Semester Final Solutions

Lecture 4,5,6,7,8

Origin42 Final

2. a. What are the purpose of Trunking and GOS? Discuss the blocked calls cleared and blocked calls delayed system used to measure GOS. [5]

Solution: 024

Trunking: Trunking is the concept that allows a large number of users to share a relatively small number of channels in a cell.

GOS: The grade of service (GOS) is related to the ability of a mobile phone to access the trunked mobile phone system during the busiest hour.

Blocked Call Cleared (BCC/LCC) Systems:
When a user requests service, there is a minimal call set-up time and the user is given immediate access to a channel if one is available. If channels are already in use and no new channels are available, call is blocked without access to the system. The user does not receive service, but is free to try again later.

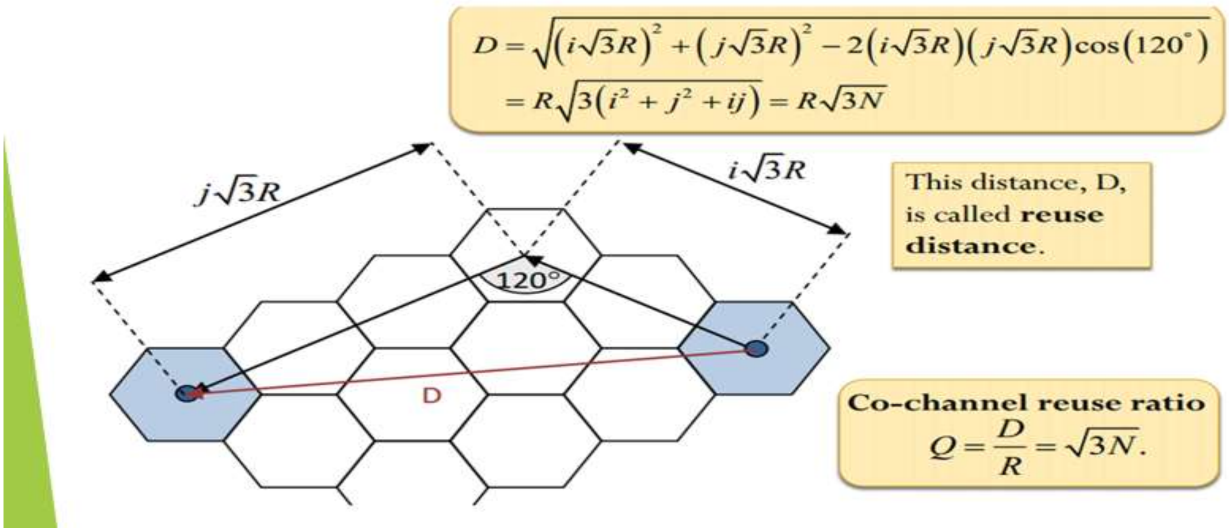
Blocked Call Delayed(BCD/LCD) Systems:
Queues are used to hold call requests that are initially blocked. When a user attempts a call and a channel is not immediately available, the call request may be delayed until a channel becomes available.

2. b. Describe the frequency reuse concept in cellular system. Prove that for a hexagonal geometry, the co-channel reuse ratio is given by $Q=\sqrt{(3N)}$, where $N = i^2 + ij + j^2$ and all symbols have their usual meaning. [5]

Solution: by Rabab 039

Frequency Reuse: By limiting the coverage area to within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated from one another by distances large enough to keep interference levels within tolerable limits.

Proof:



2. c. Suppose that a mobile station is moving at a speed of 72 km/hr along a straight line between base stations BS1 and BS2 with path loss 4. The received power at a reference distance 1 km is equal to 15 W. Let a cell radius of 1.5 km is the distance at which the power is at the threshold and a 3 second handoff time. [4]

i. Determine the minimum required margin Δ to assure that calls are not lost due to weak signal conditions during handoff.

ii. Describe the effects of the margin Δ on the performance of cellular systems.

