PCC UNIT-2

1. Why is the cellular concept incorporated?

A.

1. Efficient Spectrum Utilization

- **Challenge**: The radio frequency spectrum is limited and must be used efficiently.
- **Solution**: Divide the coverage area into smaller regions called *cells*, each served by its own base station.
- **Advantage**: Frequencies can be reused in non-adjacent cells, significantly increasing the number of users supported without requiring additional spectrum.

2. Scalability and Coverage Flexibility

- Cells can be resized or added based on user density and geographic needs.
- **Macro cells** cover large rural areas, while **micro, pico, and femto cells** serve dense urban or indoor environments.
- This modular structure allows networks to grow and adapt dynamically.

3. Reduced Transmission Power

- Smaller cells mean devices and base stations can operate at lower power levels.
- This reduces interference between cells and conserves battery life for mobile devices.
- It also improves signal quality and safety.

4. Frequency Reuse

- The cellular layout enables **frequency reuse**—the same frequency bands can be used in different cells that are spaced far enough apart.
- This increases the overall capacity of the network without expanding the spectrum.

5. Support for Mobility

- As users move, their connection can be handed off from one cell to another.
- This **handover mechanism** ensures uninterrupted service, which is critical for mobile voice and data communication.

6. Load Balancing and Traffic Management

- Traffic can be distributed across multiple cells.
- Overloaded cells can redirect users to neighboring cells to maintain service quality.
- This helps maintain **Quality of Service (QoS)** and optimizes network performance.

2. Discuss about channel assignment strategies.

A.

1. Fixed Channel Assignment (FCA)

Description:

- Each cell is allocated a predetermined set of frequency channels.
- Channels are not shared between cells.
- Frequency reuse is applied using a reuse pattern (e.g., 7-cell cluster).

Pros:

- Simple to implement.
- Predictable performance.

Cons:

- Inefficient under variable traffic conditions.
- Some cells may be overloaded while others are underutilized.

Example:

- A rural network with predictable traffic might use FCA with a 7-cell reuse pattern.

2. Dynamic Channel Assignment (DCA)

Description:

- Channels are not permanently assigned to cells.
- Instead, they are allocated dynamically based on demand and availability.
- Centralized or distributed algorithms decide channel allocation.

Pros:

- Efficient use of spectrum.
- Adapts to traffic fluctuations.

Cons:

- Requires complex control and signaling.
- Higher computational overhead.

Example:

- Urban networks with fluctuating traffic loads benefit from DCA.

3. Hybrid Channel Assignment (HCA)

Description:

- Combines features of FCA and DCA.
- Each cell has a fixed set of channels and can borrow additional channels dynamically when needed.

Pros:

- Balances simplicity and flexibility.
- Reduces blocking probability during peak loads.

Cons:

- More complex than pure FCA.
- Requires coordination between cells.

Example:

- Suburban networks with moderate variability in traffic may use HCA.

3. What is frequency reuse distance. How it is measured.

A.

Frequency reuse distance is the **minimum physical separation** between two cells using the **same frequency channel** in a cellular network. It ensures that signals from one cell do not interfere with another cell using the same frequency.

- The minimum distance which allows the same frequency to be reused will depend on the following factors
  - Number of cochannel cells
  - Type of geographical terrain contour
  - Antenna Height
  - Transmitted power at each cell site
  - The frequency reuse distance D can be determined from

$$D = \sqrt{3N} \times \mathrm{R}$$

Where N is the Cluster size

The reuse distance D depends on:

- **Cell radius** R
- **Cluster size** N, which is the number of cells in a frequency reuse pattern

Formula:

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

Where:

- D = frequency reuse distance
- R = radius of a cell
- N = cluster size (e.g., 3, 4, 7)

Example:

