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An Energy Efficient Decoding Scheme for concatenated LDPC and turbo code in Wireless Sensor Networks

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***Abstract*- For Wireless sensor network (WSN) different Error control code has been developed. The WSN has large number of simple sensor node devices spread over a large field (wireless sensing +data networking). The WSN is used in the application of humidity temperature, pressure position etc. The goal of WSN is used to increase link reliability & also transmitted power which reduce the power consumption in the sensor. The BER and power consumption has been main concerned in WSN application. Turbo code performs at low SNR and LDPC code at high SNR and the concatenation of both reduces error floor for the generation of mobile communications are shown on MATLAB platform here we propose improvement in BER analysis and power consumption. In this paper the concatenated LDPC and turbo code proposed by using turbo decoding message passing algorithm and adaptive iterative decoding process to reduce bit error rate (BER) and this work has been validated through the simulation result.**

Keywords-Error Control Code (ECC), Low Density Parity Check (LDPC), Turbo code, Wireless Sensor Network, Turbo Decoding Message Passing Algorithm (TDMP).

I. INTRODUCTION

WSN is a distributed network of sensor. In WSN energy efficiency increases their sensor life time and productivity. in the network increases the lifetime of sensors in the network by decreasing their energy consumption has become one of the main challenges of using WSN in practical application. In response to this challenges over the last few years there have been increasing efforts to minimize energy consumption via new algorithms and technique. Unlike most of the current research that focus on a single aspects of WSN.

The TDMP constitutes the optimized solution of LDPC decoding in terms of latency memory requirement and complexity. The different types of error control i.e. BCH, RS, Convolution code, turbo code, LDPC code. Based on the study & comparison concatenated LDPC and turbo scheme has been used. In this turbo code perform at low SNR and LDPC code at high SNR. The performance of both reduce error floor phenomenon. The error control strategies have its own advantages and disadvantages in terms of latency, throughput and energy efficiency. Basically two methods are used to find out the error i.e. is retransmission automatic repeat request (ARQ) and forward error correction (FEC). In C. Berrou near Shannon limit error correcting coding a new class of convolution codes called as Turbo codes [3]. That type of code which use in third generation of mobile communication. It needed to reduce error floor in turbo code, and the concatenation with other code shows that improves the performance of a turbo code R.G.Gallager, "low density parity check [4] rediscovered by Mackey [5] which shows better performance at high SNR and which uses sum and product operation. By using MAP (maximum a posterior) algorithm which improves decoding complexity of turbo decoder. The different scheme has been proposed in the literature [6-8] to serially concatenated turbo code and LDPC with global iteration between the two decoders and local iteration at each decoder. In [7] the serial concatenation of LDPC and turbo code for general packet radio service studied the behavior of the proposed scheme. The design & implementation of concatenated turbo and LDPC codes for deep space communications [8] by using BCJR algorithm used to obtain the high performance with lowered bit error rates. Error correction codes are essential components in digital communication like data encoding and decoding and data storage systems to ensure robust operation of digital application and minimizing power consumption in the sensors is an important issue for reliable and sustainable network operation. In low power channel coding for wireless sensor network in which ECC technique for sensor networks based on Turbo Codes enhances the reliability of the network communications, while being energy and delay efficient [9]. In Energy efficient protocol for wireless sensor networks (EEICCP) has been minimizes the energy usage and further increases the network life time by uniformly distributed load of energy among all the sensor nodes [10].LDPC can be considered serious competitors to turbo codes in terms of performance and complexity constrained random code ensembles and iterative decoding algorithm [13]. Owing of its simplicity, turbo code and LDPC code used in wireless sensor network succeed to attract the attention of researchers and has now been included in some of the codes and guidelines as the reliable method of seismic evaluation. We present a turbo decoding message passing algorithm in concatenated LDPC and Turbo code for minimizing the total energy consumption of WSN. This view of overall energy consumption in WSN can be applied to optimizing and balancing energy consumption and increasing the network life time the sensor energy consumption is modeled based on its energy consuming consitutents.therefore a new decoding algorithm known as TDMP will be used to decode structured LDPC code. Viewing the parity check matrix as a turbo like code has some advantages is that the TDMP algorithm converges faster than traditional algorithm.

