Unit -1

Cellular Mobile Radio Systems

Introduction to cellular System (or) Basic cellular System

There are four elements in cellular System, those are mobile unit, cell site, MTSO, Voice & data links

Mobile unit :-

→ Mobile unit consists of a transceiver, control unit, power unit, and an antenna System.

→ Transceiver means both transmitter & Receiver

→ This transceiver used by the subscriber for Voice and data calls.

→ power unit provides power Supply to all the Circuits & elements in the mobile unit.

→ Tuning the transmitter, receiver, display managem Execution of handoff & etc are monitored and controlled by control unit.

Cell site :-

→ cell site is an interface between mobile unit & MTSO.

→ A Small part of CGSA is called as 'cell'

→ A cell with antenna equipment is called as cell site.

→ cell site consists of an antenna, transmitter, receiver, control unit, power unit, radio cabinets (channels).

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→ power unit consists of supply provided by local provider & a generator as standby power supply.

→ Radio cabinetes are the channels which are assigned to the cell site, these channels will be assigned to mobile units as per the requirements.

Voice & data links (Transmission links):-

→ A transmission link is required between cell site & MTSO for the exchange of voice & data signals.

→ Optical fibre cables (OFC) are the preferred transmission links as they offer huge bandwidth, least loss, less noise etc.

→ Alternative of OFC is a microwave link between cell site & MTSO.

Mobile Telephone Switching office (MTSO):-

→ MTSO is the heart of the cellular system as it is responsible for each & every activity.

→ It consists of several switches & processors

→ Switches are used to provide a link between calling & called subscribers.

→ Processors are used for performing all the activities of MTSO.

→ MTSO activities includes

(i) Mobile unit validation

(ii) Billing meter maintenance

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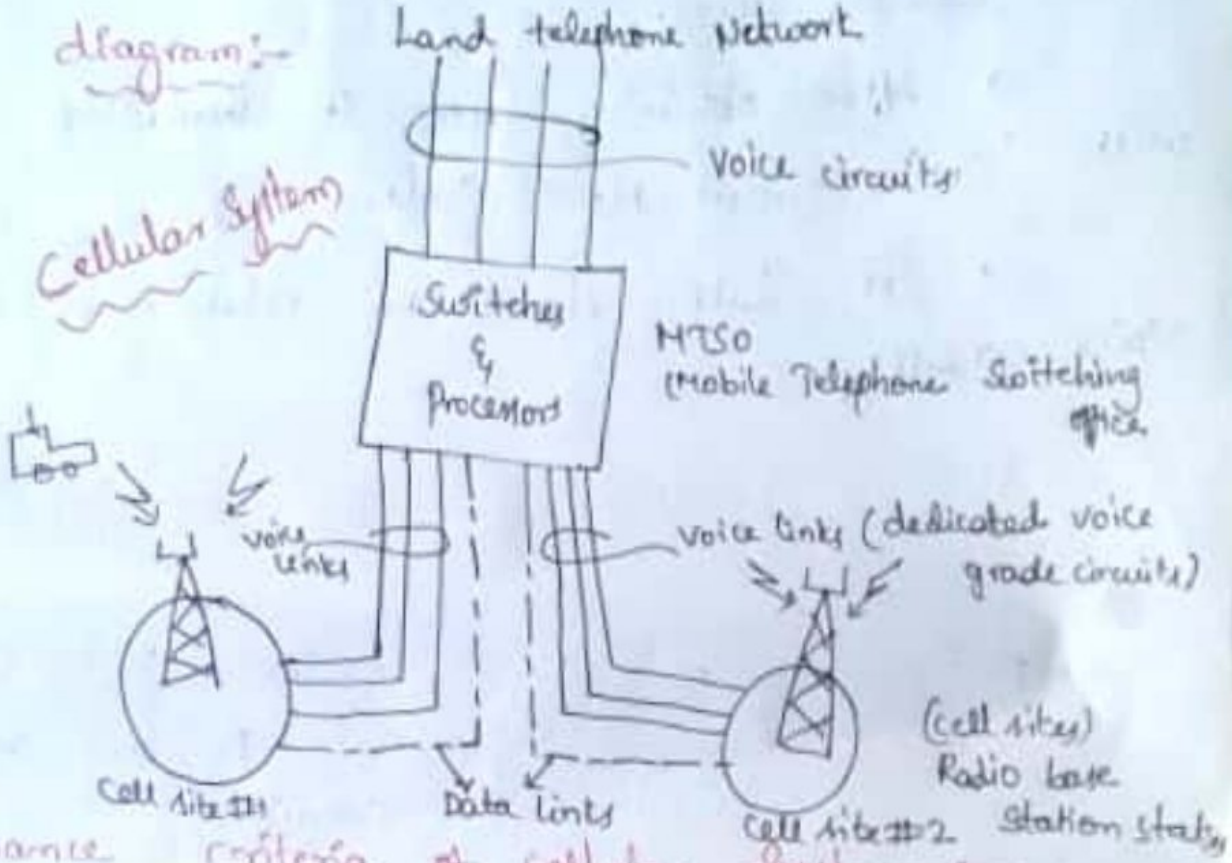
(iii) Hand off Execution

