Implementation of Different Interleaving Techniques for CDMA System

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Abstract—Telecommunication sector is consistently trying to bring improvement in wireless communication, so that it can enhance its quality of service with high performance and reduced cost. These efforts have led to different multiple access techniques. CDMA (code division multiple access) is one of the most developing technology in modern mobile communication. The core principle of spread spectrum is the use of noise-like carrier waves, and, as the name implies, bandwidths are much wider than that required for simple point-to-point communication at the same data rate. Most 3G mobile communication systems are using CDMA as their modulation technique. In CDMA interleaving is used for error correction as well as multiplexing of several input data over shared media. In this paper we study different types of interleaving schemes and analyze their performance in presence of multipath fading and additive white Gaussian noise (AWGN) channels. We conclude that different interleaving schemes have different data rates and bit error rate.

Keyword: BER, CDMA, Interleaving, System Model of CDMA

I. INTRODUCTION TO CDMA

The use of CDMA in wireless and cellular mobile communication has received considerable attention. CDMA stands for Code Division Multiple Access. It is a form of Spread Spectrum technology where the transmitted signal is encoded by special code. The code spread the signal so its bandwidth is much wider than the narrow band signal’s bandwidth. Ind this paper, we consider the problem of computing the bit error rate of CDMA using different interleavers over multipath fading and additive white Gaussian noise channels. The principle of CDMA is to spread a data symbol with a spreading sequence \( c^{(k)}(t) \) of length \( L \),

\[
c^{(k)}(t) = \sum_{i=0}^{L-1} c l(k) P_{l} (t - IT_{c}) T
\]

assigned to user \( k \), \( k = 0, \ldots, K - 1 \), where \( K \) is the total number of active users. The rectangular pulse \( P_{T_{c}}(t) \) is equal to 1 for \( 0 \leq t < T_{c} \) and zero otherwise. \( T_{c} \) is the chip duration and \( c_{l}^{(k)} \) are the chips of the user specific spreading sequence \( c^{(k)}(t) \) . After spreading, the signal \( x^{(k)}(t) \) of user \( k \) is given by

\[
x^{(k)}(t) = d^{(k)} \sum_{i=0}^{L-1} c_{l}^{(k)} P_{l} (t - IT_{c}) , \quad 0 \leq t < T_{d}
\]

for one data symbol duration \( T_{d} = LT_{c} \), where \( d^{(k)} \) is the transmitted data symbol of user \( k \). The multiplication of the information sequence with the spreading sequence is done bit-synchronously and the overall transmitted signal of all \( K \) synchronous users results in

\[
x(t) = \sum_{k=0}^{K-1} x^{(k)}(t)
\]

The received signal \( y(t) \) obtained at the output of the radio channel with impulse response \( h(t) \) can be expressed as

\[
y(t) = x(t) \otimes h(t) + n(t) = r(t) + n(t)
\]

where \( r(t) = x(t) \otimes h(t) \) is the noise-free received signal of user \( k \), \( n(t) \) is the additive white Gaussian noise (AWGN), and \( \otimes \) denotes the convolution operation. The impulse response of the matched filter (MF) \( h_{MF}^{(k)}(t) \) in the receiver of user \( k \) is adapted to both the transmitted waveform including the spreading sequence \( c^{(k)}(t) \) and to the channel impulse response \( h(t) \),

\[
h_{MF}^{(k)}(t) = c^{(k)*}(-t) \otimes h*(-t)
\]

The notation \( X^{*} \) denotes the conjugate of the complex value \( x \). Finally, threshold detection is performed to obtain the estimated information symbol. A rake receiver has \( D \) arms to resolve \( D \) echoes where \( D \) might be limited by the implementation complexity. In each arm \( d, d = 0, \ldots, D - 1 \), the received signal \( y(t) \) is delayed and
despread with the code \( c^{(k)}(t) \) assigned to user \( k \) and weighted with the conjugate instantaneous value \( h^*_d, d = 0, \ldots, D - 1 \), of the time-varying complex channel attenuation of the assigned echo. Finally, the rake receiver combines the results obtained from each arm and makes a final decision.

