Volume 5, Issue 6, June 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Bit Error Rate Analysis of DS-CDMA System with Low-Density Parity-Check Codes

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Abstract— This paper presents LDPC coded DS-CDMA technique over AWGN channel using BPSK modulation. DS-CDMA is widely used in the cellular standards as users occupy same time and frequency, but separated by their specific codes. The BER is evaluated with and without LDPC coding using AWGN, Rayleigh and Rician fading channels. The results obtained will show that coded DS-CDMA is far better than uncoded DS-CDMA.

Keywords— AWGN, BER, BPSK, DS-CDMA, LDPC

I. INTRODUCTION

Direct sequence spread spectrum is an area of growing interest owing to its attractive properties which has led to enhance in capacities over TDMA and FDMA systems [1]. The key action of spread spectrum is achieved by a PN sequence which expands the narrowband signal to a wideband signal. The spread signal for every users is then amplified to their respective powers, summed, modulated to the particular band and then transmitted. Each receiver will obtain the summed signal but extracts its own bit stream by demodulating and de-spreading the sum signal using its distinctive and scrambling codes. It provides opposition to eavesdropping, resistance to multipath fading, interference elimination and multiple access capabilities [2].

The next section contains a depiction of PN sequences. In the third section a thorough look at the LDPC codes is given. Further DS-CDMA discussion is followed by channels used and simulation results. The last section contains the concluding remarks.

II. PSEUDO NOISE SEQUENCE

A pseudo noise sequence is a periodic sequence with a noisy waveform. It is a binary sequence, generally produced by a feedback shift register, which consists of an ordinary shift register made up of a number of flip flops. The spreading codes are selected by considering following three factors:

1.) Good autocorrelation property, which helps to de-spread the original code flawlessly, and to mitigate the intersymbol interference. It is also useful for synchronization and reduction of interchip interference in a rake receiver.

2.) Desirable cross correlation property states that all the codes are orthogonal to one another so that all the other user information is demodulated as noise at the receiver.

3.) The no. of codes is also an important property since all the users must have different codes to identify them. A large no. of codes can support more users.

The popular spreading sequences are the m-sequence, Gold code, barker and Kasami code [2].

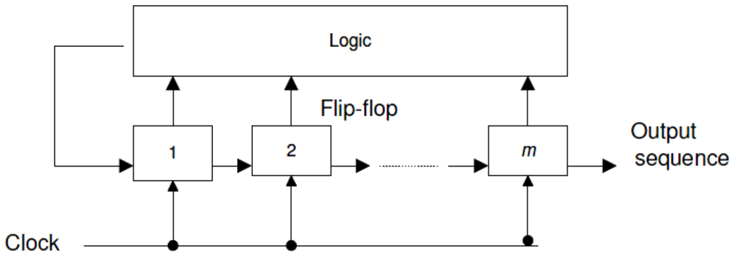

Fig.1 Block diagram of PN sequence [3].

The generation of PN sequence is carried out by feedback shift register which consists of m flip flops and a logic circuit that are organized to build a multiloop feedback circuit. A clock with single timing, regulates the flip flops in the shift register. Each flip flop changes its state to next state at each and every pulse of clock. The logic circuit computes a Boolean function of the states of the flip flop with each clock pulse. The outcome is subsequently fed back as input to the first flip flop. Hence the shift register does not get emptied. The PN sequence so generated is determined by the feedback logic, the length m of the shift register and the first state of register [3].

When the feedback logic consists entirely of modulo-2 adders, feedback shift register is called as linear. The zero state is not bearable in such a case. This is because the input produced by the feedback logic would be zero for a zero state, the shift register would then remain in the zero state, and hence the output would consist completely of 0s. As a consequence the PN sequence period generated by a linear feedback shift register consisting of m flip flops cannot go beyond 2^m-1.When the period is just 2^m-1, the psuedo noise sequence is known as a maximal length-sequence. [3].

