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REVIEW ARTICLE

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A REVIEW ON ENCODING AND DECODING OF LDPC CODES

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ABSTRACT

Low Density Parity Check (LDPC) codes gained significant research attention in current years. Due to their powerful decoding performance, LDPC codes are increasingly used in communication field. The performance and cost of using LDPC codes are determined on the basis of decoding algorithm. LDPC decoding algorithms are usually iterative in nature. They operate by exchanging messages between basic dealing out nodes. These codes are the linear error correcting codes which are used in information theory. These are the class of linear block codes. The name of this code arrives from parity- check matrix concept which has only few one's when compared with zeros. In this paper we have reviewed about LDPC codes. We have included the overview of LDPC, representation & encoding–decoding of LDPC codes.

Keywords: Low density parity check codes (LDPC), Tanner graph, decoding, encoding

INTRODUCTION

Low density parity check codes are popularly known as LDPC codes. LDPC is one of the best codes in coding theory nowadays. These codes are proposed by Galleger at MIT in the year of 1962. These codes are also known as Galleger codes [2] [8]. But these codes are neglected very much for the past 35 years. These codes are the linear error correcting codes which are used in information theory. These are the class of linear block codes. The name of this code arrives from parity- check matrix concept which has only few one's when compared with zeros. Nowadays parallel architecture is in use. Thus these codes are suited for implementation of current scenario. The forward error correction codes are dominated well on those days due to highly structured algebraic block and convolution codes. Here, the use of sparse matrix, turbo codes, Tanner graphs are enormously comes in to picture. Nowadays LDPC codes are used in Wi-max for microwave communications, CMMB i.e. china multimedia mobile broadcasting, Digital video broadcasting and for Wi-Fi standard [2].

Low Density Parity Check (LDPC) codes gained significant research attention in current years. Due to their powerful decoding performance, LDPC codes are increasingly used in communication standards. The performance and cost of using LDPC codes are partly determined by the choice of decoding algorithm. LDPC decoding algorithms are usually iterative in nature. They operate by exchanging messages between basic processing nodes [1].

LDPC codes are a sub-class of linear error control codes (ECC). Error control coding also referred to as channel coding is a powerful technique in digital communications for achieving reliable communication over an unreliable channel. ECC has evolved significantly since the advent of information theory by Shannon in 1948 [3] and has become an essential transceiver block in a wide range of applications.

Reed-Solomon (RS) codes are now being extensively used in Compact Disks, DVD players, hard drives and long-haul optical communications to protect the information bits against the storage and communication errors. Deep space satellite communications and 3G-wireless are also widely using another powerful family of codes called Turbo codes [4].

Low Density Parity Check (LDPC) codes are a form of error correcting codes using iterative decoding, with the advantage that they can achieve near Shannon-limit communication channel capacity. They offer excellent decoding performance as well as good block error performance. There is almost no error floor and they are decodable in linear time. Consequently, LDPC codes are used for various wireless communications and for reliable high-throughput disk data transfers [5]. Design of power efficient LDPC encoders and decoders with low bit-error rate (BER) in low signal-to-noise ratio (SNR) channels is critical for these environments. Efficient LDPC encoder hardware implementations have been suggested in [5].

OVERVIEW OF LDPC CODES

The LDPC codes are a class of linear block 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. Such a structure guarantees both: a lower decoding complexity and good distance properties [6].

We define two numbers describing these matrices: ρ for the number of 1's in each row and γ for the columns. For an m×n matrix to be called low-density the two conditions $\gamma \ll m$ and $\rho \ll n$ must be satisfied [6]. A parity-check matrix is said to be regular when γ is same for all the columns and ρ is constant for all the rows. If an LDPC code is described by a regular parity-check matrix, it is called a (γ, ρ)-regular LDPC code otherwise it is an irregular LDPC code.

Generally there are two different methods to represent LDPC codes. Like all linear block codes they can be described via matrices. The second method is a graphical representation.

REPRESENTATION OF LDPC CODES

LDPC codes are represented as matrix based or graph based. First Section which is based on matrices and second section based on graphs.

Matrix representation Matrix defined is the parity check matrix with the dimension of (8,4) code i.e. (n* m).Wr which is number of one's in row and Wc is the number of ones in columns. The low density matrix to be satisfied the conditions as Wc<< n and Wr<<m. [2][7].

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

Fig. 1. Parity Check Matrix

Graphical representation

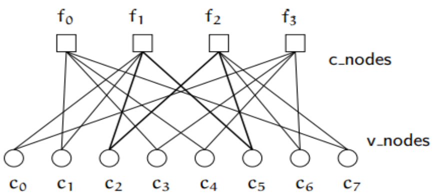

Fig. 2. Graphical Representation of LDPC codes [2] [7]

Consider above parity matrix as representation for this graph shown above. Tanner who introduced this matrix for LDPC codes [2][7]. The main advantage of this graph is that it shows the full and complete representation of the code and also describes the decoding algorithm going to be used on rest of the paper. Tanner graphs are bipartite graphs. Bipartite graph means that whose vertices are divided in to two disjoint sets .These are independent sets. Thus there will be connectivity between two disjoint sets [6]. Thus the two types of nodes in Tanner graph are named as C_ nodes and V_ nodes. There is no connectivity between C0 and F0 thence the first place is having 0.1 in the second place means that connectivity lies between F0 and C1. Check nodes are specified as m nodes that are number of parity bits and variable nodes are n which are known as number of bits in code word. Thus the element of H matrix that is parity matrix is 1 there is connectivity between Fi and Cj.