If cell radius $R = 1$ km and cluster size $N = 7$:

$$D = 1 \times \sqrt{21} \approx 4.58 \text{ km}$$

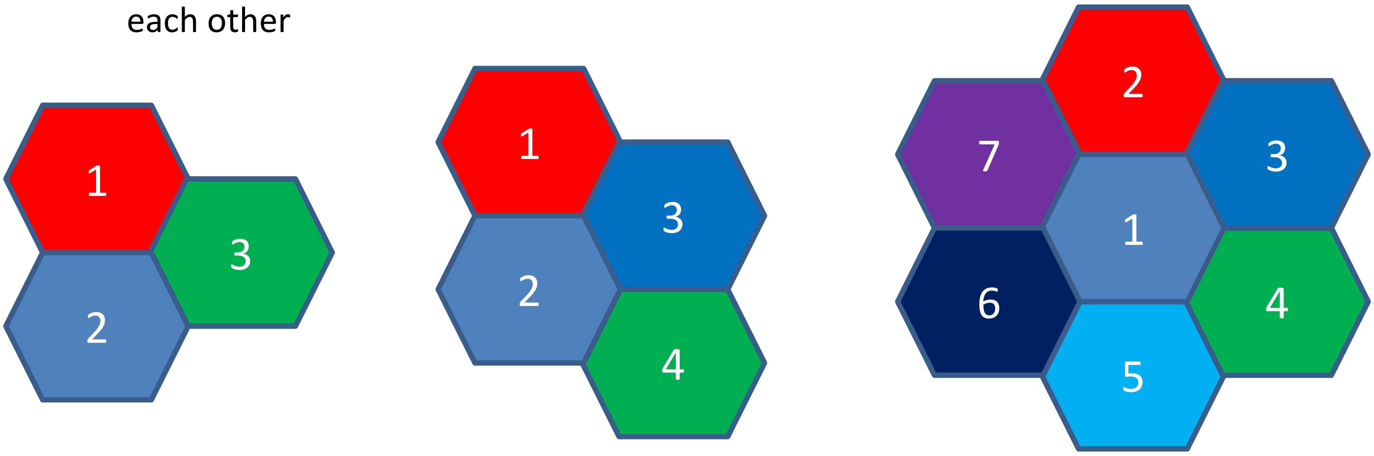
4. How to calculate number of channels in a cellular system

- A. Consider a cellular system which has a total of S duplex channels.
- Each cell is allocated a group of *k* channels, $k < S$ and *S* channels are divided among *N* cells.
- The total number of available radio channels

  S = kN
- The *N* cells which use the complete set of channels is called *cluster*
- The cluster can be repeated *M* times within the system. The total number of channels, *C*, is used as a measure of capacity

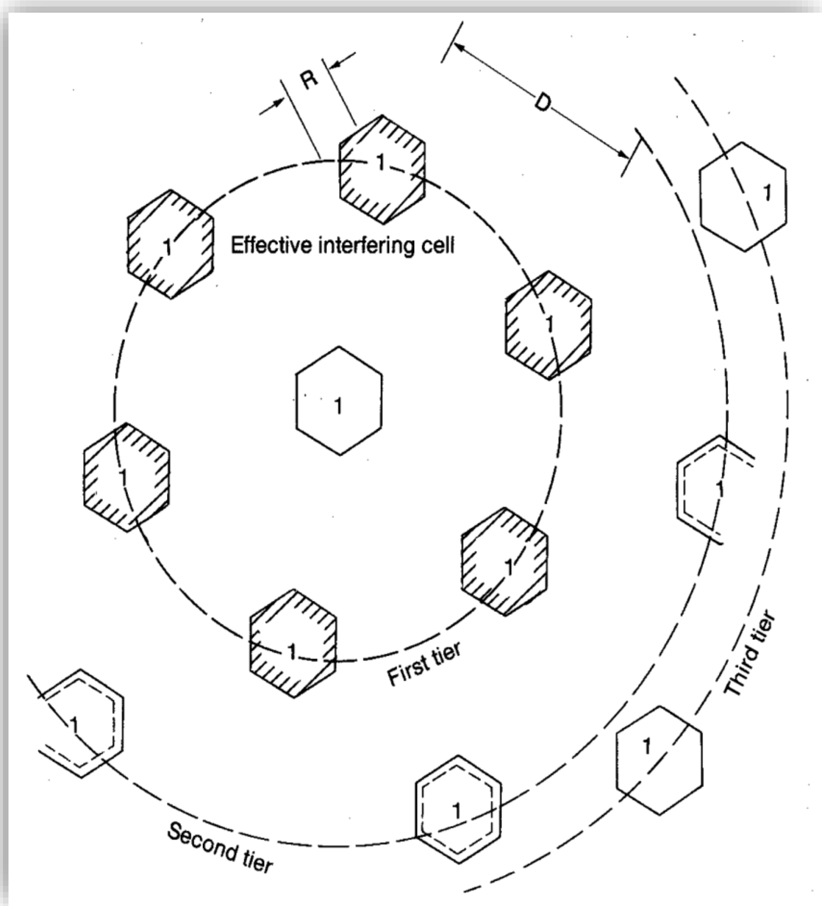
  C = MkN = MS
- The capacity is directly proportional to the number of replication *M.*

