ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

PERFORMANCE ANALYSIS OF LOW DENSITY PARITY-CHECK CODES (LDPC) IN WIMAX OFDM SYSTEM

Mohit Lakra[1], Rajiv Dahiya[2], Shaloo Kikan[3]

M-Tech Scholar, Dept of ECE, PDM College of Engineering, Bahadurgarh, India[1]

Assistant Professor, Dept of ECE, PDM College of Engineering, Bahadurgarh, India[2]

Assistant Professor, Dept of ECE, PDM College of Engineering, Bahadurgarh, India[3]

Abstract: In this paper, we designed an 802.16e-(WiMAX) wireless environment to analyze the performance of low density parity-check codes (LDPC). Low-density parity-check (LDPC) codes can be considered serious competitors to turbo codes, convolutional code (CC) and read Solomon (RS) in terms of performance and complexity. The OFDM technique is an interesting approach in mobile communications in order to achieve a high spectral efficiency. From last few decades wireless communications industry is gaining momentum in both fixed and mobile applications. The continued increase in demand for all types of wireless services (voice, data, and multimedia) is fueling the need for higher capacity and data rates not only in fixed but also in mobile applications. There are many techniques that fulfill these requirements. One of the most important techniques is Orthogonal Frequency Division Multiplexing (OFDM). The Stanford University Interim (SUI-3) channel models are selected for the wireless channel in the simulation. Perfect channel estimation is assumed. In this paper, the performance analysis based on bit error rate (BER) versus bit energy to noise rate (Eb/No) plots and spectral efficiency of different modulation and channel coding schemes according to the standard IEEE 802.16.

Keywords: Low-density parity-check (LDPC) codes, Orthogonal Frequency Division Multiplexing (OFDM), Stanford University Interim (SUI-3) channel, WiMAX IEEE 802.16e.

I. INTRODUCTION

The ambitious design goals of fourth–generation (4G) wireless cellular systems is to reliably provide very high data rate transmission, for example, around 100 Mb/s peak rate for downlink and around 30 Mb/s sum rate for uplink transmission. Due to its higher rate requirement, the downlink transmission is especially considered to be a bottleneck in system design. In this paper, we demonstrate the feasibility of downlink transmission in 4G wireless systems through the physical- layer (PHY) design and optimization of low-density parity check (LDPC) coded wireless orthogonal frequency-division multiplexing (OFDM) communications.

The IEEE WiMAX standard [4] covers a large range of wireless transmission applications. Compared to WiFi (or Wireless LAN), it can support higher throughput above 100Mbps over larger distances, even with higher mobility involved. The upcoming IEEE WiMAX 802.16e standard, also referred to as Wireless MAN [5], is the next step toward very high throughput wireless backbone architectures, supporting up to 500Mbps. Low density parity-check (LDPC) codes were originally invented and investigated by Gallager[1]. The crucial innovation was Gallager’s introduction of iterative decoding algorithms (or message-passing decoders) which he showed to be capable of achieving a significant fraction of channel capacity at low complexity. The decoding is an iterative process which exchanges information between two types of nodes. Hardware realization of LDPC decoders is a vital part in the research community.

In many ways, LDPC codes can be considered serious competitors to turbo codes. In particular, LDPC codes exhibit an asymptotically better performance than turbo codes and they admit a wide range of tradeoffs between performance and decoding complexity. One major criticism concerning LDPC codes has been their apparent high encoding complexity. Whereas turbo codes can be encoded in linear time, a straightforward encoder implementation for an LDPC code has complexity quadratic in the block length.

LDPC codes were first introduced by Gallager[1] in 1963 and one of the most attractive properties of the LDPC codes is that the complexity of the decoding process grows linearly with the length of code [2]. The design of irregular LDPC codes using the optimization technique, called density evolution, has been shown to approach the channel's capacity [3]. The drawback encountered with the length of the LDPC code is the delay provided by the encoding and decoding process.

