Journal of Engineering Science and Technology
Vol. 10, No. 6 (2015) 712 - 721

A MODIFIED UNEQUAL POWER ALLOCATION (UPA) SCHEME FOR PERFORMANCE ENHANCEMENT IN BIT REPETITION TURBO CODES IN HIGH SPEED DOWNLINK PACKET ACCESS (HSDPA) SYSTEM

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Abstract

In this paper, a modified optimal power allocation scheme for different bits in turbo encoder has been proposed to improve the performance of Turbo Codes system in High Speed Downlink Packet Access (HSDPA) service. In a typical turbo code in HSDPA system, an encoder with code rate of 1/3 was used with bit repetition scheme or puncturing system to achieve code rate of 1/4. In this study, the author has proposed a modified unequal power allocation (UPA) scheme to improve the performance of Turbo Codes in HSDPA system. The simulation and performance bound results for the proposed UPA scheme for the frame length of N = 400, code rate = 1/4 with Log-MAP decoder over Additive White Gaussian Noise (AWGN) channel were obtained and compared with the typical Turbo Codes systems, which used bit repetition scheme and puncturing method without UPA. From the results, the proposed bit repetition turbo codes system with modified UPA scheme showed better performance than the typical turbo codes system without UPA using bit repetition and puncturing approaches with coding gain of 0.35 dB to 0.56 dB.

Keywords: Turbo codes system, Unequal power allocation (UPA), HSDPA.

1. Introduction

High Speed Downlink Packet Access (HSDPA) has been proposed in Release 5 Wideband Code Division Multiple Access (WCDMA) [1, 2] to increase the data throughput and system capacity for packet services. HSDPA provides impressive enhancements over WCDMA Release 99 for the downlink communication where it offers peak data rates up to 14Mbps, which results in a better end-user experience for downlink data applications. This high speed is achieved based upon short physical layer frames with the adaptation of the following schemes: 1) Adaptive Modulation and Coding; 2) Fast Hybrid- Automatic Repeat Query-ARQ; 3) Fast Scheduling, and 4) Fast Cell Selection [3].

Turbo Codes have attracted attention since 1993 [4].Turbo Codes are codes with parallel concatenation of two or more convolutional codes separated by an interleaver. The characteristic of both constituent codes and interleaver is vital in order to achieve good performance results. The parallel concatenated version of turbo codes introduced by Berrou et al. [4] assumed the identical component codes, known as the Symmetric Turbo Codes.

Holma and Toskala [5] cited that Turbo Codes system needs to increase its code rate to achieve high speed data transmission where Turbo Codes in HSDPA system using either bit repetition scheme or puncturing method to increase the code rate from 1/3 to 1/4 in Turbo encoder where Frederiksen and Kolding [6] proposed a new code rate of 1/4 in Symmetric Turbo Codes based on the repetition of bits from code rate 1/3 in order to achieve high speed data transmission in HSDPA system.

The encoding system that uses a puncturing method is more complex compared to bit repetition scheme, where the latter is more preferable since current technology is moving towards for a less complex system with increased performance [7]. Despite the less complex Turbo Codes system that is introduced by bit repetition scheme, the overall performance of Turbo Codes system using bit repetition scheme in terms of bit error rate (BER) is weak.

Therefore, the need for less complex and good performance system is crucial, especially for Turbo Codes in HSDPA system. So, in order to enhance the performance of Turbo Codes in HSDPA system using bit repetition scheme which suffers from a weak performance, a new modified UPA scheme was proposed where, in this proposed system, each encoded bit is assigned with different power value that could improve the overall performance of Turbo Codes in HSDPA system.

This paper is organized as follows. In Section 2, we present the bit repetition scheme of Turbo Codes system. Section 3 presents the HSDPA in WCDMA system. In Section 4, simulation study was conducted to choose the optimum power distribution for the systematic and parity bits. Meanwhile, Section 5 describes the performance bound for the Turbo Codes using bit repetition scheme utilizing the proposed modified UPA scheme. The performance bound and simulation results for the proposed Turbo Codes system using bit repetition scheme with modified UPA were presented along with the performances of Turbo Codes system using typical bit repetition scheme and puncturing method for comparison purpose. The performance investigations - performance bound and simulation - were conducted for Turbo Codes system with frame size of N=400, code rate of r=1/4 and over AWGN channel with Log - Maximum A Posteriori (MAP) decoder. In Section 6, we presented all the simulation results, and the paper is concluded in Section 7.

