

IN THIS TWO
DIFFERENT
MATERIALS
AVAILABLE

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UNIT-V

HANDOFFS

WHY HAND OFF IS NECESSARY

In an analog system, once a call is established, the set-up channel is not used again during the call period. Therefore, handoff is always implemented on the voice channel. In the digital systems, the handoff is carried out through paging or common control channel. The value of implementing handoffs is dependent on the size of the cell. For example, if the radius of the cell is 32 km (20 mi), the area is 3217 km^2 (1256 mi^2). After a call is initiated in this area, there is little chance that it will be dropped before the call is terminated as a result of a weak signal at the coverage boundary. Then why bother to implement the handoff feature? Even for a 16-km radius, cell handoff may not be needed. If a call is dropped in a fringe area, the customer simply redials and reconnects the call. Today the size of cells becomes smaller in order to increase capacity. Also people talk longer. The handoffs are very essential. Handoff is needed in two situations where the cell site receives weak signals from the mobile unit: (1) at the cell boundary, say, -100 dBm , which is the level for requesting a handoff in a noise-limited environment; and (2) when the mobile unit is reaching the signal-strength holes (gaps) within the cell site as shown in Fig.1.

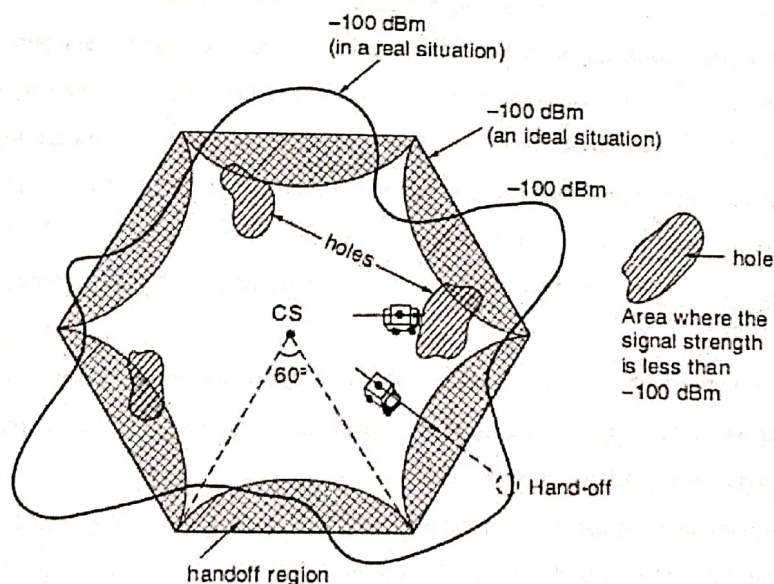


Fig.1. Occurrence of handoffs

WHAT ARE THE TWO DECISION MAKING PARAMETERS OF HANDOFF EXPLAIN

There are two decision-making parameters of handoff: (1) that based on signal strength and (2) that based on carrier-to-interference ratio. The handoff criteria are different for these two types. In type 1, the

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signal-strength threshold level for handoff is -100 dBm in noise-limited systems and -95 dBm in interference-limited systems. In type 2, the value of C/I at the cell boundary for handoff should be at a level, 18 dB for AMPS in order to have toll quality voice. Sometimes, a low value of C/I may be used for capacity reasons.

Type 1: It is easy to implement. The location receiver at each cell site measures all the signal strengths of all receivers at the cell site. However, the received signal strength (RSS) itself includes interference.

$$RSS = C + I$$

where C is the carrier signal power and I is the interference. Suppose that we set up a threshold level for RSS; then, because of the I, which is sometimes very strong, the RSS level is higher and far above the handoff threshold level. In this situation handoff should theoretically take place but does not. Another situation is when I is very low but RSS is also low. In this situation, the voice quality usually is good even though the RSS level is low, but since RSS is low, unnecessary handoff takes place. Therefore, it is an easy but not very accurate method of determining handoffs. Some analog systems use SAT information together with the received signal level to determine handoffs. Some CDMA systems use pilot channel information.

Type 2: Handoffs can be controlled by using the carrier-to-interference ratio C/I $C+I/I = C/I$

we can set a level based on C/I, so C drops as a function of distance but I is dependent on the location. If the handoff is dependent on C/I, and if the C/I drops, it does so in response to increase in (1) propagation distance or (2) interference. In both cases, handoff should take place. In today's cellular systems, it is hard to measure C/I during a call because of analog modulation. Sometimes we measure the level I before the call is connected, and the level C + I during the call. Thus $(C + I)/I$ can be obtained.

TYPES OF HANDOFF

There are four types of handoff:

1. INTERSECTOR OR SOFTER HANDOFF.

The mobile communicates with two sectors of the same cell (see Fig. 10-1). A RAKE receiver at the base station combines the best versions of the voice frame from the diversity antennas of the two sectors into a single traffic frame.

2. INTERCELL OR SOFT HANDOFF.

The mobile communicates with two or three sectors of different cells (see Fig. 10-2). The base station that has the direct control of call processing during handoff is referred to as the primary base station. The primary base station can initiate the forward control message. Other base stations that do not have control over call processing are called the secondary base stations. Soft handoff ends when either the primary or secondary base station is dropped. If the primary base station is dropped, the secondary base station becomes the new primary for this call. A three-way soft handoff may end by first dropping one of the base stations and becoming a two-way soft handoff. The base stations involved coordinate handoff by

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exchanging information via SS7 links. A soft handoff uses considerably more network resources than the softer handoff.

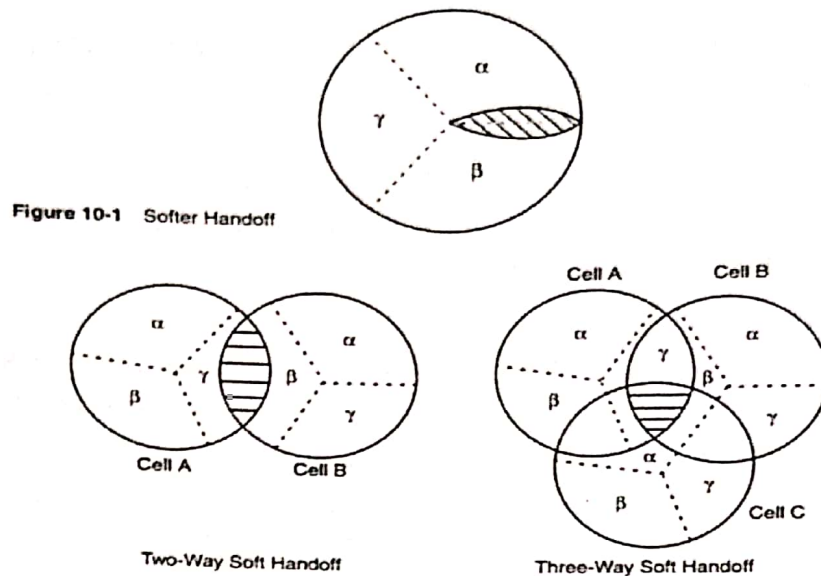


Figure 10-1 Softer Handoff

Figure 10-2 Soft Handoff

3. SOFT-SOFTER HANDOFF.

The mobile communicates with two sectors of one cell and one sector of another cell (see Fig. 10-3). Network resources required for this type of handoff include the resources for a two-way soft handoff between cell A and B plus the resources for a softer handoff at cell B.

