Class: 4th

MOBILE COMMUNICATIONS

Lecture 4

Chapter Two

Cellular Network Coverage2

By

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Lecture Outlines

2.5 Cellular Network Coverage

2.6 Frequency Reuse

2.7 Channel Assignment Strategies

Teaching Tools:

- White Board, white board marker and eraser

Teaching Methods:

1. Method of lecture.
2. Method of discussion and dialogue.
3. Brain storming

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2.5 Cellular Network Coverage

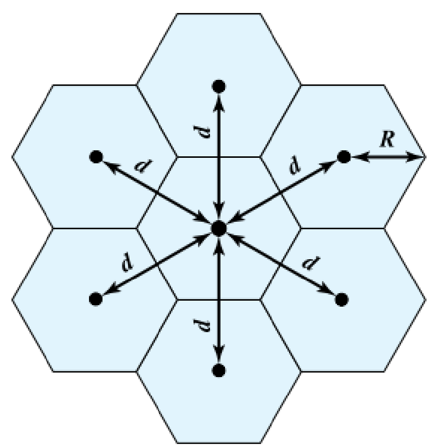
The essence of a cellular network is the use of multiple low-power transmitters, on the order of 100 W or less. Because the range of such a transmitter is small, an area can be divided into cells, each one served by its own antenna.

A- Each cell is allocated a band of frequencies and is served by a base station (consisting of transmitter, receiver, and control unit).

B- Adjacent cells are assigned different frequencies to avoid interference or crosstalk. However, cells sufficiently distant from each other can use the same frequency band.

While it might seem natural to choose a circle to represent the coverage area of a base station, adjacent circles cannot be overlaid upon a map without leaving gaps or creating overlapping regions.

The hexagon has:



- No gaps or overlapping
- The largest area compared with square and triangle.
- Fewest number of cells can cover a geographic region,
- Closely approximates a circular radiation pattern which would occur for an omnidirectional base station antenna and free space propagation.

- A hexagonal pattern provides for equidistant antennas.
- When using hexagons to model coverage areas, base station transmitters are depicted as either:

- In the center of the cell (center-excited cells): omnidirectional antennas are used in center-excited cells.
- On three of the six cell vertices (edge-excited cells): sectored directional antennas are used in corner-excited cells.

The radius of a hexagon is defined to be the radius of the circle that circumscribes it (equivalently, the distance from the center to each vertex; also equal to the length of a side of a hexagon).

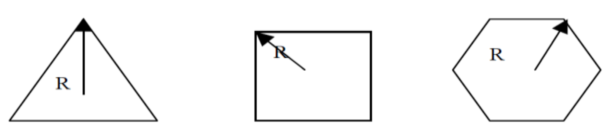
For a cell radius *R*, the distance between the cell center and each adjacent cell center is

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

Therefore the area of the hexagon is

$$Area = \frac{3\sqrt{3}}{2}R^2$$

- In practice, a precise hexagonal pattern is not used. Variations from the ideal are due to:
  - Topographical limitations.
  - Local signal propagation conditions.
  - Practical limitation on siting antennas.



$A_{tri} = 1.3R^2$ $\quad A_{sq} = 2.0R^2$ $\quad A_{hex} = 2.6R^2$

2.6 Frequency Reuse

In a cellular system, each cell has a base transceiver. The transmission power is carefully controlled

1-To allow communication within the cell using a given frequency

2-To limit the power at that frequency that escapes the cell into adjacent ones.

- The objective is to use the same frequency in other nearby cells, thus allowing the frequency to be used for multiple simultaneous conversations.
- Generally, 10 to 50 frequencies are assigned to each cell, depending on the traffic expected.
- The essential issue is to determine how many cells must intervene between two cells using the same frequency so that the two cells do not interfere with each other. Various patterns of frequency reuse are possible.

Frequency reuse (frequency planning): is the design process of selecting and allocating channel groups for all of the cellular base stations within a system.

If the pattern consists of *N* cells and each cell is assigned the same number of frequencies, each cell can have ***K/N*** frequencies, where *K* is the total number of frequencies allotted to the system.

- For Advanced Mobile Phone System (AMPS), *K* = 395, and *N* = 7 is the smallest pattern that can provide sufficient isolation between two uses of the same frequency. This implies that there can be at most 57 frequencies per cell on average.

