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Design of efficient rate compatible LDPC codes

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Abstract— Within the current research, a puncturing procedure, which is novel as well as effective for attaining rate compatibility is presented. The low-density parity check codes (LDPC) of parallel concatenation gallager codes (PCGC) has been applied which includes the Quasi-Cyclic (QC) LDPC codes as one component, and two irregular components of the (LDPC) within the forward error correction coding (FEC). The puncturing procedure is effective as well as unique within this research. The LDPC component codes help create the variable code rates and the decoding challenges are reduced. Parallel concatenation has been used to apply the (QC-PCGC). They are component codes applied with the puncturing procedure to establish code rate and to decrease decoding challenges faced with several applications. The punctured coding system is tested using different channels. The simulation outcomes indicate that there is enhanced performance as compared to using the traditional PCGC or the LDPC long unique code which makes use of the same parameters, before and after puncturing. For the communication applications in the future, for instance, the 5G, the coding system structure that has been presented can be used. It is possible since there is a need for flexibility within forward error control coding and decoding and encoding should have lower complexity levels.

Keywords— LDPC, parallel concatenation, iterative decoding, punctured codes.

1. Introduction

Parallel concatenated codes are signified through PCGCs which have been established through parallel concatenation of greater than a single LDPC component. The LDPC codes concatenated structures have been analyzed and they indicate effective performance [1-2].

Within the PCGC structure, the flexibility is high which indicates that error control coding has low energy applications. For the implementation, trade off is present for the constituent codes in mixed numbers which are concatenated based on the dynamic association of the coding performance with channel environment. The maximized the requirements of the energy resources. The PCGCs turbo code structure is used to decrease the lengthy code complexity and the complicated processes can also be decreased. It helps sustain the information flow within the component decoders [3].

Within the current research, additional assessment has been carried out for the PCGCs through the analysis of the LDPC codes puncturing process along with the coding performance enhancements of any sort. There are punctured parity check bits to make sure the system functionality is enhanced and the most effective rate compatible is attained. From the initial mother code, this helps extract the highest code rate [4]. Research has been carried out for the constructed QC-LDPC from any group or ring. As compared to the conventional efficient coding scheme, the operation number at the time of the encoding and decoding procedure has been decreased [5-6].

Observation has been done for the punctured LDPC code characteristics using a technique. The constant threshold is used for the puncturing technique so that the system can use low coding rates [7]. For the belief propagation (BP) iterative assessment, the Random puncturing across a binary input AWGN channel have been applied. The outcomes indicate specific predictions were achieved as compared to values which were extracted through the use of several puncturing density evolutions [8].

To analyse and evaluate the relevant punctured LDPC distribution, the punctured LDPC codes Gaussian Approximation was applied. The outcomes indicated that the punctured LDPC codes has enhanced performance [9]. The research indicates achievable coding rates including coding complexity. The research outcomes focused upon attaining information streams upper limits [10].

Using the QC-LDPC codes within the linear coding system, it was possible to perform essential roles. It helps reduce the intricacy of decoding and enhance the system performance. If the codes have the same cycle distribution, the term QC-LDPC codes is applied. Using shift registers, the QC-LDPC can be encoded effectively.

Since a quasi-cyclic structure is present for the codes, along with straightforward address creation process, the decoder structures are in need for lower memory needs along with local memory access [11-13]. Amongst the QC-LDPC and the PCGC system, a strong puncturing association can be established. This would help enhance the wireless coded system functioning.

Various PCGCs construction, within the cognitive radio dynamic and fragile environment, have been assessed. The Parallel concatenation proposed scheme with the interleaver is assessed using parameters which develop the bit error rate and reduce the encoding complex within the current research, the QC-PCGCS complexity assessment and BER has been analysed. The results indicate that as compared to the traditional PCGC and single LDPC codes, they perform much effectively with similar parameters in random and normal puncturing [14-15].

The following is the remainder of the research. Within section 2, the QC-PCGC proposed punctured procedure would be explained. Section 3 includes the BER performance computer simulations and complexity assessment. Section 4 presents the conclusion.