The framework of the paper is as follows, section II describes how energy efficiency based error control coding parameters can be selected. Efficient energy implementation for its proposed turbo code are presented in Section III, Efficient energy implementation for its proposed low density parity check (LDPC) codes are presented in Section IV. Simulation results of the proposed energy efficient concatenation scheme are presented in Section V, Conclusion is given in Section VI.

II. ENERGY EFFICIENCY BASED SENSOR NODES ENERGY MODEL

In communication network reability has been achieved through retransmission and error correcting technique. To enhance energy efficiency under different wireless channel condition has been used error control mechanism. In error control codes important parameters are frame length and code rate for constraint length and block codes and code rate for convolution codes. If the packet size is of large length then it results in higher error rate. In other case if size of frame is short it suffers from greater overhead. Message overhead means how many messages are exchanged between the two nodes i.e. slave and master. In WSN application energy consumption is most important because many nodes are mainly powered. Some application in energy consumption depends on sleep time and wake up of the nodes and other way to measure on the frequency of number of message exchanges. Energy consumption can be defined as energy consumed for one round of synchronization in the whole network for the purpose of decoding energy consumption. Energy for communication of the information bits divided by the sum of total energy i.e. information bits and redundant bits. The main goal of WSN is to determine the error correcting mechanism should be used in a wireless environment. Wireless network have a much higher rate than the normal wired network.

For encoded data of transmission, the energy consumption per bit of a node is the sum of radio energy per bit E_r and consumption energy per bit E_{comp}. Radio energy is sum of sleep, transient and on mode energies. The transceiver is off all the time and keeping it ON only when data is transmitting or receiving.

The radio energy per bit for transmitting N bits is calculated as in [12]:

$$E_r = \frac{p_{sleep}T_{on} + p_{tran}\,T_{tr} + p_{on}T_{on}}{N} \qquad (1)$$

Power consumed in radio during ON-mode is the sum of transmitting power pt and power consumption in circuitry $pckt$. The radio energy consumption is:

$$E_r = \frac{(p_t + p_{ckt})T_{on}}{N} \qquad (2)$$

Transmission power in free space is expressed by using Friis equation

$$p_t = \frac{p_r}{G_t G_r} \times \left(\frac{4\pi}{\lambda}\right)^2 d^n \qquad (3)$$

The received power is calculated as

$$p_r = SNR_{uncod}\, bB\, \frac{N_o}{2} NF \qquad (4)$$

Where, SNR_{uncod} is SNR for transmitting uncoded data, b is the number of bits per modulation symbol, B is bandwidth, $\frac{N_o}{2}$ is noise spectral density and NF is Noise Figure.

For coded data received power is:

$$p_r = SNR_{coded}\, bB\, \frac{N_o}{2} NF \qquad (5)$$

Transmission energy for coded data frame is expressed as:

$$E_{trans}^{frame} = E_{dec}^{bit}\,.f_{size}^{C} \qquad (6)$$

The required processing energy to decode a bit is E_{dec}^{bit}. Therefore the energy required to decode a frame E_{dec}^{frame} is computed as:

$$E_{dec}^{frame} = E_{dec}^{bit}\,.f_{size}^{C}.r(J/F) \qquad (7)$$

Where *r* is the coding rate

There is tradeoff between transmitting power and decoding power. To reduce the total power consumption, transmitting power must strictly be larger than Shannon limit. In [9] the Shannon capacity limit for both coded and uncoded systems. In [9] it show that the maximum attainable energy efficiency increases with the corresponding optimal frame length grows. and correction capability of the error control code used and In [9] studied the optimal frame length satisfied at high rate block codes in the range between 200 to 1000 bits, so the proposed system use frame lengths between 200 to 1000 bits and code rates for LDPC code 5/6 and 7/8 in the proposed system. [10], the maximum energy efficiency is limited by its code rate for convolution codes. Medium rate convolution codes are the much more energy efficient and with increasing constraint length, K, their performance improves so in this research we use two convolution codes as constituent codes in turbo codes, each with rate 1/2.

