2.7 Channel Assignment Strategies

For efficient utilization of the radio spectrum, a frequency reuse scheme that is consistent with the objectives of increasing capacity and minimizing interference is required. A variety of channel assignment strategies have been developed to achieve these objectives.

Channel assignment strategies can be classified as either fixed or dynamic. The choice of channel assignment strategy impacts the performance of the system, particularly as to how calls are managed when a mobile user is handed off from one cell to another.

a) **Fixed channel assignment strategy**: each cell is allocated a predetermined set of voice channels.
   - Any call attempt within the cell can only be served by the unused channels in that particular cell.
   - If all the channels in that cell are occupied, the call is blocked and the subscriber does not receive service.
   - ***Borrowing strategy*****:** a cell is allowed to borrow channels from a neighboring cell if all of its own channels are already occupied. The mobile switching center (MSC) supervises such borrowing procedures and ensures that the borrowing of a channel does not disrupt or interfere with any of the calls in progress in the donor cell.

b) **Dynamic channel assignment strategy**: voice channels are not allocated to different cells permanently. Instead,
   - Each time a call request is made, the serving base station requests a channel from the MSC.
   - The switch then allocates a channel to the requested cell following an algorithm that takes into account the likelihood of
     - Future blocking within the cell,
     - The frequency of use of the candidate channel,
     - The reuse distance of the channel,
     - Other cost functions.

- Accordingly, the MSC only allocates a given frequency if that frequency is not presently in use in the cell or any other cell which falls within the minimum restricted distance of frequency reuse to avoid co-channel interference.

***Advantage*:**

- Dynamic channel assignment reduces the likelihood of blocking, which increases the trunking capacity of the system, since all the available channels in a market are accessible to all of the cells.
- Increases the channel utilization and decreases probability of a blocked call.

***Disadvantage*:**

- Require the MSC to collect real-time data on channel occupancy, traffic distribution, and radio signal strength indications (RSSI) of all channels on a continuous basis. This increases the storage and computational load on the system.

2.8 Co-channel Interference

The *S/I* ratio at the desired mobile receiver is given as:

$$\frac{S}{I} = \frac{S}{\sum_{k=1}^{N_I} I_k}$$

where:

I_k = the interference due to the *k*th interferer

N_I = the number of interfering cells in the first tier.

In a fully equipped hexagonal-shaped cellular system, there are always six co-channel interfering cells in the first tier (i.e., $N_I = 6$).

- Most of the co-channel interference results from the first tier.

- Interference from second and higher tiers amounts to less than 1% of the total interference (ignored).
- Co-channel interference can be experienced both at the cell site and the mobile stations in the center cell.
- In a small cell system, interference will be the dominating factor and thermal noise can be neglected. Thus the *S/I* ratio can be given as:

$$\frac{S}{I} = \frac{1}{\sum_{k=1}^{6} \left(\frac{D_k}{R}\right)^{-\gamma}}$$

where:

$2 \leq \gamma \leq 5$: the propagation path loss, and γ depends upon the terrain environment.

D_k : the distance between mobile and *k*th interfering cell

R : the cell radius

If we assume D_k is the same for the six interfering cells for simplification, or $D = D_k$, then Equation above becomes:

$$\frac{S}{I} = \frac{1}{6(q)^{-\gamma}} = \frac{q^{\gamma}}{6}$$

Therefore

$$\therefore q = \left[6\left(\frac{S}{I}\right)\right]^{1/\gamma}$$

Since $q = \sqrt{3N}$, therefore

$$N = \frac{1}{3}\left[6\left(\frac{S}{I}\right)\right]^{\frac{2}{\gamma}}$$

Example 3

Consider the advanced mobile phone system (AMPS) in which an *S/I* ratio of 18 dB is required for the accepted voice quality. Assume γ = 4.

(a) What should be the reuse factor for the system?

(b) What will be the reuse factor of the Global System of Mobile (GSM) system in which an *S/I* of 12 dB is required?

