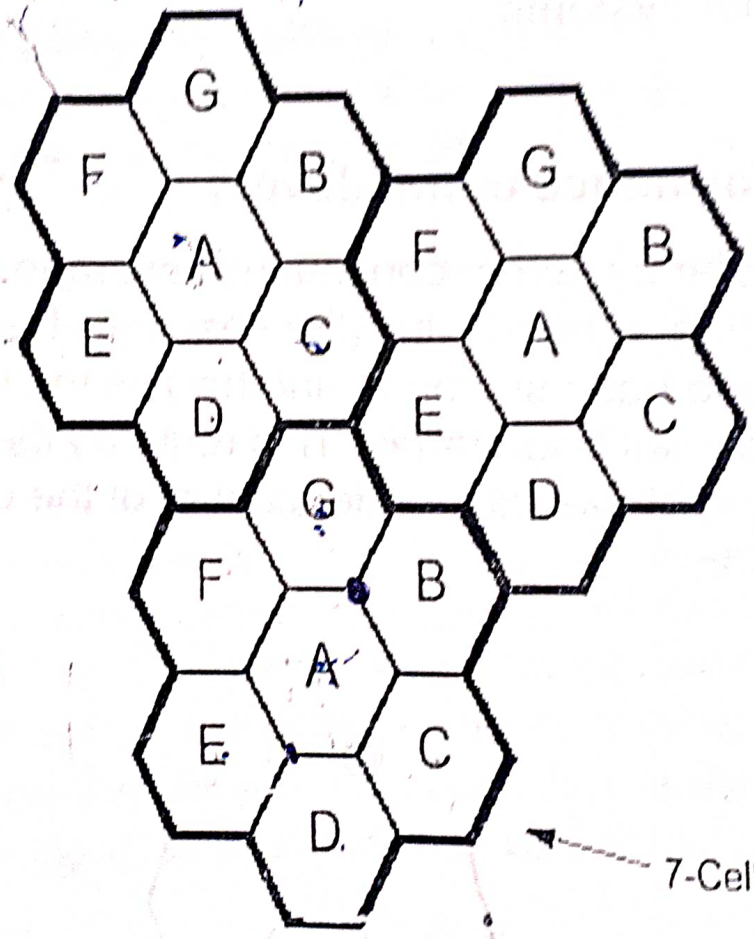
Frequency reuse in cellular telephony

Same frequency reused in the network
Optimal use of a scarce resource : frequency



Frequency Reuse

The spectrum allocated for a cellular network is limited. As a result there is a limit
to the number of frequencies or channels that can be used. A cellular network can
only provide service to a large number of subscribers, if the channels allocated to
it can be reused. Channel reuse is implemented by using the same channels
within cells located at different positions in the cellular network service area.
Cell clustering Radio channels can be reused provided the separation between cells containing the same channel set is far enough apart so that co-channel interference can be kept below acceptable levels most of the time. Cells using the same channel set are called co-channel cells. Within the service area (PLMN), specific channel sets are reused at a different location (another cell). In the example, there are 7 channel sets: A through G. Neighboring cells are notallowed to use the same frequencies. For this reason all channel sets are used in a cluster of neighboring cells. As there are 7 channel sets, the PLMN can be divided into clusters of 7 cells each. The figure shows three clusters.
The number of channel sets is called K. K is also called the reuse factor. In the
figure, K=7. Valid values of K can be found using equation (where i and j are integers):

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

- Cells are shaped ideally (hexagons).
- The distance between cells using the same channel set is always the same.