- ❑ The cluster size, *N*, is typically equal to 3, 4, 7, 12 or 19.
- ❑ Small *N* is desirable to maximize capacity.
- ❑ No frequency reuse is done within a cluster
- ❑ Large cluster size indicates ratio b/w R and D are small
- ❑ Small cluster size indicates the co-channel cells are located much closer to each other



3-cell 4-cell 7-cell

5. Define co-channel interference. Discuss about cochannel interference reduction factor.



Co-channel interference occurs when multiple cells use the **same frequency channel** and their coverage areas overlap or are too close. Since frequencies are reused in cellular systems to maximize spectrum efficiency, interference from these co-channel cells can degrade signal quality.

Key Characteristics:

- Unlike adjacent-channel interference, CCI is caused by **intentional frequency reuse**.
- It is **dominant in cellular systems**, especially when reuse distance is insufficient.
- It affects **signal-to-interference ratio (SIR)**, which impacts call quality and data throughput.

Co-Channel Interference Reduction Factor (Q)

The **co-channel interference reduction factor**, denoted by QQ, quantifies how well a cellular system can suppress co-channel interference. It is defined as the ratio of the **reuse distance** DD to the **cell radius** RR:

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

Where:

- D = reuse distance
- R = cell radius
- N = cluster size (number of cells in a reuse pattern)

Interpretation:

- A **higher Q** means greater separation between co-channel cells, leading to **lower interference**.
- Increasing N increases Q, but reduces the number of channels per cell (since $C = S/N$).

Example Calculation

Suppose:

- Cluster size $N = 7$

Then:

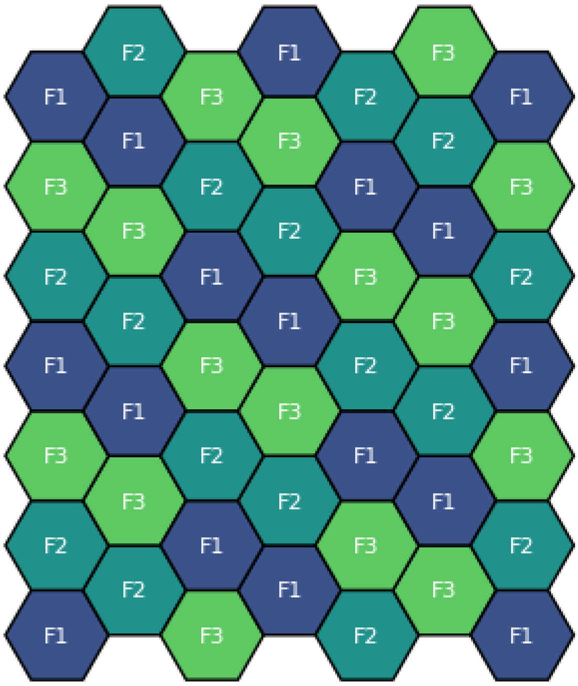
$$Q = \sqrt{3 \times 7} = \sqrt{21} \approx 4.58$$

This means co-channel cells are separated by approximately 4.58 times the cell radius, reducing interference.

6. Discuss about frequency reuse concept with diagram

A.

