Wireless Communication (EC0603)

Unit-II

B.Tech (Electronics and Communication)

Semester-VI

Omkar Pabbati

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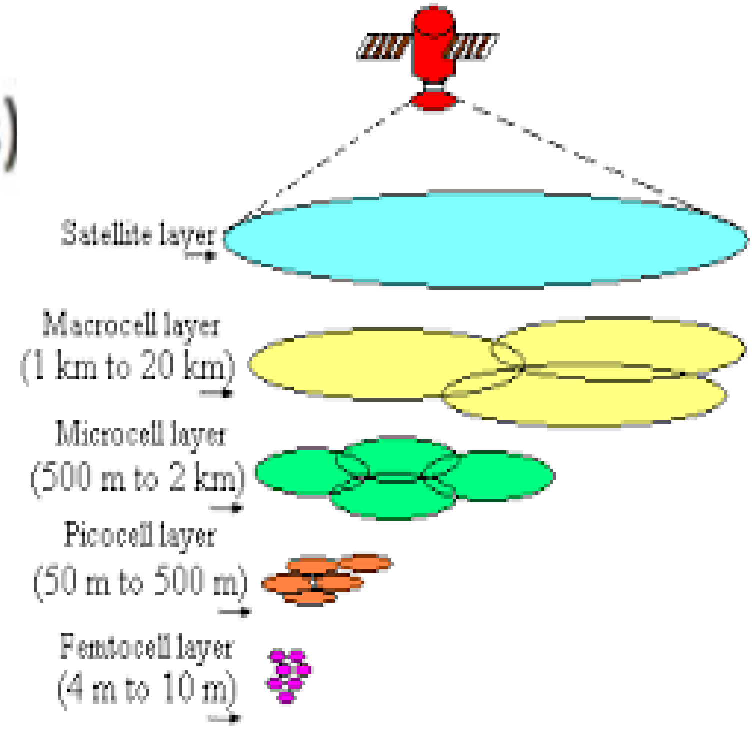
The Cellular Concepts

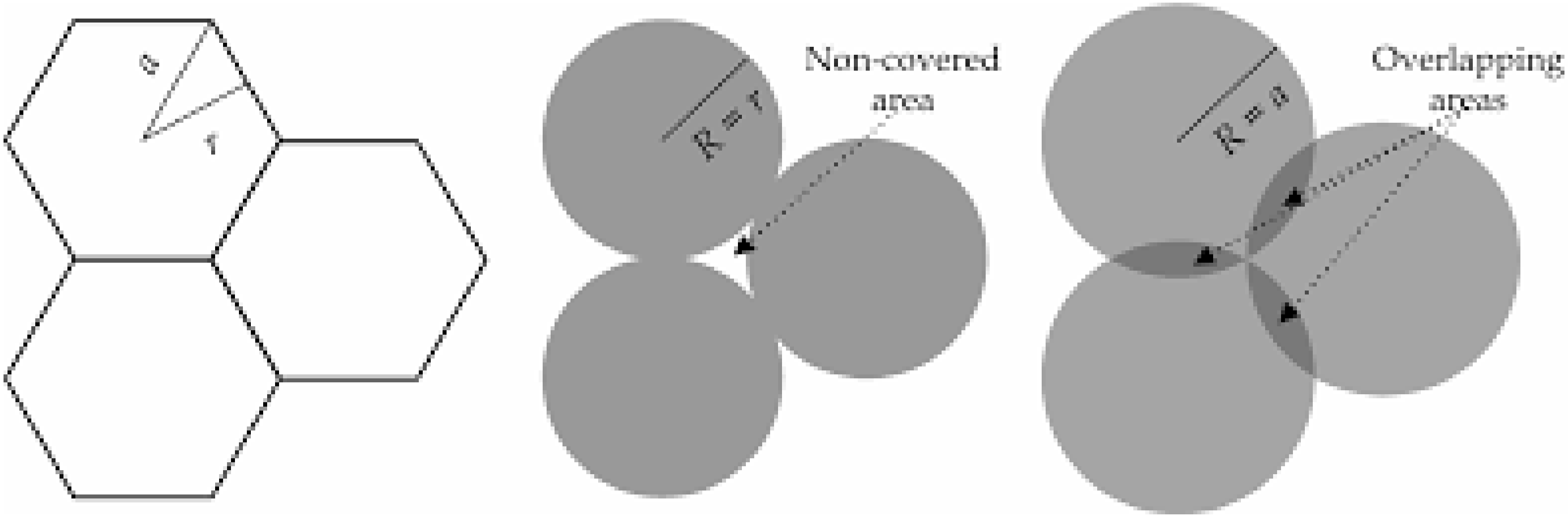
- CELL: Actual coverage area of the mobile base station is called as a cell.
- The concept of cellular telephone service was first proposed in the 1940s.
- The first cellular system was proposed by by AT&T and the Bell company, which would use many low-power transmitters with antennas mounted on shorter towers, to provide a much shorter frequency reuse distance. The area served by each transmitter would be considered a cell.

Cellular Hierarchy

- Picocells (<10 Meters)
- Microcells (100-1000 Meters)
- Macrocells (>1000 Meters)
- Megacells
- Femtocells



Cell fundamentals



ideally
Omnidirectional,
360
Overlapping

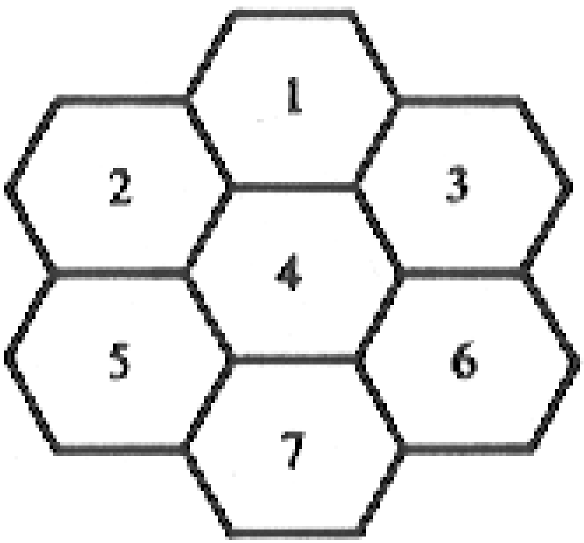
Practically
Complete area can be utiliased
No Overlapping
Closest approximation of circle
(no square)

Why Hexagonal Cell

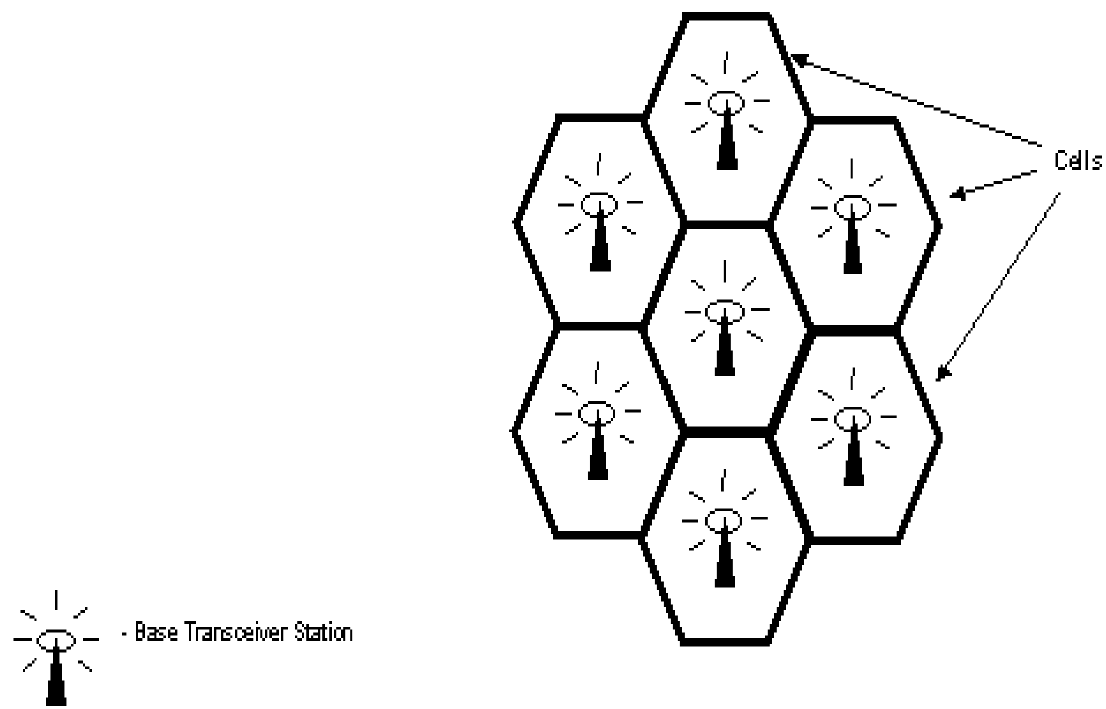
- Firstly, the distance from the centre to all the other edges should be equal. Options could be Circle, Square, Equilateral triangle and hexagon
- Circular shaped cells would leave out few spaces without any coverage.
- The cell must be designed to serve the weakest mobiles within the coverage area and these weakest points are located at the edges of a cell.
- For a given distance between centre of a polygon and its farthest perimeter points, the hexagon has the largest area out of square and triangle.
- Thus, hexagonal geometry is used which provides full coverage with fewest no. of cells.

- Hexagonal shape prefers than square or circle in cellular architecture because it covers an entire area without overlapping.
- The frequency reuse is possible using the shape.

