WLAN and Bluetooth Coexistence: A Comparative Study of Convolutional Coding versus Turbo Coding

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Abstract: The IEEE 802.11g physical layer is based on coded orthogonal frequency division multiplexing (COFDM) using the industry standard [133 171] binary convolutional code. In the presence of Bluetooth interference this code struggles to provide good packet error rate (PER) performance. In this paper Turbo coding is considered as an alternative to convolutional coding. The results show that Turbo coding substantially improves the reliability of the Coded Orthogonal Frequency Division Multiplexing (COFDM) format in Bluetooth interference and can provide reducible PER performance at Signal to Interference Ratio (SIR) values down to 0 dB.

1. Introduction.

The 2.4 GHz ISM-Band (Industrial, Scientific and Medical) is poised for strong growth by two emerging wireless technologies which are Wireless Personal Area Networking (WPAN) and Wireless Local Area Networking (WLAN). The WPAN category is dominated by a short-range wireless technology called Bluetooth which is typically used for cable replacement in short range applications ≤ 10 m and transmission speeds ≤ 700 kb/s. The WLAN category is dominated by the IEEE 802.11g standard which provides an operating range ≤ 33 m and transmission rates up to 54 Mb/s. An even higher speed extension to IEEE 802.11g is the new IEEE 802.11n draft standard which will offer speeds above 100 Mb/s. All of these wireless technologies operate in the 2.4 GHz ISM-Band and consequently are prone to coexistence interference. Of particular concern is the impact of Bluetooth interference on IEEE 802.11 reception. Hence, there is a strong requirement to improve the reliability of the IEEE 802.11 Physical Layer (PHY) to make it tolerant of Bluetooth interference.

Investigations of the interference caused by the coexistence of 802.11g and Bluetooth are not new. Arumugam et al. in [1] recommended that erasures be applied to corrupted subcarriers in the IEEE 802.11g systems whereas for the Bluetooth (BT) system, exploiting antenna diversity using space time block codes (STBC) can improve its performance. In [2] an attempt was made to cancel the interference of BT on 802.11g receivers by developing an 802.11g PHY layer algorithm. The algorithm simultaneously estimated the multipath channel impulse response and the BT interference characteristics. The estimated parameters were then incorporated as metric weights in the convolutional decoder to improve the system performance in the presence of BT interference. Park et al. in [3] used a simple approach to analyse the bit error rate (BER) performance of an OFDM based WLAN in the presence of BT interference. The effect of BT transmissions on the access point coverage of 802.11g was also investigated in [4] where symbol erasures were used in the 802.11g PHY to reduce the degradation caused by BT interference.

All of the work mentioned retained the use of the [133 171] industry standard binary convolutional code (BCC) as specified in the 802.11g standard. To our best knowledge, no work has been done employing Turbo codes (TC) for the mitigation of BT interference in an 802.11g context. Although a performance comparison of convolutional and block turbo codes for WLAN was been studied in [5], no BT interference was considered in that study.

In this paper, the impact of BT interference on the performance of COFDM when using Turbo coding instead of convolutional coding as the forward error correction (FEC) scheme in an 802.11g WLAN is investigated. Results are presented for the 16 QAM modulation mode comparing a rate 1/3 TC with a rate 1/2 BCC. The results demonstrate that a substantial improvement in PER performance is obtained with the TC.

2. Overview of 802.11g and Bluetooth Systems:

In this section, a brief overview of the key features of the physical layers of each system is described.

2.1 IEEE 802.11g System

The physical layer of 802.11g has adopted Orthogonal Frequency Division Multiplexing (OFDM) as its mandatory modulation scheme. It is implemented by using an inverse fast Fourier transform (FFT). A channel bandwidth of 20 MHz is used of which 16 MHz is occupied by the OFDM signal. The data bits for transmission are first scrambled, then convolutionally encoded, interleaved and mapped before being OFDM modulated. Various combinations of coding rate through puncturing and modulation schemes are specified to facilitate different modes of transmission [1].

2.2 Bluetooth System

Bluetooth is a point-to-point radio standard deployed in piconets. It was developed as a means to replace physical cabling by introducing a low-cost and short-range radio link. The signal bandwidth of BT is 1 MHz and it utilizes frequency hopping with terminals pseudo-randomly cycling through 79 hop channels at a hopping rate of 1600 hops/sec. As BT hops over the entire 2.4 GHz ISM band compared to 802.11g which only occupies one third of the 2.4 GHz band, it hops on to 802.11g transmissions. Hence, it can be said that an 802.11g packet can be corrupted by a BT transmission at a certain frequency at a certain instant in time.

