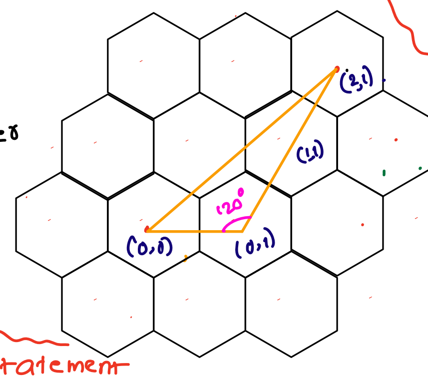
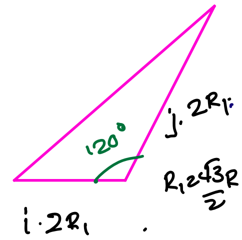
1) P.T $N = i^2 + ij + j^2$.

N = cluster size

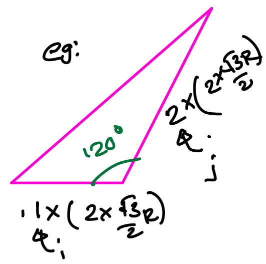
(i, j) = Coordinates of center of hexagon.

1 Mark for diagram





eg:

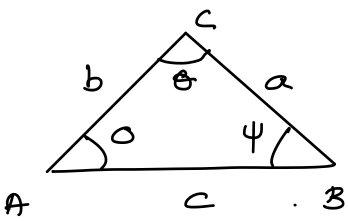


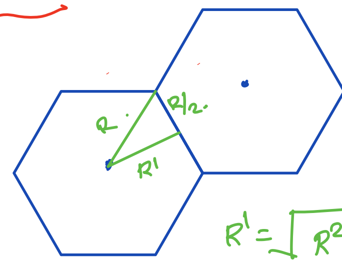
According to the law of cosines

1 Mark for the law statement

$$c^2 = a^2 + b^2 - 2ab\cos\theta$$

Where





$$R' = \sqrt{R^2 - \frac{R^2}{4}} = \frac{\sqrt{3}R}{2}$$

$$D^2 = (i \cdot R\sqrt{3})^2 + (\sqrt{3}R \cdot j)^2 - 2(R\sqrt{3})(\sqrt{3}R)\cos(120^\circ)$$

$$= 3R^2 i^2 + 3R^2 j^2 - 3R^2\cos(120^\circ)\, ij$$

$$= 3\ R^2 i^2 + \quad R^2 j^2 + \quad R^2 ij$$

$$= 3\left(R^2 i^2 + \quad R^2 j^2 + R^2 ij\right).$$

$$= 3R^2\left(i^2 + j^2 + ij\right).$$

$$D = R\sqrt{3}\sqrt{i^2 + j^2 + ij}$$

1 Mark for the derivation

$D = \sqrt{3N} \cdot R$.

$$\frac{D}{R} = \sqrt{3N}$$

$$\Rightarrow N = i^2 + j^2 + ij$$

2. $SIR_{desired} = 16\ dB$

1M

$i^2 + j^2 + ij$

$4+4+4 = 12$. (2,2)

$4+9+6 = 19$.

$$SIR = \frac{(D/R)^n}{6} = \frac{(\sqrt{3N})^n}{6}$$

Assume $n=2$ → Any n value between 2 & 4 can be assumed

$$\Rightarrow SIR = \frac{(\sqrt{3N})^2}{6} = \frac{3N}{6} \Rightarrow 10\log_{10}(0.5N).$$

$$\Rightarrow N \geq 2\times 10^{1.6}$$

$\left(\begin{matrix} \text{For } n = 4 \\ N \geq 7 \end{matrix} \right)$

2M

$$\Rightarrow N \geq 79.62$$

$$\Rightarrow N \geq 44$$ This value changes with n.

3) $BW_{Total} = 100\ MHz$

$BW_{Simplex} = 125\ KHz$

(a) Total number of duplex channels $= \dfrac{100\times 10^6}{[125\times 2]\times 10^3}$

2M

$= 400$ channels.

(b) Number of channels per cell $= \dfrac{400}{4} = 100$.