- In characterizing frequency reuse, the following parameters are commonly used:

D = minimum distance between centers of cells that use the same frequency band (called co-channels)

R = radius of a cell

d = distance between centers of adjacent cells **d =** $\sqrt{3}R$

N = number of cells in a pattern (Cluster size)

(Each cell in the pattern uses a unique set of frequency bands), termed the ***reuse factor***

In a hexagonal cell pattern: in order to tessellate (to connect without gaps between adjacent cells), only the following values of *N* are possible:

$$N = I^2 + J^2 + (I \times J) \qquad I, J = 0, 1, 2, 3, \ldots$$

Hence, possible values of *N* are 1, 3, 4, 7, 9, 12, 13, 16, 19, 21, and so on.

Choice of N (assuming constant cell size)

Small N:

•More cluster are required to cover the service area

•More capacity

•Higher probability of co-channel interference

Large N:

•Less cluster are required to cover the service area

•Less capacity

•Less probability of co-channel interference

The following relationship holds:

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

Where *q* is the reuse ratio.

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This can also be expressed as

$$\frac{D}{d} = \sqrt{N}$$

Consider a cellular system which has a total of K duplex channels available for use. If each cell is allocated a group of C channels ($C < K$), and if the K channels are divided among N cells into channel groups which each have the same number of channels, the total number of available radio channels can be expressed as

$$K = C\,N$$

where

$$K = \frac{Spectrum\,bandwidth\ \ (or\,Total\,bandwidth)}{Channel\,bandwidth}$$

The N cells which collectively use the complete set of available frequencies is called a cluster. If a cluster is replicated M times within the system, the total number of duplex channels, can be used as a measure of capacity and is given

$$Capacity = MCN = MK\_$$

The capacity of a cellular system is directly proportional to the number of times a cluster is replicated in a fixed service area.

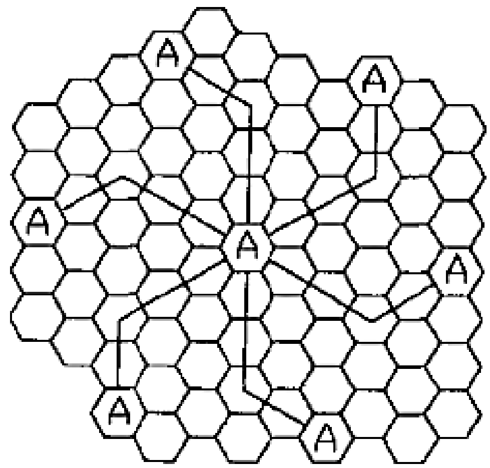
The cluster size (N) is typically equal to 4, 7, or 12.

If N is reduced while the cell size is kept constant, more clusters are required to cover a given area and hence more capacity is achieved.

- A large cluster size indicates that the ratio between the cell radius and the distance between co-channel cells is large.

- A small cluster size indicates that co-channel cells are located much closer together.

From a design viewpoint, the smallest possible value of N is desirable in order to maximize capacity over a given coverage area.



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

i. Move i cells along any chain of hexagons and then

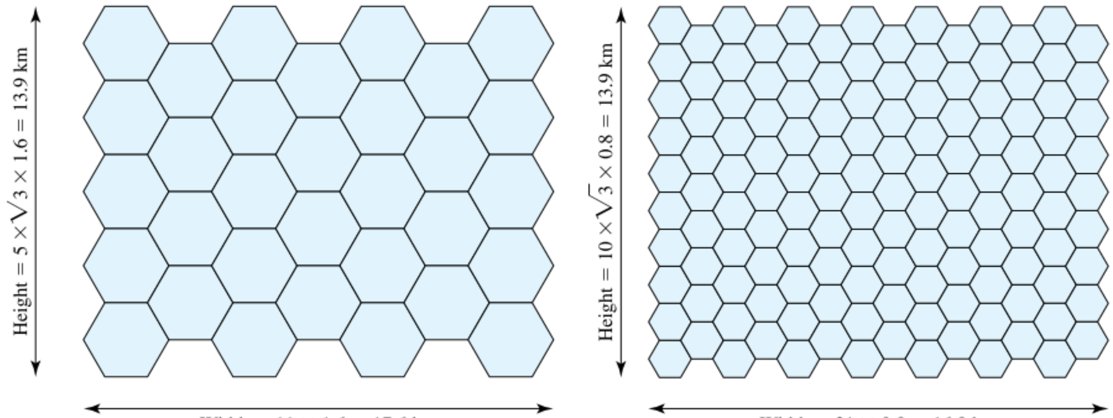
ii. Turn 60 degrees counter-clockwise and move j cells. This is illustrated in Figure below for i = 3 and j = 2 (example, N = 19).