2. The Proposed efficient rate compatible method

2.1 Efficient rate compatible Of Encoding System

The MPCGCs are established using various LDPC codes in the Turbo codes structure. The parallel concatenation, without the interleaver, is used for the MPCGC structure. It is indicated in Figure 1. The total length (N) is attained along with the codeword rate, R=1/(M+1) code. The code rate R as K/P has been considered to use puncturing in MPCGC [16-18].

In this case, K and P state the information bits length and the codeword respectively. The proposed punctured QC-PCGC system diagram is presented in Figure 2. There are two Gallager random codes and one LDPC component of circulate permutation matrices as QC-PCGC properties.

These matrices have several column weights and are similar to the WiMAX standard. The proposed punctured technique is established for codeword code rate and length. Furthermore, the codeward bits subset is removed before moving the codeward towards the receiver. From the codeward, the X bits series would be punctured which influence the codeward length decrease from the P to P-X. After puncturing the codeward, the puncturing fraction $\beta = X/P$ should be applied to attain the mentioned code rate.

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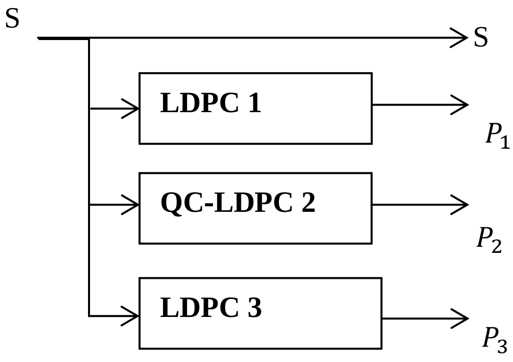

Figure1. QC-PCGC encoder.

To assess the procedures, the PCGC have been applied upon BPSK modulation where R=1/4 and block length N=768 and each code length is P = 384 and R = ½. When the PCGC is up to date, puncturing is done and the highest code rate is attained from ¼ to 1/2. Elimination of random bits is done with no sequence and randomly. The process indicated a weak BER performance by process when compared to other procedures. In the next procedure, the ensemble bits are subjected to normal puncturing. This indicates that the bits fixed part (128 bits) must be removed from the same area of each LDPC codeword. The codeword must maintain the 192 bits. Within the third procedure, the ensemble bits are punctured in an irregular manner. This indicates that a fixed part must be extract from distinct location of each LDPC codeword. At the receiver, the punctured bits location must be in accordance with the puncturing kind to de-puncture the process through the addition of zero's at the locations for the attained codeword. The calculation of the Rayleigh distribution probability density function (pdf) is mentioned [19-20].

$$f(y) = \frac{2y_j}{\sigma^2} e^{\frac{-2y_j}{\sigma^2}} \qquad (1)$$

Where σ^2=E $(|h(t)|^2)$.

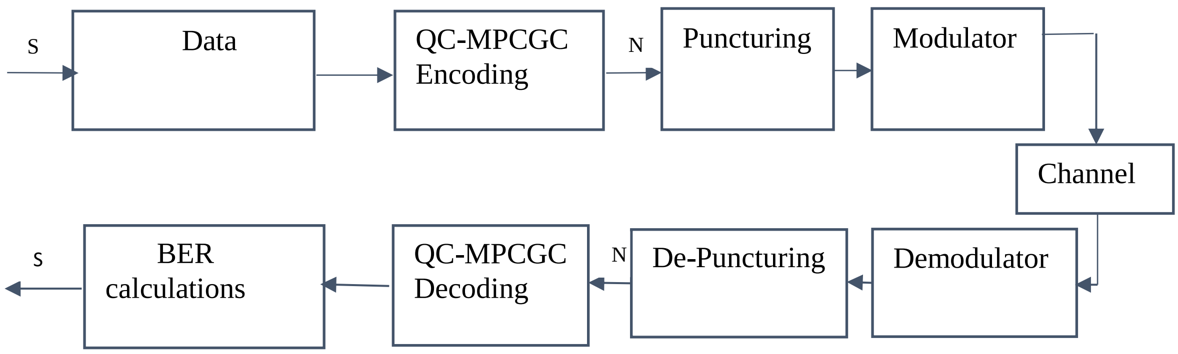

Figure. 2 Proposed efficient rate compatible of QC-PCGC model

2.2 Efficient rate compatible Of decoding System

Due the reducing in the complexity, the iterative sum product algorithm (SPA) has used with the component of the LDPC codes.