1M

4) $R = 10m$

$D = 50m$

$n_I = 2$ (intracell)

$n_o = 3$ (intercell)

$M = 4$. for diamond shaped cells. 1M

1M

$$SIR. = \frac{R^{-n_I}}{M \cdot D^{-n_o}} = \frac{10^{-2}}{4 \cdot 50^{-3}} = \frac{50 \times 50 \times 50}{4 \times 100}$$

$$= \underline{\underline{312.5}}$$ 1M

5) $SIR_{required} = 20dB$

Hexagonal cell

$n = 4.$

1M Formula.

$$100 = \frac{(D/R)^4}{6} \Rightarrow D/R = (600)^{1/4}.$$

$\Rightarrow D/R = 4.94$

$\Rightarrow \sqrt{3N} = 4.94$

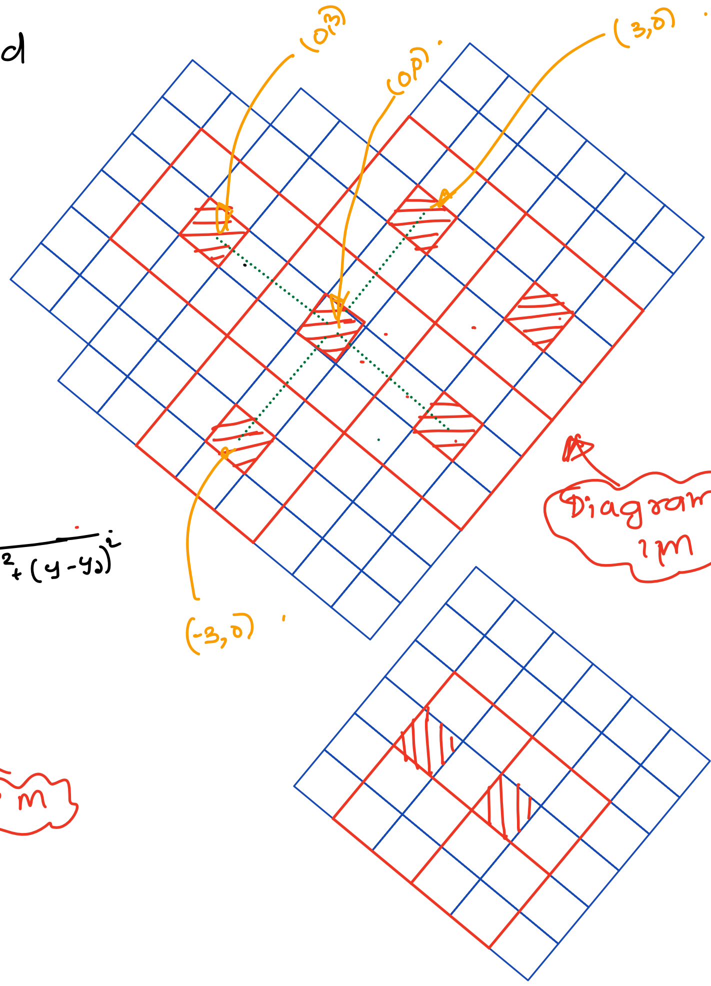
$\Rightarrow N \geq 8.16$ 1M

$\Rightarrow \underline{\underline{N \geq 12}}$ 1M

6) Diamond shaped

$R = 50m$

$D = 300m$



From the figure
Distance between
Co-channel cells

$\Rightarrow D = 2R \times K$

$K = \sqrt{(x-x_0)^2 + (y-y_0)^2}$

1M

$N = K^2 = 9$

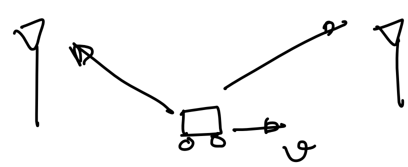
1M

7a $D = 2 Km$

$v = 80 Km/hr = 22 m/s$

$P_0 = 0 dBm$

$d_0 = 1m$



$P_{r,min} = -88 dBm$

$t_{HO} = 4s$

$n = 2.9$

Handoff initiate at $P_{r,min} = -88 dBm$

Call lost when $P_r < P_{r,HO}$.

