The WiMAX with generic MAC PDU processed by the Physical Layer using Convolution Encoding Techniques

S.J.Dawda, C.R.Parekh, and A. C. Suthar

***Abstract*—Now a day's trend is of wireless and in addition of internet everyone wants the higher speed and mobility. So one must require wireless broadband networks with higher data rates. WiMAX will give the solution of higher data rate and 8 to 10 Km mobility. Developing an understanding of the WiMAX system can be best achieved by looking at a model of the WiMAX system. In this paper we deal with the physical layer of WiMAX system. This model is very useful to analyse the WiMAX system. We use OFDM and OFDMA for WiMAX system to get better performance and mobility with higher data rate. Standards from IEÉE and ETSI have been used to develop this model. The model presented in this paper built with generic MAC PDU processed by the Physical Layer using Convolutional Encoding Rate of ½ with QPSK modulation and transmitted with 256 carrier OFDM symbols.**

***Index Terms*—Convolution Coding, OFDM, Physical Layer, WiMAX.**

I. INTRODUCTION

The World wide interoperability for Microwave Access (WiMAX) Forum has begun certifying broadband wireless products for interoperability and compliance with a standard a broad industry consortium. WiMAX is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group and adopted by both IEEE and the ETSI HIPERMAN group [1]. In this paper, we present a concise of the emerging WiMAX solution for broadband wireless. The purpose here is to provide an executive summary, the salient features of WiMAX model with the physical and MAC-layer characteristics of WiMAX.

IEEE 802.16 Wireless MAN has a connection-oriented MAC and PHY is based on non-line of sight radio operation in 2-11 GHz. For licensed bands, channel bandwidth will be limited to the regulatory provisioned bandwidth divided by any power of 2, no less than 1.25MHz.

Manuscript received April 17, 2009. S. J. Dawda is with the L. D. College of Engg., Ahmedabad, Gujarat, 360015 INDIA (phone:09275958528 ;e-mail: sandip_dawda@yahoo.co.in).

C. R. Parekh, was with Vishwakarma Institute of Technology, Ahmedabad, Gujarat, 360015 INDIA. He is now with the Department of Electronics and Communication Engineering. (e-mail: crparekh@yahoo.com).

A.C.Suthar is with the Electronics and Communication Engineering Department, C.U.Shah College of Engg and Tech., Wadhwan city,Gujarat,INDIA (e-mail: acsuthar@ieee.org,acsuthar@ccetvbt.org).

Three technologies have been defined like single carrier (SC), orthogonal frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA).

We develop a model for WiMAX using convolution coding techniques for AMC PDU process in our major paper. If a model for a system is developed after the design phase and tested correctly then early detection of a problem with the design is possible. This will reduce the time and cost to change the design at the later stages of the development. Once a model is built, tested and verified against a set criterion then using tools like Simulink and Matlab could be helpful in generating the code and exporting the model in suitable formats for implementation in hardware processors.

Models for other IEEE standards such as Bluetooth and Wireless LAN have been developed in the past using Matlab. There was a need to build a model for the WiMAX on similar lines to fill the gap.

II. THE WIMAX MODEL

The Model for the WiMAX is built from the standard documents [1,2]. The model implemented in this paper is based on the WiMAX which has the following characteristics on the overall project development lifecycle [2]:

TABLE I
THE CHARACTERISTICS OF THE OVERALL WIMAX MODEL DEVELOPMENT LIFECYCLE S

Standard	IEEE 802.16e
Carrier Frequency	Below 11GHz
Frequency Bands	2.5GHz, 3.5GHz, 5.7GHz
Radio Technology	OFDM and OFDMA
Bandwidth	1.5MHz to 20MHz
Data Rate	70 Mbps
Distance	10km

GHz = gigahertz, OFDM = orthogonal frequency division multiplexing, OFDMA = orthogonal frequency division multiplexing access, MHz = megahertz, Mbps = megabits per seconds, km = kilometer.

