UNIT-VIII

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.

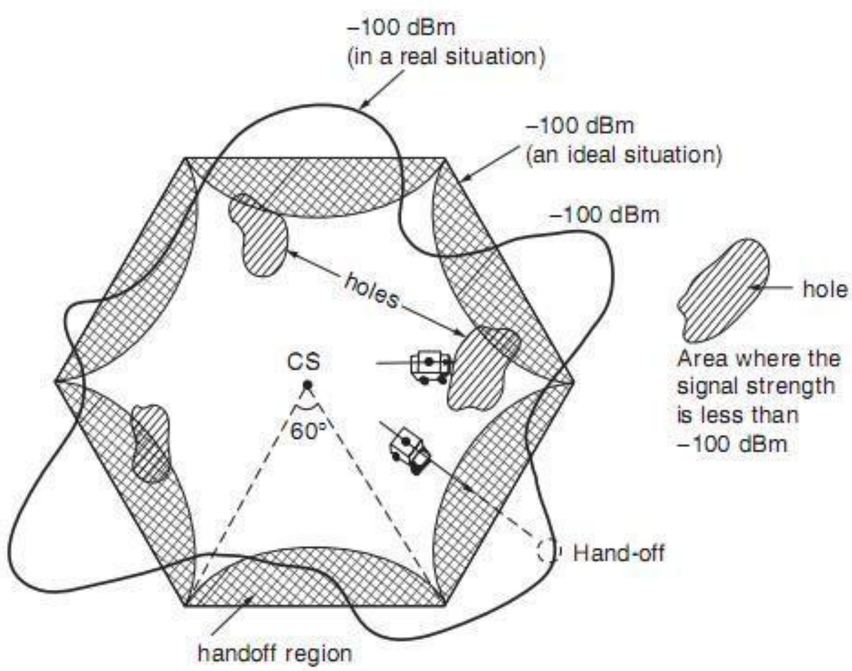

Fig.1. Occurrence of handoffs

WHAT ARE THE TWO DECISIONS 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 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. Another method of measuring C/I is described in Sec. 9.3.

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

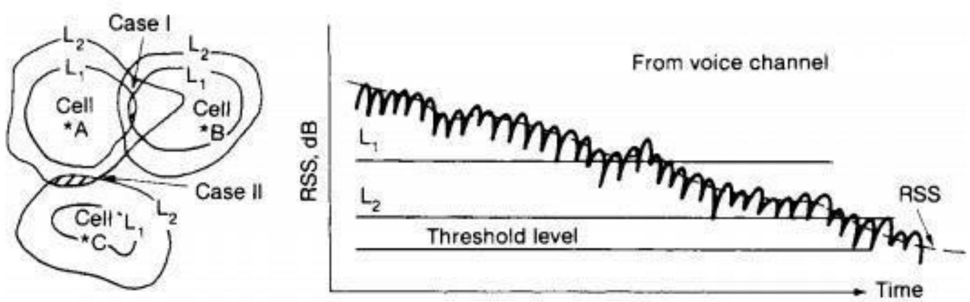

Fig.3. A two level handoff scheme

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

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.

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.

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.

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 MSO also can control a handoff by making either a handoff earlier or later, after receiving a handoff request from a cell site.

Creating a Handoff:

In this case, the cell site does not request a handoff but the MSO finds that some cells are too congested while others are not. Then, the MSO can request call sites to create early handoffs for those congested cells. In other words, a cell site has to follow the MSO's order and increase the handoff threshold to push the mobile units at the new boundary and to handoff earlier.

Queuing of handoff:

Queuing of handoffs is more effective than two-threshold-level handoffs. The MSO will queue the requests of handoff calls instead of rejecting them if the new cell sites are busy. A queuing scheme becomes effective only when the requests for handoffs arrive at the MSO in batches or bundles. If handoff requests arrive at the MSO uniformly, then the queuing scheme is not needed. Before showing the equations, let us define the parameters as follows. $1/\mu$ average calling time in seconds, including new calls and handoff calls in each cell

λ1	arrival rate (λ1 calls per second) for originating calls
λ2	arrival rate (λ2 handoff calls per second) for handoff calls
M1	size of queue for originating calls
M2	size of queue for handoff calls
N	number of voice channels
a	(λ1 + λ2)/μ
b1	λ1/μ
b2	λ2/μ

The following analysis can be used to see the improvement. We are analyzing three cases.