Let d_{min} = distance at which power at BS is $P_{r,min}$.

d_{HO} = distance at which power at BS is $P_{r,HO}$

Time taken to travel the distance $d_{min} - d_{HO}$ is

$$t_{HO} = \frac{d_{HO} - d_{min}}{v} \leq 4.5s.$$ 2M

Using path loss model

$$P_r = P_0 \left(\frac{d_0}{d}\right)^n$$ 1M

$$\Rightarrow P_{r\,min}(dB) = 10 \log_{10}(0) + 10n \log_{10}\left(\frac{d_0}{d_{min}}\right).$$

$$= 29 \log_{10}\left(\frac{1}{d_{min}}\right).$$ 2M

2M

$$\Rightarrow d_{min} = 10^{\frac{-P_{r,min}(dB)}{29}} \simeq 1083m.$$

Similarly $$d_{HO} = 10^{\frac{-P_{r,HO}(dB)}{29}}.$$

1M

$$t_{HO} = \frac{10^{\frac{-P_{r,HO}(dB)}{29}} - 1083}{22} \leq 4.5s.$$

$$\Rightarrow P_{HO} \geq -86.8\,dBm$$ 1M

$$\Delta = P_{r,min} - P_{r,HO} = -1.2dBm$$ 1M

(7b).

$$v = 160\,km/hr \Rightarrow 44.4\,m/s.$$ 2M

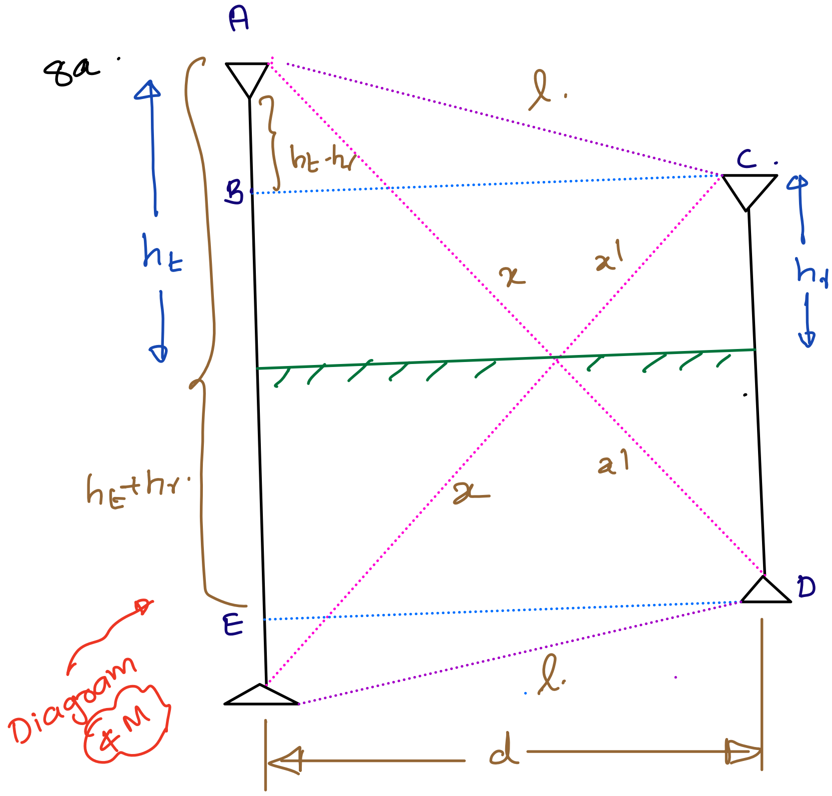
$$t_{HO} = \frac{10^{\frac{-P_{r,HO}(dB)}{29}} - 1083}{44.4} \leq 4.5s.$$

$$P_{r,HO}(dB) \geq -90.1\,dBm$$

2M

$$\Delta = 2dBm.$$ Explanation on Δ 2M

8a.



The equation is derived using the method of images.

From triangle ABC

$$l^2 = (h_t - h_r)^2 + d^2$$ 2M

From $\triangle ADE$

$$(x + x')^2 = (h_t + h_r)^2 + d^2$$ 2M

$$x + x' - l = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}$$

$$\Delta\phi = 2\pi(x + x' - l)$$

8b. Reflection coeff $= -1$

$G_t = G_r = 1$

$$P_r = P_t\left(\frac{\sqrt{G_t G_r}\cdot\lambda}{4\pi d}\right)^2 = P_t\left(\frac{\lambda}{4\pi}\right)^2 \cdot \frac{1}{d^2}$$ 2M

Power $\propto |A|^2$ wher A is the amplitude.

