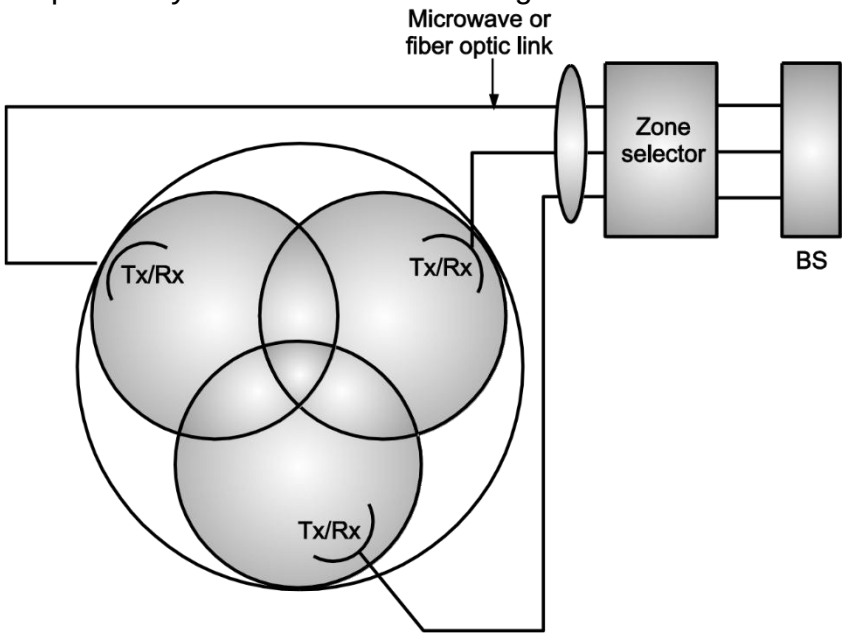
60^0 Sectoring

Microcell zone concept

When sectoring is employed, lot of handoffs is required due to this load on switching and control link element of the mobile system increases.

- To solve this problem, a microcell concept for seven cell reuse is used.

- In this scheme, each of three (possibly more) zone sites are connected to single base station. The zone are connected by a co-axial, fiber optic cable or microwave link to a base stations.
- Multiple zones and single station make a cell. As mobile travels within a cell, it served by zone with strong signal, this approach is advantageous because of sectoring placed antenna at outer edges of cell, and base station channel is assigned to any zone by the base station.
- As mobile moves from one zone to another zone in same cell, it uses same channel, thus like a sectoring, handoff is not required at mobile switching centre (MSC) when mobile travels within the cell in different zone.
- The base station simply changes the channel from one zone to another zone, and channel is active in particular zone in which mobile is travelling, hence interference is reduced.
- The advantage of zone cell technique is that, cell maintains particular area of coverage, the co-channel interference in cellular system is reduced, as larger control base station is replaced by zone transmitter on edge of cell.



Repeater

- Extends coverage range
- Directional antenna or distributed antenna system.
- Used for hard to reach areas such as within buildings, basements, tunnels, valleys
- Radio transmitters called repeaters can be used to provide coverage in these areas
- Repeaters are bidirectional
    - ♦ Receive signals from the BS
    - ♦ Amplify the signals
    - ♦ Reradiates the signals
- Received noise and interference is also reradiated.

Questions

1. State the two features and two Limitation of 3G Wireless Technology
2. What is frequency reuse and state its two advantages.
3. State three functions of mobile computing with example
4. With the help of neat diagram describe the concept of co-channel interference
5. Why power control is required? Give two reasons.
6. With the help of neat block diagram describe the logical function of mobile computing.
7. Describe fixed channel assignment and dynamic channel assignment
8. List four Mobile computing Devices and state the function of two mobile devices
9. Define frequency reuse and state two advantages
10. With neat labeled diagram describe the handoff strategies
11. **What is mobile computing? Give its functions** (4M S-15)
12. **Explain cell splitting & sectoring** (4M S-15)
13. **Explain Frequency reuse with neat sketch.** (4M S-15)
14. **Explain Handoff Strategies** (4M S-15)
15. **What is co channel Interference? How it can be controlled? (4M S 15)**
16. List various mobile computing functions (4M W15)
17. Write different channel assignment strategies in GSM. Explain in brief (4M W-15).
18. Define cell sectoring with its type(4M W-15).
19. Describe how repeaters are used in range extension.(4M W-15).
20. Define Frequency Reuse and Handoff.(4M W-15).
21. Describe microcell zone concept. (4M W-15)