CDMA

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April 9, 2007
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Introduction to CDMA

- Introduction to CDMA
- What is CDMA?
  - CDMA is the acronym for **Code Division Multiple Access**.
  - CDMA also refers to phone systems that use this signaling method.
- Is a form of *Multiplexing* (a process where multiple data streams are combined into one signal)
- The goal: To transmit several conversations over a single communications channel.
- Compare to **TDMA (Time Division Multiple Access)**
- Compare to **FDMA (Frequency Division Multiple Access)**
- Uses different pseudo-random code sequences for each data stream.

Introduction to CDMA (Continued)

- CDMA has been used in many communications and navigation systems, including GPS.
- CDMA is a form of “spread-spectrum” communication which has been used in the military. *“uses a wide bandwidth.”*
- CLAIMS of the effects of CDMA:
  - Dramatically improving the telephone traffic capacity
  - Dramatically improving the voice quality and eliminating the audible effects of multipath fading
  - Reducing the incidence of dropped calls due to handoff failures
  - Providing reliable transport mechanism for data communications, such as facsimile and internet traffic
  - Reducing the number of sites needed to support any given amount of traffic
  - Simplifying site selection
  - Reducing deployment and operating costs because fewer cell sites are needed
  - Reducing average transmitted power
  - Reducing interference with other electronic devices
  - Reducing potential health risks (lower power)
Introduction to CDMA (Continued)

- Commercially introduced in 1995
- CDMA became one of the world's fastest-growing wireless technologies.
- In 1999, the International Telecommunications Union selected CDMA as the industry standard for new "third-generation" (3G) wireless systems.
- Many leading wireless carriers are now building or upgrading to 3G CDMA networks in order to provide more capacity for voice traffic, along with high-speed data capabilities.
- The original U.S. standard defined by QUALCOMM was known as IS-95, the IS referring to an Interim Standard of the Telecommunications Industry Association (TIA).
- After a couple of revisions, IS-95 was superseded by the IS-2000 standard. This standard was introduced to meet some of the criteria laid out in the IMT-2000 specification for 3G, or third generation, cellular.

Spread-Spectrum

Spread Spectrum Communications:

- CDMA is a form of Direct Sequence Spread Spectrum communications. In general, Spread Spectrum communications is distinguished by three key elements:
  - The signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as multi-user access and immunity from interference and jamming.
  - The bandwidth is spread by means of a code which is independent of the data. The independence of the code distinguishes this from standard modulation schemes (FMDA and TDMA).
  - The receiver synchronizes to the code to recover the data – this allows multiple users to access the same frequency band at the same time.
  - In order to protect the signal, the code used is pseudo-random. It appears random, but is actually deterministic, so that the receiver can reconstruct the code for synchronous detection.
Spread-Spectrum

How Spread-Spectrum works:
- Spread Spectrum uses wide band, noise-like signals.
- Spread Spectrum signals are noise-like; they are hard to detect.
- Spread Spectrum signals are hard to Intercept or demodulate.
- Spread Spectrum signals are harder to interfere with than narrowband signals.
- The military has used it for many years.
- Spread signals are intentionally made to be much wider band than the information they are carrying to make them more noise-like.
- Spread Spectrum signals use fast codes that run many times the information bandwidth or data rate. These special "Spreading" codes are called "Pseudo Random".
- Spread Spectrum transmitters use similar transmit power levels to narrow band transmitters.
- Because Spread Spectrum signals are so wide, they transmit at a much lower spectral power density than narrowband transmitters.
- Spread and narrow band signals can occupy the same band, with little or no interference.

Spread Spectrum Communications:

\[
\text{Spreading factor} = \frac{\text{Chip rate}}{\text{Data rate}}
\]

Non-Spread Signal

Spread Signal
## Overview of CDMA

For radio systems there are two resources, frequency and time.

Division by frequency, so that each pair of communicators is allocated part of the spectrum for all of the time, results in Frequency Division Multiple Access (FDMA).