Example 1

Assume a system of 32 cells with a cell radius of 1.6 km, a total of 32 cells, a total frequency bandwidth that supports 336 traffic channels, and a reuse factor of N = 7.

(a) If there are 32 total cells, what geographic area is covered, how many channels are there per cell, and what is the total number of concurrent calls that can be handled?

(b) Repeat for a cell radius of 0.8 km and 128 cells.



(a) Cell radius = 1.6 km **(b) Cell radius = 0.8 km**

Solution:

(a)

The area of a hexagon of radius *R* is

$$Area_a = \frac{3\sqrt{3}}{2}R^2 = \frac{3\sqrt{3}}{2}(1.6)^2 = 6.65\,\text{km}^2$$

The total area covered is 6.65 × 32 = 213 km^2.

For $N = 7$, the number of channels per cell is K/N = 336/7 = 48,

Total number of concurrent calls that can be handled is

$$Capacity = 48 \times 32 = 1536 \text{ channels}$$

(b)

The area of a hexagon of radius *R* is

$$Area_b = \frac{3\sqrt{3}}{2}R^2 = \frac{3\sqrt{3}}{2}(0.8)^2 = 1.66\,\text{km}^2$$

The area covered is 1.66 × 128 = 213 km^2.

The number of channels per cell is K/N = 336/7 = 48,

Total number of concurrent calls is

$$Capacity = 48 \times 128 = 6144 \text{ calls}$$

Example 2

Consider a cellular system in which total available voice channels to handle the traffic are 960. The area of each cell is 6 km^2 and the total coverage area of the system is 2000 km^2. Calculate:

(a) The system capacity if the cluster size N is 4

(b) The system capacity if the cluster size is 7.

- How many times would a cluster of size 4 have to be replicated to cover the entire cellular area? Does decreasing N increase the system capacity? Explain.

Solution

Total available channels =960 , Cell area = 6 km^2

Total coverage area = 2000 km^2

(a) $N = 4$

Area of a cluster = $4 \times 6 = 24$ km^2

Number of clusters for covering total area = 2000/24 = 83.33 ~ 83

Number of channels per cell = 960/4 = 240

System capacity = 83×960 = 79, 680 channels

(b) $N = 7$

Area of cluster = $7 \times 6 = 42$ km^2

Number of clusters for covering total area = 2000/42 = 47.62 ~ 48

Number of channels per cell = 960/7 = 137.15 ~ 137

System capacity = 48×960 = 46,080 channels

It is evident when we decrease the value of N from 7 to 4, we increase the system capacity from 46,080 to 79,680 channels. Thus, decreasing N increases the system capacity.

2.7 Channel Assignment Strategies

For efficient utilization of the radio spectrum, a frequency reuse scheme that is consistent with the objectives of increasing capacity and minimizing interference is required. A variety of channel assignment strategies have been developed to achieve these objectives.

Channel assignment strategies can be classified as either fixed or dynamic. The choice of channel assignment strategy impacts the performance of the system, particularly as to how calls are managed when a mobile user is handed off from one cell to another.

a) **Fixed channel assignment strategy**: each cell is allocated a predetermined set of voice channels.
    - Any call attempt within the cell can only be served by the unused channels in that particular cell.
    - If all the channels in that cell are occupied, the call is blocked and the subscriber does not receive service.
    - ***Borrowing strategy*:** a cell is allowed to borrow channels from a neighboring cell if all of its own channels are already occupied. The mobile switching center (MSC) supervises such borrowing procedures and ensures that the borrowing of a channel does not disrupt or interfere with any of the calls in progress in the donor cell.

b) **Dynamic channel assignment strategy**: voice channels are not allocated to different cells permanently. Instead,

- Each time a call request is made, the serving base station requests a channel from the MSC.
- The switch then allocates a channel to the requested cell following an algorithm that takes into account the likelihood of
  - Future blocking within the cell,
  - The frequency of use of the candidate channel,
  - The reuse distance of the channel,
  - Other cost functions.
- Accordingly, the MSC only allocates a given frequency if that frequency is not presently in use in the cell or any other cell which falls within the minimum restricted distance of frequency reuse to avoid co-channel interference.

***Advantage*:**

- Dynamic channel assignment reduces the likelihood of blocking, which increases the trunking capacity of the system, since all the available channels in a market are accessible to all of the cells.
- Increases the channel utilization and decreases probability of a blocked call.

***Disadvantage*:**

- Require the MSC to collect real-time data on channel occupancy, traffic distribution, and radio signal strength indications (RSSI) of all channels on a continuous basis. This increases the storage and computational load on the system.