III. DESIGN AND IMPLEMENTATION OF ENERGY EFFICIENT BASED TURBO CODES

Turbo codes are class of high performance forward error correction (FEC) codes. It is the 1st practical codes to closely approach the channel capacity. Turbo codes are completing with LDPC codes, which provides similar performance. The turbo used the structure that approaches the Shannon limit by using recursive encoder and iterative network of soft output decoders. The coder modifies the convolution codes with short constraint length as block codes for large block length sequence and iterative soft output decoder improves the estimation of the received message signal. Basically turbo decoder used two maximum as posterior algorithm. In real system application soft output decoding algorithm for implementation of turbo codes. In error correcting codes basic BCJR algorithm is an algorithm for maximum a posteriori (MAP) decoding.

A. Turbo encoder

The designed form of turbo codes formed by two or more convolution encoders separated by interleavers.the interleavers between them to ensure that the data received by the second encoder is statically independent i.e. is an interleaved version of the same information sequence. The concatenated scheme like turbo codes does not limit themselves by passing hard decision among the decoders.

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Soft decision from the output of one decoder to the input of other decoder. In turbo code process decoding is perform on iterative way to increase reability of the decision.

The binary input data sequence is represented by $d_k = [d_1, d_2 \ldots \ldots \ldots . d_n]$.the input sequence passed through the convolution encoder1 that generates the coded bit stream X_{k1}. the data is then interleaved i.e the data bit are loaded row wise and read out column wise. The interleaved data sequence is passed to the second convolution encoder and coded bit stream X_{k2} is generated. The coded data sequence is multiplexed and punctured. It consists of systematic code bits and parity bits from the first encoder and second decoder. Turbo cods can perform effectively at low signal to noise ratio (SNR).

B. *Turbo code decoder*

In traditional demodulation on process is based on hard decision of the received bit for that better rule is to take into a priori probabilities of the input. The maximum likelihood decoder (MLD) will decided whether a particular bit was 0 or 1. Another algorithm used for turbo decoding is the soft output viterbi algorithm (SOVA). It uses viterbi algorithm but with soft output instead of hard.

The process of MAP decoding includes a posteriori probabilities (APP) of each information the data bit value corresponding to MAP probability for that data bit. In decoding process, the decoder receives as input a soft value of the signal. In the case of turbo codes both decoder provide estimate of the same set of data bits, but in a different order due to the presence of interleaver. The logarithmic form of likelihood ratio is the log likelihood ratio (LLR).

In turbo decoding implement encoded information sequence () is transmitted over AWGN Channel and a Noisy signal () is received at the destination.

The LLR is calculated for each bit () of data block length N is defined as

$$L(d_k) = \log\left[\frac{P_r(d_k=1)|Y}{P_r(d_k=0)|Y}\right] \quad (8)$$

Where $(P_r(d_k = 1)|Y)$ is a posterior probabilities (APP) of the information input data at time k (d_k). In turbo decoding algorithm MAP algorithm gives best performance at iterative decoding until the decoder receives the entire bit sequence. Due to this BCJR algorithm leads to large decoding delay power consumption and also required more memory size for iteration. The turbo code used the MAX log max algorithm.max log map algorithm is less complex than log MAP algorithm but its BER Performance is very close to Log MAP algorithm.