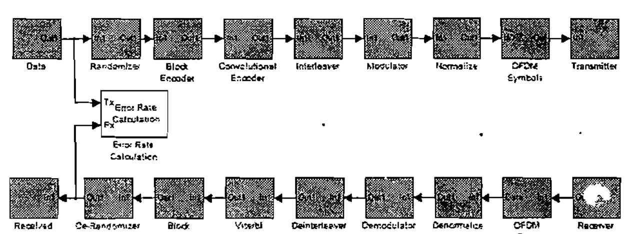

Figure 1 : WiMAX Physical Layer model

TABLE II
PARAMETERS FOR WIMAX MODEL

Scenario	16-Channel Full Bandwidth
Modulation	QPSK
RS Code Rate	3/4
CC Code Rate	1/2

QPSK = quadrature phase shift keying, RS = reed-solomon, CC = convolution coding.

The Model itself consists of three main components namely transmitter, receiver and channel. Transmitter and receiver components consist of channel coding and modulation sub-components whereas channel is modelled as AWGN.

III. CHANNEL CODING

Channel coding can be described as the transforming of signals to improve communications performance by increasing the robustness against channel impairments such as noise, interference and fading. The radio link is a quickly

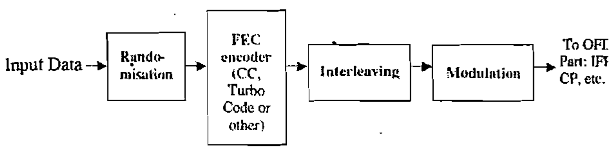

Fig. 2. OFDM physical transmission channel

varying link, often suffering from great interference. Channel coding, whose main tasks are to prevent and to correct the transmission errors of wireless systems, must have a very good performance in order to maintain high data rates. The 802.16 channel coding chain is composed of three steps: Randomiser, Forward Error Correction (FEC) and Interleaving as shown in figure 2. They are applied in this order at transmission. The corresponding operations at the receiver are applied in reverse order [3],[4].

A. *Randomization:*

Randomisation introduces protection through information-theoretic uncertainty, avoiding long sequences of consecutive ones or consecutive zeros. It is also useful for avoiding non-centred data sequences. Data randomisation is performed on each downlink and uplink burst of data.

Randomizer operates on a bit by bit basis. The purpose of the scrambled data is to convert long sequences of O's or 1's in a random sequence to improve the coding performance.

The Pseudo-Random Binary Sequence (PRBS) generator used for randomisation is shown in Figure 3.

The generator defined for the randomizer is given by

$$1 + X^{14} + X^{15} \quad (1)$$

The bits issued from the randomiser shall be applied to encoder.

B. *Forward Error Correction (FEC)*

Forward Error Correction is done on both the uplink and the downlink bursts and consists of concatenation of Reed-Solomon Outer Code and a rate compatible Convolutional Inner Code.

For OFDM PHY, the RS-CC encoding is performed by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder. (Figure 4)

1. Reed-Solomon encoding

The purpose of using Reed-Solomon code to the data is to

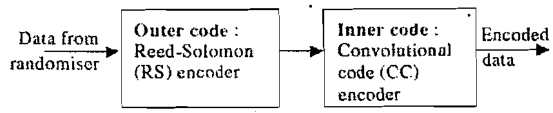

Fig. 4. Channel Coding

add redundancy to the data sequence. This redundancy addition helps in correcting block errors that occur during transmission of the signal [4].

A Reed–Solomon code is specified as RS(N,K) with T-bit symbols. The data points are sent as encoded blocks. The total number of T-bit symbols in an encoded block is $N = 2^T-1$. The number K, $K < N$, of uncoded data symbols in the block is a design parameter. Then, the number of parity symbols added is $N > K$ symbols (of T-bits each). The RS decoder can correct up to $(N - K)/2$ symbols that contain an error in the encoded block. WiMAX uses a fixed RS Encoding technique based on $GF(2^8)$ which is denoted as RS ($N = 255$, $K = 239$, $T = 8$).

Eight tail bits are added to the data just before it is presented to the Reed Solomon Encoder stage. This stage requires two polynomials for its operation called code generator polynomial g(x) and field generator polynomial p(x). The code generator polynomial is used for generating the Galois Field Array whereas the field generator polynomial is used to calculate the redundant information bits which are appended at the start of the output data.

