ECE 5325/6325: Wireless Communication Systems
Lecture Notes, Fall 2011

Lecture 4

Today: (1) Sectoring (2) Cell Splitting

- Reading – today: 3.7; Tue: 4.1-4.3, 4.9.
- HW 1 due Friday 10am in HW locker (#3). Please put solutions in order (1a through 1h).

1 Increasing Capacity and Coverage

1.1 Sectoring

In sectoring, we divide each cell into three or six "sectors" which are then served by three or six separate directional antennas, each with beamwidth of about 120 or 60 degrees.

We showed in Lecture 2 that the S/I ratio is given by $\frac{(3N)^{n/2}}{i_0}$, where N is the reuse ratio, and i_0 is the number of first-tier co-channel base stations. When we used omnidirectional antennas at each BS, we saw that $i_0 = 6$ regardless of N. By using sector antennas at the BSes, we will show that i_0 reduces. By reducing the S/I ratio for a given N, we allow a system to be deployed for a lower N, and therefore a higher capacity system.

However, each cell's channel group must be divided into three sub-groups. These new groups have 1/3 or 1/6 the number of channels, and thus the trunking efficiency will be lower.

Example: Decrease in trunking efficiency for constant N
Let $N = 7$, each cell has $C = 100$ channels, and users who make calls with $\lambda = 0.01$ per minute with average holding time 3 minutes. For blocked-calls-cleared and a GOS of 2%, what is the number of users which can be supported in this cell? Next, using 120 degree sectoring, and otherwise identical system parameters, what is the number of users which can be supported in this cell? What percentage reduction in capacity does sectoring with constant N cause?
Solution: For $C = 100$ and GOS$= 0.02$, from Figure 3.6, I read $A \approx 99$. Thus with $A_u = 0.01(3) = 0.03$, we could support $U = 99/0.03 = 3300$. For the sectoring case, $C = 33.3$ in each sector, and from Figure 3.6, $A = 24$. So we could support $U = 24/0.03 \approx 800$ per sector, or 2400 total in the cell. The number of users has reduced by 28%.

Example: Reducing N with sector antennas
For the same system, now assume that with 120 degree sectoring, that N can be reduced from 7 to 4. What number of users can be supported?
Solution: Now, the number of channels in each cell goes up to $100(7/4) = 175$. So each sector has $C = 58$ channels. With GOS = 2%, from Figure 3.6, $A \approx 48$, so $U \approx 1600$, for a total of 4800 users per cell. This is a 45% increase upon the $N = 7$ non-sectored cell.

Why does i_0 reduce? Consider again a mobile at the edge of a cell. We need to determine which of the first tier BSes contribute significantly to the interference signal. Refer to Figures 3.10, 3.11, for $N = 7$, P3.28(b) for $N = 3$, and to Figure 1 for $N = 4$.

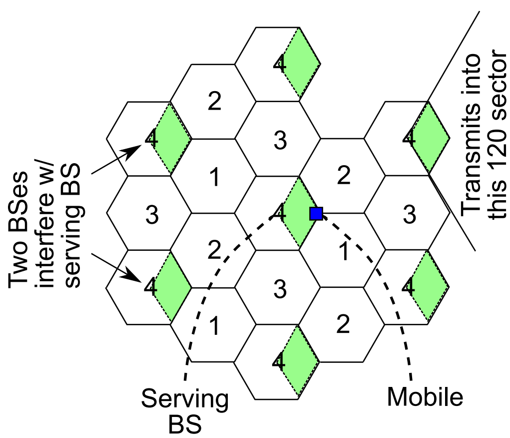

Figure 1: 120 degree sectoring for cellular system with $N = 4$. Only two first tier BSes significantly interfere with the middle BS.

Compared to when $i_0 = 6$, how much does S/I improve with sectoring?

Recall that $S/I = \frac{(3N)^{n/2}}{i_0}$. In dB terms,

$$\frac{S}{I}(dB) = 5n\log_{10}(3N) - 10\log_{10} i_0$$

So with $i_0 = 6$, the latter term is 7.8 dB. If $i_0 = 1, 2$, and 3, the same term is 0, 3.0, or 4.8 dB. So, the improvement is 3, 4.8, or 7.8 dB. The particular value of i_0 that can be obtained is a function of N and whether 60 or 120 degree sectoring is used.

For a particular SIR and path loss exponent, how does i_0 affect the necessary N? From lecture 3,

$$N = \frac{1}{3}(i_0 \mathrm{SIR})^{2/n}$$

So N is proportional to $i_0^{2/n}$.

1.1.1 Determining i_0

What is i_0 for 120 or 60 degree sector antennas? In short: it depends on N. You need to check on the hex plot to see how many sectors' base stations will "cover" the serving sector. My argument (not proven) is that when $i \neq j$, we have $i_0 = 2$ for 120^o antennas and $i_0 = 1$ for 60^o antennas. But for $i = j$, you need $i_0 = 3$ for 120^o antennas and $i_0 = 2$ for 60^o antennas. The case of $i = j$ happens at $N = 3$, and $N = 12$ (and $3i^2$ in general).