3. Turbo coding:

Turbo coding was introduced in 1993 by Berrou et al. [6] and in an AWGN channel it can achieve a performance in terms of Bit Error Rate close to the Shannon Limit. Turbo coding uses Recursive and Systematic convolutional (RSC) codes as the constituent sub-codes. The arrangement is known as Convolutional Turbo coding but simplified to Turbo coding.

The enhanced performance of Turbo coding is due to the iterative use of two soft in/soft out decoders as shown in Figure 1 which illustrates the relationship between the two component decoders. The decoding algorithm does not limit itself to the passing of hard decisions among the decoders but effectively exchanges soft decisions by passing extrinsic information (EXT_2 ,EXT_1) from the output of $DECODER_1$ to the input of $DECODER_2$ and to iterate this process several times so as to produce more reliable decisions of hard decision estimates d_k, from the log-likelihood value $\Lambda(d_k)$.

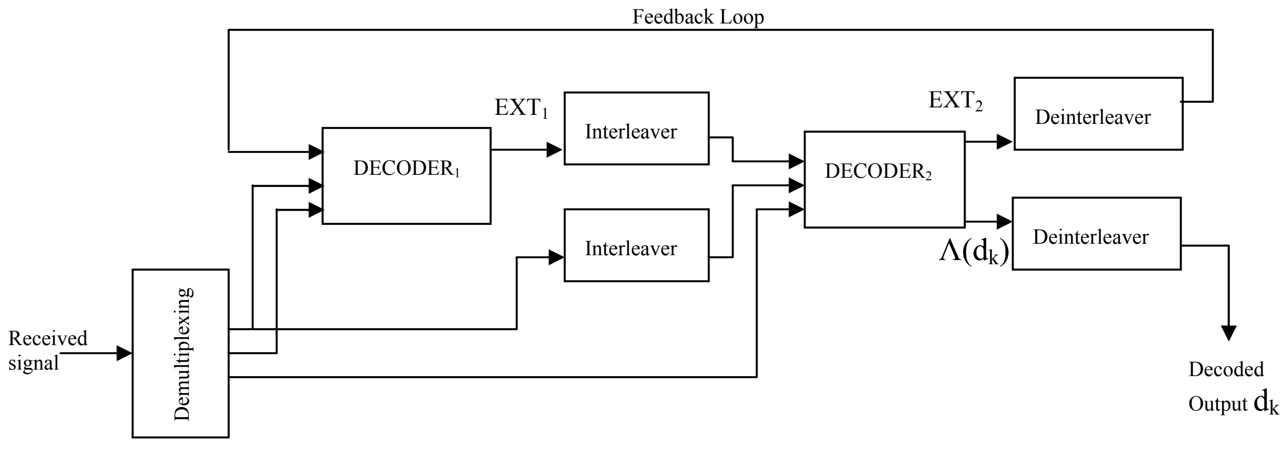


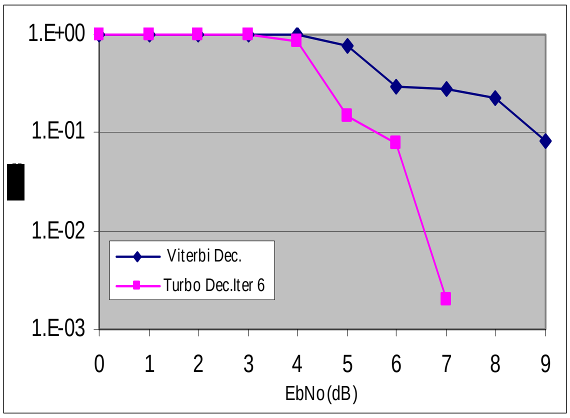
Figure 1 : The Turbo Decoder Structure of Berrou and Glavieux

Interleaving is a key component of the Turbo coding process [6]. Interleaving or permuting of the data bits helps to ensure large Hamming distances between codewords.

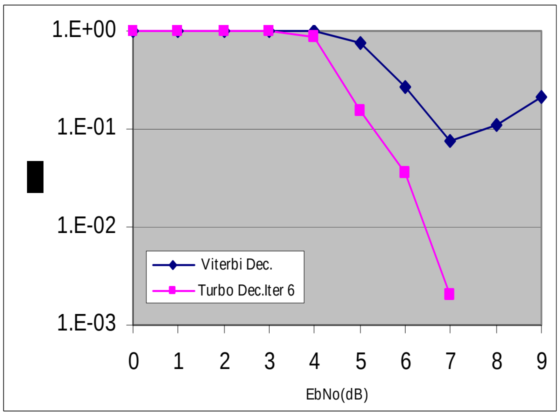
4. Simulation Results:

Results were obtained by the method of computer simulation for the 16 QAM transmission mode of 802.11g when transmitting over an AWGN channel. A single BT interferer was introduced at various distances from the 802.11g receiver corresponding to SIR values of 0,2,5,10 and 15 dB. The PER performance was determined as a function of Eb/No with SIR as a parameter for a rate 1/2 BCC and a rate 1/3 TC which corresponds to operating data rates of 24 Mb/s and 16 Mb/s, respectively. In the study a rate 1/3 TC with generator polynomial [7 5] and block size [800] with 6 iterations was used.

