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GeneralizedWeighted Bit Flipping Algorithm For LDPC Decoding

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***Abstract*—In this paper, an generalized weighted bit flipping algorithm is proposed for low density parity check codes. Compared to the other bit flipping algorithms, the proposed method improves the decoding speed and the number of iterations are reduced. The proposed weighted bit flipping algorithm is the combination of both hard decision decoding and the soft decision decoding. It is mainly based on check node update and variable node update process. The main objective of this method is to achieve the better bit error rate at less signal to noise ratio using LDPC decoder based on Bit-Flipping Algorithm and increase the decoding speed with low complexity with the minimum performance loss degradation.**

***Keywords*—Low Density Parity Check (LDPC) Codes. Weighted Bit Flipping (WBF). Bit Flipping (BF) decoding.**

Introduction

LDPC codes were invented by Robert Gallager. LDPC codes are linear codes obtained from sparse bipartite graphs which are mainly used in Communication system. Low-density parity-check (LDPC) codes are a class of linear block LDPC codes. The name comes from the characteristic of their parity-check matrix which contains only a few 1's in comparison to the amount of 0's. Their main advantage is that they provide a performance which is very close to the capacity for a lot of different channels and linear time complex algorithms for decoding.Shannon introduced the noisy channel coding theorem in 1948, and the error correcting codes has been gradually approaching the Shannon limit.

Low-density parity check (LDPC) codes, was originated in the early 1960s, which has received a lot of attention on the error correcting codes. This powerful error correcting capabilities have been evaluated and validated, and it has been included in various standards as a channel coding scheme. Data transmission in communication system from source to transmitter is done through a channel or medium such as wired or wireless. The reliability of received data is based on the channel medium and external noise and this noise creates interference to the signal and hence the error is introduced in transmitted data. Figure 1 shows the Block diagram of LDPC Decoder. Shannon from his coding theorem showed that only if data rate is less than that of channel capacity the reliable transmission could be achieved.

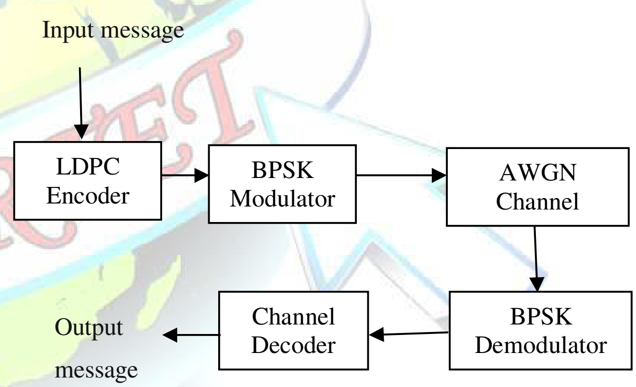

Figure 1 Block diagram of LDPC Decoder

The theorem shows that a sequence of codes of rate less than the channel capacity have the capability even when the code length goes to infinity. By adding redundant symbols to the original data, error detection and correction can be achieved which is called as error correction and correction codes (ECCs).Without ECCs data need to retransmit if it could detect there is an error in the received data. ECC are also called as forward error correction (FEC) can also correct bits without retransmission. For long distance one way communications such as deep space communication or satellite communication ECCs is really helpful. They also have application in wireless communication and storage devices. Communication system shows the movement of data from source to destination. Data from input is given to the Encoder for Encoding and then it is modulated using standard modulation techniquethen it is

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transmitted through Additive White Gaussian Noise channel. The output then is fed to demodulation and finally it is decoded with the decoder. There is increased demand for reliable and proficient digital data transmission and storage systems. There is also an increased demand for High speed, large-scale networks for data exchange, processing and storing of digital information in government, military and commercial areas. Control of errors is the major task for a system designer for efficient reproduction of data. LDPC codes have attracted a tremendous amount of research interest related to their excellent error correction capabilities. However, the tremendous improvement in error correction capabilities gives a penalty of high decoding complexity.

Notations

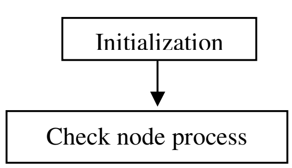
The H-matrix is the combination of both check node and variable node. Let the set of variables presented in mth check node is denoted as N(m), and the set of check nodes presented in the nth variable node is denoted as M(n).The following notations are used in the decoding process.

