The Cellular Concept

Overview of Cellular Radio

The cellular wireless network concept has made mass-market "cell" service possible. Cellular systems use the concept of frequency reuse to provide wide-area wireless phone and data services to an ever-increasing number of users without increasing the amount of bandwidth allocated for these services (almost).

The cellular concept divides the geographical service area into a number of "cells". Each cell is typically 1 to 10 km in radius although recent trends include very small cells (microcells, nanocells and picocells) that cover ever smaller areas, down to the area of one residence.

Each cell is assigned a set of radio channels. These same channels can be reused by cells that are sufficiently far away that they don't interfere with each other. By reducing the physical sizes (radii) of the cells we can increase number of times the channels are reused within the service area and increase the total number of users that can be supported.

Cluster Size and Reuse Factor

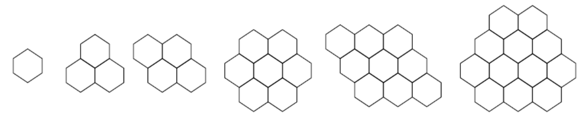
We model cells as hexagonal areas arranged in regular groups called "clusters." Only some cluster sizes/patterns can be used to tessellate the coverage area (cover all the area using a regular pattern).

The allowed cluster sizes are such that the cluster size, N, obeys the equation $N = i^2 + ij + j^2$ where i and j are integers.

Some possible values are:

i	j	N
0	1	1
0	2	4
0	3	9
1	1	3
1	2	7
2	2	12

Some of the resulting cluster shapes are:



While hexagonal cells are a useful approximation for system design, propagation conditions and site availability will determine the actual coverage areas.

Channel Assignment and Capacity

A fixed total number of channels, S is available. These are typically divided evenly with k channels per cluster of N cells so that $S = kN$.

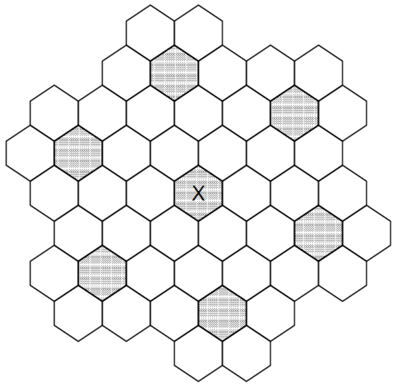
If the whole system has M clusters, the total number of channels available to provide service in the system is $C = MS = MkN$. Therefore to increase capacity the service provider must increase the number of cells (or ask the government to re-allocate bandwidth from other users).

The *frequency reuse factor* is $1/N$ (or often just "N") and is limited by interference considerations (see below). If the number of cells is fixed, a smaller N results in more channels per cell (larger k) and thus a higher capacity. Advances in digital modulation and adaptive antennas have made reuse factors of $N = 1$ possible for 4G cellular systems.

Co-Channel Interference

The value of N is determined by interference considerations: we must make sure that at the minimum reuse distance (determined by the cluster size and geometry) no cell will cause interference to its neighbors. The level of interference that can be tolerated depends on the type of modulation (analog, digital) and on any special techniques employed to dynamically cancel or limit this interference.

An example of potential co-channel interferers in other clusters:



Exercise 1: What is N for the example above?

In the simplest case, interference is determined by the ratio of desired to interfering signal strengths. The signal strength is determined by path loss and distance. Assuming the interference sources are uncorrelated the interference powers add and the SIR (signal to interference ratio) is:

$$\text{SIR} = \frac{S}{I} = \frac{S}{\sum_{i=1}^{N} I_i}$$

where I_i is the interference power of the i'th base (on the forward channel).

Cell Splitting

As usage grows, a cell can be split into smaller cells using the same cluster size. The SIR will still be maintained because it is only dependent on the cluster size, not on the physical size of the cell.

Channel Assignment

Most cellular systems use fixed channel assignment. Some improvement is possible by using dynamic channel assignment where more channels can be assigned to one cell within a cluster. We still need to ensure that minimum re-use distance is maintained.

Handoff

Mobile users may travel out of a cell. The base (and/or mobile) determines this by measuring quality of the link to current base and to adjacent bases. If another base would provide better service, a channel is allocated in that base and the mobile switches channels. Hysteresis is built into system to avoid too-frequent handovers. A "soft" handover, where a mobile receives from multiple bases, is possible in some systems.