The Gaussian probability.

$$p\left(y_j \middle| x_j = +1\right) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{\frac{-(y_j-1)^2}{2\sigma^2}}. \quad (2)$$

and the message vector probability at site l be

$$f_j^1 = p\left(x_j = +1 \middle| y_j\right) = \frac{1}{1+\exp\left(\frac{-2y_j}{\sigma^2}\right)} . \quad (3)$$

The PCGC decoder at the received bits has managed to add zeros at the knowing positions of the removed bits. In addition the likelihood ratios (LLR's) could be calculated as 0.5.
Through the super iteration of the PCGC, all component decoders has ability to control on the processing information through the SPA. The sequence got is utilized by each of these without using extrinsic input. The decoding techniques happen in a continuous way till (M) part decoders combine to approve codewords, or to accomplish the full number of super iterations [21-22].

3. Simulation Result And Discussion

A. BER Performance Analysis

Three LDPC component codes have been chosen within this research as the parallel concatenation with puncturing influence. The coding rate is controlled using the lower decoding complexity. Furthermore, 45 local iterations at maximum and 30 super iterations have overall PCGC within each LDPC component.
The PCGC parameters have three LDPC component with ½ code rate, different MCWs and the same parity dimension H (192,384).
The total code rate R=1/4, MCW1=1.89, MCW2=2.82, MCW3=1.83 and N=768. In addition to, the original LDPC component have R=1/2, N=384, MCW=2.83. Figure 3. illustrated the properties of the proposed puncturing QC-PCGC with BPSK over AWGN channel.
The first and third order is present with the Gallger LDPC component but the second LDPC component maintains a circular construction QC-LDPC.
The QC-LDPC component parameters are that 3, 6 are the row and column weight of the parity check matrix. 64 of submatrices rank is the prime number for the parity check matrix. The QC-LDPC component use provides advantages within the proposed QC-MPCGC since the high Eb/No region can be controlled and there is regular circular permutation.
Illustration has been presented for the proposed QC-PCGC puncturing performance and the traditional MPCGC. After encoding, the codeword N=768 would be passed to the puncturing process using the puncturing fraction β =0.5 to be N=384. At the high Eb/No region, the proposed QC-PCGC irregular punctured indicates effective performance and the coding gain is 0.6 dB at 1e^ (-3) when compared to the conventional PCGC irregular punctured [14] using similar parameters. The original single LDPC by 0.3 dB at BER 1e^ (-5) has been outperformed by the proposed QC-PCGC irregular punctured.
Figure 4 and Figure 5 illustrate the different BER and packet error ratio PER comparison of the proposed QC-PCGC irregular punctured over a flat Rayleigh fading channel. The proposed QC-PCGC and PCGC irregular punctured in Figure 4 provides coding gain 1.8 dB and 1.6 dB at BER $1e^{-3}$ compared to the single LDPC component regular punctured.