Solution:
Toufique 116
i.
Gainrms

i. distance covered $= 3s \times 72\ km/hr$

$$= 3s \times \frac{72 \times 1000}{3600}\ ms^{-1}$$

$$= 60m$$

$$P_r(\text{min useable}) = P_0 - 10n\log d \quad \ldots\ldots (i)$$

$$P_r(\text{handoff}) = P_0 - 10n\log(d - 60) \quad \ldots\ldots (ii)$$

(ii) − (i),

$$\Delta = -10n\log(d-60) + 10n\log d$$

$$= 10n\log\left(\frac{d}{d-60}\right)$$

$$= 10n\log\left(\frac{1500}{1500-60}\right) \quad \left[\because \text{Power at threshold at } 1.5km\right]$$

$$= 10 \times 4 \times \log\frac{1500}{1440}$$

$$= 0.71\ dB$$

ii.

Figure 3.3 Illustration of a handoff scenario at cell boundary.

- Δ can not be too large
  - b/c unnecessary handoffs which burden the MSC may occur
- Δ can not be too small
  - There may be insufficient time to complete a handoff before a call is lost due to weak signal conditions.

3. a. What is adjacent-channel interference? Discuss the problem of near-far effect. How can it be solved? [4]

Solution: by Rabab 039 (correct if necessary)

Interference resulting from signals which are adjacent in frequency to the desired signal is called adjacent channel interference.

Near-Far Effect happens when an interferer close to the base station radiates in the adjacent channel while the subscriber is actually far away from the base station. In this case, a problem arises where the SIR becomes very low; it shows negative decibel value. It can be solved by Power Control. There are 2 types of power control mechanism:

1. Closed-Loop: BS makes power adjustment decisions and communicates to MU, which adjusts its signal strength for the reverse (mobile to BS) channel.
2. Open-Loop: MU monitors the RSS of the pilot (continuous unmodulated signal from BS) and sets the transmitted power in the reverse channel.

3. b. Show that cell sectoring decreases co-channel ratio, trunking efficiency, increases SIR which in turn decreases the cluster size and hence increases the capacity. [4]

Solution: 039 (from slide)

Increases SIR and capacity:

Without Sectoring: N = 7 and n= 4, SIR = $sqrt(3N)^4/i$ = $sqrt(3x7)^4/6$ = 18.66dB
With 120 Sectoring: N = 7 and n = 4, SIR = 24.2 dB. If we need 18 db then we can reduce N. Reducing N will increase capacity.

Decreases Q, trunking efficiency:

Consider a cellular system in which:

- An average call lasts 2 minutes, the probability of blocking is to be no more than 1%. Assume that every subscriber makes 1 call per hour, on average.
- If there are a total of 395 traffic channels for a 7-cell reuse system, there will be about 57 traffic channels per cell.
- Assume that blocked calls are cleared so the blocking is described by the Erlang B distribution. From the Erlang B distribution, it can be found that **the unsectored system** may handle

44.2 Erlangs or 1326 calls per hour.

- Now employing **120° sectoring**, there are only **19 channels per antenna sector (57/3 antennas).**
- For the same probability of blocking and average call length, it can be found from the Erlang B distribution that each sector can handle

11.2 Erlangs or 336 calls per hour.

- Since each cell consists of 3 sectors, this provides a cell capacity:

3 X 336 = 1008 calls per hour,

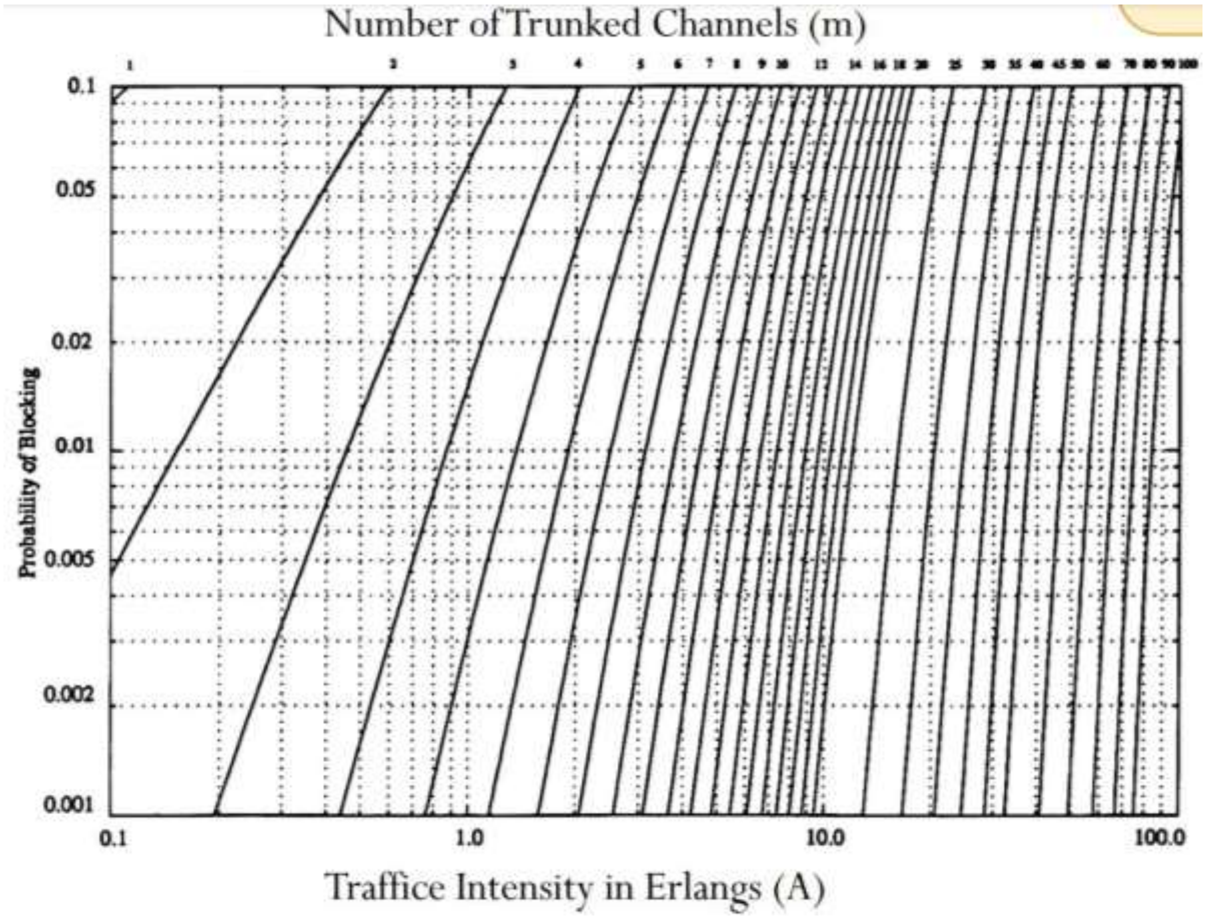
which amounts to a **24%** decrease compared to the unsectored case.

- **Thus, sectoring decreases the trunking efficiency while improving the S/I for each user in the system.**

3. c. A city has a population of 3 million people that are evenly distributed over an area of 1000 km². We know that a percentage of the population is subscribed to a cellular system. Assume that the cellular system is an Erlang B system with a total band of 14 MHz, full duplex channel bandwidth of 40 kHz, covers the city using hexagonal cells with radius 2 km, and a cluster size of 7 cells. Assume that each user makes 1 call each 2 hours with average call duration of 1 minute and the desired probability of call blocking is 0.005. Find:

a. The total number of cells in the system
b. The number of channels per cell
c. The total number of channels in the system
d. Traffic intensity per cell
e. Maximum carried traffic for the whole system
f. The total number of users who can use the system. [6]

Erlang-B Chart:



Solution: 024

a.

Total area = 1000 km^2

Hexagonal cell radius, R = 2 km

Hexagonal cell area = (3 x sqrt(3) / 2) x R^2 = 6 sqrt(3) km^2

The total number of cells in the system = 1000 / 6 sqrt(3) = 96.2250 ~ 96

b.

Total bandwidth, = 14 MHz

Full duplex channel bandwidth = 40 kHz

Cluster size, N = 7

The number of channels per cell, C = 14 MHz / (40 kHz x 7) = 50

c.

