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OPTIMIZATION OF FEC IN IEEE 802.16D

Neha[1], Abhijeet Kumar[2]

[1](Electronics & Communication Department, M. M. University, India)

[2] (Electronics & Communication Department, M. M. University, India)

ABSTRACT

WiMAX based on IEEE Std. 802.16 carries high data rates and large coverage to wireless networks. It provide high speed wireless broadband connectivity building the gap between 3G and Wireless LAN (WLAN).The main focus of this paper is on 802.16d OFDM PHY layer. The simulation will compare the performance of SF and STF – OFDM over different SUI channel models. Forward error correction is used to improve the reliability of transmitted data. The main categories of FEC are block and convolutional codes. In the simulation block and convolutional codes are frequently combined in concatenated coding schemes in which the convolutional codes does most of the work and the block code "mops up" any errors made by the convolutional decoder.

Keywords- WiMAX, IEEE 802.16, SUI, OFDM

I INTRODUCTION

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Vol. 2 Issue 1 January 2012

WiMAX (Worldwide Interoperability for Microwave Access) technology that offer high speed data rate, voice and video service to the customer end, that dominates the cable and digital subscriber line(DSL) technologies[2]. 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 wireline, 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. WiMAX broadband MAN, based on the IEEE 802.16d/e standard supports fixed as well as mobile wireless access services. The underlying subscriber data links are characterized by different radio conditions such as interference rejection capability, propagation. This results in significant coverage mismatch, different user throughput, spectrum efficiency and system capacity. Performance of mobile and fixed subscribers has been analyzed for homogeneous hexagonal 3.5 GHz cellular deployments of an OFDM-based WiMAX system depending on cell size, frequency reuse and offered traffic load [4]. The hardware implementation of Wireless MAN-OFDM Physical Layer of IEEE Std 802.16d Transmitter on FPGA proposed in [5].

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Vol. 2 Issue 1 January 2012

II PHY LAYER SPECIFICATIONS

Different techniques that can be used in PHY layer

i) Two channel sizes used are- 3.5 MHz & 20 MHz [3]. To prevent inter symbol interference (ISI) caused by delay spread, part of the OFDM symbol is appended at the beginning of the symbol. The repeated symbol fraction is called cyclic prefix (CP) and its size depends on type of environment. Bandwidth size and CP can be derived symbol time duration. In case of OFDM modulation used in 802.16 standards, the bandwidth is divided into 256 subcarriers. When pilot and null subcarriers are subtracted, only 192 subcarriers can be used to carry user's data. The capacity of each subcarrier depends on the order of used modulation. WiMAX standard supports BPSK (1 bit per subcarrier), QPSK (2 bits per subcarrier), 16QAM (4 bits per subcarrier) and finally 64 QAM (6 bits per subcarrier). Because of errors introduced by imperfection on the air link connection, redundant bits must be carried with useful information for purpose of error detection and correction at the side of the receiver. The ratio of information to redundant bits is called coding rate and may vary from ½ to ¾.

ii) Mingxi Wang uses subcarrier layer operating in 10-66 GHz[1], supports both time division duplex (TDD) and frequency division duplex (FDD). The PHY operates in a framed format. In each frame, there are downlink sub-frames and uplink sub-frames. The uplink channel is divided into several time slots. The downlink employs time division multiplexing (TDM), in which information from multiple mobile station (MS) are multiplexed into one stream. The system structures for uplink and downlink transmitters are similar. In the digital baseband part, data bits are randomized, forward error correction (FEC) encoded, modulated and finally pulse shaped. More details are explained in the following:

1) Randomization: The stream of packets is randomized using a pseudo-random binary sequence (PRBS) generator. The randomized bits are the modulo-2 summation of the data with the PRBS output. The generator polynomial is chosen to be $c(x) = x^{15} + x^{14} + 1$.

2) FEC: SC PHY specifies four types of FECs:

• Code Type 1: Reed-Solomon (RS) over Galois field (GF) (256) with 0 to 16 byte correction capability. This code is useful for large data block.

• Code Type 2: RS outer code over GF (256) + (24, 16) block convolutional code (BCC) inner code. This case is useful for low to moderate coding rates.

• Code Type 3 (Optional): RS outer code over GF (256) + (9, 8) parity check inner code. This code is suited for moderate to high coding rates with small to medium size blocks.

