

# Comparison between Turbo Code and Convolutional Product Code (CPC) for Mobile WiMAX

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**Abstract**—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. It adopts Orthogonal Frequency Division Multiple Access (OFDMA) for improved multi-path performance in Non-Line-Of-Sight (NLOS) environments. Scalable OFDMA (SOFDMA) is introduced in the IEEE 802e[1]. WIMAX system uses one of different types of channel coding but The mandatory channel coding scheme is based on binary nonrecursive Convolutional Coding (CC). There are other several optional channel coding schemes such as block turbo codes, convolutional turbo codes, and low density parity check (LDPC).

In this paper a comparison between the performance of WIMAX using turbo code and using convolutional product code (CPC) [2] is made. Also a combination between them had been done. The CPC gives good results at different SNR values compared to both the turbo system, and the combination between them. For example, at BER equal to  $10^{-2}$  for 128 subcarriers, the amount of improvement in SNR equals approximately 3 dB higher than turbo code and equals approximately 2dB higher than the combination respectively. Several results are obtained at different modulating schemes (16QAM and 64QAM) and different numbers of sub-carriers (128 and 512).

**Keywords**—Turbo Code, Convolutional Product Code (CPC), Convolutional Product Code (CPC).

## I. INTRODUCTION

WIMAX [3] is a new wireless technology that provides high throughput broadband connection over long distances based on IEEE.802.16 wireless MAN air interface standard. It is designed to accommodate both fixed and mobile broadband applications. It can be used for many applications, including "last mile" broadband connections, hotspots and cellular backhaul, and high-speed enterprise connectivity for business, due to its high spectrum efficiency and robustness in multi path propagation. Comparing WIMAX to Wi-Fi and 3G, the wimax has an improved important characteristic, the throughput capabilities of wimax depends on the channel bandwidth used [4]. Unlike the 3G systems which have fixed channel bandwidth, WIMAX defines a selectable channel bandwidth from 1.25MHz to 20MHz. In WIMAX systems, there are many researches had been made for the different stages such as coding stage [5-9]. Our investigations are focused on studying the performance of wimax using convolutional product code (CPC) compared to turbo code. In the CPC coding method, a stream of bits, forming the

message, is converted into a matrix ( $n \times m$ ). First each row will be coded by recursive systematic convolutional encoder. After interleaver, each column will be coded by another recursive systematic convolutional encoder. The same or different generator polynomials are used to code both rows and columns. CPC will be described in more details in section III. In this paper, CPC method is studied for improving BER at different SNR for WIMAX system. The comparison between this method and turbo code will be investigated. Moreover a combination between CPC and turbo code will be done. These different code methods will be used at different modulation techniques (16QAM and 64QAM).

The paper is organized as follows: in Section II, description of physical layer of the WIMAX is introduced. Description of turbo code scheme used in this comparison is presented in Section III. Section IV contains detailed description of CPC scheme. The combination between the previous two techniques of coding is given in Section V. Section VI contains Simulation results. Finally conclusions are reflected in Section VII.

## II. DESCRIPTION OF PHYSICAL LAYER OF WIMAX

The downlink transmission using the wireless Man is being considered. Wimax system depends on OFDMA physical layer as specified in the IEEE .802.16 standard [10]. A block diagram of the physical layer of wimax is depicted in Fig. 1.

The binary data bits after randomization are fed into the encoder. The turbo encoder or CPC will be used in this stage. After interleaving, the sequence of binary bits, is fed into the modulator for mapping which means converting them to a sequence of complex values and modulating them by QPSK, 16 QAM or 64 QAM. The QAM symbols are allocated onto the appropriate data sub-carriers. Pilot symbols are allocated onto pilot sub-carriers which allow the receiver to estimate and track the Channel State Information (CSI). By this procedure the OFDM symbols are constructed in the frequency domain, then Inverse Fast Fourier Transform (IFFT) is used for converting them into the time domain.

