

Lecture 10: 1.10 Multiple Access Techniques: FDMA, TDMA, CDMA, SDMA

Fundamental of Cellular Communication

DI05011011: Mobile Communication

Agenda for Today

- 1. What is Multiple Access?
- 2. The Cocktail Party Analogy
- 3. Frequency Division Multiple Access (FDMA)
- 4. Time Division Multiple Access (TDMA)
- 5. Code Division Multiple Access (CDMA)
- 6. Space Division Multiple Access (SDMA)
- 7. Comparison of Techniques
- 8. Summary and Unit 1 Conclusion

The Problem of Multiple Access

- In a cellular system, a single Base Station serves hundreds of mobile users.
- The wireless medium (air) is shared by everyone.
- If everyone transmits at the same time on the same frequency, the signals collide and interfere.
- Multiple Access techniques are protocols that coordinate how users share the spectrum without causing unacceptable interference.

The Cocktail Party Analogy

- Imagine a large room where many pairs of people want to talk.
- **FDMA (Frequency)**: Each pair talks in a different pitch (some high, some low).
- **TDMA (Time)**: Everyone takes turns. Pair 1 talks for a second, then Pair 2, then Pair 3...
- **CDMA (Code)**: Everyone talks at the same time, but each pair speaks a completely different language. You tune out the languages you don't understand as background noise.
- **SDMA (Space)**: People go to different corners of the room to talk.

Frequency Division Multiple Access (FDMA)

- The available frequency band is divided into multiple narrow frequency channels.
- Each user is assigned a specific, dedicated frequency channel for the duration of the call.
- Guard bands are placed between channels to prevent adjacent channel interference.
- Primarily used in 1G Analog systems (like AMPS).

- **Advantages:**

- - Simple to implement.
- - Low overhead.

- **Disadvantages:**

- - Wastes capacity: If a user is not talking, the channel sits idle.
- - Maximum capacity is strictly limited by the number of available frequencies.
- - Requires strict filtering.

Time Division Multiple Access (TDMA)

- The frequency band is divided into time slots.
- Multiple users share the same frequency, but they transmit in rapid, sequential time slots.
- The mobile device buffers audio, transmits a quick burst during its slot, and waits for its turn again.
- Used in 2G Digital systems (like GSM).

- **Advantages:**

- - More efficient than FDMA (3 to 8 times higher capacity).
- - Handsets can turn off the transmitter between slots, saving battery life.

- **Disadvantages:**

- - Requires strict synchronization between the base station and all mobiles.
- - Multipath interference can cause time slots to overlap.

Code Division Multiple Access (CDMA)

- All users transmit at the same time, using the entire frequency band.
- Signals are separated by assigning a unique mathematical code (pseudorandom sequence) to each user.
- The receiver uses the same code to extract the desired signal from the combined noise.
- Used in 3G systems.

- **Advantages:**

- - High capacity (soft capacity limit).
- - Excellent security and resistance to jamming.
- - No strict time synchronization required.

- **Disadvantages:**

- - Suffers severely from the 'Near-Far Problem'.
- - Requires extremely fast and accurate power control.

Space Division Multiple Access (SDMA)

- Controls radiated energy in space to serve users.
- Uses advanced 'smart antennas' (phased arrays) to direct a narrow beam exactly at a specific user.
- Users in different physical locations can reuse the exact same frequency and time slot because the beams do not overlap.
- A foundational technology for 5G (Massive MIMO).

Comparison Summary

- — Technique — Resource Split — Key Requirement — Technology Era —
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- — **FDMA** — Frequency — Sharp Filters — 1G (Analog) —
- — **TDMA** — Time — Synchronization — 2G (GSM) —
- — **CDMA** — Code — Power Control — 3G —
- — **SDMA** — Space — Smart Antennas — 4G/5G —

Lecture & Unit 1 Summary

- Multiple access is essential for sharing limited spectrum.
- FDMA gives users specific frequencies.
- TDMA gives users specific time slots on a shared frequency.
- CDMA separates users by mathematical codes, sharing all time and frequency.
- SDMA separates users by physical location using smart antennas.
- This concludes Unit 1! We have covered the foundations of cellular concepts, interference, and architecture.

- In the next lecture, we begin Unit 2: GSM and CDMA Systems.
- We will dive deep into the most successful cellular standard in history:
- **GSM Architecture:**
 - - What is the MSC, BSC, and BTS?
 - - How does the network know who you are and where you are?