# EE451 Mobile Communication Systems

## Homework 1

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- Problem 1 | $P_B = 1\%$, $H = 120s$, $A = 2$ call/hr

a)

$C = 4$ channels :

↳ From Erlang B chart,

Maximum system capacity $A_{max} = 0.9$ Erlangs

$C = 20$ channels :

↳ From Erlang B chart,

Maximum system capacity $A_{max} = 13$ Erlangs

$C = 40$ channels :

↳ From Erlang B chart,

Maximum system capacity $A_{max} = 29$ Erlangs

b)

$A = 2$ call / hour $= 5.55e-04$ call / s

$A_u = AH = 0.0667$ Erlangs

$$U = \frac{A_{max}|_{C=40}}{A_u} = \frac{29}{0.0667} = 435 \text{ users}$$

c) $t > 30s$ $\rightarrow$ $P(\text{delay} > 30s \mid \text{delay}) = e^{-(C-A)30/H}$

$C = 4$ channels :

↳ Substituting values,

$$P(\cdot) = e^{-(4-0.9)30/120} = 46.07\%$$

$C = 20$ channels :

↳ Substituting values,

$$P(\cdot) = e^{-(20-13)30/120} = 17.37\%$$

$C = 40$ channels :

↳ Substituting values,

$$P(\cdot) = e^{-(40-29)30/120} = 6.39\ \%$$

- Problem 2

$\boxed{1}$

Co-channel Interference occurs due to the presence of a cell operating on the same frequency channel as the cell under subject, separated by some distance d and in another cluster. Whereas, $\boxed{2}$ Adjacent Channel Interference occurs due to spectral leakage of frequency channel of adjacent cell in the same cluster, caused by filter imperfections and other factors.

$\boxed{1}$ can be reduced by ;

- increasing cluster size and thus, increasing d between co-channel cells
- using directional antennas to reduce the number of interferers
- use coordinated multi-point (CoMP) transmission technique

$\boxed{2}$ can be reduced by ;

- using better and sharper filters
- add guardbands to the frequency spectrum

- Problem 3 | $C_t = 78$ channels, $A_u = 0.8$ Erlangs

a) $N = 4$ (cells / cluster)

$$C = \frac{C_t}{N} = 19.5 \approx 20 \text{ channels / cell}$$

With $P_B = 0.01$, and from Erlang B chart;

$A = 13$ Erlangs

» $U = \frac{A}{A_u} = \frac{13}{0.8} = 16.25 \approx 16$ users

b) $N = 12$ (cells / cluster)

$C = \frac{C_t}{N} = 6.5 \approx 6$ channels

With $P_B = 0.01$, and from Erlang B chart;

$A = 1.9$ Erlangs

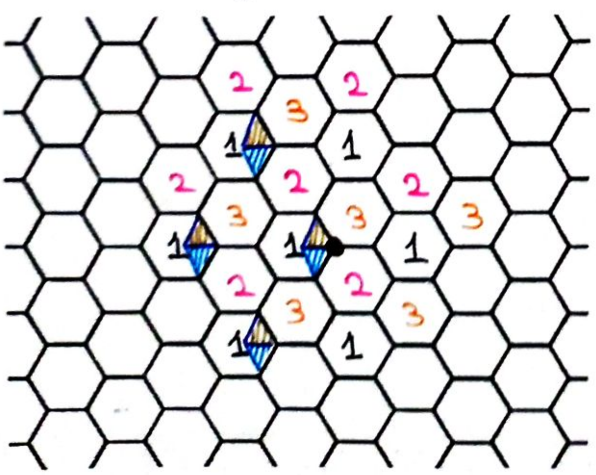
» $U = \frac{A}{A_u} = \frac{1.9}{0.8} = 2.375 \approx 2$ users