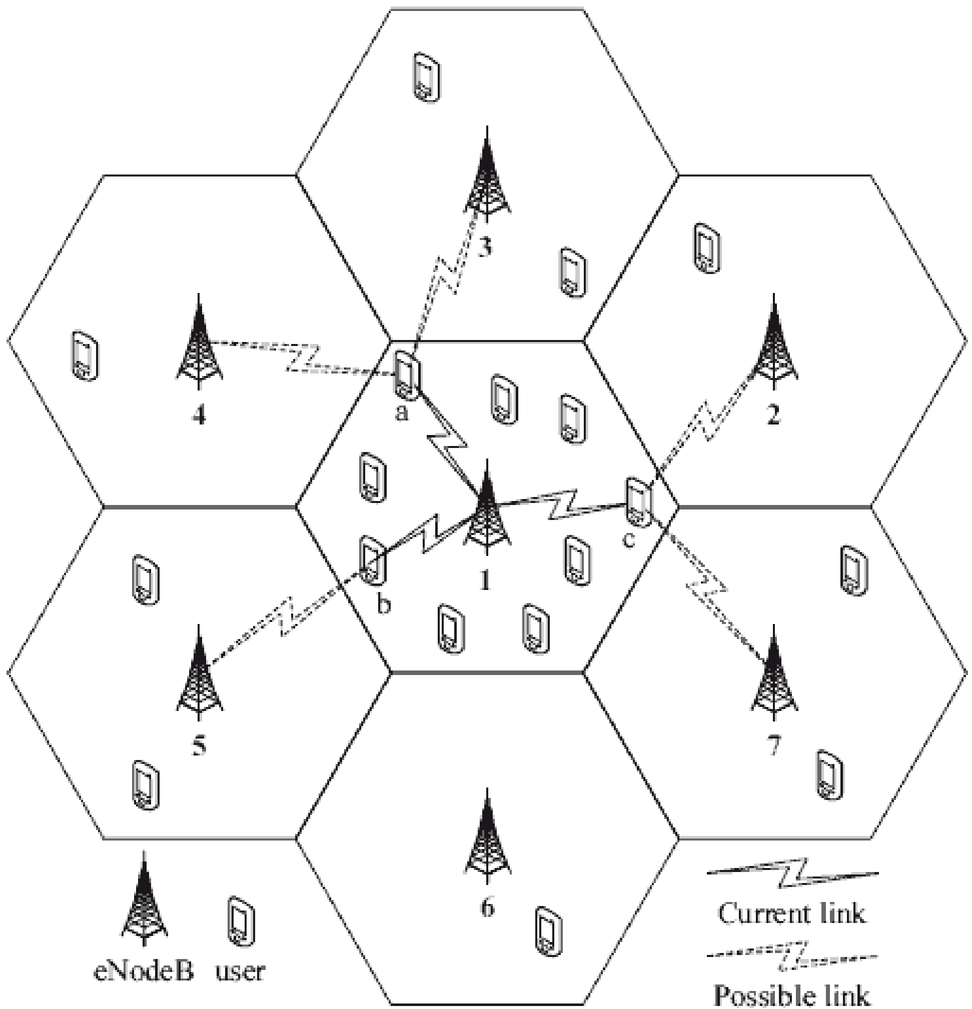
Clusters



Cluster



Network Model



Frequency re-use or frequency planning

Because of limited number of frequency spectrum

- Frequency reuse implies that in a given coverage area there are several cells that use same set of frequencies.
- These channels are called co-channel cells and the interference between signals from these cells called co-channel interference.
- Adjacent cell uses different frequency

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

$$S=KN$$

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

$$C=MKN=MS$$

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

Definition

Frequency reuse :

"The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called *frequency reuse* or *frequency planning*"

Footprint :

The actual radio coverage of a cell is known as the footprint. It is determined from field measurements or propagation prediction models.

Cluster :

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

Total number of channels available

$$S = k*N$$

Where k is number of channels allocated to one cell

N is number of cells in a cluster

$$C = M*k*N = MS$$

Cont....

Each cell in one cluster using different frequencies.

Need of frequency reuse

- Limitation of frequency spectrum
- To improve system capacity
- To increase coverage area
- To remove interference between cells

Interference

- **Co-Channel Interference**
  - **Conception:** the interference among the signals of co-channel cells is called co-channel interference.
  - **Result from :** Frequency reuse
  - **Reduction method:** co-channel cells must physically be spaced at a minimum interval to ensure adequate isolation of transmissions.
- **Adjacent Channel Interference**
  - **Conception:** The signal interference from the frequency adjacent to that of the signal used is called adjacent channel interference.
  - **Reduction method:** accurate filtering and channel allocation (maximizing channel intervals of the cell). Interval of frequency reuse inter-cell interference, such as C/I

Frequency reuse

- In the cellular concept, frequencies allocated to the service are re-used in regular pattern of areas (called cells), each covered by one base station.
- It is a technique of reusing frequencies and channels within a communication system to improve capacity and spectral efficiency.

Frequency reuse ratio

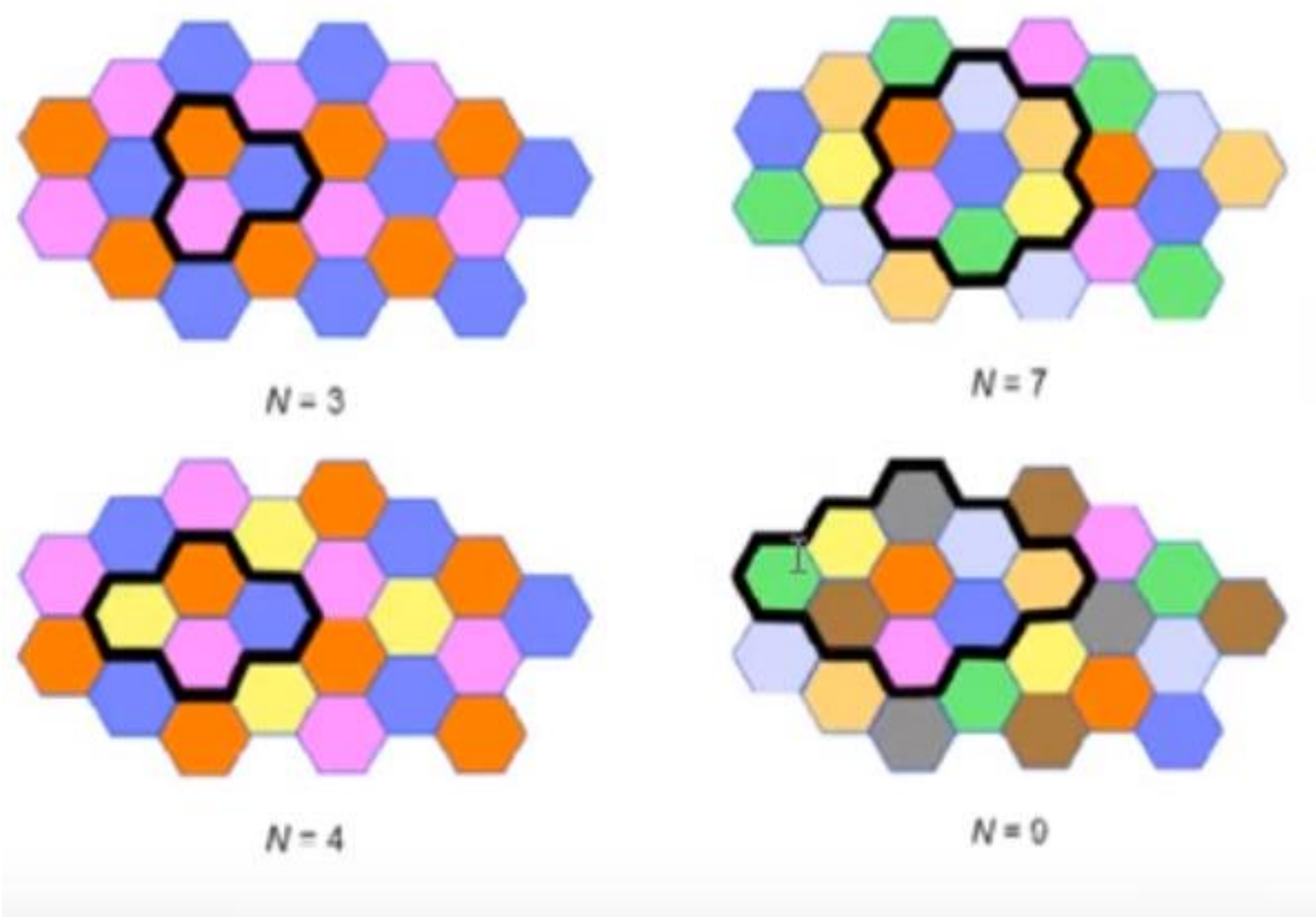
Assuming hexagonal shape cells of equal size

$$\frac{D}{R} = q = \sqrt{3N}$$

where:

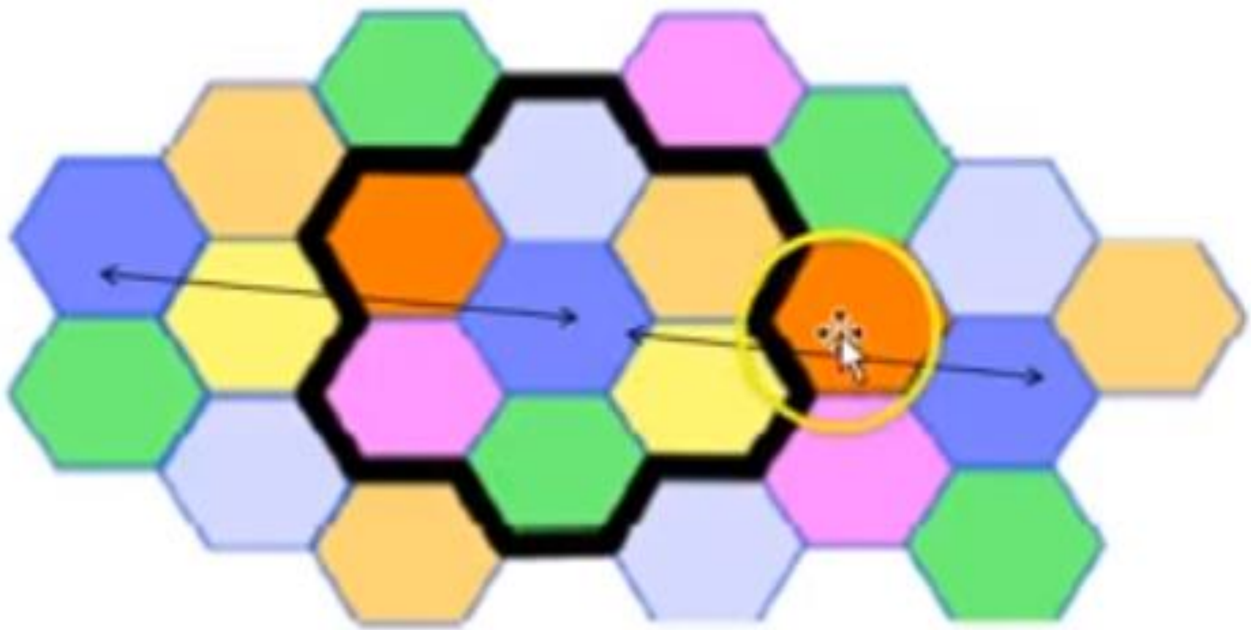
D:	Distance between the centres of cells
R:	Radius of the cell
q:	Reuse ratio
N:	Cluster size

Cont.....



Example

- For a mobile system cluster size of 7, determine the frequency reuse distance if the cell radius is five kilometers. Repeat the calculation for a cluster size of 4.