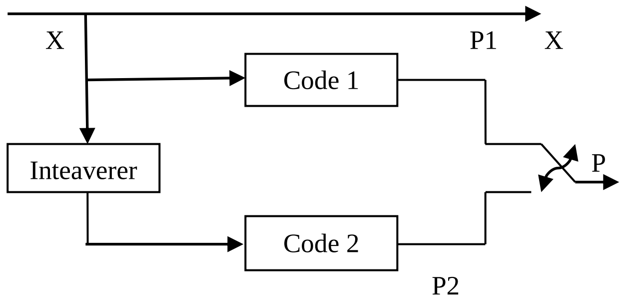

Fig.1. Turbo code encoder

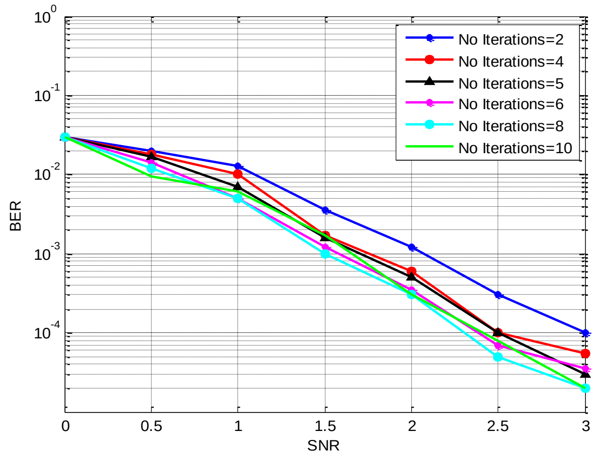

Fig. 2.The effect of number of iteration of turbo code

IV.LOW DENSITY PARITY CHECK (LDPC) CODES AND ITS EFFICIENT ENERGY IMPLEMANTAION

Low density parity check (LDPC) codes are linear block codes constructed by sparse parity check matrices, which introduced by Gallager in 1960.These codes have low decoding complexity and powerful in terms of error performance. MacKay showed that random LDPC codes have good performance approaching Shannon limits. In LDPC structured of the code is given by parity check matrix H. different codes have different parity check matrices. An error control coding scheme involves a mapping from some information or a message word to a codeword of greater length where there exist one to one relationship between each information word and its corresponding word. This relationship is necessary in order that information word is recoverable from the codeword.

$$M = N\text{-}K \quad (9)$$

Where k= Length of information word

N= Length of the codeword

M= encoding process introduces redundancy

The number of elements transmitted in each code word. Binary codes are consider for each element of the message and codeword are either 0 or 1.for systematic schemes message word is contain within the codeword as follows

$$C= [mP] \quad (10)$$

Where m = length k message vector input to the encoder.

P = length M vector of redundant bit introduces by the Encoder.

In LDPC important parameter of the error control code is the code rate(R). This gives an identification of the amount of redundancy introduces by the code and is defined as

$$R=\frac{k}{N} = \frac{N-M}{N} \quad (11)$$

The linear block code describe by the binary generator matrix G the matrix whose row space equal c from the definition, it is clear that for ever

$$C=mG \quad (12)$$

And

$$cH^T=0 \quad (13)$$

Where both operations are carried out under modulo2 arithmetic.

LDPC codes are characterized by sparse parity check matrices is there is a low density of non-zero elements in the parity check matrix H of the LDPC code related to the number of zero.

The tanner graph is a bipartite graph, with the node classes representing code bits in one case and parity checks in the other. The node representing the code bit is referred to as the variable node; while that representing the parity check is called check nodes from our definition of H there are N variable nodes and m check nodes. The j^{th} variable node is connected to the i^{th} check node by an edge. If and only if h_{ij}=1. Where h_{ij} is an element in the H matrix at the i^{th} row and j^{th} column in this graph the number of edges incident upon a node is called the degree of node. The belief propagation proposed for LDPC to achieve lowest error probability .in LDPC tanner graph can be used to estimate codeword in which iterative propagation has been done on hard and soft decision the sparseness of enables efficient decoding, while the randomness ensures a good code. The following matrix will serve as an example

$$H=\begin{bmatrix}1&1&1&0&0&0\\0&0&0&1&1&1\\1&0&1&0&1&0\\0&1&0&1&0&1\end{bmatrix}$$