Division by time, so that each pair of communicators is allocated all (or at least a large part) of the spectrum for part of the time results in Time Division Multiple Access (TDMA).

In Code Division Multiple Access (CDMA), every communicator will be allocated the entire spectrum all of the time. CDMA uses codes to identify connections.

### Signal Generation

- In the CDMA technique the signal transmissions among the multiple users completely overlap in both time and frequency.

- The separation between the users is made by assigning each user a unique code. Generally, CDMA converts analog voice signal to a digital signal, encodes the digital signals, and separates voice and control data into data streams called channels.

- Generating a CDMA signal is a five steps process:

  1. Voice
  2. A/D converter
  3. Codec
  4. FEC
  5. Code generator
  6. Code
  7. BPSK
  8. BPSK
  9. BPSK
  10. BPSK
The first step is analog to digital conversion, or A/D. The incoming voice signal is an analog signal. The CDMA uses a digital signal for its further manipulations. That digital signal is characterized by discrete states.

The second step is voice coding or Vocoding. Voice encoding is the process of compressing the audio into as small a stream of bits as possible. The vocoder takes advantage of the pauses in speech to accomplish maximum compression.

The third step is encoding and interleaving. The purpose is to reduce the errors when receiving the signal.

Interleaving is a method of reducing the effects of burst errors and recovering lost bits. The symbols are interleaved such that neighboring symbols will be transmitted far away from each other.

The various encoding methods add redundancy to the signals to help the recovery of information at the receiver, in case of errors.

The fourth step is channelizing: The signal of each user is further encoded to create a separation between different users.

A unique identification code is given to each user and the signals of all users are transmitted together, sharing the same frequency and time.

The CDMA receiver decodes the signal by multiplying it by a decoding sequence of the desired user.
Signal Generation (Continued)

- The fifth step is digital to radio frequency (RF) conversion.
- The stream of bits should be somehow delivered from one end to the other. RF is a method of carrying the information through the air.
- Digital data signals are combined into one signal and converted to a RF signal for the transmission process.

Signal Restoration

- A reverse process is done at the receiver to recover the voice from the RF (Radio Frequency) signal received:
  - Conversion of RF signal to digital
  - Decoding and de-spreading the users and signals
  - De-interleaving
  - Decompression of voice signals
  - D/A (digital to analog conversion)
### CDMA Features

#### Frequency reuse

- In CDMA, users are distinguished by code channels - not by frequency channels.
- Each Base Station (BTS) in the network can use all available frequencies.
- Two different stations may transmit at the same frequency with no interference as long as they are far enough from each other, meaning they belong to separate cells. However, in the overlapping area of two cells there might be frequency conflicts and interference.
- In the two other techniques TDMA and FDMA, adjacent cells cannot use the same frequency. Only distant cells can share the same frequency.
- As a result, each cell can use not more than 1/7 of the possible frequencies in its area.

![CDMA Frequency Reuse Diagram](image)

#### CDMA Features Continued

#### Power control

- This feature makes sure that all mobiles will transmit their signals in an appropriate strength.
- It is meant to solve the near-far problem where signals from mobiles will arrive to the Base Station (BTS) in varying strengths.
- The goal is to achieve an optimal power - high enough to assure a reasonable call quality, but not too high, in order to limit interference.
- Power control employs two processes: Open Loop and Close Loop.
**Power Control – Open Loop**

- Open loop: The mobile identifies the strength of transmission according to a pilot signal that it receives from the Base Station (BTS).
- For example, if the pilot signal is low, the mobile will know that it should transmit with a higher power.
- Open loop is used to provide a first rough estimate of the power level the mobile should use.