$N = 7$

Co-channel Interference

- co-channel interference depends on:
  - R : cell radius
  - D : distance to base station of nearest co-channel cell where $D=R(\sqrt{3N})$
- if $D/R \uparrow$ then spatial separation relative to cell coverage area $\uparrow$
  - improved isolation from co-channel RF energy
- $Q = D / R$: co-channel reuse ratio
  - hexagonal cells $\rightarrow Q = D/R = \sqrt{3N}$
- Smaller value of Q provides larger capacity, but higher CCI
- Hence there is tradeoff between capacity and interference.
  - small Q $\rightarrow$ small cluster size $\rightarrow$ more frequency reuse $\rightarrow$ larger system capacity
  - small Q $\rightarrow$ small cell separation $\rightarrow$ increased CCI

Method to locate co-channel cells

- In order to connect without gaps between adjacent cells, the geometry of the cells is such that the number of cells per cluster N can have the values which satisfies $N=i^2+i*j+j^2$.

Where i & j are the non negative integers.

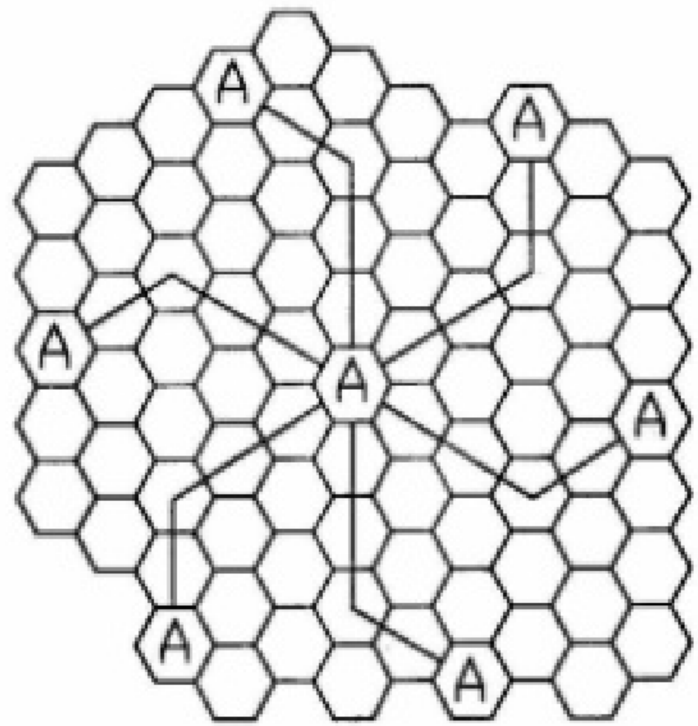
- To find the nearest co-channel neighbors of a particular cell, one must do the following:

(a) move I cells along any chain of hexagons and

(b) turn 60 degree counter clock wise & move j cells

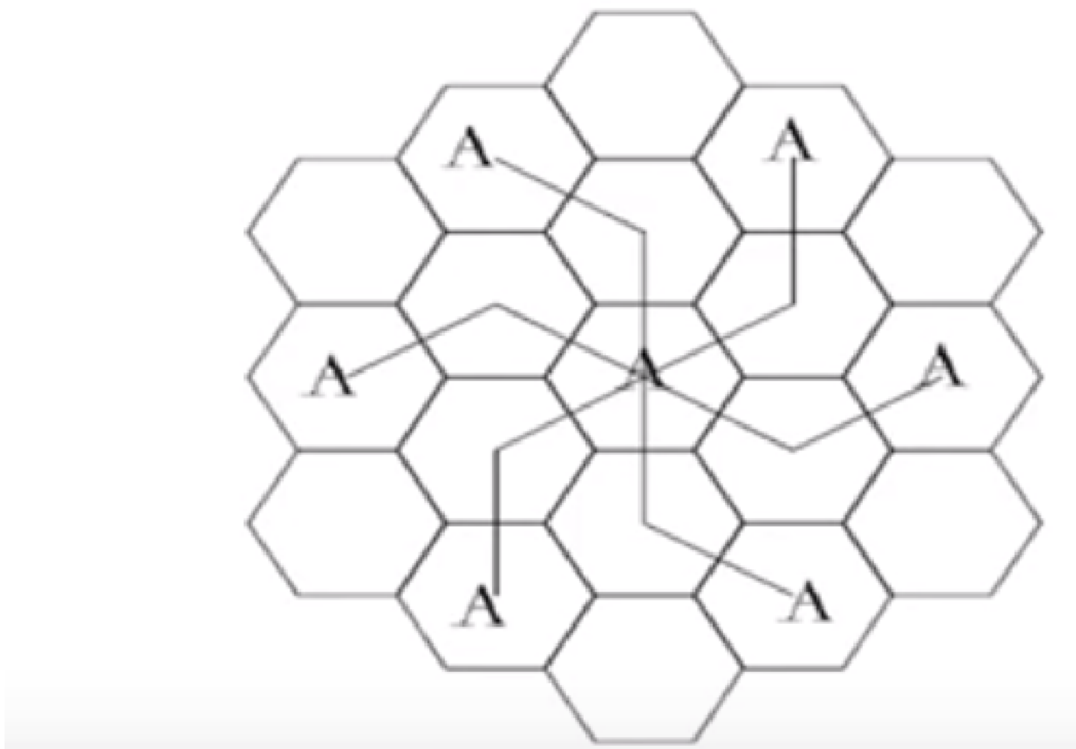
Cont..

- Move i cells along any chain of hexagons.
- Turn 60º counter-clockwise and move j cells.
- For example:
  - N=19: i =3, j =2;
  - N=12: i =2, j =2;
  - N=7; i =2, j =1;



Cont..

Example for N=3 , i.e i=1 &j=1



Assignments of Frequencies to cell

- Fixed channel allocation
- Borrowing Channel allocation
- Dynamic channel allocation

cellular system with Small cells

- Higher capacity
- Low Power
- Reduced interference
- Large infrastructure
- Frequent Handover
- Frequency planning

Frequency reuse

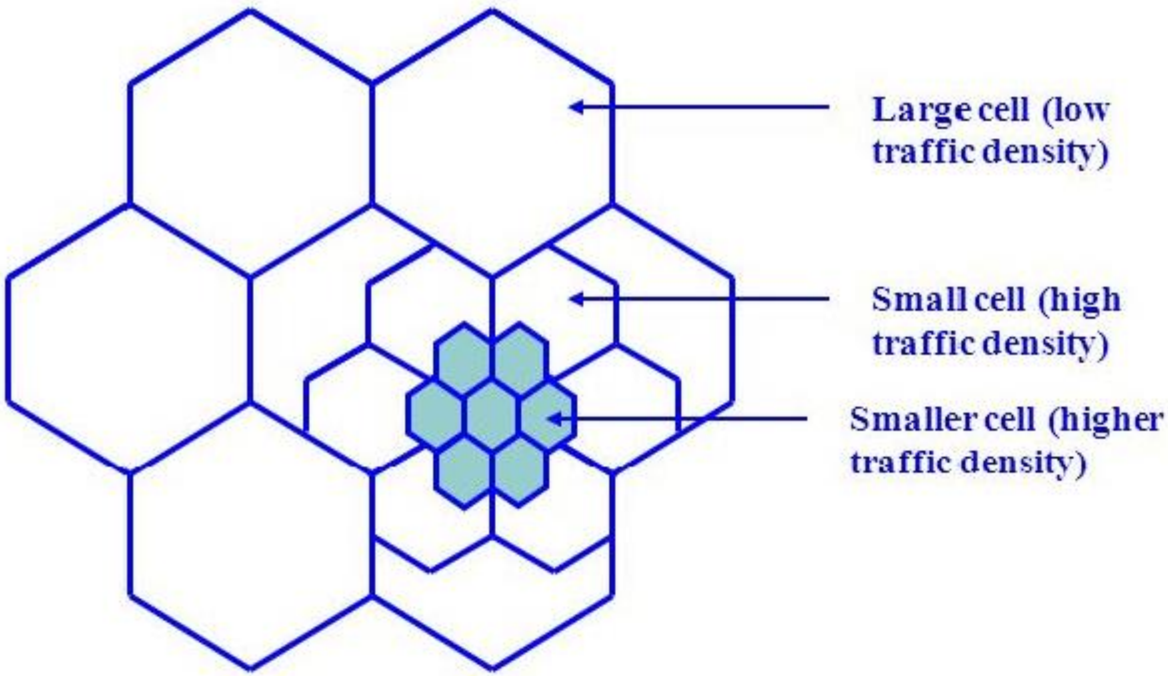
- There are several techniques to expand on already existing network or to add more capacity to a network being built.

Two techniques:

(1) cell splitting

(2) cell sectoring

Cell splitting



- Depending on traffic patterns, the smaller cells may be activated/deactivated in order to efficiently use cell resources.
- Smaller cell size, smaller transmitting power, and reduces cochannel interference

Cell splitting

- Cell splitting: one cell is divided into two more cells to achieve the higher network capacity and increase the coverage.

Smaller cell covers less area , network capacity increase

What about co-channel interference?

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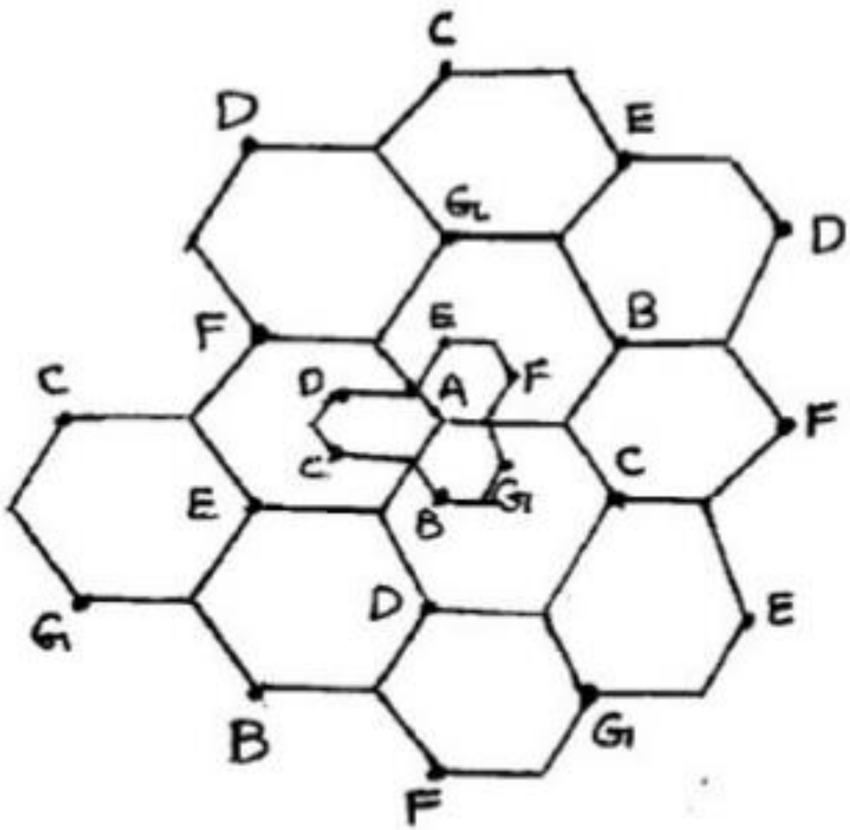