Fig.3. Sparse parity check matrix H, example

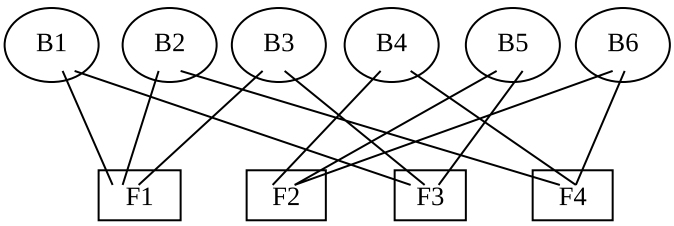

Fig.4. Tanner graph of the example

In the theory of LDPC codes is focus on particular codes but to consider ensembles of codes. These ensembles are defined in terms of ensembles of bipartite graphs [13], [15]. For example, the bipartite graph which represents the code defined in Example 1 is shown in Fig. 1. The left set of nodes represents the variables whereas the right set of nodes represents the constraints. An ensemble of bipartite graphs is defined in terms of a pair of degree distributions. There is one variable nod bits in the code and there is one check node rows of H. An edge exists between the ith variable node and the jth check node if and only if h_{ij} = 1. Here, h_{ij} is matrix at the ith row and jth column. LDPC codes can achieve very good performance decoded with the belief-propagation (BP) or Sum of product algorithm (SPA).

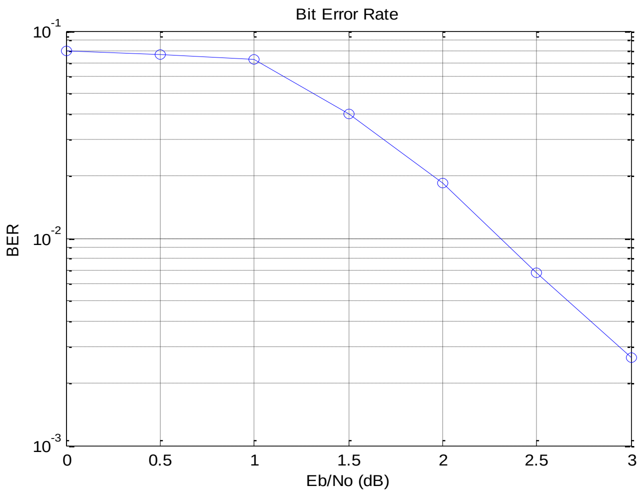

Fig. 5.The BER performance for LDPC

The algorithm calculates a posteriori log-likelihood ratio, (for binary phase shift key BPSK) that is the logarithm of the ratio of the probabilities can be represented as +1 or - 1,

$$L(\hat{u}) = L(u|\bar{y}) = \ln\left(\frac{P=((u=+1/\widehat{y}))}{P=((u=-1/\widehat{y}))}\right) \quad (14)$$

The algorithms iteratively update the a posteriori probabilities until the events occur

$$cH^T = 0 \quad (15)$$

And reached up to maximum iteration Practically, LDPC decoders provide correct bit errors within the first few decoding iteration process. Subsequent iterations provide diminishing incremental improvements in decoder performance. The number of iterations performed by the decoder, I_M determined by a priori and hard coded based on worst-case simulations. Therefore, the decoder performs I_M iterations as well as it will usually converge to its final output early. In [14] that automatically detects when it has converged to its final output and all variable node update units (VNUs) and check node update units (CNUs).

V. CONCATENATED SYSTEM MODEL

The added complexity and power consumption of the decoder which is involved in wireless sensor systems avoid using ECC.A novel coding architecture, presented in [15] with several simple sensor and a few sensor with complex decoder is presented in this section. The novelty of this work is not on designing a new code as convolution codes have been out there for many years. Instead, it is shown that using convolution codes in distributed wireless sensors can be beneficial despite the added decoding complexity. The main idea of adding convolution coding to wireless sensor systems may be easily extended to include other classes of channel codes, noting the decoding complexity and gain trade-off.

For achieving a desired Bit Error Rate (BER), we introduce some fundamental results on the basis of iterative message-passing algorithms for Low Density Parity Check Code (LDPC). To reduce energy dissipation in decoder, LDPC based coded communications between sensors are

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considered. Moreover, we evaluate the performance of LDPC at different code rates and introduce Adaptive Iterative Decoding (AID) by exploiting threshold on the number of iterations for a certain BER (10−8). In iterative LDPC decoding, the total energy consumption of network is reduced by 20 − 25%.