## III. TURBO CODE

The fundamental turbo encoder Fig. 2 is built using two identical Recursive Systematic Convolutional (RSC) encoders with parallel concatenation [11,12,13]. An RSC encoder has a rate equals  $1/2$  and is termed a component encoder. The two

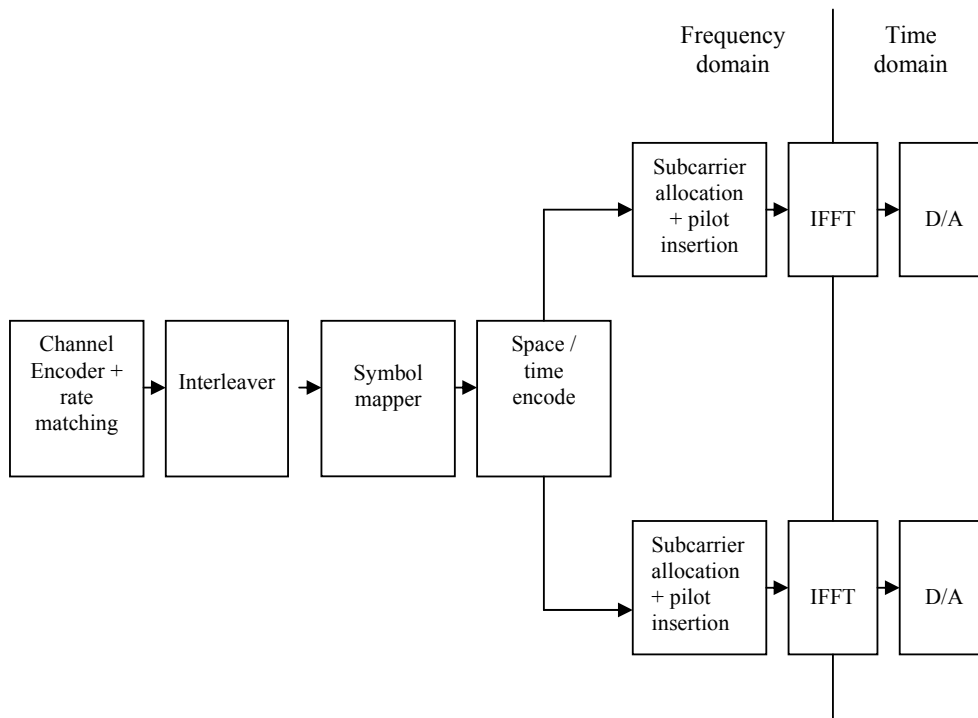


Fig. 1 Physical layer of Wimax system

component encoders are separated by an interleaver. Only one of the systematic outputs from the two component encoders is used, because the systematic output from the other component encoder is just a permuted version of the chosen systematic output.

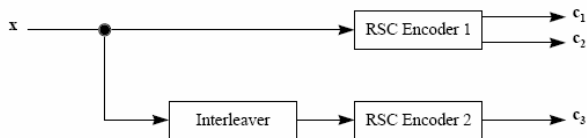


Fig. 2 Fundamental turbo encoder

In this paper, a turbo code with rate 1/3 is used for encoding the message. The two (RSC) encoders that form the turbo coder, are separated by an interleaver, both of them has generator polynomials (1,5/7), constraint length 3 and code rate 1/2 Fig. 3. The first RSC codes the message bits directly. It has two output components, one of them is systematic version of the input, denoted by 'a' and the other is a coded version of the input, denoted by 'b'. The second RSC codes the message bits after interleaving. Also it has two output components, one of them is systematic version of the interleaved input, denoted by 'c' and the other is a coded version of the interleaved input, denoted by 'd'. The coded word is formed using three outputs 'a', 'b' and 'd' only because the output 'c' is just a permuted version of 'a' Fig. 4.

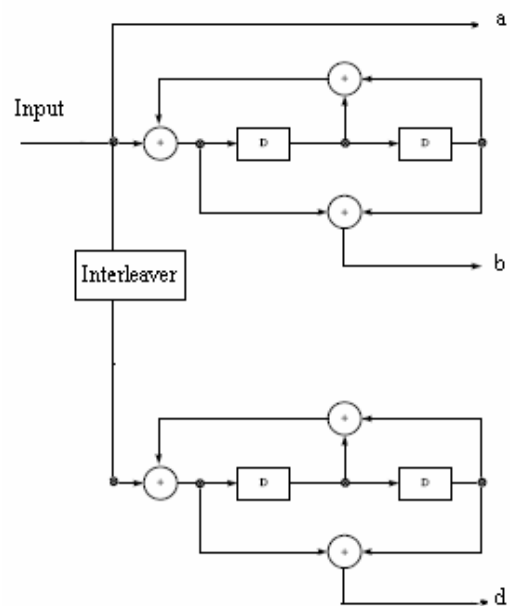


Fig. 3 Turbo encoder with generator polynomials (1,5/7)