4. HARD HANDOFF.

Hard handoffs are characterized by the break-before-make strategy. The connection with the old traffic channel is broken before the connection with the new traffic channel is established. Scenarios for hard handoff include

- ◆ Handoff between base stations or sectors with different CDMA carriers
- ◆ Change from one pilot to another pilot without first being in soft handoff with the new pilot (disjoint active sets)
- ◆ Handoff from CDMA to analog, and analog to CDMA
- ◆ Change of frame offset assignment—CDMA traffic frames are 20 ms long. The start of frames in a particular traffic channel can be at 0 time in reference to a system or it can be offset by up to 20 ms (allowed in IS-95). This is known as the frame offset. CDMA traffic channels are assigned different frame offset to avoid congestion. The frame offset for a particular traffic channel is communicated to the mobile. Both forward and reverse links use this offset. A change in offset

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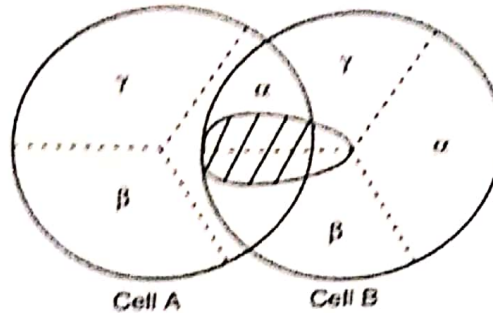


Figure 10-3 Soft-Soft Handoff

Assignment will disrupt the link. During soft handoff the new base station must allocate the same frame offset to the mobile as assigned by the primary base station. If that particular frame offset is not available, a hard handoff may be required. Frame offset is a network resource and can be used up

HANDOFF INITIATION

A hard handoff occurs when the old connection is broken before a new connection is activated. The performance evaluation of a hard handoff is based on various initiation criteria [1, 3, 13]. It is assumed that the signal is averaged over time, so that rapid fluctuations due to the multipath nature of the radio environment can be eliminated. Numerous studies have been done to determine the shape as well as the length of the averaging window and the older measurements may be unreliable. Figure 1.2 shows a MS moving from one BS (BS1) to another (BS2). The mean signal strength of BS1 decreases as the MS moves away from it. Similarly, the mean signal strength of BS2 increases as the MS approaches it. This figure is used to explain various approaches described in the following subsection.

1.3.1 RELATIVE SIGNAL STRENGTH

This method selects the strongest received BS at all times. The decision is based on a mean measurement of the received signal. In Figure 1.2, the handoff would occur at position A. This method is observed to provoke too many unnecessary handoffs, even when the signal of the current BS is still at an acceptable level.

1.3.2 RELATIVE SIGNAL STRENGTH WITH THRESHOLD

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. The effect of the threshold depends on its relative value as compared to the signal strengths of the two BSs at the point at which they are equal. If the threshold is higher than this value, say T1 in Figure 1.2, this scheme performs exactly like the relative signal strength scheme, so the handoff occurs at position A. If the threshold is lower than this value, say T2 in Figure 1.2, the MS would delay handoff until the current signal level crosses the threshold at position B. In the case of T3, the delay may be so long that the MS drifts too far into the new cell.

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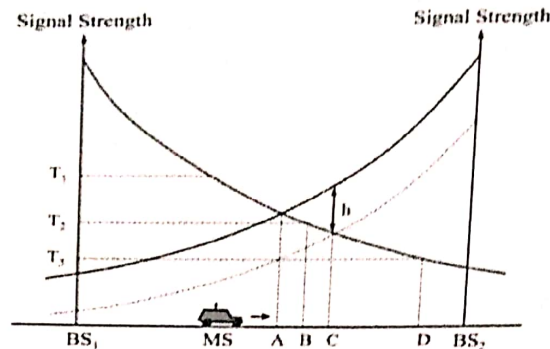


Figure 1.2 Signal strength and hysteresis between two adjacent BSs for potential handoff.

This reduces the quality of the communication link from BS1 and may result in a dropped call. In addition, this results in additional interference to cochannel users. Thus, this scheme may create overlapping cell coverage areas. A threshold is not used alone in actual practice because its effectiveness depends on prior knowledge of the crossover signal strength between the current and candidate BSs.

1.3.3 RELATIVE SIGNAL STRENGTH WITH HYSTERESIS

This scheme allows a user to hand off only if the new BS is sufficiently stronger (by a hysteresis margin, h in Figure 1.2) than the current one. In this case, the handoff would occur at point C. This technique prevents the so-called ping-pong effect, the repeated handoff between two BSs caused by rapid fluctuations in the received signal strengths from both BSs. The first handoff, however, may be unnecessary if the serving BS is sufficiently strong.

1.3.4 RELATIVE SIGNAL STRENGTH WITH HYSTERESIS AND THRESHOLD

This scheme hands a MS over to a new BS only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin. In Figure 1.2, the handoff would occur at point D if the threshold is T_3 .

1.3.5 PREDICTION TECHNIQUES

Prediction techniques base the handoff decision on the expected future value of the received signal strength. A technique has been proposed and simulated to indicate better results, in terms of reduction in the number of unnecessary handoffs, than the relative signal strength, both without and with hysteresis, and threshold methods.

CONCEPT OF DELAYING A HANDOFF

In many cases, a two-handoff-level algorithm is used. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available cell could take the call. A plot of signal strength with two request handoff levels and a threshold level is shown in Fig.3. The plot of average signal strength is recorded on the channel received

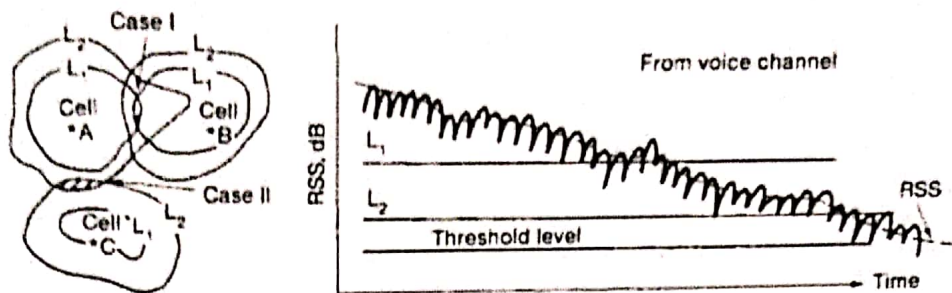


Fig.3. A two level handoff scheme

Signal strength indicator (RSSI), which is installed at each channel receiver at the cell site. When the signal strength drops below the first handoff level, a handoff request is initiated. If for some reason the mobile unit is in a hole (a weak spot in a cell) or a neighboring cell is busy, the handoff will be requested periodically every 5 s. At the first handoff level, the handoff takes place if the new signal is stronger. However, when the second handoff level is reached, the call will be handed off with no condition. The MSO always handles the handoff call first and the originating calls second. If no neighboring calls are available after the second handoff level is reached, the call continues until the signal strength drops below the threshold level; then the call is dropped. In AMPS systems if the supervisory audio tone (SAT) is not sent back to the cell site by the mobile unit within 5 s, the cell site turns off the transmitter.

ADVANTAGES OF DELAYED HANDOFF

1. Consider the following example. The mobile units are moving randomly and the terrain contour is uneven. The received signal strength at the mobile unit fluctuates up and down. If the mobile unit is in a hole for less than 5 s (a driven distance of 140 m for 5 s, assuming a vehicle speed of 100 km/h), the delay (in handoff) can even circumvent the need for a handoff. If the neighboring cells are busy, delayed handoff may take place. In principle, when call traffic is heavy, the switching processor is loaded, and thus a lower number of handoffs would help the processor handle call processing more adequately. Of course, it is very likely that after the second handoff level is reached, the call may be dropped with great probability.
2. The other advantage of having a two-handoff-level algorithm is that it makes the handoff occur at the proper location and eliminates possible interference in the system. Figure 3, case I, shows the area where the first-level handoff occurs between cell A and cell B. If we only use the second-level handoff boundary of cell A, the area of handoff is too close to cell B. Figure 3, case II, also shows where the second-level handoff occurs between cell A and cell C. This is because the first-level handoff cannot be implemented.

POWER DIFFERENCE HANDOFF

A better algorithm is based on the power difference (Δ) of a mobile signal received by two cell sites, home and handoff. Δ can be positive or negative. The handoff occurs depending on a preset value of Δ .

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- Δ = the mobile signal measured at the candidate handoff site
- Δ - The mobile signal measured at the home site

For example, the following cases can occur.

- $\Delta > 3$ dB request a handoff
- $1 \text{ dB} < \Delta < 3$ dB prepare a handoff
- $-3 \text{ dB} < \Delta < 0$ dB monitoring the signal strength
- $\Delta < -3$ dB no handoff

Those numbers can be changed to fit the switch processor capacity. This algorithm is not based on the received signal strength level, but on a relative (power difference) measurement. Therefore, when this algorithm is used, all the call handoffs for different vehicles can occur at the same general location in spite of different mobile antenna gains or heights.