(iv) Channel sharing & borrowing

diagram:-

Cellular System



Performance criteria of cellular System :-

There are 3 factors on which the performance of cellular System depends.

1. Voice Quality
2. Service Quality
3. Special Features

Voice Quality :-

→ Voice Quality is a basic factor and it must be maintained at very good (or) excellent level for any cellular System

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→ To estimate the voice Quality subscriber opinion must be collected & based on this 'MOS' (Mean opinion Score).

→ After obtaining MOS, it should be verified with 'CM' (circuit Merit) Scale.

→ CM Scale shows the relation between MOS Voice Quality

CM Scale	Score (MOS)	Voice Quality
CM5	5	Excellent - Voice is clear, no repetitions are required
CM4	4	Very good - Voice is clear, occational repetitions are required
CM3	3	Good - voice is understandable Frequent repetitions are required.
CM2	2	Average / Fair - Speech is Understandable with effort
CM1	1	Poor - Speech is not Understandable

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→ As per the CM Scale, voice Quality must be either in CM4 (or) CM5, so MOS must be greater than 4.

→ If the voice call is maintained as Excellent (or) Very good then performance of the cellular System is high w.r.to the voice Quality

Service Quality:-

Service Quality depends on 3 parameters

(i) Coverage

(ii) Grade of Service

(iii) No. of dropped calls.

i) Coverage:- It is not mandatory to provide 100% coverage but the following conditions must be maintained for good performance of cellular System

→ In flat area, coverage must be 90% and 75% subscribers must be Satisfied with the Coverage.

→ In hilly area, coverage must be 75% and 90% subscribers must be satisfied with the coverage.

ii) Grade of Service (blocking):-

→ During the busy hour, no. of call attempts are highest.

→ In that case there is a Possibility of

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blocking.

→ As per cellular standards, allowed blocking B = 2% max.

→ If blocking is less than 2% then the performance of cellular system is considered as good.

(ii) No. of dropped calls :—

→ During the busy hour if 'Q' calls are made & 'Q-1' calls are completed then no. of incomplete (or) dropped call is 'one'.

→ Dropped call rate is given by $\frac{1}{Q}$

→ The dropped call rate must be zero (or) near zero to make good performing system.

Special Features :—

Any feature (or) service which attracts more subscribers into system is considered as special feature.

Such as

1. Unlimited calls
2. Unlimited data
3. Voice stored (VSR) box
4. Call forwading
5. Call waiting
6. Automatic roaming (or) Navigation services

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Operation of cellular System:-

The operation of cellular System includes 5 steps:

1. Mobile unit initialization.
2. Mobile originated call
3. N/w originated call
4. Call termination.
5. Hand off.

(1) Mobile Unit initialization:-

Powering up the mobile unit, Scanning & searching for strongest set up channel, Muting the mobile unit to the nearest cell site & obtaining the network auth these are the different activities of mobile unit initialization.

Mobile originated call:-

→ It is an outgoing call made from the mobile unit.

→ Sends MIN (Mobile Identification no) & called subscriber no to nearest cell site

→ Receives the nearest & delivers it to the MTSO.

→ Receives the request from the cell site

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→ Instructs the cell site to move the mobile unit onto a free voice channel pair.

→ Connects the mobile unit to the called subscriber through a switch

→ Voice transmission

→ Voice Reception

→ Voice transmission

→ Voice Reception.