- Problem 4 | $\Lambda_{tol} = 15\,dB$ , $\beta = 4$

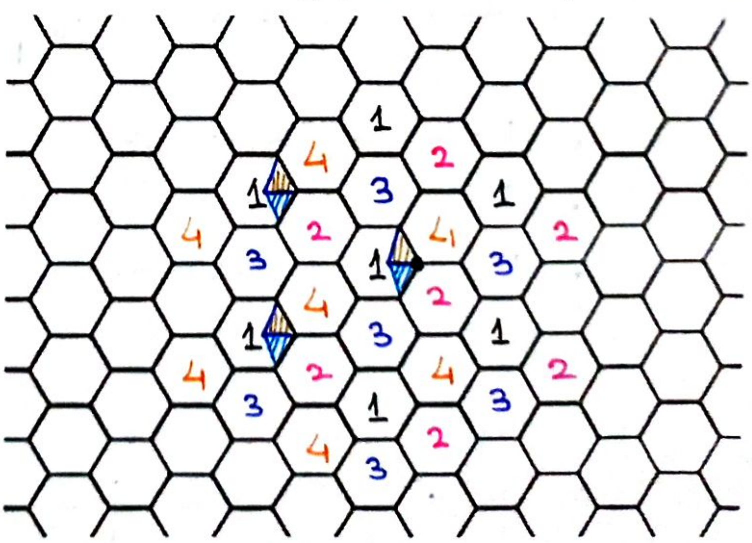
» Before analysis, let us find the number of tier 1 interferers for cases $N = 3, 4,$ and $7$, and write an according equation through it.

$N = 3$ | No sectoring => $T_{1count} = 6$
120° sectoring => $T_{1count} = 3$
60° sectoring => $T_{1count} = 2$

i=1 j=1 N=3



i=2 j=0 N=4



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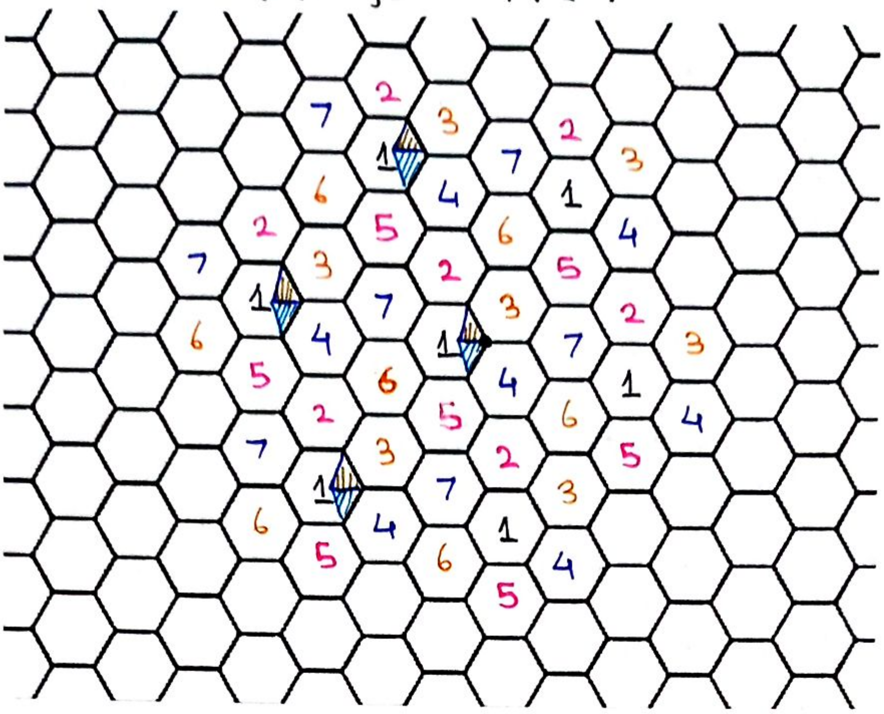
$i = 2 \quad j = 1 \quad N = 7$



$N = 4$

- No sectoring $\Rightarrow$ $T_i$ count $= 6$
- $60°$ Sectoring $\Rightarrow$ $T_i$ count $= 1$
- $120°$ Sectoring $\Rightarrow$ $T_i$ count $= 2$

$N = 7$

- No sectoring $\Rightarrow$ $T_i$ count $= 6$
- $60°$ Sectoring $\Rightarrow$ $T_i$ count $= 1$
- $120°$ sectoring $\Rightarrow$ $T_i$ count $= 2$