FORCED HANDOFF

A forced handoff is defined as a handoff that would normally occur but is prevented from happening, or a handoff that should not occur but is forced to happen.

MOBILE-ASSISTED HANDOFF

In a mobile-assisted handoff process, the MS makes measurements and the network makes the decision. In the circuit switched GSM (global system mobile), the BS controller (BSC) is in charge of the radio interface management. This mainly means allocation and release of radio channels and handoff management. The handoff time between handoff decision and execution in such a circuit-switched GSM is approximately 1 second.

SOFT HANDOFF

SOFT HANDOFF (FORWARD LINK)

In this case all traffic channels assigned to the mobile are associated with pilots in the active set and carry the same traffic information with the exception of power control subchannel. When the active set contains more than one pilot, the mobile provides diversity by combining its associated forward traffic channels.

SOFT HANDOFF (REVERSE LINK)

During intercell handoff, the mobile sends the same information to both base stations. Each base station receives the signal from the mobile with appropriate propagation delay. Each base station then transmits the received signal to the vocoder/selector. In other words, two copies of the same frame are sent to the vocoder/selector. The vocoder/selector selects the better frame and discards the other.

SOFTER HANDOFF (REVERSE LINK)

During intersector handoff, the mobile sends the same information to both sectors. The channel card/element at the cell site receives the signals from both sectors. The channel card combines both inputs, and only one frame is sent to the vocoder/selector. It should be noted that extra channel cards are not required to support softer handoff as is the case for soft handoffs. The diversity gain from soft handoffs is more than the

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diversity gain from softer handoffs because signals from distinct cells are less correlated than signals from sectors of the same cell.

10.2.4 BENEFIT OF SOFT HANDOFF

A key benefit of soft handoff is the path diversity on the forward and reverse traffic channels. Diversity gain is obtained because less power is required on the forward and reverse links. This implies that total system interference is reduced. As a result, the average system capacity is improved. Also less transmit power from the mobile results in longer battery life and longer talk time. In a soft handoff, if a mobile receives an up power control bit from one base station and a down control bit from the second base station, the mobile decreases its transmit power. The mobile obeys the power down command since a good communications link must have existed to warrant the command from the second base station.

INTERSYSTEM HANDOFF

Occasionally, a call may be initiated in one cellular system (controlled by one MSO) and enter another system (controlled by another MSO) before terminating. In some instances, intersystem handoff can take place; this means that a call handoff can be transferred from one system to a second system so that the call is continued while the mobile unit enters the second system. The software in the MSO must be modified to apply this situation. Consider the simple diagram shown in Fig.7. The car travels on a highway and the driver originates a call in system A. Then the car leaves cell site A of system A and enters cell site B of system B. Cell sites A and B are controlled by two different MSOs. When the mobile unit signal becomes weak in cell site A, MSO A searches for a candidate cell site in its system and cannot find one. Then MSO A sends

The handoff request to MSO B through a dedicated line between MSO A and MSO B, and MSO B makes a complete handoff during the call conversation. This is just a one-point connection case. There are many ways of implementing intersystem handoffs, depending on the actual circumstances. For instance, if two MSOs are manufactured by different companies, then compatibility must be determined before implementation of intersystem handoff can be considered.

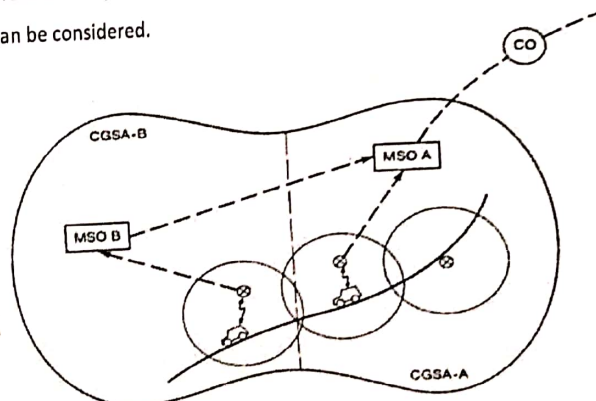


Fig.7. Intersystem handoffs

Unit - 5

Hand off Strategies

- Concept of Handoff
- Types of Handoff
- Hand off Initiation
- delaying Handoff
- Forced Handoff
- Mobile Assigned Handoff (MAHO)
- Inter System Handoff
- Vehicle locating Methods
- Dropped call rates and their evaluation

Unit - V

HAND OFF STRATEGIES

Concept of Handoff :-

→ During a call, if the mobile unit is moving from one cell site to the other cell site then it must be moved from existing voice channel to a new voice channel pair.

→ This process is called "Hand off".

→ Hand off is required at different conditions

(or) situations such as

(i) Moving the mobile unit from one cell site to other cell site.

(ii) Mobile unit is moving from one sector to the another sector.

(iii) Mobile unit is moving from underlay region to overlay region.

(iv) Mobile unit entering into coverage hole

(v) Mobile unit assigned with a poor channel.

(2m)

Coverage hole :-

A low signal strength area within the coverage area of cell site (or) sector is called as

"Coverage hole".

→ In coverage hole, signal strength is less than normal (or) threshold level for few channels.

Types of Hand off's :-

→ As per the procedure & function, handoff's are classified as

- (i) Forced hand off
- (ii) Power difference handoff
- (iii) Mobile Assisted handoff
- (iv) Soft hand off
- (v) Inter system handoff
- (vi) cell site hand off

(i) Forced hand off :-

→ If the mobile unit is reading to the handoff threshold then the process of initiation handoff must be initiated.

→ If load on the reference cell site is high then to create free channels, handoff may be given for the mobile units present in the common coverage areas.

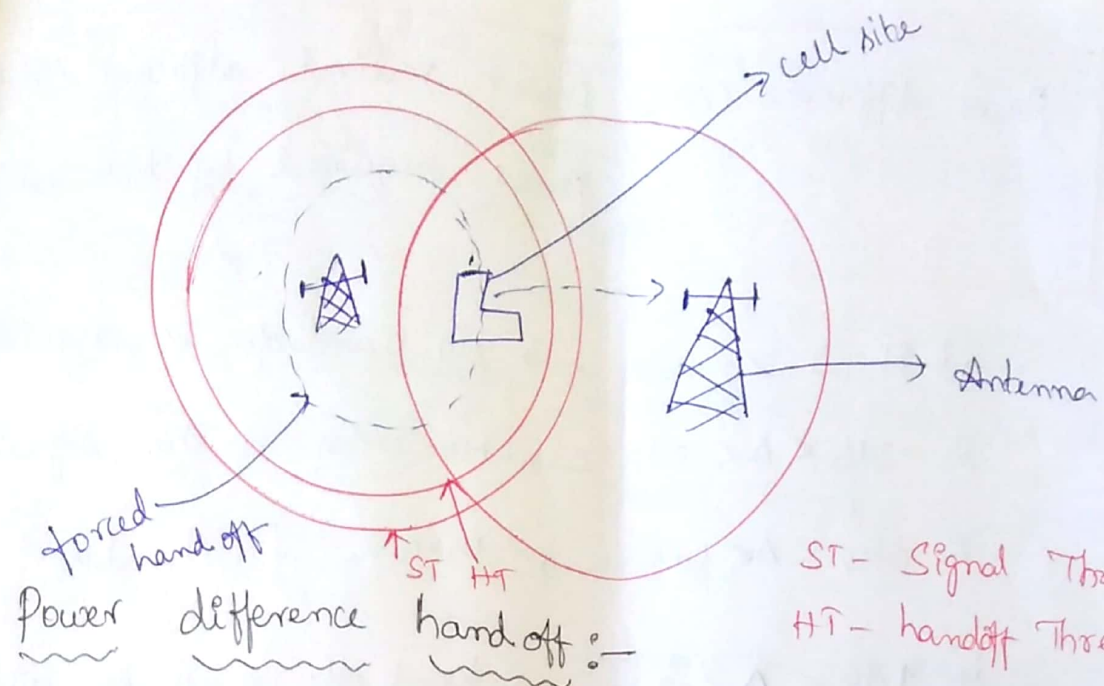
→ This is called forced hand off.