• Code Type 4 (Optional): Block Turbo code (BTC).

3) Modulation: The PHY supports QPSK, 16-QAM and 64-QAM modulation. The multilevel modulation schemes are adopted to maximize utilization of the channel conditions. For each subscriber, the constellation is selected based on the quality of channels. If the link conditions is good, high level modulation scheme like 64-QAM can be used to obtain high spectrum efficiency. On the other hand, if the air link degrades, the system uses less complex constellation for reliable transmission.

4) Pulse Shaping: After modulation, the in-phase and quadrature-phase signals go through square-root raised cosine (SRRC) filters with 0.25 roll-off factor.

B. OFDM PHY

The OFDM PHY is based on OFDM modulation and designed for NLOS environment. The frequency domain description includes the basic structure of an OFDM symbol. In the frequency domain, an OFDM symbol consists 256 subcarriers. There are three types of subcarriers: data subcarriers (for data transmission), pilot subcarriers (for channel estimation), and null subcarriers (for guard bands, and the direct current subcarrier).

1) Channel Coding: Channel coding is composed of three steps: randomization, FEC and interleaving. The randomizer is similar as in PHY SC. The OFDM PHY provides three types of FEC:

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http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

• Code Type 1: Concatenated Reed-Solomon-convolutional code (RS-CC).The RS code is derived from a systematic RS (N = 255, K = 239, T = 8) code over GF (2^8). Convolutional code coding rate is 1/2, 2/3, 3/4, and 5/6

• Code Type 2: (Optional) Block turbo code

• Code Type 3: (Optional) Convolution Turbo code (CTC) with rate 1/3, 2/3, 3/4, and 5/6

2) Modulation: After interleaving, BPSK, Gray-mapped QPSK, 16-QAM or 64 QAM modulation schemes are supported.

3) Space Time Coding: The OFDM PHY specifies optional space-time coding (STC) for transmit diversity.

4) Preamble Structure: For synchronization and channel estimation purpose, preambles are needed in addition to data symbols. The preamble includes one or two OFDM symbols and each OFDM symbols contains a cyclic prefix.

C. OFDMA PHY

Similar as OFDM PHY, the WirelessMAN-OFDMA PHY is designed for NLOS operation in the frequency bands below 11 GHz for licensed bands. However, the fast Fourier transform (FFT) size of OFDMA PHY can be 128, 512, 1024, or 2048. Therefore, the MS needs a scanning mechanism to detect the FFT size and channel bandwidth of downlink signals. In the OFDMA scheme, the subcarriers are divided into groups of subcarriers. In the downlink, a sub channel may be intended for different users. In the uplink, a MS may be assigned to one or more sub channels. OFDMA PHY supports QPSK, 16-QAM and 64-QAM modulations. There are three types of FECs in OFDMA PHY:

• Code Type 1: Convolutional code with rate 1/2, 2/3, 3/4 and 5/6.

• Code Type 2: (Optional)Convolution Turbo code with rate 1/3, 2/3, 3/4, and 5/6.

• Code Type 3: (Optional) LDPC with rate 1/2, 2/3, 2/3, 3/4, and 5/6.

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Vol. 2 Issue 1 January 2012

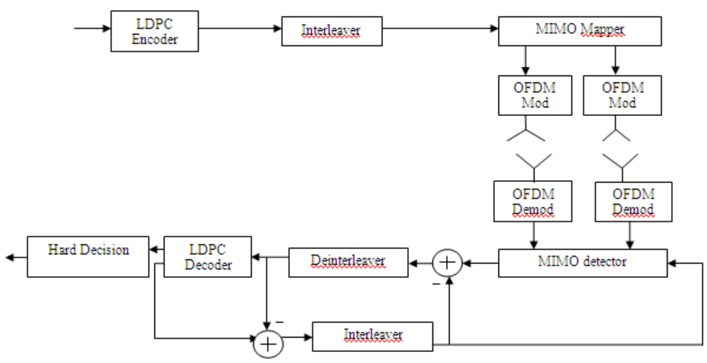

Fig 1: Simplified system model

The system model is shown in Fig. 1. At the transmitter, the data source is composed of sequences of binary bits with equal probability. After LDPC encoding, the codewords are interleaved and modulated to symbols. The sequence of symbols is then converted to N_s parallel sub streams. We choose the Ns to be equal to the number of transmit antennas N_t, and do not consider space time coding in our current system. At each transmit antenna, the OFDM modulator performs IFFT and adds CP. At the receiver side, after CP removal and FFT operation in OFDM demodulators, the signals at frequency domain are fed into a soft MIMO detector. Although the MIMO MAP method suffers an exponentially growing complexity as the number of antennas and constellation point's increases, it may be feasible to implement for systems with BPSK and/or QPSK modulation.