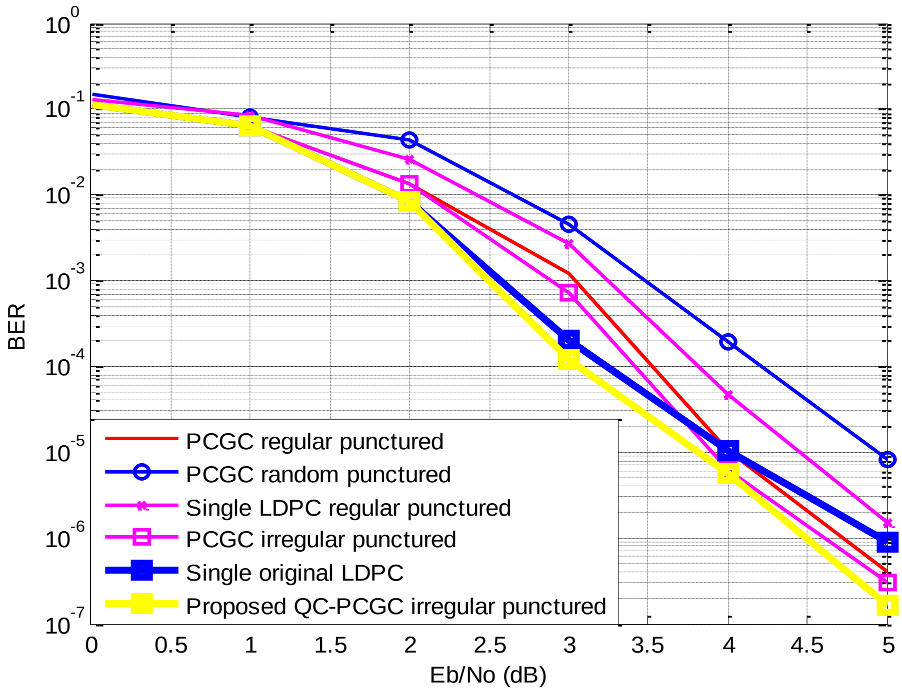

Figure 3. BER performance of different punctured QC-PCGC over AWGN channel

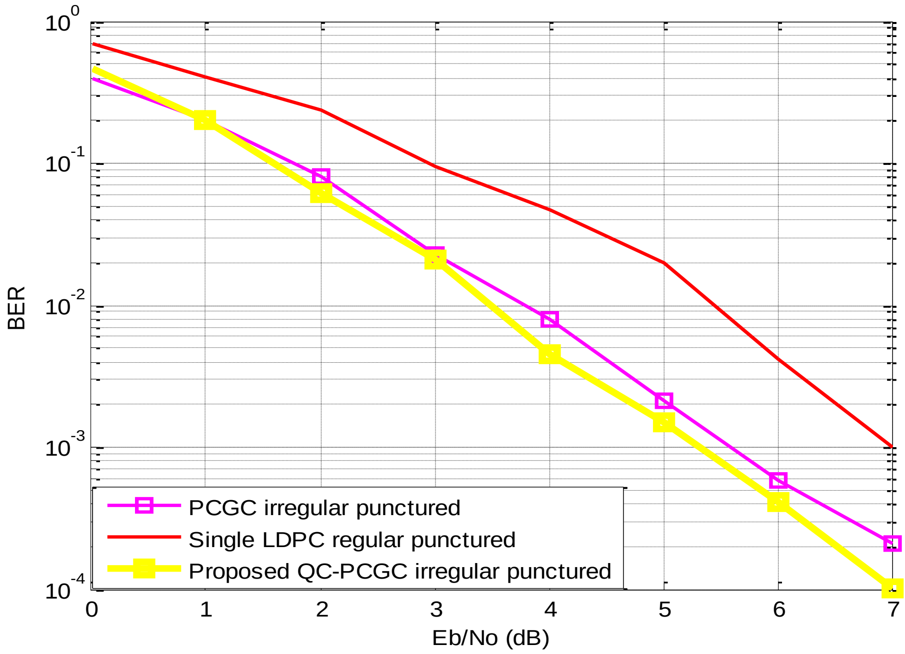

Figure 4. BER comparisons of punctured QC-PCGC with LDPC over flat Rayleigh fading channel

