Date 2/sep/2022 (Wed)

Sessional-1 (syllabus)

Unit-1 (Complete) (Numericals only)
Unit-2 :- GSM Transmission Process, GSM channels, GSM Handoff (Theory Only)

Tutorial Unit-1

Q1. (2021-session-1 Q1 same) A region with area 10,000 km² has an evenly distributed population of 2.5 million people and is covered by a cellular system using a 12-cell reuse pattern and each cell has a radius of 3.08 km and the area allotted is 40 MHz of spectrum with a full duplex channel bandwidth of 60 KHz. Assume GOS of 2 percent of an Erlang B system is specified if the offered traffic per user is 0.03 Erlangs. Find the following :-

(i.) Number of channel per cell.
(ii.) Traffic Intensity of each cell.
(iii.) Total no. of each cells.
(iv.) Maximum carried traffic.
(v) Total no. of users served for 2% of GOS.

[Note :- From Erlang chart it is given that for No. of channels/cell (calculated in part (i)) and GOS = 0.02, The traffic intensity/cell = 45 Erlangs/cell.]

Sol 1. A = 10000 km²
Population = 2.5 million
Cell frequency reuse pattern = 12-cell reuse pattern.
factor

(i) No. of channel per cell = Allocated spectrum / (channel width * freq. reuse factor)
(C)
= $\frac{40 \times 10^6}{60 \times 10^3 \times 12}$ = 55.56 ≈ 56 channels/cell

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(ii) Traffic intensity of each cell = 45 Erlangs/cell.

(from Erlang B chart, $C = 56$ & GOS = 0.02) ≈ 2.5981

(iii) Total no. of cells (N_c) = $\frac{\text{Area}}{\text{area of each cell (hexagon)}} = \frac{10000}{\frac{3\sqrt{3}R^2}{2}}$

(or Total no. of cells in the service area)

$= \frac{10000}{(2.5981)(3.06)^2} = 411.056$

≈ 411 cells.

(iv) Maximum carried traffic

$= \underset{(N_c)}{\text{total no. of cells}} * \underset{(A)}{\text{traffic intensity per cell.}}$ (or of each cell)

$= 411 * 45$

$= 18,495$ Erlangs.

(v) Total no. of users served for 2% of GOS

$= \frac{\text{total traffic}}{\text{traffic per user}}$

$= \frac{18495 \text{ Er.}}{0.03 \text{ Er.}} = 616,500$ users

(extra) The no. of mobiles per unique channel (where it is understood that channels are reused.)

$= \frac{\text{No. of users}}{\text{No. of channels}}$

$= \frac{616500}{56 * 12} = 917.4...$

≈ 917 mobiles / unique channel.

↳ no. of channels per cell (C) * no. of cell * 12

(extra) Theoretical max^m. no. of users that could be served at one time by the system. (or theoretical max^m. no. of mobiles served or total channels in use in system.)

$= C * N_c = 56 * 411 = 23,016.$

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ie, $\frac{23016}{616500} \times 100 = 3.73\%$ of the customer base.

Q2.

Sol 2.

Area = $1300\ (\text{mile})^2$

7 cell reuse pattern (frequency)

$R = 4$ mile

Allocated spectrum = 40 MHz

channel bandwidth = 60 kHz

Traffic intensity per cell, $A = 84$ Er./cell (GOS 2%)

offered traffic per user = 0.03 Er.

(a) No. of cells in the service area (N_c)

$$= \frac{\text{Area}}{\text{Area of each cell}} = \frac{1300\ \text{mile}^2}{2.5891 * 4^2\ \text{mile}^2}$$

$$= \frac{1300}{2.5891 * 16} = 31.3816 \simeq 31 \text{ cells}$$

(b.) No. of channels per cell (C)

$$= \frac{\text{Allocated spectrum}}{\text{channel bandwidth} * \text{freq. reuse factor}} = \frac{40 \times 10^6}{60 \times 10^3 * 7}$$

$$= \frac{4000}{42} \simeq 95.24 \simeq 95 \text{ channels/cell.}$$

(c) Traffic intensity of each cell = $A = 84$ Erlangs/cell.

