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An Overview of CDMA Correlation Techniques In 3G Systems

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ABSTRACT

Code Division Multiple Access (CDMA) technology was chosen for the air interface of the upcoming third generation wireless systems (3G). In this paper defined an overview of CDMA correlation techniques in 3G systems. Different CDMA systems are introduced and classified as to provide multiple access capability. The basic principles of spread spectrum and wireless communication systems are Multi-Code CDMA. The classical method is Frequency Division Multiple Access and a more recent technique is Time Division Multiple Access. Both techniques assign particular frequency or time slices to different wireless terminals. The most common techniques of CDMA are Frequency hopped CDMA or Direct-sequence CDMA. Spread spectrum techniques are Direct sequence spread spectrum, Time Hopper spread spectrum, and Frequency Hopper spread spectrum and Hybrid System.

Keywords:- 3g, Spread Spectrum, Code, Correlation Techniques, Call Processing

I. INTRODUCTION

This introduction to CDMA proceeds heuristically, we use very little mathematics in developing the theories, and do not assume a deep mathematical or engineering background. The founders of QUALCOMM realized that CDMA technology could be used in commercial cellular communications to make even better use of the radio spectrum than other technologies. They developed the key advances that made CDMA suitable for cellular, then demonstrated a working prototype and began to license the technology to telecoms equipment manufacturers.

The first CDMA networks were commercially launched in 1995, and provided roughly 10 times more capacity than analog networks - far more than TDMA or GSM. Since then, CDMA has become the fastest-growing of all wireless technologies, with over 100 million subscribers worldwide. In addition to supporting more traffic, CDMA brings many other benefits to carriers and consumers, including better voice quality, broader coverage and stronger security. The world is demanding more from wireless communication technologies than ever before. More people around the world are subscribing to wireless services and consumers are using their phones more frequently. Add in exciting Third-Generation (3G) wireless data services and applications - such as wireless email, web, digital picture taking/sending and assisted - GPS position location applications - and wireless networks are asked to do much more than just a few years ago. And these networks will be asked to do more tomorrow. This is where CDMA technology fits in. CDMA consistently provides better capacity for voice and data communications than other commercial mobile technologies, allowing more subscribers to connect at any given time, and it is the common platform on which 3G technologies are built. CDMA is a "spread spectrum" technology, allowing many users to occupy the same time and frequency allocations in a given band/space. As its name implies, CDMA assigns unique codes to each communication to differentiate it from others in the same spectrum.

II. CODE FOR CDMA

CDMA codes are not required to provide call security, but create a uniqueness to enable call identification. Codes should not correlate to other codes or time shifted version of itself. Spreading codes are noise like pseudo-random codes, channel codes are designed for maximum separation from each other and cell identification codes are balanced not to correlate to other codes of itself. The following figure shows code for CDMA.

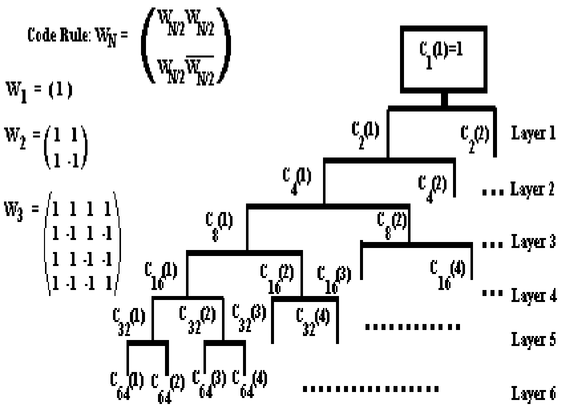

Figure 1.1 CDMA code

III. USES OF CDMA

CDMA is a form of Direct Sequence Spread Spectrum communications [1]. The figure 1.1 CDMA code uses the Spread Spectrum communications distinguished by three key elements:

1. The signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as immunity to interference and jamming and multi-user access, which we'll discuss later on.

2. 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 in which the data modulation will always spread the spectrum somewhat.

3. The receiver synchronizes to the code to recover the data. The use of an independent code and synchronous reception allows multiple users to access the same frequency band at the same time.

IV. SPREAD SPECTRUM COMMUNIATIONS

Three Types of Spread Spectrum Communications are Frequency Hopping, Time Hopping and Direct Sequence[1].