iii) In fixed WiMAX OFDM PHY [2], the FFT size is fixed at 256, with 192 subcarriers used for carrying data, 8 used as pilot subcarriers for channel estimation and synchronization purposes, and the rest used as guard band subcarriers. Since the FFT size is fixed, the subcarrier spacing varies with channel bandwidth. When larger bandwidths are used, the subcarrier spacing increases, and the symbol time decreases. Decreasing symbol time implies that a larger fraction needs to be allocated as guard time to overcome

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http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

delay spread. WiMAX allows a wide range of guard times that allow system designers to make appropriate trade-offs between spectral efficiency and delay spread robustness. For maximum delay spread robustness, a 25 percent guard can be used, which can accommodate delay spreads up to 16 pts when operating in a 3.5MHz channel and up to 8 pts when operating in a 7MHz channel.

III 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.

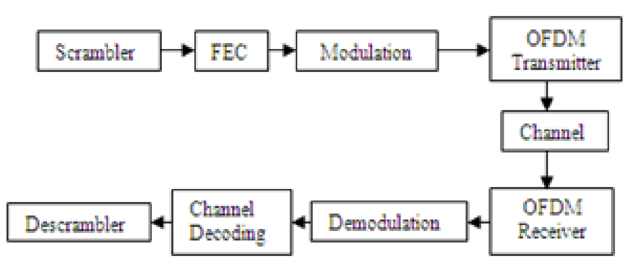

Fig 2: Block diagram of 802.16d OFDM PHY layer

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

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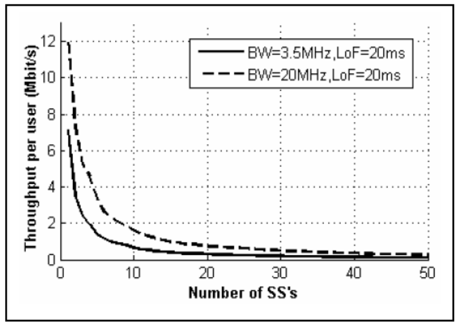
http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

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 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.

IV EXPERIMENTAL RESULTS

For one of the above mentioned PHY layer specifications throughput depending on the number of SS is calculated



International Journal of Enterprise Computing and Business Systems

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http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

Fig 3: Throughput depending on the number of SS [3]

The Fig 3 shows that for more than 10 users the system throughput is considerably limited. In comparison with theoretical maximum WiMAX capacity, the results are much poorer; for 3.5 MHz channel, approximately only 7 Mbit/s is acquired (theoretically 13 Mbit/s) and for 20 MHz channel only 15 Mbit/s data rates were achieved (theoretically 75 Mbit/s) . The reason is that in reality, majority of users cannot put to use the most effective modulation and coding rate scheme due to high SNR requirements. If the outputs for both channel size are compared, the wider channel offers approximately twice as much capacity as the narrow one[3]. On the other hand, the narrow channel consumes much less bandwidth in the frequency spectrum (20 MHz channels needs nearly 6 times more bandwidth).

Using different specifications BER analysis for different channels is plotted

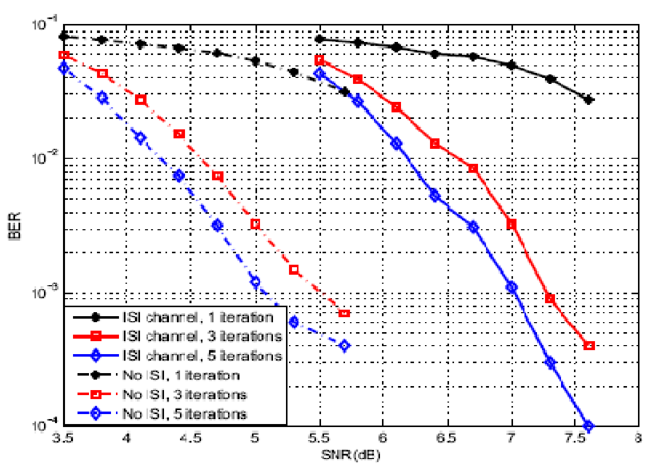

Fig 4: BER performance under different channels [1]

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http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

Fig.4: shows the bit error rate (BER) performance under different channels. The signal to noise ratio (SNR) is the defined as the ratio of signal power at each transmit antenna and noise power at each receive antenna. The LDPC coding rate is 1/2, and the codeword length is chosen to be 1536. From the figure, we can see that the system performance improves as the iteration time increases under both channels [1]. The performance gain is significant when the iteration number is small.