→ A handoff that should not occur but is forced to happen is forced hand off.

→ To execute forced hand off, handoff threshold must be changed accordingly.

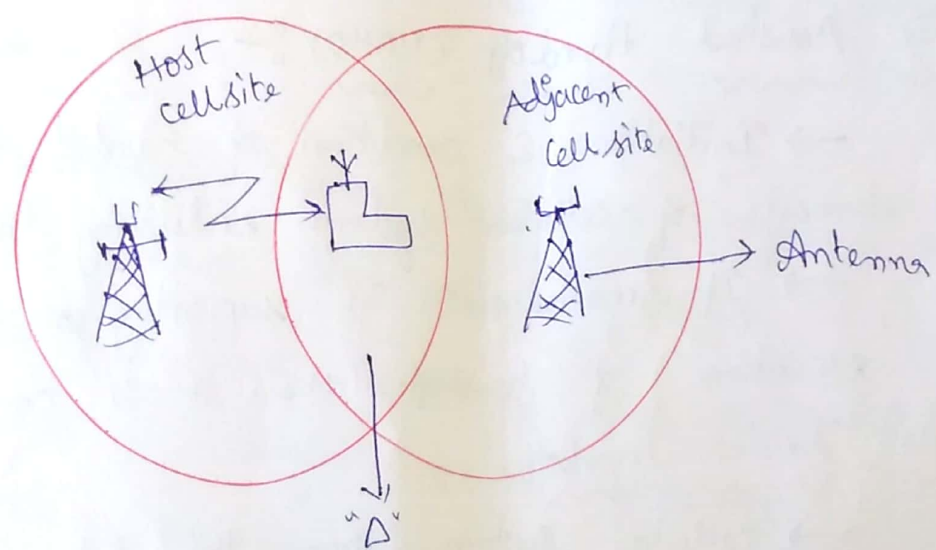
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ls.



(ii)

Power difference handoff :-



→ During a call, if the mobile unit is entering into common coverage area of host and adjacent cell site then the signal transmitted by mobile unit is received by both cell sites.

→ Based on this, a better algorithm can be desired to execute hand off process by means of power difference.

→ Host cell site is used to execute various steps of hand off process, it is called as "power difference hand off."

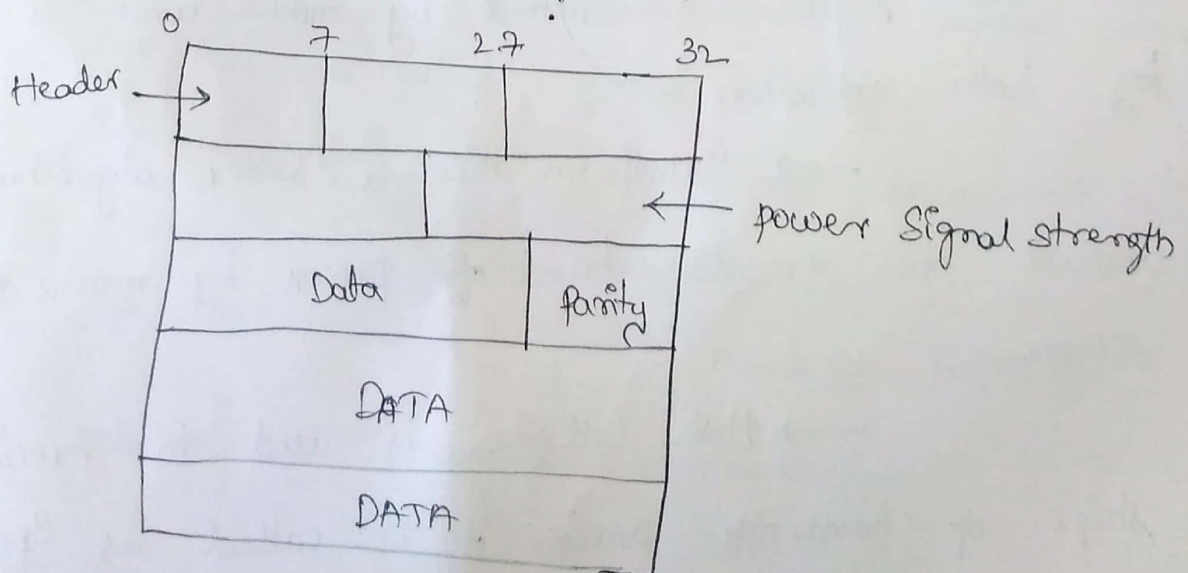
Power difference (Δ) = $\frac{\text{Power received adjacent cell}}{\text{Power required by host cell}}$

- i) If $\Delta < -3\text{dB}$ → No handoff is required
- ii) $-3\text{dB} < \Delta < 0\text{dB}$ → Monitoring of the signal strength
- iii) $0\text{dB} < \Delta < 1\text{dB}$ → prepare for handoff
- iv) $1\text{dB} < \Delta < 3\text{dB}$ → handoff must be given

iii) Mobile Assisted Handoff (MAHO) :-

- Initiation & execution of handoff is carried out by elements of cellular system excluding the mobile unit
- If mobile unit is supporting or participating in the execution of handoff then it is considered as Mobile Assisted handoff.
- Cellular system then the data transmission may follow frame format.

Data frame @ mobile unit



→ Different fields are present in the frame, in which one field is reserved to accommodate power information by the mobile unit.

→ After receiving this frame MTSO extracts the power (or) signal strength information & maintains a record.

→ Based on the power profile, the process of handoff is executed by MTSO.

→ As this power information provided by mobile unit, it is called mobile assisted handoff.

(iv) Soft hand off :-

→ Handoff involves change of frequency at mobile unit, if it enters into adjacent cell site.

→ In CDMA technology, all the mobile units operate with a single carrier frequency.

→ CDMA technology uses a single carrier but different coding schemes.

→ Therefore, change of existing code to a new code at mobile unit is called soft handoff.

(v) Inter System hand off :-

→ If a call is initiated by the mobile unit in the last cell site of CGSA, & if it is entering into a cell site, which belongs to CGSA of other system

→ Then call may be terminated at the boundary.