③ MSC originated call :-

→ Receives the request from PSTN (or) other MSC & delivers MIN details to all cell site

→ Transmits the page information in the entire coverage area.

→ Sends the acknowledgment to the cell site about matching of MIN.

→ Sends the control signal with voice channel frequency information.

④ Call termination :-

→ At the end of conversation, if the mobile use turns off the transmitter by pressing call end button. Then it is called as call termination.

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(5) Hand off :-

During a call, if the mobile unit is moving from one cellsite to the other then it must be moved from old voice channel to new voice channel pair is called as handoff.

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Analog cellular System)

1) AMPS

2) NMT

3) NTT

AMPS — Advanced mobile phone Systems

→ It is the analog mobile phone system developed by Bell Labs and officially introduced in America in 1983 & Australia in 1987

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→ In the first generation cellular technology that uses separate frequencies (or) channels for each conversation.

→ In AMPS, the cell center can flexibly assign channels to handsets based on signal strength..

NMT — Nordisk Mobile Telephone

NMT Nw :-

→ NMT Network is also known as Nordic System

→ This system was mainly developed by Scandinavian Countries (Denmark, Norway, Sweden, Finland) in collaboration (co-operation) with Spain & Saudi Arabia.

→ The NMT System serves about 100,000 subscribers and provides handoffs, roaming facilities.

NTT Nw :- NIPPON TELEGRAPH And Telephone corporation.

→ This corporation has developed an 800MHz land mobile telephone system in 1979. to provide service to Tokyo area

→ This s/m provides service to approximately 40,000 subscribers in 100 cities.

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Uniqueness of mobile radio environment

Cell Splitting :-

→ If the load of the cell site is more and the channels assigned to that site are not sufficient then various techniques such as Channel Sharing & borrowing may be use.

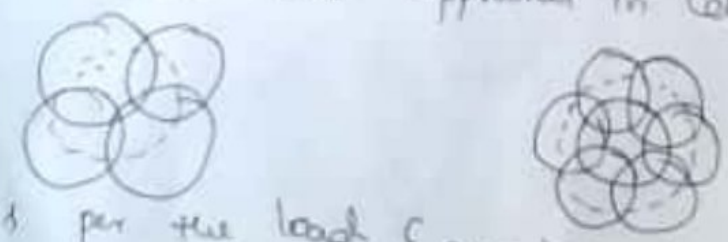
→ If all the above methods fails in handling the additional load then only option left out is cell splitting.

→ Dividing the big old cell site into several smaller new cell sites is cell-splitting.

→ After splitting, each part of old cell site is considered as full cell site.

→ No. of cell sites and the no. of channels in the system increases.

→ There are two approaches in cell splitting.



→ As per the load & requirement, different approaches can be used in cell splitting

→ Considering the 1st approach ie dividing old cell site to 4 new cell sites

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New cell area = $\frac{\text{old cell area}}{4}$

New cell radius = $\frac{\text{old cell radius}}{2}$

New traffic load handling = old traffic load handling X 4

→ There are two types of cell splitting
1. permanent splitting
2. Dynamic splitting.

Permanent Splitting:-

→ This is recommended for loads which are created on long term basis

→ After P.S, each new cell site must be equipped with an antenna & other elements on permanent basis

→ The existence of old cell site will not be there after permanent splitting. i.e., this process cannot be reversed.

Ex: If new business zones (or) slow parts are established in specific cell site area then permanent splitting is used to handle the additional load.

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Dynamic Splitting:-

→ This is recommended for the loads which are created on short term basis i.e., for the days/weeks.

→ The process of dynamic splitting is similar to the permanent splitting but the antenna/equipment installation is not concrete.

→ Portable cell sites are used in dynamic splitting i.e., a truck with antenna and all other necessary equipment installed.

→ The process of dynamic splitting is reversible i.e., old cell site can be restored after the completion of event.

Ex: Exhibition, fairs, and event in a stadium & etc needs dynamic splitting.

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Cellular Structures :-

Micro cell zone concept :-

→ In sectoring, cell site must be divided into sectors and appropriate antennas must be used designed for each sector.