1. No queuing on either the originating calls or the handoff calls. The blocking for either an originating call or a handoff call is

$$B_o = \frac{a^N}{N!} P(0)$$

Where

$$P(0) = \left(\sum_{n=0}^{N} \frac{a^N}{n!} \right)^{-1}$$

2. Queuing the originating calls but not the handoff calls. The blocking probability for originating calls is

$$B_{oq} = \left(\frac{b_1}{N} \right)^{M_1} P_q(0)$$

Where

$$P_q(0) = \left[N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1 - (b_1/N)^{M_1+1}}{1 - (b_1/N)} \right]^{-1}$$

The blocking probability for handoff calls is

$$B_{oh} = \frac{1 - (b_1/N)^{M_1+1}}{1 - (b_1/N)} P_q(0)$$

3. Queuing the handoff calls but not the originating calls. The blocking probability for handoff calls is

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

The blocking probability for originating calls is

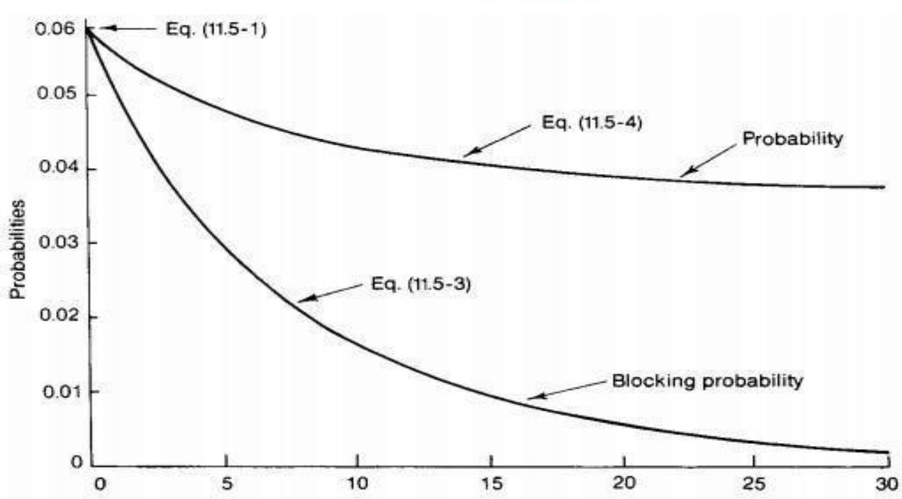

Fig.5. Originating queue size

We have seen (Fig.5.) with queuing of originating calls only, the probability of blocking is reduced. However, queuing of originating calls results in increased blocking probability on handoff calls, and this is a drawback. With queuing of handoff calls only, blocking probability is reduced from 5.9 to 0.1 percent by using one queue space. Therefore it is very worthwhile to implement a simple queue (one space) for handoff calls. Adding queues in handoff calls does not affect the blocking probability of originating calls. However, we should always be aware that queuing for the handoff is more important than queuing for those initiating calls on assigned voice channels because call drops upset customers more than call blockings.

POWER DIFFERENCE HANDOFF

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

_ = the mobile signal measured at the candidate handoff site

− the mobile signal measured at the home site

For example, the following cases can occur.

_> 3 dB request a handoff

1dB <_< 3 dB prepare a handoff

−3dB <_< 0 dB monitoring the signal strength

_< −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.

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.