Figures 2(a),(b),(c),(d) and (e) show graphs of PER versus Eb/No comparing the performance of the BCC and TC schemes at SIR values of 0,2,5,10 and 15dB, respectively. The results were determined for the case of inserting a single erasure at the BT carrier frequency. Two main characteristics are observed. Firstly, for low SIR values the BCC scheme exhibits an irreducible PER characteristic at high Eb/No values. In contrast, the TC scheme shows no irreducibility even at an SIR of 0 dB. Secondly, the TC scheme exhibits a SNR gain of > 2 dB at PER = 1%. The large improvement in performance is attributable to two effects. Firstly, the TC offers a lower code rate and hence greater redundancy. Secondly, the TC can mitigate the large distortion of the soft decoding metric caused by BT interference through correction by the extrinsic information.



(a)



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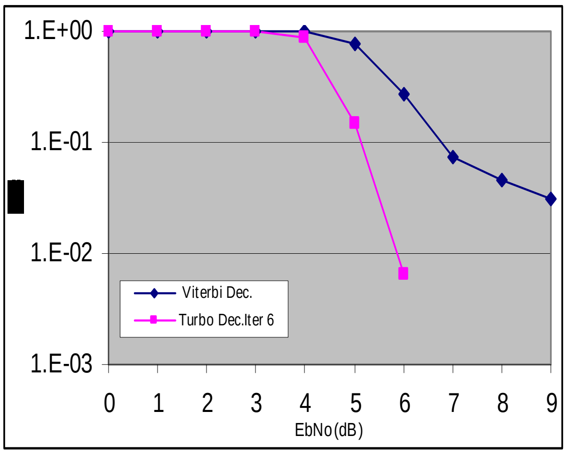

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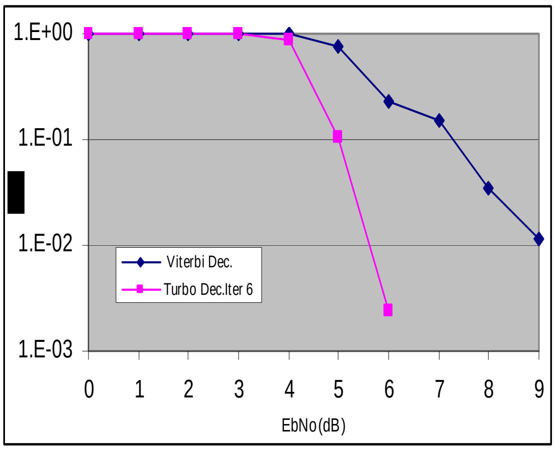

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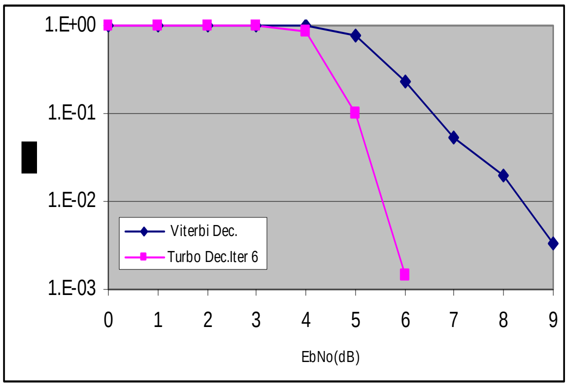

(e)

Figure 2: PER vs Eb/No comparing BCC and TC scheme for SIR values (a) 0dB (b) 2dB (c) 5dB (d) 10dB and (e) 15dB with a single erasure.

5. Conclusion:

This paper has presented initial results from an investigation of IEEE 802.11g and BT coexistence comparing the PER performance of BCC with TC. The results demonstrate that TC substantially enhances the PER performance and in particular removes the irreducibility introduced by BT interference at low SIR values. The implication of these results is that the coverage of an 802.11 WLAN can be significantly extended in the presence of BT devices. The authors intend to extend the study by evaluating the other transmission modes of 802.11g and including the effects of frequency selectivity due to multipath propagation.

References:

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