Personal Communication Systems (Lecture 14)

Estimation of offered traffic in cellular networks

- Handheld telephones - location of every telephone known
- Mobile users - distributed in a relatively random fashion over system coverage area
- To provide system design, geographic distribution of the traffic needs to be estimated. Thus assume condition of two limiting cases:

1) Geographic distribution of mobile users
   - Average traffic generated per user in a busy hour

2) Geographic distribution of mobile users
   - Commonly estimated using various Geographic Information System (GIS) data
   - GIS data - various census and statistical information
   - Some typical data:
     - Average population density
     - Average family income
     - Land use type (census information)
     - Social classification, usage

- GIS data is usually given in form of absolute and

Example:

<table>
<thead>
<tr>
<th>Population density in this small geographic area (people)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1043639864</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unit area</th>
</tr>
</thead>
</table>
GIS grids provide useful information. However, none provides complete picture of subtle biochemical processes

Example: Distribution of wildlife within a given market is to be obtained. Follow GIS data acquisition.

1) Acquire population data.
   a) Read and assign values to appropriate categories:
      - Age: category 1
      - Weight: category 2
      - Gender: category 3
   b) Log population data with associated values
      - US citizens: (number at 1)
      - Us citizens: (number at 2)
      - Mexican nationals: (number at 3)
      - Secondary: (number at 4)
      - Total population (number at 1)

Using above information, distribution of data can be assigned to appropriate locations.

2) Convert all GIS data in crime demand grids.
   a) Eliminate GIS data outside market boundaries.
   b) Determine total number of cases within market boundaries.
   c) Use the following formula:

   \[ D(G) = \left( \frac{\text{Crime}}{\text{Pop}^2} \right) \times \left( \text{Licht} + \left( \frac{\text{Crime}}{\text{Pop}^2} \right) \right) \times \text{Pop} \times (1 + 2k) \]
Where

$S_{pop}$ = Fraction of users that are in place at their residence

$R_{pop} / L_{pop}$ = Relative demand and obtained from population density

$S_{ave}$ = Fraction of users that are distributed through various subsections of road

$L_{ave} / L_{pop}$ = Relative demand and obtained from land use data and associated relative weights

$S_{road}$ = Fraction of users that are on the road

$D_{ave} / L_{pop}$ = Relative demand and obtained from road use data

$W_{ave}$ = Total population in the water

$p$ = penetration rate

$f$ = freezing factor

*To implement these methodologies one need to be able to manipulate demand grid.
*This is usually done through some form of planning software.

Example of created demand grid (units: gpm/hr)

```
  0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
2  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
3  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
4  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
5  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
6  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
7  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
8  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
9  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
10 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
11 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
12 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
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16 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
17 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
18 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
19 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
20 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
21 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
22 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
23 0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
```
2) Estimation of average hold per user

\[ Q_{av} = \frac{\text{Ncells} \times \text{CHT}}{60} \]

- **Ncells**: number of cells per busy hour
- **CHT**: call holding time

**Example**: In a given cellular system, there are an average 12 phone calls in a busy hour. Estimate the hold time generated per user if average call holding time is 2.34 min.

\[ Q_{av} = \frac{12 \times 2.34}{60} = 0.508 \times 10^3 \approx 508 \text{ E} \]

In practice, the hold time generated per user is assumed to be in the range from 15 to 150 E.

**Example**: Consider placement of a cellular network in Brevard County. Assume that the county has a population of 700 thousand if the penetration rate is 10% and 1 phone call is generated per user in a busy hour. Estimate the required capacity of the network in E. If a single cell is capable of serving 4000 phone calls, estimate the number of cells to have capacity beyond that point.

\[ \text{Atm} = \text{Pop} \times 0.1 \times 0.1 \times 50 \times 10^3 = 3500 \text{ E} \]

\[ \text{Ncells} = \frac{\text{Atm}}{4000} = 8.75 \text{ cells} \]

In actual design, one would deploy the number of cells sufficient to meet both coverage and capacity requirements.
Helixs due to excess capacity caused in cellular sectors

Initial stage of deployment - volume at small sites is small. Network is const. Growth
as network gains the traffic increases to congestion problems

- as network is deployed in a nonuniform way, congestion problems occur at
different locations at different time
- level of site control is limited through examination of switch reports

Two approaches for elimination of congestion

Congestion control

Resource allocation

Traffic balancing

- addition of radios (trans.)
- loc. allocation
- cell splitting

- overlay-underrlay
- hierarchal cell structure
- RF opimization
- Parameter opimization
- pic-cell deployment, etc

1) Congestion control - through addition of resources

Addition of new radios/antennas

- integration of new radios provides additional capacity in a uniform
- ideally, a determinate increase of capacity that should be added
- small. Waterfall the basis of a hilly treanding process
- that may be curbed on heavy winter and other seem seasons
- complete

- however, in practice, traffic remains our critical od a site that is already
- completed and on concrete need to be done on the number of resource that would
bring G65 into acceptable range. Consider following example

Example: Consider an 151 kHz cell site seeing a 55 E of traffic using 3 radios. This site is sharing a control channel with 2 more co. cell. How much
connection time all users receives for control channel. Therefore 3 radios per slot (3 x 3 minutes).
The site is experiencing G65 = 7%. Using Erlang b formula: estimate the
number of radios needed in bring G65 to below 2%.

Assumed = Amount x A blocked =

Assumed = Erlang - Available x Erlang (1 - Available (1 - Erlang (1 - G65/100)))

Thus Bar,

Available = Assumed = 0.65
1 - G65/100

Using Erlang B table B = 0.55 & G65 = 2% one obtains C = 0.0004

Adding a single radio brings C = 0.0004. The site has 3 channels
around G65 = 1%. (Erlang B table A = 5 E & C = 0.0004 G65 = 5%)

Adding of new radio is limited by

1) Available of a cell to accommodate new radios
2) Plateau or not. Each radio needs a new frequency.