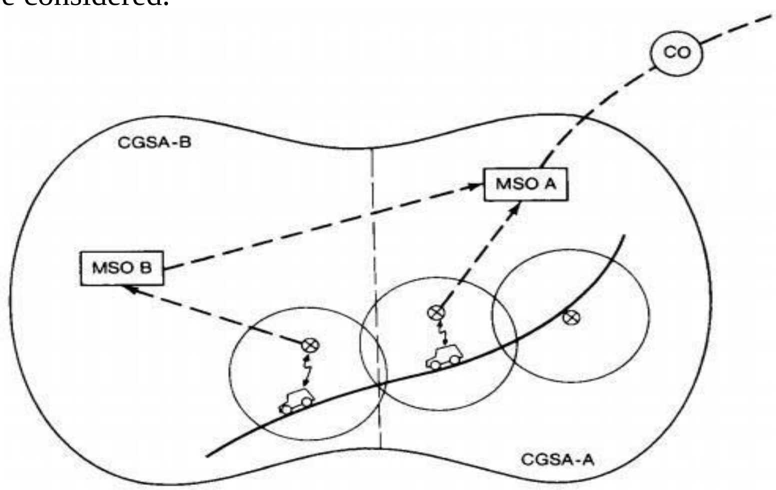

Fig.7. Intersystem handoffs

DEFINITION OF DROPPED CALL RATE AND CONSIDERATION OF DROPPED CALL RATES

The definition of a dropped call is after the call is established but before it is properly terminated. The definition of "the call is established" means that the call is setup completely by the setup channel. If there is a possibility of a call drop due to no available voice channels, this is counted as a blocked call not a dropped call. If there is a possibility that a call will drop due to the poor signal of the assigned voice channel, this is considered a dropped call. This case can happen when the mobile or portable units are at a standstill and the radio carrier is changed from a strong setup channel to a weak voice channel due to the selective frequency fading phenomenon.

The perception of dropped call rate by the subscribers can be higher due to:

1. The subscriber unit not functioning properly (needs repair).

2. The user operating the portable unit in a vehicle (misused).

3. The user not knowing how to get the best reception from a portable unit (needs education).

In principle, dropped call rate can be set very low if we do not need to maintain the voice quality. The dropped call rate and the specified voice quality level are inversely proportional. In designing a commercial system, the specified voice quality level is given relating to how much C/I (or C/N) the speech coder can tolerate. By maintaining a certain voice quality level, the dropped call rate can be calculated by taking the following factors into consideration:

1. Provide signal coverage based on the percentage (say 90 percent) that the entire received signal will be above a given signal level.

2. Maintain the specified co-channel and adjacent channel interference levels in each cell during a busy hour (i.e., the worst interference case).

3. Because the performance of the call dropped rate is calculated as possible call dropping in every stage from the radio link to the PSTN connection, the response time of the handoff in the network will be a factor when the cell becomes small, the response time for a handoff request has to be shorter in order to reduce the call dropped rate.

RELATION AMONG CAPACITY, VOICE QUALITY, DROPPED CALL RATE

Radio Capacity m is expressed as follows:

$$m = \frac{B_T / B_c}{\sqrt{\frac{2}{3}(C/I)_S}}$$

Where BT/Bc is the total number of voice channels. BT /Bc is a given number, and (C/I) s is a required C/I for designing a system. The above equation is obtained based on six co-channel interferers which occur in busy traffic (i.e., a worst case). In an interference limited system, the adjacent channel interference has only a secondary effect.

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

Because the (C/I)s is a required C/I for designing a system, the voice quality is based on the (C/I)s .When the specified (C/I)S is reduced, the radio capacity is increased. When the measured (C/I) is less than the specified (C/I)S , both poor voice quality and dropped calls can occur.

GENERAL FORMULA OF DROPPED CALL RATE

The general formula of dropped call rate P in a whole system can be expressed as:

$$P = 1 - \left[\sum_{n=0}^{N} \alpha_n X^n\right] = \sum_{n=0}^{N} \alpha_n \cdot P_n$$

Where

$$P_n = 1 - X^n$$

P_n is the probability of a dropped call when the call has gone through n handoffs and

$X = (1-\delta)(1-\mu)(1-\theta\tau)(1-\beta)^2$

δ = Probability that the signal is below the specified receive threshold (in a noise-limited system).

μ = Probability that the signal is below the specified cochannel interference level (in an interference-limited system).

τ = Probability that no traffic channel is available upon handoff attempt when moving into a new cell.