Where:

N = Number of Bytes after encoding

K = Data Bytes before encoding

T = Number of bytes that can be corrected

The following polynomials are used to generate systematic code:

Code generator polynomial:

$$g(x) = (x - \lambda^0)(x - \lambda^1)(x - \lambda^2)\ldots(x - \lambda^{2T-1}),\ \lambda = 02_{HEX}; \quad (2)$$

Field generator polynomial:

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \quad (3)$$

2. Convolutional Encoding

Convolutional codes are used to correct the random errors in the data transmission. A convolutional code is a type of FEC code that is specified by CC(m, n, k), in which each in-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n > m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code.

To encode data, start with k memory registers, each holding 1 input bit. All memory registers start with a value of 0. The encoder has n modulo-2 adders, and n generator polynomials, In WiMAX Physical Layer each RS block is encoded by the binary convolutional encoder, which has a code rate of 1/2 and a constraint length equal to 7. This encoder has two binary adders X and Y and uses two generator polynomials, A and B.

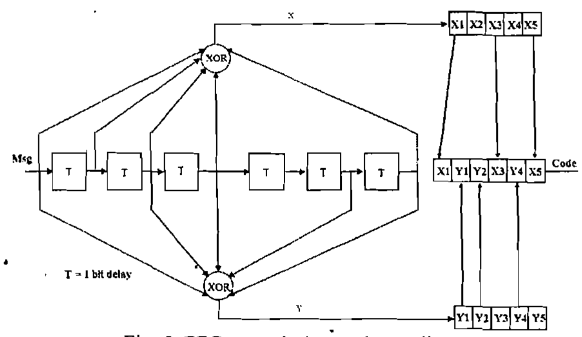

Fig. 5. FEC convolution and encoding

These generator polynomial codes are:

A = 171 octal = 1111001 binary for X (4)

B = 133 octal = 1011011 binary for Y (5)

The output of the convolutional encoder is then punctured to remove the additional bits from the encoded stream. The number of bits removed is dependent on the code rate used one for each adder.

IV. Interleaving

RS-CC encoded data are interleaved by a block interleaver. The size of the block is depended on the numbers of bit encoded per sub channel in one OFDM symbol, Nc bps. In IEEE 802.16, the interleaver is defined by two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second permutation ensures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of unreliable bits [4],[5].

Using a matlab tool implement WiMAX 802.16 interleaver was performed calculating the index value of the bits after first and second permutation using Equation (7) and (8) respectively.

$$f_k = (N_{cbps}/12).k_{mod12}+\text{floor}(k/2) \qquad k = 0,1,2,\ldots N_{cbps}-1 \qquad (7)$$

$$s_k = s.\text{floor}(f_k/s) + (m_k + N_{cbps} - \text{floor}(12.m_k/N_{cbps}))_{mod(s)} \qquad k=0,1,2,\ldots N_{cbps}-1 \qquad (8)$$

where s= ceil(N_{cpc}/2) , while N_{cpc} stands for the number of coded bits per subcarrier, i.e.,1,2,4 or 6 for BPSK,QPSK 16QAM,or 64QAM, respectively.

The default number of subchannels i.e. 16 is used for this implementation. The receiver also performs the reverse operation two step permutation using equations (9) and (10) respectively.

$$f_j = s.\text{floor}(j/s)+(j + \text{floor}(12.j/N_{cbps}))_{mod(s)} \qquad \text{where } j=0,1,\ldots N_{cbps}-1 \qquad (9)$$

$$s_j = 12.f_j - (N_{cbps}-1).\text{floor}(12.f_j/N_{cbps}) \qquad \text{where } j=0,1,2\ldots N_{cbps}-1 \qquad (10)$$

where:

N_{cpc} = Number of coded bits per carrier

N_{cbps}= Number of coded bits per symbol

K = Index of coded bits before first permutation

m_k = Index of coded bits after first permutation

j_k = Index of coded bits after second permutation

V. Modulation

As for all recent communication systems, WiMAX/802.16 uses digital modulation. Four modulations are supported by the IEEE 802.16 standard: BPSK, QPSK, 16-QAM and 64-QAM. In this section the modulations used in the OFDM and OFDMA Physical layers are introduced for modulations. In the modulation phase the coded bits are mapped to the IQ constellation, starting with carrier number -100 on up to carrier number +100. To simplify transmitter and receiver designs, all symbols in the FCH and DL data bursts are transmitted with equal power by using a normalization factor.