Mobile WiMAX is a broadband wireless solution that enables convergence of mobile and fixed broadband networks through a common wide area broadband radio access technology and flexible network architecture. The Mobile WiMAX Air Interface adopts Orthogonal Frequency Division Multiple Access (OFDMA) for improved multipath performance in non-line-of-sight environments. Scalable OFDMA (SOFDMA) [3] is introduced in the IEEE 802.16e Amendment to support scalable channel bandwidths from 1.25 to 20 MHz.

The outline of this paper is as follows. In section II Orthogonal Frequency Division Multiplexing (OFDM) is explained. In section III, we review the LDPC code used within the WiMax standard and the optimized LDPC code that will be evaluated. In section IV, we review the LDPC decoder algorithm used within the WiMax standard. In section V we present our simulation results. We present our conclusions in section VI.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation technique that employs N_s separate subcarriers to transmit data instead of one main carrier. Input data is grouped into a block of N bits, where

$$N=N_s.\, m_n \qquad (1)$$

and m_n is the number of bits used to represent a symbol for each subcarrier. In order to maintain orthogonality between the subcarriers they are required to be spaced apart by an integer multiple of the subcarrier symbol rate, Rs. The subcarrier symbol rate is related to the overall coded bit rate Rc of the entire system by

$$Rs = Rc/N \qquad (2)$$

In many OFDM systems a guard time is added to the symbol period. A cyclic extension is applied to each subcarrier signal during the guard period to maintain orthogonality of the subcarriers during timing offsets. The subcarriers are assumed to have no timing offsets, i.e. no multipath delay spread, therefore a guard time has not been included in the analysis.
The output signal of an OFDM transmitter takes on the form

