Review on Decoding Algorithms Useful in Modified Low Density Parity Check Code for Optical Fibre Communication

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ABSTRACT:
Low-density parity-check (LDPC) codes are linear block codes. It is called low density parity check code because their parity-check matrix contains only a few 1's in comparison to the amount of 0's. These codes were first introduced by Gallager. It is a very powerful code for forward error correction system. The presently used LDPC code in optical fibre communication systems is not meeting the requirements of the high speed fibre optics communication systems. So the LDPC code can be modified and with which the quality factor can be improved. This modification is beneficial for the high speed fibre optic communication systems. We present here a comprehensive review of decoding algorithm of modified Low density parity check code useful in Optical fibre communication. BP and the MS decoding algorithms which are modified decoding algorithm are use for a better performance in high speed fibre optic communication.

KEYWORDS: Low density parity check codes (LDPC), Belief propagation (BP), Min-sum decoding (MS), Bit error rate (BER), additive white Gaussian noise (AWGN)

1. INTRODUCTION
The recent studies have verified that soft-decoding of low-density parity-check (LDPC) code requires high quantisation resolution which is difficult to achieve for high-speed fibre-optic communication systems. The low-density parity-check (LDPC) code is a powerful forward error correction code for fibre optic communication. In this paper we present review in which decoding algorithm of

Low density parity check code is modified which effectively improve the performance at quantisation resolution as low as two-bit or one-bit. By proper implementation of this technique, the Q-factor improvement of 2-dB can be obtained in comparison to RS code. [1]

A. LDPC CODE
LDPC codes are described by two ways either matrices or with graphical representation.

I) MATRIX REPRESENTATION
Take an example for a low-density parity-check matrix first. The matrix is a parity check matrix with dimension n × m for a (8, 4) code. for defining the number of 1's in each row wr is used and wc is used for the columns. For a matrix to be called low-density the two conditions wc << n and wr << m must be satisfied. For that reason the parity check matrix should usually be very large.

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

Fig 1: Parity check matrix

II) GRAPHICAL REPRESENTATION
The graphical representation for LDPC code is tanner graph. This code not only provide the complete representation of the code, they also help to describe the decoding algorithm.
Basically tanner graphs are bipartite graphs. That means that the nodes of the graph are separated into two distinctive sets and edges are only connecting nodes of two different types. The two types of nodes in a Tanner graph are called variable nodes (v-nodes) and check nodes.

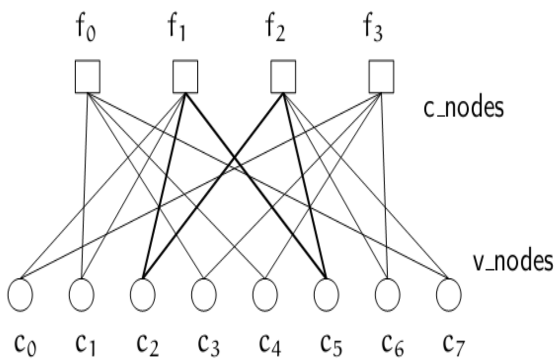

Fig 2: Tanner graph corresponding to the parity check matrix in Fig 1. The marked path c2 → f1 →c5 → f2 → c2 is an example for a short cycle. Those should usually be avoided since they are bad for decoding performance. [11]

B. DECODING ALGORITHMS OF LDPC
In this technique the BP and the MS decoding algorithms are use for a better performance. The decoding performance of LDPC code is also verified by experiment where 2-dB coding gain over RS (255, 239) code can be obtained at the same redundancy with the quasi-cyclic LDPC code studied in the simulation. The experimental data are used for processing timing synchronisation, frame synchronisation and channel estimation for each data frame before decoding in the experiment. [1]
LDPC codes provide a significant system performance enhancement with respect to the FEC schemes employed in

optical communication systems. In the area of error control coding during the last few years ignited by the excellent bit-error-rate (BER) performance of the turbo decoding algorithm demonstrated by Berrou et al[3]. Low density parity check codes (LDPC) is a prime examples of codes on graphs. LDPC codes per-form nearly as well as earlier developed turbo codes in many channels [such as additive white noise Gaussian (AWGN) channel, binary symmetric channel and erasure channel]. The theory of codes on graphs has improved the error performance [2]. Pearl developed the belief propagation algorithms and graphical models in the expert systems literature [3].

The belief propagation (BP) algorithm [5] provides a powerful tool for iterative decoding of LDPC codes. LDPC codes with iterative decoding based on BP achieve a remarkable error performance that is very close to the Shannon limit [6]. For that reason LDPC codes have received significant attention recently.

A LDPC code is specified by a parity-check matrix, it contains more number of zeros and only a small number of ones. Generally, LDPC codes can be divided into regular LDPC codes and irregular LDPC codes. If the weights of rows and columns in a parity check matrix are equal then an LDPC code is called as regular and it is called as irregular if not. It is proved that with properly chosen structure, irregular LDPC codes have better performance than regular ones [7].