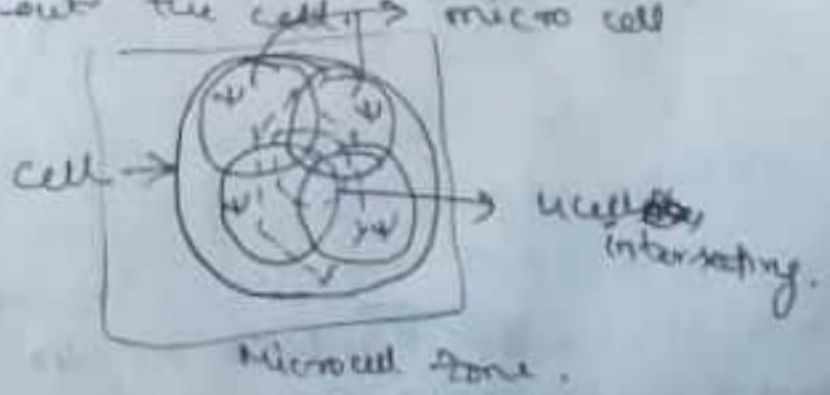
→ To avoid these issues of sectoring micro cell zone concept is used.

→ Improvement in coverage can be achieved by microcells i.e., conceptual division of a cell site.

→ Each microcell zone uses a directional antenna & it radiates the power into the cell site.

→ During a call if the mobile unit travels from one zone to other, then it retains the existing channel i.e., no hand off.

→ This mechanism offers good coverage at the boundaries & throughout the cell.



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→ It is called "Time division multiplexing"

→ freq. reuse in the Spain domain can be divided into two categories.

(i) Same freq assigned in two different geographic areas, such as AM or FM radio stations using the same freq. in different cities.

(ii) Same freq. repeatedly used in a same general area in one system is used in cellular systems.

(iii) Freq reuse distance:-

→ The min. distance which allows the same freq. to be reused will depend on many factors, such as a) the no. of cochannel cells.

b) the type of geographic terrain.

c) the antenna height

d) the transmitted power at each cell site.

→ The freq reuse distance

$$D = \sqrt{3k}\,R.$$

k is the freq reuse pattern.

$k = 4$; $D = 3.46R$

$k = 7$; $D = 4.6R$

$k = 12$; $D = 6R$

$k = 19$; $D = 7.55R$

→ If the cell sites transmitt the same power, then k increases and the freq reuse distance D increases.

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iii) Number of channels Customers in the System :-

→ The traffic conditions in the area during a busy hour are some of the parameters that will help determine both the sizes of different cells and the no. of channels in them.

→ The maximum no. of calls per hour per cell is driven by the traffic conditions at each particular cell.

→ After the max. no. of freq. channels per cell has been implemented in each cell.

Cell Sectoring :- coverage ↑

→ Improvement in coverage is difficult in omni directional antenna System, as it may leads to interference

→ Therefore to improve the coverage without getting interference directional antennas are required.

→ To use directional antennas in cellular system each cell must be divided into sectors.

→ There are two types of sectorization possible for each cell

i) 3- Sector case

ii) 6-Sector case.

3-Sector case :-

→ 3 Sector case requires 3 antenna elements. 120° beam reflectors are used as antennas.

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6-Sector case:-

In 6-sector case, 6 antenna elements are required & 60° ~~angle b/w antenna elements~~ beam reflectors are used as antenna

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Problem

An antenna has $D = 4$, $R_{rad} = 40\Omega$, $R_{dis} = 10\Omega$ Find antenna efficiency and maximum power gain

Given that,

For an antenna,

Directivity $D = 4$

Radiation resistance, $R_{rad} = 40\Omega$

dissipation resistance, $R_{dis} = 10\Omega$

Antenna efficiency $\eta = ?$

Max power gain, $G_{Power} = ?$

Then, the expression for efficiency of an antenna is given by

$$\text{Efficiency } \eta = \frac{R_{rad}}{R_{rad} + R_{dis}}$$

$$\eta = \frac{40}{40+10} = \frac{40}{50} = \frac{4}{5} = 0.8$$

$= 0.8 \times 100\%$

$= 80\%$

$$\boxed{\eta = 80\%}$$

Then, the expression for max power gain interms of directivity and efficiency of antenna is given by;

$G_{power} = \eta D$

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$G_{p(max)} = \eta D$

$= 0.8 \times 4$

$= 3.2$

And $G_{p(max)}(dB) = 10 \log_{10} (3.2$

$= 5.05\, dB$

$$\boxed{G_{p(max)} = 5.05\, dB}$$

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Problem

During busy hour, the number of calls per hour Q_i for each 10 cells is 2000, 1500, 3000, 500, 1000, 1200, 1800, 3200, 2600 & 800. Assume that 60% of the car phones will be used during this period and that one call is made per car phone. Find the no. of customers in the system.