III. LDPC CODES

Low-density parity-check (LDPC) codes were originally proposed by Robert Gallager [4-5] near the beginning of 1960's and later on reinvented by Mackay and Neal in late 90's [6]. These codes attain an extraordinary performance with iterative decoding which is extremely close to the Shannon limit. It is the theoretical upper limit sum of digital data which can be transmitted in a given bandwidth with certain noise interference. As a result, these codes give tough competition to turbo codes for controlling error in many communication and digital storage systems. These systems require high reliability i In 2003, an LDPC code beat several turbo codes to be preferred as the error correcting code in the new DVB-S2 standard. In 2008, LDPC outperforms convolutional codes and turbo codes as the Forward Error Correction scheme in definite other standards.

Low-density parity-check (LDPC) codes are a set of linear block LDPC codes. They are named from the point of their parity-check matrix which contains only a small number of 1's as compare to the number of 0's. For an m×n parity-check matrix (where m = n - k), the column weight w_c is the same as the number of nonzero elements in a column and the row weight w_r is same the number of nonzero elements in a row[7].LDPC codes are called as regular codes if they consist of constant w_c and constant $w_{r.}$.However if column weight and row weight are not fixed, LDPC codes are said to be irregular. The class of irregular LDPC codes is basically a super-set of the set of regular LDPC codes and there is an irregular degree distributions that beat regular LDPC codes for a number of different channels under sum-product decoding. Eqn. 1 shows the parity check matrix for a (3, 4) LDPC code.

$$H = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \end{bmatrix} \quad (1)$$

A graphical elucidation of parity check matrix is a bipartite graph which is referred to as tanner graph which consists of nodes and edges. The nodes are grouped into two sets. One set consists of n bit nodes (or variable nodes), and the other of m check nodes (or parity nodes). Each and every bit nodeis known as "left node" and represents a bit of the codeword. While each check node is known as "right node" and represents a parity check of the code. An edge exists between a bit node and a check node depending upon the position of 1 in the parity-check matrix. Hence, there are total mw_r (or nw_c) edges in a Tanner graph for a regular code[6].

The number of edges connecting to nodes determines the degree of graph. A path comprising j edges in a Tanner graph that closes back on itself is called a cycle of length j. The length of shortest cycle in a Tanner graph is known as the girth of the graph. Length-4 cycle is the shortest possible cycle in a tanner graph.

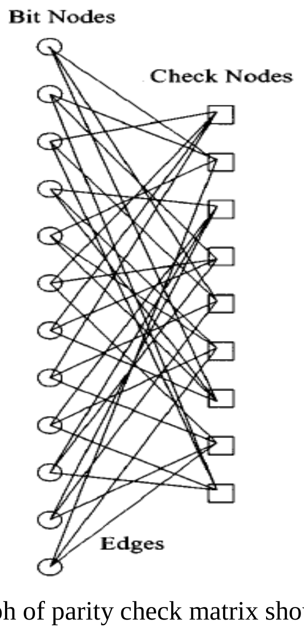

Fig.2 Tanner graph of parity check matrix shown in eqn.1 [8]

Encoding of long LDPC codes is quite difficult code structure such as cyclic or quasi-cyclic structure are not easily available.. Moreover their minimum distance is tough to determine [5]. Gallager gives a way for random construction of H. The transpose of a matrix H of a regular (n, $w_{c,}$ $w_{r.,}$) is of following form:

$$H' = [H_1' \; H_2' \ldots\ldots H_{wc}'] \quad (2)$$

Where H_1 has n columns and n/w_r rows, containing a single 1 in each column ,and contains 1s in its ith row from column (i-1) w_r+1 to column i/w_r. Matrices H_2 to H_{wc} are obtained by randomly permuting the columns of H_1[9].The generator matrix can next be constructed from H by Gaussian elimination. The codeword can be obtained simply by C = Gm where m is the message signal.

