STUDY THE PERFORMANCE OF MOBILE WIMAX CONVOLUTIONAL TURBO CODE
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ABSTRACT
A useful tool in the design of reliable digital communication systems is channel coding. Turbo codes have been shown to yield an outstanding coding gain close to theoretical Shannon limit in the Additive White Gaussian Noise (AWGN) channel. This is due to relatively large coding gains that can be achieved. Over the past decade, turbo codes have been widely considered to be one of the most powerful error control code of a practical importance. This paper introduces the topic of WiMAX turbo coding. First, it gives an overview about the WiMAX Standards, then the WiMAX convolutional turbo code is introduced and its bit error rate performance is evaluated, by simulation, for different transmission conditions.

keywords - WiMAX, OFDM, OFDMA, Turbo codes, Log-MAP, Max-Log-Map.

I. INTRODUCTION
The WiMAX technology, based on the IEEE 802.16-2004 Air Interface Standard is rapidly proving itself as a technology that will play a key role in fixed broadband wireless metropolitan area networks. The first certification lab, established at Cetecom Labs in Malaga, Spain is fully operational and more than 150 WiMAX trials are underway in Europe, Asia, Africa and North and South America. Unquestionably, Fixed WiMAX, based on the IEEE 802.16-2004 [1] Air Interface Standard, has proven to be a cost effective fixed wireless alternative to cable and DSL services. In December, 2005 the IEEE ratified the 802.16e amendment [2] to the 802.16 standard. This amendment adds the features and attributes to the standard necessary to support mobility.

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 uses Orthogonal Frequency Division Multiple Access (OFDMA) for improved multi-path performance in non-line-of-sight environments.

Mobile WiMAX systems offer scalability in both radio access technology and network architecture, thus providing a great deal of flexibility in network deployment options and service offerings. Some of the salient features supported by Mobile WiMAX are: High data rates, Quality of services (QoS), scalability, security, mobility.

II. PHYSICAL LAYER OF WiMAX
The physical (PHY) layer of WiMAX is based on the IEEE 802.16-2004 and IEEE 802.16e-2005 standards. This suite of standards defines within its scope four PHY layers, any of which can be used with the media access control (MAC) layer to develop a broadband wireless system. The PHY layers defined in IEEE 802.16 are:

- Wireless MAN SC, a single-carrier PHY layer intended for frequencies beyond 11GHz requiring a LOS condition. This PHY layer is part of the original 802.16 specifications.
- Wireless MAN SCa, a single-carrier PHY for frequencies between 2GHz and 11GHz for point-to-multipoint operations.
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- WirelessMAN OFDMA, a 2,048-point FFT-based OFDMA PHY for point-to-multipoint operations in NLOS conditions at frequencies between 2GHz and 11GHz. In the IEEE 802.16e-2005 specifications, this PHY layer has been modified to SOFDMA (scalable OFDMA), where the FFT size is variable and can take any one of the following values: 128, 512, 1,024, and 2,048. The variable FFT size allows for optimum operation/implementation of the system over a wide range of channel bandwidths and radio conditions. This PHY layer has been accepted by WiMAX for mobile and portable operations and is also referred to as mobile WiMAX.

III. TURBO CODES
In 1993, Claude Berrou, Alain Glavieux and Punya Thitimajshima introduced an invention of new error control coding scheme. They published the paper [3, 4] which first described turbo codes. This novel method provides virtually error-free communications. They showed that turbo codes could achieve low BERs at signal to noise ratios (SNR) very close to the Shannon limit of -1.6 dB. It had previously been thought that the Shannon limit on code performance could only be approached using codes with extremely long codeword lengths; i.e. codes which are potentially very complex to decode. Berrou et al. showed how the Shannon limit could be approached with realizable decoding complexity.

Gradually, turbo code became an important topic for communication research and now turbo codes are one of the most powerful types of error control codes currently available.

Channel coding theorem [5] implies that arbitrarily low decoding error probabilities can be achieved at any transmission rate less than the channel capacity by using sufficiently long block (or constraint) length, usually at least several thousand bits. In particular, Shannon showed that large block length random codes achieve channel capacity. However, codes must contain enough structure that permits decoding with actual hardware. Owing to this reason, little attention was given to the design of random codes, because they lacked structure. Turbo coding technique succeeds in achieving a random code design with...
just enough structure to allow for an efficient iterative decoding method. Turbo codes have, mainly, three important characteristics permitting them to obtain an excellent BER performance (close to Shannon limit):

1. The information sequence is encoded twice, using two Recursive Systematic Convolutional (RSC) encoders concatenated in parallel [6].
2. A random interleaver is used between the two encoders to make the two encoded data sequences approximately statistically independent of each other.
3. The decoding is performed by means of an iterative decoder that makes the resulting BER performance close to the Shannon limit.

