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Low Complexity Rate Compatible Puncturing For Future Communication network

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Abstract. An efficient low complexity puncturing method has studied to achieve rate compatible. The parallel concatenation codes are use mixing of one component of Quasi-Cyclic (QC) low-density parity check codes LDPC codes with two components of (LDPC) in linear coding. The proposed QC-PCGC have lower computation complexity when compared with traditional punctured PCGC. The decreasing in the complexity analysis yields to the reducing in the memory requirement for the encoding/decoding system. It is possible to use the suggested coding system structure in the future communication applications like fifth generation (5G), where it is needed to have coding flexibility, with less complexity in encoding and decoding.

Keywords: LDPC, parallel concatenation, iterative decoding, punctured codes. Complexity analysis

1. Introduction

PCGCs signify a parallel concatenated codes that have been developed from parallel concatenation of more than one LDPC component [1]. The concatenated structures of LDPC codes were examined and it was found that they exhibit good performance [2].

There is greater flexibility of the PCGC structure, which exhibits low energy uses of error control coding; in these implementations, trade-offs with respect to a mix of the number of constituent codes that are to be concatenated may be according to a dynamic matching of coding performance to channel conditions, which optimizes the energy resources needed. Using this turbo code structure that is inherent in PCGCs, the complexity of a lengthy code can be decreased to have a lower number of complicated steps, while sustaining the flow of information among the component decoders [3]. PCGCs are additionally examined in this paper by analysing the puncturing process of the LDPC codes and any enhancements in the coding performance.

The parity check bits have punctured so that the functionality of the system can be improved to achieve the best rate compatible (RC) which brings about the highest code rate from the initial mother code [4-5]. The constructed QC-LDPC from any ring and group has studied. The number of operations during the encoding and decoding process has been reduced compared to the conventional efficient coding scheme [6].



A technique from the basic characteristics of punctured LDPC codes has been put forward and taken into account. This puncturing technique relies on the constant threshold to achieve low coding rates that can be attained for the system [7].

Random puncturing LDPC code ensembles across a binary input AWGN channel are used to examine an effective process for forecasting iterative belief propagation (BP). The findings that have been achieved depict that precise predictions were attained in comparison to the values that were computed by employing density evolution for various puncturing [8].

Gaussian Approximation for punctured LDPC codes was used to examine and evaluation appropriate punctured LDPC distribution. It was demonstrated in the findings that there was better improvement of punctured LDPC codes [9]. The paper elaborates on the attainable coding rates with coding intricacy. The focus of the findings was on obtaining upper limits of the information streams [10].

Vital roles have been performed by QC-LDPC codes in the linear coding system to decrease decoding intricacy and improve the way the system performs. QC-LDPC codes is the term given to the codes having identical cycle distribution. It is possible to encode QC-LDPC effectively with shift registers because of these codes have quasi cyclic structure and straightforward address creation method, lower memory requirement with local memory access is needed by their decoder structures [11-13].

It is possible to create a powerful puncturing integration between QC-LDPC and the PCGC system so as to enhance the working of the wireless coded systems. A several of PCGCs construction has discussed and analysed in a fragile and dynamic cognitive radio environment. A proposed scheme of Parallel concatenation with interleaver has analysed with some parameters to enhance bit error rate and less encoding complex [14-15].

In this paper BER and complexity analyses for QC-PCGCS is examined and it is found to exhibit better performance in comparison to conventional PCGC and single LDPC codes having the same parameters under normal as well as random puncturing.

The remaining of this paper as follows. In section 2, we explain the proposed punctured method for QC-PCGC. Computer simulations for BER performance and complexity analyses is presented in section 3 then the conclusion in section 4.