2. Bit Repetition Scheme

In typical Turbo Code system, a turbo encoder consists of two identical Recursive Systematic Convolutional (RSC) encoders with a pseudo-random interleaver preceding the second constituent encoder as shown in Fig. 1. The turbo decoder also consists of two identical component decoders as illustrated in Fig. 2. The performance of a turbo code may be affected by different parameters of the component codes, block size, interleaver design, and weight spectrum.

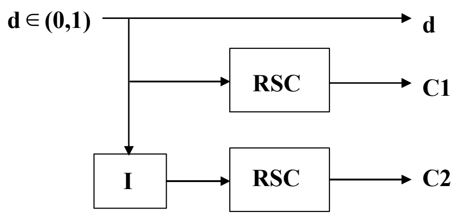

Fig. 1. Typical Turbo Encoder.

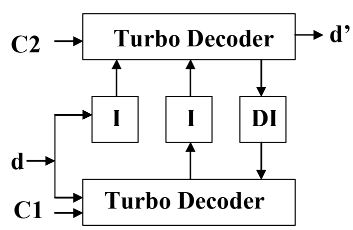

Fig. 2. Typical Turbo Decoder.

The bit repetition has been proposed in [8] in order to achieve high speed for the use of HSDPA system, where it could increase the data transmission. Code rate 1/4 is achieved through a method where one of the three bits in each set (set of output from the encoder using 1/3 rate turbo encoder) is repeated equally to produce a set of four bits for each input bit. The time interval between the fourth bits is increased before transmitting the set of four bits on the communication channel. In the receiver, the time interval between the set of four bits is combined into a received set of three bits, and then a single 1/3 rate turbo decoder is used to recover an output for each input bit [8].

3. High Speed Downlink Packet Access (HSDPA) in WCDMA System

HSDPA is a 3G mobile telephony communications protocol in the High Speed Packet Access (HSPA) family [7]. The throughput is expected to excess 10Mbps, increases nearly 20Mbps when combined with Multiple Input Multiple Output (MIMO) antennas structure [3]. The large increment in throughput achieved by implementing a fast and complex channel control mechanism based upon short physical layer frames. Some features of HSDPA in WCDMA are summarised in Table 1.

Table 1. HSDPA in WCDMA System Parameters [3].

Features	HSDPA
Downlink Frame Size	2 ms TTI (3 Slots)
Channel Feedback	Channel Quality reported at 2ms rate or 500 Hz
Data User Multiplexing	TDM/CDM
Adaptive Modulation and Coding	QPSK & 16 QAM
Hybrid-ARQ	Chase or Incremental Redundancy (IR)
Spreading Factor	SF = 16 using UTRA OVSF

4. Proposed Modified Unequal Power Allocation (UPA) Scheme in Turbo Code System

In typical Turbo Codes System [4] with code rate of 1/3, the fractions of power allocated to all transmitted bits are same; equal power distribution. The α, β, and χ represent the power that allocated to systematic bits (d) and both parity bits (C1) and (C2) - referring to Fig. 1 - at the Turbo encoder. In the typical Turbo Code System, the power allocated is equal for each bit. This method of typical power allocation does not guarantee an optimal power allocation, as it produces less optimum performance. To overcome the less performance problem in Turbo Codes System, a UPA scheme was introduced by Mohammadi and Khandani in [9]. This method was used to improve the performance by allocating different power levels to systematic bits (d) and both parity bits (C1 and C2).

The performance of the Turbo Codes System was enhanced using bit repetition scheme in HSDPA system; this UPA scheme was adopted to optimize the energy that allocated for each bit stream [10]. Turbo Codes in HSDPA system has different code rate – code rate of 1/4 - from the typical Turbo Codes mechanism – code rate of 1/3; thus, the standard UPA scheme need to modify in order to optimize the power allocation and at the same time, enhance the Turbo Codes performance.