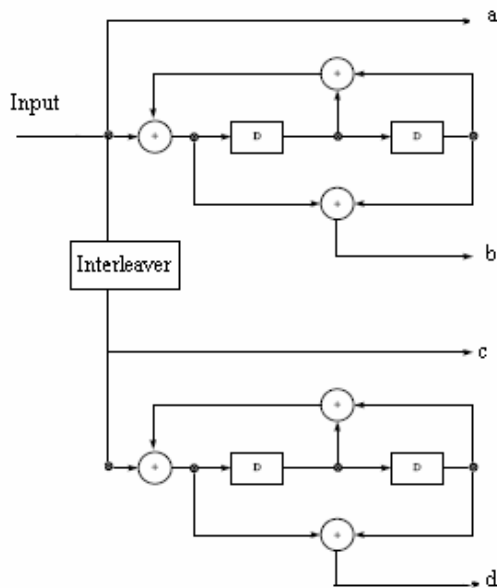


Fig. 4 Turbo encoder in details

#### IV. DESCRIPTION OF CPC METHOD

CPC is a new coding method in which the information bits are placed into two dimensions (2D) matrix. The rows and the columns are encoded separately by using recursive systematic convolutional encoders. The same recursive systematic convolutional code is used to encode each row. Once all rows have been encoded, the matrix is sent, if desired, to an interleaver. Our original data matrix dimensions are  $(n \times k)$ , and the encoded data matrix dimensions will be  $(2n \times k)$ . The coded rows matrix is then recoded column by column using the same or different recursive systematic convolutional encoder. CPC uses a recursive systematic convolutional code with rate  $1/2$  and generator polynomials  $(1,5/7)$  octal to encode each row and column Fig. 5. Hence, the overall code rate will be  $1/4$ .

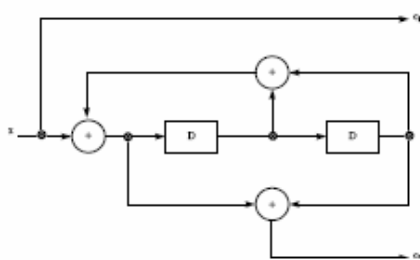


Fig. 5 Convolutional encoder [1,5/7]

In this work, the same technique is used for coding the message, except we use nonrecursive nonsystematic convolutional encoder instead of recursive systematic convolutional encoders for coding both rows and columns. The sequence of bits is fed into 2D matrix and fills it column by column. The size of this matrix will be  $(n \times 4)$  for 16 QAM and  $(n \times 6)$  for 64 QAM, to simplify the process of mapping, as

the symbol size in 16 QAM is 4 bits and in 64 QAM is 6 bits. So each row will form one QAM symbol. The 'n' refers to the number of data subcarriers of OFDM, 128 or 512. The coding by CPC will be done in 2 stages. First each column will be independently coded, then each row of the resulting matrix will be recoded by the same generator polynomials. The generator polynomials used for coding both rows and columns are  $(5,7)$  with constraint length 3, not following the standard of WIMAX, Fig. 6. Each column is padded with two zeros for terminating its encoder but each row is padded with two or three zeros according to the number of used subcarriers, 128 or 512, respectively to form the suitable size of the overall matrix. That matrix is then divided into smaller matrices with sizes  $(n \times 4)$  or  $(n \times 6)$  as described later.

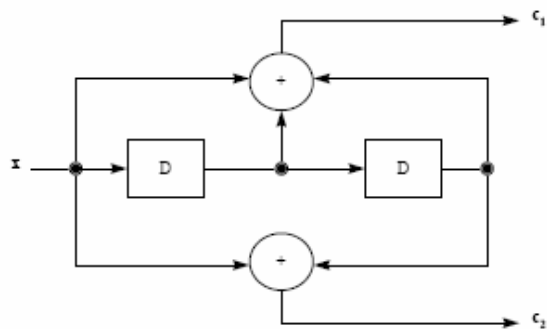


Fig. 6 Convolutional coding [5,7]

The reason for using nonrecursive nonsystematic convolutional encoder instead of recursive systematic convolutional encoders is simplifying the termination of the encoder, as RSC contains a feedback and its termination will be more difficult. Also using the generator polynomials  $(5,7)$  leads to a little increase in the complexity of the system because of a few number of zeros will be added to terminate the two encoders. After coding, the total number of bits will be more than the original message's bits as the overall code rate becomes  $1/4$ , and the zeros added to both column and rows for termination process. Therefore the following steps are done,

- (1) Dividing the overall matrix produced from CPC into three matrices. Each one has a size  $(n \times 4)$  or  $(n \times 6)$  according to the type of QAM used as mentioned before. The reason for using three matrices only is to have a number of message bits equals to bits used in the turbo code method, as a comparison between it and CPC is done.
- (2) Applying symbol mapping for each one independently (16QAM or 64QAM).
- (3) Inserting the pilot and DC subcarriers for each matrix.
- (4) Performing the IFFT independently resulting in three OFDMA symbols.
- (5) Applying (cyclic prefix) CP for each symbol.
- (6) Sending each symbol independently.