The total number of channels in the system = 96 x 50 = 4800

d.

From graph, using C = 50, Pr = 0.005,

Traffic intensity per cell, A = 37 Erlang/cell

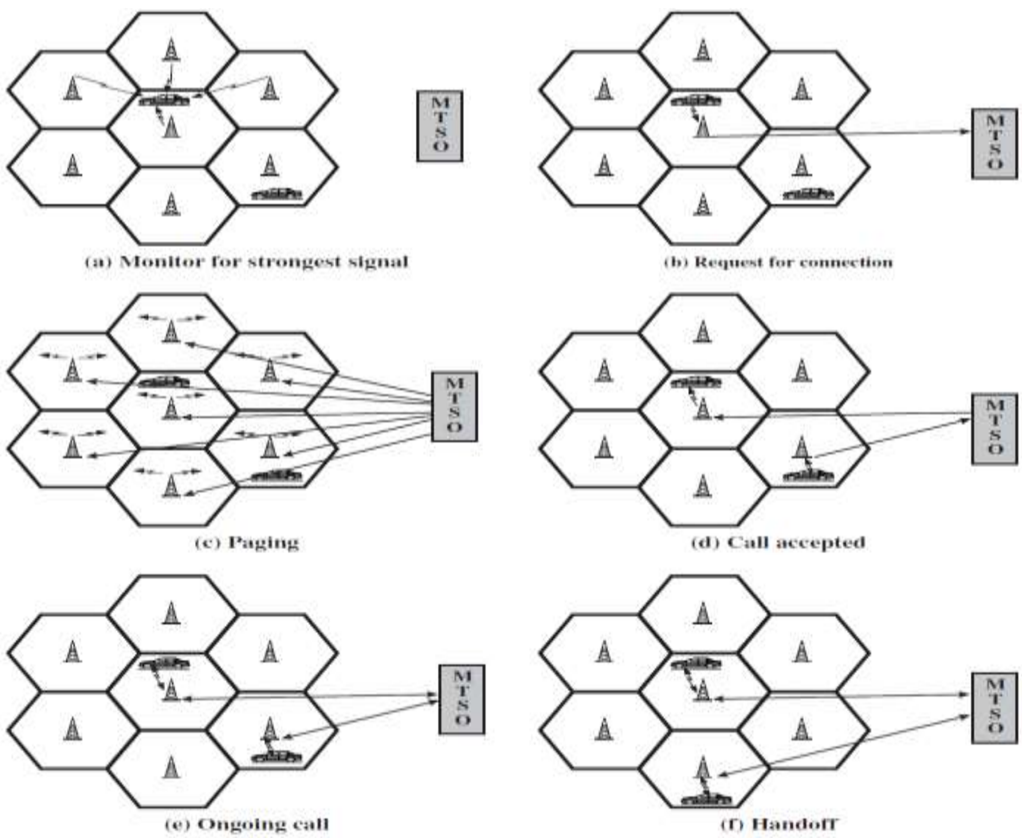
e.
Maximum carried traffic for the whole system = 96 x 37 = 3552

f.
lambda = 1 call each 2 hour = 0.5 call/hour
H = average duration = 1 min = 1/60 hour
Traffic per user, Au = lambda x H = 0.5 call/hour x 1/60 hour = 1/120
A = U x Au => User, U = A / Au = 37 / (1/120) = 4440 user
The total number of users who can use the system = 4440 user x 96 cell = 426240

Enigma41 Final

2. a. Illustrate with figure the steps (mobile unit initialization, mobile originated call, paging, call accepted and ongoing call) in a typical call between two mobile users within an area controlled by a single MTSO. [5]

Solution: O24



• **Mobile unit initialization:** When the mobile unit is turned on, it scans and selects the strongest setup control channel used for this system (Figure 10.6a). Cells with different frequency bands repetitively broadcast on different setup channels. The receiver selects the strongest setup channel and monitors that channel. The effect of this procedure is that the mobile unit has automatically selected the BS antenna of the cell within which it will operate. Then a handshake takes place between the mobile unit and the MTSO controlling this cell, through the BS in this cell. The handshake is used to identify the user and register its location. As long as the mobile unit is on, this scanning procedure is repeated periodically to account for the motion of the unit. If the unit enters a new cell, then a new BS is selected. In addition, the mobile unit is monitoring for pages, discussed subsequently.

