Lower Computation and Storage Complexity of QC-LDPC Codes in Rayleigh Fading Channel

Abid Yahya, Othman Sidek, M. F. M. Salleh and Farid Ghani

Abstract—**This paper presents the construction of large girth Quasi-Cyclic low density parity check (QC-LDPC) codes and a new multicarrier frequency hopping spread spectrum (MCFH-SS) system. The performance of newly obtained codes is evaluated by comparing with Reed Solomon (RS) codes. The computer simulation results show that the two girth-twelve QC-LDPC codes significantly outperform conventional RS codes with a gain of 2.1 dB at**

Index Terms—**Bit error rate, DPSK, Girth, QC-LDPC, Rayleigh fading**

I. INTRODUCTION

A thought-provoking mission for wireless channels to communicate authentic data postulates many unusual problems. Low-density parity-check codes [1] have acquired considerable attention due to its near-capacity error execution and powerful channel coding technique with an adequately long codeword length. The performance of LDPC codes has been investigated in [2, 3], and are encountered to outperform turbo codes.

The potency of LDPC codes is outclass over the additive White Gaussian noise (AWGN) channel [4], where coherent detection employing phase shift keying (PSK)[5] can be carried out with carrier phase estimation. Precise phase tracking and high-quality estimation of channel state information (CSI) is required for the appropriate execution of coherent detection.

The coherent detection of PSK often experiences problems while performing on Rayleigh fading channels. The reason is inaccurate CSI, due to complex channel gains variation with a passage of time, specified that LDPC codes characteristically function at a very low signal-to-noise ratio (SNR).

In order to acquire accurate CSI, the authors in [6], have derived the estimates of the complex channel gain and variance of the additive noise from known pilot symbols and an estimation filter. In their work the authors have employed Turbo codes which have been detected coherently over for transmission.

Other authors have designed three capacity approaching LDPC codes having CSI at transmitter and receiver. In [7], authors have used extrinsic information transfer (EXIT) function method to design the LDPC codes in the SNR regime for flat Rayleigh fading channels by employing quadrature phase-shift keying (QPSK) modulation. The power consumption problem arises again, because the QPSK modulation uses twice the power of PSK, since two bits are transmitted simultaneously.

Wireless communications are impacted by respective channel imperfectness that considerably degrades system execution. One of the aftermaths is the loss of carrier phase synchronization. Differential and noncoherent techniques do not entail a phase reference and, for this reason, have acquired esteem recognition in wireless communications

To avoid CSI, some authors [8] have employed frequency shift keying (FSK) modulation scheme for noncoherent detection with LDPC codes. Nevertheless, the power efficiency of FSK is less than PSK.

No channel estimation or equalization is expected if DPSK modulation is employed. Accordingly, the receiver can be more elementary and pilot symbols can be neglected at the cost of higher SNR.

In [9,10], the authors have prevailed over the CSI by employing differential PSK modulation over Rayleigh fading channels with regular LDPC codes. However, the metric, which has been derived in [9], requires accurate estimates of the amplitudes of the complex channel gains, which can degrade the performance of the system if estimation falls erroneous.

In [10], authors have emphasized the operation of differential detection relatively to codes themselves. They have employed LDPC codes with column weights 3 and 4, which have high computation and storage complexity. While LDPC codes with column weight $j = 2$, have respective advantage, since they have lower computation and storage complexity and their encoders and decoders are merer to employ. In work [9, 10], authors have used differential PSK modulation but with regular LDPC codes.

In this work, large girth QC-LDPC codes have been developed by deriving the basic idea from Bit-Filling (BF) and Progressive Edge-Growth algorithms proposed by Campello et al. (2001) [11] and Hu et al. (2005)[12], respectively. Some more constraints have been employed in this work by keeping the row weight dependable on group size. A degree of distribution is designed carefully, since a degree of distribution particularly variable-node degree distribution, deeply affects the error correcting performance.

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A degree of distribution is said to be concentrated if every node has the same degree.

II. Proposed for Paper Submission

The bit-filling (BF) algorithm designs a LDPC code by connecting rows and columns of a code one at a time without violating the girth condition. In the BF algorithm, the number of row connections is almost uniformly distributed by first selecting randomly the rows with the least number of connections. The codes so obtained are either with a fixed row or fixed column weight. The structure of row-column connections in the BF algorithm is, therefore, almost random and hence increases the complexity of the decoder. In order to simplify the hardware implementation, the BF algorithm must be modified to incorporate some form of structured decoder interconnections. In the proposed algorithm this structuring in interconnections is brought about by dividing the rows with respect to the group size. Such a division guarantees a concentrated node degree distribution and reduces the hardware complexity.

The proposed algorithm for the construction of a (N, j, k) code is best described in the form of following steps.

1. Rows in the set could be chosen randomly or sequentially, preferable choice is random since random searches will result in a variety of codes.
2. The rows are evenly divided with respect to the group size. Each group must contain k rows. The row groups are paired in such a way that each group appears k times so that there are 2k row group pairs.
3. Note: The dependence of row weight on group size keeps the constructed codes regular. Otherwise the groups with different number of appearances will generate irregular codes.
4. Rows in the second and following groups are placed in descending order; this satisfies the least desired distance to search, for each group.

As an example Figure 1 shows row connections for a (16, 2, 4) LDPC code construction using steps 1 to 3 above. There are two groups of size 4. The first group and row 1 are always chosen as the reference group and row, respectively. The Girth of this code is found to be eight.