- The process of subdividing a congested cell into smaller cell.
- Each with its own base station and a corresponding reduction in antenna height.
- leads to increase in capacity

- The original congested cell is known as Macro cell

- The smaller one is known as Micro cell

- The micro cells are to be added in such a way so as to preserve frequency reuse

Limitations

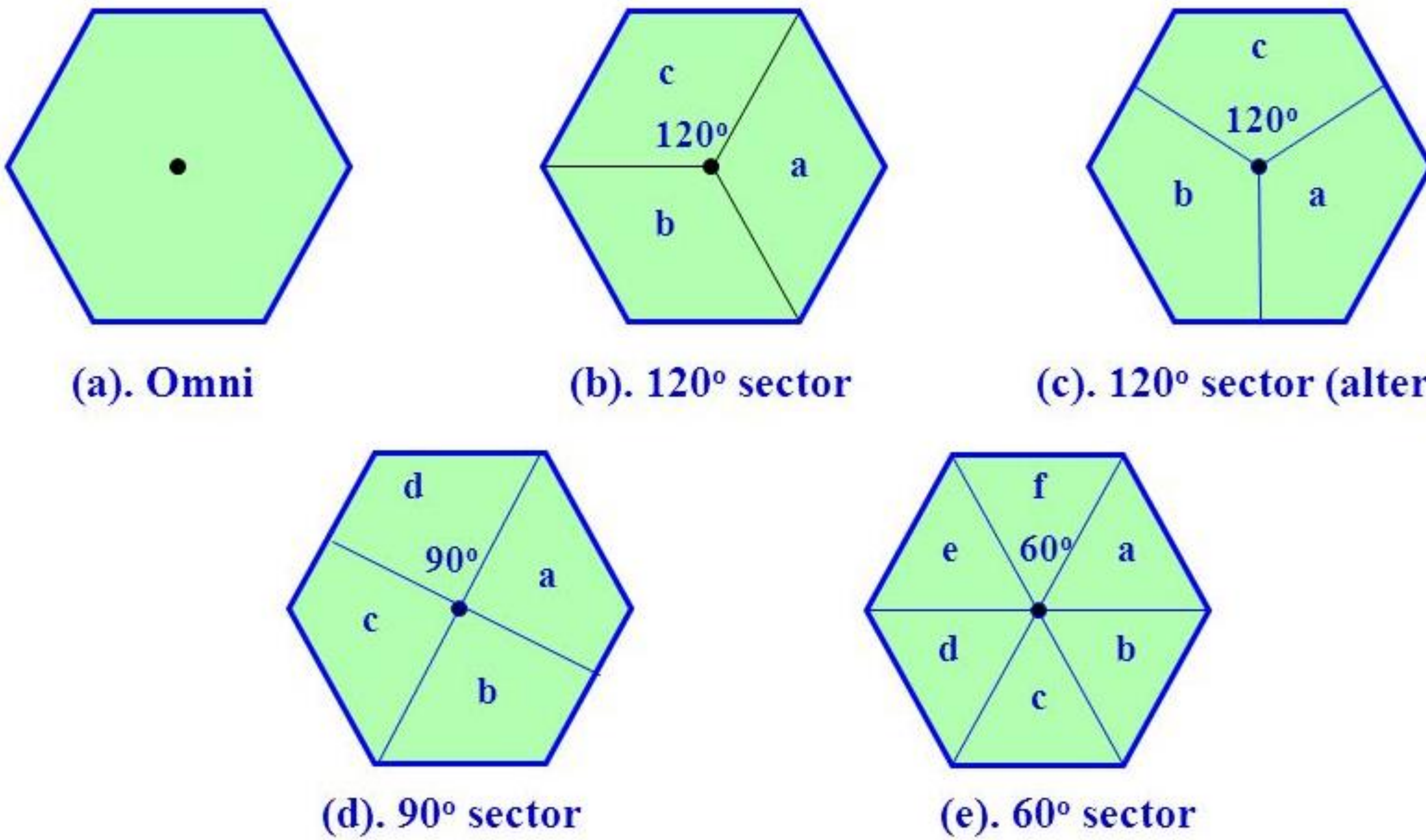
- Handoffs are more frequent
- Channel assignments become difficult
- All cells are not split simultaneously so special care have to be taken for proper allocation of problem
- Power levels for all cells must be redesigned.

Cell sectoring

- The main aim of cell sectoring is to provide more channels per unit area.

- Use directional antennas to further control the interference and frequency reuse of channels
- Examples: Omnidirectional, 120^o ,60^o ,90^o

Cell sectoring



(a). Omni

(b). 120° sector

(c). 120° sector (alternate)

(d). 90° sector

(e). 60° sector

Cont..

- Single Omni directional antenna radiates in the all directions.
- In cell sectoring only 3 or 6 directional antennas are used as they covers less area and hence, improves the capacity

To overcome some limitations of co channel interference, sectoring can be done.

Cell sectoring involves directional antenna by replacing Omni directional antennas at the base stations.

Sectoring improves S/I

A cell is normally partitioned into

- three 120° sectors or
- six 60°

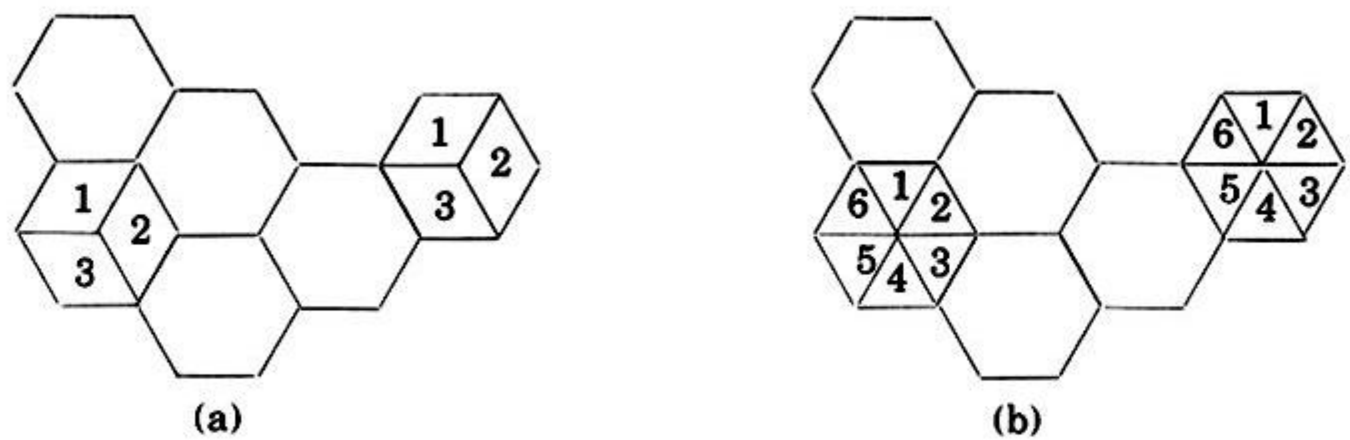


Figure (a) 120° sectoring; (b) 60° sectoring.

Cell sectoring

- The co-channel interference in a cellular system may be decreased
  - by replacing a single omni directional antenna at the base station by several directional antennas,
  - each radiating within a specified sector.
- By using directional antennas,
  - a given cell will receive interference and
  - transmit with only a fraction of the available co-channel cells.

Problems with Sectoring

- Increases the number of antennas at each BS
- Decrease in trunking efficiency due to sectoring(dividing the bigger pool of channels into smaller groups)
- Increase number of handoffs(sector-to sector)

Trunking & Grade of Service

- Cellular radio systems rely on *trunking to accommodate a large number of users in a limited radio spectrum.*

- Trunking allows a large no of users to share a relatively small number of channels in a cell by providing access to each user, on demand, from a pool of available channels.

- In a trunked radio system (TRS) each user is allocated a channel on a per call basis, upon termination of the call, the previously occupied channel is immediately returned to the pool of available channels.

Trunking efficiency or channel utilisation is given by:

carried traffic / number of channels

Grade of Service

- ***Grade of Service*** is a measure of the ability of a trunked system to give access to a user requiring service during the busiest hour (4-6pm, Thu, Fri)
- Grade of Service is usually measured in two ways
  1. Probability that a call is blocked
  2. Probability that a call will be delayed more than specified queuing time (some tolerable delay)

Grade of Service

- The grade of service is a benchmark used define the desired performance of a particular trunked system by specifying a desired likelihood of a user obtaining channel access given a specific number of channels available in the system.