Solution

$$N = \frac{1}{3}\left[6\left(\frac{S}{I}\right)\right]^{\frac{2}{\gamma}}$$

$$N_{AMPS} = \frac{1}{3}\left[6\left(10^{\frac{18}{10}}\right)\right]^{\frac{2}{4}} = 6.486 \approx 7$$

(b)

$$N_{GSM} = \frac{1}{3}\left[6\left(10^{\frac{12}{10}}\right)\right]^{\frac{2}{4}} = 3.251 \approx 4$$

Example 4

Consider a cellular system with 395 total allocated voice channel frequencies. Calculate the mean *S/I* ratio for cell reuse factor equal to 4, 7, and 12. Assume omnidirectional antennas with six interferers in the first tier and a slope for path loss of 40 dB/decade (γ = 4). Discuss the results.

Solution

For a reuse factor N = 4, the number of voice channels per cell site = K/N = 395/4 = 99.

$$N = \frac{1}{3}\left[6\left(\frac{S}{I}\right)\right]^{\frac{2}{\gamma}}$$

$$4 = \frac{1}{3}\left[6\left(\frac{S}{I}\right)\right]^{\frac{2}{4}}$$

$$\frac{S}{I} = 24\ (13.8\,dB)$$

The results for $N = 7$ and $N = 12$ are given in Table below.

N	Voice channels per cell	Mean *S/I* (dB)
4	99	13.8
7	56	18.7
12	33	23.3

It is evident from the results that, by increasing the reuse factor from $N = 4$ to $N = 12$, the mean *S/I* ratio is improved from 13.8 to 23.3 dB.

2.9 Co-channel Interference Reduction

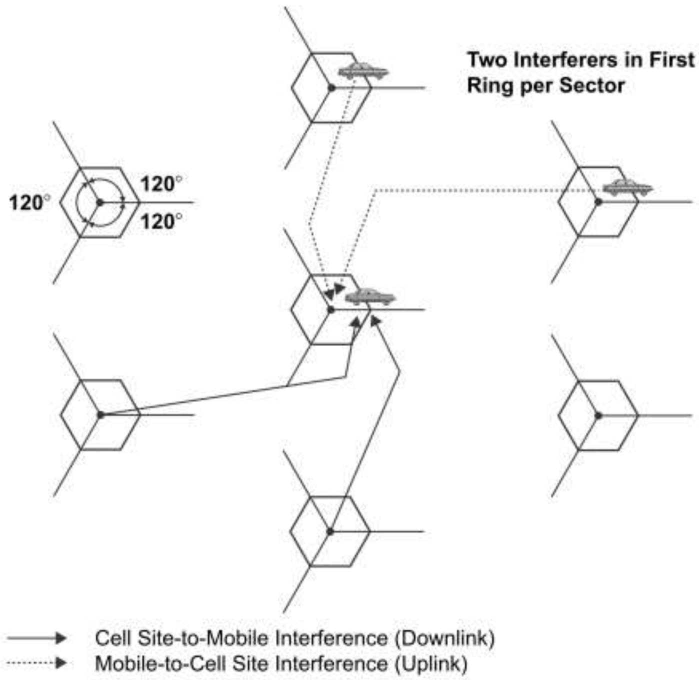
In the case of increased call traffic, the frequency spectrum should be used efficiently. We should avoid increasing the number of cells *N* in a frequency reuse pattern. As *N* increases, the number of frequency channels assigned to a cell is reduced, thereby decreasing the call capacity of the cell.

Instead of increasing N, we either

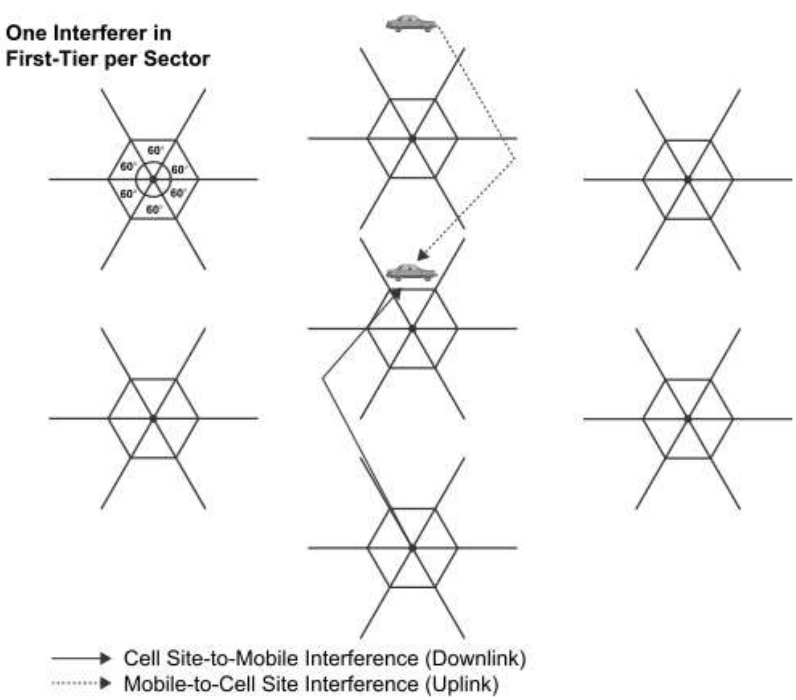
a. Perform cell splitting to subdivide a congested cell into smaller cells.