$H_{m,n}$: mth row and nth column of parity check matrix.
$Z_n^{(k)}$: received sequence from hard decision decoding.
$e_n^{(k)}$: extrinsic information
λ: Quantization factor.

For a (P,Q) LDPC code both the variable node and check nodes are less when compared with the length of (P,Q). Block length is represented by P and information length is represented by Q. Let the codeword C having the values from $C_0, C_1 \ldots C_{N-1}$. The AWGN with zero mean is independent of the input values. The hard decision output sequence is $Z_0, Z_1 \ldots Z_{N-1}$

I. DECODING OF LDPC

There are three categories for decoding the LDPC codes.(1) Soft decision decoding (2) Hard decision Decoding (3) Generalized decoding method. The soft decision decoding algorithm is done by message passing process. In soft decision decoding channel information is considered in the decoding process. Compared to hard decision decoding process it has little complicated decoder construction. It follows the message passing algorithms.Among various soft decision decoding algorithms Belief Propagation Algorithm(BPA) [4] is the best decoding performance with largest computational complexity.The min - sum algorithm is the simplest form of BPA [5] reduces the computational complexity. Slow converging speed, but more powerful methods are used for decoding.



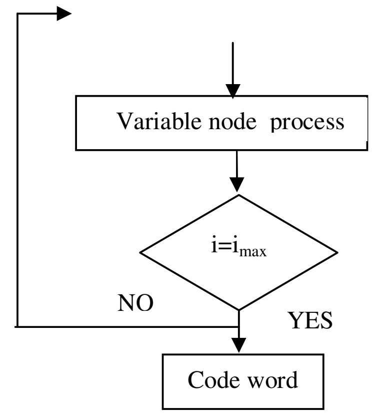
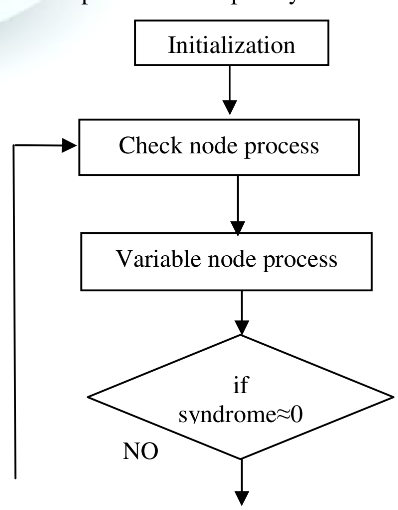


Figure 2 Flow of Hard Decision Decoding Algorithm

Fig 2 shows the flow of Hard Decision Decoding Algorithm. The hard decision based decoding algorithms with bit-flipping (BF) methodologies the less amount of complexity with average decoding performance. In the hard decision decoding scheme, computational complexity is less when compared to soft decision decoding. It has simple decoder construction and the input values are not considering the channel information The reliable channel information leads to some performance degradation. It follows the bit flipping algorithm.

The convergence speed is higher than the soft decision decoding scheme. In this amount of logarithmic and arithmetic operations are reduced. In recent days, many of the application uses the weighted bit flipping algorithms with reduced computational complexity and generalized decoding performance.

In this paper, an generalized weighted bit flipping algorithm is proposed for decoding the Low Density Parity Check (LDPC) codes. This algorithm can detect multiple errors at a time and can correct the error in the number of iterations. The proposed method improves the decoding speed with reduced computational complexity.



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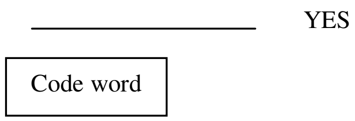

Figure 3 Flow of Soft Decision Decoding Algorithm

II. AN WEIGHTED BIT FLIPPING ALGORITHM

Low Density Parity-Check codes are one of the forward error correction codes and can be applicable to large number of applications, from data storage to telecommunications. Basic understanding of the decoding process can be dealt by introducing hard decision decoding. Different iterative decoding algorithms exists which has two derivations. They are mainly classified as hard decision decoding and soft decision decoding respectively.

LDPC codes are a sub-set of linear block codes, defined by sparse parity check matrix H, for which a Tanner graph can be coupled for any linear block code. The bipartite graph can be formed by two types of nodes, Check Nodes (CN), and Bit Nodes (BN). The connections between the check node and the bit node can be given by H. The importance of the Tanner graph is highlighted by the fact that best known LDPC decoding algorithms, such as the Sum Product Algorithm (SPA) are all formed from the Tanner Graph structure. The iterative procedure depends on the exchange of messages between the VNUs and CNUs of the Tanner graph, containing the value of each codeword bit with the messages being represented in the domain using logarithm likelihood ratios (LLR). The valid codeword is achieved or the maximum number of iterations is reached andthe iterative procedure stops. A simple iterative decoder can thus be structured by taking into account each CN and BN of the Tanner graph as processing units.

