HANDWRITTEN NOTES - ①.

Factors Influencing Hand-off:

The following factors influence the entire hand-off process:

a) Transmitted power: As we know that the transmission power is different ~~cells~~ for different cells, the hand-off threshold or the power margin varies from cell to cell.

b) Recived power: The received power mostly depends on the Line of Sight (LOS) path between the user and the BS. Specially, when the user is on the boundary of the two cells, the LOS path plays a critical role in ~~had~~ hand-offs, and therefore, the power margin Δ depends on the minimum recived power value from cell-to-cell.

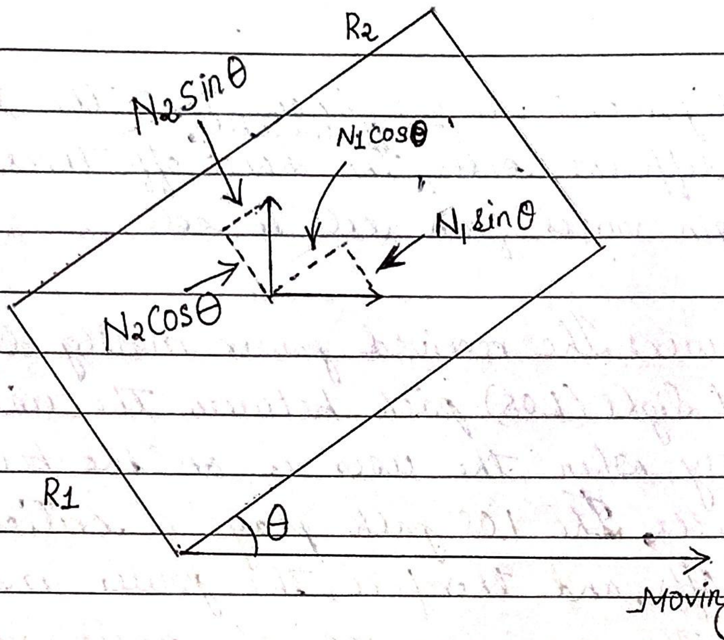
c) Area and shape of the cell: Apart from power levels, the cell structure also plays an important role in the hand-off process.

d) Mobility of users: The number of mobile users entering or going out of a particular cell also dicides the hand-off stratigy of a cell.

To illustrate the reason ⓒ and ⓓ, let us derive the following equation:

Dependence of Hand-off on Area and Shape of the cell and mobility of users:

Let us a consider a rectangular cell with sides R_1 and R_2 inclined at an angle θ with horizon as shown in Fig①. Assume N_1 users are having hand-off in horizontal direction N_2 in vertical direction per unit length.



Fig①: Hand-off process with a rectangular cell inclined at an angle θ.

The number of crossing along R_1 side is,

$$(N_1 \cos\theta + N_2 \sin\theta) R_1$$

and the number of crossing along R_2 side is,

$$(N_1 \sin\theta + N_2 \cos\theta) R_2$$

Then the hand-off rate λ_H can be written as:

$$\lambda_H = (N_1 \cos\theta + N_2 \sin\theta) R_1 + (N_1 \sin\theta + N_2 \cos\theta) R_2 \longrightarrow ①$$

Now, given the fixed area $A = R_1 R_2$, we need to find λ_H^{min} for a given θ. Replacing R_2 by A/R_1 in equation ①

$$① \Rightarrow \lambda_H = (N_1 \cos\theta + N_2 \sin\theta) R_1 + (N_1 \sin\theta + N_2 \cos\theta) A/R_1$$