The TDMP constitutes the optimized solution of LDPC decoding in terms of latency, memory requirement and complexity. The appropriate number of iterations and code rate with TDMP decoding algorithm can be taken

Step I: Extrinsic Message for i^{th}row and variable message

$$I_i = [I_1, I_2, \dots, I_{Dc}]$$

Where, $I_i = [I_1, I_2, \dots, I_{Dc}]$- the set of indexes in i^{th}row

Step II: The input message which is the i^{th} variable message subtract the old extrinsic message

$p = [p_1, p_2, \dots, p_{Dc}] = r(I_i) - \lambda_i$ Where, $\lambda^i = [\lambda_1^i, \lambda_2^i, \dots \lambda_{Dc}^i]$ extrinsic message corresponding to the nonzero in ith row and $r(I_i) = [r_1, rI_2, \dots, r_{Dc}]$- a vector of variable messages with the corresponding I_i in i^{th}row

Step III: Computation for the extrinsic message which use p as inputs using decoding Algorithm,

$$M_{C_i \to v_j} = \prod_{i'\in N_{i/j}} sign(u_{i'j'}) . \phi[\sum_{i'\in N_{i/j}} \phi(|u_{i'j'}|)]$$

Step IV: The new extrinsic messages vectors $Z_i$replace the old extrinsic messages, and then add the new extrinsic then add the new extrinsic message Z_i to the corresponding variable message.

$$r_i = p_i + Z_i$$

The Hard decision for layered message passing algorithm is different from the TPMP, in each iteration r is updated then the hard decisions are made. If the hard decision appears it is the correct variable message, the decoding stop immediately, the hard decision in each sub iteration helps this algorithm getting correct vector faster and significant memory saving.

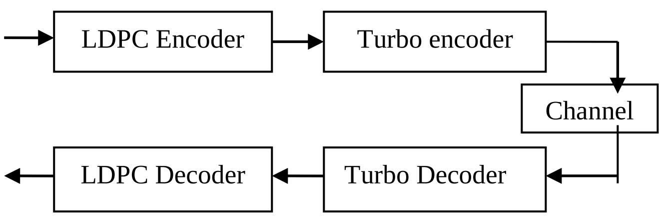

Fig. 6.The concatenation for LDPC and turbo code scheme

We propose an efficient early stopping method to reduce the number of iterations for LDPC decoders. This method is efficient at low SNR Turbo code shows low BER at low and medium SNR with iterative decoding. But error floor is occurred as SNR is increased. The concatenation of another code and turbo code can be an alternative scheme to reduce this error floor phenomenon. The concatenated code should have decoding complexity as low as possible, because decoding complexity in concatenated scheme is higher than an original code. Most concatenated system has interleaves between two codes. Interleave makes interleaving gain by dispersing burst errors. But interleave results in time delay in encoding and decoding.

VI. SIMULATION RESULT

The Performances of LDPC and turbo code are compared with the same 1000 input bits and code rate of 1/2. LDPC code is made by 128 x256 parity check matrix. And turbo code is composed of the convolution code with the generator polynomial of $(7, 5)_8$. The number of iterations in turbo code is set to 5, because the performance improvement is almost saturated after 5 iterations. And AWGN (Additive white Gaussian noise channel) channel is assumed.

The simulation result shows in and for concatenated scheme with frame length 1000 bits in fig.7. And 200 bits in fig.8. In this simulation serially concatenated LDPC and Turbo code shows good performance. in this for frame length 1000 bits about 2.6 dB is required to get BER of 10^-8 when outer LDPC code rate is 7/8 and inner code rate is ½.and for frame length 200 bits about 3 dB is required to get BER of 10^-5 when outer LDPC code rate is 5/6 and inner code rate is ½.

Fig.9.shows the performance of serially concatenated LDPC and turbo code with different memory depth (constraint length, *K*=3, 4 and 5).the simulations are performed over an Additive white Gaussian noise (AWGN) with BPSK modulation.