$$Z(t) = \sum_{m=0}^{N_s-1} C_k e^{2\pi j(m-N_s/2)t/T_s}, \qquad (3)$$

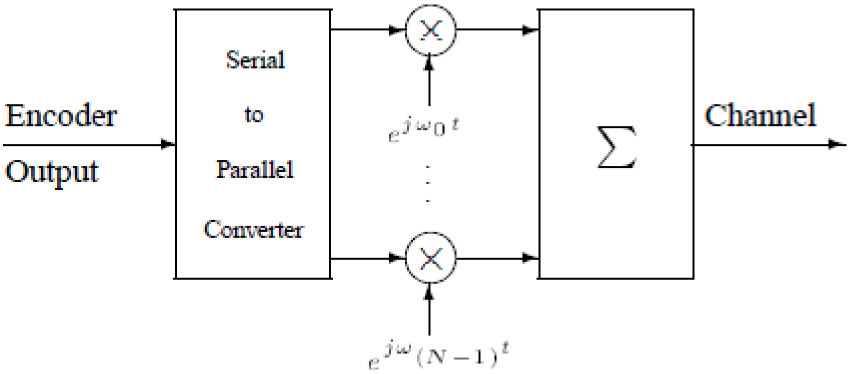

Fig. 1 OFDM Transmitter

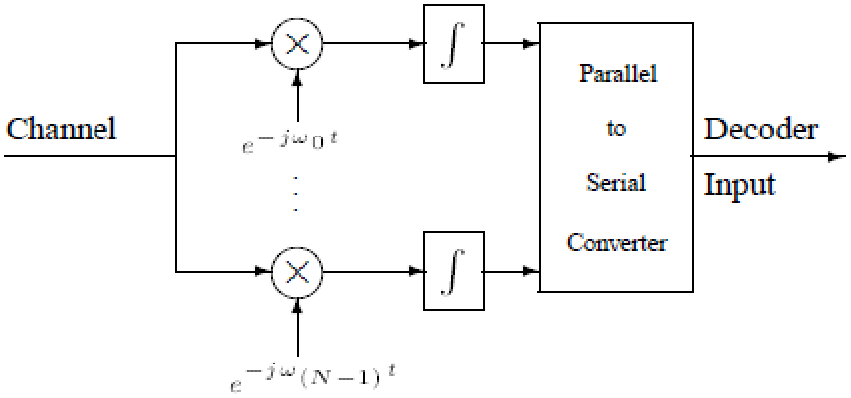

Fig. 2 OFDM Receiver

where Ck are the complex representations of the subcarrier symbols and Ts is the symbol period. This expression is very similar to that of the inverse Discrete Fourier Transform (DFT), and it is common practice to implement (3) using an inverse FFT. Likewise, the receiver typically recovers the transmitted subcarrier symbols by using a forward FFT. The simulated wideband system is shown in Figure 1 and 2. Because the underlying architecture of OFDM is implemented using the FFT algorithm, Ns = 1024 subcarriers were used for the simulations. Also, it was assumed that perfect channel information was available to the receiver, except the noise variance which was estimated prior to LDPC decoding.

III. LOW DENSITY PARITY-CHECK (LDPC) CODES

LDPC codes are linear codes obtained from sparse bipartite graphs. Suppose that G is a graph with n left nodes (called message nodes) and r right nodes (called check nodes). The graph gives rise to a linear code of block length n and dimension at least n-r in the following way[7]: The n coordinates of the codewords are associated with the n message nodes. The codewords are those vectors $(c_1,.., c_n)$ such that for all check nodes the sum of the neighbouring positions among the message nodes is zero.

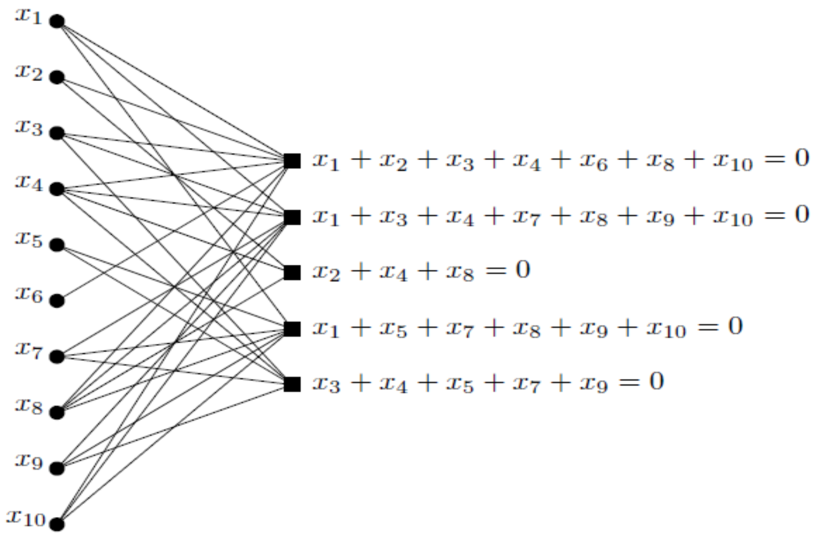

Fig. 3 LDPC Codes

The graph representation in fig: 3 is analogous to a matrix representation by looking at the adjacency matrix of the graph: let **H** be a binary r x n-matrix in which the entry (i, j) is 1 if and only if the ith check node is connected to the jth message node in the graph. Then the LDPC code defined by the graph is the set of vectors $c = (c_1,..., c_n)$ such that **H** $,c^T = 0$. The matrix **H** is called a parity check matrix for the code. Conversely, any binary r x n-matrix gives rise to a bipartite graph between n message and r check nodes, and the code defined as the null space of **H** is precisely the code associated to this graph. Therefore, any linear code has a representation as a code associated to a bipartite graph (note that this graph is not uniquely defined by the code). However, not every binary linear code has a representation by a sparse bipartite graph. If it does, then the code is called a low-density parity-check (LDPC) code[6].