Equating $\frac{d\lambda_H}{dR_1} = 0$

$$\Rightarrow \frac{d}{dR_1}\left[(N_1 \cos\theta + N_2 \sin\theta) R_1 + (N_1 \sin\theta + N_2 \cos\theta) A/R_1\right] = 0$$

$$\Rightarrow \frac{d}{dR_1}\left[(N_1 \cos\theta + N_2 \sin\theta) R_1\right] + \frac{d}{dR_1}\left[(N_1 \sin\theta + N_2 \cos\theta) A/R_1\right] = 0$$

$$\Rightarrow (N_1\cos\theta + N_2\sin\theta) + (N_1\sin\theta + N_2\cos\theta)A\frac{d}{dR_1}\left(\frac{1}{R_1}\right) = 0$$

$$\Rightarrow (N_1\cos\theta + N_2\sin\theta) + A(N_1\sin\theta + N_2\cos\theta)\left(-\frac{1}{R_1^2}\right) = 0$$

$$\Rightarrow (N_1\cos\theta + N_2\sin\theta) - A/R_1^2\,(N_1\sin\theta + N_2\cos\theta) = 0.$$

$$\Rightarrow A/R_1^2\,(N_1\sin\theta + N_2\cos\theta) = (N_1\cos\theta + N_2\sin\theta)$$

$$\Rightarrow R_1^2 = \frac{A(N_1\sin\theta + N_2\cos\theta)}{(N_1\cos\theta + N_2\sin\theta)} \Rightarrow R_1 = \sqrt{\frac{A(N_1\sin\theta + N_2\cos\theta)}{(N_1\cos\theta + N_2\sin\theta)}} \longrightarrow ②$$

Similarly $R_2^2 = A\dfrac{(N_1\cos\theta + N_2\sin\theta)}{(N_1\sin\theta + N_2\cos\theta)}$

$$\Rightarrow R_2 = \sqrt{\frac{A(N_1\cos\theta + N_2\sin\theta)}{(N_1\sin\theta + N_2\cos\theta)}} \longrightarrow ③$$

Putting the value of R_1 and R_2 in equ^n ①.

$$\lambda_H = (N_1\cos\theta + N_2\sin\theta)\sqrt{\frac{A(N_1\sin\theta + N_2\cos\theta)}{(N_1\cos\theta + N_2\sin\theta)}}$$

$$+ (N_1\sin\theta + N_2\cos\theta)\sqrt{\frac{A(N_1\cos\theta + N_2\sin\theta)}{(N_1\sin\theta + N_2\cos\theta)}}$$

$$\Rightarrow \lambda_H^2 = (N_1\cos\theta + N_2\sin\theta)^{\cancel{2}}\,\frac{A(N_1\sin\theta + N_2\cos\theta)}{\cancel{(N_1\cos\theta + N_1\sin\theta)}}$$

$$+ (N_1\sin\theta + N_2\cos\theta)^{\cancel{2}}\,\frac{A(N_1\cos\theta + N_2\sin\theta)}{\cancel{(N_1\sin\theta + N_2\cos\theta)}}$$

$$+ 2(N_1\cos\theta + N_2\sin\theta)(N_1\sin\theta + N_2\cos\theta)\sqrt{\frac{A^2\cancel{(N_1\sin\theta + N_2\cos\theta)}\cancel{(N_1\cos\theta + N_2\sin\theta)}}{\cancel{(N_1\cos\theta + N_1\sin\theta)}\cancel{(N_1\sin\theta + N_2\cos\theta)}}}$$

$$= A(N_1\cos\theta + N_2\sin\theta)(N_1\sin\theta + N_2\cos\theta)$$
$$+ A(N_1\cos\theta + N_2\sin\theta)(N_1\sin\theta + N_2\cos\theta)$$
$$+ 2A(N_1\cos\theta + N_2\sin\theta)(N_1\sin\theta + N_2\cos\theta)$$

$$= 4A(N_1\cos\theta + N_2\sin\theta)(N_1\sin\theta + N_2\cos\theta)$$

$$= 4A[N_1^2\sin\theta\cos\theta + N_1N_2\cos^2\theta + N_1N_2\sin^2\theta + N_2^2\sin\theta\cos\theta]$$

$$\Rightarrow \lambda_H^2 = 4A[N_1N_2 + (N_1^2+N_2^2)\sin\theta\cos\theta]$$

$$\Rightarrow \lambda_H = 2\sqrt{A[N_1N_2 + (N_1^2+N_2^2)\sin\theta\cos\theta]} \longrightarrow ④$$

At $\theta = 0°$, λ_H^{min} is the minimum i.e., $\lambda^{min} = 2\sqrt{N_1N_2}$

Putting $\theta = 0°$ in equation ② & ③ $\Rightarrow \dfrac{R_1}{R_2} = \dfrac{N_1}{N_2}$

This has two implications—

① The hand-off is minimized if rectangular cell is alligned with the X-Y axis ie. $\theta = 0°$.

