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RESEARCH ARTICLE

Analysis of Improved Rate Adaptive Irregular Low Density Parity Check Encoding for Fifth Generation Networks Using Software Defined Radio

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Abstract – Low Density Parity Check Codes are appropriate for high data rate applications like Internet of Things and 5G communication due to its support for bigger block size and higher code rate. In this paper an improved LDPC encoding algorithm is proposed to reduce girth 4 short cycles. This reduction helps in achieving lesser Bit Error Rate (BER) for various channel models with different code rates and modulation schemes. The proposed work is analyzed both for Pseudo Random sequence and audio messages. The simulation results demonstrate that the algorithm achieves low BER of 10^{-8} for code rate of 0.7 when tested for various code rates. The proposed algorithm also achieves reduced short cycles when compared with conventional LDPC encoding algorithm. Simulation results were verified by implementing the proposed algorithm in NI USRP Software Defined Radio. The SDR results verify that proposed algorithm provide low BER with reduced short cycles.

Index Terms – 5G, LDPC codes, PCM, Code rate, fading channel, Software Defined Radio, Girth.

1. INTRODUCTION

The number of interconnected networks and devices has rapidly increased in recent years that undoubtedly raised traffic demand. Fifth-generation (5G) technology development has advanced in response to this need. The decrease of error probability (BER) during transmission is one of the key needs for any wireless communication system [1]. This problem has been addressed using a variety of channel coding approaches, including cutting-edge methods like LDPC codes [2]. Because of their sparse nature, LDPC codes perform better [3]. The communication quality is improved when the channel capacity rises and the BER declines [4]. The 5G standard uses LDPC code for encoding data and Polar codes for encoding control information.[5] The choice is being made based on 5G requirements like high data rate, low BER, high degree of parallelism, low decoding latency, wide range of code rates and block length specifications.[6]. As the PCM gets sparser, the density reduces and gives a better performance [7].Due to the sparse matrix multiplication-based encoder and properly constructed graphs, LDPC codes benefit from low-complexity encoding a and faster decoding [8]. LDPC codes are preferred over Turbo codes and polar codes because of following factors

Lower decoding complexity: In contrast to Turbo and Polar codes, irregular LDPC codes can be built with irregular check node degrees, leading to a more adaptable structure.

Better performance: LDPC codes sometimes outperform Turbo and Polar codes and reach near-Shannon limit performance using iterative decoding algorithms, specifically in the moderate to high signal-to-noise ratio (SNR) regime.

Lower latency: Compared to Turbo and Polar codes, LDPC codes have a potential for lower decoding delay, making them suited for low latency applications like real-time video streaming and communication systems.

Effective hardware implementation: As LDPC codes have a flexible and regular structure, they can be implemented in hardware easily. This qualifies them for applications like wireless communication systems and storage devices, since they both need low power consumption and high throughput.

1.1. Problem Statement

Irregular LDPC codes find its application in 5G communication. However most of the literature focusses on

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reducing decoder complexity for the achievement of reduced Bit Error Rate. But there is a need for less complex LDPC encoding algorithm which reduces error rate by nullifying the girth 4 short loops. Hence considering this requirement this paper proposes an improved LDPC encoding algorithm to achieve high data rate and low BER by increasing the sparseness of the PCM. Nullifying the girth 4 short loops leads to following advantages

Reduced error floor: Short loops in the PCM might result in an error floor. The error floor can be considerably decreased or removed by nullifying the girth 4 loops.

Better decoding efficiency: Short loops in the parity check matrix might complicate the decoding process leading to errors. The decoding performance can be enhanced by eliminating these short loops, which will decrease bit errors and improve overall performance.

Lower complexity: When compared to other techniques for enhancing LDPC codes, nullifying girth 4 loops may be accomplished with a comparatively low degree of complexity. This makes it a desirable choice for real-world use in communication systems where complexity and power consumption are crucial considerations.

1.2. Objectives

The objectives of the work presented in this paper are

Design of improved irregular LDPC encoder which is also rate adaptive with lower Error rate (BER).

Analysis of the working of improved LDPC encoding algorithm for different channel types, modulation techniques and code rates.

Implementation of the proposed encoding algorithm in Software Defined Radio NI USRP 2920 for real time analysis.