For decoding of LDPC codes, soft decision, hard decision or hybrid decision decoding can be used. It has been shown that one of the most powerful decoding methods for LDPC codes is soft decision decoding based on BP. Although BP decoding offers good performance, because of floating point computations it can become too complex for hardware implementation. The min-sum (MS) algorithm reduces the complexity of BP by approximating the calculation at the check nodes with a simple minimum operation [4].

2. LIMITATIONS

The quantisation effect on the soft decoding of LDPC codes in fibre-optic communication systems is studied through simulation and the decoding performances for several quantisation resolutions are compared. It is found that low-bit quantisation may cause severe deterioration in the soft decoding performance. Also even though Q-factor fluctuation cannot be avoided in the experiment. [1]

Compared with the RS(255, 239) code with hard decoding in the present systems, soft decoding of LDPC code give better result. Unfortunately, analogue-to-digital conversion (ADC) with high quantisation resolution for soft decoding of LDPC codes is not available for 10 Gbps or higher speed fibre-optic communication systems. Several recent experiments for maximum-likelihood sequence estimation (MLSE)-based electrical dispersion compensation (EDC) use the ADCs at 10 Gbps.[1]

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3. RELATED WORK

An approach is present for constructing LDPC codes without cycles of length 4 and 6. Here we design 3 sub matrices with different shifting functions, and then these sub matrices are combine into the matrix specified by the proposed approach, finally, this matrix expand into a desired parity-check matrix using identity matrices and cyclic shift matrices of the identity matrices. By simulation result of AWGN channel it is verified that the BER of the proposed code is close to those of Mackay's random codes and Tanner's QC codes.

A bipartite graph called Tanner graph describe LDPC codes, and the girth of a Tanner graph is the length of the shortest cycle in the graph. To prevent the sum-product algorithm from converging girths in the Tanner graphs of LDPC codes is use. Short cycles; degrade the performance of LDPC decoders, because they affect the independence of the extrinsic information exchanged in the iterative decoding. Hence, LDPC codes with large girth are desired. There are many possible ways to construct the LDPC codes with large girths. Due to the complicated constraints for the structures of parity-check matrices, some of the code constructions are not satisfied for application. To solve the problem, this letter provides a different construction of LDPC codes with large girth. [8]

4. FUTURE WORK

Low-bit quantisation may cause severe deterioration in the decoding performance. For the improvement of the low-bit quantised soft decoding, a simple modification to the decoding algorithms is proposed.[1]

Analogue-to-digital conversion (ADC) with high quantisation resolution for soft decoding of LDPC codes is not available for 10 Gbps or higher speed fibre-optic communication systems. But the ADCs at 10 Gbps used in several recent experiments for maximum-likelihood sequence estimation (MLSE)-based electrical dispersion compensation (EDC). For that reason the original LDPC min-sum (MS) decoding algorithm can be modify and this modified algorithm can help to improve the decoding performance at low quantisation resolution. [1]

For computing the capacity of low-density parity-check (LDPC) codes under message-passing decoding density evolution algorithm is use. For memory less binary-input continuous-output additive white Gaussian noise (AWGN) channels and sum-product decoders, we use a Gaussian approximation for message densities under density evolution to simplify the analysis of the decoding algorithm. We convert the infinite-dimensional problem of iteratively calculating message densities, which is needed to find the exact threshold, to a one-dimensional problem of updating means of Gaussian densities. This simplification not only allows us to calculate the threshold quickly and to understand the behaviour of the decoder better, but also makes it easier to design good irregular LDPC codes for AWGN channels. [9]

we derived the density evolution for two im-proved BP-based algorithms of the LDPC decoding, i.e., the normalized and the offset BP-based algorithms. The den-sity evolution of these two improved BP-based algorithms was studied in a practical way, with no efforts on theoretic issues such as concentration and convergence theorems. The numerical results show that both algorithms can achieve performance very close to that of the BP algorithm with properly chosen decoder parameters, and the simulation results validate it. The discretized density evolution of the BP-based algorithm has also been derived and extended to the offset BP-based algorithm. The simulations show that with uniform quantization of only 6 bits, the quantized offset BP-based algorithm has degradation less than 0.1 dB compared to the BP algorithm. [10]

5. CONCLUSION

The quantisation effect on the soft decoding of LDPC codes in fibre-optic communication systems is studied through simulation and the decoding performances for several

quantisation resolutions are compared. In the decoding performance it is found that low-bit quantisation may cause severe deterioration. For the improvement of the low-bit quantised soft decoding, a simple modification to the decoding algorithms is proposed. Simulation results show that, comparison to the without modified decoding algorithm the modified 2-bit quantised MS decoding can achieve about 0.6 dB performance gain. The proposed modification scheme can also be applied to the BP and the MS decoding algorithms for a better performance.
By experiment the decoding performance of LDPC code is also verified where 2-dB coding gain over RS (255, 239) code can be obtained at the same redundancy with the quasi-cyclic LDPC code. Even though Q-factor fluctuation cannot be avoided in the experiment, the experimental BER is only slightly worse than the one from the simulation. Quasi-cyclic structure of LDPC code provides a way for distributed memory storage and access of LLR information during row and column operations of the information exchange in an orderly way. The encoder and decoder implementation of such a LDPC code can more easily meet the high-speed requirement for fibre-optic communication systems.

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