- It is the wireless engineer's job to estimate the maximum required capacity and to allocate the proper number of channels in order to meet the *GOS.*

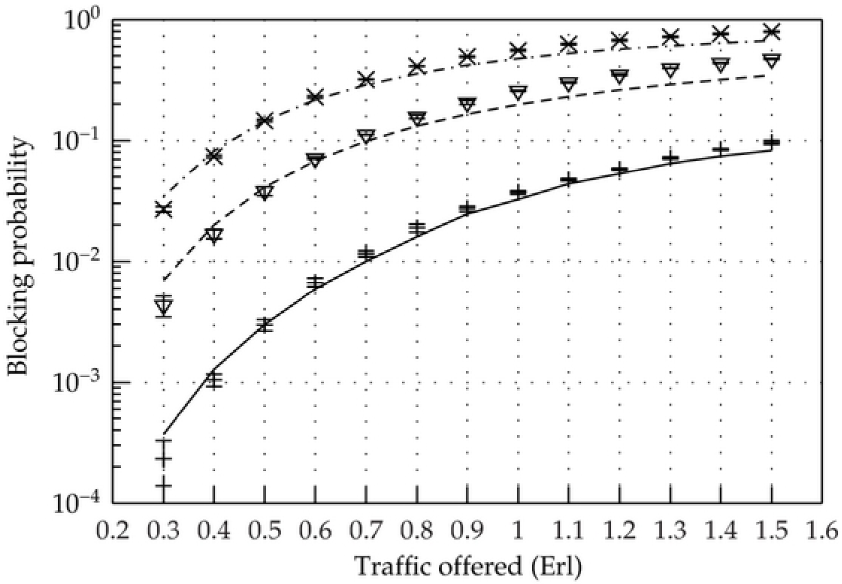
- <u>G</u>rade <u>o</u>f <u>S</u>ervice (GOS)
  - Measure of user access to a trunked radio system during **<u>busiest</u>** hour of the week
  - Specified as probability (Pr) that call is blocked or delayed
  - Busiest hour → typically 4-6 pm on Thu or Fri (cellular)
  - Erlang (erl) : **<u>unitless</u>** measure of traffic intensity
    - » Example: 0.5 erl = 1 channel occupied 30 minutes during 1 hour

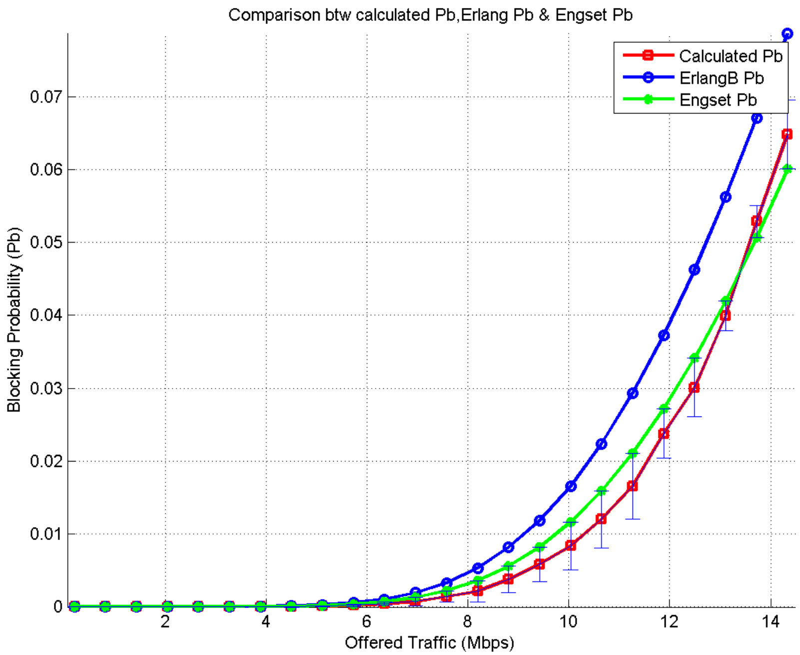
$$\text{Grade of Service} = \frac{\text{Number of lost calls}}{\text{Number of attempted calls}}$$

$$\text{Grade of Service} = \frac{\text{number of blocked calls}}{\text{number of offered calls}}$$

The lower this number, the higher the GOS.

- Ratio of the number of lost calls to the total number of attempted calls, same as the *probability of blockage*.
- The lower the number the better the system (A GoS of 0.01 is better than a GoS of 0.05)


Blocking probability
Traffic offered (Erl)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6


Comparison btw calculated Pb,Erlang Pb & Engset Pb
Calculated Pb
ErlangB Pb
Engset Pb
Blocking Probability (Pb)
Offered Traffic (Mbps)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
2 4 6 8 10 12 14

Handoff

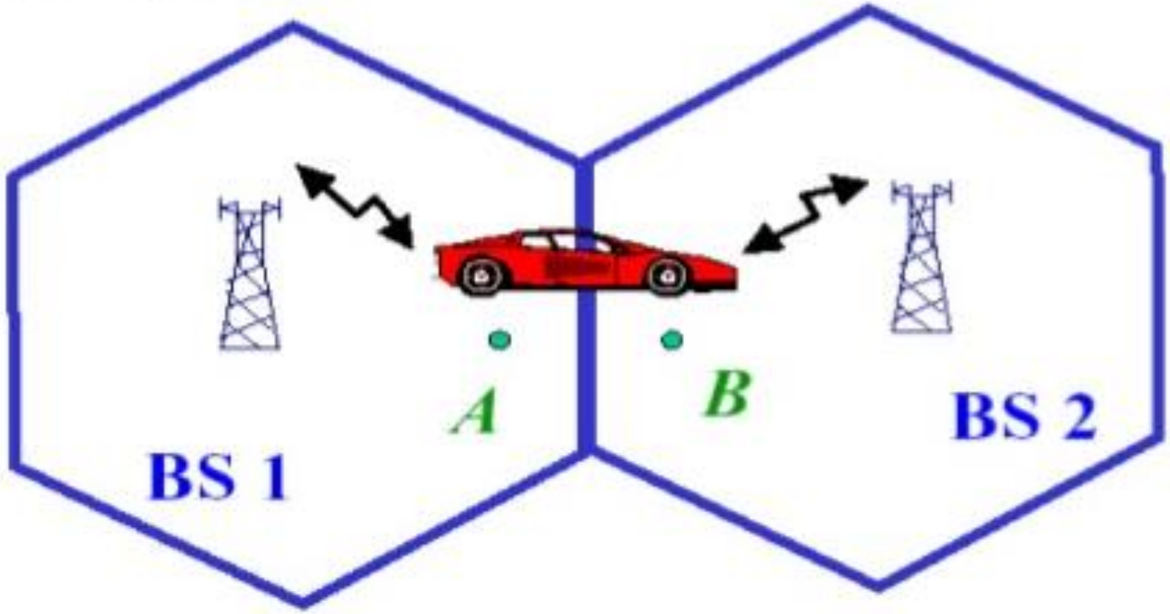
Handoff is the mechanism that transfers on going call from one cell to another as a user moves through the coverage area of a cellular system.

It is the process of switching frequency from one cell to another

Types of handoffs:

- Hard handoff
- Soft handoff
    - Softer handoff

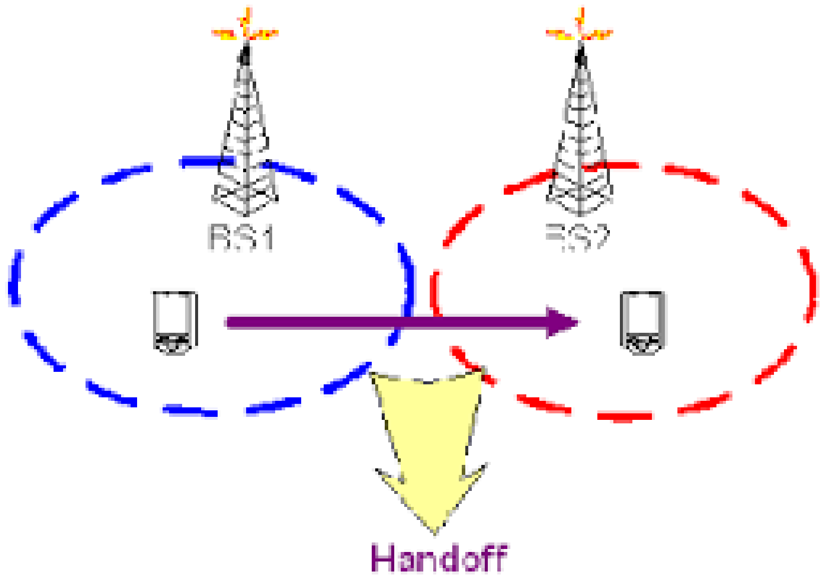
- The process of transferring a mobile user from one channel or base station to another.

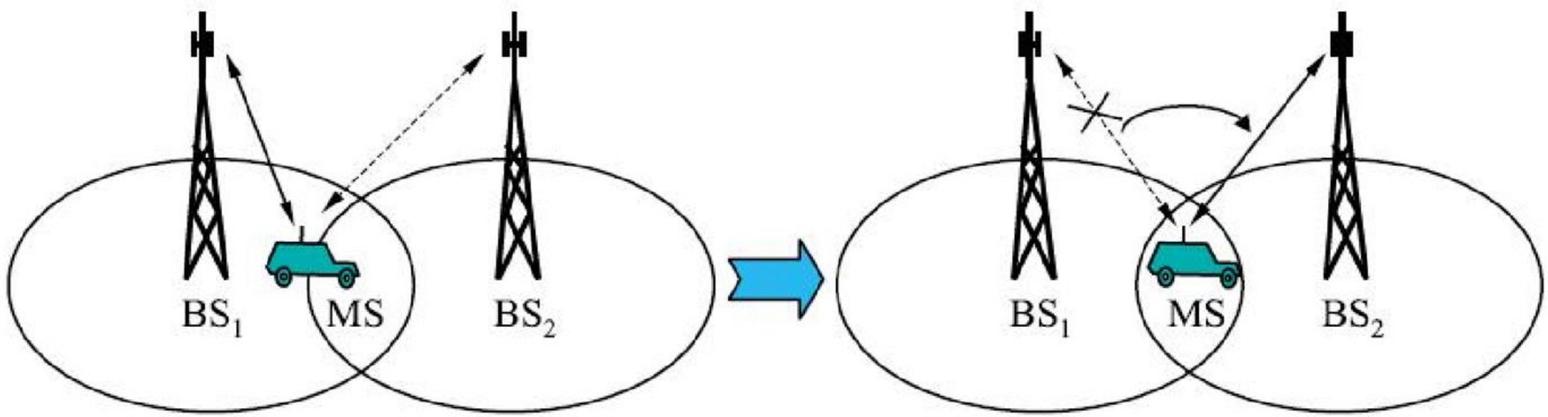


Handoff must be:

Performed quickly
Perform infrequently
Perform successfully

Hard Hand off

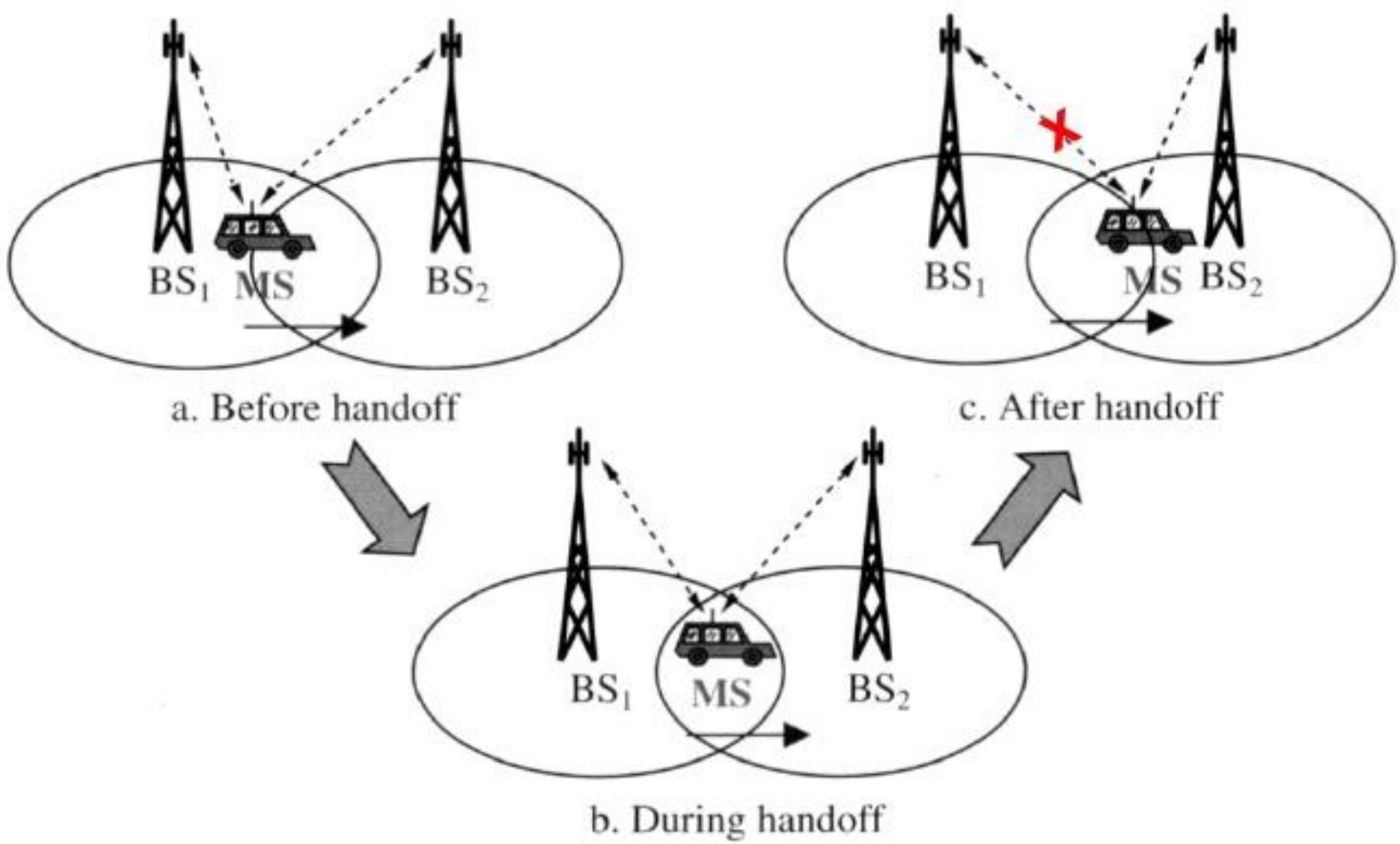




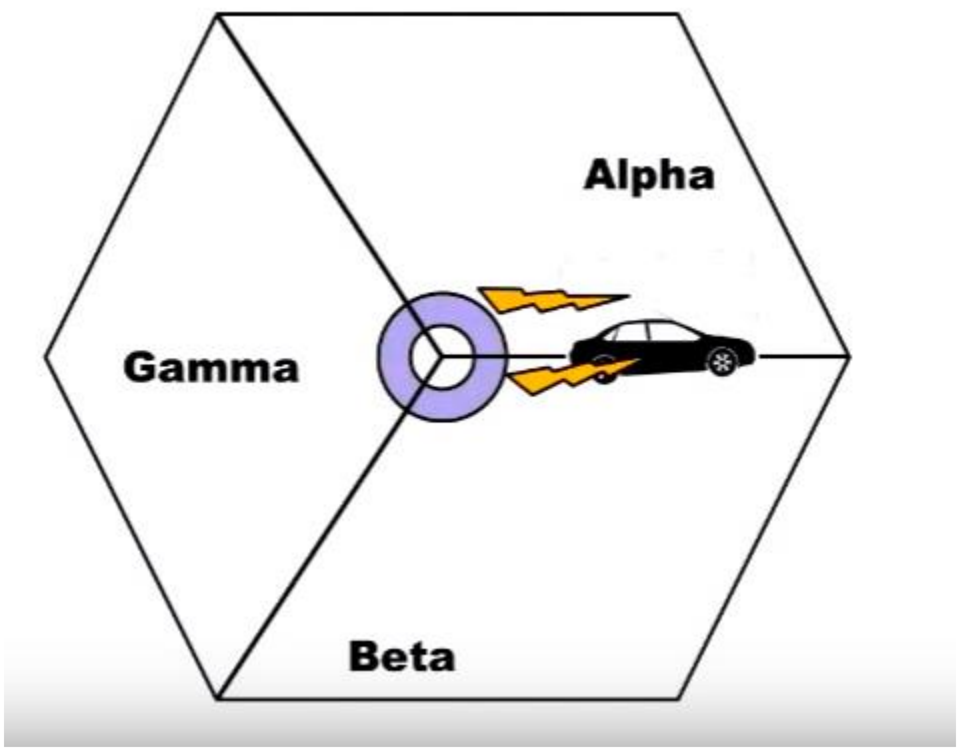
a. Before handoff

b. After handoff

Soft Handoff



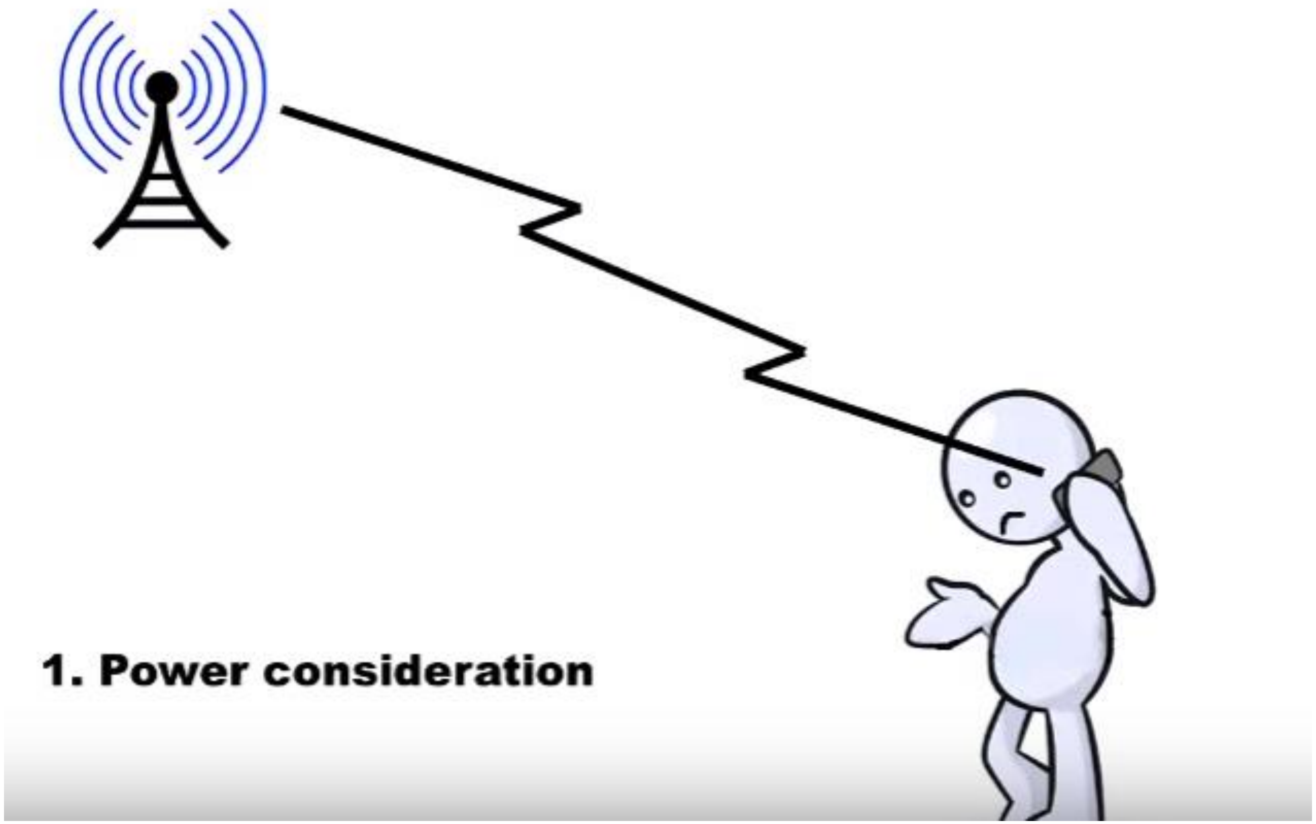
Softer handoff



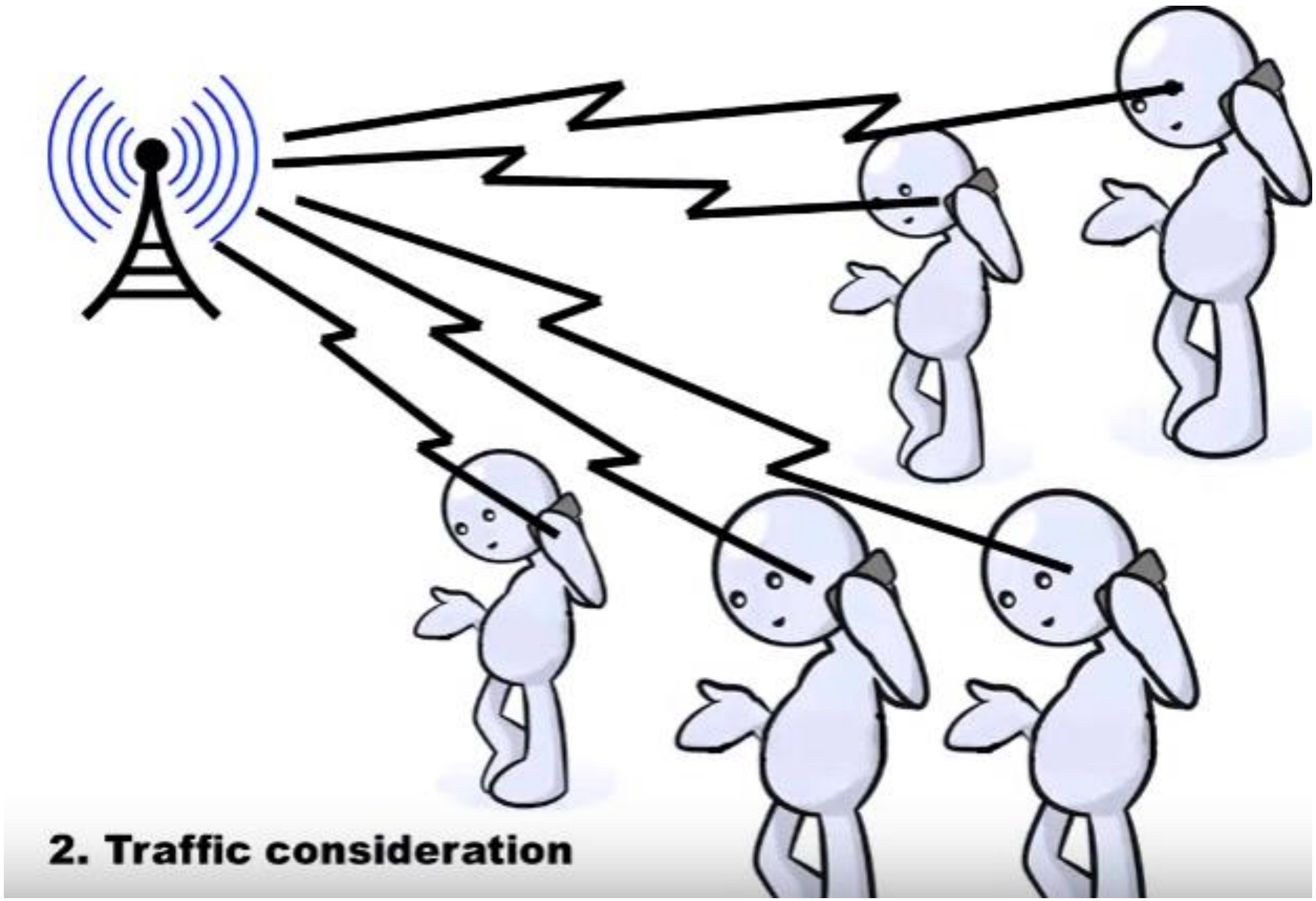
Need of handoff

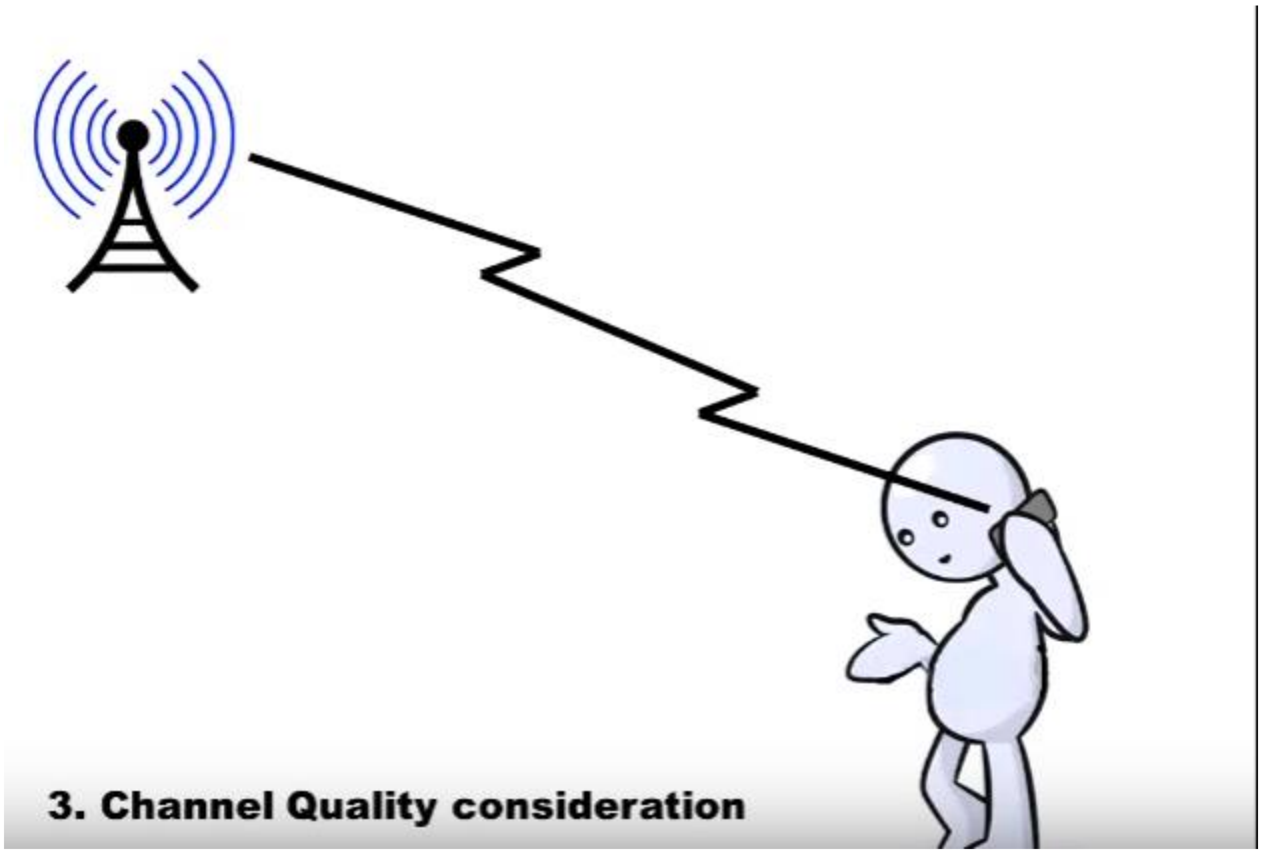
1. Power consideration
2. Traffic consideration
3. Channel quality consideration
4. Distance consideration