**Power Control – Close Loop**

- The BTS senses the signal received from the mobile and sends commands telling the mobile to increase or decrease the power of transmission accordingly.
- It is used for improving the open loop’s first estimation during a call.
CDMA Features Continued

**Rake Receiver**
- The signals received may arrive directly in a straight line, but also as reflections from different objects.
- The result: several transmissions of the *same signal* are received with *different time delays*.
- This is known as the multipath problem.
- CDMA uses Rake Receivers both in the BTS and in the mobiles.
- The three most dominant multipath signals are combined into a single, stronger signal.
- It enables transmission of weak signals with low power.
- The Rake Receiver will eventually combine them as one strong signal.

**Handoffs**
- When a user travels between the cells, the call has to be passed from one cell to another; this is called handoff.
- There are three main types of handoff in CDMA.
- Soft: Soft handoffs are known as *make before break*, meaning that the connection between the user and the new BTS is made before breaking the connection with the old one.
- When the user reaches the edge of the cell, there is a connection with two BTS simultaneously.
- This is possible in CDMA since all cells can use the same frequency.
CDMA Features Continued

- **Handoffs – Hard**
  - Hard Handoff: Known as \textit{break before make}
  - Is used in other Cell Phone systems such as TDMA
  - The connection with the current cell is broken \textit{before the new connection is established}.
  - Its major use in CDMA is when moving from a CDMA system to an analog system where soft handoff is no longer possible.

- **Idle Handoffs**
  - Idle handoff occurs when the mobile is not being used and without any assistance from the Base Station (BTS).
  - All the time the mobile searches for pilots from surrounding BTS.
  - When it identifies a signal with a higher power than the current one, it starts using the new BTS.
CDMA Pros & Cons

Pros:

Flexible network planning
  - Thanks to CDMA’s frequency reuse feature, frequency planning is no longer needed.

Greater coverage
  - Power control expands the coverage area.
  - Based on Coding and Interleaving, CDMA provides an ability to cover a larger area for a given amount of power in comparison to other techniques.

CDMA Pros Continued

Higher capacity
  - The amount of information that can be delivered from the source to the destination is greater than in other techniques. The main reasons for this are:
    - Users are distinguished by codes and not by frequencies or time slots.
    - Power control provides the ability to transmit lower power signals; this reduces interference and increases capacity.
    - Soft handoffs require less power thus provide increased capacity.

Lower Cost
  - Greater coverage demands fewer BTS, resulting in lower infrastructure costs.
  - The larger capacity of CDMA enables larger profits for the providers.
  - Lower power use gives a longer life span of BTS power amplifiers.
CDMA Pros Continued

- **High Clarity**
  - CDMA can often provide very high clarity:
  - Power control reduces interference and errors.
  - Rake Receivers reduce errors.
  - Soft handoffs require less power, therefore reduce interference and errors.
  - CDMA, being a wideband system, reduces fading.
  - Encoding and Interleaving reduce errors that result from fading.
  - CDMA’s variable rate vocoders reduce interference.

- **Higher Customer Satisfaction**
  - CDMA’s unique coding provides privacy and prevents cross-talk.
  - Better call quality.
  - Longer mobile battery life as a result of lower power demands.
  - CDMA’s soft handoffs, which allow make before break when traveling between cells, gives fewer dropped calls.

- **Compatibility**
  - Dual modes that enables working in older analog systems.
### CDMA Cons

- **Cons**

- **Synchronization**
  - Difficulty to satisfy synchronization requirements.

- **Self jamming**
  - Self jamming is a steep deterioration of performance as a result of poor synchronization.
  - Poor synchronization causes partial-correlation with the codes of other users and the result will be a vast increase of the interference.

- **Near-far problem**
  - Power control is necessary for mitigating the Near-far problem.
  - There are some factors for imperfect power control such as: feedback delays, imperfect power estimates, traffic conditions, or errors in the feedback channel.

### CDMA Cons Continued

- **Network complexity**
  - Complex network support is needed for implementing soft handoff, and also for countering multipath and fading effects.

- **Throughput**
  - Low throughput efficiency when a large number of users connect.
CDMA Questions

Any Questions?

CDMA References