At the receiver, the three OFDMA symbols are combined to form the original matrix which is decoded by Viterbi decoder,

that uses the same generator polynomials (5,7) with hard decision for each row then for each column to obtain the results shown in Figs. 4,5,6 and 7. To match the CPC method, the number of data bits will be reduced due to the number of zero bits added to terminate the two encoders.

The advantages of this method are,

1. Do not need another interleaver after channel coding because of converting into matrix (nx4) or (nx6) do almost the same job as the overall matrix will be filled column by column and will be read row by row after coding processes (block interleaver) since each row is used for making QAM symbol.
2. Reducing the BER.

But on the other hand it causes more delay for obtaining the original message because the code rate becomes 1/4 not 1/2 as convolutional code so the system will be more complex. The performance of the system will be reduced and this is the price to be paid for the improvement obtained.

#### V. COMBINATION OF THE TWO METHODS

In this section a combination between turbo code and CPC is done. In this type of coding the CPC is used directly without any modification which means using RSC for code both rows and columns with generator polynomial (1,5/7) and constrain length 3. This type of coding will have code rate=1/4. Fig. 5.

#### VI. RESULTS

In this work, a simulation of physical layer of wimax was made as described in section II by matlab. AWGN will be assumed only. The Figs. 7,8,9 and 10 show the BER versus the received SNR obtained at different modulation and different number of OFDMA sub-carriers.