(ii) the number of users crossing the cell boundary is inversely proportional to the dimension of the ~~cell~~ other side of the cell.

Hand-off Priority:

Hand-off priority in mobile communication is a strategy for managging which call get preference during the process of transferring a mobile device's connection from one cell or base station to another.

While assigning channels using either FCA or DCA strategy, a guard channel concept must be followed to facilitate the hand-offs. This means, a fraction of total available channels must be kept for hand-off requests. But this would limit the carried traffic and only fewer channels can be assigned for the residual users of a cell. A good solution to avoid such a dead-lock is to use DCA with hand-off priority (demand-based allocation).

A Few Practical Problems in Hand-off Scenario:

ⓐ Different speed of mobile users:

With the increase of mobile users in urban areas, microcells are introduced in the cells to increase the capacity. The users with high speed frequently crossing the microcells become burdened to MSC as it has to take care of hand-offs. Several schemes thus have been designed to handle the simultaneous traffic of high-speed and low-speed users while minimising the hand-off intervation from the MSC, one of them being the "Umbrella Cell" approach. This technique provides large area coverage to high speed users while providing small area coverage to users travelling at low speed. By using different antenna heights and different power levels, it is possible to provide larger & Smaller cells at a ~~sm~~ same location. As illustrated in The Fig②, umbrella cell is co-located with few other microcells. The BS can measure the speed of the user's by its short term average signal strength over the RVC (Reverse Voice Channel) and decides which cell to handle that call. If the speed is less, Then the corresponding microcell handles The call so that there is good corner coverage. This approach assures That hand-off's are minimized for high-speed users and provides additional microcell channels for pedestrian users.

ⓑ Cell draging problem:

This is another practical problem in The urban area with additional microcells. For example, consider there is a LOS path between the MS and BS, While the user is in the cell covered by BS_2. Since There is a LOS (Line of sight) with The BS_1, the signal strength received from BS_1 would be greater Than That received from BS_2. However, since the user is in cell covered by BS_2, hand-off cannot Take place and as a result, it experiences a lot of interferences. This problem can be solved by carefully choosing the handoff threshold along with adjusting the covering area.

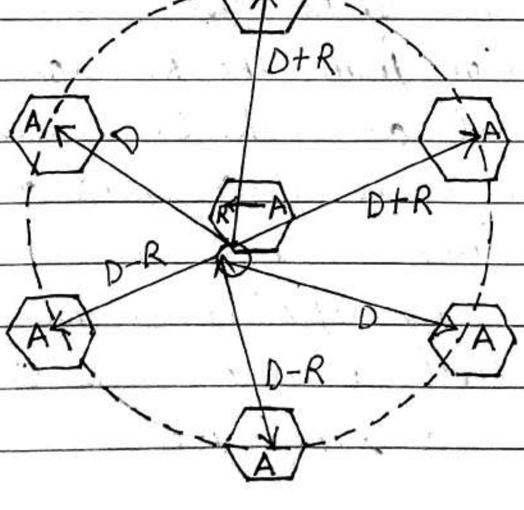


Fig: 2

ⓒ Inter-system hand-off:

If one user is leaving the coverage area of one MSC (Mobile Switching Circuit) and is entering the area of another MSC, then the call might be lost if there is no hand-off in this case too. Such a hand-off is called inter-system hand-off. and in order to faccilitate this, mobiles usually have roaming facility.