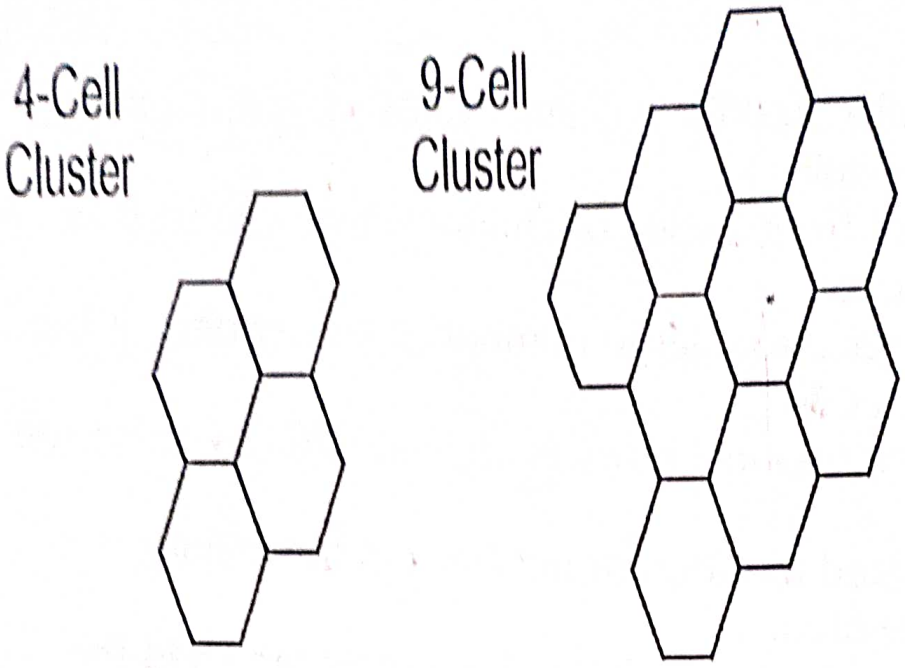
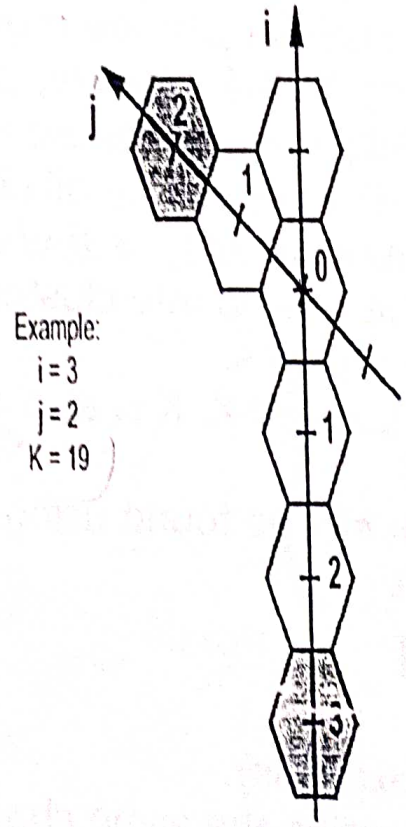


Figure 3. Other Cell Clusters



Example:
i = 3
j = 2
K = 19

Signal attenuation with distance

Frequencies can be reused throughout a service area because radio signals typically attenuate with distance to the base station (or mobile station). When the distance between cells using the same frequencies becomes too small, co-channel interference might occur and lead to service interruption or unacceptable quality of service.

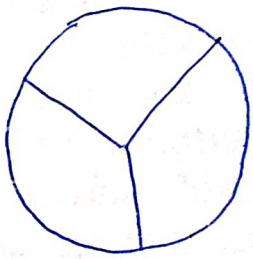
As Frequency reuse distance/Cell radius $=D/R$ ratio is greater than some specified value, the ratio Reed. radio carrier power/Reed. interferer radio carrier power $= C/I$ will be greater than some given amount for small as well as large cell sizes when all signals are transmitted at the same power level. The average attenuation of radio signals with distance in most cellular systems is a reduction to about 1/16 of the received power for every doubling of distance (1/10000 per decade).

The frequency reuse distance is also known as separation distance. is also known as the signal-to-noise ratio.Interference is caused by cells using the same channel set.The ratio D/R needs to be large enough in order for the base station to be able to cope with the interference.