Or

b. Use a directional antenna arrangement (sectorization) to reduce co-channel interference. In this case, each cell is divided into three or six sectors and uses three or six directional antennas at the base station to reduce the number of co-channel interferers



Co-channel interference with 120° sectorized cells.



Co-channel interference with 60° sectorized cells.

Each sector is assigned a set of channels (frequencies) (either 1/3 or 1/6 of the frequencies of the omnidirectional cell).

2.10 Adjacent Channel Interference (ACI)

Signals which are adjacent in frequency to the desired signal cause adjacent channel interference. ACI is brought about primarily because of imperfect receiver filters which allow nearby frequencies to move into the pass band, and nonlinearity of the amplifiers.

The ACI can be reduced by:

(1) Using modulation schemes which have low out-of-band radiation.

(2) Carefully designing the band-pass filter (BPF) at the receiver front end.

(3) Assigning adjacent channels to different cells in order to keep the frequency separation between each channel in a given cell as large as possible.

The effects of ACI can also be reduced using advanced signal processing techniques that employ equalizers.

Review

We developed a relationship between the reuse ratio (q) and cell cluster size (N) for the hexagonal geometry. Co-channel interference ratios for the omnidirectional and sectorized cell were derived. A numerical example was given to demonstrate that, for a given cluster size, sectorization yields a higher S/I ratio, but reduces spectral efficiency. However, it is possible to achieve a higher spectral efficiency by reducing the cluster size in a sectorized system without lowering the S/I ratio below the minimum requirement.

2.11 Handoff (Handover) Strategies

When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.

The Handoff decision is made depending on:

a. Power
b. Traffic
c. Channel quality
d. Distance
e. Administration

The handoff operation involves:

1. Identifying a new base station,
2. Allocate the voice and control signals to channels associated with the new base station.

Once a particular signal level is specified as the minimum usable signal for acceptable voice quality at the base station receiver (normally taken as between -90 dBm and -100 dBm), a slightly stronger signal level is used as a threshold at which a handoff is made. This margin (cannot be too large or too small) is given by

$$A = P_{r_{Handoff}} - P_{r_{Minimum\ usable}}$$

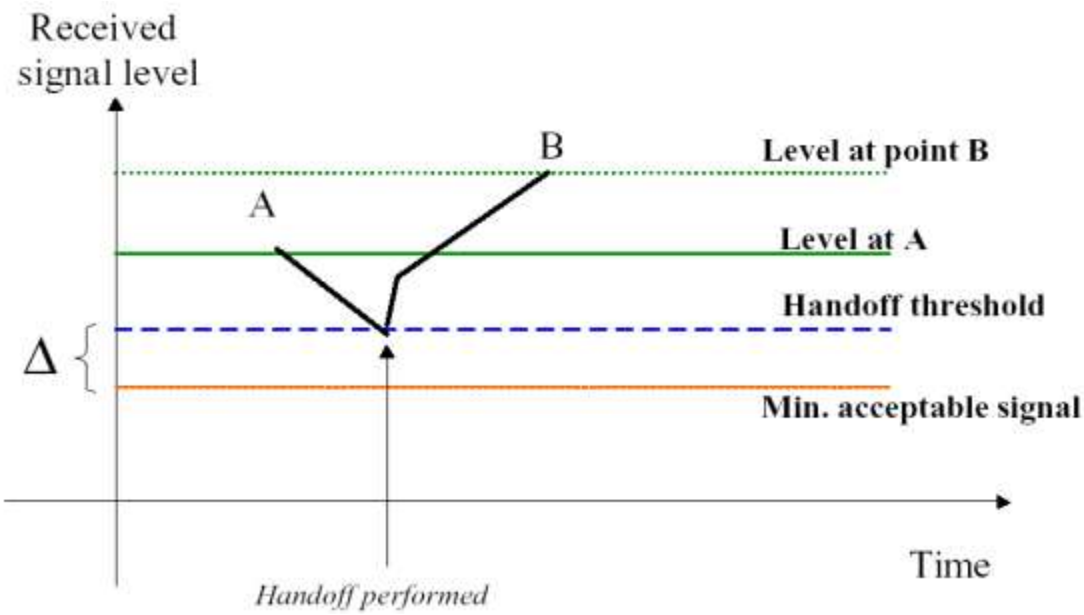
- If *A* is too large, unnecessary handoffs which burden the MSC may occur.
- If *A* is too small, there may be insufficient time to complete a handoff before a call is lost due to weak signal conditions.