In typical Turbo Codes System, the total power that allocated is equally proportionate for each encoded bit; the power was divided into three. Thus,

$$\alpha = \beta = \chi = 1/3 \qquad (1)$$

The standard UPA scheme for systematic bits of the turbo code is to allocate a fraction of $(1-\alpha)/2$ for each parity bits because of the overall symmetry introduced by the random interleaver [9]. Therefore,

$$\beta = \chi = (1- \alpha) / 2 \qquad (2)$$

But, in order to implement UPA scheme for the bit repetition turbo code system, we need to modify the existing UPA power equation because of the existence of extra parity bits in the system - C3, which represented by δ. In this investigation, we assumed that extra repeated bits in the system; C3, is the repetition of parity bits of C2; χ. Therefore, the power equation for modified UPA scheme to suit the bit repetition turbo code system is given in Eq. (3).

$$\delta = \chi = \beta / 2 \tag{3}$$

Simulations were performed for frame length N=400 and code rate = ¼ to choose the optimal power distribution for the bit repetition turbo code. The AWGN channel is assumed with Log-MAP decoder with the maximum number of iterations is 5. The power fractions for the systematic bits, d (α), parity bits - C1 (β) , C2 (χ) and C3 (δ) were varied and based on exhaustive search method, the optimum power distribution which results better performance has been achieved.

Figure 3 shows the simulation results of the bit repetition turbo code with modified UPA scheme and without any UPA scheme. The optimum power fractions for all transmitted bits in the turbo code with modified UPA scheme are presented in Table 2.

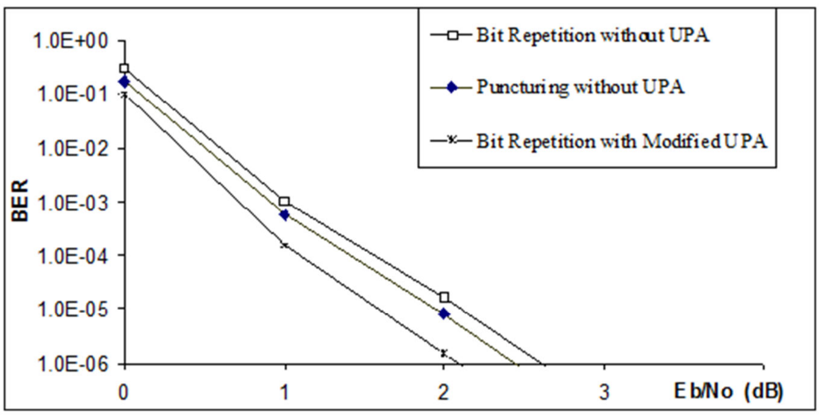

Fig. 3. Simulation Result for Typical; without UPA and Modified UPA Turbo Code System using Bit Repetition and without UPA Puncturing Schemes over AWGN Channel, N=400, r=1/4.

Table 2. Power Allocation for the Bit Repetition Turbo Code System over AWGN Channel, N = 400 Bits, r = 1/4.

E_b/N_o (dB)	α	β	χ	δ
0	0.800	0.100	0.050	0.050
0.5	0.600	0.200	0.100	0.100
1.0	0.400	0.350	0.125	0.125
1.5	0.300	0.400	0.150	0.150
2.0	0.150	0.350	0.250	0.250

5. Performance Bound for the Turbo Codes using Bit Repetition Method using Modified UPA Scheme

The union bound for turbo code system assuming Binary Phase Shift Keying (BPSK) modulation and AWGN channel is given by [11-13]

$$P_{bit} \leq \sum_{j} \sum_{w} \frac{w}{N} A_{w}^{TC}(Z) P_2(j) \tag{4}$$

where N is the frame length and A_w^{TC} represents the number of code words produced in parallel Turbo Codes with weight (j) generated by word of information with weight, w, d_1 and d_2 corresponding to systematic and both the parity bits, respectively. Therefore, the total weight, $j = w + d_1 + d_2$. $P_2(j)$ is the pair-wise error probability between the all-zero codeword and the codeword with weight, j and is given by:

$$P_2(j) = Q\left[\sqrt{2\, jr \frac{Eb}{No}}\right] \tag{5}$$

where, r is the code rate of the code and Q[*] is the tail integral of Gaussian density with zero mean and unit variance. We define a uniform interleaver as a statistical device which maps a given input sequence of length, N and weight, w, into all distinct N_{cw} permutation of it with equal probability $1/N_{cw}$. Making use of the properties of a uniform interleaver, the average Conditional Weight Enumerate Function (CWEF) of all possible Turbo Codes with respect the whole class of interleavers can be evaluated as given in Eq. (6) [14]:

$$A_w^{TC}(Z) = \frac{A_w^{C_1}(Z).A_w^{C_2}(Z)}{N_{cw}} \tag{6}$$

where, $N_{cw} = \binom{N}{w} = \frac{N!}{(N-w)!w!}$; A^{c1} and A^{c2} are the weight enumerating functions for RSC1 and RSC2 encoders respectively. Equation (6) represents an average Turbo Codes with given constituent codes at block size, N over all possible interleavers. In typical Turbo Codes System, the squared Euclidean distances between all-zero-codeword and the codeword with weight j is rjE_b [15].