Frequency Reuse Pattern in Cellular Communication



Explanation of Frequency Reuse

- ☐ The figure represents the concept of cellular frequency reuse, where cells labelled with same letters use same frequency group.
- ☐ Hexagon cell shape is universally used for representing a cell because they closely approximated to circle also the permit easy and manageable analysis of cellular systems.
- ☐ These cells can be of two types
    - ▪ Centre excited cell-BS are placed at centre
    - ▪ Edge excited cell-BS are placed at the edges of the cell

Concept Overview

- **Frequency reuse** is a technique used to optimize the use of limited spectrum by assigning the same frequency channels to multiple cells separated by sufficient distance.
- It enables **increased capacity** and **efficient spectrum utilization** while minimizing interference.

Key Elements in the Diagram

- **Hexagonal Cells**: Represent individual coverage areas in a cellular network.
- **Frequency Groups (F1, F2, F3)**: Each color-coded cell uses one of three frequency groups.
- **Reuse Pattern**: Frequencies are reused in non-adjacent cells to avoid co-channel interference.

Reuse Factor

- The **reuse factor (N)** is the number of distinct frequency groups used before reuse.
- In the diagram, a reuse factor of 3 is shown, meaning three unique frequency sets (F1, F2, F3) are used cyclically.

7. Explain about general description of the problem in cellular radio system design.

A. **General Description of the Problem in Cellular Radio System Design**

Cellular radio system design is a complex engineering task that involves optimizing multiple parameters to ensure reliable communication, efficient spectrum usage, and scalable infrastructure. The primary design problems can be categorized as follows:

1. Spectrum Scarcity

- **Problem**: The radio frequency spectrum is limited and heavily regulated.
- **Impact**: Designers must maximize spectral efficiency through reuse techniques and advanced modulation schemes.
- **Solution Approaches**:
  - Frequency reuse
  - Dynamic spectrum allocation
  - Efficient multiple access methods (e.g., OFDMA, CDMA)

2. Coverage vs. Capacity Trade-off

- **Coverage**: Ensuring signal availability across the geographic area.
- **Capacity**: Supporting a large number of simultaneous users.
- **Design Conflict**:
  - Larger cells improve coverage but reduce capacity.
  - Smaller cells increase capacity but require more infrastructure and frequent handoffs.

3. Interference Management

- **Types of Interference**:
  - Co-channel interference (same frequency reused in nearby cells)
  - Adjacent channel interference (overlapping frequencies)
- **Design Challenge**: Minimizing interference while maximizing reuse.
- **Techniques**:
  - Frequency planning
  - Power control
  - Sectoring and smart antennas

4. Mobility and Handoff

- **Problem**: Maintaining seamless connectivity as users move between cells.
- **Design Considerations**:
  - Efficient handoff algorithms (hard vs. soft handoff)
  - Location tracking and paging
  - Minimizing dropped calls and latency during transitions

5. Power Control

- **Objective**: Adjust transmission power to maintain link quality and reduce interference.
- **Challenge**: Dynamic adaptation based on user location, channel conditions, and network load.
- **Importance**: Especially critical in CDMA and 5G systems where users share spectrum.

6. Cell Planning and Site Selection

- **Factors Influencing Design**:
  - Terrain and urban density
  - Population distribution
  - Regulatory and zoning constraints
- **Goal**: Optimize cell placement to minimize coverage gaps and overlaps.

7. Traffic Load Distribution

- **Issue**: Uneven user distribution leads to congestion in some cells and underutilization in others.
- **Design Requirement**: Adaptive load balancing and dynamic resource allocation.