To emphasis the idea of approaching the Shannon limit, simulation is presented here for a turbo coder with rate 1/2, and a constraint length of 5, encoder implemented with generators \( g_1 = \{1 \ 1 \ 1 \ 1 \} \) and \( g_2 = \{1 \ 0 \ 0 \ 0 \ 1 \} \), using parallel concatenation and a 256 × 256 array interleaver. The RSC constituent encoder is shown in Fig. 1. The Log-MAP algorithm [7] was used with a data block length of 65,536 bits. After 18 decoder iterations, the BER was less than \( 10^{-5} \) at \( E_b/N_0 = 0.7 \) dB as shown in Fig. 2.

Note that, as the Shannon limit is approached, the required system bandwidth approaches infinity. Therefore, the Shannon limit represents an interesting theoretical bound, but it is not a practical one. For binary modulation, we can use \( BER = 10^{-5} \) and \( E_b/N_0 \) equals to 0.2 dB as a practical Shannon limit reference for a rate 1/2 code.

IV. WiMAX CONVOLUTIONAL TURBO CODE

Different classes of turbo codes exist. Convolutional Turbo Codes (CTC) [8] is defined as optional forward error correcting codes (FEC) for OFDM and OFDMA PHY. According to mobile WiMAX profiles, the CTC is mandatory for OFDMA PHY. The convolutional turbo encoder, including its constituent encoder, is depicted in Fig. 3. It uses a double binary Circular Recursive Systematic Convolutional Code. The bits of the data to be encoded are alternatively fed to A and B, starting with the MSB of the first byte being fed to A. The encoder is fed by blocks of \( k \) bits or \( N \) couples \((k = 2N \) bits\). For all the frame sizes, \( k \) is a multiple of 8 and \( N \) is a multiple of 4. Further, \( N \) is limited to \( 8 \leq N/4 \leq 1024 \). The generator polynomial for the Y parity bit: \( 1+D^2+D^3 \), for the W parity bit: \( 1+D \) and the generator polynomial for the feedback branch is \( 1+D^2+D^3 \).

V. SIMULATION RESULTS

Simulation results for WiMAX convolutional turbo codes (WiMAXCTC) using Quadrature Phase Shift Keying (QPSK) over AWGN channels are demonstrated. There are many parameters which affect the performance of WiMAXCTC. Some of these parameters are:

- The number of decoding iterations used
- The frame size of the input data.
- The code rate used.
- The component decoding algorithm used.
- The modulation techniques used.

In this section we investigate how all of these parameters affect the performance of WiMAXCTC. The standard parameters we have used in our simulations are: AWGN channel, QPSK modulation, frame size of 288 bits, code rate 1/2 and Log-MAP Decoder.

Fig. 4 shows the performance of the WiMAXCTC versus the number of decoding iterations which were used. It is clearly shown that as the number of iterations used by the turbo decoder increases, the turbo decoder performs significantly better. Fig. 5 shows how the performance of WiMAXCTC depends on the frame-length used in the encoder. As the figure indicates, as the frame size increases (within the acceptable range), the BER performance increases.

As described in Section III, in the WiMAX turbo encoder, two parity information are generated from an input data sequence, thus the overall code rate is 1/3. However puncturing techniques are used to generate a various code rates. In this paper two code rates are used; 1/2 and 3/4. The performance of 1/2 code rate, compared to the 3/4 code rate, is shown in Fig. 6. It could be noted that the 1/2 code rate gives a better performance than puncturing the sequence to code rate 3/4.

Fig.7 shows a comparison between WiMAXCTC using two different component decoders, the original Log-MAP and the Max-Log-MAP [9, 10]. It can be seen that, the Max-Log-MAP gives degradation in the BER performance compared to the Log-MAP technique.

The effect of the used modulation techniques on the BER performance is shown in Fig. 8. For this simulation, three different modulation techniques, QPSK, 16 – QAM and 64 – QAM, are used. It could be seen that the QPSK gives the best performance then the 16-QAM and the 64-QAM modulation technique.

VI. CONCLUSION

In this paper, the performance of WiMAXCTC schemes using QPSK modulation when communicating over AWGN has been characterized. The effects of the various decoding algorithms, the frame size, number of iterations and code rate of encoder, as well as the influence of the modulation techniques used on the achievable performance, has been demonstrated.

As expected, the turbo codes have been shown to perform significantly better when increasing both the frame size and the number of iterations, and decreasing the code rate. It also performs better when using Log-MAP rather than Max-Log-MAP decoding algorithms, as well as when using QPSK rather than 16-QAM and 64-QAM modulation techniques.

VII. REFERENCES


Fig. 1 The RSC Encoder used to construct the turbo coder

Fig. 2 Turbo Code performance simulation

Fig. 3 Mobile WiMAX convolutional turbo code

Fig.4 WiMAXCTC BER performance using different numbers of iterations
Fig. 5 Effect of frame length on the BER performance of WiMAXCTC.

Fig. 6 WiMAXCTC BER performance comparison between one-third and half rate.

Fig. 7 WiMAXCTC BER performance comparison between different decoding components.

Fig. 8 WiMAXCTC BER performance comparison between different modulation techniques.