A. Frequency Hopping

The signal is rapidly switched between different frequencies within the hopping bandwidth pseudo-randomly, and the receiver knows before hand where to find the signal at any given time.

B.Time Hopping

The signal is transmitted in short bursts pseudo-randomly, and the receiver knows beforehand when to expect the burst.

C.Direct Sequence

The digital data is directly coded at a much higher frequency. The code is generated pseudo-randomly, the receiver knows how to generate the same code, and correlates the received signal with that code to extract the data.

V. DIRECT SEQUENCE SPREAD SPECTRUM

CDMA is a Direct Sequence Spread Spectrum system.[2] The CDMA system works directly on 64 kbit/sec digital signals. These signals can be digitized voice, ISDN channels, modem data, etc.

Figure 1.2 Direct Sequence Spread Spectrum

Figure 1.2 shows a simplified Direct Sequence Spread Spectrum system used in one channel operating in one direction only. Signal transmission consists of the following steps:

1. A pseudo-random code is generated, different for each channel and each successive connection.
2. The Information data modulates the pseudo-random code.
3. The resulting signal modulates a carrier.
4. The modulated carrier is amplified and broadcast.

Input Data

CDMA works on Information data from several possible sources, such as digitized voice or ISDN channels. Data rates can vary, here are some examples: Data Source, Data Rate, Voice Pulse Code Modulation (PCM) 64 kBits/sec Adaptive Differential Pulse Code Modulation (ADPCM) 32 kBits/sec Low Delay Code Excited Linear Prediction (LD-CELP) 16 kBits/sec ISDN Bearer Channel (B-Channel) 64 kBits/sec Data Channel (D-Channel) 16 kBits/sec The system works with 64 kBits/sec data, but can accept input rates of 8, 16, 32, or 64 kBits/sec. Inputs of less than 64 kBits/sec are padded with extra bits to bring them up to 64 kBits/sec.

In this context, correlation has a specific mathematical meaning. In general the correlation function has these properties:

- It equals 1 if the two codes are identical
- It equals 0 of the two codes have nothing in common
- Intermediate values indicate how much the codes have in common. The receiver to extract the appropriate signal.

VI. CORRELATION FUNCTIONS

Cross-Correlation: The correlation of two different codes. As we've said, this should be as small as possible.

Auto-Correlation: The correlation of a code with a time-delayed version of itself. In order to reject multi-path interference, this function should equal 0 for any time delay other than zero.

The receiver uses cross correlation to separate the appropriate signal from signals meant for other receivers, and auto-correlation to reject multi-path interference. The following figure 1.3 shows the coded Information data modulates the pseudo-random code.

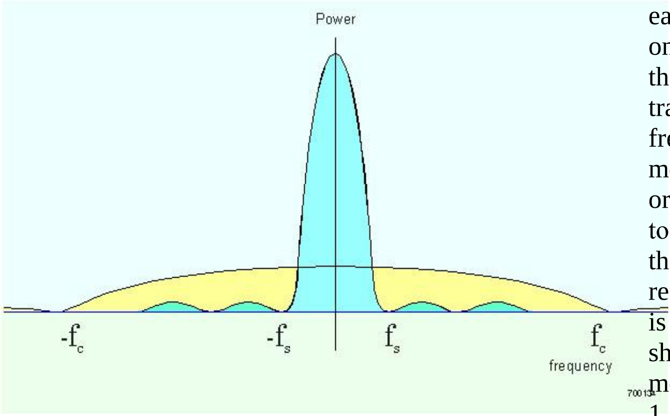

Figure 1.3 Frequency hopped Spread Spectrum

Some terminology related to the pseudo-random code:

• Chipping Frequency (fc): the bit rate of the PN code.

• Information rate (fi): the bit rate of the digital data.

• Chip: One bit of the PN code.

• Epoch: The length of time before the code starts repeating itself (the period of the code). The epoch must be longer than the round trip propagation delay (The epoch is on the order of several seconds). Figure 1.3 shows the process of frequency spreading.[3] In general, the bandwidth of a digital signal is twice its bit rate. The bandwidths of the information data (fi) and the PN code are shown together. The bandwidth of the combination of the two, for fc>fi, can be approximated by the bandwidth of the PN code.