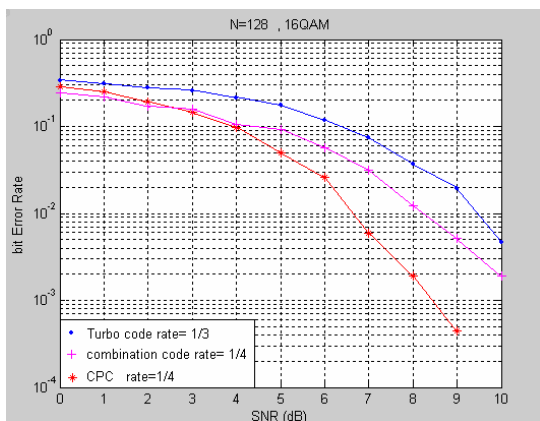


Fig. 7 16QAM, N=128

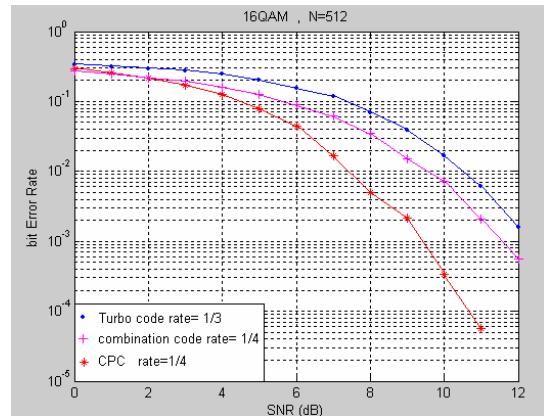


Fig. 8 16QAM, N=512

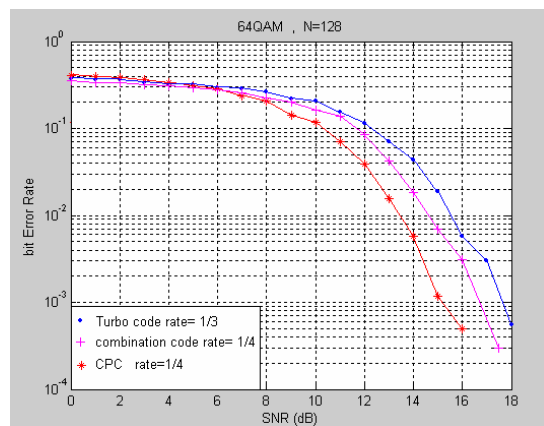


Fig. 9 64QAM, N=128

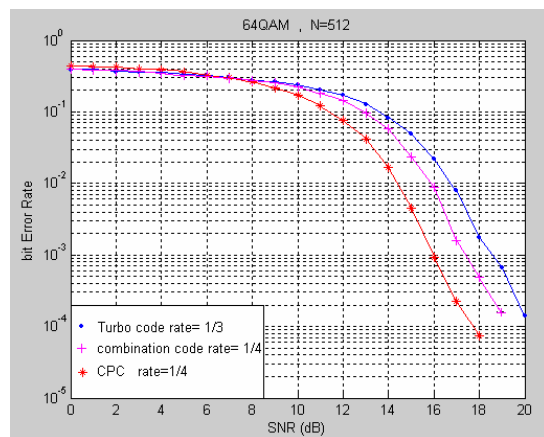


Fig. 10 64QAM, N=512

Fig. 7 shows the relation between SNR and BER at 16 QAM and 128 subcarriers. From this figure, we conclude that SNR will be improved by approximately 3 dB at BER equals to  $10^{-2}$  compared to turbo code and by approximately 2 dB at BER equals to  $10^{-2}$  compared to the combination between the two code methods. Also, improvement will be obtained when the number of subcarriers increases to 512 as shown in Fig. 8.

When different modulation is used, CPC still gives better results as shown in Figs. 9 and 10. This improvements comes from using CPC method in which the overall code rate is 1/4 not 1/3 as in turbo coding method.

## VII. CONCLUSION

In this paper, performance of wimax systems is studied under using CPC coding method. This method leads to reduce BER at any SNR. We investigated the effects of this method at different modulation schemes (16QAM – 64QAM) and for different number of OFDMA sub-carriers (128-512), it gives a good improvement. for example at BER equals to  $10^{-2}$  for 16QAM, 128 subcarriers and 16QAM, 512 subcarriers, the amount of improvements in SNR approximately equal to 2 dB better than convolutional code.

## REFERENCES

- [1] IEEE. Standard 802.16-2005, Part 16: Air interface for fixed and mobile broadband wireless access systems, December 2005.
- [2] Orhan Gazi and Ali Özgür Yılmaz “Turbo Product Codes Based on Convolutional Codes” ETRI Journal, Volume 28, Number 4, August 2006.
- [3] J.Andrews, A.Ghosh, and R.Muhammed “fundamentals of wimax :understanding broadband wireless networking ” .Prentic Hall communication engineering and emerging series February 2007.
- [4] Jeffrey G Andrews. Arunabha Ghosh . Rias Muhammed “ Fundamentals of WIMAX ”
- [5] Changlong Xu “Soft Decoding Algorithm for RS-CC Concatenated Codes in WIMAX System” Vehicular Technology Conference, 2007.
- [6] Torben Brack, Matthias Alles, Frank Kienle, Norbert Wehn “A SYNTHESIZABLE IP CORE FOR WIMAX 802.16E LDPC CODE DECODING” The 17th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'06),2006.
- [7] Gunnam, K.K. Choi, G.S. Yeary, M.B. Atiquzzaman, M. “VLSI Architectures for Layered Decoding for Irregular LDPC Codes of WiMax” Communications, 2007. ICC '07. IEEE International Conference ,2007.
- [8] Salmon, B.P.; Olivier, J.C. “Performance Analysis of Low Density Parity-Check Codes on a WiMAX Platform” Wireless Communications and Networking Conference, 2007.WCNC 2007. IEEE.
- [9] Lin, Zhang; Shunzheng, Yu. “Turbo Codes for 10-66GHz WiMax Systems” International Journal of Infrared and Millimeter Waves, Volume 26, Number 8, August 2005.
- [10] IEEE. Standard 802.16-2004, Part 16: Air interface for fixed broadband wireless access systems, June2004.
- [11] Divsalar, D. and Pollara, F., “On the Design of Turbo Codes,” TDA Progress Report 42-123, Jet Propulsion Laboratory, Pasadena, California, November 15, 1995, pp. 99-121.
- [12] Pietrobon, S., “Implementation and Performance of a Turbo/MAP Decoder,”Int'l. J. Satellite Commun., vol. 16, Jan-Feb 1998, pp. 23-46.
- [13] Divsalar, D. and Pollara, F., “Multiple Turbo Codes for Deep-Space Communications,” TDA Progress Report 42-121, Jet Propulsion Laboratory, Pasadena, California, May 15, 1995, pp. 66-77.