Performance comparison of Decoding Algorithm for LDPC codes in DVBS2

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ABSTRACT

Low density parity check code being the most powerful Error correcting code with performance near to Shannon limit is studied and simulated in this paper. Because of its performance it is used in Digital Video Broadcasting Satellite for Second Generation (DVBS2).In this paper, LDPC encoding algorithm named "Irregular repeat accumulated code" has been illustrated in detail. There are several algorithms existing for the decoding of the LDPC decoder. Among them here, two decoding algorithm named "Turbo decoding message passing Algorithm" and "Two phase message passing algorithm" has been illustrated and simulated in MATLAB. The results comparing these two decoding algorithms and different iterations have been presented in this paper.

Keyword *: - Low Density Parity check code(LDPC), Digital video broadcasting satellite for second generation(DVBS2),Two phase message passing algorithm(TPMP) and Turbo decoding message passing algorithm(TDMP)*

1. INTRODUCTION

Low density parity check code is forward error correcting code technique that is discovered by Robert G. Gallager in 1963 and later, it was rediscovered by Mackay and Neal in 1990[1][2].Due to the stronger advantage of LDPC have been adopted by many of the standards such as DVB-S2, DVB-T2, DVB-C2, Wi-Fi (802.11e) and Wi-Max (802.16e)[3].LDPC code is linear block code with sparse parity check matrices, which can also represented by Tanner graph.

Normally, encoding of the LDPC code has been done by parity check matrix designed first and then determining generator matrix. while DVBS2 standard defines irregular repeat accumulate (IRA) code for the construction of parity check matrix H can be directly used in encoding.DVBS2 standard has specified LDPC block codes with two types of frames i.e. Normal frames(64800 bits) and short frames(16200 bits)[4].Eleven code rates are specified for normal frames and ten code rates for short frames. But for the broadcast application normal frames are used.

2. LDPC ENCODING ALGORITHM IN DVBS2

The application of DVBS2 is wider than DVBS, including HDTV and definition TV, the interactive application, the professional application and the networks. The Kind of LDPC is irregular repeat accumulate code is subset of the LDPC codes. The characteristic of structural parity check matrix H is not only related to the encoding algorithm but also useful to select the decoding algorithm. The IRA parity check matrix H is composite of two sub matrices. This parity check matrix have the number of nonzero elements in rows are same but different in column, so, IRA is a mix of regular and irregular code. If the code length and information length of LDPC is n and k respectively. The Parity check matrix has in the form of,

$$H = [H1 | H2] \tag{1}$$

Where, H1 is base (n-k) x k matrix and H2 is lower triangular (n-k) x (n-k) matrix and H2 matrix having two nonzero element in each column.

$$H2 = \begin{bmatrix} 1 & & & & & \\ 1 & 1 & & & 0 & \\ & 1 & 1 & & & \\ & & & \cdots & & \\ & 0 & & & 1 & \\ & & & & 1 & 1 \end{bmatrix} \tag{2}$$

The encoding process of IRA code is much simpler with reduced complexity. The information bits ($i_0, i_1, i_2, \ldots, i_{k-1}$) of size k is encoded into the code word of size n, that contains (n-k) parity bits. Here, for the encoding of the IRA code directly parity check matrix is used.

The research of DVB-S2 has found that LDPC code in DVB-S2 has 360 cyclic structures. By interleaving the serial number in the order that 0, q, 2q …,1, q+1,2q+1, ….The interleaved parity check matrix is composed of sub-block matrixes with the size 360*360. There is at most one element that equal to 1 in each column of sub-block matrix [4]. These characteristics provide the basis for improving the decoding algorithm. In decoding process, one sub-block matrix is treated as a node that can save processing time and improve the throughput. q is a constant which is different for code length n and code rate r. The value of q can be obtained by below equation,

$$Q = \frac{n}{360}(1 - r) \tag{3}$$

3. LDPC DECODING ALGORITHM

In this section, two different decoding algorithms named two phase message passing algorithm and Turbo decoding message passing algorithm or layered message passing algorithm is evaluated briefly.

