Lecture 20: 2.12 Limitations of GSM and CDMA Technology (Part 3 - Evolution)

GSM and CDMA Systems

DI05011011: Mobile Communication

Agenda for Today

- 1. Summary of 2G Bottlenecks
- 2. The Data Demand Explosion
- 3. How 3G Addressed GSM Limitations (UMTS/WCDMA)
- 4. How 3G Addressed CDMA Limitations (EV-DO)
- 5. The Ultimate Limit of Spread Spectrum
- 6. The Paradigm Shift: Leaving CDMA for OFDM
- 7. Introduction to 4G LTE Concepts
- 8. Summary of Unit 2

Summary of 2G Bottlenecks

- **GSM's Core Flaws:**
- - Spectrally inefficient (TDMA rigid time slots).
- - Hard handoffs dropping calls.
- - Circuit-switched architecture unable to handle bursty IP data efficiently.
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- **CDMA's Core Flaws:**
- - Interference limited (Near-far problem, cell breathing).
- - Enormous signaling overhead for power control.
- - Closed ecosystem, lacking global standardization initially.

The Data Demand Explosion

- **The Paradigm Shift:** Communication shifted from symmetrical voice (same data rate up and down) to asymmetrical data (heavy download, light upload).
- **Multimedia:** Users wanted to browse HTML web pages, send MMS, and eventually stream video.
- **IP Networking:** The world standardized on Internet Protocol (IP). 2G networks had to 'translate' IP packets over circuit-switched voice channels, which was incredibly slow and expensive.

3G: The WCDMA Compromise

- **The Solution to GSM:** The GSM world recognized CDMA's superior capacity and adopted it for 3G, creating **WCDMA (Wideband CDMA)**, part of the UMTS standard.
- **How it fixed GSM:**
- - Replaced rigid TDMA with spread spectrum, increasing capacity.
- - Implemented soft handoffs.
- - Used a wider 5 MHz channel (compared to GSM's 200 kHz) for higher data rates.
- **Retaining the Good:** Kept the GSM core network and SIM card architecture for seamless roaming.

3G: The CDMA2000 Path

- **The Solution for CDMA:** The CDMA camp evolved into CDMA2000 (and EV-DO).
- **How it improved:**
- - Dedicated entire carrier frequencies solely for packet data (EV-DO).
- - Implemented adaptive modulation (changing encoding based on signal strength).
- - Added SIM-like capabilities (CSIM/RUIM) to improve roaming.
- **The Result:** Provided broadband-like speeds (up to 3.1 Mbps) but maintained the inherent complexity of power control.

The Ultimate Limit of Spread Spectrum

- Even with 3G (WCDMA/EV-DO), the industry hit a new ceiling.
- **Multipath at High Speeds:** At very high data rates (broadband speeds), the multipath echoes in CDMA become so severe that the RAKE receivers cannot resolve them.
- **Inter-Symbol Interference (ISI):** The symbols arrive so fast they smear into each other.
- **The Conclusion:** Spread spectrum (CDMA) is excellent for voice and moderate data, but mathematically breaks down when trying to push 100+ Mbps.

The Paradigm Shift: OFDM

- **The 4G Solution:** To achieve true broadband speeds (LTE), the industry abandoned both TDMA (GSM) and CDMA completely.
- **Enter OFDM (Orthogonal Frequency Division Multiplexing):**
- - Instead of one fast, wide signal (CDMA), OFDM splits the data into hundreds of slow, narrow signals transmitted simultaneously.
- - Because each sub-signal is slow, multipath (ISI) is essentially eliminated.
- - Highly spectrally efficient and easily scalable.

The Shift to All-IP

- **4G LTE Core:** Alongside changing the RF technology to OFDM, 4G fundamentally changed the core network.
- **Death of Circuit Switching:** LTE is an 'All-IP' network. There are no dedicated voice circuits.
- **VoLTE (Voice over LTE):** Even voice calls are treated as IP data packets, just like a Skype or WhatsApp call, but with guaranteed Quality of Service (QoS) by the carrier.

Case Study: The Complete Transition

- **The Journey of a Carrier (e.g., AT&T/Vodafone):**
- - **1990s:** Deploys GSM (TDMA). Excellent roaming, poor data.
- - **2000s:** Upgrades to 3G UMTS (WCDMA). Adopts CDMA RF tech for better capacity, keeps SIMs.
- - **2010s:** Deploys 4G LTE (OFDM). Abandons CDMA RF tech entirely for OFDM, moves to All-IP core.
- - **2020s:** Shuts down 2G and 3G networks to refarm spectrum for 5G (Advanced OFDM).

Unit 2 Summary

- GSM (TDMA) provided global roaming and standardized digital voice but failed at high-speed data due to spectral inefficiency.
- CDMA provided higher capacity and soft handoffs but was plagued by complex power control and the near-far problem.
- 3G technologies attempted to blend the best of both (e.g., WCDMA).
- Ultimately, the limitations of spread spectrum at high data rates forced the entire industry to adopt OFDM and All-IP architectures for 4G LTE.

Next Lecture Preview

- In the next lecture, we transition to Unit 3, looking at the hardware in the user's hand:
- **1. Mobile Device Architecture.**
- **2. Mobile Handset Block Diagram.**
- **3. Baseband and RF Sections.**