IV. DECODING ALGORITHM

LDPC codes can be decoded using the message passing algorithm [2]. It exchanges soft-information iteratively between variable and check nodes which is called belief propagation (BP). Updating the nodes can be done with a canonical, twophased scheduling: In the first phase all variable nodes are updated, in the second phase all check nodes respectively. This scheduling is denoted as two-phase BP in the following. The processing of individual nodes within one phase is independent and can thus be parallelized. The exchanged messages are assumed to be log-likelihood ratios (LLR). Each variable node of degree d_v calculates an update of message *k* according to:

$$\lambda_k = \lambda_{ch} + \sum_{l=0}^{d_v-1} \lambda_l - \lambda_k^{old} \qquad (4)$$

with λ_{ch} the corresponding channel LLR of the VN and λ_l the LLRs of the incident edges. To subtract the own old extrinsic information $\lambda^{old}{}_k$ is the basic principle of iterative decoding. The check node LLR update can be done in an either optimal or suboptimal way, trading of implementation complexity against communications performance. The simplest suboptimal check node algorithm is the well-known Min-Sum algorithm [3], where the incident message with the smallest magnitude mainly determines the output of all other messages:

$$\lambda_k = \prod_{\forall l, l \neq k}^{d_c-1} \operatorname{sign}(\lambda_l) \cdot \min_{\forall l, l \neq k}(|\lambda_l|) \qquad (5)$$

The resulting performance comes close to the optimal Sum- Product algorithm only for high rate LDPC codes ($R \geq 3/4$) with relatively large CN degree. For lower code rates the communications performance strongly degrades. Thus a more sophisticated suboptimal algorithm has to be used for low rates. The λ-3-Min algorithm [3] uses the three smallest absolute input values and applies a correction term δ to counter the introduced approximation:

$$\delta(x,z) = \ln\left(1 + e^{-|\lambda_x + \lambda_z|}\right) - \ln\left(1 + e^{-|\lambda_x - \lambda_z|}\right) \qquad (6)$$

While increasing implementation complexity, this decoding scheme almost approaches the optimal algorithm for any given code rate and is therefore the best solution if a wide range of codes has to be supported.

V. RESULT AND DISCUSSION

In this experiment, Analysis of WiMax OFDM using LDPC Code with BPSK Modulation technique is explained. Bit error rate (BER) and Spectral Efficiency are the parameters that are used for the analysis of WiMax OFDM using LDPC Codes. After channel equalizer ,the data symbols are parallel to series converted , and then symbol demapping is done to get the data bits. Channel decoding is performed with LDPC decoder and we can calculate bit error rate (BER). The spectral efficiency of a channel is a measure of the number of bits transferred per second for each Hz of bandwidth. Spectral efficiency for various modulation levels as a function of short-term average SNR is depicted.

$$\eta = (1 - BER)^n kr \qquad (7)$$

where,

BER: bit error rate.

n: number of bits in the block.

k: number of bits per symbol.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

r=overall code rate.

Fig:4 shows the BER vs EbNo for BPSK using LDPC codes. Fig:5 shows the Constellation diagram for BPSK using LDPC codes. Fig:6 shows the Spectral Efficiency vs EbNo for BPSK using LDPC codes