θ = Probability that the call will return to the original cell.

β = Probability of blocking circuits between BSC and MSC during handoff.

α_n = The weighted value for those calls having n handoffs, and $\sum_{n=0}^{N} \alpha_n = 1$

N = N is the highest number of handoffs for those calls.

1. z1 and z2 are two events, z1 is the case of no traffic channel in the cell, z2 is the case of no-safe return to original cell. Assuming that z1 and z2 are independent events, then

2. (1 − β) is the probability of a call successfully connecting from the old BSC to the MSC. Also, (1 − β) is the probability of a call successfully connecting from the MSC to
3. $P(z_2|z_1) \cdot P(z_1) = P(z_2) \cdot P(z_1) = \theta \cdot \tau$

4. the new BSC. Then the total probability of having a successful call connection is

$$\begin{matrix} \text{BSC (old)} \rightarrow \text{MSC} & (1-\beta) \\ \text{MSC} \rightarrow \text{BSC (new)} & (1-\beta) \end{matrix} \Big\} \rightarrow (1-\beta)^2$$

3. The call dropped rate P expressed in above Eq can be specified in two cases:

1. In a noise limited system (startup system): there is no frequency reuse, the call dropped rate PA is based on the signal coverage. It can also be calculated under busy hour conditions.

In a noise-limited environment (for worst case)

$$\delta = \delta_1$$

$$\mu = \mu_1$$

$$\left.\begin{aligned} \tau &= \tau_1 \\ \theta &= \theta_1 \\ \beta &= \beta_1 \end{aligned}\right\} \text{the conditions for the noise limited case}$$

2. In an interference-limited system (mature system): frequency reuse is applied, and the dropped rate PB is based on the interference level. It can be calculated under busy hour conditions.

In an interference-limited environment (for worst case)

$$\delta = \delta_2$$

$$\mu = \mu_1$$

$$\left.\begin{aligned} \tau &= \tau_2 \\ \theta &= \theta_2 \\ \beta &= \beta_2 \end{aligned}\right\} \text{the conditions for the interference limited case}$$

In a commonly used formula of dropped call rate, the values of τ , θ, and β are assumed to be very small and can be neglected. Then

$$X = (1-\delta)(1-\mu)$$

Furthermore, in a noise-limited case, $\mu \rightarrow 0$,

$$P_A = \sum_{n=0}^{N} \alpha_n P_n = \sum \alpha_n [1 - (1-\delta)^n]$$

and in an interference-limited system, $\delta \rightarrow 0$,

$$P_B = \sum^{N} \alpha_n P_n = \sum \alpha_n [1 - (1-\mu)^n]$$

CELL SITE HANDOFF SCHEME

This scheme can be used in a non cellular system. The mobile unit has been assigned a frequency and talks to its home cell site while it travels. When the mobile unit leaves its home cell and enters a new cell, its frequency does not change; rather, the new cell must tune into the frequency of the mobile unit (see Fig. 10.). In this case only the cell sites need the frequency information of the mobile unit. Then the aspects of mobile unit control can be greatly simplified, and there will be no need to provide handoff capability at the mobile unit.

The cost will also be lower. This scheme can be recommended only in areas of very low traffic. When the traffic is dense, frequency coordination is necessary for the cellular system. Then if a mobile unit does not change frequency on travel from cell to cell, other mobile units then must change frequency to avoid interference. Therefore, if a system handles only low volumes of traffic, that is, if the channels assigned to one cell will not reuse frequency in other cells, then it is possible to implement the cell-site handoff feature as it is applied in military systems.

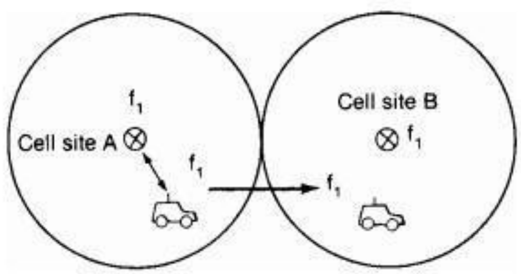

Fig.10. Cell site handoff only scheme