Therefore, *A* is chosen carefully to meet these conflicting requirements.

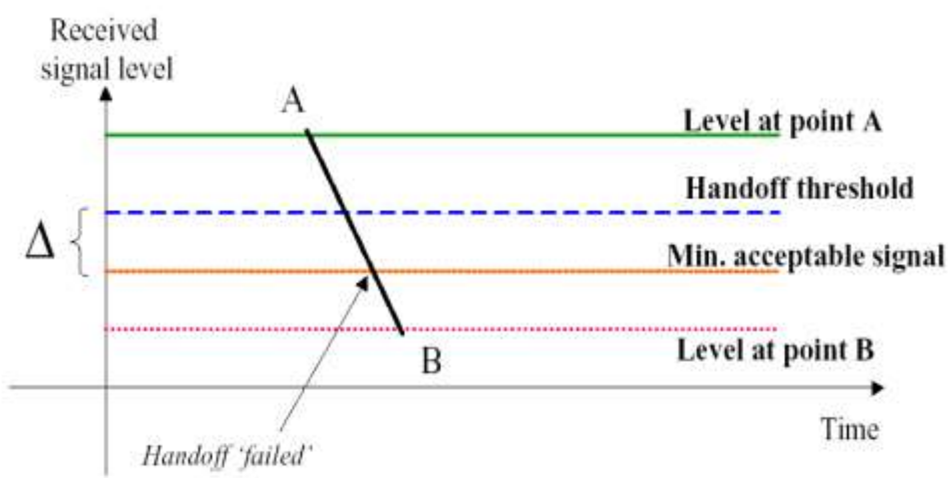
Figure below demonstrates the case where a handoff is not made and the signal drops below the minimum acceptable level to keep the channel active. This dropped call event can happen when there is an excessive delay by the MSC in assigning a handoff, or when the threshold *A* is set too small for the handoff time in the system. ***The length of time needed to decide if a handoff is necessary depends on the speed at which the vehicle is moving***

Excessive delays may occur during high traffic conditions due to

- Either computational loading at the MSC
- Or no channels are available on any of the nearby base stations



Value of delta is large enough. When the $P_{Handoff}$ is reached, the MSC initiates the handoff.



In this case, the MSC was unable to perform the handoff before the signal level dropped below the minimum usable level, and so the call was lost.