2. The Proposed Punctured method for QC-PCGC

2.1. Punctured of Encoding System

Multiple LDPC codes within a Turbo structure are used to create PCGCs. The PCGC structure makes use of the parallel concatenation (in the absence of interleaver), as depicted in Figure 1, so as to obtain the total codeword N and the code rate, $R=1/(M+1)$ code [16-17]. Puncturing is used in the PCGC [18] by considering the code rate R as K/P , where K and P signify the total message length and codeword, correspondingly. Figure 2 demonstrates the diagram of the suggested punctured QC-PCGC system. The properties of the QC-PCGC are consist from two random codes and one LDPC component of circulate permutation matrices with different column weight and similar to those that are employed in the WiMAX standard. The punctured techniques suggested can be created for the codeword for any codeword length and code rate. In addition, a part of bits from the codeword is eliminated before shifting the codeword to the next side. A series of Z bits are removed from the bit stream which have an impact on decreasing the block length from P to $P-Z$. Once a codeword is punctured using a puncturing fraction $\alpha= Z/ P$, the following code rate is attained:

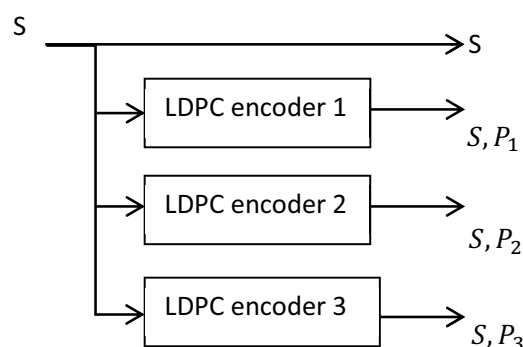


Figure 1. Block diagram of QC-PCGC encoder.

$$R_{new}(\alpha) = \frac{R_{old}}{1-\alpha} \quad \alpha \in (0,1). \quad (1)$$

Here, R_{new} and R_{old} signify the newest and main code rate. A study of three distinct novel methods of puncturing PCGC codewords is put forward in this paper, as will be illustrated below.

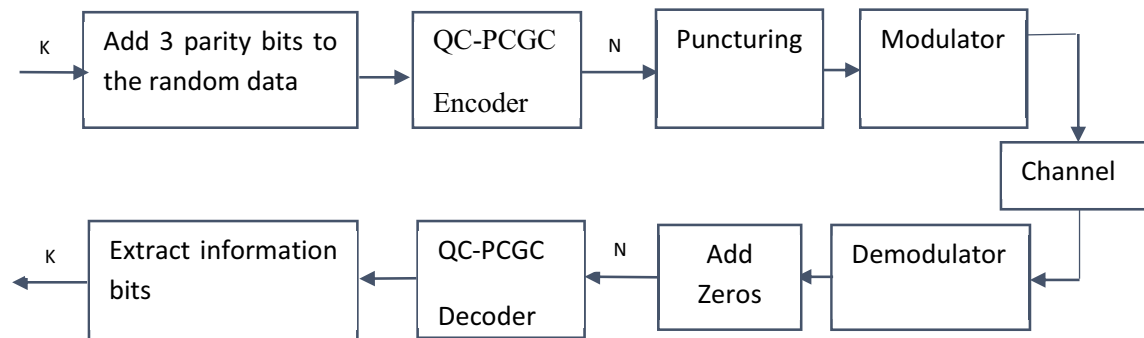
A PCGC is used to evaluate these methods over BPSK modulation, having $R=1/4$ and block length $N=768$, where the length of each code is $P = 384$ and $R = 1/2$. Puncturing is carried out with PCGCs to update and achieve the highest code rate from $1/4$ to $1/2$.

Random bits can be eliminated randomly without sequence. Weaker BER performance is exhibited by the process in comparison with other techniques. There is regular puncturing of the ensemble bits in the next method, which suggests that a fixed part (128 bits) from bits should be eliminated from the same area from every LDPC codeword. Respective, to maintain 192 bits from the codeword.

There is irregular puncturing of the ensemble bits in the third method, which suggests that a fixed part should be taken out at distinct locations from every LDPC codeword. The location of the punctured bits in accordance with the kind of the puncturing should be evident at the receiver so that the de-puncturing process taken by adding zeros to the locations of the received codeword. The Rayleigh distribution probability density function (pdf) can be calculated as shown below [14][19-20].

$$f(y) = \frac{2y_i}{\sigma^2} e^{-\frac{2y_i}{\sigma^2}}, \quad (2)$$

Where $\sigma^2 = E(|h(t)|^2)$, the flat fading channel has complex impulse response $h(t)$

