Personal Communication Systems (Lecture 23)

Frequency planning templates:

- Sufficient available for cellular service is channelized.
- Channels are subdivided into common/access channels and helper channels.
- For frequency planning purpose, channels are equally channel planning template.

Channel planning template designer:

\[ \frac{N}{k} \]
- Number of groups (same as the same channel size)
- Number of sets, \( K = \frac{m}{p} \), \( p \) number of pairs in a cell.

Some common channel planning templates:

\[ T_1 = \frac{7}{21}, \quad (N=7, \ K=21) \]
\[ T_2 = \frac{4}{12} \]
\[ T_3 = \frac{8}{24} \quad \text{rate} \ K \text{- number of control channels} \]
\[ T_4 = \frac{7}{42} \]
\[ T_5 = \frac{9}{27} \quad \text{ek} \]

Example: Consider a system that has 24 available channels. Proper assignment of these channels in a form of a channel template 4/12

- \( N=4 \) - Base channel size \( 4 \) groups \( A, B, C, D \)
- \( K=12 \) - Number of control channels \( = 12 \) sets \( 1, 3, 5, 7, 9, 11, 12 \)

<table>
<thead>
<tr>
<th>Group</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Group</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>-------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Channel 1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Channel 2</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
</tr>
</tbody>
</table>
Hand out 2 templates. T/D 1 & side cellular pad. and
4/12 G/B template

And test students' understanding by having them select the solution using
4/12 template.

Suspension

Suspension is additional signaling used in certain cases of co-channel
interference. Despite all efforts of frequency planners the co-channel
interference would still occur. When co-channel interference happens the RX
needs to detect if the interferer is happening and turn the output off at the
RX. To the end users, it is better to have perfect all the output instead then to
try to decode it. Identify for each system with some co-channel interference.

Depending on the cellular technology, suspension is implemented through the use of
either

1. Suppression Audio Tone (SAT), if the system is analog
2. Digital Tone Injection (DTI), if the system is digital

SAT IDARS in AMPS

AMPS deploy FM suppression.

FM tones are pre-minimized at frequencies 5970 Hz, 6070 Hz, and 6170 Hz.
On the RX side:
- SAT tone is extended through filtering.
- SAT tone is assigned upon establishment of the call.
- Signal is detected not if the two tones are the same.

Channel A
SAT m1

Channel B
SAT m2

CCE

Serving cell
S1

S1

S1

S1

SAT tone are assigned on per cell basis.

Same channel - different SAT

Frequency planning is done so that the co-channel (or adjacent channel) is separated as far as possible.

The co-channel interference is not eliminated by use of SAT planning reduce its bad effects.

Coded DVCC - Used in IS-136, GSM, TDEN

- The principle is the same as in the case of SAT tone.
- Every cell is assigned with a digital code.
- Digital code is sent with every data burst.
- The RX decodes the DVCC and compares it against the one that was assigned at the call establishment.
- The signal is recognized and passed to the user only if the DVCC codes are the same.

Usually the number of DVCC code is quite large - 16-255 depending on technology.
Frequency planning of practical sessions

1. Practical sessions do not follow regular geographical grid.
2. Different cells have different capacity requirements.
3. Result of assignment of frequencies does not follow regular pattern prescribed by the frequency template.
4. Planning outside of frequency template is usually referred to as the "ad-hoc" planning.

Ad-hoc planning provides in-flexible frequency plans from the performance standpoint.
Tract-off "ad-hoc" frequency plans are not easy to understand & reuse.
Use of contemporary CAD tools.
Tools that are used for frequency planning are referred to as the AFP tools (AFP: Automatic Frequency Planning).

Inputs to AFP tool:

1. Permission matrix
2. Reuse matrix
3. Traffic requirements (coverage, etc.)
4. Various customs (spectrum, regulatory coordination, neighbor list, ...)
5. List of channels

Based on the above inputs, AFP tools perform assignment of the frequencies in a manner that minimizes some global penalty function.

Inputs \( \rightarrow \) \text{AFP tool} \( \rightarrow \) \text{frequency plan}

Contemporary AFP tools produce frequency plans that are both lean & usually produce frequency plans
Impacts to APP

1) Permission war: used to determine priority of the frequency reuse between different cell sites.

Example 1 (Area-based permission war)

![Diagram of cell overlap]

- If two cells use the same channel, they will interfere on the overlapping area.
- Based on the overlapping area, one can find a metric of a channel

<table>
<thead>
<tr>
<th>Channel</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>X</td>
<td>a1</td>
<td>a2</td>
<td>a3</td>
<td>a4</td>
</tr>
<tr>
<td>C2</td>
<td>a1</td>
<td>X</td>
<td>a5</td>
<td>a6</td>
<td>a7</td>
</tr>
<tr>
<td>C3</td>
<td>a2</td>
<td>a5</td>
<td>X</td>
<td>a8</td>
<td>a9</td>
</tr>
<tr>
<td>C4</td>
<td>a3</td>
<td>a6</td>
<td>a8</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>C5</td>
<td>C6</td>
<td>C7</td>
<td>C8</td>
<td>C9</td>
<td></td>
</tr>
</tbody>
</table>

- If a channel is large, then two cells cannot reuse the same frequency.
- If a channel is small (ideally zero), the two cells can use the same frequencies.
Example (tree based permission matrix)

```
+----+----+----+
|    | G1  | G2  | G3  |
+----+----+----+----+
| G1 | X   | a2/a1| a3/a4|
+----+----+----+----+
| G2 | a12/a2| X   | a3/a2|
+----+----+----+----+
| G3 | a13/a3| a33/a3| X   |
+----+----+----+----+
| G4 |     |     |     |
+----+----+----+----+
| G5 |     |     |     |
+----+----+----+----+
| G6 |     |     |     |
+----+----+----+----+
```

From this above figure, the following should be derived.

1. G1 & G2, G3, G4, G5, ... cannot have the same permission
2. G1, G2 can reuse the same permission

Permission matrix tries to capture these relationships using a compact format suitable for computer-based processing.