(d.) The max^{m} carried traffic = total no. of cells (N_c) * traffic intensity per cell (A)

$= 31 * 84$

$= 2604$ Erlangs

(e) No. of users that can be served with 2% GOS

$$= \frac{\text{total traffic}}{\text{traffic per user}} = \frac{2604 \text{ Er}}{0.03 \text{ Er/user}}$$

$= 86,800$ users.

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(f) No. of mobiles per channel = $\frac{\text{no. of users}}{\text{no. of channel}}$

$= \frac{86800}{(95\times 7)} = \frac{86800}{665} \approx 130$ mobiles/channel.

Sol 3. Each Base station uses = 60 channels

Radius of original cell = 1 km

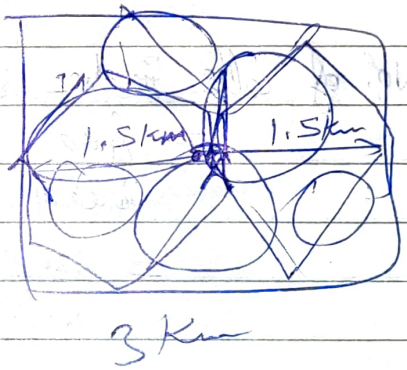
" " microcells = 0.5 km

find the no. of channels contained in (3×3) km^2 centered around A.

(a) Without the use of microcells :-

To cover 3 km by 3 km square

we need to cover 1.5 km (left, right, up, down) 3 km



15 base stations

⇒ total channels in (3×3) km^2

$= 5 \times 60$

$= 300$ channels

(b.) With the use of the microcells :-

5 base stations + 6 microcells (surrounding base station A)

$= 11$

⇒ total channels (3×3) km^2 $= 11 \times 60$

$= 660$ channels

$\frac{660}{300} = 2.2$ times (a)

(c) If all the base stations are replaced by microcells.

$5 + 12 = 17$

∵ each station has 60 channels

17 stations will have $17 \times 60 = 1020$ channels.

$\frac{1020}{300} = 3.4$ times (a)

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P_r

Sol 4. (1mW) signal at $d_0 = 1m$

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(Q.3.) signal < -100 dBm

$n = 3$ (path loss exponent)

$R = ?$, $N = 4$ cell sense pattern

$P_r = P_0 \left(\frac{d}{d_0}\right)^{-n}$ $\left(\frac{D}{R} = \sqrt{3N}\right)$

signal to noise ratio

$\Rightarrow P_r = P_0 \left(\frac{\sqrt{3N} \cdot R}{d_0}\right)^{-n}$

path-loss exponent

or

$P_r\,(dBm) = P_0\,(dBm) - 10n \log\left(\frac{d}{d_0}\right)$

$\Rightarrow P_r(dBm) = P_0(dBm) - 10n \log \frac{\left(\sqrt{3N}\, R\right)}{d_0}$

for $N = 4$

$-100\,dBm = 0 - 40 \log \frac{\left(\sqrt{12} \cdot R\right)}{1}$

$\Rightarrow \log \frac{\sqrt{12} \cdot R}{d_0} = \frac{5}{2}$

$\Rightarrow \sqrt{12} \cdot R = 10^{2.5}$

$\Rightarrow R = \frac{10^{2.5}}{\sqrt{12}} = 91.287$

$-100\,dBm = 0 - 30 \log_{10} \frac{\left(\sqrt{12} \cdot R\right)}{1}$

$\Rightarrow \sqrt{12} \cdot R = 10^{\left(\frac{100}{30}\right)}$

$\Rightarrow R = \frac{2154.43}{\sqrt{12}} \approx 621.93\,m$

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Power (dBw) → decible Watt $= 10 \log_{10}$ (Power (Watt))

$P_0 = 1$ mwatt

$\Rightarrow P_0$ (in dBm) $= 10 \log_{10} \frac{1}{1} = 0$

$\Rightarrow -100 (dBw) \geq 0 - 30 \log_{10} \left(\frac{\sqrt{2} \cdot R}{1}\right)$

$\Rightarrow R > 621.93$ m

$\Rightarrow \boxed{R >= 622 \text{ m.}}$

sol 5. $N = 4$ (freq. reuse factor)

$n = 4$ (path-loss exponent)

$R = 5$ km

find in dB :-

$4 = 0^2 + 2^2 + 0.2$

$\Rightarrow i_0 = 2, j_0 = 0.$

(a) SNR (with no cell sectoring) or SIR

$= S/I = \frac{(D/R)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0}$

i_0 = co-channel cells.