**Figure 2.** Proposed efficient punctured QC-PCGC system

2.2. Punctured of Parallel Decoding

The iterative sum product algorithm (SPA) is used by the LDPC component decoder because of its decreased lower decoding complexity compared with other decoding algorithms. The Gaussian probability should be centred at +1 [21].

$$p(y_i|x_i = +1) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(y_i-1)^2}{2\sigma^2}}. \quad (3)$$

When the source information bits are equally likely $P(x_i = -1) = P(x_i = +1) = 1/2$ the probability of $x_i = +1$ at site i be

$$f_i^1 = p(x_i = +1|y_i) = \frac{1}{1 + \exp\left(-\frac{2y_i}{\sigma^2}\right)}. \quad (4)$$

When y_i is the channels output

It is presumed that the QC-PCGC decoder have known the locations of the removed bits at the receiver end so that the zeros can be added to these locations to let the likelihood ratios (LLR's)=0.5.

In the initial super iteration, processing information is simultaneously introduced by all M components decoders through the SPA. The sequence obtained is used by each of these without implement a priori (extrinsic) data. The decoding procedures takes place in an uninterrupted manner till (M) component decoders join together to validate codewords, or to achieve the full number of super iterations [22].

3. Simulation Result and Discussion

A. BER Performance Analysis

This paper chooses three LDPC component codes as parallel concatenation with puncturing effect. To ensure controlling on the coding rate with lower decoding complexity. Moreover, each LDPC component allowed a maximum 50 local iterations and 35 super iterations have overall PCGC.

The PCGC parameters have the same parity H (192,384) with three LDPC components and half code rate and different MCWs for each LDPC component. The total coding rate $R=1/4$, $MCW1=1.91$, $MCW2=2.79$, $MCW3=1.79$ and $N=768$. Furthermore, the single LDPC component without puncturing have $N=384$, $MCW=2.79$, $R=1/2$. The BPSK with AWGN and flat Rayleigh fading channel have included with the proposed puncturing design of QC-PCGC as shown in Figure 3 and Figure 4 respectively. The proposed QC-PCGC of three LDPC components have different MCWs with the same dimension of check parity.

The Gallger LDPC component have the first and third order whereas the second LDPC part has circular design QC-LDPC. The parameters of the QC-LDPC component as follow, the parity check matrix have row and column weight are 3, 6 respectively. While the prime number of LDPC component is 64 of the submatrices rank. The benefit of utilizing one quasi cyclic component in the proposed QC-MPCGC because the regular circular permutation and to control on the higher region from E_b/N_0 . The performance of puncturing of the proposed QC-PCGC and conventional PCGC was illustrated. The codeword $N=768$ after encoding is passed to the puncturing process with a fraction $\alpha = 0.5$ to let the code length=384.

The proposed QC-PCGC irregular punctured achieves high performance at higher E_b/N_0 region and have coding gain 0.5 dB at $1e^{-3}$ compared to the conventional PCGC irregular punctured [14] at precisely the same parameters. Moreover, the proposed QC-PCGC irregular punctured got better improvement than original conventional LDPC by 0.25 dB at BER $1e^{-5}$. Figure 4 shows the proposed QC-PCGC irregular punctured over flat fading channel has better improvement than conventional MPCGC by 0.25 dB at BER $1e^{-3}$ at the same parameters.

