ISSN 2047-3338

Performance Analysis of Optimized FEC Based on IEEE 802.16d

Neha[1] and Abhijeet Kumar[2]
[1,2]Electronics & Communication Department, M. M. Engineering College, M. M. University, India
nehaer2007@gmail.com, abhijeet.kumar@mmumullana.org

***Abstract*– WiMAX is one of the most promising IEEE 802.16 standards. This paper carries out a study of IEEE 802.16d OFDM layer and mainly concentrates on the Forward Error Correction (FEC) based on IEEE 802.16 standard. Forward error correction coding is a system of error control for data transmission. FEC is accomplished by adding redundancy to the transmitted information using a predetermined algorithm. It may improve the reliability of transmitted data. We will verify this result through MATLAB (Version 7.8).**

***Index Terms*– WiMAX, IEEE 802.16, SUI and OFDM**

I. INTRODUCTION

WIRELESS networks are largely invisible to consumers, yet powerful enough to transform their lives. Wireless offers consumers a new freedom – the ability to communicate and connect with the world anytime, anywhere. Mobile communications, originating from fixed circuit switched voice traffic in public phone networks, has evolved to support stringent QoS and packet based traffic together with global mobility. Wireless broadband technologies has gone from indoor, fixed high speed networks with 802.11, to outdoor wireless access with support for mobility with standards such as 802.16 for broadband wireless access. The impact of wireless technologies is magnified by their ability to be coupled with other communications technologies – including wire-line, cable, broadband over power line and satellite technologies – in ways that enable endless combinations of mixing and matching of technologies to suit the needs of different applications. The promise of the benefits of wireless broadband is no longer reserved only for the future. The future is now. Consumers using wireless broadband technologies have the freedom to access the Internet from coffee shops, on moving trains, and in their own backyards. Consumers can access the Internet using a single device – to make phone calls, pay bills electronically, and access entertainment and data – all with a seamless high-speed wireless connection. One device now opens up the world.

II. HISTORY

Many papers have been proposed on FEC based on IEEE 802.16d. Authors in [1] proposed the performance of WiMAX PHY layer with turbo coding mechanisms has been investigated and compared with the existing mechanisms. The results obtained show that turbo coding offers lower BER and enhance the performance of the PHY layer in mobile (multipath) environments. Authors in [2] proposed WiMAX (Worldwide Interoperability for Microwave Access) technology which can offer high speed data, voice and video service to the customer end, which is presently, dominated by the cable and digital subscriber line (DSL) technologies. The aims of this paper are to model and simulate the fixed OFDM IEEE 802.16d physical layer under variant combinations of digital modulation (BPSK, QPSK and 16-QAM) over diverse combination of fading channels(AWGN,SUIs). Authors in [3] proposed Broadband Wireless Access (BWA) technology which can offer high speed voice, video and internet connection. The leading candidate for BWA is WiMAX, a technology that complies with the IEEE 802.16 family of standards. This paper provided the hardware implementation of Wireless MAN-OFDM Physical Layer of IEEE Std 802.16d Transmitter on FPGA. The proposed design is fully supportive to adaptive modulation schemes described in IEEE Std 802.16d and equipped with soft interfaces for MAC layer and RF-front end, so that in future more work could be done in order to deploy complete WiMAX CPE IP core. In [5] the authors presented a FPGA prototyping of the MIMO Decoder for the IEEE 802.16e WiMAX mobile systems. Authors in [6] considered iterative receiver for a multiple-input-multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) system to jointly decode the transmitted bits and estimate the channel state.