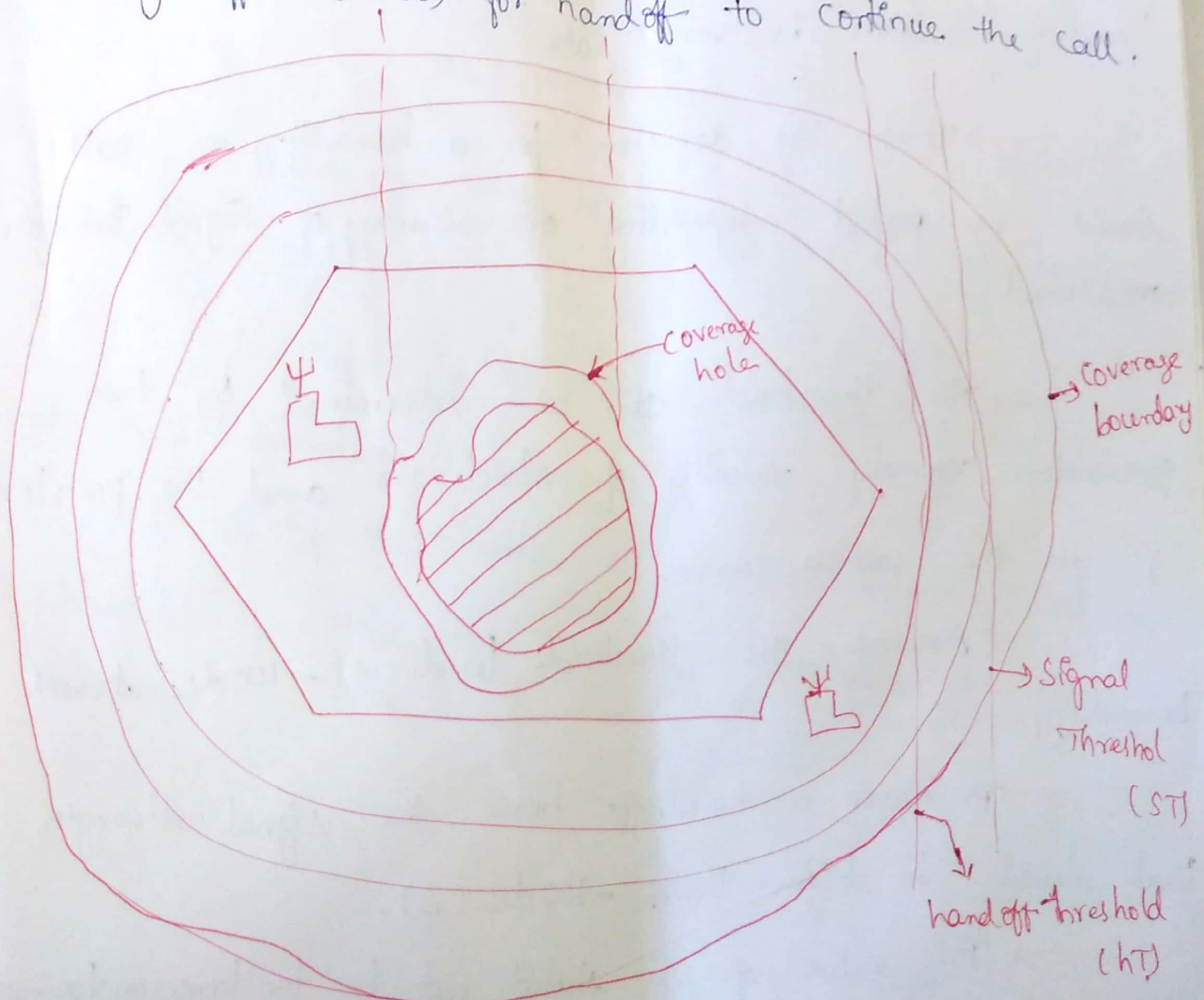
Hand off Initiation:-

→ In the cell site the signal strength is continuously monitored using a reverse voice channel.

→ Depending on the signal strength the decision for hand off is made.

→ Whenever this strength is reducing to threshold level, hand off request will be placed.

→ If the signal strength reaches a level that is higher than the threshold level set for minimum voice quality, cell site will request the Switching office (MISO) for hand off to continue the call.



→ occurrence of handoff either earlier or later can be determined by intelligence within the cell site.

→ If the mobile unit is reaching the handoff threshold (or) coverage hole then the handoff must be initiated.

→ Handoff threshold can be determined from signal threshold.

→ Now, we have considered the two points, and should be avoided.

(i) An unnecessary handoff will be required if the handoff decision is very early.

(ii) A failure handoff would result if the handoff decision is very late.

→ Thus, the decision for a handoff on call should be perfect depending on accuracy of signal strength measured.

→ The threshold can be determined by two parameters namely velocity of vehicle 'V' and the path loss 'P' in the path loss curve.

→ Assume the threshold level is -100 dB at cell boundary.

→ To have a handoff here the signal strength level should be higher than -100 dB (Δ).

→ The value of ' Δ ' should not be too large (or) too small.

→ we can calculate the velocity 'v' of the mobile unit based on the predicted level - crossing rate (LCR), at a -10dB level with respect to the root mean square (rms), level which is at -90 dB.

Thus,

$$v = \frac{\eta \lambda}{\sqrt{2\pi} (0.27)} \quad \begin{matrix} \text{f/s} \\ \text{mi/h} \end{matrix} \quad \text{at -10dB level}$$

where,

η - is the LCR counting positive slopes

λ - is the wavelength in feet.

→ Hand off may be necessary, but can't be done at following cases.

(i) Mobile is at signal strength hole and not at cell boundary.

(ii) If the mobile is at cell boundary but no channel in the new cell is available to make hand off's.

Delaying Hand off :-

When a base station wants to handover the to the base station of new cell where the subscribers entered the new base station will accept it and takes call control. This smooth handoff is possible only if the new cell is free to take it. If there the cell not available then the handoff will be delayed. This is known as the "delayed handoff".

Advantages of delayed handoff :-

① If the neighbouring cells are busy delayed handoff helps to continue the call in progress smoothly till the new cell gets free.

② In two handoff level algorithm only after the second handoff the call will be dropped. Thus probability of call blocking is very less.

③ This algorithm also makes handoff to take place at correct location.

④ ~~It~~ It also eliminates the possible interference.

⑤ It avoids insignificant handoffs.

⑥ It helps in identifying the exact location, where the handoff should occur.

Two-level handoff algorithm:-

→ The purpose of creating two request handoff level is to provide more opportunity for a successful handoff.

→ Two level handoff scheme is used to avoid interference in the system.

→ In this hand off scheme the cell is divided into two sub cells.

That is

- (i) Underlaid cell
- (ii) Overlaid cell.

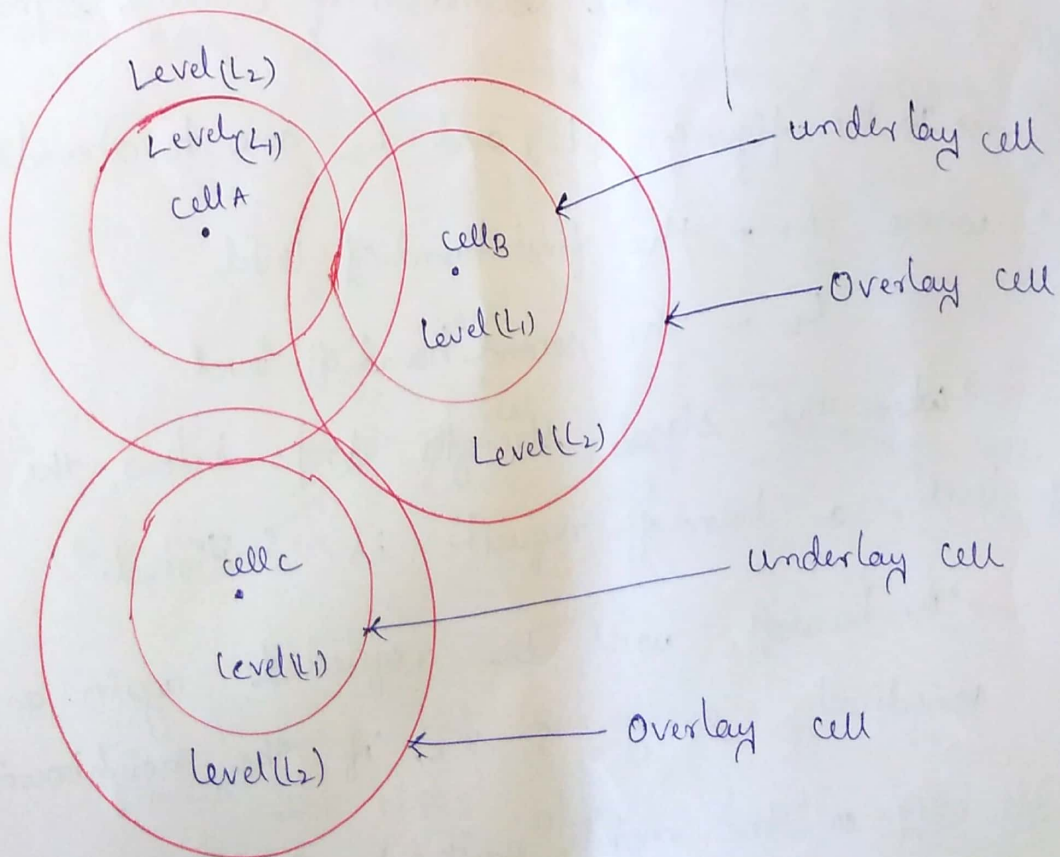
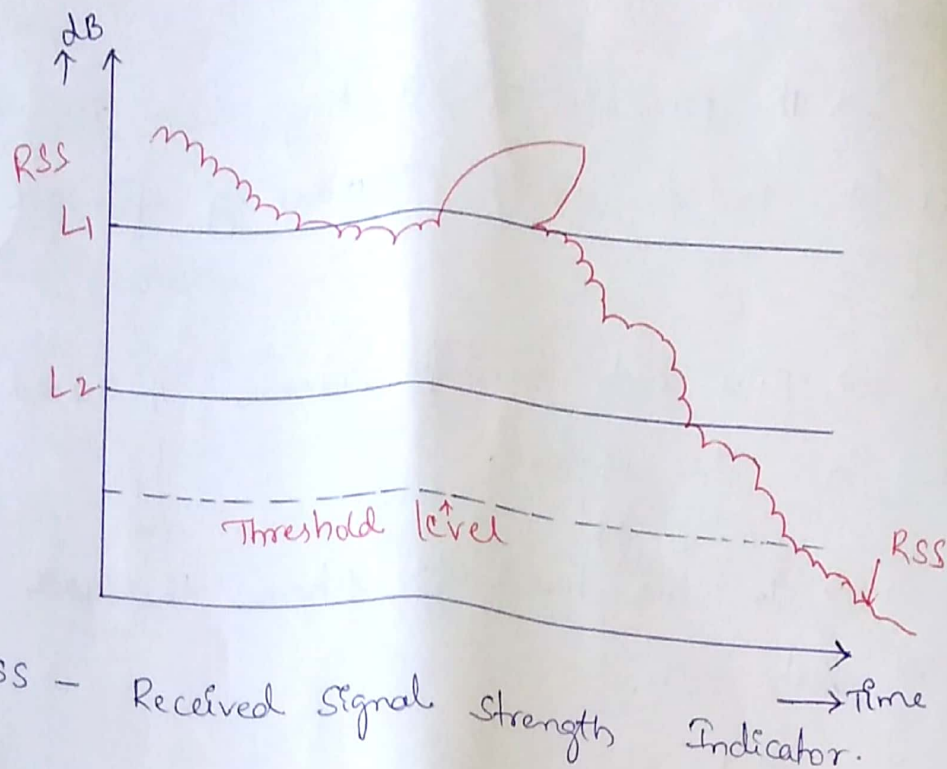