Sol Given that,

In a cellular system during a busy hour, the number of calls per hour for each 10 cells is,

$Q_1 = 2000$; $Q_2 = 1500$; $Q_3 = 3000$; $Q_4 = 500$

$Q_5 = 1000$; $Q_6 = 1200$; $Q_7 = 1800$; $Q_8 = 3200$

$Q_9 = 2600$; $Q_{10} = 800$

The percentage of car phones used during the busy period, $\eta_c = 60\%$

Total no. of customers in the system $M_t = ?$

Then, the total no. of calls per hour per car phone is given by

$$Q = \sum_{i=1}^{10} Q_i$$

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$$Q_t = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6 + Q_7 + Q_8 + Q_9 + Q_{10}$$

$$= 2000 + 1500 + 3000 + 500 + 1000 + 1200 + 1800 + 3100 + 2600 + 800$$

$$= 17600$$

$Q_t = 17600$ calls per hour

$\therefore$ The total no. of customers in the system is given by

$$M_t = \frac{Q_t}{\eta_c}$$

$$= \frac{17600}{0.6}$$

$$= 29333.33$$

$$\boxed{M_t \cong 29334}$$

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Uniqueness of Mobile radio Environment :-

→ when compared to any other wireless communication system, few features are unique in mobile / cellular communication.

→ this includes.

1) propagation loss
2) Fading
3) Delay Spread
4) Coherence Bandwidth.

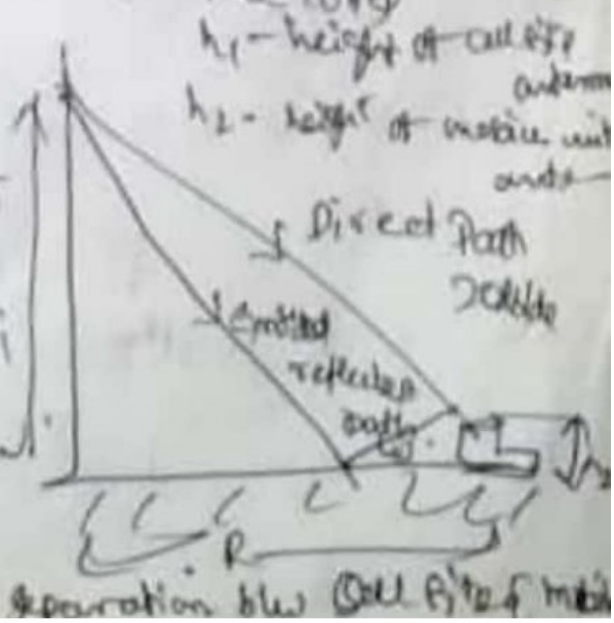
Propagation loss :-

→ propagation loss depends on the propagation distance.

→ If the distance is more the loss will be more

→ If the direct path is existing b/w cell site & Mobile unit, loss is considered as 20dB/dec

→ If the signal is hitting the ground propagation loss is considered as 40dB/dec



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→ If the signal is reflected from surface of the water loss will be either 20 dB/dec (or) 40 dB/dec for fresh water & salt water.

→ If the signal is propagating through the forest the loss will be 65 dB/dec.