5. Administrative consideration

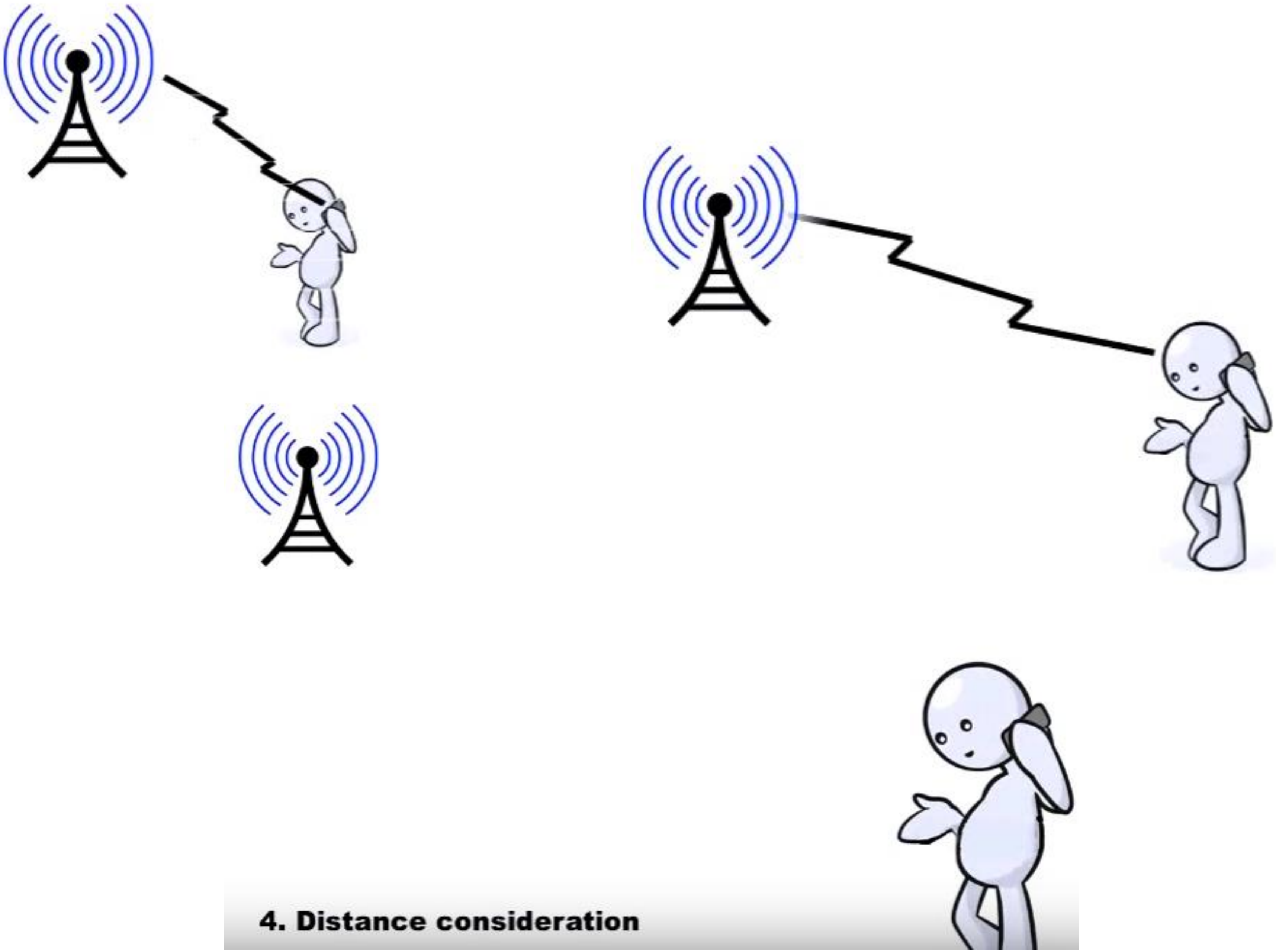
Power consideration



Traffic consideration




3. Channel Quality consideration



4. Distance consideration

5. Administrative consideration

Advantages of Hard Handover

1. Only one channel is occupied at a time.
2. It is very short and usually is not perceptible by the user.
3. In hard hand-off, the phone hardware does not need to be capable of receiving two or more channels in parallel, which makes it cheaper and simpler.