Fig - Two Level handoff scheme using different cells



→ Received signal strength Indicator is installed at each channel receiver at the cell site.

→ It records the scenario of average signal strength.

→ In the figure L_1 and L_2 are two handoff levels, where L_1 - the first handoff level
 L_2 - the second handoff level.

→ When the signal strength drops below the first handoff level, a handoff request is initiated.

→ The handoff will be requested again and again periodically every 5 sec; if the neighbouring cell is busy or the mobile unit is in a weak location in a cell.

→ At the first handoff level, the handoff takes place

if the new signal is stronger.

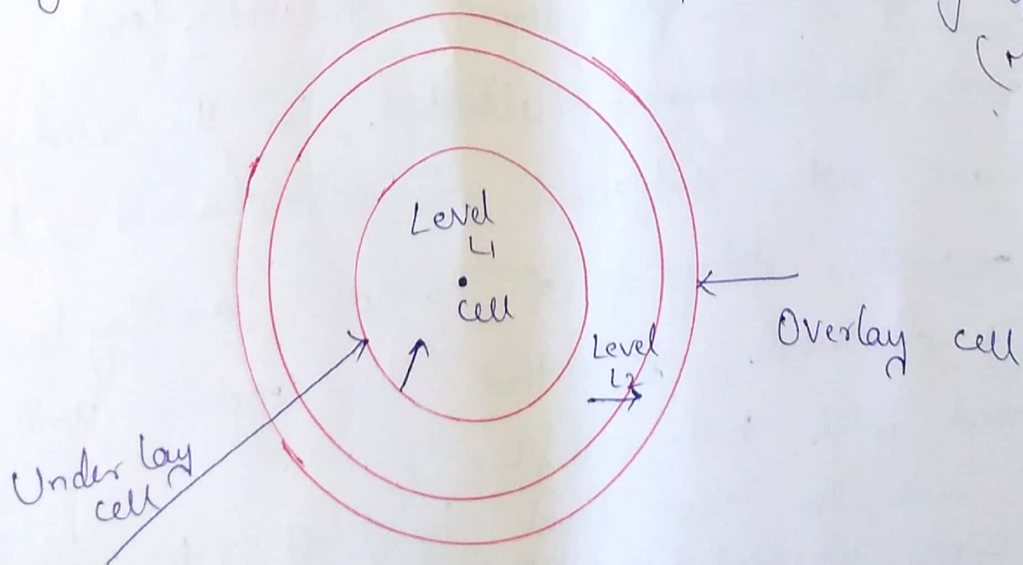
→ If the signal is strong enough at the first handoff level, then handoff occurs.

→ The call will be handed off, as the signal touches second handoff level.

→ When the second handoff level is reached, the call will be handed off with no condition.

→ After reaching second handoff level, if no calls are available from neighbouring cells, the call will be continued till the signal strength drops below the threshold level, then call is dropped.

→ The handoff calls are given priority over originating calls at the Mobile Telephone Switching office (MTSO).



Two level handoff scheme

→ The MTSO always handles the handoff call first and the originating calls second.

→ If the Supervisory Audio Tone (SAT) sent back to the cell site by the mobile unit within the 5 sec the cell site turns off the transmitter.

→ The inner circle represents the underlaid cell.

→ The outer circle represents the overlaid cell.

→ These two cells are assigned with different threshold levels L_1 and L_2 .

→ L_1 is the highest threshold level.

→ L_2 is the lowest threshold level.

→ The channels allocated in the underlaid cell are not subjected to co-channel interference.

→ In delaying of handoff, existing handoff level is decreased so that the mobile unit is continued with host cell site.

→ In two level hand off, two handoff levels are used where level-1 is active if free channels are available in the adjacent cell site.

→ The level-2, is active, if all channels are occupied in the adjacent cell site.

→ If both levels are active, then the repetition rate of handoff request is different

between level-1 & level-2 and level-2 & signal threshold.

Controlling & creating hand.off :-

→ Either cell site (or) MTSO can assign new (or) lower threshold levels for handoffs to control its occurrence, this is referred as controlling a handoff.

→ MTSO can create a hand off irrespective of the hand off threshold levels depending on channel availability and requirement.

Advantages of Hand off :-

→ Hand off's are required to reduce the no. of dropped calls and dropped call rate in cellular system.

→ Hand offs are required to continue the call if the mobile unit is moving from one sector to the other sector.

→ If the mobile unit is entering into coverage hole then the call may be continued if hand off is given.

→ Hand offs are useful to improve the quality of service during underlay - overlay coverage arrangement at cell site.

→ To ensure the performance and quality of cellular system, hand off may be given to the stationary mobile units which are not given.

→ Availability of channels in the cell site be optimized by delayed or forced handoff's

Queuing of hand off's:-

→ Thousands of cell sites and a large number of mobile units are associated to the cellular system.

→ Therefore huge number of handoff requests are placed at HTSO for execution per second.

→ Queuing of handoffs is the most effective technique for execution of handoff based on loading in the adjacent cell site.

→ If handoff requests are reaching to HTSO in large number then Queuing is required.

→ If Queuing is implemented and handoffs are executed properly by the HTSO then no blocking and number of dropped calls in the system.

→ Based on Queuing of handoffs, the following '3' conditions are considered in cellular system.

i) No queuing on either the originating calls or the hand off calls

→ Non-availability of channels leads to blocking of originating calls.