Implementing UPA scheme in Turbo Codes System can be viewed as changing the SNR of the transmitted bits while keeping the average SNR constant. In order to implement our proposed UPA scheme for the bit repetition Turbo Codes system, we need to modify the Euclidean distance. In each frame, we have systematic bits, w, parity bits d_1 , d_2, and d_3 with power fractions of α, β, χ, δ, respectively. Therefore, we can rewrite the modified squared Euclidean distance as $[\alpha w + \beta d_1 + \chi d_2 + \delta d_3]\, E_b$.

Thus, by substituting the modified squared Euclidean distance in Eqs. (4) and (5), we derived the modified performance bound as below:

$$P_{bit} \leq \sum_{j} \sum_{w} \frac{w}{N} A_w^{TC}(Z).Q\left[\sqrt{\frac{2(\alpha w + \beta d_1 + \chi d_2 + \partial d_3)Eb}{No}}\right] \tag{7}$$

Figure 4 shows the performance bounds for the bit repetition Turbo Codes System without UPA, with modified UPA schemes and Turbo Codes System using the puncturing method without UPA scheme.

The power allocations for modified UPA schemes are provided in Table 2. We noticed that the proposed Turbo Code System with modified UPA scheme performs better than the system without UPA scheme, where the coding gain ranges from 0.35-0.42 dB at BER of 10^{-5}.

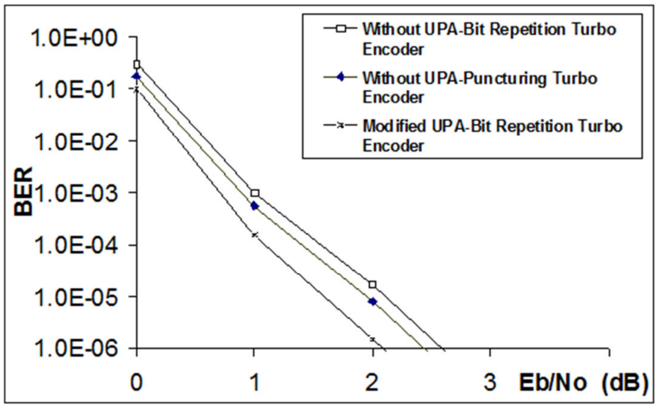

Fig. 4. Performance Bound for Typical; without UPA and Modified UPA Turbo Code System using Bit Repetition and without UPA Puncturing Schemes over AWGN Channel, N=400, r=1/4.

6. Simulation Results

Simulations were carried out to analyse the performance of the system mentioned in Section 4 in terms of Bit Error Rate (BER). Most of the parameters for the simulations are based on the specifications of HSDPA (refer to Table 1). The polynomial generator with constraint length 4 for the Turbo encoder is (15,13). Both puncturing and bit repetition schemes were studied in the system. Log-MAP Turbo decoder utilized with the maximum number of iterations are 6 and 8 for the number of bits, N=1000 and N=5114 respectively. The simulation results for both N=1000 and N=5114 of both Turbo encoder systems using different schemes are provided in Figs. 5 and 6. The optimum power allocations for systematic and parity bits are shown in Tables 3 and 4.

The performance results of the different proposed Turbo Codes System with modified UPA scheme performs better than the system without UPA scheme where the coding gain ranges from 0.35-0.42 dB at BER of 10^{-5}. Turbo Codes System using proposed UPA scheme on bit repetition Turbo Codes System showed good advantages. Figure 5 shows that the coding gain at BER of 10^{-5} is 0.56 dB for bit repetition method without UPA and 0.35 dB for puncturing scheme without UPA for N=1000 bits. Figure 6 shows the coding gain at BER of 10^{-5} is 0.52 dB for bit repetition scheme without UPA and 0.48 dB for puncturing method without UPA for N=5114 bits. From Tables 2-4, we also observed that for all frames lengths; as the E_b/N_o increases, the α decreases while β, χ, and δ increase. It is worth to take note that after certain E_b/N_o, $(\chi + \delta) > \beta$.