A. *Two Phase Message Passing Algorithm:*

LDPC codes are decoded by iterative standard message passing algorithm known as Two phase message passing algorithm. LDPC code is defined by the parity check matrix of by M rows and N columns. Each column in H is associated with one bit code word and each row corresponds to the parity check equation. A LDPC decoder is described by the tanner graph[7] which is graphical representation of the association between Variable Node(VN) and Check Node(CN).A Message going from CN c to VN v is called $M_{c\rightarrow v}$ and a message going from VN v to CN c is called $M_{v\rightarrow c}$.

The TPMP consists of two phases in one iteration. The message from VN propagated to CN in phase 1 ,then CN send Message to VN and update phase 2.These messages provides the soft information about s tate (0 or 1).This algorithm considers probability messages in log domain and are called Log Likelihood Ratio(LLR).The LLR are defined by:

$$LLR_v = \log\left(\frac{P(v=0)}{P(v=1)}\right) \quad (3)$$

Where, P(v= x) is the probability that give v equals to x.
The design steps for the TPMP algorithm [6] are as follows:
Initialization

Set all the $M_{v\rightarrow c}$ to the channel values, i.e., for all(c,v) such that H=1, $M_{v\rightarrow c}=LLR_v$

Step I: Check node update:

The update of node means that a node reads the incoming message and then updates the outgoing messages. For all the CNs , update of the message by applying the Bayes law in the logarithmic domain. For c_i with $M(i)=\{l \mid h_{i,j}=1\}$

$$M_{ci\rightarrow vj} = 2\tanh^{-1}\left(\prod_{j'\in L(i)-j} \tanh\left(\frac{1}{2}M_{vj'\rightarrow ci}\right)\right) \quad (4)$$

Step II: Variable node update:
Every variable node processes the message received from neighboring check nodes during check node update step and replies to neighboring check node $M_{vj\rightarrow ci}$, ,

$$M_{vj\rightarrow ci} = M_{vj} + \sum_{i'\in M(j)-i} M_{ci'\rightarrow vj} \quad (5)$$

After the variable node update the soft decision code word is given by,

$$M_{vj} = M_{vj} + \sum_{i'\in M(j)} M_{ci'\rightarrow vj} \quad (6)$$

Hard decision code word is given by,

$$Z_i = 1 \text{ if } M_{vj} < 0$$

$$=0 \text{ if } M_{vj} \geq 0 \quad (7)$$

This Hard decision code word is checked for parity check constraints by using following parity check equation:

$$ZH^T=0 \quad (8)$$

Steps 1, 2 are repeated until iteration limit is reached or parity check constraints are satisfied [5].
The main drawback of this TPMP algorithm, it requires two types of computation and the inter-media message need to be saved at every round at each iteration, which increase the memory requirement of the system.

B. *Turbo Decoding Message Passing Algorithm:*

Because of the regularity of the LDPC in DVBS2, layered message passing algorithm which also known as “Horizontal Shuffled decoding ”, “Turbo-like coding” will be introduced[6].The TDMP constitutes the optimized solution of LDPC decoding in terms of convergence speed, latency, memory requirement and complexity.

In this TDMP, the CNs are update one by one. The VNs connected to an updated CN are immediately updated with newly generated Mc→v messages. The next CNs will thus benefit from newly updated VNs which improves the convergence speed. The design steps for TDMP algorithm[10] are as follows:

Step I: Extrinsic Message for i”th row and variable message

$$I_i = [I_1, I_2, ..., I_{Dc}] \quad (9)$$

where, $I_i = [I_1, I_2, ..., I_{Dc}]$- 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

$$p = [p_1, p_2, ..., p_{Dc}] = r(I_i) - \lambda_i \quad (10)$$

where, $\lambda^i = [\lambda_1^i, \lambda_2^i, ..., \lambda_{Dc}^i]$ extrinsic message corresponding to the nonzero in ith row and $r(I_i) = [r_1, r_2, ..., r_{Dc}]$- 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,

$$M_{c_i\rightarrow v_j} = \prod_{i'\in N_{i\backslash j}} \mathrm{sign}(u_{i'j}).\phi[\sum_{i'\in N_{i\backslash j}} \phi(|u_{i'j}|)] \quad (11)$$

Step IV: The new extrinsic message 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.

$$r_i = p_i + Zi \quad (12)$$

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.