→ It is given by,

$$B_0 = \frac{A^N}{N!} P(0) \quad \text{--- (1)}$$

where,

$$p(0)_{og} = \left[\sum_{n=0}^N \frac{A^n}{n!} \right]^{-1} \longrightarrow \textcircled{2}$$

where

A = Total number of calls

N = Number of voice calls

$$A = \frac{\lambda_1 + \lambda_2}{\mu}$$

here,

$$\frac{1}{\mu} = \text{Average calling time (Sec)}$$

λ_1 = Arrival rate for originating calls

λ_2 = Arrival rate for handoff calls

(ii) Queueing the originating calls but not handoff calls:-

→ Blocking reduces if originated calls are queued

→ The blocking probability for originating calls is given by,

$$B_{og} = \left[\frac{b_1}{N} \right]^{M_1} p_q(0) \longrightarrow \textcircled{3}$$

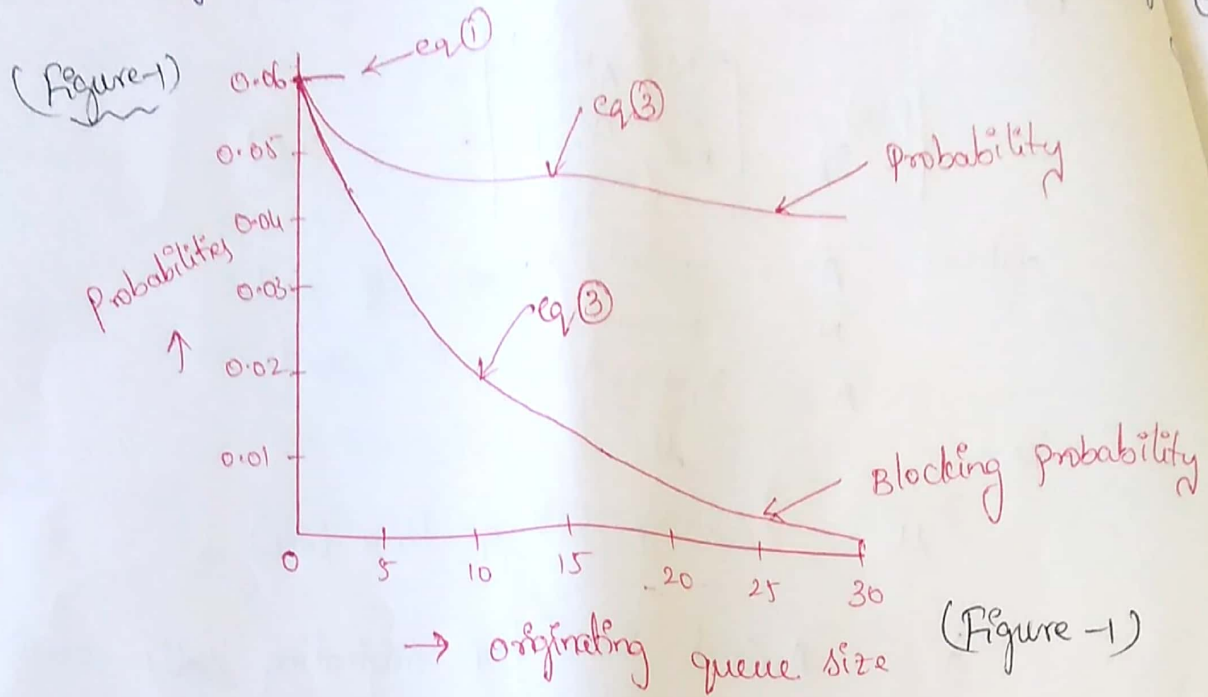
where,

b_1 = Total number of originating calls

$$b_1 = \frac{\lambda_1}{\mu}$$

$$p_q(0) = \left[N! \sum_{n=0}^N \frac{A^n}{n!} + \frac{1 - (b_1/N)^{M_1+1}}{1 - (b_1/N)} \right]^{-1} \longrightarrow \textcircled{4}$$

→ Fig-1 shows the plot for blocking probability of Orig Queue



→ As hand off calls are not Queued.

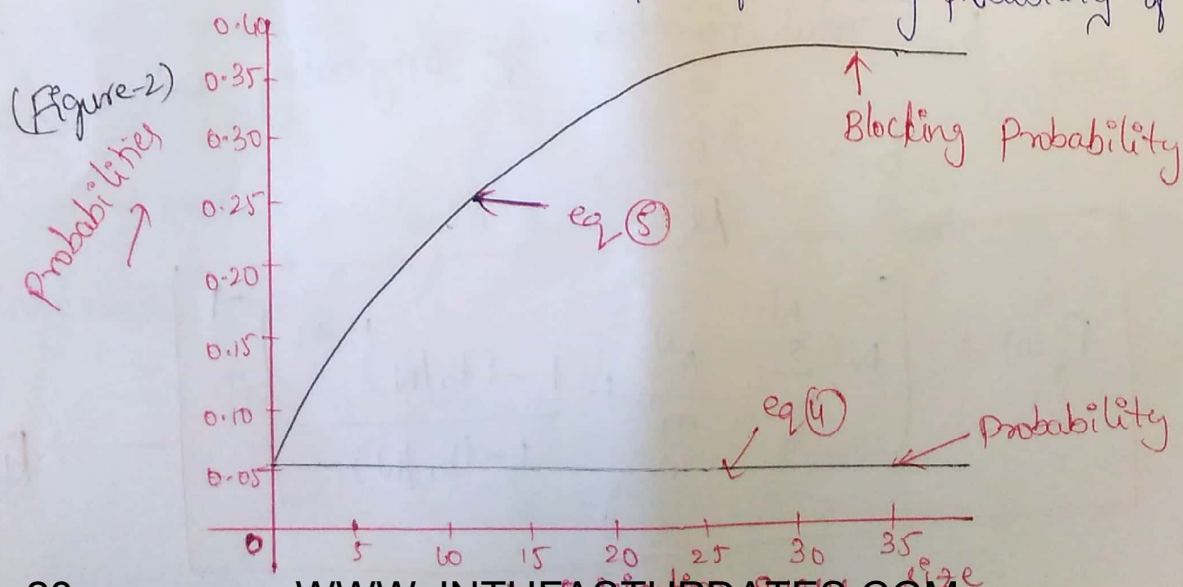
→ The blocking probability for hand off calls is given by,

$$P_{oh} = \frac{1 - (b_1/N)^{M_1+1}}{1 - (b_1/N)} P_q(0) \quad \rightarrow (5)$$

where,

M_1 = Size of queue for originating calls

→ Fig-2 shows the plot for blocking probability of handoff calls



Queueing the handoff calls but not the originating calls
 → If handoff calls are Queued then the blocking reduces when compared to case (i).