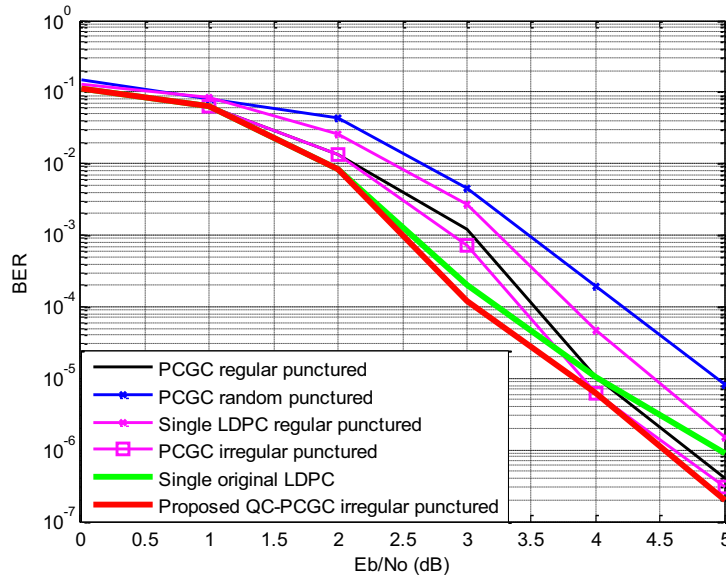


Figure 3. BER performance of various punctured QC-PCGC over BPSK-AWGN channel

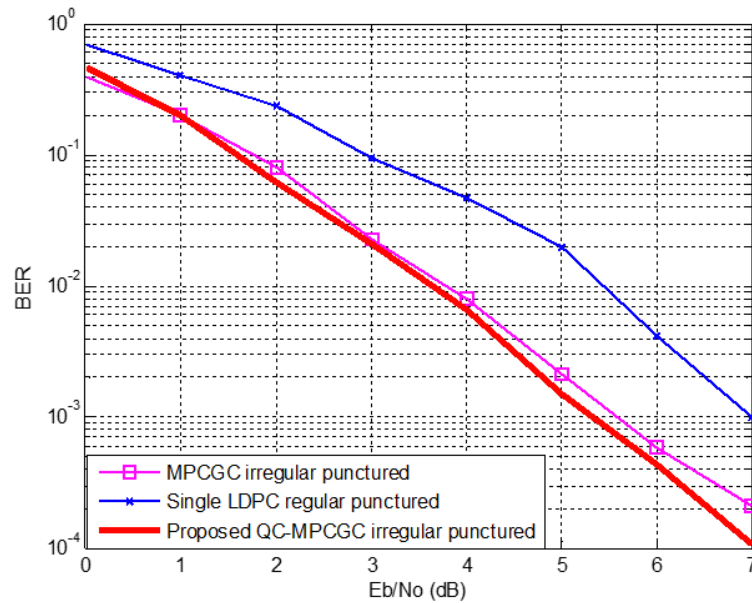


Figure 4. BER performance of various punctured QC-MPCGC over BPSK- flat Rayleigh fading channel

B. Proposed QC-PCGC Complexity Analysis

It can be seen in the findings that the complexity of the suggested punctured QC-PCGCs can be decreased in comparison to the traditional punctured multiple PCGC (MPCGC) mechanism. In addition, The LLR values at the decoder are computed as 0.5 because the punctured bits values are fixed at 0, and this causes

the decoder complexity to decline as there is a decrease in the total number of iterations needed, whilst enabling the decoder to converge quickly.

In addition, it is possible to use the benefits of the suggested punctured MPCGCs without increasing complexity. To estimate the encoding/decoding complexity per each iteration by the value of the maximum number that could be counted in the code Tanner graph by $N_M MCW_M$ for single LDPC [14][23]. To calculate the maximum edges in each super iteration of the PCGC as bellow,

$$\text{Maximum edges} = \text{Iterations number} \sum_{j=1}^M N_j MCW_j \quad (5)$$

Where, N is the codeword length, MCW is the mean column weight if the parity check bits

A preliminary complexity comparisons have studied depends on E_b/N_0 and the outcomes have analyzed depending on the iterations and edges of the LDPC as shown in Table (1). Figures 5 and 6 show the advantages of MPCGC compared to the conventional LDPC of the published result of Kim et. al at exactly parameters [24].

Table 1. Comparisons results of the complexity.

Eb/No	BER		Iterations number		Maximum Edges	
	LDPC	PCGC	LDPC	PCGC	LDPC	PCGC
0	1.7e-1	9.1e-2	3.72e3	3.3e3	8.2e6	7.9e6
0.5	1e-1	7e-2	3.75e3	2.6e3	7.9e6	4.8e6
1	7.4e-2	2e-2	1.420e2	1.4e3	2.9e6	3.2e6
1.5	1e-2	1.3e-3	400	500	9.82e5	1.3e6
2	1e-3	2e-4	305	400	7.3e5	9.2e5

