

Summary Mobile Communications

1. GSM System Overview

- **Components:**
 - **Mobile Station (MS):** User's device.
 - **Base Station (BS):** Handles communication within a cell.
 - **Mobile Switching Center (MSC):** Core of call control, mobility management, and inter-network connections.
 - **Registers:**
 - **HLR (Home Location Register):** Stores user data (e.g., subscription info).
 - **VLR (Visitor Location Register):** Temporary data storage for roaming users.
 - **Authentication Center (AuC):** Validates user credentials.
- **Subsystems:**
 - **Radio Subsystem (RSS):** Radio transmission and reception.
 - **Network & Switching Subsystem (NSS):** Call setup, handovers, and system control.
 - **Operation Subsystem (OSS):** Network maintenance and monitoring.

2. Cell Types

- **Macro Cell:** Covers large areas (~6 miles), used in rural or remote locations.
- **Micro Cell:** Small coverage (~0.5 miles), suited for urban areas.
- **Pico Cell:** Indoor spaces like malls and offices.
- **Selective Cells:** Limited coverage (e.g., tunnels, entrances).
- **Umbrella Cells:**
 - Large cells for high-speed traffic, minimizing handoffs.
 - Small cells for low-speed traffic.

3. RF Planning

- **Coverage:** Signal strength over a geographical area.
- **Capacity:** Number of users a system can handle.
- **Trade-offs:**
 - Increasing coverage may reduce capacity.
 - Increasing capacity may require more base stations.

4. Frequency Reuse

- Assigns unique frequencies to adjacent cells to avoid interference.
- Reuse patterns depend on cluster size (**N**):
 - **Small N:** Higher capacity but more interference.
 - **Large N:** Lower interference but reduced capacity.

5. Interference Management

- **Co-channel Interference:**
 - Interference from cells using the same frequency.
 - Minimized through frequency reuse and sectorization.
- **Adjacent Channel Interference (ACI):**
 - Caused by signal overlap due to imperfect filters.
 - Reduced by:
 - Better filter design.
 - Assigning adjacent channels to distant cells.

6. Channel Assignment

- **Fixed Assignment:** Predetermined channels for each cell.
- **Dynamic Assignment:**
 - Real-time allocation based on traffic demand.
 - Reduces call blocking and improves channel utilization.

7. Handoff (Handover)

- **Types:**
 - **Intra-cell:** Frequency change within the same cell.
 - **Intra-BSS:** Between cells under the same BSC.
 - **Inter-BSS:** Between cells managed by different BSCs.
 - **Inter-MSC:** Between regions controlled by different MSCs.
- **Factors** influencing handoff decisions:
 - Signal strength, traffic, channel quality, distance, and administrative policies.
- **Umbrella Approach:**
 - Reduces handoffs for fast-moving users by keeping them in larger cells.

8. Cell Splitting

- Dividing larger cells into smaller ones to handle congestion.
- Improves capacity but increases system complexity.

9. Hexagonal Cell Geometry

- Hexagons are used because:
 - They minimize gaps and overlaps.
 - They provide consistent coverage and efficient frequency reuse.

10. Channel Utilization and Capacity

- Total channels depend on cluster size (**N**) and available spectrum.
- Capacity increases with more clusters and optimized frequency reuse.

11. Optimization Strategies

- **Directional Antennas:**
 - Reduces co-channel interference by focusing signal coverage.
- **Sectorization:**
 - Divides cells into sectors, each served by its own antenna.
- **Dynamic Channel Allocation:**
 - Assigns channels on demand to minimize blocking.

12. Definitions and Components

- **BTS (Base Transceiver Station):** Communicates with mobile devices.
- **BSC (Base Station Controller):** Manages multiple BTSs and handles handovers.
- **PSTN (Public Switched Telephone Network):** Interconnects mobile and fixed networks.
- **SIM (Subscriber Identity Module):** Identifies and authenticates subscribers.

13. Handoff Types Summary

- **Hard Handoff:** Disconnects from one cell before connecting to another.
- **Soft Handoff:** Maintains simultaneous connections to multiple cells during transition.
- **Softer Handoff:** Happens within sectors of the same cell.
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The Handoff decision is made depending on:

or

Factors influencing handoff decisions:

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

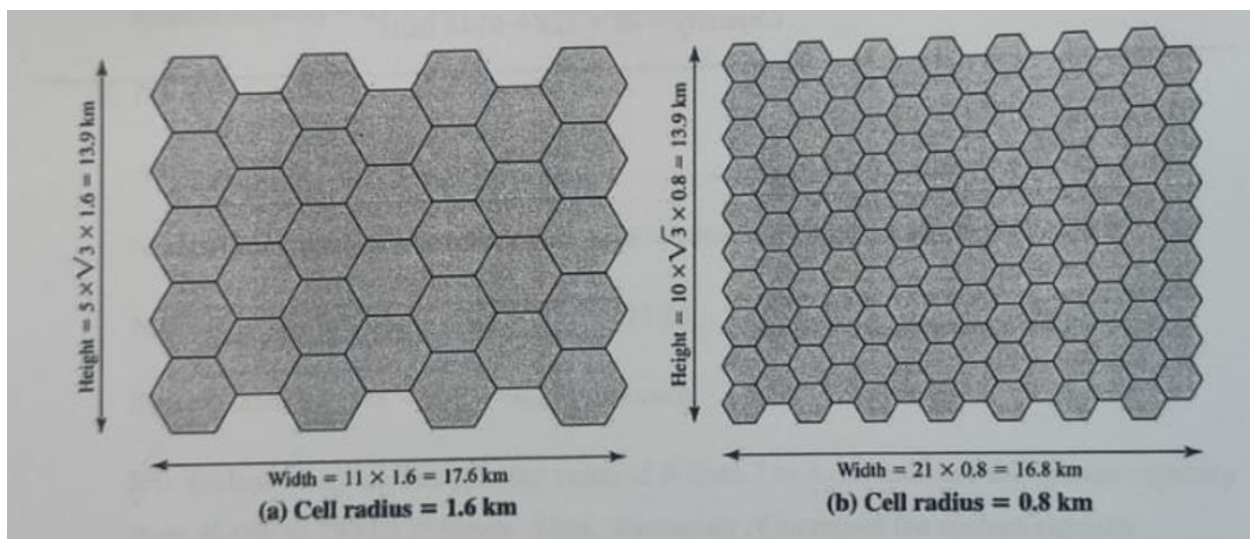
14. Key Calculations and Design Principles

- Frequency reuse patterns are based on the formula:
$$N = I^2 + J^2 + (I \cdot J)$$
$$N = I^2 + J^2 + (I \cdot J)$$
, where I, J, J are integers.
- Signal-to-Interference Ratio (S/I) is a critical metric:
 - Higher S/I means better call quality but lower capacity.

Example 1

Assume a system of 32 cells with a cell radius of 1.6 km, a total of 32 cells, a total frequency bandwidth that supports 336 traffic channels, and a reuse factor of $N=7$.

(a) If there are 32 total cells, what geographic area is covered, how many channels are there per cell, and what is the total number of concurrent calls that can be handled? (b) Repeat for a cell radius of 0.8 km and 128 cells.



Solution:

(a)

The area of a hexagon of radius R is

Area,

$$\text{Area} = 3\sqrt{3}/2 \times R^2 = 3\sqrt{3}/2 \times (1.6)^2 = 6.65 \text{ km}^2$$

The total area covered is $6.65 \times 32 = 213 \text{ km}^2$.

For $N=7$, the number of channels per cell is $K/N=336/7=48$,

Total number of concurrent calls that can be handled is

Capacity $48 \times 32 = 1536$ channels

(b)

The area of a hexagon of radius R is

$$\text{Area} = \frac{3\sqrt{3}}{2} \times R^2 = \frac{3\sqrt{3}}{2} \times (0.8)^2 = 1.66 \text{ km}^2$$

The area covered is $1.66 \times 128 = 213 \text{ km}^2$.

The number of channels per cell is $K/N=336/7=48$,

Total number of concurrent calls is

Capacity $48 \times 128 = 6144$ calls

Example 2

Consider a cellular system in which total available voice channels to handle the traffic are 960. The area of each cell is 6 km² and the total coverage area of the system is 2000 km². Calculate:

(a) The system capacity if the cluster size N is 4

(b) The system capacity if the cluster size is 7.

. How many times would a cluster of size 4 have to be replicated to cover the entire cellular area? Does decreasing N increase the system capacity? Explain.

Solution

Total available channels=960, Cell area = 6 km²

Total coverage area = 2000 km²

(a) $N=4$

Area of a cluster = $4 \times 6 = 24$ km²

Number of clusters for covering total area = $2000/24 = 83.33 \sim 83$

Number of channels per cell = $960/4 = 240$

System capacity = $83 \times 960 = 79,680$ channels

(b) $N=7$

Area of cluster = $7 \times 6 = 42$ km²

Number of clusters for covering total area = $2000/42 = 47.62 \sim 48$

Number of channels per cell = $960/7 = 137.15 \sim 137$

System capacity = $48 \times 960 = 46,080$ channels

It is evident that when we decrease the value of N from 7 to 4, we increase the system capacity from 46,080 to 79,680 channels. Thus, decreasing N increases the system capacity.

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 $\gamma = 4$.

- (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 :

a)

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

$$N_{AMPS} = \frac{1}{3} \left[6 \left(10^{1.8} \right) \right]^{\frac{2}{4}} = 6.486 \approx 7$$

b)

$$N_{GSM} = \frac{1}{3} \left[6 \left(10^{1.2} \right) \right]^{\frac{2}{4}} = 3.251 \approx 4$$

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 ($\gamma = 4$). Discuss the results.

Solution:

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

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

$$4 = \frac{1}{3} \left[6 \left(\frac{S}{I} \right) \right]^{\frac{2}{4}}$$
$$\frac{S}{I} = 24 \text{ (13.8 dB)}$$

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.