More recently binary LDPC codes considered in standards are DVB-S2, WI-MAX, DSL, W-LAN etc. However they began to show their access when the code size is small and moderated and higher order modulation can be used for transmission.LDPC codes are linear block codes that can be denoted as (n, k) or (n, w_c, w_r), where n is the length of the codeword, k is the length of the message bits, w_c is the column weight (i.e. the number of nonzero elements in a column of the parity-check matrix), and w_r is the row weight (i.e. the number of nonzero elements in a row of the parity-check matrix). There are two obvious characteristics for LDPC codes.

The binary check sum used as the FF

$$E_n = -\sum_{m\in M(n)}(1 - 2S_m)$$

Parity-check LDPC codes are represented by a parity-check matrix H, where H is a binary matrix that, must satisfy $cH^T = 0$, where c is a codeword. Low Density H is a sparse matrix (i.e. the number of 1's is much lower than the number of '0's). It is the sparseness of H that guarantees the low computing complexity.

By taking into account soft-valued channel information andassigning checksum weights,

$$E_n = -\alpha_1 \cdot \varphi(u_n, y_n) - \sum_{m\in M(n)} w_{mn}(1 - 2S_m)$$

In order to perform decoding architecture, H matrix plays a major role. H matrix of a linear block code describes the linear relations of the component of the codeword must satisfy. It is specifically used to decide whether a particular vector is a codeword and it is used in decoding algorithms. They are used as data sparse approximations of non sparse matrices. While a sparse matrix of dimension 'n' can be represented efficiently in the order of n units of storage by storing only its non-zero entries, a non-sparse matrix would require order of n^2 units of storage, and using this type of matrices for large problems would therefore be prohibitively expensive in terms of storage and computing time. Hierarchical matrices provide an approximation requiring only order of nk(log(n)) units of storage, where k is a parameter controlling the accuracy of the approximation. In typical applications.

For exhibiting the least amount of computational complexity with average decoding performance, the hard decision based decoding algorithms with bit-flipping (BF) methodologies were implemented. By quantizing the received data as the set of smaller elements which belongs to the transmitted data, the computational complexity and the hardware complexity is reduced to a greater extent This decoding process mainly leads to the loss of some channel information which causes considerable performance degradation. For energy-sensitive mobile applications the hard decision based decoding algorithms with less computational complexity are most preferred over soft decision based decoding algorithms with good decoding performance. Some of the bit flipping based decoding algorithms are weighted bit flipping (WBF) algorithm,modified WBF algorithm, improvement on the modified WBF algorithm, combined MWBF algorithm, implementation-efficient reliability ratio based (IRRWBF) algorithm were implemented which does not compromise the decoding complexity.

A. Bit Flipping Algorithm

The hard decision is done by the detector and sent to another detector. The messages are passed along the Tanner Graph and the bit node sends it after verifying it as one or zero and the check node sends the message to the bit node which is connected to it. This finally arrives at what value the information is based on and the output is obtained. The modulo-2 sum is done for the input bits and if the output is zero, the parity check equations are satisfied.

If the majority of the messages received by a bit nodes are not same from its received value, the bit node flips its current value. The no of times the process getting repeated is called as iteration. The process repeats even until all the parity equations are satisfied.

B Proposed Weighted Bit Flipping Algorithm

Step 1 Initialization

The hard decision bit flipping and the soft decision bit flipping process

$\boldsymbol{w_m} = \mathbf{min}_{n\in N(m)}\{|\boldsymbol{y_n}|\}$ and

$\boldsymbol{w'_{m,n}}=\mathbf{min}_{i\in N(m)\backslash n}\{|\boldsymbol{y_i}|\}$ using[5]

Step 2 Fix the iteration from k=0 to k_{max}

Step 3 Check node update process

$\sum_{n=0}^{N-1} \boldsymbol{Z_n}(\mathbf{k}).\boldsymbol{H_{m,n}}$ where m=1,2,3...M

Step 4 Variable node update process

$$\boldsymbol{e_n^{(k)}} = \frac{\mathbf{1}}{\{|\boldsymbol{y_n}|\}} \sum_{\boldsymbol{m\in M(n)}} (\mathbf{2}\boldsymbol{S_m} - \mathbf{1}).\boldsymbol{w'_{m,n}}.\boldsymbol{\theta_{attn}}$$

Step 5 The process is repeated until it reaches the maximum number of iterations.