II. SYSTEM MODEL OF CDMA

This paper is concerned with the calculation of the bit error rate of a CDMA system in presence multipath fading and additive white Gaussian noise channels, using different interleavers. Figure 1 shows a CDMA transmitter. It consists of a forward error correction (FEC) encoder, mapping, spreader, pulse shaper, and analog front-end. Channel coding is required to protect the transmitted data against channel errors. The encoded and mapped data are spread with the code \( c^{(k)}(t) \) over a much wider bandwidth than the bandwidth of the information signal. As the power of the output signal is distributed over a wide bandwidth, the power density of the output signal is much lower than that of the input signal.

The General CRC Generator block generates cyclic redundancy code (CRC) bits for each input data frame and appends them to the frame.

The Convolutional Encoder block encodes a sequence of binary input vectors to produce a sequence of binary output vectors.

Figure 1. CDMA Transmitter

Convolutional codes are one of the most widely used channel codes in practical communication systems. These codes are developed with a separate strong mathematical structure and are primarily used for real time error correction. Convolutional codes convert the entire data stream into one single codeword. It is a type of forward error correction (FEC) which its function is to improve the capacity of a channel by adding redundant information to the data being transmitted through the channel [3].

Convolutional codes are usually described using two parameters: the code rate and the constraint length. The code rate, \( k/n \), is expressed as a ratio of the number of bits into the convolutional encoder (k) to the number of channel symbols output by the convolutional encoder (n) in a given encoder cycle. Constraint length denotes how many k-bit stages are available to feed the combinatorial logic that produces the output symbols.

The General Block Interleaver block rearranges the elements of its input vector without repeating or omitting any elements. The input can be real or complex. If Elements is \[4, 1, 3, 2\] and the input vector is \[40; 32; 59; 1\], then the output vector is \[1; 40; 59; 32\].

Figure 2 shows a CDMA receiver. The received signal is first filtered and then digitally converted with a sampling rate of \( 1/T_c \). It is followed by a rake receiver. The rake receiver is necessary to combat multipath, i.e., to combine the power of each received echo path. The echo paths are detected with a resolution of \( T_c \). Therefore, each received signal of each path is delayed by \( lT_c \) and correlated with the assigned code sequence. The total number of resolution paths depends on the processing gain. After correlation, the power of all detected paths are combined and, finally, the demapping and FEC decoding are performed to assure the data integrity.

Figure 2. CDMA Receiver
Viterbi decoding is one of two types of decoding algorithms used with convolutional encoding. The other type is sequential decoding. Viterbi decoding essentially performs the maximum likelihood decoding. It reduces the computational load by taking advantage of special structure in code trellis. The Viterbi decoder computes a metric for each path and makes a decision based on this metric. All paths are followed until two paths converge on one node. Then the path with the higher metric is kept and the one with lower metric is discarded. The paths selected are called the survivors.

III. CDMA INTERLEAVING SCHEMES

Interleaving is a way to arrange data in a non-contiguous way to increase performance. It is typically used in error-correction coding, particularly within data transmission, for multiplexing of several input data over shared media. In telecommunication, it is implemented through dynamic bandwidth allocation mechanisms, where it may particularly be used to resolve quality of service and latency issues. In streaming media applications, it enables quasi-simultaneous reception of input streams, such as video and audio. In CDMA different type of interleaving schemes can be used such as:

**Block Interleaver**

The Block Interleaver rearranges the elements of its input without repeating or omitting any elements. The input can be real or complex. If the input contains N elements, then the Elements parameter is a vector of length N that indicates the indices, in order, of the input elements that form the length-N output vector. For example, if Elements is [4,1,3,2] and the input is [40;32;59;1], then the output vector is [1;40;59;32].

**Convolutional Interleaver**

A convolutional interleaver consists of a set of shift registers, each with a fixed delay. In a typical convolutional interleaver, the delays are nonnegative integer multiples of a fixed integer[5].

Each new symbol from an input vector feeds into the next shift register and the oldest symbol in that register becomes part of the output vector. A convolutional interleaver has memory; that is, its operation depends not only on current symbols but also on previous symbols[6].