Interference and System Capacity:

Susceptibility and interference problems associated with mobile communication equipment are because of the problem of time congestion within the electromagnetic spectrum. This interference can occur from clash with another mobile in the same cell or because of a call in the adjacent cell. There can be interference between the base stations (BS) operating at same frequency band or any other non-cellular systems energy leaking ~~in~~ accidently into the frequency band of the cellular system. If there is an interference in the voice channels, crosstalk is heard will apper as the noise between the users. The interference in the control channels leads to missed and error calls because of digital signalling. Interference is more severe in urban areas because of the greater RF noise and greater density of mobiles and base stations.

The interference can be divided into two parts—

ⓐ Co-channel interference
ⓑ Adjacent channel interference

ⓐ Co-channel interference: (CCI): For the efficient use of ~~a~~ ~~variable~~ available spectrum, it is necessary to reuse frequency bandwidth over relatively small geographical areas. However, increasing frequency reuse also increases interference, which decreases system capacity and service quality. Co-channel interference is the crosstalk between two different radio transmitters using the same RF as is the case with the co-channel cells. The reasons of CCI can be because of either adverse weather conditions or poor frequency planning or overly-crowded radio spectrum.

If the cell size and the power transmitted at the BS are same, then CCI will become independent of the transmitted power and will depend on the radius of the cell (R) and the distance between the interfering co-channel cells (D). If D/R ratio is increased, then the effective distance between the co-channel cells will increase and interference will decrease. The parameter Q is called the frequency reuse ratio and is related to the cluster size. For hexagonal geometry,

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

From the above equation, small Q means small value of cluster size (N) and increase in cellular capacity. But large Q leads to decrease in system capacity but increase in transmission quality.

Choosing the options is very careful for the selection of N,

The signal to interference ratio (SIR) for a mobile receiver which monitors the forward channel can be calculated as

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

where i_0 is the number of co-channel interfering cells, S is the desired signal power from the BS and I_i is the interference power caused by the i^{th} interfering co-channel BS.

The average power in the mobile radio channel decays as a power law of the distance of separation between transmitter and receiver. The expression for the received power P_r at a distance 'd' can be approximately calculated as,

$$P_r = P_0 \left(\frac{d}{d_0}\right)^{-n}$$ and in the dB expression as

$$P_r(dB) = P_0(dB) - 10_n \log\left(\frac{d}{d_0}\right)$$

where P_0 is the power received at a close-in reference point in the far field region at a small distance d_0 from the transmitting at antenna, and 'n' is the path loss exponent.

ⓑ Adjacent Channel Interference (ACI): It is the signal damage which occurs to one frequency due to presence of another signal on a nearby frequency. This occurs when imperfect receiver filters allow nearby frequencies to leak into the passband. This problem is increased if the adjacent channel user is transmitting in a close range compared to the subscriber's receiver while the receiver attempts to receive a BS on the channel. This is called "near-far effect".

The more adjacent channels are packed into the channel block, the higher the spectral efficiency, provided that the performance of degradation can be tolerated in the system link budget. This effect can also occur if a mobile close to a BS transmits on a channel close to the one being used by a weak mobile. This problem might occur if the BS has problem in discriminating the mobile user from the "bleed over" caused by the close adjacent channel mobile.

ACI occurs more frequently in small cell clustor and heavily used cells. If the frequency seperation between the channels is kept large, this inference can be reduced to some extent, Thus assignment of channels is given such that they do not form a contiguous band of frequencies within a particular cell and frequency separation is maximized. If the frequency factor is small then distance between the adjacent channels cannot put the interference level within tolerance limits. If a mobile is 10 times close to the BS, then other mobile and has energy spill out of its passband, then SIR for weak mobile is approximately,

$$\frac{S}{I} = (10)^{-n}$$

Thus in ACI perfect BS filters are needed when close-in and distant users share the same cell. Practically, each ~~Bs~~ BS receiver is preceded by a high Q cavity filter in order to remove ~~ad~~ ACI. Power control is also very much important for the prolonging of the battery life for the subscriber unit but also reduces reverse channel SIR in the system. Power control is done such that each mobile transmits the lowest power required to maintain a good quality link on the reverse channel.