The receiver consists of a list detector, a turbo decoder and a channel estimator that is based on the space-alternating generalized expectation-maximization (SAGE) algorithm. This paper proposed a way to improve the convergence of the iterative detection and decoding by using *a* priori information to also recalculate the candidate list, aside from the log-likelihood ratios (LLRs) of the coded bits. It is also shown that the list PIC detector with good initialization outperforms the *K*-best list sphere detector (LSD) in the case of small list sizes, whereas the complexities of the algorithms are of the same order. Despite the low preamble density and fast-fading channel, the proposed iterative receiver shows robust performance. Authors in [8] worked on the performance of combined FECIARQ techniques for a direct-sequence CDMA system using coherent binary phase shift keying (BPSK) modulation has investigated. Authors in [9] worked on the broadband wireless access industry, which provides high-rate network connections to stationary sites, has matured to the point at which it now has a standard for second-generation wireless metropolitan area networks. Authors in [10] specified improved mechanisms, as policies and medium access control enhancements, to enable coexistence among license-exempt systems based on IEEE Std 802.16 and to facilitate the coexistence of such systems with primary users.

III. BROADBAND WIRELESS ACCESS

Wireless broadband gives “broadband on the go”. Broadband wireless access is a technology aimed at providing wireless access to data networks, with high data rates. The task force setup by FCC Chairman Michael K. Powell in May 2004 [4] used the term “broadband” to describe a general set of transmission capabilities and characteristics, such as always-on, high speed Internet access with a sufficiently robust functionality suitable for evolving, bandwidth-hungry applications. Wireless broadband networks can span the length of a room, a building, reach several miles, or even cover the nation. As means to consider the scale of management and deployment of communication networks, this section briefly recapitulates different network sizes. Following figure gives an overview of different network sizes.

Personal Area Networks use license exempt equipment to send signals short distances – a few feet or yards – between and among mobile devices (*e.g.* mobile telephones, laptops, PDAs, and cameras) and stationary devices (*e.g.* computers, printers, televisions, personal video recorders, and home appliances). Broadband personal network technologies include Bluetooth, ZigBee and ultra-wideband. Their data transfer speeds range from 300 kbps to 100 Mbps.

Local Area Networks typically use license-exempt equipment developed under the IEEE 802.11 family of standards, commonly referred to as “Wi-Fi.” LANs are networks build to cover a building or group of buildings. Local area network’s speed ranges from 11 to 54 Mbps.

Metropolitan Area Networks are data networks built from high speed infrastructure to service a whole town or city. MAN gives its consumers portable, “last-mile” wireless broadband access – using devices such as a wireless modem connected to a laptop computer – within cities or towns at shared data rates of up to 75 Mbps.

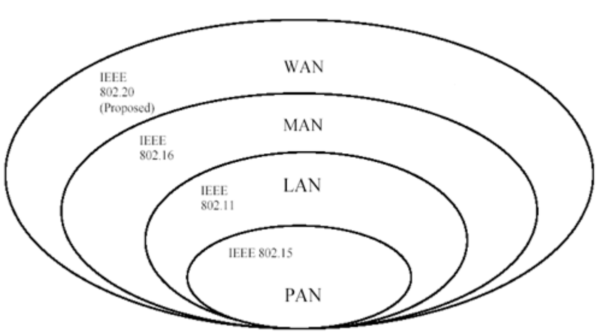

Fig. 1: Overview of different network sizes [4]

IV. IEEE 802.16 FAMILY OF STANDARDS

Forming the base of WiMAX technology is the IEEE Std. 802.16. It defines the air interface and medium access control (MAC) protocol for a wireless metropolitan area network (WMAN™). It provides specifications for both fixed Line of sight (LOS) communication in the range of 10-66GHz (802.16c), and fixed, portable, Non-LOS communication in the range of 2-11GHz (802.16a & 802.16d). In addition, it defines wireless communication for mobiles, moving at a speed of 125 KMPH, in the range of 2- 6 GHz (802.16e). Support for both time division duplex (TDD) and frequency division duplex (FDD) SS is provided, both using a burst transmission format whose framing mechanism supports adaptive burst profiling in which transmission parameters, including the modulation and coding schemes, may be adjusted individually to each SS on a frame by- frame basis, thus providing high data rates. The IEEE 802.16 families of standards include:

802.16a: The 802.16a standard, completed in Jan 2004, is targeted for frequencies below 11 GHz and NLOS. The lower frequencies make non-line of sight a possibility, which can also be helped by OFDM's ability to handle multipath signals. Support for both TDD and FDD is provided. Since single carrier in multipath environment is used, a receiver needs to perform efficient channel estimation and equalization techniques to overcome the multipath effects. Optionally to improve the performance support is provided for BTC, CTC, Adaptive antenna systems (AAS) are provided.