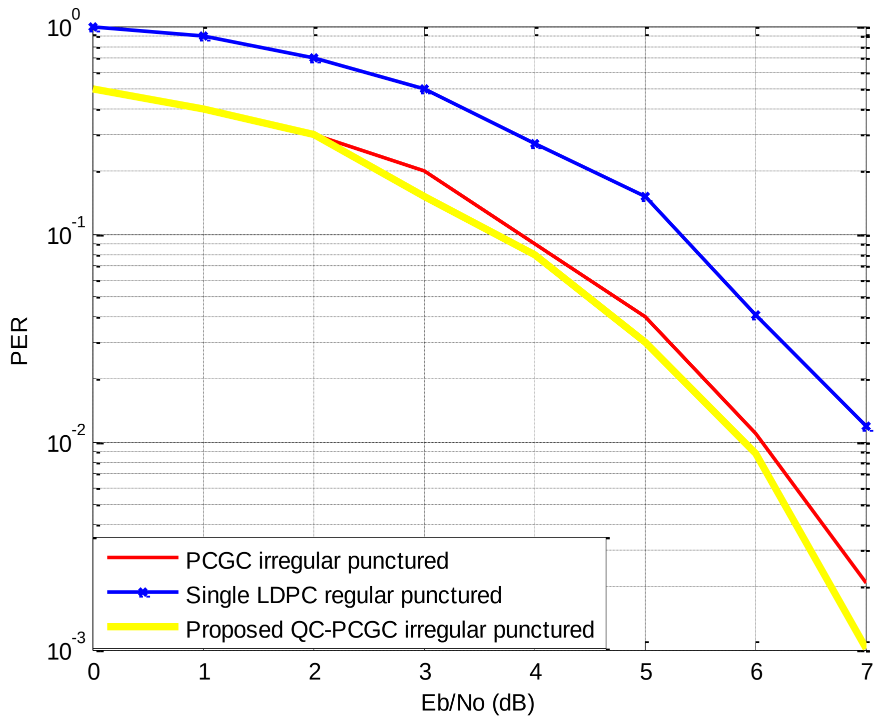

Figure 5. PER comparisons of punctured QC-PCGC with LDPC over flat Rayleigh fading channel

B. Proposed rate compatible Computational Complexity Analysis

The outcomes indicate that the proposed punctured QC-PCGCs complexity would decrease if compared to the traditional punctured multiple (MPCGC) mechanism. Furthermore, the decoder LLR values are 0.5 since there is a fixed 0 value for the punctured bits.

The decline in complexity within the decoder is due to this since there is a decrease in the required total iterations. At the same time, the decoder is enable to converge rapidly. Furthermore, the proposed punctured PCGCs advantages can be attained without enhancing the complexities.

The encoding/decoding complexity estimation can be done for each iteration through the maximum number value which can be counted within the code Tanner graph by *(N* MCW)* for each LDPC [14][23][24].

For the PCGC system the maximum number of edges per each super iteration can be calculated as below,

$$\text{Maximum edges per each super iteration} = \text{Iterations number} \sum_{l=1}^{M} N_l MCW_l \quad (4)$$

Comparisons have been made upon complexity in a preliminary manner based on the Eb/No. Results indicate that analysis is based on the LDPC edges and iterations. The PCGC benefits are indicated in figures 6 and 7 when being compared to the traditional LDPC for the Kim et al published outcomes at specific parameters [12][24].