$i_0 = 1$

$= \frac{(\sqrt{3*4})^4}{1}$

$= (\sqrt{12})^4$

$= (144)$ Ans

$= 10 \log 144$

$= 21.58$ dB

(b) $i_0 = 2$, $SNR = \frac{(\sqrt{3N})^n}{i_0} = \frac{144}{2} = 72$

(as there, 2 cells instead of 6.)

$\left(\frac{1}{2} = 3 * \frac{1}{6}\right)$ (120° sectoring)

(c) $i_0 = 6$, $SNR = \frac{(\sqrt{3N})^n}{i_0} = \frac{144}{6} = 24$

omni → (60° sectoring)

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Note:- S/I ratio ↑ as no. of sectors ↑ but at the cost of additional handoff that might be required for the movement of a user from one sector to another.

Sol 6. Area = 1500 km^2
N = 12 cell reuse freq. pattern
R = 1.387 km
total allocated spectrum = 28.5 MHz
channel Bandwidth = 25 kHz
offered traffic per user = 0.03 Erlangs

(1.) No. of cells in service Area = $\frac{1500\ km^2}{2.5981 * (1.387)^2\ km^2}$
= 301.15
≈ 301 cells

(2.) No. of channels per cell = $\frac{28.5 \times 10^6}{25 \times 10^3 * 12}$ = 95 channels/cell

(3.) Traffic intensity of each cell = 84 Er./cell.
(C = 95, GoS = 0.02)

(4.) maximum carried traffic = 84 Er./cell * 301 cell
= 25,284 Er.

(5.) Total no. of users that can be served for 2% GoS
= $\frac{25,284\ Er.}{0.03\ Er./user}$ = 842800 users

(6.) No. of mobiles per channel = $\frac{842800}{(95 * 12)}$ = 739.298
≈ 739 mobiles/channel

(7) Theoretical max^m no. of users that could be served at one time by the system.

= C * N_c

= 95 (channels/cell) * 301 cells.

= 28595 users.

= (28595 * 100 / 842,800) = 3.39 % of the customer base.

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

Sol (7.) B. Station → 15 watt Power

after cell splitting, $R' = \frac{1}{4} R$

new cell power $P' = ?$, to maintain SNR at the cell boundaries.

n = 4. (path loss - exponent)

$P_r \propto \left(\frac{d}{d_0}\right)^{-n} \propto (R)^{-n} \Rightarrow P_r = P_0 \left(\frac{d}{d_0}\right)^{-n}$

$\frac{P_r}{P'_r} = \left(\frac{R}{\frac{1}{4}R}\right)^{-4} = (4)^{-2} = \frac{1}{16}$

$P_r \propto \left(\frac{1}{R}\right)^{n/2}$

$P_r = \frac{P_{r_1}}{(R_1)^2} = \frac{P_{r_2}}{((R_1/4))^{4/2}}$ $\quad R_2 = R_1/4$

$\Rightarrow \frac{P_{r_1}}{(R_1^2)} = \frac{P_{r_2}}{(R_1^2/16)} \Rightarrow \boxed{P_{r_2} = \frac{1}{16} \cdot P_{r_1}}$

$= \frac{1}{64} \times 15 = 0.0585$ watt.

$$\rho(\text{in decibels}) = 10\log_{10}(0.0585) = -12.3\text{dB}.$$

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if a cellular layout is replaced by a new layout with a smaller cell radius, the SIR will not change provided the cluster size does not change.
Therefore the only way to avoid interference b/w the large cell and small cell systems is to assign entirely diff^{t} sets of channels to the two systems.

