Radio Resource Management

1. Frequency reuse among cells

2. Multiple Access within cells: How to share radio resources among multiple users
Frequency Division Multiple Access: FDMA
Every user has its own frequency channel

Time Division Multiple Access: TDMA
Users share the same bandwidth but transmit one after the other

Code Division Multiple Access: CDMA
User signals overlap in frequency and time. Orthogonality of waveforms is used to separate user signals
Frequency Reuse

- Frequency Reuse is the core concept of cellular mobile radio.
- Users in different geographical areas (in different cells) may simultaneously use the same frequency.
- Frequency reuse drastically increases user capacity and spectrum efficiency.
- Frequency reuse causes mutual interference (trade off link quality versus subscriber capacity).
Geometry of a Hexagon

Surface area is 6 $R^2$ times $(\sqrt{3})/4$
Cluster: set of different frequencies used in group of cells

Cluster is repeated by linear shift
  $i$ steps along one direction
  $j$ steps in the other direction

How many different frequencies does a cluster contain?
**Reuse Distance**

Distance between cell centers  =  $\sqrt{3} \times$ Cell Radius

Reuse distance

distance between the centers of two co-channel cells

$$R_u = \sqrt{i^2 + j^2 + 2ij \cos \frac{\pi}{3}} \sqrt{3} R$$

where

- $R$ is Cell Radius
- $R_u$ is Reuse Distance

and

$$\cos(\pi/3) = 1/2$$
Cluster Radius

Radius of a cluster

\[ R_c = \frac{R_u}{\sqrt{3}} = \sqrt{\frac{i^2 + j^2 + ij}{3}} R \]
Cluster Size

$C$: number of channels needed for $(i,j)$ grid

$C$: is proportional to surface area of cluster

Surface area of one hexagonal cell is

\[ S_R = \frac{3\sqrt{3}}{2} R^2 \]

Surface area of a (hexagonal) cluster of $C$ cells is

\[ S_{Ru} = CS_R = \frac{3\sqrt{3}}{2} \left\{ \frac{R_u}{\sqrt{3}} \right\}^2 \]

Combining these two expressions gives

\[ R_u = R \sqrt{3C} \]
Possible Cluster Sizes

We have seen
\[ R_u = R \sqrt{3C} \]

and also
\[ R_u = \sqrt{i^2 + j^2 + ij} \sqrt{3} R \]

Thus:
\[ C = i^2 + j^2 + ij \]

with integer \( i \) and \( j \).
Cellular Telephony

Choose $C$ to ensure acceptable link quality at cell boundary

Typical Cluster Sizes

Cluster size $C = i^2 + ij + j^2 = 1, 3, 4, 7, 9, ...$

<table>
<thead>
<tr>
<th>$C$</th>
<th>$i$</th>
<th>$j$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<tr>
<td>7</td>
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</tr>
<tr>
<td>12</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
Design Objectives for Cluster Size

- High spectrum efficiency
  many users per cell
  *small* cluster size gives much bandwidth per cell

- High performance
  Little interference
  *Large* cluster sizes
Adaptation to growth of system

Decrease Cell Sizes

- Macro-cellular  1 - 30 km
- Micro-cellular  200 - 2000 m
- Pico-cellular  4 - 200 meter

Cell Sectorization
The effect of decreasing cell size

- Increased user capacity
- Increased number of handovers per call
- Increased complexity in locating the subscriber
- Lower power consumption in mobile terminal:
  - Longer talk time,
  - Safer operation
- Different propagation environment, shorter delay spreads
- Different cell layout,
  - lower path loss exponent, more interference
  - cells follow street pattern
  - more difficult to predict and plan
  - more flexible, self-organizing system needed (cf. DECT vs. GSM)
Advantages of Digital Transmission

Digital speech transmission reacts differently to changing performance of the radio link

Higher capacity:
1) speech coding
2) smaller protection ratios, denser reuse
   (NB: same reuse of IS-54 and analog AMPS in US)

Security
1) Privacy
2) Protected against unauthorized use

Additional services