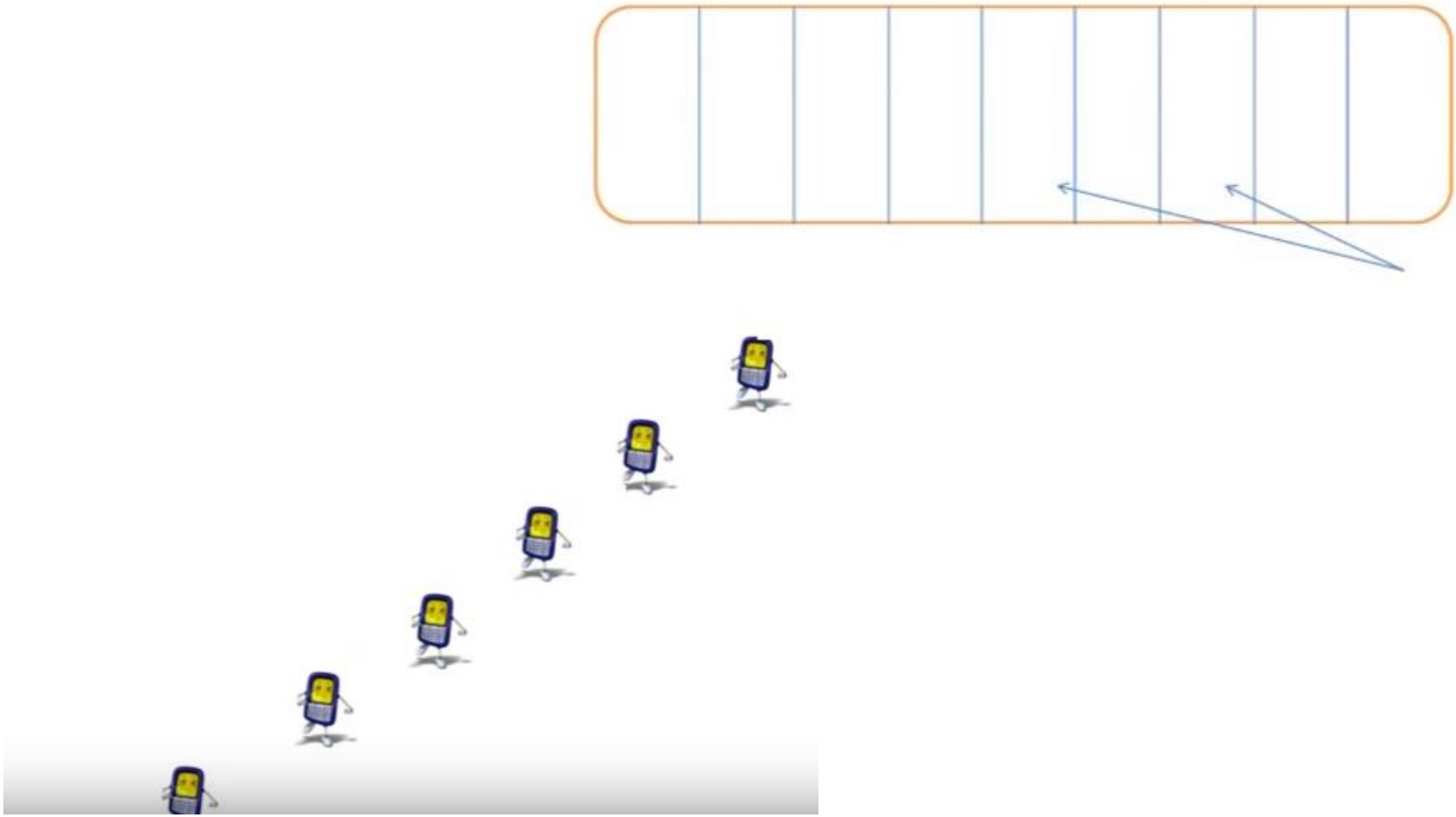
Advantages of Soft Handover :

1. There is change in frequency or timing during the mobility of user so that there are practically no dead zones.

2. It possesses more reliable continuity in networking with very less chance of call termination than that of hard handoff.

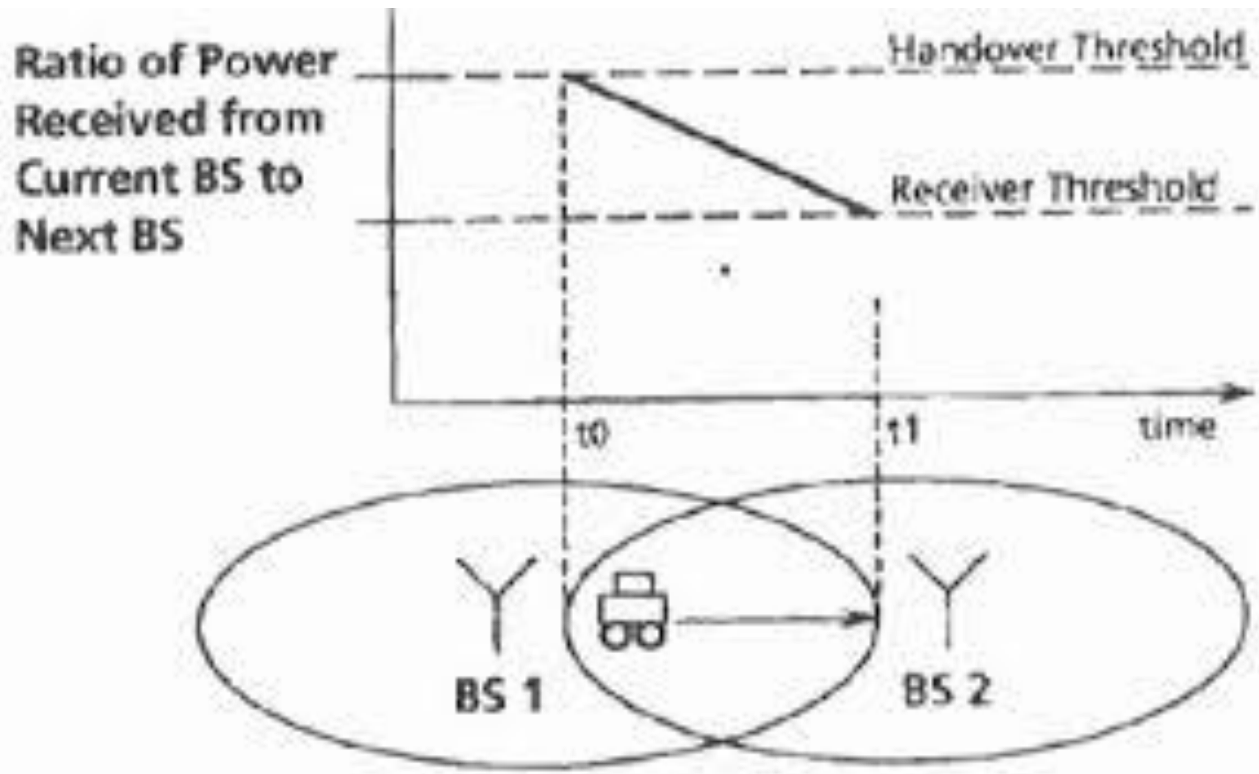
Prioritizing Handoff

- Guard channels concept
- Queuing handoff requests

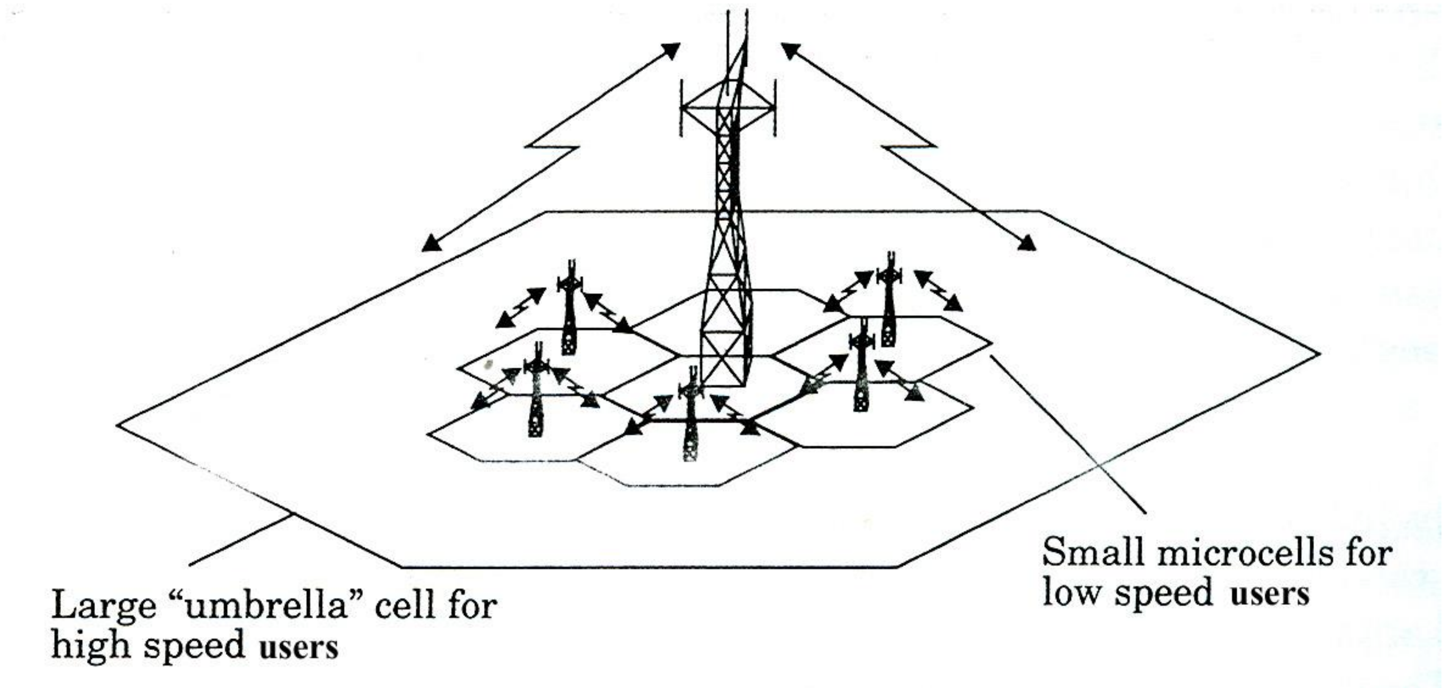


- One method for giving priority to handoffs is called the guard channel concept, whereby a fraction of total available channels in a cell is reserved exclusively for handoff requests from ongoing calls which may be handled off into the cell.
- This method has the disadvantage of reducing the total carried traffic, as fewer channels are allocated to originating calls.

- Queuing of handoff requests is another method to decrease the probability of forced termination of a call due to lack of available channels.
- There is a tradeoff between the decrease in probability of forced termination and total carried traffic.
- Queuing of handoff is possible due to the fact that there is a finite time interval between the time the received signal level drops below the handoff threshold & the time the call is terminated due to insufficient signal level.


Ratio of Power
Received from
Current BS to
Next BS
Handover Threshold
Receiver Threshold
t0
t1
time
BS 1
BS 2

Practical Handoff considerations



By using different antenna heights (often on the same building or tower) and different power levels, it is possible to provide large and small cells which are located at a single location. This technique is called the umbrella cell approach and is used to provide large area coverage to high speed users while providing small area coverage to users travelling at low speed.

- The umbrella cell approach ensures that the number of handoffs is minimized for high speed users and provides additional microcell channels for pedestrian users

High speed users are serviced by large (macro) cells, while low speed users are handled by small (micro) cells.