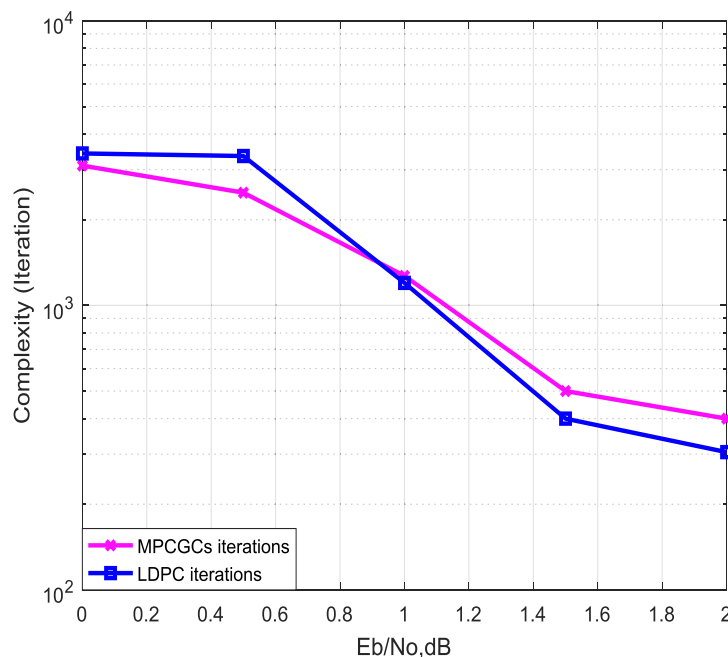


Figure 5. Comparison results of the complexity between MPCGC and LDPC.

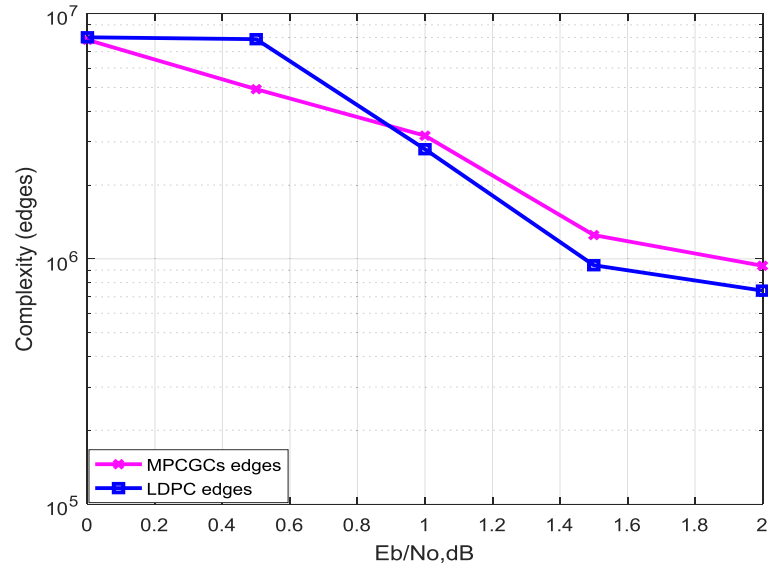


Figure 6. Comparison results of the complexity between MPCGC and LDPC.

Figure 7 and Figure 8 show the complexity outcomes of the proposed punctured QC-PCGC as regards of the iterations number and maximum edges per each Eb/No. The complexity of the proposed system compared to the traditional punctured MPCGC system, could be reduced. .