802.16c: It contains the profiles, conformance standards, and test suites for 802.16 (10-66GHz) implementations. Wireless metropolitan area network- single carrier physical layer (Wireless MAN-SC PHY) specification is targeted for operation in the 10–66 GHz frequency band. The BS is essentially an isotropic radiator, which transmits data (downlink) to all the users designated by their connection identifier (CID). The subscriber station (SS) shall use highly directional antennas directed towards the BS. Application of this standard includes point to point (PPP) and point to multi point (PMP) microwave communication, interconnection between remote locations and backhaul services.

802.16d: This is targeted to provide a broadband internet connection to indoor users. 802.16d uses orthogonal frequency division multiplexing (OFDM) as its physical layer specification to enable NLOS communication below 11 GHz. Since OFDM is used, the receiver is made simple by ‘elimination’ of bulky equalizer. FEC includes concatenated RS-CC followed by interleaving. Similar to 802.16a, AAS, STC schemes are provided but are kept optional. Variable FFT size and symbol time is specified, which could be fixed depending on type of environment and allocated bandwidth.

802.16e: Specifications are provided such that mobility of the SS at 125 KMPH is allowed. Orthogonal frequency division multiple access (OFDMA) is used as the physical layer scheme. Channel coding is provided by use of mandatory CC and optional BTC, CTC and low density parity check codes (LDPC). In addition to AAS, STC, optional multi input multi output (MIMO) scheme has been specified. Similar to 802.16d, variable FFT size and symbol time is provided which could be set depending on the environment and allocated bandwidth. Put together, the 802.16 technology would enable the SS to get broadband wireless access (BWA) at all times in all locations, either when stationary, or at pedestrian speed or when traveling at 125 KMPH.

V. WiMAX APPLICATIONS

The 802.16 standard will help the industry provide solutions across multiple broadband segments:

1). Broadband on-demand: Last-mile broadband wireless access can help to accelerate the deployment of 802.11 hotspots and home/small office wireless LANs, especially in those areas not served by cable or DSL. Broadband Internet connectivity is very critical for many businesses, to the extent that these organizations may actually re-locate to areas where service is available.

2). Residential broadband: filling the gaps in cable and DSL coverage. Practical limitations prevent cable and DSL technologies from reaching many potential broadband customers. The cost of deploying cable is also a significant deterrent to the extension of wired broadband service in areas with low subscriber density. The range of 802.16a solutions, the absence of a line of sight requirement, high bandwidth, inherent flexibility and low cost helps to overcome the limitations of traditional wired and proprietary wireless technologies.

3). Best-connected wireless service: As the number of IEEE 802.11 hotspots proliferates, users will naturally want to be wirelessly connected, even when they are outside the range of the nearest hotspot. The IEEE 802.16e extension to 802.16a introduces nomadic capabilities which will allow users to connect to a Wireless Internet Service Provider even when they roam outside their home or business.

VI. STRUCTURE OF 802.16d OFDM PHY LAYER

The output bit stream from MAC is fed into the baseband transmitter. As specified in the standard, 802.16d OFDM PHY layer baseband transmitter is composed of three major parts: channel coding, modulation, and OFDM transmitter. For the receiver complimentary operations are applied in the reverse order. The structure of IEEE 802.16d OFDM PHY layer is shown in Fig. 2. The first block in the transmitter is scrambler, which is used for randomization. The use of scrambler is to prevent a long sequence of 1s and 0s, which will cause timing recovery problem at the receiver. In 802.16d standard the scrambler is implemented with a 15 bits shift register and two XOR gates. The scrambler should be reset at the start of each frame and at the receiver; the same structure is used for descrambler.