VI. OFDM System Implementation

The digital implementation of OFDM system is achieved through the mathematical operations called Discrete Fourier Transform (DFT) and its counterpart Inverse Discrete Fourier Transform (IDFT). These two operations are extensively used for transforming data between the time domain and frequency domain. In case of OFDM, these transforms can be seen as mapping data onto orthogonal subcarriers. In practice, OFDM systems employ combination of fast fourier transform (FFT) and Inverse fast fourier transform (IFFT) blocks which are mathematical equivalent version of the DFT and IDFT.

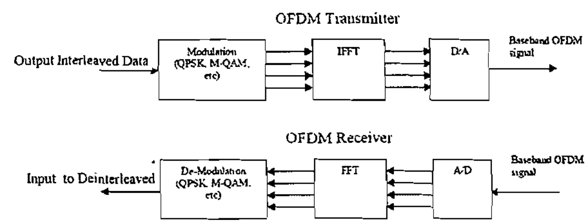

Fig. 5. FEC convolution and encoding

At the transmitter side, an OFDM system treats the source symbols as though they are in the frequency domain. These symbols are feed to an IFFT block which brings the signal into the time domain. If the N numbers of subcarriers are chosen for the system, the basis functions for the IFFT are N orthogonal sinusoids of distinct frequency and IFFT receive N symbols at a time. Each of N complex valued input symbols determines both the amplitude and phase of the sinusoid for that subcarrier. The output of the IFFT is the summation of all N sinusoids and makes up a single OFDM symbol. The length of the OFDM symbol is NT where T is the IFFT input symbol period. In this way, IFFT block provides a simple way to modulate data onto N orthogonal subcarriers. At the receiver side, The FFT block performs the reverse process on the received signal and bring it back to frequency domain.

Cyclic Prefix Addition

The subcarrier orthogonality of an OFDM system can be jeopardized when passes through a multipath channel. CP is used to combat ISI and ICI introduced by the multipath channel. CP is a copy of the last part of OFDM symbol which is appended to the front of transmitted OFDM symbol.

The length of the CP (T_g) must be chosen as longer than the maximum delay spread of the target multipath environment. Figure 6 depicts the benefits arise from CP addition, certain position within the cyclic prefix is chosen as the sampling starting point at the receiver, which satisfies the criteria $t_{max} < T_x < T_g$ where t_{max} is the maximum multipath spread. Once the above condition is satisfied, there is no ISI since the previous symbol will only have effect over samples within $[0, t_{max}]$. And it is also clear from the figure that sampling period starting from T_x will encompass the contribution from all the multipath components so that all the samples experience the same channel and there is no ICI.

VII. The WiMAX Model Test Results And Performance

The WiMAX standard document provides several test cases and test vectors for each test case. Below are the test results

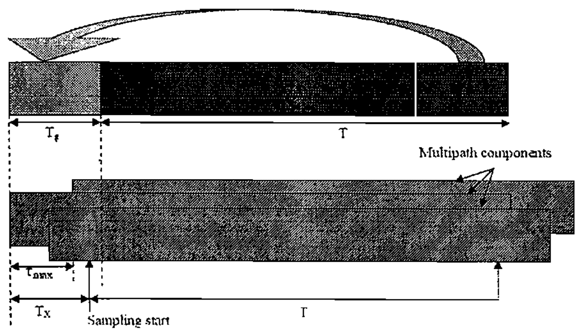

Fig. 6. Cyclic Prefix in OFDM

for each component in hexadecimal format [4].

Data Payload from the MAC Layer (29 bytes frame)
45 29 C4 79 AD OF 55 28 AD 87 B5 76 1A 9C 80 50 45 lB 9F D9 2A 88 95 EB AE B5 2E 03 4F 09 14 69 58 OA SD

Data Frame after Randomization Stage (35 bytes frame)

D4 BA A1 12 F2 74 96 3027 D4 88 9C 96 E3 A9 52 B3 15

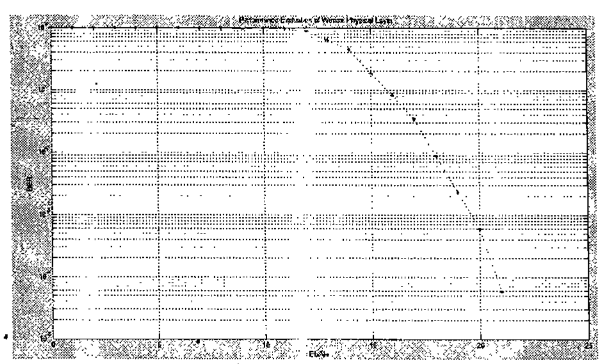

Fig. 7. BER Result

AB FD 92 53 07 32 CO 62 48 FO 19 22 E0 91 62 IA CI

Data Frame after Reed-Solomon Encoding (40 bytes frame)