• **Mobile-originated call:** A mobile unit originates a call by sending the number of the called unit on the preselected setup channel (Figure 10.6b). The receiver at the mobile unit first checks that the setup channel is idle by examining information in the forward (from the BS) channel. When an idle is detected, the mobile may transmit on the corresponding reverse (to BS) channel. The BS sends the request to the MTSO.

• **Paging:** The MTSO then attempts to complete the connection to the called unit. The MTSO sends a paging message to certain BSs depending on the called mobile number (Figure 10.6c). Each BS transmits the paging signal on its own assigned setup channel.

• **Call accepted:** The called mobile unit recognizes its number on the setup channel being monitored and responds to that BS, which sends the response to the MTSO. The MTSO sets up a circuit between the calling and called BSs. At the same time, the MTSO selects an available traffic channel within each BS's cell and notifies each BS, which in turn notifies its mobile unit (Figure 10.6d). The two mobile units tune to their respective assigned channels.

• **Ongoing call:** While the connection is maintained, the two mobile units exchange voice or data signals, going through their respective BSs and the MTSO (Figure 10.6e).

• **Handoff:** If a mobile unit moves out of range of one cell and into the range of another during a connection, the traffic channel has to change to one assigned to the BS in the new cell (Figure 10.6f). The system makes this change without either interrupting the call or alerting the user.

2. b. Why does frequency reuse important and how is it achieved while designing a cellular network? Describe with an example. [5]

Solution:

2. c. Assume a system of 128 cells with a cell radius of 0.8 km, a total frequency bandwidth that supports 336 traffic channels, and a reuse factor of N = 7. [4]

i) What geographic area is covered by the system?

ii) How many channels are there per cell?

iii) What is the capacity of the system?

Solution: 024

a.

Hexagonal cell radius, R = 0.8 km

Hexagonal cell area = (3 x sqrt(3) / 2) x R^2 = 24 sqrt(3) / 25 km^2

Total area = 128 x 24 sqrt(3) / 25 km^2 = 212.8344032 km^2

b.

Total channel = 336

Cluster size, N = 7

The number of channels per cell, C =336 / 7 = 48

c.

Capacity of the system = 128 x 48 = 6144

4. a. Describe co-channel interference and its importance with respect to SNR. Prove that for a hexagonal geometry, the signal to interference ratio is given by SIR= √(3N)/io. Symbols have their usual meaning. [5]

Solution: by Rabab 039 (add information if necessary)

The interference between signals from co-channel cells (cells that use the same frequency bands) is called Co-Channel Interference (CCI).

SNR is an important issue in terms of CCI. As the SNR lowers, CCI increases, creating a problem. The number of co-channels is thus necessary to calculate the SNR or SIR:

$$\mathbf{SIR} = \mathbf{S/\ I} = \frac{S}{\sum_{i=1}^{i_0} I_i}$$

When the transmit power of each base station is equal and the path loss exponent is the same throughout the coverage area, *S/I* for a mobile can be approximated as

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}$$

Considering only the first layer of interfering cells, if all the interfering base stations are equidistant from the desired base station and if this distance is equal to the distance *D* between cell centers, then Equation simplifies to

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

4. b. Briefly discuss Microcell zone concept and show that Microcell zone concept decreases co-channel ratio, increases SIR which in turn decreases the cluster size and hence increase the capacity. [5]

Solution:087

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Microcell Zone Concept:

For single zone,
N = 7, Dz/Rz = Q = sqrt(3N) = 4.6, SIR = Q^4/i = 4.6 ^4/6 = 18.66 dB