8. Quality of Service (QoS)

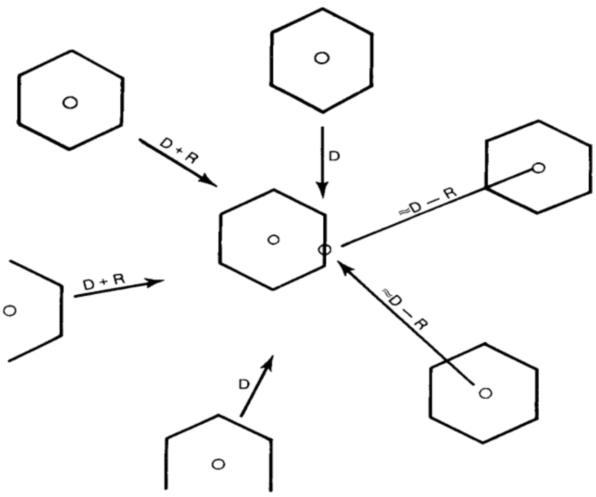
- **Parameters**: Signal strength, latency, throughput, call drop rate.
- **Challenge**: Maintaining consistent QoS under varying traffic and environmental conditions.
- **Solutions**:
  - Prioritization of traffic types
  - Real-time performance monitoring
  - Adaptive modulation and coding

9. Scalability and Evolution

- **Problem**: Systems must support future growth in user base and data demand.
- **Design Goal**: Ensure modularity, upgradeability, and compatibility with emerging technologies (e.g., 5G, IoT).

8. Derive the desired C/I from a worst case in an Omni directional Antenna System.

A.



Assumptions

- **Omni-directional antennas**: Each base station radiates uniformly in all directions.
- **Hexagonal cell layout**: Standard model for cellular systems.
- **Worst-case location**: Mobile user is at the cell boundary, equidistant from interfering co-channel cells.
- **Reuse factor (N)**: Number of cells in a frequency reuse pattern.

- **Path loss exponent (n)**: Typically ranges from 2 (free space) to 4 (urban environments).
- The worst case is at the location where the mobile unit would receive the weakest signal from its own cell site but strong interferences from all interfering cell sites.
- A N=7 cellpattern does not provide a sufficient frequency reuse distance even when the ideal condition of flat terrain is assumed.
- The distances from all six cochannel interfering sites are shown in the figure: Two distances of $D - R$, Two distances of D, and Two distances of $D + R$

$$C \propto R^{-4} \ , \mathrm{I} \propto D^{-4}$$

$$\frac{C}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D)^{-4} + 2(D+R)^{-4}} = \frac{1}{2(q-1)^{-4} + 2(q)^{-4} + 2(q+1)^{-4}}$$

- ☐ For q=4.6, C/I=17dB,which is lower than18dB.
- ☐ If we use the shortest distance $D - R$, *then*

$$\frac{C}{I} = \frac{R^{-4}}{6(D-R)^{-4}} = \frac{1}{6(q-1)^{-4}} = 28 = 14.47dB$$

- ☐ Therefore, in an Omni-directional-cell system, N =9 or N =12 would be a correct choice. Thenthe values of q are:

$$q = \begin{cases} \frac{D}{R} = \sqrt{3N} \\ 5.2; \quad N = 9 \\ 6; \quad N = 12 \end{cases}$$

$$\frac{C}{I} = 84.5 = 19.25\ dB; \mathrm{N} = 9$$

$$\frac{C}{I} = 179.33 = 22.54\ dB; \mathrm{N} = 12$$

- ❑ N=9 and N=12 Cell patterns are used when the traffic is light. Each cell covers an adequate area with adequate number of channels to handle the traffic.

9. How the interference is different from Apply noise and explain different types of interference in a cellular system. How co-channel interference is measured at the mobile unit and at the cell site?

A.

1. Interference vs. Noise

Aspect	Interference	Noise
Origin	Caused by other transmitters (intentional or unintentional)	Intrinsic to electronic systems or external natural sources
Nature	Deterministic or semi-deterministic (e.g., from nearby cells)	Random and unpredictable
Examples	Co-channel interference, adjacent channel interference	Thermal noise, shot noise
Impact	Degrades signal quality due to overlapping transmissions	Adds uncertainty and limits minimum detectable signal
Mitigation	Frequency planning, power control, filtering	Noise figure optimization, shielding, cooling

2. Types of Interference in Cellular Systems

a. Co-channel Interference (CCI)

- **Definition**: Interference from cells using the same frequency in a reuse pattern.
- **Cause**: Frequency reuse in non-adjacent cells.
- **Impact**: Reduces signal quality, especially at cell edges.
- **Mitigation**:
  - Increase reuse distance
  - Use directional antennas
  - Employ power control

b. Adjacent Channel Interference (ACI)