Step 6 Estimation of decoded code word.

The Weighted BF (WBF), which first bridged the performance gap between BP-based algorithm and BF-based algorithm, and a series of generalized algorithms are proposed to further improve the decoding performance of WBF algorithm, defined as WBF-based algorithms.. In terms of the update of the check message in the min-sum algorithm, an generalized MWBF (IMWBF) algorithm was further proposed.To improve the convergence speed of IMWBF algorithm,. Wu proposed a parallel version of the IMWBF algorithm (PWBF).

Because of their low computation complexity, based algorithms can be utilized to design a high-speed LDPC decoder, and two multi-bit flipping algorithms are adopted to improve the convergence speed. In the multi-bit flipping algorithms, it is critical to choose the bits flipped in every iteration. The method proposed by Wu is efficient to obtain well decoding performance. However, its complex structure limits the decoding speed of the LDPC decoder. MLP-WBF has a simple method to choose the flipped bits. However, the process of the bits choose can only been executed sequentially, which also limits the decoding speed. For further improving the decoding speed of the LDPC decoder, we propose a partially parallel choose mechanism, which utilizes the received vector with stochastic distribution noise.

The steps are more related to existing methods it can be observed from the comparison. The difference between normal weighed bit flipping algorithm and the generalized weighted bit flipping algorithm is the attenuation factor. The attenuation factor is used to improve the accuracy of the received sequence for each and every iteration. This improves the overall decoding performance of the extrinsic information. To achieve a better trade-off between decodingperformance and computational complexity the attenuation factor is used in the proposed method.

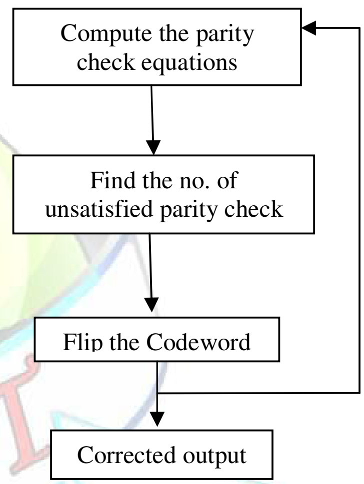

Figure 3 Design Flow of Bit Flipping Algorithm

III. SIMULATION RESULTS AND DISCUSSION

The decoding performance for two different matrix size are considered that are named as Mackay's (2,000,1,000) with rate 0.5 The modulation is done by using binary phase shift keying and transmitted over the additive white gaussian

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noise channel. The iterations for LDPC code is 200.

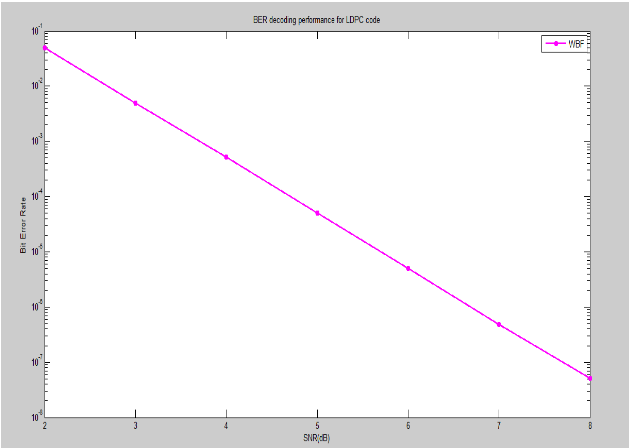

Figure 4 BER Decoding Performance of LDPC Codes

Figure 4 shows the output performance of BER vs SNR.The better BER is achieved for less signal to noise ratio.

TABLE 1
PERFORMANCE OF LDPC DECODING

Matrix size	BER	SNR	Θattn
(1000,2000)	10^{-6}	8	0.5

CONCLUSION

In this paper, the performance of an generalized reduced complex weighted bit-flipping algorithm is analyzed in terms of decoding performance and computational complexity. This algorithm is mainly suitable for energy sensitive applications. The proposed algorithm reduce the decoding time and also the complexity. It provides the confidentiality when the data is transmitted over the noisy channel also. This simple decoding algorithm is suitable for wide range of channels.

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