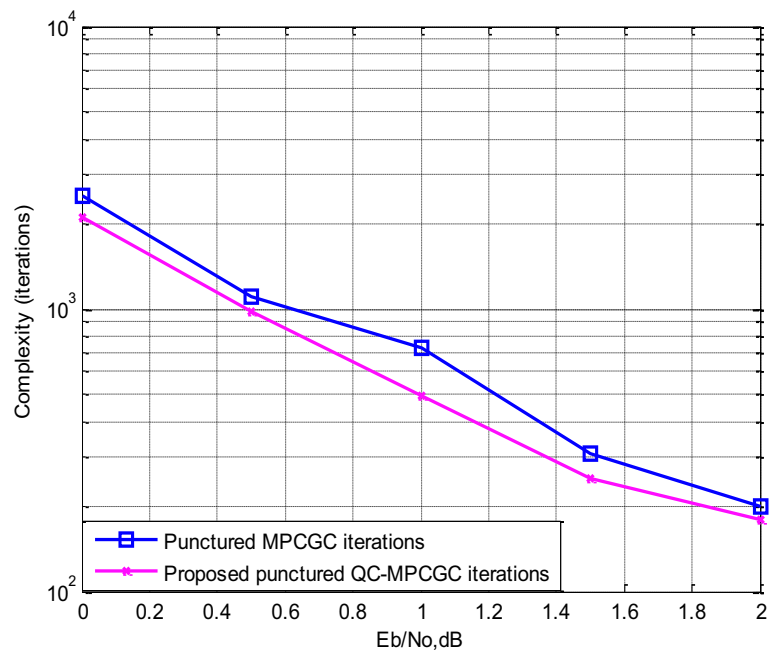


Figure 7. Comparison results of the complexity between punctured QC-PCGC and conventional MPCGC.

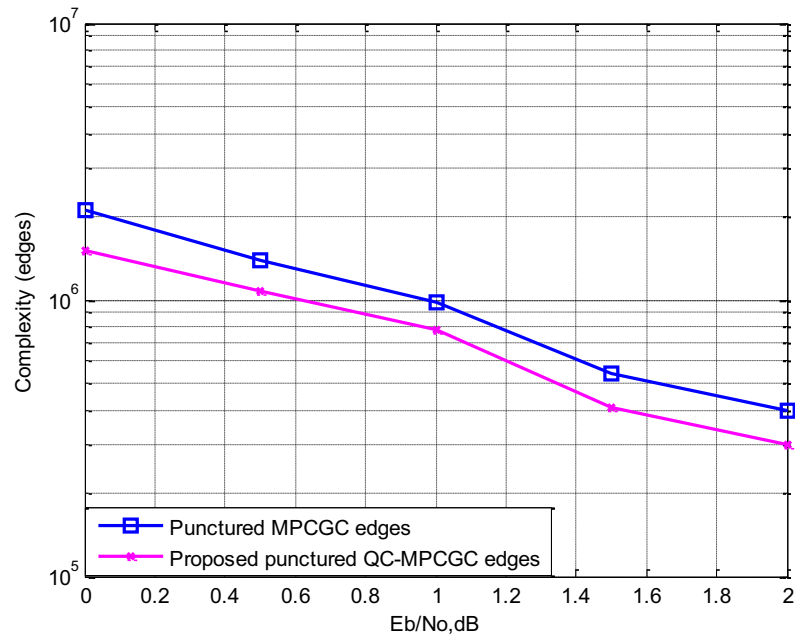


Figure 8. Comparison results of the complexity between punctured QC-PCGC and conventional MPCGC.

4. Conclusions

In this paper a novel and attractive punctured system has applied to the proposed QC-PCGC over AWGN to control on the compatible rate. It is proved that the proposed punctured QC-PCGC performs better and less complex compared to the traditional punctured MPCGC and other punctured coding model. Furthermore, the effective proposed QC-PCGC analyzes are less complex as regards of the iterations number and maximum edges compared with the traditional punctured PCGC. The reduction in the complexity analysis yields to the reducing in the memory requirement for the encoding/decoding system. The applications of this motivated punctured scheme is required in the 5G network.

References

- [1] Behairy, Hatim M., and Mohammed Benaissa. 2013 Multiple parallel concatenated gallager codes: Code design and decoding techniques. *IETE Journal of research* **59**(6): 659-664.
- [2] K. ElMahgoub and M. Nafie, 2010 Symbol based log-map in concatenated LDPC-convolutional codes, in *Consumer Communications and Networking Conference (CCNC), 2010 7th IEEE*, pp. 1-4.
- [3] H. Behairy and S. C. Chang, 2000 Parallel Concatenated Gallager Codes, In *Proc. 5th CDMA Inter. Conf. (CIC2000)*, pp. 123-127, Seoul, R. O. Korea.
- [4] H. Pishro-Nik and F. Fekri, 2007 Results on punctured low-density parity-check codes and improved iterative decoding techniques, *IEEE Transactions on Information Theory* **53**, pp. 599-614.
- [5] H. Y. Park, J. W. Kang, K. S. Kim, and K. C. Whang, 2007 Efficient puncturing method for rate-compatible low-density parity-check codes, *IEEE Transactions on Wireless Communications*, **6**, pp. 3914-19.
- [6] Khodaiemehr, Hassan, and Dariush Kiani. 2017 Construction and encoding of QC-LDPC codes using group rings. *IEEE Transactions on Information Theory* **63**(4): 2039-60.
- [7] H. Pishro-Nik and F. Fekri, 2004 Results on punctured LDPC codes, *Inf. Theory Work.*, pp. 215-219.