- **Definition**: Interference from signals in neighboring frequency bands.
- **Cause**: Imperfect filtering, transmitter leakage, receiver selectivity.
- **Impact**: Affects users near strong adjacent signals.
- **Mitigation**:
  - Improved filtering
  - Guard bands
  - Receiver design enhancements

c. Intermodulation Interference

- **Definition**: Nonlinear mixing of multiple signals producing spurious frequencies.
- **Cause**: Nonlinear components in transmitters or receivers.
- **Impact**: Can fall within the operating band and degrade performance.
- **Mitigation**:
  - Use linear amplifiers
  - Isolate transmit paths

d. Intersymbol Interference (ISI)

- **Definition**: Overlapping of symbols due to multipath or delay spread.
- **Cause**: Time dispersion in the channel.
- **Impact**: Bit errors in digital communication.

- **Mitigation**:
  - Equalization
  - Spread spectrum techniques

e. External Interference

- **Definition**: Interference from non-cellular sources (e.g., microwave ovens, radar).
- **Cause**: Shared spectrum or unintentional emissions.
- **Mitigation**:
  - Spectrum monitoring
  - Regulatory enforcement

3. Measurement of Co-channel Interference

a. At the Mobile Unit

- **Method**: Measure the ratio of desired signal power to interfering signal power.
- **Tools**:
  - Signal strength indicators (RSSI)
  - SINR (Signal-to-Interference-plus-Noise Ratio) metrics
- **Procedure**:
  - Mobile scans neighboring frequencies
  - Reports interference levels to the network
  - Used for handoff decisions and power control

b. At the Cell Site (Base Station)

- **Method**: Monitor uplink signals from mobile units and measure interference from other users.
- **Tools**:
  - Spectrum analyzers
  - Network performance monitoring systems
- **Procedure**:
  - Analyze received signal quality
  - Identify overlapping transmissions
  - Adjust frequency assignments or initiate handoffs

10. Derive the desired C/I from a normal case Apply in an Omni directional Antenna System.

A.

☐ As long as the received C/I ratio at both mobile unit and cell site are same, the system is called a balanced system.

☐ We know that, $\frac{C}{I} = \frac{1}{\sum_{k=1}^{K_I}\left(\frac{D_k}{R}\right)^{-\gamma}} = \frac{1}{\sum_{k=1}^{K_I}(q_k)^{-\gamma}}$

☐ Assuming all the D_k are same, $D = D_k$ and $q = q_k$

$$\frac{C}{I} = \frac{R^{-\gamma}}{6D^{-\gamma}} = \frac{q^{\gamma}}{6}$$

Thus, $q^{\gamma} = 6\frac{C}{I}$

and $q = \left(6\frac{C}{I}\right)^{1/\gamma}$

- ☐ C/I of 18db is measured by the acceptance of voice quality from cellular mobile receivers and considering γ=4 for mobile radio environment,

$$q = (6 \times 63.1)^{1/4} = 4.41$$

- ❑ But we know that $q = \frac{D}{R} = \sqrt{3N}$

- ❑ For q=4.41, N=7, indicates that a seven cell reuse pattern is needed for a C/I of 18dB.

- ❑ The value of q may not be large enough to maintain a C/I ratio of 18dB, which is particularly true in worst case.

11. Explain cell splitting and its effect on the performance of cellular systems.

A. **Cell splitting** is a technique used to increase the capacity of a cellular system by subdividing a congested cell into smaller cells, each with its own base station and reduced coverage area.

- ❑ Transmissionpower reductionfrom P_{t1} to P_{t2}
- ❑ Examiningthereceivingpoweratthenew and old cellboundary

$$P_{r1}\ [at\ old\ cell\ boundary] = P_{t1}R^{-\gamma}$$
$$P_{r2}\ [at\ new\ cell\ boundary] = P_{t2}(R/2)^{-\gamma}$$

- ❑ If wetake γ= 4(pathloss)andset thereceivedpower equalto eachother

$$P_{t2} = \frac{P_{t1}}{16}$$

- ❑ Thetransmitpowermustbe reducedby12dBinorderto fillin theoriginalcoveragearea.
- ❑ If onlypartof the cells aresplitted, then
  - ❑ Different cell sizeswillexistsimultaneously
  - ❑ Handoff issues: highspeedand lowspeed trafficcan besimultaneouslyaccommodated

Cell Splitting Works

Original Cell

- Covers a large area with a single base station.
- Limited capacity due to finite number of channels.