The FEC block is composed of Reed-Solomon encoder, convolutional coding and puncture (used to adjust different data rate). These are the mandatory blocks on the standard. An FEC, consisting of the concatenation of a Reed–Solomon outer code and a rate-compatible convolutional inner code, shall be supported on both uplink and downlink. Block Turbo codes (BTC) and Convolutional Turbo Codes (CTC) are specified as optional in the standard. The modulation used in

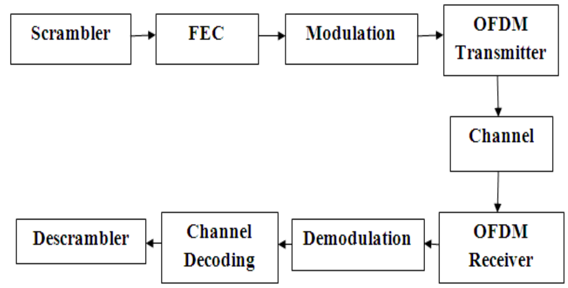

Fig. 2. Block diagram of 802.16d OFDM PHY layer

802.16d is Gray-mapped QPSK, 16-QAM, and 64-QAM. The OFDM transmitter is composed of three parts: assemble OFDM frame, create OFDM signal by performing IFFT/FFT, and add cyclic prefix (guard interval used to cancel inter symbol interference). Data is sent in the form of OFDM symbols. Accurate synchronization is necessary to ensure correct baseband processing. OFDM systems are very sensitive to frequency offset because there might be loss of orthogonality between sub symbols. The frequency offset can be estimated with the aid of preambles because the phase shifts on the constellation means the frequency shifts of carriers. The estimation can be performed both on time domain and frequency domain based on certain statistical criteria, such as Maximum Likelihood.

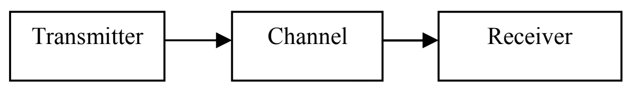

Fig. 3. Block Diagram of Wireless Communication [7]

Where,
Transmitter side:

1. Input the data and viterbi encoding(Viterbi polynomial + Walsh code generation)
2. Interleaving and pn generation
3. Scrambling and modulation

Channel: Add AWGN noise in the data

Receiver side:

1. Demodulation
2. Deinterleaving
3. Viterbi Decoding

VII. SIMULATION RESULTS

Systematic computer simulations were carried out to evaluate the Bit Error Rate (BER) performance of FEC based on IEEE 802.16 d. The platform employed for performing the simulations is MATLAB v7. An OFDM system in a pure additive white Gaussian noise (AWGN) environment with synchronization and channel equalization disabled will have the exact same BER as that of the sub-carrier modulation. For a given value of E_b/N_0, the SNR is given as:

$$\frac{E_b}{N_o} = \left(\frac{\#\,of\ data\ carriers}{\#\,of\ time\,domain\,samples + cyclic\,prefix\ length}\right)$$

$$\blacksquare \left(\frac{\#\, of\ data\ carriers}{\#\, of\ data\ carriers + \#\, of\ pilot\ carriers}\right) SNR$$

For this system:

MATLAB simulations confirmed that the OFDM system (with no synchronization algorithms or channel estimation enabled) has the exact same BER as BPSK for an AWGN channel. The next step is to compare the BER of the simulated with the theoretical values.

The Fig. 4 presents a Bit Error Rate (BER) Vs Signal to Noise Ratio (SNR) plot, with the analytical BER curve for BPSK for reference.