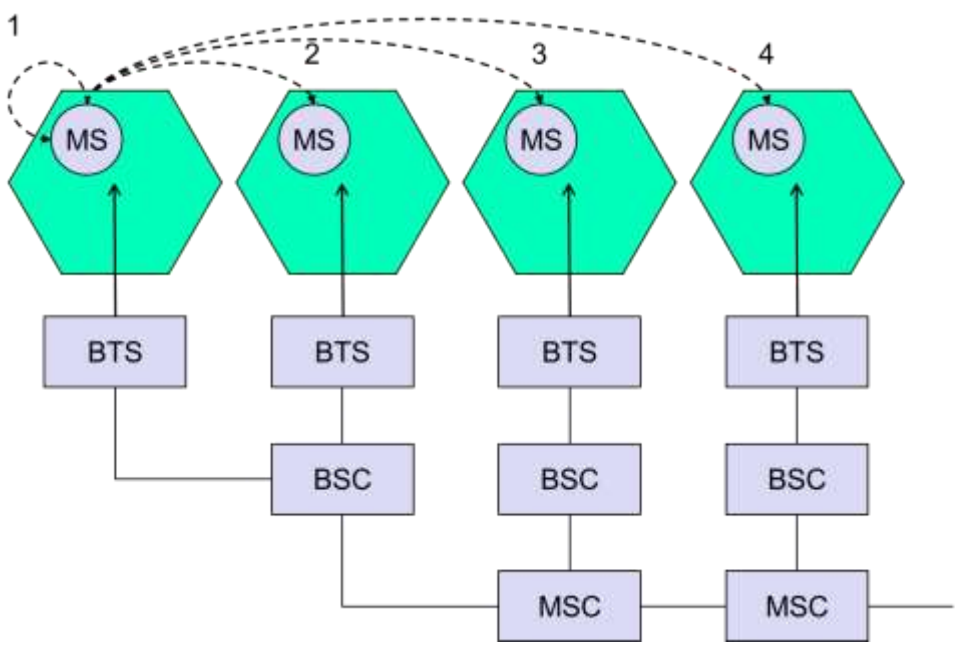
2.12 Handoff Types

Handoff can be categorized as hard handoff, soft handoff, and softer handoff.

If the hand-off is needed between two cells (BTS) controlled by the same Base Station Controller (BSC), the MSC is not needed as the BSC does it all.

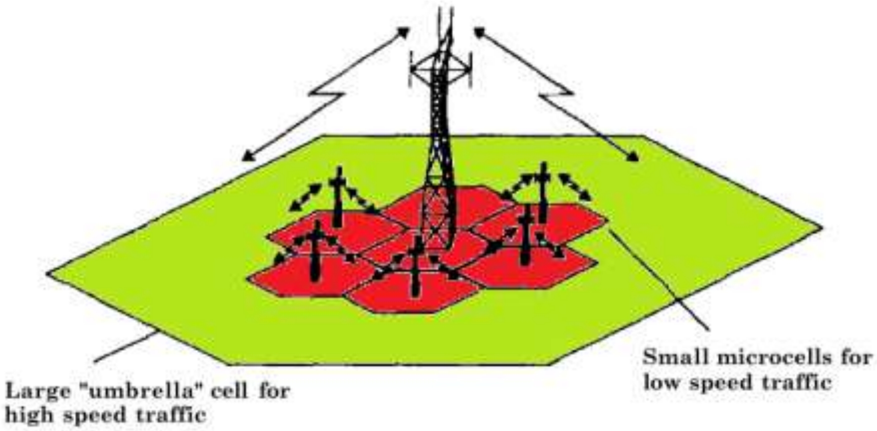
Types of hand-off are:

1. INTRA-CELL, within a cell, narrow-band interferences could make transmission at a certain frequency impossible. The BSC decides to change the carrier frequency.
2. INTRA BSS, between cells controlled by the same BSC. The BSC performs the handover, assigns a new radio channel in the new cell and releases the old one
3. INTER BSS, between cells controlled by different BSCs, and the MSc is involved.
4. INTER MSC-from region to region where more than one MSC is involved. Between two cells belonging to different MSCs. Both MSCs perform the handover together



2.13 Umbrella cell approach

- By using different antenna heights (often on the same building or tower) and different power levels, it is possible to provide "large" and "small" cells which are co-located at a single location. This technique is called the umbrella cell approach
- Used to provide large area coverage to high speed users while providing small area coverage to users traveling at low speeds.



- The umbrella cell approach ensures that the number of handoffs is minimized for high speed users and provides additional microcell channels for pedestrian users.
- The speed of each user may be estimated by the base station or MSC by evaluating how rapidly the short term average signal strength on the RVC changes over time, or more sophisticated algorithms may be used to evaluate and partition users.
- If a high speed user in the large umbrella cell is approaching the base station, and its velocity is rapidly decreasing, the base station may decide to hand the user into the co-located microcell, without MSC intervention.
- **When the speed of the mobile is too high**, the mobile is handed off to the umbrella cell. The mobile will then stay longer in the same cell (in this case the umbrella cell).

- large cell → high speed traffic → fewer handoffs
- small cell → low speed traffic