If $x_1(t)$ is the LOS wave and $x_2(t)$ is the reflected wave then at receiver 2M

$$y(t) = \left(x_1(t) + R.x_2(t)e^{-j\Delta\phi}\right)$$

$$= \left(x_1(t) - x_1(t)e^{-j\Delta\phi}\right).$$

$$|y(t)|^2 = \underbrace{|x_1(t)|^2}_{P_r}\left|1 - e^{-j\Delta\phi}\right|^2.$$ 2M

$\Rightarrow$ Since $x_1(t)$ travels a distance of 'l' and $-x_1(t)e^{-j\Delta\phi}$ travels a distance of $x+x'$

$$P_r = P_t\left[\frac{\lambda}{4\pi}\right]^2 \left|\frac{1}{l} - \frac{e^{-j\Delta\phi}}{x+x'}\right|^2.$$ 2M

Where $\Delta\phi$ is given in 7a.

(9a) TDMA scheme $\quad M = \#$ of co-channel cells

SIR = 15 dB $\quad n = 4$.

(a) $M = 6$.

$$SIR = \frac{(\sqrt{3N})^n}{M} \Rightarrow 15 = 40\log_{10}\left(\frac{\sqrt{3N}}{6}\right).$$

$\Rightarrow$ $N > 4.5 \Rightarrow \underline{\underline{N = 7}}$ 2M

(b) $M = 2$.

$SIR > 15\,dB \Rightarrow 10\log_{10}\left(\frac{3N}{M^2}\right) > 15\,dB$ 2M

$\Rightarrow N = 3$.

(c) $M = 1$

$\Rightarrow N = 3$. 2M

Will select 120° as

(1) Directional antennas are costly

(2) Using 60° sectoring doesn't change cluster size

(3) Increase in capacity. 2M

9b.

$P_{noise} = -160\,dBm = 10^{-19}\,W$ 1M

$d_0 = 1m$

$f_c = 1\,GHz$

$n = 4$

$P_t = 10\,mW$

$SIR = 20\,dB = 100$

$P_r = P_t K \left(\frac{d_0}{d}\right)^n$

$K = \left(\frac{\lambda}{4\pi d_0}\right)^2$

$= \left(\frac{0.3}{4\pi}\right)^2$

$= 5.7 \times 10^{-4}$ 2M

$SNR = 100 = \frac{\text{Signal Power}}{\text{Noise power}} = \frac{P_{sig}}{10^{-19}}$ 2M

$\Rightarrow P_{sig} = 10^{-17}$ 2M

$10^{-17} = 10 \times 10^{-3} \times 5.7 \times 10^{-4} \left(\frac{1}{d}\right)^4$

$d \leq 868.89$ 1M

(10a) Contribution from 1st tier $= \sum_{i=1}^{6} P_{r,i}$ 2M

" " 2nd tier $= \sum_{i=1}^{6} P_{r,i} + \sum_{j=7}^{12} P_{r,j}$

$= \sum_{i=1}^{6\times 2} P_{r,i}$

From p^{th} tier $= \sum_{i=1}^{6p} P_{r,i}$ 2M

Where $P_{r,i}$ is the received signal power from the i^{th} Co-channel cell.

$$P_{r,i} = P_0 \left(\frac{d_0}{d_i}\right)^{n}$$ 2M

2M

$$\Rightarrow \quad P_r = P_t \sum_{i=1}^{6 \cdot p} \left(\frac{1}{d_i}\right)^{n} = P_0 \sum_{t=1}^{p} \sum_{i=1}^{6t} \left(\frac{d_0}{d_i}\right)^{n}$$

(c) b)

$P_0 = 1\,dBm = 10^{-31}\,W$

$d_0 = 1\,m$

$p = 4$

$N = 7$

Interference from 2^{nd} tier

2M

$$SIR_2 = 10^{-31} \sum_{i=1}^{6} \left(\frac{1}{2}\right)^{n}$$

2M

Total Interference

$$SIR_{total} = 10^{-31}\left[\sum_{i=1}^{6}\left(\frac{1}{1}\right)^{n} + \sum_{i=1}^{6}\left(\frac{1}{2}\right)^{n} + \sum_{i=1}^{6}\left(\frac{1}{4}\right)^{n} + \sum_{i=1}^{6}\left(\frac{1}{8}\right)^{n}\right]$$

Contribution of 2^{nd} tier $= \dfrac{SIR_2}{SIR_{total}}$ 2M

Simplified Final Expression 2M