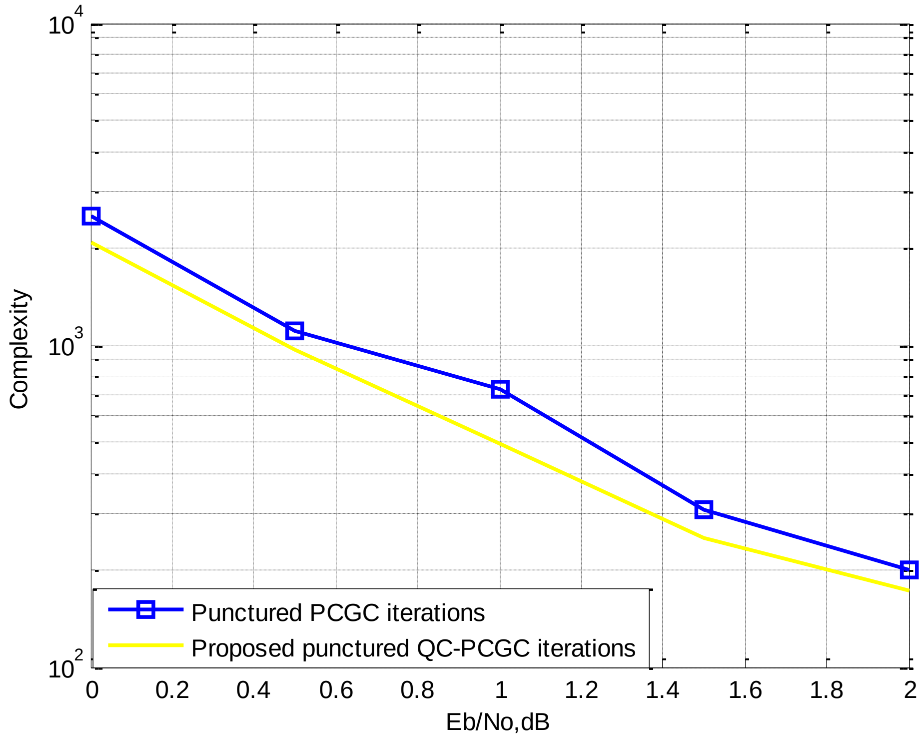

Figure 6. Complexity comparisons between punctured QC-PCGC and conventional PCGC

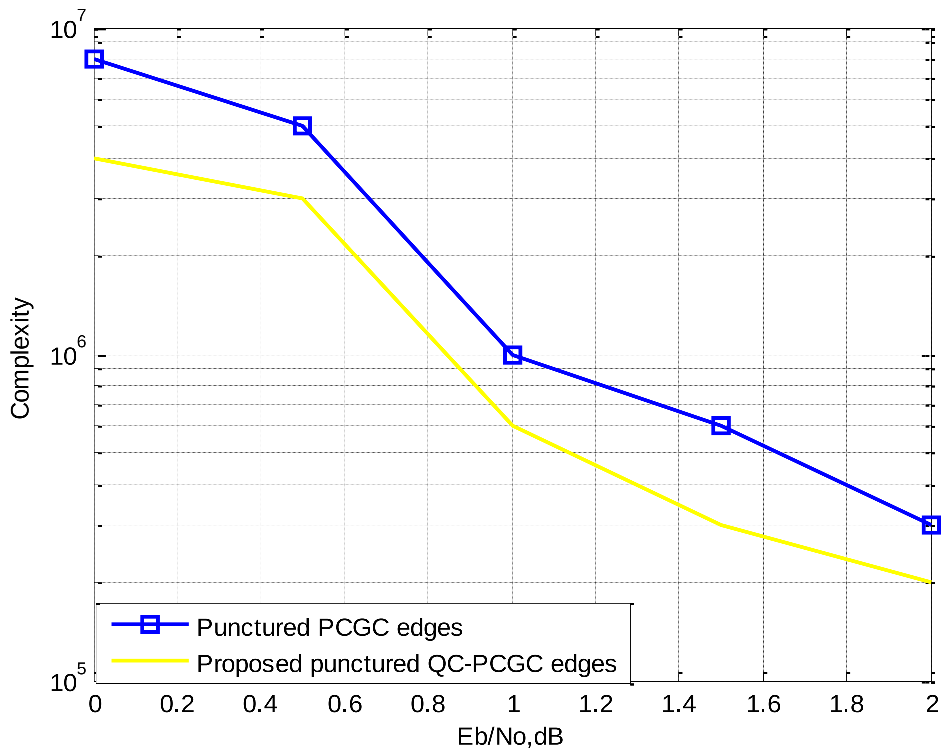

Figure 7. Complexity comparisons between punctured QC-PCGC and conventional PCGC.

4. Conclusion

Within the current research, the punctured system for the proposed QC-PCGC over AWGN and flat Rayleigh fading channel for control upon the compatible rate, is quite attractive and novel. The outcomes state that the proposed punctured QC-PCGC is effective in performance and maintains lower complexities when compared to conventional punctured PCGC or any other punctured coding model. Additionally, the proposed QC-PCGC analysis effectiveness indicates lower complexities with reference to the maximum edges and iterations numbers as compare to conventional punctured PCGC. The complexity assessment reduction shows that memory requirement is reduced for encoding/decoding system. For the 5G network, it is necessary to have the motivated punctured scheme applications.

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