**Matrix Interleaver**

The Matrix Interleaver block performs block interleaving by filling a matrix with the input symbols row by row and then sending the matrix contents to the output port column by column. The Number of rows and Number of columns parameters are the dimensions of the matrix that the block uses internally for its computations. For example, if the Number of rows and Number of columns parameters are 2 and 3, respectively, then the interleaver uses a 2-by-3 matrix for its internal computations. Given an input signal of [1; 2; 3; 4; 5;6], the block produces an output of [1; 4; 2; 5; 3;6].

**Random Interleaver**

The Random Interleaver block rearranges the elements of its input vector using a random permutation. The Number of elements parameter indicates how many numbers are in the input vector. If the input is frame-based, then it must be a column vector[8].

IV. PERFORMANCE ANALYSIS OF INTERLEAVING SCHEMES

The performance analysis presented in this section are based on computer simulations. The basic scenario of the simulation is represented by the CDMA transmission system performing through multipath fading and AWGN transmission channel, at sample time (20e-3*1/44) and 44 samples per frame. The simulation results of CDMA system are shown in the figures below:
Figure 3. CDMA Transmitted Signal

Figure 4. CDMA Received Signal

Figure 5. Scatter Plot of CDMA Transmitted Signal

Figure 6. Scatter Plot of CDMA Received Signal

Figure 3 shows the CDMA transmitted signal to the channel. This signal is passed through the multipath fading and additive white Gaussian noise channel. After passing this signal from channel we get the CDMA received signal as shown in Figure 4 which is full of distortions. Figure 5 shows the scatter plot of transmitted signal of CDMA system. The scatter plot is used to reveal the modulation characteristics, such as pulse shaping or channel distortions of the signal. Similarly Figure 6 shows the scatter plot of CDMA received signal. The scatter plot illustrates the effect of fading on the signal constellation.

For all the interleaving schemes the transmitted and received signal has same bandwidth but these schemes effect the transmission rate and bit error rate of CDMA system. These effect of interleaving schemes is shown in tabular form in Table 1.

<table>
<thead>
<tr>
<th>Interleaver</th>
<th>Total Bits Transmitted</th>
<th>Error Bits</th>
<th>Bit Error Rate (BER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block Interleaver</td>
<td>42830</td>
<td>21490</td>
<td>.5018</td>
</tr>
<tr>
<td>Convolutional Interleaver</td>
<td>42830</td>
<td>2564</td>
<td>.0590</td>
</tr>
<tr>
<td>Helical Interleaver</td>
<td>42830</td>
<td>21350</td>
<td>.4985</td>
</tr>
<tr>
<td>Matrix Interleaver</td>
<td>42830</td>
<td>21490</td>
<td>.5017</td>
</tr>
<tr>
<td>Random Interleaver</td>
<td>42830</td>
<td>21410</td>
<td>.4998</td>
</tr>
</tbody>
</table>

On comparing these interleaving schemes we get that the transmission rate of all the interleaving
schemes used in CDMA system is same but the bit error rate is different. This is shown in Figure 7 below.

BER of Interleaving Schemes

![BER of Different Interleaving Techniques](image)

Figure 7.BER of Different Interleaving Techniques

V. CDMA ENCODING SCHEME

In CDMA system we generally use CRC (Cyclic Redundancy Code)

- CRC Encoding: The General CRC Generator block generates cyclic redundancy code (CRC) bits for each input data frame and appends them to the frame.

VI. CONCLUSION

In CDMA interleaving is used for multiplexing of several input data over shared media. Interleaving is a technique for randomizing the bits in a message stream so that burst errors introduced by the channel can be converted to random errors. In CDMA system different type of interleaving schemes are used. The transmission bandwidth of the CDMA system with all these interleaving schemes is same. But in a transmission system main concern is on efficient transmission i.e. number of errors or distortion is less. By observing the results it is found that when convolutional Interleaver is used under the influence of AWGN and Multipath Fading channel, the BER rate is less than other interleaving schemes namely Block, Helical, Matrix, Random. Thus, it is concluded that convolution interleaving is best suited scheme for the proposed system.

REFERENCES