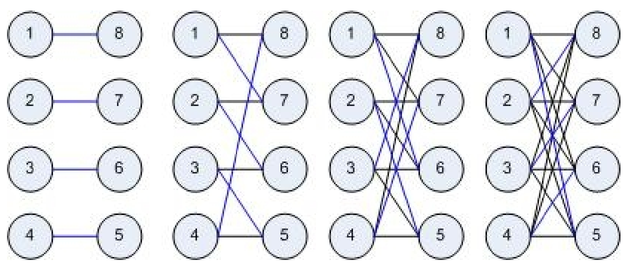

Fig.1 Graphical representation of a (16, 2, 4) code

With reference to Figure 1 the following may be noted:

5. The regular codes make it easy to construct the parity check matrix due to uniform distribution of 1's and 0's from the column formation.
6. The row groups are paired two times the row weight, which has cut down hardware implementation cost and complexity as compared to the connection of individual columns and rows. The complexity of directing within groups computes on the transposition employed to connect rows and columns between groups. This modifies handling, when messages are communicated between functioning nodes.

It may also be pointed out that:

7. Adopting Algebraic methods [13], are used to determine bounds on girth, rate or code dimensions for QC-LDPC codes.
8. Rows are used to form a distance graph, which is then transformed to a parity-check matrix. To acquire a given girth, rows that are at desired distance from each other are searched sequentially or randomly in each group and connected.
9. QC-LDPC codes have encoding advantage over conventional LDPC codes and their encoding can be carried out by shift register with complexity linearly proportional to the number of parity bits of the code. Additionally, QC-LDPC codes require less amount of memory as compared to general LDPC codes, since their parity check matrices consist of circulant permutation matrices or the zero matrix. Actually, their expected memory for storing them can be cut down by a factor $\frac{1}{p}$, when $p \times p$ circulant permutation matrices are employed. The entire parity check matrix can be partitioned into an array $p \times p$ block matrices, each one denoted as $H_{i,j}$, each block matrix $H_{i,j}$ is either a zero matrix or right cyclic shift of an identify matrix.
10. For each, decoding iteration, to be accomplished, 2 p clock cycles are the requisite. The decoder works in check node and variable node processing mode during the first and second p clock cycles respectively. The decoder performs the computations of all the check node and variable nodes and brings in the message passing between neighboring nodes.

III. Results And Discussion

The focal intention of the algorithm is to generate high-rate LDPC codes specified a particular code length

The allowable maximum number of iteration for decoder is set to 60 with 5 microseconds symbol period and 1.1 milliseconds coherence time in a flat Rayleigh fading environment by employing DPSK modulation scheme.

The curves in Figure 2 show slight performance enhancement at diversity levels L=2 and L=3. However, by increasing the diversity level to L=4 the newly obtained codes outperform the results obtained in Figure 6 of [9], by about 1.5 dB gain at 10^{-5} BER.

LDPC codes with column weight j = 2, have respective advantage, since they have lower computation complexity and storage complexity, their encoders and decoders are merer to employ. They have ameliorated block error statistics properties which have been mentioned by Song et al. in [14].

The performance of two twelve-girth QC-LDPC against

10.7763/IJCTE.2009.V1.17

RS codes in PBNJ environment over AWGN channel is revealed in Fig.3. The signal noise ratio is set to be 20 dB to attain a packet error ratio of 10^{-3} against the value fractional bandwidth. The curves in Fig.3 show that newly obtained codes cater a gain of 2.1 dB compared with RS codes at the worst condition of partial band r =1.

This shows the robustness of the system by employing newly obtained codes as FEC code.

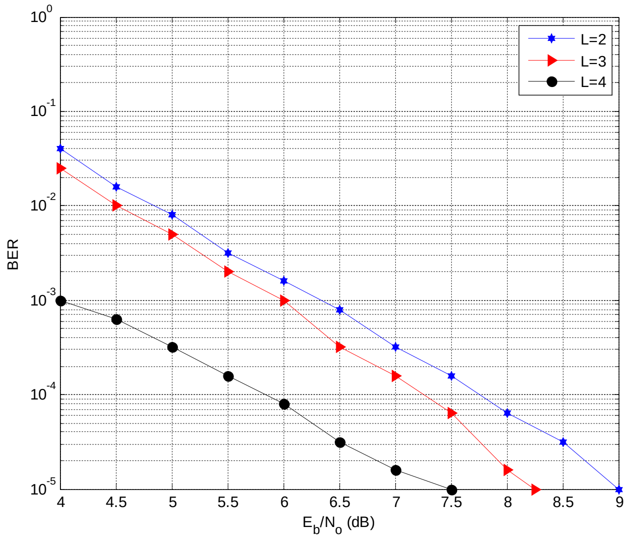

Fig. 2 BER of two girth-twelve QC-LDPC codes for given value of E_b / N_o in Rayleigh fading channels at diversity levels 2, 3 and 4

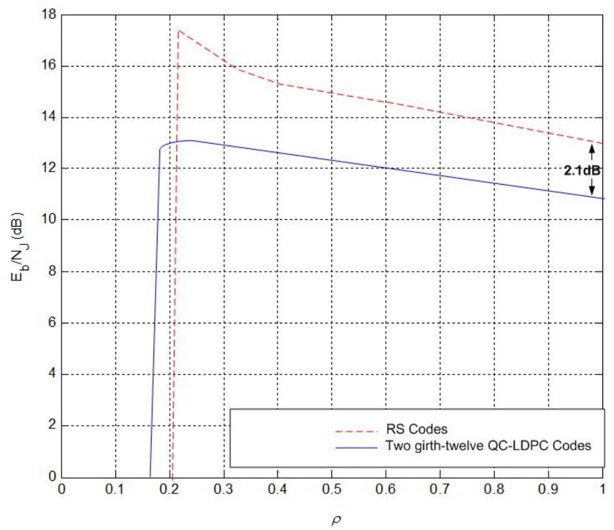

Fig. 3 Performance evaluation of two girth-twelve QC-LDPC codes and conventional RS codes over PBNJ environment

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