1.1.2 Example

Example: Assume we have $S = 533$ full-duplex channels. Assume blocked-calls cleared with a GOS of 2%, and per user offered traffic of 0.015 Erlang. Further assume we're using modulation with minimum required SIR(dB) of 19.5 dB and we've measured for our deployment area that $n = 3.3$. Find the total number of users possible per channel assuming (a) omni-directional antennas and (b) 120^o sector antennas.

Solution: Note linear SIR $= 10^{19.5/10} = 89.1$. (a) For omni antennas, $i_0 = 6$ so

$$N \geq \frac{1}{3}(6 \cdot 89.1)^{2/3.3} = 15.0$$

Since the given SIR is a minimum, we need $N \geq 15.0$. Since there is no 15-cell reuse, we need to increase to $N = 16$, which is possible with $i = 4$ and $j = 0$. Thus there are $533/16 = 33$ channels per cell available. With a GOS of 2%, from the Erlang B chart, $A \approx 25$. With $A_u = 0.015$, this means $U = A/A_u = 25/0.015 = 1667$ users per cell. (b) For 120^o antennas, we need to guess at N since i_0 is a function of N. For larger N, $i_0 = 2$ when using 120^o antennas. So let's plug in $i_0 = 2$ and see what N we get:

$$N \geq \frac{1}{3}(2 \cdot 89.1)^{2/3.3} = 7.7$$

So $N = 9$ would work. (Checking, sure enough, $i_0 = 2$ for $N = 9$.) Thus there are $533/9 = 59.22$ channels per cell or $533/(9 \cdot 3) = 19.7$ channels per sector available. With a GOS of 2%, from the Erlang B chart, $A \approx 14$ per sector. With $A_u = 0.015$, this means $U = A/A_u = 14/0.015 = 933$ users per sector, or 2800 per cell. This is a $(2800 - 1667)/1667 = 68\%$ improvement over the omni case.

1.2 Microcells

When we introduced "cells" we said the radius was a variable R. The idea of using microcells is that for a densely populated area, we cut the size of the cell by half. In this microcell-covered area, the concept of frequency reuse occurs described earlier, only with smaller R. The smaller R also has the benefit that transmit powers would be cut by a factor of 2^n (see Rappaport 3.7.1 for details). The other main benefit is that by reducing the area of a cell by a factor of four (forced by cutting R by two) the capacity in the microcell area is increased by four. For example, consider Figure 2, which shows an original macrocell grid, next to an "inserted" microcell area.

However, at the edges of the microcell area, there is a conflict. Cells that were separated by distance $R\sqrt{3N}$ for the initial R are no longer separated by that much. Conflicts in channel assignments at the edges are solved by splitting the channel group into two subgroups. These subgroups can have different sizes, *e.g.*, the subgroup used for the microcell might have fewer channels assigned to it compared to the macrocell.

Another problem in GSM is that the number of handoffs is increased, since users travel through microcells more quickly. This can be addressed using umbrella cells (page 66) or microcell zones (Section 3.7.4).

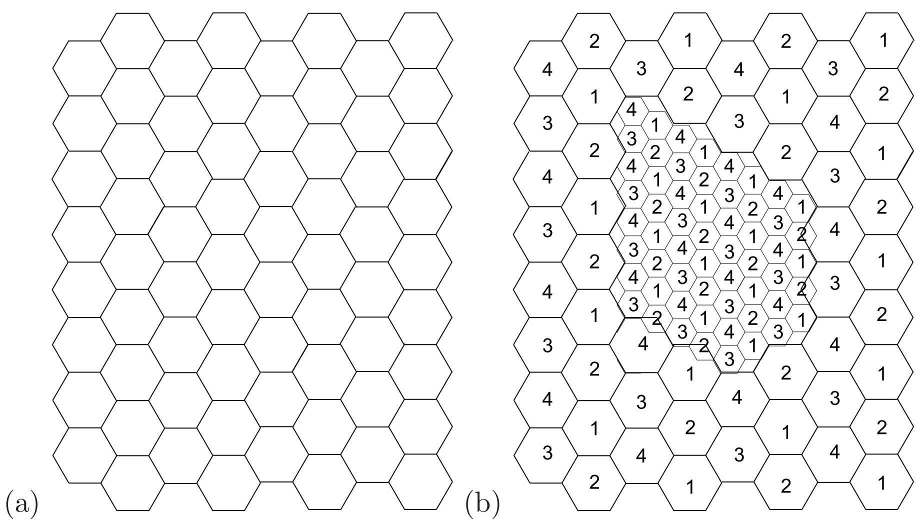

Figure 2: (a) 68 macrocells vs. (b) 53 macrocells plus 57 microcells.

1.3 Repeaters

This is Section 3.7.3 in Rappaport. Repeaters can be used to increase the coverage area, particularly into buildings, tunnels, and canyons. They are bidirectional (they amplify forward and reverse channels). However, repeaters don't add any capacity to the system, they just increase the reach of a BS or MS into "shadowed" areas.

1.4 Discussion

What are some of the problems with the assumptions made in this analysis?