Transmitting Data

The resultant coded signal next modulates an RF carrier for transmission using Quadrature Phase Shift Keying (QPSK). QPSK uses four different states to encode each symbol. The four states are phase shifts of the carrier spaced 90_ apart.[4] By convention, the phase shifts are 45, 135, 225, and 315 degrees. Since there are four possible states used to encode binary information, each state represents two bits. This two bit "word" is called a symbol. Figure 3 shows in general how QPSK works. First, we'll discuss Complex Modulation in general, applying it to a single channel with no PN-coding (that is, we'll show how Complex Modulation would work directly on the symbols). Then we'll discuss how we apply it to a multi-channel, PN-coded, system.

Complex Modulation

Algebraically, a carrier wave with an applied phase shift, (t), can be expressed as a sum of two components, a Cosine wave and a Sine wave, as:

I(t) is called the real, or In-phase, component of the data, and Q(t) is called the imaginary, or Quadrature-phase, component of the data. We end up with two Binary PSK waves superimposed. These are easier to modulate and later demodulate[3]. This is not only an algebraic identity, but also forms the basis for the actual modulation/ demodulation scheme. The transmitter generates two carrier waves of the same frequency, a sine and cosine. I(t) and Q(t) are binary, modulating each component by phase shifting it either 0 or 180 degrees. Both components are then summed together. Since I(t) and Q(t) are binary, we'll refer to them as simply I and Q. The receiver generates the two reference waves, and demodulates each component. It is easier to detect 180_ phase shifts than 90_ phase shifts [4] . The following table summarizes this modulation scheme. Note that I and Q are normalized to 1.Symbol I Q Phase shift

00 +1 +1 45
01 +1 -1 315
10 -1 +1 135
11 -1 -1 225

For Digital Signal Processing, the two-bit symbols are considered to be complex numbers, I +jQ.

Working of Complex Data

In order to make full use of the efficiency of Digital Signal Processing, the conversion of the Information data into complex symbols occurs before the modulation[4]. The system generates complex PN codes made up of 2 independent components, PNi + jPNq. To spread the Information data the system performs complex multiplication between the complex PN codes and the complex data. Summing Many Channels Together Many channels are added together and transmitted simultaneously. This addition happens digitally at the chip rate.

Receiving Data

The receiver performs the following steps to extract the Information: Demodulation receiver generates two reference waves, a Cosine wave and a Sine wave. Separately mixing each with the received carrier, the receiver extracts I(t) and Q(t). Analog to Digital converters restore the 8-bit words representing the I and Q chips. Code Acquisition and Lock The receiver generates its own complex PN code that matches the code generated by the transmitter [4].However, the local code must be phase-locked to the encoded data. The RCS and FSU each have different ways of acquiring and locking onto the other's transmitted code. Each method will be covered in more detail in later sections.

Correlation and Data Spreading

Once the PN code is phase-locked to the pilot, the received signal is sent to a correlate that multiplies it with the complex PN code, extracting the I and Q data meant for that receiver [5] .The receiver reconstructs the Information data from the I and Q data.

Call Processing

Call processing puts together everything we've covered so far. There are slight differences in the way the RCS and FSU process calls, so we will cover the Forward link (RCS to FSU). In the forward direction, the RCS Generates CDMA data signal for each traffic channel FEC codes the Information data, and converts the data to two-bit symbols. Converts the symbols to I and Q data, and pads each data stream to 64 kbits/sec. Generates the Complex PN code for each channel.

1. Extracts the I and Q data: Receives and amplifies the modulated carriers. Demodulates the signal and extracts the I and Q data.

2. Filters the I and Q data: Extracts multi-path information from the Pilot Rake filter and supplies it to the Adaptive Matched Filter. Removes multi-path interference from I and Q data using the Adaptive Matched Filter. Performs Automatic Gain Control on received signal

3. Extracts the CDMA data signal for each traffic channel: Generates the Complex PN code for each channel. Multiplies the Complex signal and the Complex PN code together. Converts the I and Q data to symbols. Decodes the symbols for error correction. Extracts the signal data.

VII. CONCLUSION

We have studied CDMA techniques in 3G systems and code for CDMA, uses of CDMA and various spread spectrum communications of Frequency spread spectrum, Time Hopping spread spectrum, and Direct sequence spread spectrum using correlation functions and its types of gross correlation and auto correlation techniques are used for spread spectrum technology. CDMA is a "spread spectrum" technology, allowing many users to occupy the same time and frequency allocations in a given band/space. CDMA consistently provides better capacity for voice and data communications.

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