ERROR CORRECTION CODES USING PARITY – CHECKS

Here all the communications are based on bits 0's and 1's.Hence transmitted messages and received messages are 0's and 1's. For the forward error control coding techniques to the augmented message bits have to introduce the redundancy bits that are check bits to produce a code word for the particular message. Hence for every message there is a different code word in such a way a message sent from transmitter and the message received by receiver can be ensured. The coding scheme discussed here is SPC. Single parity check code which involves the addition of a single extra bit to the binary message and that value which depends upon the message bits [2].

REGULAR AND IRREGULAR LDPC CODES

There are two types of LDPC codes as regular and irregular. If Wc is constant for every column and Wr and WC are equal as well as n/m is constant for every row. There is regularity at the graphical representation. There are same numbers of edges lies between C_nodes and V_ nodes. This type is a regular LDPC codes. If the numbers of 1's are not constant in each row and column then that code is termed as Irregular LDPC codes [6].

LDPC ENCODING

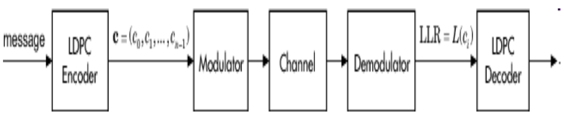

Fig. 3. Communication system with LDPC Encoder & Decoder

There are mainly two methods of LDPC Encoding:

i) General encoding method

ii) Efficient encoding method

LDPC ALGORITHMS

DECODING ALGORITHMS FOR LDPC CODES

Different authors come up independently with more or less the same iterative decoding algorithm. They call it different names: the sum-product algorithm, the belief propagation algorithm, and the message passing algorithm. There are two derivations of this algorithm: hard-decision and soft-decision schemes.

HARD DECISION DECODING

In this decoding scheme the check nodes finds the bit in error by checking the even/odd parity [7]. The messages from message nodes are transmitted to check nodes, check node checks the parity of the data stream received from message nodes connected to it. If number of 1's received at check nodes satisfies the required parity, then it sends the same data back to message node, else it adjusts each bit in the received data stream to satisfy the required parity and then transmits the new message back to message nodes. The bit-flipping algorithm is an example of hard-decision message-passing algorithm for LDPC codes [7]. The bit-flipping decoder can be immediately terminated whenever a valid codeword has been found by checking if all of the parity-check equations are satisfied. This is true of all message-passing decoding of LDPC codes and has two important benefits; firstly additional iterations are avoided once a solution has been found, and secondly a failure to converge to a codeword is always detected.

SOFT DECISION DECODING

Soft-decision decoding of LDPC codes, which is based on the concept of belief propagation, yields in a better decoding performance and is therefore the preferred method [7]. The underlying idea is exactly the same as in hard decision decoding. In this decoding scheme, the messages are the conditional probability that the received bit is a 1 or a 0 given the received vector. The sum-product algorithm is a soft decision message-passing algorithm [7]. The input bit probabilities are called the a priori probabilities for the received bits because they were known in advance before running the LDPC decoder. The bit probabilities returned by the decoder are called the a posteriori probabilities. In the case of sum-product decoding these probabilities are expressed as log-likelihood ratios. For a binary variable x it is easy to find P(x = 1) given P(x = 0), since P(x = 1) = 1−P(x = 0) and so we only need to store one probability value for x. Log likelihood ratios are used to represent the metrics for a binary variable by a single value:

$$L(x) = \log\left(\frac{P(x=0)}{P(x=1)}\right)$$

Where log to mean loge.

ERROR DETECTION AND CORRECTION

Suppose a code word sent from transmitting section to receiving section which gets flipped. In LDPC codes it is easily possible to detect and correct the flipped bit. Every code word should satisfy the equation given below. If this equation is not satisfied then we should know that the received bits are error. HyT = 0 [2] where H represents parity check matrix. The vector s=HyTwhich specifies the syndrome of y. The numbers of bit positions differ between two code words which are termed as HAMMING DISTANCE.Minimum hamming distance is the measure of ability of the code to detect error. For example c1 = [1 0 0 0 1 0 1 1] and c2 = [1 0 1 0 1 1 1 1]. The hamming distance is 2 since bit 3 and bit 6 gets flipped.

DISADVANTAGES OF LDPC CODES

Disadvantages of the LDPC decoder include

- Complicated memory structure for serial architecture
- Complexity with interconnect routing for parallel architectures.
- Serial architectures are slower, resulting in reduced cost.
- Parallel architectures have higher throughput and lower power dissipation.
- It is found that low-bit quantization may cause severe deterioration in the soft decoding performance. Also even though Q-factor fluctuation cannot be avoided in the experiment.
- Soft decoding of LDPC codes is not available for 10 Gbps or higher speed fiber-optic communication systems.
- BP decoding algorithm offers good performance, because of floating point computations it can become too complex for hardware implementation.

APPLICATIONS OF LDPC

It is error correcting codes in DVB-s2 standard for satellite communication for digital television. It is also used in Ethernet 10 base T. It is also a part of Wi-Fi 802.11 standard. The optional parts of it are 802.11 ac and 802.11n. It is also used in OFDM networks where data transmission to be without error. It is even with low bit rate also.

CONCLUSION & FUTURE SCOPE

Low-density parity-check (LDPC) code, a very promising near-optimal error correction code (ECC), is being widely well thought-out in next generation industry standards. LDPC code implementations are widely used in DVB-S2, T2 or Wi-MAX standards. Unlike many other classes of codes LDPC codes are already equipped with very fast (probabilistic) encoding and decoding algorithms. These algorithms can recover the original codeword in the face of large amounts of noise. New analytic and combinatorial tools make it possible to solve the design problem. This makes LDPC codes not only attractive from a theoretical point of view, but also perfect for practical applications. LDPC codes have been the subject of intense research lately because of their capacity achieving performance and linear decoding complexity. Current hardware speeds make them a very attractive option for wired and wireless systems.

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