After Splitting

- The original cell is divided into multiple smaller cells.
- Each new cell has its own base station and frequency allocation.
- Smaller cells mean shorter distance between user and base station, improving signal strength.

Effects on Cellular System Performance

1. Increased Capacity

- More cells mean more frequency reuse opportunities.
- Each cell handles fewer users, reducing congestion.

2. Improved Signal Quality

- Reduced path loss due to shorter transmission distances.
- Better signal-to-interference ratio (SIR) at the receiver.

3. Enhanced Coverage in Dense Areas

- Allows finer granularity in coverage planning.
- Ideal for urban environments with high user density.

4. Higher Infrastructure Cost

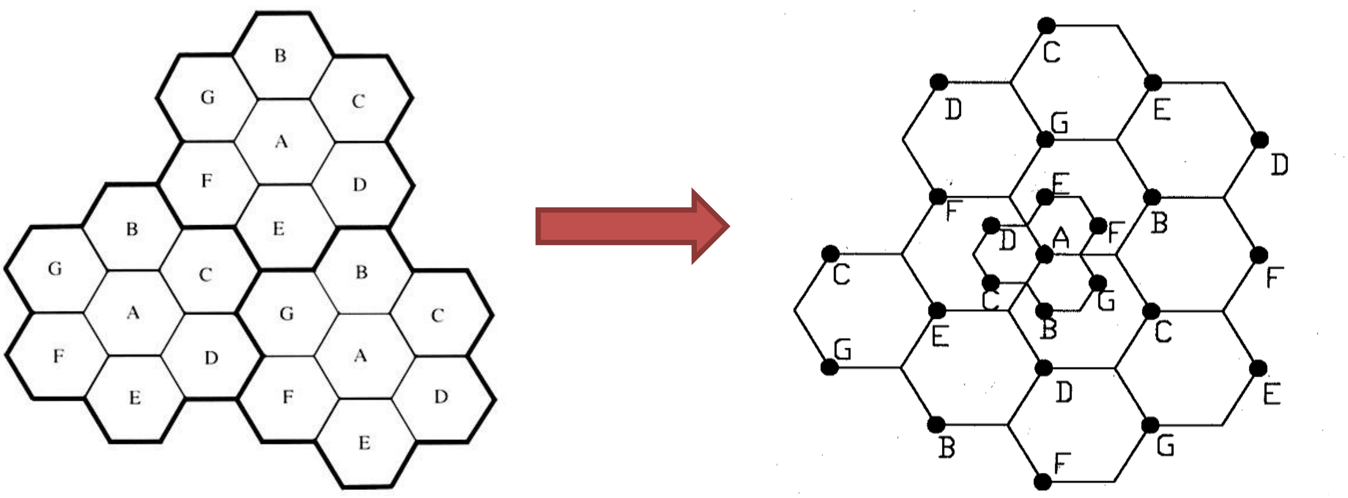
- Requires additional base stations and backhaul connections.
- Increased operational complexity and maintenance.

5. More Frequent Handoffs

- Smaller cells lead to more handoffs as users move.
- Requires efficient mobility management to avoid dropped calls.

6. Frequency Planning Challenges

- More cells increase the complexity of frequency reuse.
- Risk of co-channel and adjacent channel interference if not managed properly.