1.3. Contribution

The improved LDPC encoding algorithm proposed in this paper

Increases the sparsity of Parity Check Matrix

Provides girth4 free LDPC codes

Reduces BER to achieve Shannons capacity

1.4. Paper Structure

In this paper section 3 describes theoretical back ground needed for work. Section 4 describes the proposed algorithm for PCM generation. The system model is being explained in detail in the section 5. The section 6 deals with the analysis of improved algorithm both in simulation and in software defined radio. The section 7 deals with the conclusion.

2. LITERATURE SURVEY

Xu, J et al. [9] analyzed the 5 methods of encoding regular LDPC codes based on code rates .To apply the encoding techniques to quantum information tested with the application of quantum distribution key. .

Telagam, et al. [10] investigates the performance of parallel concatenation of LDPC codes in the view of the Generalized FDM (GFDM) waveform, which is a suggested waveform candidate for the fifth generation communication system. The work focuses on applying several pulse shaping filters, such as the Raised Cosine (RC), Root Raised Cosine (RRC), Gaussian, and Xia 4th order filter, to GFDM waveform in the presence of Gaussian noise and Rayleigh fading channels. The paper offers details on how LDPC codes function in GFDM systems with various pulse shaping filters. Y. Hu et al. [11] analyzed the application of LDPC coding to protect the transmitted signal for Reconfigurable Intelligent surface (RIS) assisted wireless communication systems. The results analyzed based on Error rate.

Mahalakshmi et al.[12] proposed a novel encoding algorithm which reduces BER by reducing the number of girth 4 short cycles. The proposed algorithm is tested with different modulation techniques and code rates.

Arora et al. [13] elaborates on the key requirements for 5G networks with respect to transmission rate, BER and data transmitted rate. It also highlights the necessity of enhanced LDPC encoding and decoding techniques for various applications based on specific parameters.

Sarvaghad-Moghaddam et al. [14] presents a new construction technique for LDPC matrices suitable for mobile networks. The focus of the paper is on medium and low code rates. The proposed technique is evaluated using an AWGN channel and 2-PSK modulation technique. The paper aims at enhancing the performance of LDPC codes in the context of mobile networks.

Harbi, Y., and Aftan, A. [15] discusses the design of rate-compatible LDPC codes. The work specifically focuses on the punctured system for the QC-PCGC (Quasi-Cyclic Parallel Concatenated Convolutional) codes. The proposed system is evaluated over a non-fading channel (AWGN) and a fading channel like Rayleigh. The paper aims to optimize the rate compatibility of LDPC codes for better performance in different channel conditions.

Amine, T.M., and Ali, D. [16] published in the "International Journal of Technology" presents a new method for constructing low-density-parity-check (LDPC) codes. The proposed method focuses on reducing the cycles of length 4 in the LDPC code structure. The paper evaluates the new encoding technique using an additive white Gaussian noise

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(AWGN) channel and binary phase-shift keying (BPSK) modulation technique.

Mansoor, B. M., and Ismaeel, T. Z. [17] proposes a modified channel code for 5G systems. The focus of the paper is on designing a code with high throughput and flexibility. The proposed code is evaluated using Quadrature modulation 4-PSK and the AWGN channel. The paper contributes to enhancing the error correction capabilities of LDPC codes in the context of 5G communication systems.

Chen et al [18] introduces a less complex encoding method and encoder architecture specifically designed for LDPC codes in space applications. This method leverages generator matrix partitioning and decomposition techniques to derive a significantly smaller dense core matrix. Consequently, only a fraction (one quarter) of the dense block matrices is required to be implemented, as opposed to the traditional circulant encoding structure.

Richardson et al.[19] mention the necessity for innovative structural alterations in LDPC codes in order to apply for the new radio system as well as the requirement for new error correction codes for the 5G New Radio.. Overall, LDPC encoding algorithms have been an active research area in recent years, with a focus on achieving a balance between encoding complexity and error correction performance. Different strategies, such as adaptive matrix construction, weight distribution, and girth elimination, have been proposed to achieve this balance.

3. THEORETICAL BACK GROUND

3.1. Message

The message to be encoded is given as input to the system model. The improved encoder is analyzed by considering various PN sequence and audio data as messages to be encoded. The PN sequence of size 1024 bits is generated using PN sequence generator in lab view. Audio signal of 3 seconds that has a huge number of samples (18432 bits) was considered. The conversion of audio samples to binary using the A/D converter with sampling rate of 40 KHz and a midrise quantizer is shown in Figures 1 and 2.