49 31 40 BF D4 BA A1 12 F2 74 96 30 27 D4 88 9C 96 E3 A9 52 B3 15 AB FD 9253 07 32 CO 62 48 FO 19 22 E0 91 62 1A C1 00

Data Frame after Convolutional Encoding (48 bytes frame)

3A SE E7 AE 49 9E 6F IC 6F Cl 28 BC BD AB 57 CD BC CD E3 A7 92 CA 92 C2 4D BC 8D 78 32 FB3 BF DF 23 ED 8A 94 16 27 AS 65 CF 7D 16 7A 45 B8 09 CC

Data Frame after Interleaving (48 bytes frame)

77 FA 4F 17 4E 3E E6 70 E8 CD 3F 76 90 C4 2C DB3 F9 B7 F13 43 6C Fl 9A BD ED OA IC D8 lB EC 9B 30 15 BA DA 31 F5 50 49 7D 56 ED B4 88 CC 72 FC SC

Based on the model presented in this paper, and tests carried out, the performance was established based on 10 million symbols in each case. The performance is displayed in the following figure in terms of the BER versus SNR logarithmic plot, time-scatter plots for 10, 20 and 30dB; Signal-to-Noise Ratios, time-scatter plot for the output from the transmitter and FFT scope diagram for the transmitted signal.

The BER plot obtained in the performance analysis showed that model works well on SNR above 20dB. The time-scatter plots demonstrate the scattering of the transmitted and received signals at different values of the Signal-to-Noise Ratios.

VIII. Conclusion

The model built in this paper demonstrates the importance of modelling a system to understand its functionality. Tests can the carried out on the model to calculate the performance indicators. Components of the system can be tested against a defined standard, IEEE 802.1 6e in this case, to prove the complete working of the component itself and the system as a whole. The same model can be used to implement coding and modulations schemes. The results of the simulation from the models will enable the researchers to choose the best option for their requirements. In future this model can be expanded to include the components of the MAC layer and a complete end to end WiMAX system could be built based on this model.

References

[1] IEEE 802.16-2006: "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems"

[2] Thesis: "Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer" Mohammad Azizul Hasan, July 2007.

[3] ETSI TS 102 177 Version 1.3. 1, February 2006, "Broadband Radio Access Networks (BRAN); HiperMAN : Physical (PHY) Layer"

[4] Practical Applications for Wireless Networks, Paris, 10 October 2006, IET Workshop 2006

[5] WiMAX and Mesh Networks, London, 14-15 June 2005, IEEE Seminar 2005.

[6] Nuaymi Loutfi, 2007, WiMAX Technology for Broadband Wireless Access, Wiley, London.

[7] Mathworks Whitepaper, 2006, "Creating an Executable Specification for WiMAX Standard"2. Oxford: Clarendon, 1892, pp. 68-73.

S. J. Dawda became a Member (M) of IEEE in 2009. Born in Surendranagar . He is PG Student Electronics and Communication in L.D.College of Engg. Ahmedabad, Gujarat, Completed BE (EC) from C. U. Shah College of Engg and Tech., Wadhwan city, Gujarat. His area of interest is Wireless Communication.

C. R. Parekh is working with Vishwakarma Institute of Tech. Gandhinagar as Assistant Professor in Electronics and Communication Department. His area of interest is Communication.

A. C. Suthar became a Member (M) of IEEE in 2009 and a Life Member (LM) of ISTE. Born in Ahmedabad,1973. He is Research scholar Electronics and Communication) in Kadi University, Gandhinagar, Gujarat, Completed ME (CSE) from L. D. College of Engg. Ahmedabad, Gujarat in 2007, BE (EC) from L. D. College of Engg. Ahmedabad, Gujarat in 1998, DE (EC) from Govt. Polytechnic, Gandhinagar, Gujarat in 1995. His area of interest is signal processing and communication.