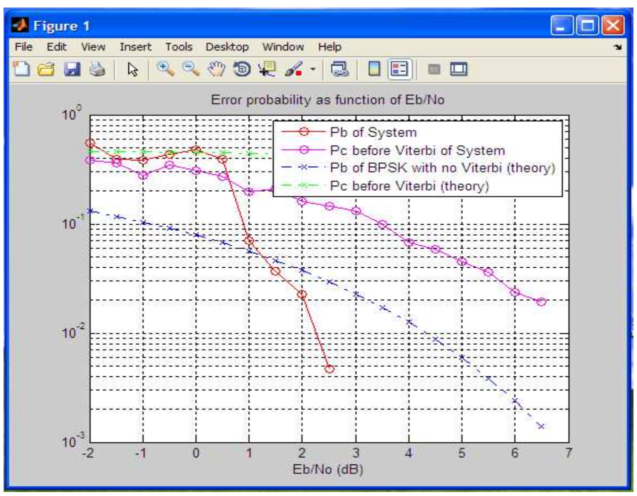

Fig. 4. Probability of Error (Bit error rate) Vs Signal to Noise ratio of BPSK

VIII. CONCLUSION

WiMAX based on IEEE 802.16 standard promises to provide high speed wireless broadband connectivity building the gap between 3G and Wireless LAN (WLAN). The IEEE 802.16 standard, defines the air interface and medium access control (MAC) protocol for a wireless metropolitan area network (WMAN). Forward error correction is a system of error control for data transmission. It allows the receiver to correct some errors if the number of errors falls within the error correction capacity for which it is designed. FEC is accomplished by adding redundancy to the transmitted information using a predetermined algorithm. The encoder as well as the decoder blocks along with interleaver is implemented in MATLAB. The data is transmitted on a frame by frame basis. The performance was evaluated for SUI – 3 channel model. The simulation results clearly indicate the performance advantages FEC have over passing the information without FEC.

REFERENCES

[1] Mingxi Wang, “WiMAX physical layer: Specifications overview and Performance evaluation” 2nd IEEE CCNC Research student workshop, pp. 10 - 12, IEEE 2011.

[2] S. Askar, H S AI-Raweshidy, “Performance Evaluation of IEEE 802.16-2004 WiMAX with fixed High Fading Channels”, Crown 2011.

[3] Shahid Abbas, Waqas Ali Khan, Talha Ali Khan, Saba Ahmed, “Implementation of OFDM Baseband Transmitter Compliant IEEE Std 802.16d on FPGA”,2ND International Conference on Communication Software and Networks, pp. 22 – 26, IEEE 2010.

[4] Federal Communications Commission, “Connected & on the Go: Broadband goes wireless”, Wireless Broadband Access Task Force Report, pp 1-14, February 2005.

[5] M. S. Khairy, M. M. Abdallah, and S. E.-D. Habib, “Efficient FPGA implementation of MIMO decoder for mobile WiMAX system,” in *Proc. IEEE International Conference on Communications*, Dresden, Germany, 2009, pp. 2871-2875.

[6] J. Ylioinas, and M. Juntti, “Iterative joint detection, decoding, and channel estimation in Turbo-coded MIMO-OFDM”, *IEEE Trans. Veh. Technol.*, vol. 58, pp.1784-1796, May. 2009.

[7] Kanchan Sharma, Anagha Chougaonkar, “Performance Evaluation of Convolutional coded WiMAX System for BPSK & QAM Modulation Techniques”, IJCEM International Journal of Computational Engineering & Management, vol. 14, pp. 53-56, October 2011.

[8] Mqhele E. Dlodlo, Rogier N. van Wolfswinkel, Richard D. J. van Nee, “Performance Analysis of Hybrid Forward Error Correction Schemes in a Fast and Slow Rician Fading Wideband Land-Mobile Satellite Channel with BPSK and Path Diversity”, 5th IEEE International Symposium, vol. 2, pp. 579-583, PIMRC 1994.

[9] Carl Eklund, Roger B. Marks, Kenneth L. Stanwood and Stanley Wang, “IEEE Standard 802.16: A Technical Overview of the Wireless MAN Air Interface for Broadband Wireless Access”, IEEE Communications Magazine, vol. 40, no. 6, pp. 98-107, June 2002.

[10] IEEE Std 802.16h™-2010, “IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems”, 30 July 2010.