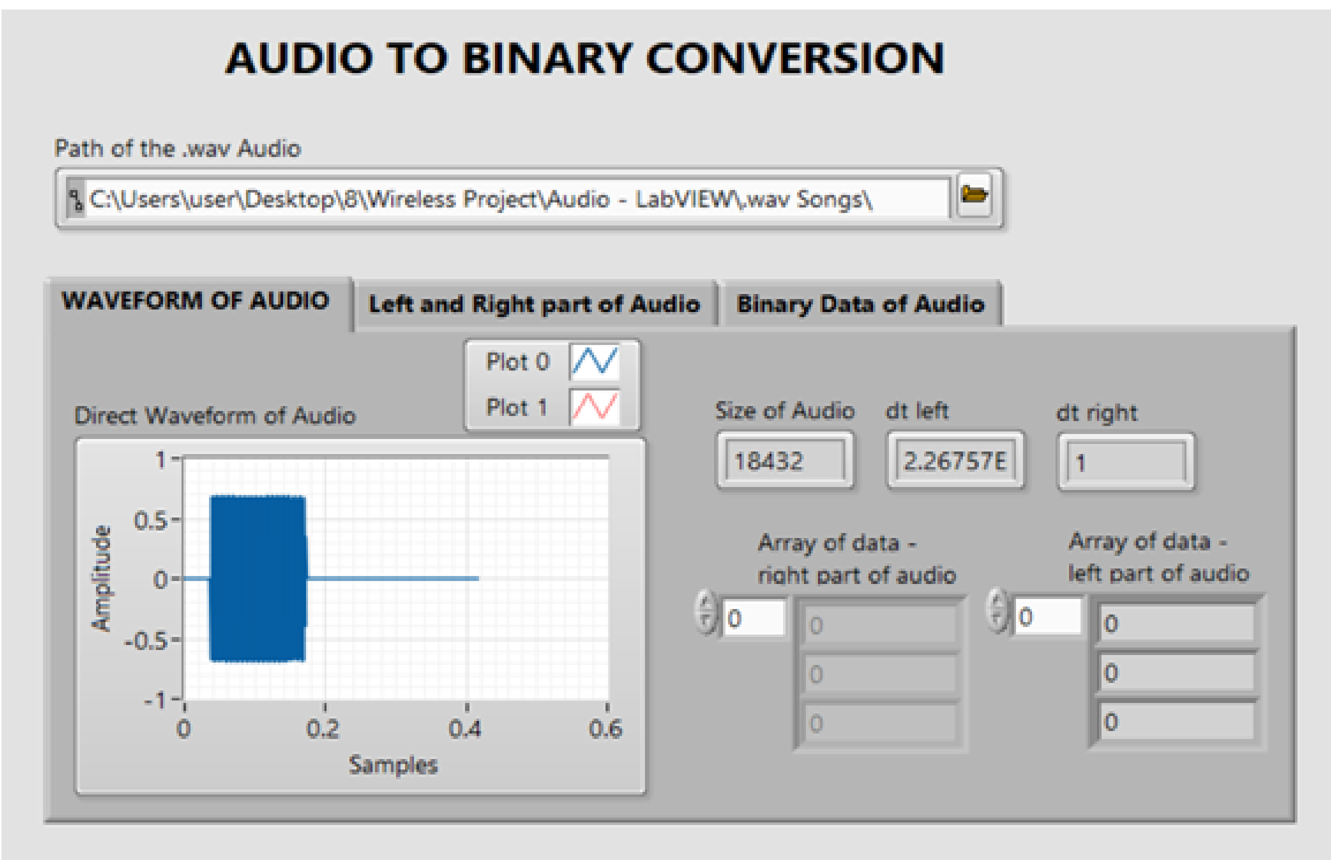

Figure 1 Audio Data in Waveform Representation

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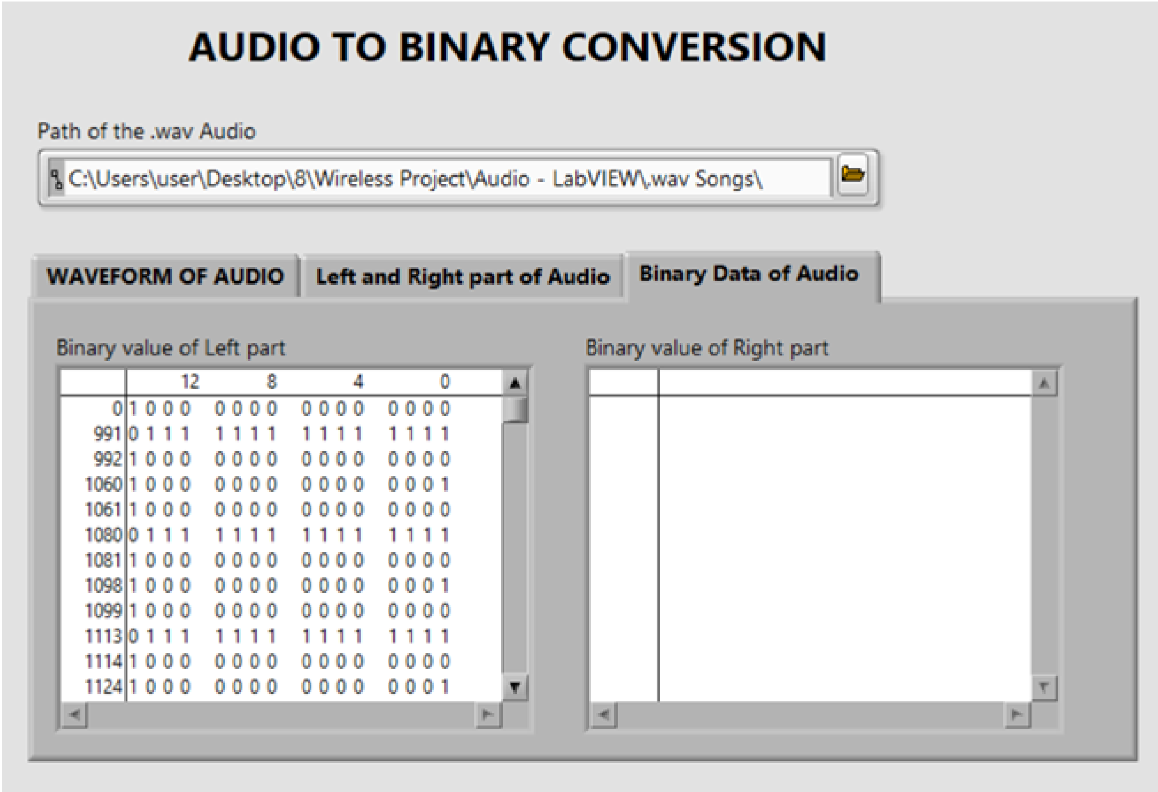

Figure 2 Audio Data in Digital Format

3.2. Channel

A channel is defined as the interface between transmitter and receiver. Channels can be classified into many types based on path loss, attenuation and noise distribution etc. In this paper the performance of the improved LDPC code has been analysed in non-fading channel and different fading channels like Rayleigh and Rician [20].

3.2.1. AWGN Channel

The AWGN channel is abbreviated as Additive White Gaussian Noise Channel. It is an ideal channel model employed in theoretical analysis to study the behaviour of RF chain. This channel is modelled using Gaussian distribution. AWGN channel modelling is less complex as the mean value of noise over a period of time is zero AWGN channel is free from fading, frequency selectivity and interference. AWGN channel is used in some applications such as satellite and deep space application and used in producing background noise for the channel in the study [20]. The probability Density Function of AWGN channel is mentioned in equation (1)

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\left(\frac{x^2}{2\sigma^2}\right)} \qquad (1)$$

Where ‘x’ refers to noise components at various time intervals and the variance is σ^2.

3.3. Fading Channel

Fading is defined as the weakening of signal strength due to various factors like multiple paths, frequency and attenuation etc.

3.3.1. Rayleigh Fading

When there are several obstructions between the transmitter and receiver and no Line of Sight component is present, Rayleigh fading is employed for channel modelling.[21] The signal from the transmitter is scattered many times because of multi path.. It is generally applied in mobile communication scenarios.

Probability function of Rayleigh fading profile is given in equation(2)

$$\begin{aligned} F(y) &= \frac{y}{\sigma^2} \exp\left(-\frac{y^2}{2\,\sigma^2}\right) && \text{for} y \geq 0 \\ &= 0 && \text{otherwise} \end{aligned} \qquad (2)$$

3.3.2. Rician Fading

If there is one dominant LoS path is available across transmitter and receiver Rician fading Profile is the preferable one. This Profile includes one LoS path and many non LoS paths. Rician fading is mainly affected by signal strength from

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direct path. Outage probability increases in Rician fading model because of the direct path [22].