For 3 zone form a group or cell,
From figure we can identify N = 3, D/R = Q = 3, SIR = Q^4/i=1; SIR =
20dB
Here, I = 1 coz directional antenna and radiates in to cell makes only
one co cell interference.
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4. c. Consider a cellular system in which an average call lasts 2 minutes, the probability of blocking is to be no more than 1% and every subscriber makes 1 call per hour on average. Assume that there are a total of 395 traffic channels for a 7-cell reuse system. Show that 120° sectoring decreases trunking efficiency. [4]

Solution: 024

Total traffic channel = 395
Cluster size, N = 7
lambda = 1 call per hour = 1 call/hour
H = average duration = 2 min
Pr <= 1%

Traffic channel per cell, C = 395 / 7 = 56.42857143 ~ 57

From Erlang B graph, using C = 57, Pr = 0.01,
Traffic intensity per cell, A = 44.2 Erlang/cell

Traffic per user, Au = lambda x H = 1 call/hour x 2/60 hour = 1/30
A = U x Au => User, U = A / Au
Users who can use the system = 44.2 / (1/30) = 1326 user

Now employing 120° sectoring, each cell will be divided into 3 sectors.

So, 57/3 = 19 channels per antenna sector

From Erlang B graph, using C = 19, Pr = 0.01,
Traffic intensity per cell, A = 11.2 Erlang/cell
Per sector user = 11.2 / (1/30) = 336
Since each cell consists of 3 sectors, this provides a cell capacity of 3 × 336 = 1008 user

So, 120° sectoring decreases trunking efficiency by = (1 – (1008 / 1326))x100 % = 24%

Recursive40 Final

2. a. What is cell? What are the features of cellular system? While organizing a cellular network, which pattern is used as a shape of a cell and why? [5]

Solution: 130

Cell: A large geographic area is divided into small areas called cells.

Features of cellular system:
1.High capacity – offer very high capacity in a limited spectrum.
2.Frequency reuse – same frequency in many cell sites.
3.Cellular expansion – easy to add new cells.
4.Handover – moving between cells.
5.Roaming between networks.
6.Communication is always between mobile and base station (not directly between mobiles).

Hexagon
- Provides equidistant antennas.
- Cover an entire area without overlapping.
- Cover the entire geographical region without any gaps.
- More neighbors

2. b. Describe the channel assignment strategy for dynamic channel assignment and channel borrowing strategy for fixed channel assignment technique. [5]

Solution: 039
Assignment Strategy for dynamic channel assignment:

1. MSC monitors all cells and all channels,
2. Each time a call request is made, serving BS requests a channel from the MSC,
3. MSC runs an algorithm that takes into account:
   a. Possibility of future blocking in cells
   b. Frequency being used for channel
   c. The reuse distance of the channel
4. MSC assigns a channel only if it is not used and if it will not cause co-channel interference with any cell in range,

Borrowing strategy for fixed channel assignment:

a) Cells in this strategy are allowed to borrow channels from adjacent cells if their channels are fully occupied while adjacent cells have free channels,

b) MSC (Mobile Switching Center) monitors the process and gives permission to borrowing cell to borrow channels putting in mind (i) donating cell is not affected by the borrowing process, (ii) no interference will occur by moving the channel from one cell to another.

2.c. If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular system which uses two 25 KHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if system uses 4 cell reuse. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell. [4]

Solution: O24

Total bandwidth = 33 MHz
Channel bandwidth = 25 kHz × 2 simplex channels = 50 kHz
Total available channels = 33 MHz / 50 kHz = 660 channels

N = 4
Total number of channels available per cell = 660/4 ≈ 165 channels

Control channel bandwidth = 1 MHz
Total control channels = 1 MHz / 50 kHz = 20 channels

So, total voice channels = 660 - 20 = 640 channels

As, N = 4

Total number of voice channel per cell = 640/4 = 160 channels
Total number of control channel per cell = 20/4 = 5 channels

(However, each cell only needs a single control channel. The control channels have a greater reuse distance than the voice channels. Thus, one control channel and 160 voice channels would be assigned to each cell.)