Capacity/Performance Trade-offs:

- If K increases, then performance increases

- If K increases, then call capacity decreases per cell



K and D/R relationship

There is a relationship between K and ratio D/R

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

may be $D/R = \sqrt{3N}$ (same)

There is a direct relationship between K and ratio D/R. The result is that when the reuse factor K, and so the shape of the cluster is chosen, ratio D/R is fixed.

Capacity performance trade off

When engineering a cellular network, the most important trade-off to make is the one between call capacity and performance:

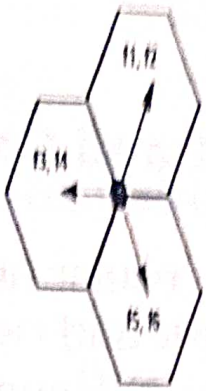
- Relationship between K and Performance

The performance of a cellular network can be expressed in quality of service. An acceptable quality of service means a low (co-channel) interference level in the network.

The relationship between the reuse factor K and the network performance Is: if K increases, then the co-channel interference decreases, and so the performance increases (there is a fixed relationship between K & ratio D/R).

Relationship between K and Call Capacity

The other key relationship in cellular networks is the one between the reuse factor K and call capacity. First of all, call capacity depends on the number of available channels. In GSM, a limited number of frequencies is available (for GSM: 124 frequencies, and for GSM-1800: 374 frequencies).
The frequencies are grouped into frequency sets. If K increases, the number of frequencies per set (and so per cell) decreases, and so the call capacity per cell. The value of K in GSM cellular networks varies between 4 and 21. In real networks, K is not constant within the whole PLMN area, but varies depending on the traffic capacity needed in certain regions. Typically, K is high in urban regions and low in rural regions.

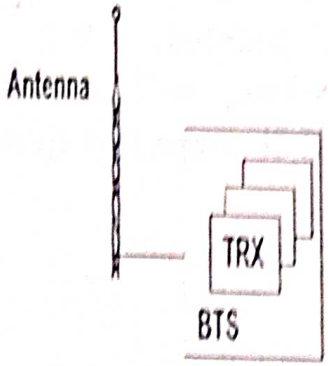


3 sector site
consisting of
- 3 cells
- 2 frequencies/cell
- 6 TRXs

2 sector site
consisting of
- 2 cells
- 1 frequency/cell
- 2 TRXs

omni site
consisting of
- 1 cell
- 4 frequencies/cell
- 4 TRXs

BTS



azimuth - placement of antenna from north is called azimuth.

Types of Cell

Cell - A cell is a unit of choice as seen by the mobile station. A cell uses a specific set of frequencies. The two main cell types are:

- **Omni cells**

The antenna transmits omni-directional. The coverage area of an omni-cell is in principle a hexagon/circle.