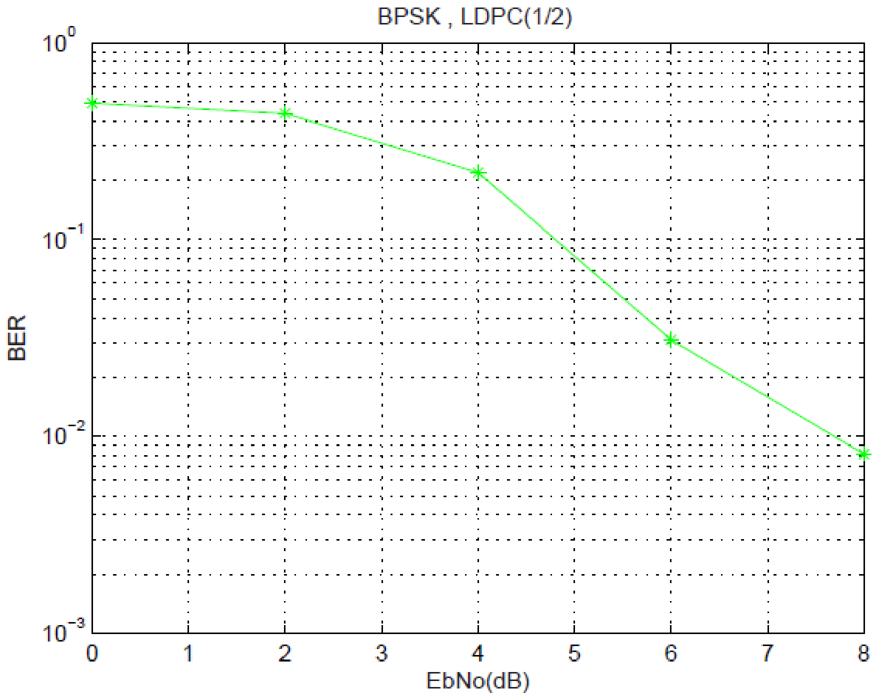

Fig. 4 BER vs EbNo for BPSK using LDPC codes with (r=1/2)

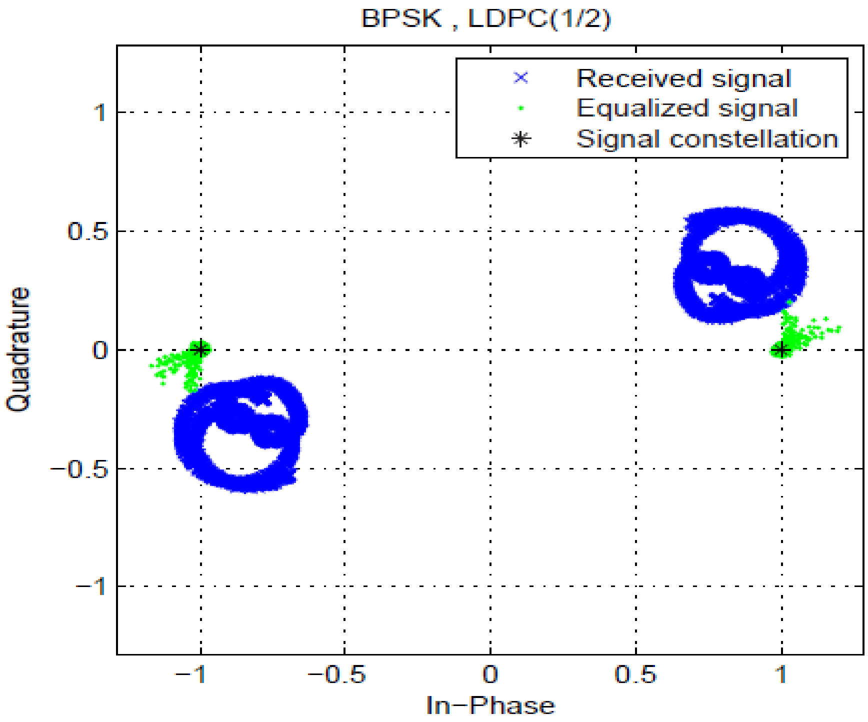

Fig. 5 Constellation diagram for BPSK using LDPC codes with (r=1/2)

