Lecture 19: 2.12 Limitations of GSM and CDMA Technology (Part 2)

GSM and CDMA Systems

DI05011011: Mobile Communication

Agenda for Today

- 1. The CDMA Promise vs. Reality
- 2. Limitation 1: The Near-Far Problem
- 3. Limitation 2: Strict Power Control Requirements
- 4. Limitation 3: Self-Interference and Cell Breathing
- 5. Limitation 4: PN Code Exhaustion
- 6. Limitation 5: Lack of Global Roaming & SIMs
- 7. Real-world Example: Cell Breathing in Urban Areas
- 8. Summary

The CDMA Promise vs. Reality

- **The Promise:** Universal frequency reuse (Reuse = 1), massive capacity, high security, and smooth soft handoffs.
- **The Reality:** While theoretically vastly superior to GSM, CDMA is extremely complex to implement at the radio frequency (RF) level.
- **The Core Issue:** Because everyone shares the *exact same frequency at the same time*, every other user on the network acts as interference to your signal.
- **Consequence:** CDMA is completely bounded by interference. Manage the interference, and the network works; fail to manage it, and the network collapses.

Limitation 1: The Near-Far Problem

- **The Scenario:** Imagine two mobile users connected to the same base station.
- - User A is very close to the tower.
- - User B is at the edge of the cell, far away.
- **The Problem:** If both transmit at the same power level, User A's signal will arrive at the tower vastly stronger than User B's.
- **The Result:** The strong signal from User A will completely drown out (jam) the weak signal from User B, dropping User B's call.
- **Significance:** This is the most critical flaw in any DSSS system.

Limitation 2: Strict Power Control

- **The Solution to Near-Far:** The base station must constantly command all phones to adjust their transmit power.
- **The Goal:** Every signal from every phone *must* arrive at the base station at the exact same power level.
- **The Limitation:**
- - Requires incredibly fast, continuous feedback loops (up to 800 times per second).
- - Consumes network signaling bandwidth.
- - Drains mobile battery if the phone is forced to transmit at max power at the cell edge.
- - If power control fails, the whole cell drops calls.

Limitation 3: Self-Interference & Cell Breathing

- **Self-Interference:** As more users join a CDMA cell, the overall noise floor (interference) rises.
- **Cell Breathing Phenomenon:**
- - As the noise floor rises, phones at the edge of the cell can no longer penetrate the noise to reach the tower, even at max power.
- - The effective coverage area (footprint) of the cell physically *shrinks* under heavy load.
- - When the load decreases, the cell footprint expands again.
- **Impact:** Makes network planning incredibly difficult, leading to coverage holes during busy hours.

Limitation 4: PN Code Exhaustion

- **Finite Codes:** While CDMA has a 'soft capacity', it is still constrained by the number of available orthogonal Pseudo-Noise (PN) codes.
- **Walsh Codes:** Used to separate users in the forward link (Tower to Mobile). There are typically 64 Walsh codes available per carrier.
- **Overhead:** Several codes are consumed by pilot, paging, and sync channels.
- **Exhaustion:** In a highly dense area, a base station might run out of available Walsh codes before it reaches its RF interference limit, creating a hard cap on capacity.

Limitation 5: Roaming & Ecosystem

- **No SIM Standard (Initially):** Early CDMA networks did not use SIM cards. Subscriber IDs were hardcoded into the phone.
- **Device Lock-in:** Users could not simply swap a card to change phones or networks. They needed carrier intervention.
- **Global Fragmentation:** Because GSM captured Europe and most of Asia, CDMA users from the US (Verizon/Sprint) often could not roam internationally without carrying a separate GSM 'world phone'.
- **Ecosystem Cost:** Lower global volume meant CDMA network equipment and handsets were often more expensive than GSM counterparts.

Engineering Example: Urban Cell Breathing

- **Scenario:** A downtown business district covered by a CDMA network.
- **9:00 AM (Low Traffic):** Cell towers cover a 2 km radius. A user in a suburban fringe connects perfectly.
- **12:00 PM (Lunch Rush):** Thousands of workers make calls. Interference spikes.
- **The Effect:** The cell radius shrinks to 1 km due to cell breathing. The user in the suburban fringe drops their call, not because they moved, but because the cell shrank away from them.
- **The Fix:** RF Engineers have to over-deploy base stations (adding more towers) to ensure coverage overlaps even at maximum shrinkage.

Lecture Summary

- CDMA is fundamentally interference-limited, meaning capacity is determined by the total noise on the shared frequency.
- The Near-Far problem is a critical vulnerability requiring complex, high-speed power control to manage.
- Cell Breathing causes coverage areas to shrink dynamically under heavy load, complicating network design.
- Commercial limitations, such as the lack of SIM cards and global roaming standardization, hindered CDMA's market share against GSM.

Next Lecture Preview

- In the next lecture, we will wrap up our discussion on 2G/3G limitations by looking at how they drove the industry forward:
- **1. The Evolution to 3G (UMTS/WCDMA & CDMA2000).**
- **2. The shift from Circuit Switched to Packet Switched.**
- **3. Why both GSM and CDMA were abandoned for OFDM in 4G LTE.**