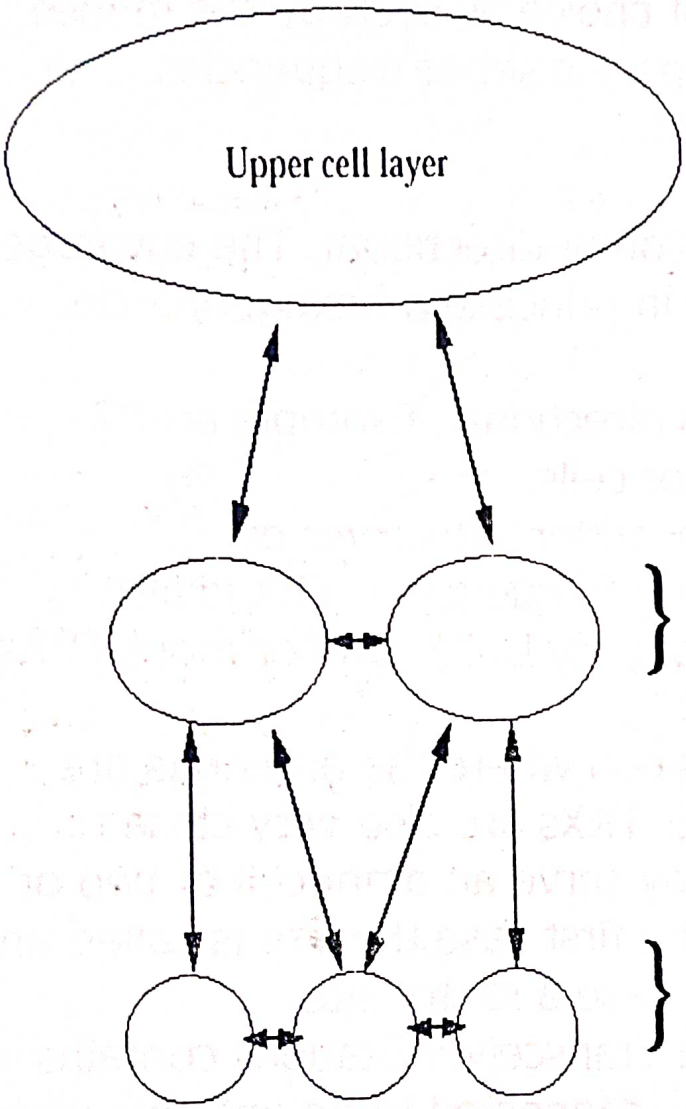
- **Sector cells**

The antenna transmits directional. Example are: 2-sector cells and 3-sector cells.

TRX - Each TRX (Transmitter - Receiver or transceiver) handles one frequency. A TRX is also called RFU (Radio Frequency Unit). One or more TRXs cover one cell.

Site - A site is the position where the antennas are located. Normally, their TRXs are also very close to that position. A site may serve an omni-cell or two or more sector cells. In the first case the site is called an omni site, in the latter case a sector site.

BTS - Each BTS (Base Transceiver Station) contains one or more TRXs. It is connected to an antenna which is located on a mast.



- in highway 22 to 25 km.

town - 5 to 10 km.

city - 2 to 3 km.

Micro, Macro, Umbrella and Standard Cells

The GSM cellular network is organized into one of the following structures:

• Hierarchical cellular network structure

It is composed of three different layers:

— the lower cell layer with rather small cells (micro-cells),

— The middle cell layer with medium size cells (macro-cells), and

— an upper cell layer with large cells (umbrella-cells).

• Non-hierarchical cellular network structure

It is composed of standard cells.

In general, fast mobiles are served by cells of the upper layer, which are often called umbrella-cells. Umbrella-cells have a large serving area and fulfills the requirements for the high velocity of mobiles (e.g., considering the frequency of necessary handovers. Medium fast mobiles are served by the cells of the middle layer. This layer consists of macro-cells. Former macro-cells from a non-hierarchical network are handled similar as cells of this layer. Slow or stationary mobiles are served by the cells of the lower layer. This layer consists of micro-cells as well as pico-cells in the future, and it can provide In-building coverage.

Micro cell

Micro-cells cover areas that are small compared to standard cells. Micro-cells increase capacity and coverage quality and are located in areas where subscribers have communities of interest (hot spots) as well as areas that standard cells cannot penetrate (dead spots). Micro-cells are characterized by the following:

- Small radius: a few hundred meters, from about 100 m up to 1 km
- Antennas are typically deployed below roof level. Antenna heights are kept low, 7 - 10 m above ground level, mounted on street lights and flag poles.
- Frequency reuse is very extensive due to low transmit power and the fact that buildings are used as isolation.

The coverage area of both an umbrella cell and a micro-cell is mapped on a street plan. The area which is covered by the micro-cell is a high traffic density area

Umbrella cell

Umbrella cells cover areas that are large compared to standard cells.

Services provided by GSM

- Tele-service : Telephony.
- Data Service :
  - Circuit Switched data upto 9600 bps.
  - G3 Fascimile.
  - SMS (Short Message Service).
- Supplementary Service.
  - Call Forwarding, when subscriber unavailable.
  - Call Barring for O/g or I/c calls.
  - Caller Identification.
  - Call Waiting.
  - Multiparty Conversation.