12. What is cell sectorization? Explain briefly?

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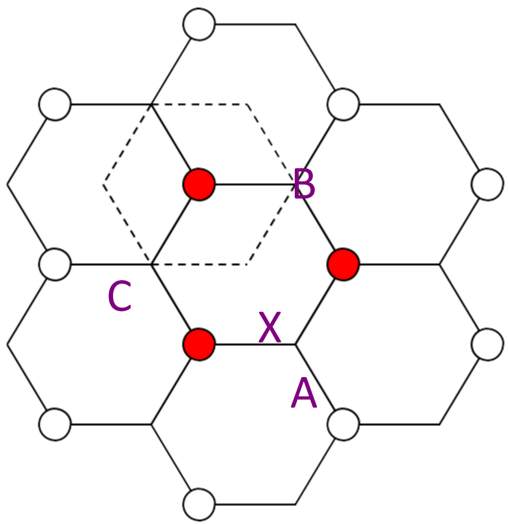
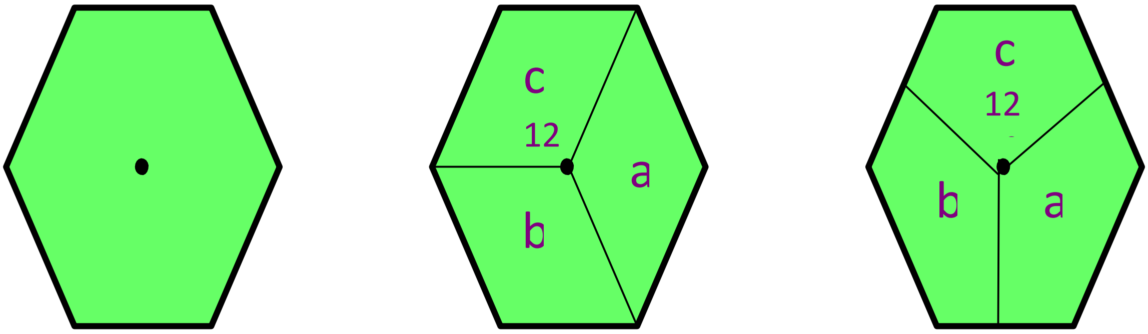


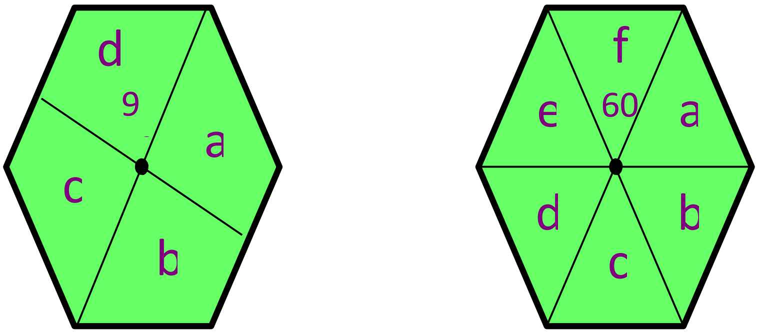
Cell sectorization is a technique used in cellular system design to improve capacity and reduce interference by dividing a cell into multiple sectors, each served by a directional antenna.

Key Concepts of Cell Sectorization

Definition



(a) (b) 120° (c) 120° sector



(d) 90° (e) 60°

- Illustration of how 120° sectoring reduces interference from co-channel cells. Out of the 6 co-channel cells in the first tier, only 2 of them interfere with the center cell.
- If omni-directional antennas were used at each base station, all 6 co-channel cells would interfere with the center cell.

- A single cell is split into **two, three, or six sectors**, each covering a portion of the cell area.
- Each sector uses a **directional antenna** that transmits and receives signals within a confined angular range (e.g., 120° for three-sector configuration).

Purpose

- To **reduce co-channel interference** by limiting the radiation pattern.
- To **increase frequency reuse** and **enhance system capacity** without reducing cell size.

Sectorization Configurations

Configuration	Number of Sectors	Coverage per Sector
2-sector	2	180° each
3-sector	3	120° each
6-sector	6	60° each

Advantages

- **Improved C/I Ratio**: Directional antennas reduce interference from other cells.
- **Higher Capacity**: Each sector can reuse frequencies independently.
- **Better Coverage Control**: Allows targeted coverage in high-traffic zones.

Disadvantages

- **Increased Complexity**: Requires more antennas and precise alignment.
- **Higher Cost**: More equipment and maintenance.
- **Handoff Management**: More frequent intra-cell handoffs between sectors.