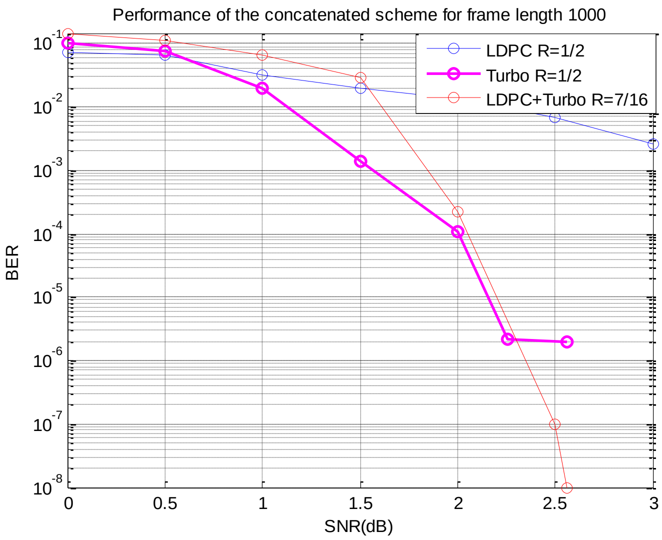

Fig.7. Performance of the concatenated scheme with frame length 1000 bit.

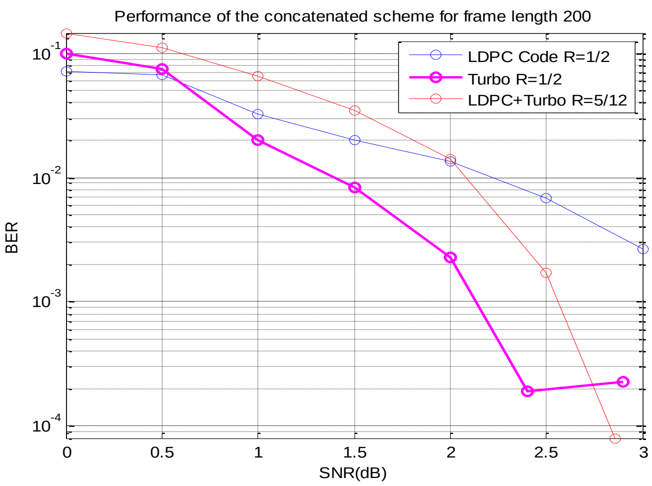

Fig.8. Performance of the concatenated scheme with frame length 200 bit.

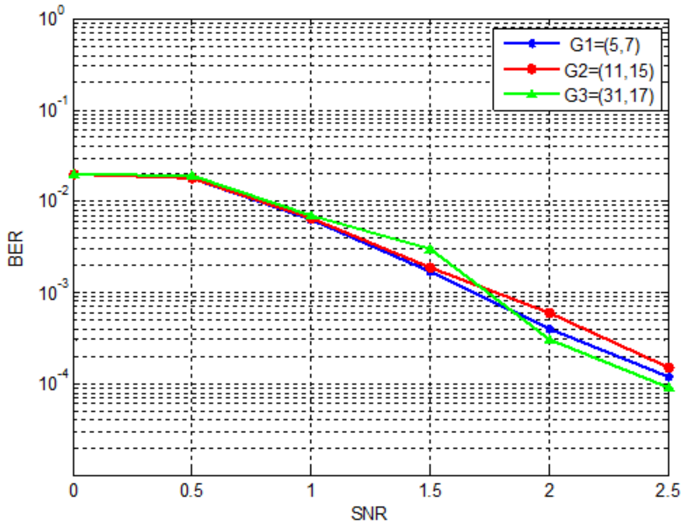

Fig. 9. Performance of concatenated scheme for different generating polynomials.

VII. CONCLUSION

The concatenation of LDPC and turbo code is proposed to improve the error performance at high SNR for the next generation multimedia mobile communications and the performance is analyzed in this paper by using TDMP and iterative decoding process. Turbo code shows poor performance at high SNR due to error floor. But LDPC code shows no error floor and outperforms turbo code at high SNR. And the decoding algorithm is very simple as compared to turbo code. In addition, LDPC code does not need interleaves when it is used in a concatenated scheme. So the concatenation of LDPC and turbo code without interleave is a good combination to get high quality multimedia services.

Thus the LDPC-Turbo concatenated code is expected to be suitable to the future mobile communication systems which need low BER with low decoding complexity as well as high throughput efficiency.

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