The Cellular Concept
System Design Fundamentals
Adjacent channel interference

Adjacent channel interference: interference from adjacent in frequency to the desired signal.
- Imperfect receiver filters allow nearby frequencies to leak into the passband
- Performance degrade seriously due to *near-far* effect.

Adjacent channel interference can be minimized through careful filtering and *channel assignment*.
- Keep the frequency separation between each channel in a given cell as large as possible
- A channel separation greater than six is needed to bring the adjacent channel interference to an acceptable level.
The Cellular Concept

Figure 3.1  Illustration of the cellular frequency reuse concept. Cells with the same letter use the same set of frequencies. A cell cluster is outlined in bold and replicated over the coverage area. In this example, the cluster size, $N$, is equal to seven, and the frequency reuse factor is $1/7$ since each cell contains one-seventh of the total number of available channels.
19-cell reuse example (N=19)

Figure 3.2 Method of locating co-channel cells in a cellular system. In this example, \( N = 19 \) (i.e., \( l = 3, j = 2 \)). (Adapted from [Oet83] © IEEE.)
**Table 3.1 Co-channel Reuse Ratio for Some Values of N**

<table>
<thead>
<tr>
<th>Cluster Size (N)</th>
<th>Co-channel Reuse Ratio (Q)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$i = 1, j = 1$</td>
<td>3</td>
</tr>
<tr>
<td>$i = 1, j = 2$</td>
<td>7</td>
</tr>
<tr>
<td>$i = 2, j = 2$</td>
<td>12</td>
</tr>
<tr>
<td>$i = 1, j = 3$</td>
<td>13</td>
</tr>
</tbody>
</table>
Handoffs – the basics

Figure 3.3 Illustration of a handoff scenario at cell boundary.
Umbrella Cells

Large “umbrella” cell for high speed traffic

Small microcells for low speed traffic

Figure 3.4 The umbrella cell approach.
Figure 3.5  Illustration of the first tier of co-channel cells for a cluster size of $N = 7$. An approximation of the exact geometry is shown here, whereas the exact geometry is given in [Lee86]. When the mobile is at the cell boundary (point X), it experiences worst case co-channel interference on the forward channel. The marked distances between the mobile and different co-channel cells are based on approximations made for easy analysis.
\[ \frac{S}{I} = \frac{S}{\sum_{k=1}^{N^1} I_k} \]

From Fig. 3.5

\[ \frac{S}{I} = \frac{S}{\sum_{k=1}^{6} \left( \frac{D_k}{R} \right)^{-n}} = \frac{1}{6(q)^{-n}} = \frac{q^n}{6} \]

\[ 2 \leq n \geq 5 \] Path loss exponent depend upon the terrain environment

**Worst Case With Omni Directional Antenna**

\[ \frac{S}{I} = \frac{R^{-n}}{2(D - R)^{-n} + 2D^{-n} + 2(D + R)^{-n}} \]

\[ \frac{S}{I} = \frac{1}{2(q - 1)^{-n} + 2q^{-n} + 2(q + 1)^{-n}} \]

q = 4.6 for a normal 7-cell cellular Pattern

S/I = 54.3 or 17.3 dB
Cells are split to add channels

Receive power at the old and new cells:

\[ P_r \sim P_{to} R^{-n} \]
\[ P_r \sim P_{tn}(R/2)^{-n} \]

\[ P_{t2} = \frac{P_{t1}}{16} \]

Figure 3.8 Illustration of cell splitting.
Cell Splitting increases capacity

Example

Original cell radius $R = 1$ km

Micro cell radius $R = 0.5$ km

Each BS has $N_{bs} = 60$ channels

Number of channels

a) Without microcells
   $5 \times 60 = 300$ ch.

b) With lettered microcells
   $(5+6) \times 60 = 660$ ch.

b) If original BS replaced by microcells
   $(5+12) \times 60 = 1020$ ch.

Figure 3.9 Illustration of cell splitting within a 3 km by 3 km square centered around base station A.
Sectoring improves S/I

Three-Sector Case:

$$\frac{S}{I} = \frac{R^{-4}}{(D + 0.7R)^{-4}} = (q + 0.7)^4$$

For q=4.6, S/I = 285 or 24.5 dB

Six-Sector Case:

$$\frac{S}{I} = \frac{R^{-4}}{D^{-4} + (D + 0.7R)^{-4}} = \frac{1}{q^{-4} + (q - 0.7)^{-4}}$$

For q=4.6, S/I = 785 or 29dB

Worst case, without sectoring

$$\frac{S}{I} = \frac{1}{2(q - 1)^{-n} + 2q^{-n} + 2(q + 1)^{-n}}$$

For q=4.6, S/I = 54.3 or 17.3 dB

Penalty: Increasing hand-off; decreasing trunking efficiency.
Sectoring improves S/I

Figure 3.11  Illustration of how 120° sectoring reduces interference from co-channel cells. Out of the 6 co-channel cells in the first tier, only two of them interfere with the center cell. If omnidirectional antennas were used at each base station, all six co-channel cells would interfere with the center cell.
In-building deployment is the next great growth phase

Figure 3.12  Illustration of how a distributed antenna system (DAS) may be used inside a building. Figure produced in SitePlanner®. (Courtesy of Wireless Valley Communications Inc.)
The Zone Cell Concept

Figure 3.13  The microcell concept [adapted from [Lee91b] © IEEE].
Figure 3.14 Define $D$, $D_1$, $R$, and $R_z$ for a microcell architecture with $N = 7$. The smaller hexagons form zones and three hexagons (outlined in bold) together form a cell. Six nearest co-channel cells are shown.