3. a. Briefly explain any three handoff' strategies to process handoff from base station A to base station. B. [5]

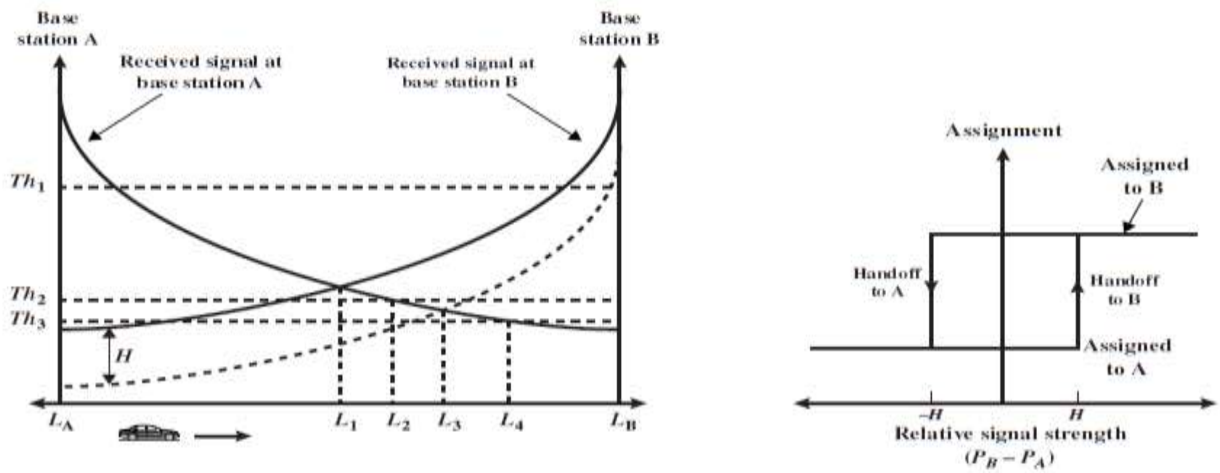
Solution: O24

Relative Signal Strength (Pnew> Pold):
This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. SS fluctuates due to multipath effects.
Problem: This may result in a ping-pong effect.

Relative Signal Strength with Threshold (Pnew> Pold and Pold< T):
Introduces a threshold value to overcome the ping-pong effect. This method allows a MS to hand off only if the current signal is sufficiently weak (less than threshold) and the other is the stronger of the two.

Relative Signal Strength with Hysteresis (Pnew> Pold + H):
This scheme allows a user to hand off only if the new BS is sufficiently stronger by a hysteresis margin H than the current one. Prevents the ping-pong effect, because once handoff occurs, the effect of the margin H is reversed. Handoff mechanism has two states 1) While the MU is assigned to BS A, the mechanism will generate a handoff when the relative SS reaches or exceeds the H. 2) Once the MU is assigned to B, it remains so until the relative SS strength falls below –H, at which point is handed back to A.

Relative SS with hysteresis and Threshold (Pnew> Pold+ H and Pold< T):
Handoff occurs only if the current signal level drops below a threshold, and the target BS is stronger than the current one by a hysteresis margin H.



(a) Handoff decision as a function of handoff scheme

(b) Hysteresis mechanism

3.

b) Suppose that a mobile station is moving along a straight line between BS_1 a
The distance between the base station is D =2000 m. Consider that the m
currently in BS_1 and is moving toward a handoff to BS_2. Assume, the minimum
signal level for acceptable voice quality at base station receiver is P_r, min =
and threshold level used by Mobile Switching Center for handoff initiation is
-90 dBm. Determine the minimum required signal margin Δ and illustrate th
of the signal margin on the performance of cellular networks.

Solution:
(Toufique 116)
Given,
Pr(min useable) = –88 dBm
Pr(handoff) = -90 dBm
Margin, Δ= Pr(handoff) - Pr(min useable) = -90 + 88 = -2 dBm