LDPC decoding follows an iterative approach. The decoding is carried by operating alternatively on the bit nodes and the check nodes. This is done to locate the most likely codeword C that can satisfy the condition $CH^T = 0$. For hard-decision decoding, there is the Bit-flipping (BF) algorithm and for soft-decision decoding, the sum-product algorithm (SPA), which is also known as the brief propagation algorithm and Pearl's algorithm is used[7]. All these algorithms come under the class known as message passing algorithm. The message-passing algorithms are often referred as iterative decoding algorithms because the messages pass back and forward between the bit and check nodes again and again, until a result is attained [10]. In case of bit flipping algorithm, the messages are binary while in belief propagation decoding, the messages are probabilities which represent a level of belief about the value of the codeword bits.

IV. DS-CDMA SYSTEM

In this system, the original data signal is linearly modulated into a BPSK signal m(t).Instead of transmitting this signal directly over its required bandwidth, DSSS modifies the modulated signal by multiplying the spreading chip signal c(t) with the modulated narrowband signal[11]. Although the signal carrier frequency does not change, the new signal after spreading becomes:

$$r(t)=m(t)c(t) \quad (3)$$

Thus the transmitted signal r(t) is a product of two signals whose spread bandwidth is equal to the bandwidth sum of the modulated signal and the spreading signal. At the receiver, PN sequence is multiplied again by the received signal. Since each user has its own unique code, the data intended for a particular user will appear as noise to the unwanted users. This is due to the low cross correlation among different pair of PN sequences [4].

In the system model shown in fig.3 data is first encoded using LDPC codes. After modulating the coded data, it is spreaded using PN sequence. Then the signal passes over the AWGN channel. At receiver end, exactly reverse procedure is carried out, that is, after de-spreading of received signal, it is demodulated and then decoded using decoding algorithm.

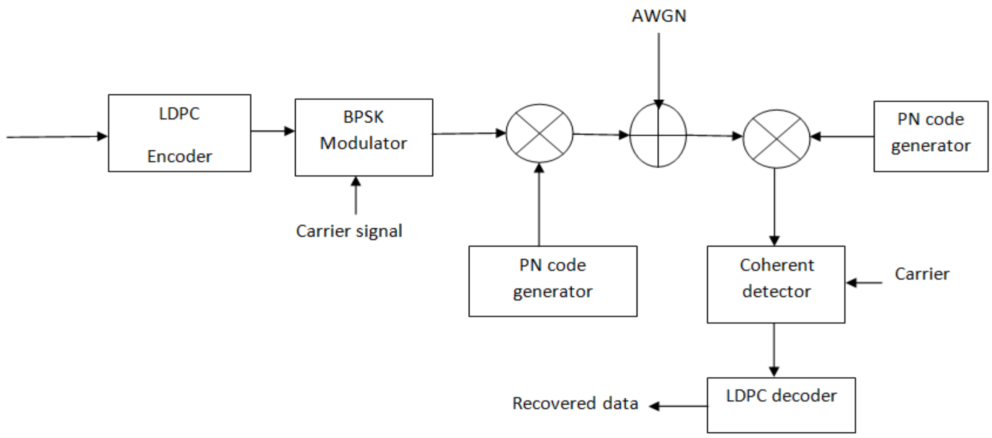

Fig.3 Block diagram of DSSS technique with LDPC coding

V. CHANNEL MODELS USED

Fading is the variation in the strength of received radio signals due to variations in the transmission medium. It changes according to radio frequency, time and position and therefore it is a random process. To model the effects of electromagnetic transmission of data in cellular networks, fading channel models are mostly used. A channel comprising of fading is known as fading channel. In this paper, two types of fading are considered –Rayleigh and Rician. The Rayleigh channel model is most appropriate in situations where there are a number of different signal paths and none of which is dominant. While travelling from the source to the receiver, each and every signal copy will experience attenuation, delay and phase shift. This can result in either constructive or destructive interference. The signal power seen at the receiver can be amplifying or attenuating. Hence all the signal paths will have certain variation and effects the overall signal gain at the receiver. In Rician fading, the received signal envelope distribution shows only one of the multipath components as line of sight component. This component is stronger while others are weaker [12].