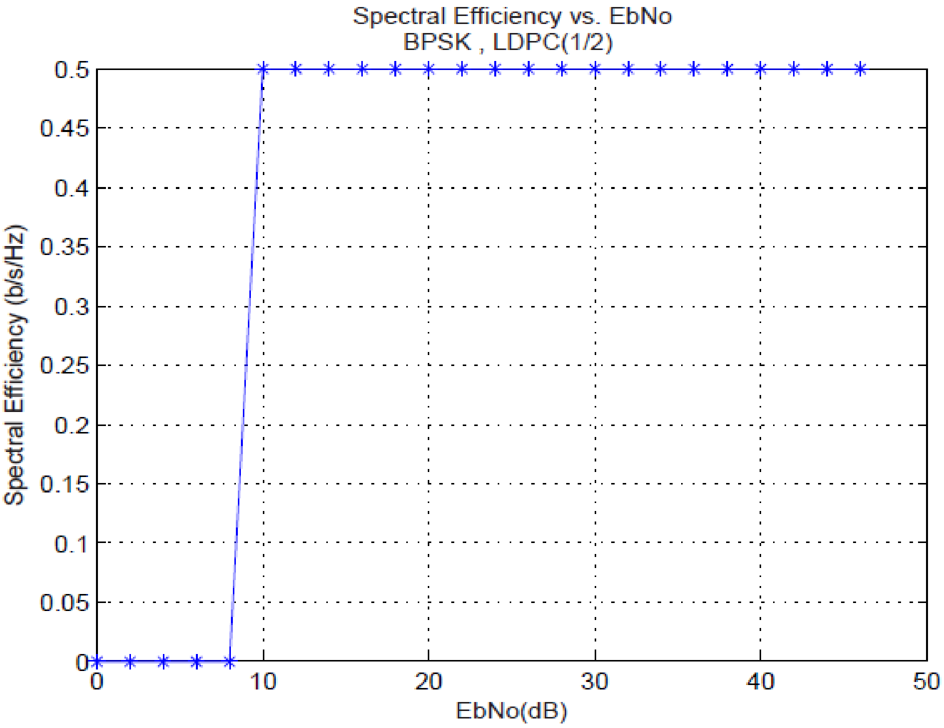

Fig. 6 Spectral Efficiency vs EbNo for BPSK using LDPC codes with (r=1/2)

VI.CONCLUSION

In this paper LDPC codes are used for the analysis of WiMAX OFDM system. he Stanford University Interim (SUI-3) channel models are selected for the wireless channel in the simulation. Perfect channel estimation is assumed. The simulation results include the performance analysis based on bit error rate (BER) vesus bit energy to noise rate (Eb/No) plots and spectral efficiency of different modulation and channel coding schemes according to the standard IEEE 802.16.

REFERENCES

[1] R. G. Gallager, Low-Density Parity- Check Codes. Cambridge, MA: MIT Press, 1963.
[2] R. Urbanke and T. Richardson, "Design of Capacity-Approaching Irregular Low- Density Parity-Check Codes," IEEE Trans. Inform. Theory, Vol.47m no. 2, pp. 619-637, Feb. 2001.
[3] IEEE 802.16. Worldwide Interoperability for Microwave Access. www.wimaxforum.org.
[4] IEEE 802.16e. Air interface for fixed and mobile broadband wireless access systems. IEEE P802.16e/D12 Draft, Oct 2005.
[5] Gupta, S.H. ; Virmani, B. LDPC for Wi-Fi and WiMAX technologies", Emerging Trends in Electronic and Photonic Devices & Systems, 2009. ELECTRO '09. International Conference, Pag:262-265, 2009.
[6] Salbiyono, A. ; Adiono, T. LDPC decoder performance under different number of iterations in mobile WiMax", Intelligent Signal Processing and Communication Systems (ISPACS), 2010 International Symposium, Pag:1-4, 2010.
[7] J.W. Cooley and J.W. Tukey, An Algorithm for the Machine Calculation of Complex Fourier Series, Math. Computation, vol. 19, pp. 297 301, 1965.
[8] M. Rahman , S. Das , F. Fitzek, OFDM based WLAN systems, Technical Report, Aalborg University, Denmark, February 2005.
[9] R.V. Nee & R. Prasad, OFDM for Wireless Multimedia Communications. Artech House Publishers", 2000.