Sol 8. $SIR = 10.\log_{10}\left(\frac{Q}{i_0}\right)^n$, $Q = \frac{D}{R} = \sqrt{3N}$ $\quad i_0 = 6$

$\Rightarrow 20 = 10.\log_{10}\left(\frac{Q}{i_0}\right)^n \Rightarrow \boxed{\frac{Q}{i_0} = 100} \rightarrow \boxed{Q = 600}$

(a) $n = 6$

Let us consider a 7-cell freq. reuse pattern

The co-channel reuse ratio, $\frac{D}{R} = \sqrt{3N} = \sqrt{3*7} = 4.583$

$$SIR = \frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{(4.583)^6}{6} = 1544.357 \simeq 1544$$

$$= 10.\log_{10}(1544) = 31.89\ dB$$

$31.89\text{dB} > 20\text{dB}$ (this is greater than the minimum required value)

$\therefore$ $N = 7$ can be used.

(b.) $n = 2$

Let us consider a 7-cell reuse freq. pattern

$$\frac{S}{I} = \frac{(\sqrt{3*7})^2}{6} = 3.5 = 10\log_{10}^{3.5} = 5.44\ dB$$

$5.44 < 20\text{dB}$ $\therefore$ we need to use a large N.

$N = i^2 + j^2 + i.j$

next possible value of N is 12. $\quad \frac{S}{I} = 10.\log_{10}\left(\frac{(\sqrt{3*12})^2}{6}\right)$

$= 7.78\text{dB}$

It is still less so for higher N.

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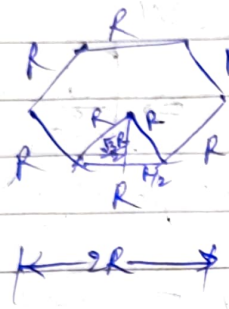
Sol 9: Proof for hexagonal geometry, the co-channel reuse ratio is

$$\boxed{Q = \frac{D}{R} = (3N)^{1/2}}$$

$N = i^2 + i.j + j^2$ (no. of cells per cluster)



$$\text{Area} = 6 * 2 * \left(\frac{1}{2} * \frac{\sqrt{3}}{2} R * \frac{R}{2}\right)$$

$$= 12 * \frac{\sqrt{3}}{8} * R^2$$

$$= \frac{3\sqrt{3}}{2} R^2 \approx 2.598 R^2$$

Center to Center Distance b/w closest co-channels (interfering cells)

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

$$= R.\sqrt{3i^2 + 3j^2 - 2.3.i.j\left(-\frac{1}{2}\right)}$$

$$= R.\sqrt{3.(\underbrace{i^2 + j^2 + i.j}_{N})} = R.\sqrt{3N}$$

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

$$\Rightarrow \boxed{Q = \frac{D}{R} = \sqrt{3N}}$$

Hence Proved

Sol: 84 cells. (N_c)
cluster size N
280 voice channels
each user has average (λ) 2 calls/hr & holds call for (H) 1.2 mins
blocking probability = 0.01.

(a.) maximum carried traffic per cell (for $N=4$ & $N=7$).
(b.) " number of users that can be served (for $N=4$ & $N=7$.

no. of channels per cell = $\frac{\text{no. of channels}}{\text{cluster size}}$

$N=4$. $C = \frac{280}{4} = 70$ & GOS = 0.01

maximum carried traffic per cell = 84 (cells) * 57 (from table) = 4788

maximum no. of users (can be served) = $\frac{\text{total traffic}}{\text{traffic per user}} = \frac{A}{A_u} = \frac{A}{\lambda H}$

$= \frac{4788}{2 \text{ calls/hr} * 1.2 \text{ mins} * \frac{1}{60} \text{ hr/min}}$

$= \frac{4788 * 60}{2.4}$ users

$= 119{,}700$ users

$N=7$. $C = \frac{280}{7} = 40$ & GOS = 0.01

maximum carried traffic per cell = 84 * 29 (from table) = 2436

maximum no. of users [can be served] = $\frac{A}{\lambda H} = \frac{2436}{2 \text{ calls/hr} * 1.2 \text{ min} * \frac{1}{60} \text{ hr/min}}$

$= \frac{2436 * 60}{2.4} = 60900$