The PDF of Rician fading channel is given in equation (3)

$$F(y) = \frac{y}{\sigma^2} \exp\left(-\frac{y^2 + A^2}{2\,\sigma^2}\right) I_0 \frac{yA}{\sigma^2} \quad \text{for} y \geq 0, A \geq 0 \quad (3)$$

$$= 0 \quad \text{Otherwise}$$

3.4. Low-Density Parity Check Codes

The low-density parity check code is a linear block code characterized by Sparse Parity Check Matrix. Sparse means number of 1's is very less compared to number of 0's. i.e. Low density Matrix.[23] It is constructed either using Gallagher construction or Mackay construction methods. LDPC codes are of two types. They are Regular and Irregular.[24] In Regular LDPC, each row will be having w_r number of 1's, and each column will be having w_c number of 1's. w_r Will be greater than w_c. In Irregular LDPC Codesthe degree distribution is not uniform.This is also applicable to columns in PCM. Generally irregular LDPC performs more than the regular LDPC code [25].

3.4.1. LDPC Encoding

As discussed earlier LDPC codes are represented by the sparse parity check matrix H . Parity check matrix is denoted by the letter H. The size of the H matrix is given as $(n-k) * n$. [26] Graphical representation of Parity Check Matrix is known as Bipartite graph or Tanner graph. There are two nodes in Tanner graph. Bit node represents column elements. Check node represents row elements. Sample Tanner graph for a (6,3) code is shown in Figure 3 Connection between check nodes and bit nodes represents the 1 in the PCM.

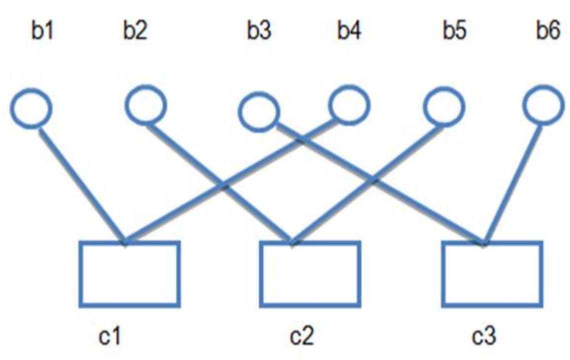

Figure 3 Tanner Graph for (6, 3) Code

From the theory of Linear Block codes it is clear that the code word C can be calculated using the equation (4)

$$C = m \,.\, G \quad (4)$$

C and m are code word and message respectively. G refers to Generator matrix.

C is given using equation(5)

$$C = [m : b] \quad (5)$$

Where m is message part and b is parity part of code word. According to Gallager Construction the G matrix can be obtained from Parity Matrix(PCM) .The representation of PCM is given using equation (6).

$$H = \begin{bmatrix} H_1 \\ -- \\ H_2 \end{bmatrix} \quad (6)$$

In equation (6) H_1 is the square part of PCM of dimension $(n-k)\ X\ (n-k)$ and H_2 is the rectangular part of PCM of dimension $k\ X\ (n-k)$. The generator matrix and Coefficient matrix are denoted by equations (7) and (8) respectively.

$$G = [P : I_K] \quad (7)$$

$$P = H_2 {H_1}^{-1} \quad (8)$$

Where P is known as coefficient matrix. So in this way generator matrix and PCM are interrelated with each other.

3.4.2. LDPC Decoding

The success of LDPC codes is mainly because of its decoder. The paper uses iterative message passing soft decoding algorithm. Single Parity check is the important ingredient for LDPC decoding. Each row of the Parity Check Matrix indicates Single Parity Check code. Message Passing Decoder is simple SISO iterative decoder. [27] It will use simple Min-sum approximation. Steps in Message passing decoding described below.

3.4.2.1. Soft decision Decoding

- Process the Real Values Received From Channel

We know that $C = [c_{1,} c_{2,} c_{3,} \dots, c_{n,}]$ is the code word to be transmitted (modulated) thru the channel using BPSK modulation. where c_i= code word bit.