## Optimal Value of N

### a) Omni-directional Antenna

$\frac{C}{I}$ Ratio $\quad \Lambda(N) = 10 \log_{10} \left[ \frac{1}{2} \cdot \frac{1}{(\sqrt{3N}-1)^{-4} + (\sqrt{3N}+1)^{-4} + (\sqrt{3N})^{-4}} \right]$

- $\Lambda(3) = 8.02$ dB
- $\Lambda(4) = 11.35$ dB
- $\Lambda(7) = 17.27$ dB $\rightarrow$ Minimum $\underset{N}{\boxed{7}}$ attaining $\Lambda > \Lambda_{tol}$

### b) $120°$ Cell-Sectoring

$\frac{C}{I}$ Ratio $\quad \Lambda(3) = 10 \log_{10} \left[ \frac{1}{2(\sqrt{3 \times 3} + 0.7)^{-4} + (\sqrt{3 \times 3} + 1)^{-4}} \right]$

- $\lambda(3) = \underline{18.36 \text{ dB}}$ → Since $\boxed{N=3}$ with $120°$ satisfies the $\lambda_{tol}$; there is no need to compute any further

c) <u>60° Sectoring</u>

$$\frac{C}{I} \text{ Ratio } \lambda(3) = 10\log_{10}\left[\frac{1}{(\sqrt{3\times3}+0.7)^{-4}+(\sqrt{3\times3}+1)^{-4}}\right]$$

- $\lambda(3) = \underline{20.34 \text{ dB}}$ → As before, $\boxed{N=3}$ satisfies the condition and there is no need to find $\lambda$ for $N=4$, 7, etc.

=> Sectoring should be used as it allows us to use fewer cells / cluster and still meet the worst case $\frac{C}{I}$ ratio. However, since sectoring also incurs a decrease in trunking efficiency, we opt for choosing $120°$ sectoring, instead of $60°$ sectoring, with $N=3$.

- Problem 5 | $\beta = 3$

a) <u>No Sectoring</u>

$$\frac{C}{I} \text{ Ratio } \lambda(N) = 10\log_{10}\left[\frac{1}{2}\cdot\frac{1}{(\sqrt{3N}+1)^{-3}+(\sqrt{3N}-1)^{-3}+\sqrt{3N}^{-3}}\right]$$

- $\lambda(7) = 11.20 \text{ dB}$
- $\lambda(9) = 13.03 \text{ dB}$
- $\lambda(12) = \underbrace{15.07 \text{ dB}}_{> \lambda_{tol}}$ → $\boxed{N=12}$

b) <u>120° Sectoring</u>

$\frac{C}{I}$ Ratio ; $\lambda(3) = 10\log_{10}\left[\frac{1}{2(\sqrt{3\times3}+0.7)^{-3}+(\sqrt{3\times3}+1)^{-3}}\right]$

$= 12.58$ dB

$\lambda(4) = 10\log_{10}\left[\frac{1}{2(\sqrt{3\times4}+0.7)^{-3}}\right]$

$= \underbrace{15.57 \text{ dB}}_{>\lambda_{tol}} \longrightarrow \boxed{N=4}$

c) <u>60° Sectoring</u>

$\frac{C}{I}$ Ratio ; $\lambda(3) = 10\log_{10}\left[\frac{1}{(\sqrt{3\times3}+0.7)^{-3}+(\sqrt{3\times3}+1)^{-3}}\right]$

$= 14.514$ dB

$\lambda(4) = 10\log_{10}\left[\frac{1}{(\sqrt{3\times4}+0.7)^{-3}}\right]$

$= \underbrace{18.5856 \text{ dB}}_{>\lambda_{tol}} \longrightarrow \boxed{N=4}$

- With $\beta = 3$ ;
  - No sectoring case's optimal N changes from 7 to 12
  - 120° sectoring case's as well as 60° sectoring case's optimal value of N changes from 3 to 4.
  - Once again, we should opt to use 120° sectoring case to preserve trunking efficiency, with <u>N = 4</u>.