Fading :-

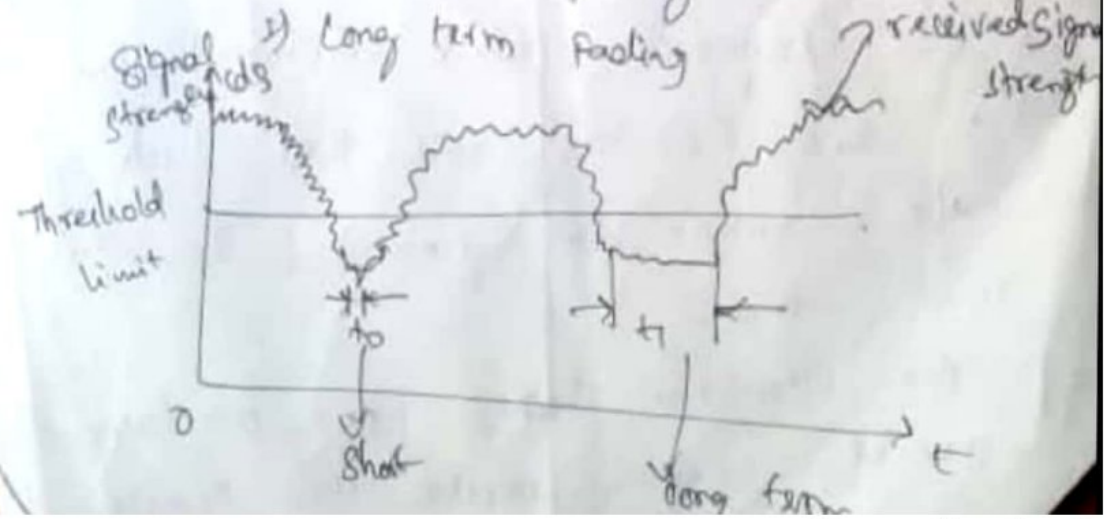
→ Variations in the received signal strength due to the channel characteristics is called as Fading

→ If the received signal strength is above the threshold then the effect of fading is negligible.

→ If the received signal strength is bellow the threshold, then the effect of fading must be reduced.

→ 2 types of fading

1) Short term fading
2) Long term fading



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Delay spread (Δ)

→ In multipath fading environment, due to the delay in the arrival rate of different paths, delay spread occurs.

Coherence bandwidth (β):-

→ It is the bandwidth in which either amplitude (or) phase of multipath signals are having high degree of similarity.

→ For fading amplitudes, the coherence bandwidth is given by

$$\beta_c = \frac{1}{2\pi\Delta}$$

→ Similarly for fading phases the

$$\beta_c' = \frac{1}{4\pi\Delta}.$$

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(1) Aslam SK

Hexagonal Shaped cells :-

→ the hexagonal shaped communication cells are artificial and that such a shape cannot be generated in the real world.

→ The circular shapes have overlapped areas which make the unclear

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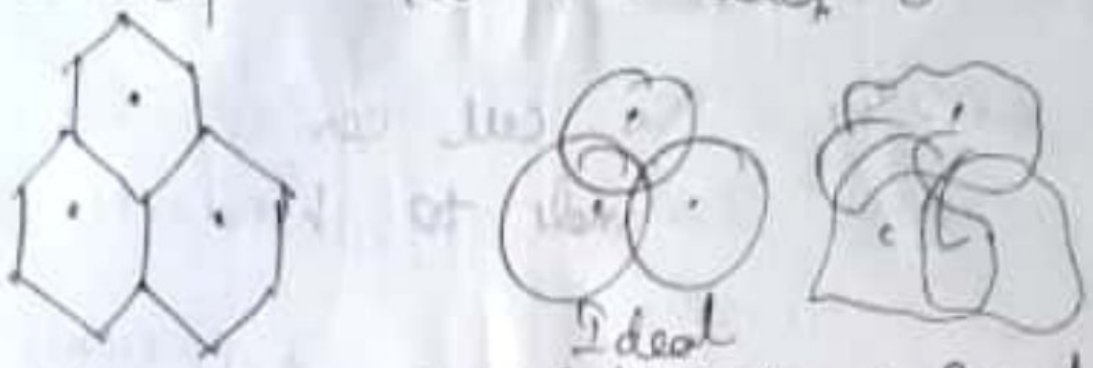
→ The hexagonal shaped cells fit the planned area nicely with no gap and no overlap. b/w the hexagonal cells



Fictious

→ our Engineers draw hexagonal shaped cells on layout to simplify the planning & design of a cellular system.

→ when compared to all the three shapes, the hexagonal cell shape has the largest area for a given distance b/w the perimeter pts and center of a polygon.

→ Hexa ~~gonal~~ shape is suitable for omni directional antennas, thus hexagonal shaped cells are widely accepted for mobile communication.

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