→ The blocking probability for the handoff calls is given by,

$$B_{hq} = \left[\frac{b_2}{N} \right]^{M_2} P_q(0) \rightarrow (6)$$

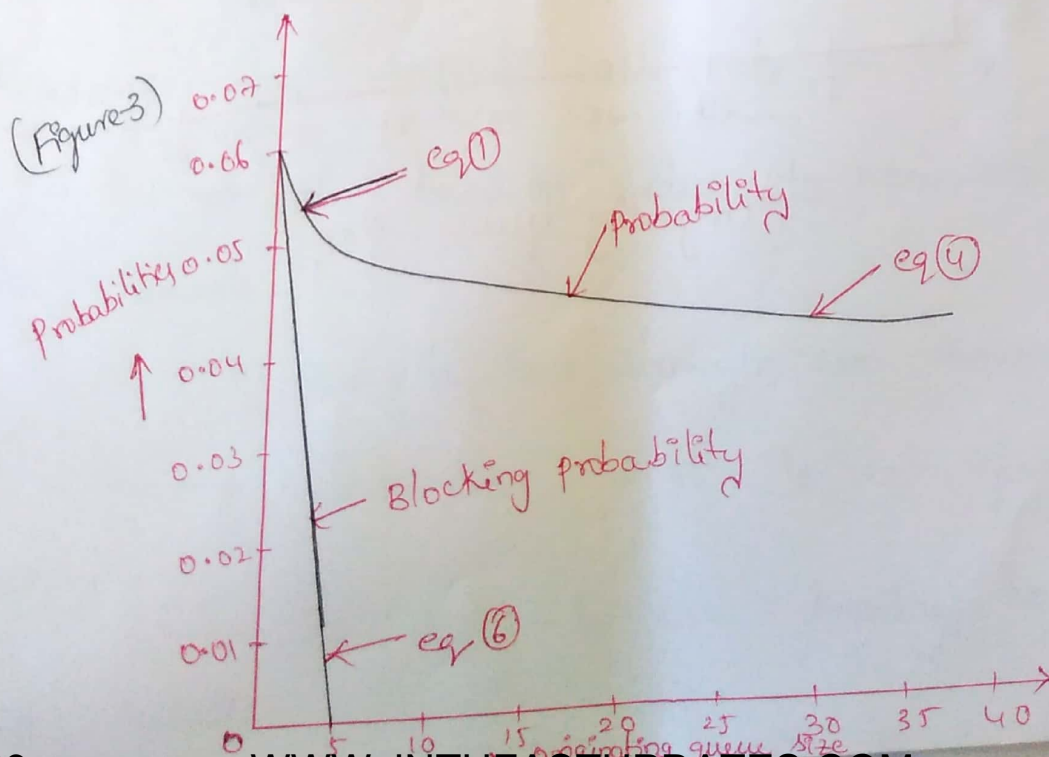
where,

M_2 = Sizes of queue for handoff calls

b_2 = Total number of handoff calls

$$b_2 = \frac{\lambda_2}{\mu}$$

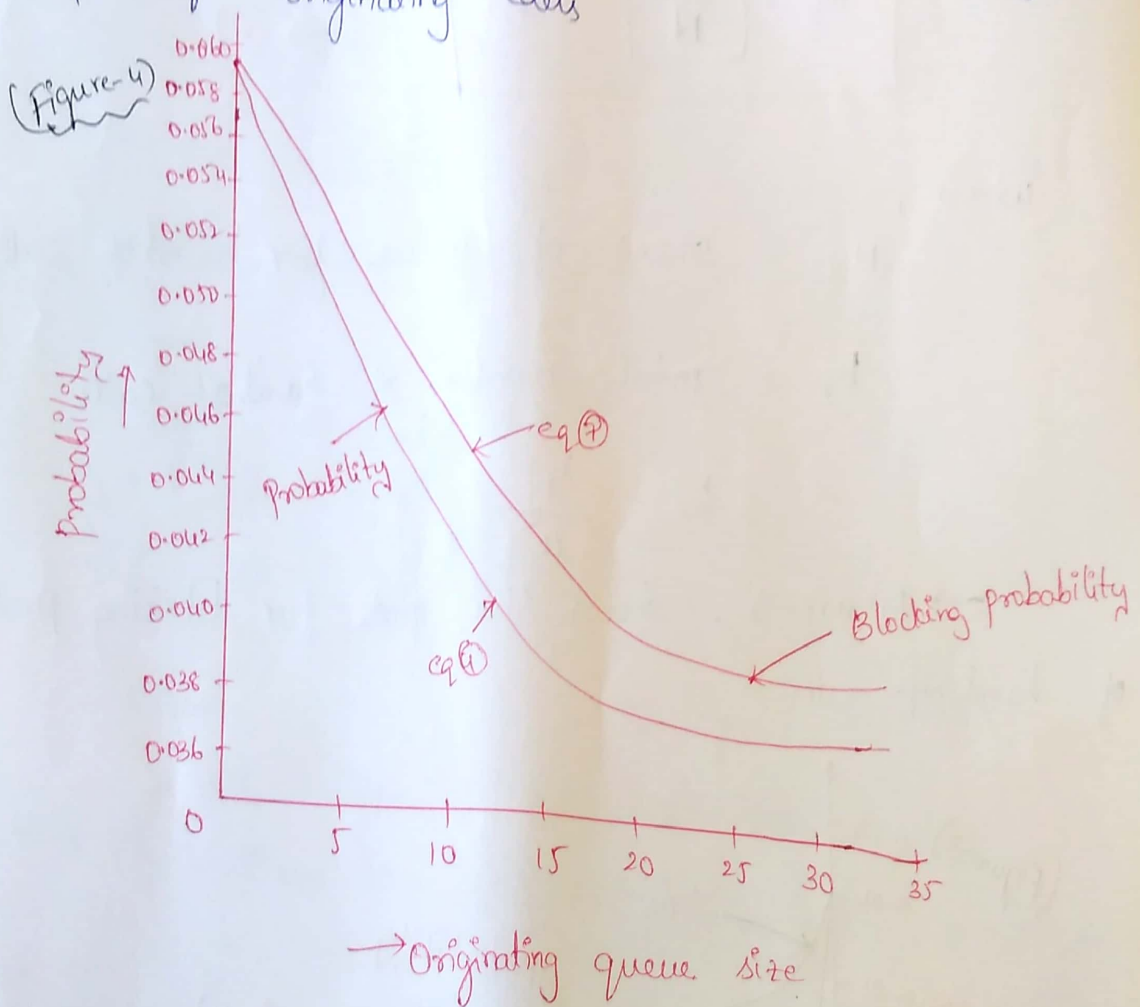
→ Figure-3, shows the plot for blocking probability of handoff calls



→ The blocking probability for originating calls given by,

$$B_{ho} = \frac{1 - (b_2/N)^{M_2+1}}{1 - (b_2/N)} P_q(0) \rightarrow \textcircled{P}$$

→ Figure - 4 shows the plot for blocking probability of originating calls



Dropped Call rate :-

→ At the end of conversation, if the call is terminated by the user then it is considered as a completed call.

→ During the conversation, if the call is terminated due to network issues (or) other then it is considered as dropped call.

→ Termination of call without user's intention (or) knowledge is a dropped call.

→ If Q calls are placed during the busy hour & $Q-1$ calls are completed then the no. of dropped calls are $Q - (Q-1) = 1$.

→ Therefore the dropped call rate is defined as the ratio of no. of dropped calls to no. of calls placed & $\frac{1}{Q}$ is the dropped call rate.

Reasons for dropped call rate :-

→ No hand off due to non-availability of voice channels.

→ Due to low strength (or) coverage hole area.

→ Subscriber unit is not functioning properly.

→ The user is not knowing, how to get best results.

→ poor voice quality

→ No queuing of handoff's at MTSO.

Reduction (or) minimization of dropped call rate:-

→ Hand off must be given at appropriate time to reduce dropped calls.

→ Each cellsite must be provided with desired no. of voice channels for successful handoff.

→ All channels must be good performing to work in the coverage hole areas.

→ If coverage holes are filled by proper repeater mechanism then dropped call rate can be minimized.

→ By proper training (or) knowledge on equipment usage, dropped calls due to improper use can be minimized.

→ If dropped calls are due to hardware limitations, then the equipment must be replaced (or) repaired.

→ Queuing of handoff request must be done at MTSO to minimize dropped call rate.

Relationship among capacity, voice quality & dropped call rate :-

→ The relationship between capacity, voice quality, dropped call rate can be expressed using a common c/p parameter.

→ The capacity of the cellular system is denoted by m .

→ Capacity depends on number of channels in the system.

→ Then it is given by,

$$m = \frac{B_T / B_c}{\sqrt{\frac{2}{3} (C/I)_s}} \longrightarrow \text{eqn ①}$$

where,

B_T / B_c is total number of voice channels in the system.

$(C/I)_s$ is the required parameter to design a system (or) the required c/p ratio.

→ Eqn ① is acquired by taking six co-channel interferers that occur during busy hour that is the equation is acquired in worst case conditions

→ Squaring on both sides of eqn ①,

Then we get,

$$m^r = \left(\frac{(B_T / B_C)^r}{\sqrt{\frac{2}{3}} (C/I)_S} \right)^2$$

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$$m^r = \frac{(B_T / B_C)^r}{\frac{2}{3} (C/I)_S}$$

$$\frac{2}{3} (C/I)_S = \frac{(B_T / B_C)^r}{m^r}$$

$$(C/I)_S = \frac{(B_T / B_C)^r}{\frac{2}{3} m^r} \rightarrow \text{desired } C/I \text{ ratio}$$

(Or)

$$(C/I)_S = \frac{3}{2} \left(\frac{B_T}{B_C} \right)^r \cdot \frac{1}{m^r}$$

→ The voice quality of the system is dependent on the value of $(C/I)_S$.

→ If $(C/I)_S$ decreases the system capacity increases.

Controlling a handoff :-

The cell site can assign a low handoff threshold in a cell to keep a mobile unit in a cell longer or assign a high handoff threshold level to request a handoff earlier. The MTSO also can control a handoff by making either a handoff earlier or later receiving a handoff request from cell site.

Creating a handoff :-

The cell site does not request a handoff but the MTSO finds that some cells are too congested while others are not. Then MTSO request cell sites to create early handoffs for these congested cells.

A cell site has to follow the MTSO's order and increase the handoff threshold to push the mobile units at the new boundary and to handoff earlier.

Thus handoff threshold level in cell site may be high or low according to the order to MTSO given to cell sites.