By using BER analysis for different channels with QPSK modulation technique is plotted

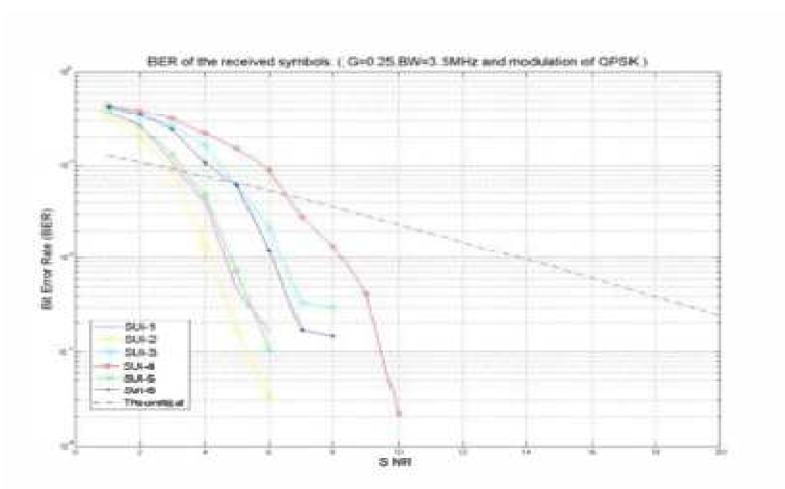

Fig 5: BER of the received symbols for different SUI channels with guard equal to ¼, channel bandwidth is 3.5 MHz with QPSK modulation technique [2]

The Bit Error Rate (BER) plot obtained in the performance analysis shows that model works well on Signal to Noise Ratio (SNR) less than 20 dB [2].

V CONCLUSION

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http://www.ijecbs.com

Vol. 2 Issue 1 January 2012

In this paper we have evaluated the WiMAX system performance over PHY layer by using different channels. We have given a brief overview of OFDM PHY layer. In the simulation, block and convolutional codes are frequently combined in concatenated coding schemes in which the convolutional codes does most of the work and the block code "mops up" any errors made by the convolutional decoder.

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 Al-Raweshidy, "Performance Evaluation of IEEE 802.16-2004 WiMAX with fixed High Fading Channels", Crown 2011.

3 Pavel Mach, Robert Bestak, "WiMAX performance evaluation" in Proc. IEEE 6th International Conference on Networking, 2007.

4 C. F. Ball, E. Humburg, K. Ivanov, F. Treml, "Performance evaluation of IEEE802.16 WiMax with fixed and mobile subscribers in tight reuse", 29 March 2006.

5 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.

6 (2010, May.). About the WiMAX Forum. WiMAX Forum. USA. [Online]. Available: http://www.wimaxforum.org/about

7 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.

8 IEEE Std 802.16-2004, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, Oct. 2004.

9 C. Hoymann, “Analysis and performance evaluation of the OFDM-based metropolitan area network IEEE 802.16”, Computer networks, 2005.

10 IEEE Std 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment for Physical and Medium Access Layers for Combined Fixed and Mobile Operation in Licensed Bands, Feb. 2006.

11 T. Kaitz, *FEC Performance of the 802.16.3 OFDM,* IEEE 802.16 Broadband wireless access working group, 2001.

12 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.

13 S. M. Alamouti, “A simple diversity technique for wireless communications,” *IEEE J. Select. Areas Comm.*, vol. 16, pp. 1451-1458, Oct.1998.

14 Betancur, L., Hincapie, RC, and Bustamante, R. "Wimax Channel - PHY Model in NS2" ACM International Conference Proceeding Series, 2006.

15 Andrews, Jeffrey; Ghosh, Arunabha; Muhamed, Rias. "Fundamentals of Wimax". Prentice Hall. ISBN: 0132225522. 2007.