VI. SIMULATION RESULTS

The performance of DS-CDMA system is evaluated by plotting the graph between BER vs. E_b/N_o. MATLAB 2013a is used for the implementation of DS-CDMA. The theoretical formulae for calculation of BER performance of a coherent BPSK communication system is:-

$$BER = (½)\ \mathrm{erfc}\ (E_b/N_o)^{1/2} \quad (4)$$

Where E_b = average energy of a received bit

N_o = noise density

Uncoded CDMA signal is compared with coded CDMA signal. As the signal passes over the channel, noise is added along with jamming. Simulation has been done over AWGN channel using BPSK modulation technique. The number of bits taken for simulation is 57600. Hard decision decoding method is being used. The following table shows the values of various parameters used.

TABLE I Values of Various Parameters

S No.	Parameter	Value
1.	No. of bits	57600
2.	Modulation	BPSK
3.	Channel	AWGN
4.	Code rate	8/9
5.	Standard used	DVB-S2

The graph below clearly shows us the performance improvement in BER with the use of LDPC coding.

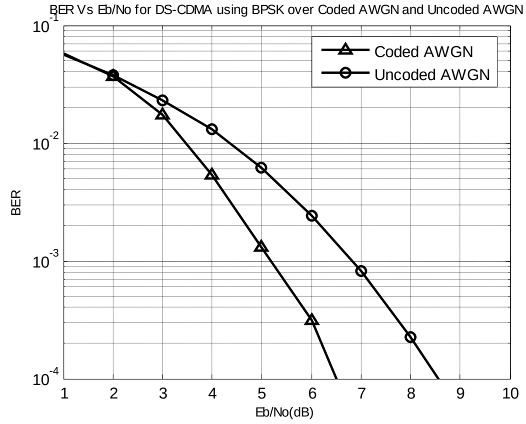

Fig.4 BER vs E_b/N_o curve for DS-CDMA using LDPC coding

From the result shown in Fig. 4, we observe that there is an improvement in BER by using LDPC coding over uncoded data. For e.g. at E_b/N_o=5dB, BER with coding has a value of 0.0013 while BER without coding has a value of 0.0062 which is much greater than for coded BER.

The following graph shows bit error rate of LDPC encoded data over AWGN, Rayleigh and Rician channels.

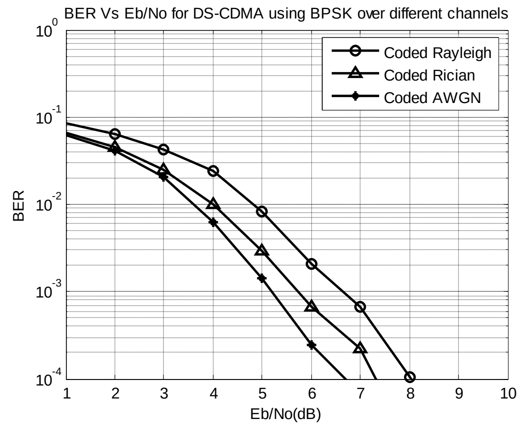

Fig.5 BER Vs E_b/N_o curve for DS-CDMA for different channels

By Simulation in Fig. 5, it is shown that by using LDPC coding over different channels, AWGN channels have better performance than channels with fading introduced. For e.g., at E_b/N_o=4dB, BER of coded AWGN has a value of 0.0063 while BER of coded Rician and coded Rayleigh channel is 0.0102 and 0.0238 respectively.

VII. CONCLUSION

By comparing the received data with transmitted data, performance is evaluated. We observed that DS-CDMA system without coding has much higher BER than coded DS-CDMA at the same value of BER. It clearly shows the improvement in performance of DS-CDMA. LDPC coding reduces the error rate and hence provides a more secure communication. When the performance is compared over AWGN, Rayleigh and Rician channels, it is observed that AWGN channel is best among all three. Rayleigh shows the worst performance of all as it has no line of sight component.

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