4. SIMULATION RESULTS

MATLAB model for DVBS2 LDPC encoder and decoder for 64800bit have been simulated in this paper. The LDPC decoder has been decoded using two different decoding algorithms TDMP and TPMP. The LDPC decoder performance has been analyzed by measuring Bit Error Rate (BER) for different SNR values.

In figure 1 shows the comparison result of two decoding algorithm TPMP and TDMP at code rate ½ with 64800 bits. The Results shows that two phase message passing algorithm achieves the BER value 10^{-5} at SNR 5.5 dB, whose coding gain is 4.5dB at 10^{-5} BER value. While the TDMP Algorithm achieves same BER value at SNR 3.2 dB. This TDMP algorithm achieves the coding gain 6.9 dB at 10^{-5} BER value.

The Performance of LDPC code is also depends up on the number of iteration used in decoding algorithm. The performance analysis based on number of iteration is shown in the Figure 4.The analysis shows that as number of iteration increases the BER performance is also increases. The graph shows that more the number of iterations better BER performance but in cost of processing time. For the BER 10^{-5} the SNR for 10 iteration is 3.3 dB, whereas for 7and 5 iterations the SNR values are 4 dB and 4.5 dB, respectively.

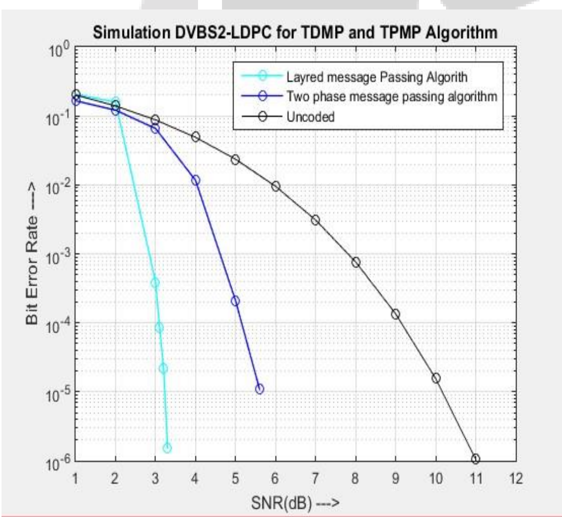

Fig.1. performance result of TDMP and TPMP

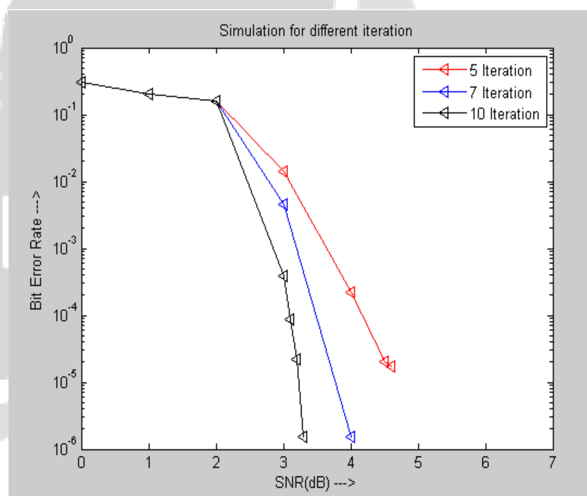

Fig.2. Performance result for different iteration

5. CONCLUSION AND FUTURE WORK

The simulation result shows that the TDMP algorithm performs better than the two phase message passing algorithm. The turbo decoding message passing algorithm has coding gain 2.4 dB over the two phase message passing algorithm. Moreover, the TDMP is having the less complexity, less memory requirement and higher convergence speed. So, TDMP algorithm is adopted for decoding algorithm in LDPC will be more efficient. Using more number of iteration we can get better BER performance at lower SNR and achieve nearer performance to

Shannon limit. For the future ,as per the user requirement we can get appropriate number of iterations and code rate with TDMP decoding algorithm can be taken.

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