Lecture 5: 1.5 Frequency reuse and system capacity

Fundamental of Cellular Communication

DI05011011: Mobile Communication

Agenda for Today

- 1. What is Frequency Reuse?
- 2. The Frequency Reuse Factor
- 3. Defining System Capacity
- 4. Mathematical Formulation of Capacity
- 5. Example Calculation 1
- 6. Example Calculation 2
- 7. Impact of Cluster Size on Capacity
- 8. Summary

What is Frequency Reuse?

- Spectrum is scarce and expensive.
- **Frequency Reuse** is the process of using the exact same radio frequencies repeatedly in different geographic areas.
- As long as the coverage areas (cells) are far enough apart, the radio signals will decay over distance and won't interfere with each other.
- This allows a network to provide service to millions of users using only a few hundred channels.

The Frequency Reuse Factor

- In a cluster of 'N' cells, the total available spectrum is divided into N groups.
- Each cell in the cluster uses exactly **1/N** of the total available channels.
- Therefore, the **Frequency Reuse Factor** is defined as **1/N**.
- - For a 7-cell cluster, the frequency reuse factor is $1/7$.
- - For a 4-cell cluster, the factor is $1/4$.
- This factor tells us what fraction of the total spectrum is allocated to a single cell.

Defining System Capacity

- **System Capacity (C)** is the total number of simultaneous calls or data connections a cellular network can handle.
- It depends on:
- 1. The total number of channels allocated by the government (S).
- 2. The number of times the cluster is replicated across the geographic area (M).
- If you want to increase capacity, you either need more spectrum (hard/expensive) or you need to reuse your existing spectrum more times (M).

Mathematical Formulation of Capacity

- Let's define the variables:
- - **S:** Total number of channels available to the operator.
- - **N:** Cluster size (number of cells in a cluster).
- - **k:** Number of channels per cell (k = S / N).
- - **M:** Number of times the cluster is repeated over the coverage area.
- - **C:** Total system capacity.
- **Formula 1:** Total channels in a cluster = k * N = S
- **Formula 2:** Total System Capacity = M k N
- **Simplified:** C = M * S

Example Calculation 1

- **Scenario:**
- - An operator has a total of 700 channels (S = 700).
- - They design a system using a 7-cell cluster (N = 7).
- **Questions:**
- 1. How many channels does each cell get?
- 2. If the cluster is repeated 10 times across a city, what is the total system capacity?
- **Answers:**
- 1. Channels per cell (k) = S / N = 700 / 7 = 100 channels/cell.
- 2. Total Capacity (C) = M * S = 10 700 = 7,000 simultaneous users.

Example Calculation 2: Splitting Cells

- **Scenario:** The city from Example 1 grows rapidly. The operator needs more capacity but has no more spectrum.
- **Solution:** Make the cells smaller (Cell Splitting).
- - Original: 10 clusters (M = 10). Capacity = 7,000.
- - New Design: By cutting the cell radius in half, the same city area can now fit 40 smaller clusters (M = 40).
- **New Capacity:**
- - C = M $S = 40$ 700 = **28,000 simultaneous users.**

Impact of Cluster Size (N) on Capacity

- Let's look at capacity from the perspective of an individual cell.
- Channels per cell: **k = S / N**
- For a fixed total spectrum (S), if we *decrease* the cluster size (N), the number of channels per cell (k) *increases*.
- - e.g., S=700. If N=7, k=100. If N=4, k=175.
- Therefore, smaller cluster sizes provide higher capacity per cell.
- **But remember:** Smaller N means co-channel cells are closer together, increasing interference.

How to Increase Capacity? (Summary of Strategies)

- If a cellular network gets congested, engineers can:
- **1. Add new channels:** (Obtain more spectrum 'S' from the government - Very expensive).
- **2. Borrow channels:** (Dynamic channel allocation - complex to manage).
- **3. Cell Splitting:** (Reduce cell radius, build more base stations to increase 'M' - High infrastructure cost).
- **4. Cell Sectoring:** (Use directional antennas to reduce interference, allowing a smaller 'N' to be used).

Lecture Summary

- Frequency Reuse allows the same spectrum to be used repeatedly across a geographic area.
- The Frequency Reuse Factor is 1/N, representing the fraction of spectrum allocated per cell.
- Total System Capacity (C) is calculated as C = M * S.
- Capacity can be drastically increased by reducing cell sizes (increasing M).
- Decreasing cluster size (N) increases capacity but risks higher interference.

Next Lecture Preview

- We mentioned that reusing frequencies causes interference. What exactly is this interference?
- In the next lecture, we will cover:
- **1.6 Co-channel and adjacent channel interference**
- - Understanding Co-channel interference (CCI).
- - Understanding Adjacent channel interference (ACI).
- - How to calculate the Signal-to-Interference Ratio (SIR).