Lecture 22: Limitations of CDMA Technology

GSM and CDMA Systems

DI05011011: Mobile Communication

Agenda for Today

- 1. The Interference-Limited Nature of CDMA
- 2. The Near-Far Problem
- 3. Strict Power Control Requirements
- 4. Cell Breathing Phenomenon
- 5. Soft Handoff Overhead
- 6. Summary

1. CDMA: An Interference-Limited System

- In CDMA, all users transmit on the SAME frequency at the SAME time.
- Users are separated only by their unique spreading codes.
- Other users' signals act as background noise (interference).
- **Core Limitation:** The capacity of a CDMA cell is strictly limited by the total amount of interference the base station can tolerate.

2. The Near-Far Problem

- A critical issue in Direct Sequence CDMA (DS-CDMA).
- If a mobile device is very near the base station, its signal is received strongly.
- If another device is far away, its signal is received weakly.
- The strong signal from the near user will drown out the weak signal from the far user, acting as overwhelming interference.

3. Strict Power Control Requirements

- **The Solution:** The base station must ensure that signals from ALL mobile devices arrive at the exact same power level.
- Requires highly complex, fast power control algorithms.
- Base station sends power adjustment commands 800-1500 times per second.
- **Limitation:** If power control fails or is delayed, the entire cell's capacity degrades instantly.

Example: Power Control Loop

- **Scenario:** User A is driving towards the base station.
- 1. User A's signal gets stronger at the receiver.
- 2. Interference for User B (who is stationary) increases.
- 3. Base station detects User A is too loud.
- 4. BS sends 'Power Down' command to User A.
- 5. User A reduces power.
- 6. Equilibrium is restored.
- *This cycle repeats every 1.25 milliseconds.*

4. Cell Breathing Phenomenon

- In CDMA, the coverage area (footprint) of a cell changes dynamically based on traffic load.
- **Low Traffic:** Less interference, cell footprint expands, reaching users further away.
- **High Traffic:** More users = more interference. The base station cannot hear users at the edge. The effective cell footprint shrinks.
- This dynamic shrinking and expanding is called 'Cell Breathing'.

Consequences of Cell Breathing

- Network planners cannot guarantee coverage at the edges of a cell.
- A user who has a signal in the morning might lose it in the afternoon without moving, simply because the cell got busy and shrank.
- Requires complex deployment of overlapping cells to ensure no coverage gaps appear during peak load.

5. Soft Handoff Overhead

- CDMA uses 'Soft Handoff' (Make-before-break).
- A mobile device can connect to 2 or 3 base stations simultaneously during a handoff.
- **Advantage:** Very few dropped calls.
- **Limitation:** Consumes extra network resources (channel cards at multiple base stations) for a single user.

Code Scarcity and Orthogonality

- CDMA uses Walsh Codes to separate users within a cell.
- There is a finite number of mathematically perfectly orthogonal codes (e.g., 64 in IS-95).
- Multipath fading can destroy the orthogonality of these codes.
- When orthogonality is lost, users start interfering with each other, rapidly reducing capacity.

Summary of CDMA Limitations

- **Interference-Limited:** Capacity drops as noise increases.
- **Near-Far Problem:** Requires strict, rapid power control.
- **Cell Breathing:** Cell coverage shrinks as traffic increases.
- **Resource Overhead:** Soft handoffs tie up multiple base stations.
- **Code Limits:** Multipath interference ruins orthogonal codes.

Next Lecture Preview

- In the next lecture, we will conclude our discussion on 2G systems by comparing GSM and CDMA limitations, and discussing the specific security vulnerabilities of both systems that drove the push for 3G/4G standards.