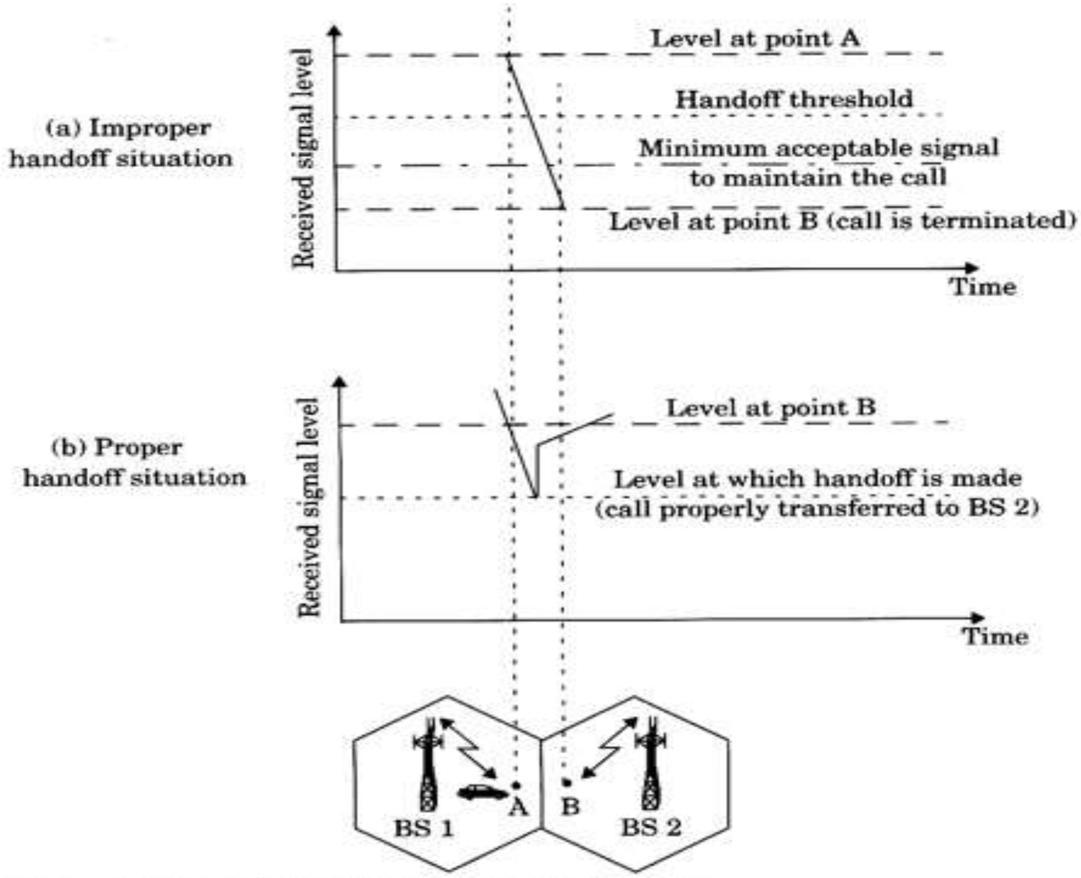


Figure 3.3 Illustration of a handoff scenario at cell boundary.

- Δ can not be too large
  - b/c unnecessary handoffs which burden the MSC may occur
- Δ can not be too small
  - There may be insufficient time to complete a handoff before a call is lost due to weak signal conditions.

3.c. If Signal to interference ratio (SIR) of 15 dB is required for satisfactory forward link performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is n = 4? Assume that the mobile receiver is located at the boundary of its omnidirectional operating cell. Use suitable approximation. [4]

Solution: by Rabab 039 (correct if necessary)

Recursive 40, #3 ©

Required $SIR_{dB} = 15$ dB

for $n = 4$,

If we assume $N = 7$, then,

co-channel reuse ratio, $Q = \frac{D}{R} = \sqrt{3N} = \sqrt{21}$

Now, for receiver at the boundary of the cell,

$$SIR = \frac{1}{2(Q-1)^{-n} + 2(Q+1)^{-n} + 2Q^{-n}}$$

$$= \frac{1}{2(\sqrt{21}-1)^{-4} + 2(\sqrt{21}+1)^{-4} + 2(\sqrt{21})^{-4}}$$

$$= 53.375$$

$\therefore SIR_{dB} = 10 \log_{10}(53.375) = 17.273$

As this is greater than required SIR, $N = 7$ can be used.