Q: Apply the concept of frequency reuse to calculate the cluster size (N) and reuse factor for a cellular network with a given reuse distance to cell radius ratio ($D/R = 4.6$).

Ans: For a hexagonal cellular layout, the co-channel reuse distance (D) and cell radius (R) are related to cluster size (N) by the relation,

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

$$\Rightarrow N = \frac{1}{3}\left(\frac{D}{R}\right)^2$$

Given $D/R = 4.6$

$$\therefore N = \frac{1}{3}(4.6)^2 = 7.053.$$

Now, the cluster size (N) must be an integer of the form $N = i^2 + ij + j^2$ (with integer i and j) for hexagonal geometry.

$\therefore$ Common valid values near 7.053 are,

For $(i,j) = (2,1)$

$$N = 2^2 + 2 \times 1 + 1^2 = 7$$

For $N = 7$ if we cross-check the consistency then

$$\frac{D}{R} = \sqrt{3 \times 7} = \sqrt{21} = 4.58 \approx 4.6 \text{ (the given value)}.$$

Finally, Reuse factor $= \frac{1}{N} = \frac{1}{7} \approx 0.1429$
or 14.29%

Cell-Splitting:

Cell splitting involves the process of sub-dividing a conjusted cell into smaller cells, each with its own BS. and a corresponding reduction in antenna size and transmitting power. This increases the capacity of a cellular system since it increases the number of times that channels are reused. Since the new cells have smaller radii, than the existing cells, inserting these smaller cells, known as Microcells, between the already existing cells result in an increase of capacity due to the additional number of channels per unit area. Clearly, if cells are small there would have to be more of them and so additional base stations will be needed in the system.

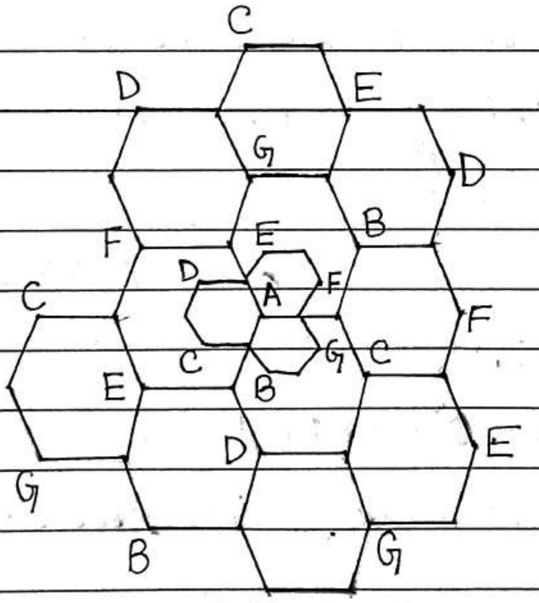


Fig3: Splitting of congested seven-cell clusters

Fig③ shows a cellular layout with a ~~sevel~~ seven cell clusters. Consider that the cells in the center of the diagram are becoming conjusted, and cell A in the centre has reached its maximum capacity. The new smaller cells have half the cell radius of the original cells. At half the radius, the new cells will have one-fourth of the area and will consequently need to support one-fourth the number of subscribers. If we assume that the B.S are located in the cell centers, this allows the original BS to be maintained even in the new system layout. However, new BS ~~sta~~ will have to be added for new cells that do not lie in the center of the larger cells. The ~~orig~~ organization of cells into clusters is independent of the cell radius, so that the cluster size can be the same in the small cell layout as it was in the large cell layout. Consequently, if the cluster size is maintained, the Signal-to-Interference (SIR) ratio will be the same after cell splitting as it was before. If the entire system is replaced with new half-radius cells, and the cluster size is maintained, the number of subscribers per cell will have been reduced.