Table 3. Power Allocation for the Proposed Asymmetric Turbo Code System over AWGN Channel, N = 1000 bits, r = 1/4.

E_b/N_o (dB)	α	β	χ	δ
0	0.700	0.150	0.050	0.050
0.5	0.450	0.350	0.100	0.100
1.0	0.250	0.450	0.200	0.200
1.5	0.150	0.350	0.250	0.250

Table 4. Power Allocation for the Proposed Asymmetric Turbo Code System over AWGN Channel, N = 5114 bits, r = 1/4.

E_b/N_o (dB)	α	β	χ	δ
0	0.600	0.200	0.100	0.100
0.5	0.350	0.300	0.175	0.175
1.0	0.150	0.350	0.250	0.250

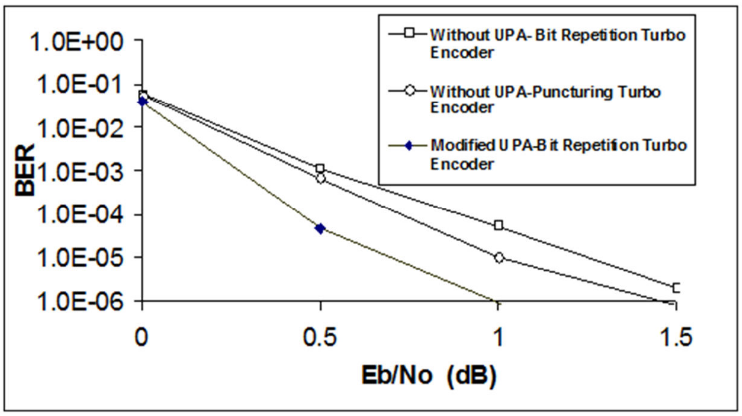

Fig. 5. Performance Results for N=1000 bits.

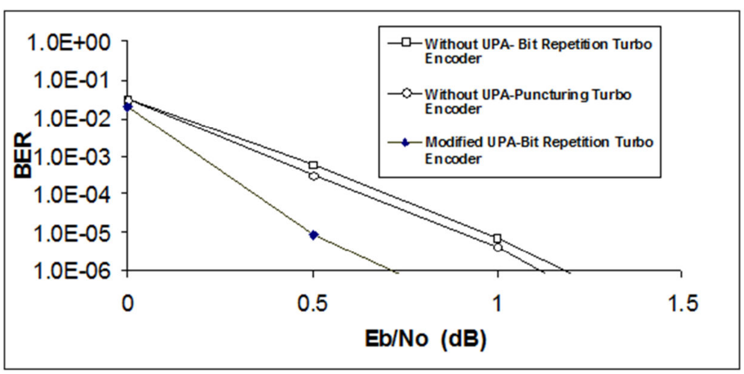

Fig. 6. Performance Results for N=5114 Bits.

7. Conclusion

In this paper, the investigation of the proposed modified UPA scheme for the bit repetition Turbo Codes in HSDPA system showed better performance results. The performance enhancement in the Turbo Codes System was proven through both theoretical – performance bound - and simulation investigations. The search procedure of optimum power allocations for each transmitted bits at every E_b/N_o is quite exhaustive, but the proposed UPA scheme for Turbo Codes System using bit repetition scheme contributes to the performance improvements for Turbo Codes in HSDPA system. From the theoretical results, the proposed Turbo Codes system with modified UPA scheme performs better than the systems without UPA scheme where the coding gained ranges from 0.35-0.42 dB at BER of 10^{-5}. The simulations results showed that the performance of the Turbo Codes System using proposed UPA scheme is superior to the performance of typical Turbo Codes in HSDPA system which used bit repetition scheme and puncturing method without UPA. The performance of the proposed Turbo Codes System is better than the typical Turbo Codes System's performance because the proposed system recorded a performance gain with coding gain ranging from 0.35 dB to 0.56 dB for different number of bits, N. Overall, the proposed UPA scheme for Turbo Codes using bit repetition scheme in HSDPA system is able to mitigate the problems of weak BER performance. Thus, the Turbo Codes in HSDPA System could operate with less complexity and good performance values.

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