- [8] D. G. M. Mitchell, M. Lentmaier, A. E. Pusane, and D. J. Costello, 2015 Approximating decoding thresholds of punctured LDPC code ensembles on the AWGN channel, *IEEE Int. Symp. Inf. Theory - Proc.*, **2015**(June), pp. 421–425.
- [9] S. W. McLaughlin, 2003 Optimal puncturing of irregular low-density parity-check codes, 2003 *IEEE Int. Conf. Commun.* **5**(0), pp. 3110–14.
- [10] I. Sason and G. Wiechman, 2005 On Achievable Rates and Complexity of LDPC Codes for Parallel Channels with Application to Puncturing, pp. 1–35.
- [11] W. Ullah, Y. Fengfan, and A. Yahya, 2014 QC LDPC Codes for MIMO and Cooperative Networks using Two Way Normalized Min-Sum Decoding, *Indones. J. Electr. Eng. Comput. Sci.*, **12**(7), pp. 5448–57.
- [12] M. P. C. Fossorier, M. Mihaljevic, and H. Imai, 1999 Reduced complexity iterative decoding of low-density parity check codes based on belief propagation, *IEEE Trans. Commun.*, **47**(5), pp. 673–680.
- [13] L. XI, X. ZHAO, and K. Wang, 2009 VLSI decoding design of low-density parity-check codes based on circulant matrices, *J. Zhejiang Univ. (Engineering Sci.)*, **2**, p. 14.
- [14] Aftan, Ahmed. *Multiple Parallel Concatenated Gallager Codes and Their Applications*. PhD diss., University of Sheffield, 2018.
- [15] Aswathy, G. P., K. Gopakumar, and Imthias Ahamed TP. 2019 Parallel concatenated Gallager codes for reliable data transmission in cognitive radio networks. *Physical Communication* **37**: 100831.
- [16] Wu, X., Ge, J., Wang, Y. and Yue, A., Performance of turbo irregular LDPC codes. In *Information and Communication Technologies, 2006. ICTTA'06. 2nd* (Vol. **2**, pp. 2382-87). IEEE.
- [17] H. Behairy and S. C. Chang, 2002 “On the Design, Simulation, and Analysis of Parallel Concatenated Gallager Codes, in *Proc. 2002 IEEE Int. Conf. Com-(ICC.02)*, New York, NY, pp. 1850-54.
- [18] J. Hagenauer, 1988 Rate-compatible punctured convolutional codes (RCPC codes) and their applications, *IEEE Transactions on Communications*, **36**, pp. 389–400.
- [19] P. Matthias, 2002 *Mobile fading channels: modelling, analysis & simulation*. John Wiley.
- [20] M. K. Simon and M.-S. Alouini, 2005 *Digital communication over fading channels*, **95**. John Wiley & Sons.
- [21] R. G. Gallager, 1962 Low-density parity-check codes, *IRE Trans. Information Theory*, vol. **IT-8**, pp. 21–28.
- [22] Aftan, Ahmed, Mohammed Benaissa, and Hatim Behairy. 2018 Efficient coding Method of Multiple Parallel Concatenated Gallager Codes for WiMAX. *2018 Wireless Advanced (WiAd)*. IEEE.
- [23] Behairy, Hatim M. 2002 *Parallel concatenated gallager codes and their applications in CDMA wireless networks*. Diss. George Mason University.
- [24] K. S. Kim, S. H. Lee, Y. H. Kim, and J. Y. Ahn, 2004 Design of binary LDPC code using cyclic shift matrices, *Electron. Lett.*, **40**(5), pp. 325–326.