The received code word from the channel is given as $r = [r_{1,} r_{2,} r_{3,} \dots, r_{n,}]$ where r is given by equation(9) and s_i by equation (10)

$$r = s_i + n \quad (9)$$

Where n=channel noise. For BPSK modulation

$$s_i = 1 - 2C \quad (10)$$

- Calculating Channel LLRs(Log Likelihood Ratio) for the received vector r

$$l_i = \log[\text{prob}\{c_i = 0/r_i\}/\text{prob}\{c_i = 1/r_i\}] \quad (11)$$

In equation (11) $l_i$is the LLR of each received bit

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- Calculating output LLR L_i

$L_i = \log[\text{prob}\{c_i = 0/r\}/\text{prob}\{c_i = 1/r\}]$ (12)

Calculation of L_i from equation (12) includes high complexity when n and k are very large. So iterative message passing approximation method is used

- Row Iteration

1. Each bit node passes the first l LLRs $m_i$received from channel to corresponding check nodes.
2. From equation (13) it is clear that check nodes calculates corresponding LLRs$l_i$using $m_i$received from bit nodes .(It uses SPC decoding algorithm)

$|l_i| = \min(\text{abs}[l_1, l_2, \ldots . l_z])$ (13)

- Column Iteration

I. Now the check nodes pass the conditional LLRs to corresponding bit nodes.

II. Each bit node will be having multiple copies of the received value. So repetition decoding algorithm is used here.

➢ The above two process can be repeated for multiple iterations. Increasing the number of iterations may slightly increase accuracy of output.

Tanner graph approach is used mainly in message passing decoder.

3.5. Software Defined Radio

The concept of software-defined radio (SDR) is introduced, where radio functions are defined in the digital domain, allowing for easy reconfiguration and implementation of new communication advances. The NI Universal Software Defined Radio Peripheral (USRP) 2920 is mentioned as an example of an SDR. It is a tunable RF transceiver that can operate in the frequency range of 50 MHz to 2.2 GHz with a bandwidth of 20 MHz and a gain of 31 dB.

4. IMPROVED LDPC ENCODING ALGORITHM FOR PCM GENERATION

The rate adaptive improved irregular LDPC algorithm is used in this work to analyze the performance for various channel models, code rate and block size. The basic calculation required for LDPC encoding to generate code vector C, Generator Matrix G and Parity Check Matrix H have been mentioned under the section.

4.1. LDPC Encoding

The improved PCM generation algorithm is described below:

Step 1: Random binary matrix M of size [m x n] is generated considering message size 'l' and code rate R. Row density and column density is denoted as w_r and 'w_c.The matrix M is generated in such a way that each row has least number of ones and the row weight $w_r$is odd

$$W_r = \text{minimum}\ \mathit{odd\ value}, \left(\begin{cases} 1 \\ 3 \\ . \\ . \\ 9 \\ 13 \\ 15 \\ . \\ . \end{cases} \right) \quad (14)$$

Step 2: The generated random matrix M is modified into the Linear Nonsingular Independent matrix P with the help of below mentioned row/column manipulations.

The row matrix q is defined below in equation (15)

$$q = \begin{cases} 1\ \mathit{if}\ \ m = n\ ;\ m \neq 2{,}4 \\ 1\ \mathit{if}\ m = 2\ \ ;\ \ n = 4 \\ 1\ \mathit{if}\ m = 4\ \ ;\ \ n = 2 \\ 0\ \mathit{else} \end{cases} \quad (15)$$

We Know that Linear Independent Matrix P_1 can be obtained by using equation (16).As a first step the Matrix M defined already is pre multiplied with this q matrix and shown by equation (17).Then it is multiplied by Identity Matrix (I) as shown in equation (18)

$$M.X = P \quad (16)$$

$$(\ldots q_{3,}q_{2,}q_{1,}M) = \ldots q_{3,}q_{2,}q_{1,}P \quad (17)$$

$$(I).X = ..\ldots q_{3,}q_{2,}q_{1,}P \quad (18)$$

$$X = \ldots q_{3,}q_{2,}q_{1,}P \quad (19)$$

So a linearly independent matrix P is generated from equation (19).The purpose of this conversion is to avoid singularity and short cycles. Size of matrix gets reduced.

Step 3: The generated Linear Independent square matrix P is converted to sparse PCM Hp using Matrix operations given below.

- Compute transpose Matrix P= P^T
- To obtain matrix Q, columns in P^T are eliminated such that the column weight for each column is always the least odd integer.
- The resultant Sparse PCM $Hp$is computed by taking the transpose of matrix Q.

Step 4: Calculate the number of short cycles (Girth 4) for the resultant

sparse PCM Hp

Step 5: If the number of girth 4 loops is not equal to 0 then that PCM is discarded and the process is repeated till the required PCM is achieved.

The pictorial representation of the algorithm is mentioned in the Figure 4 given below.

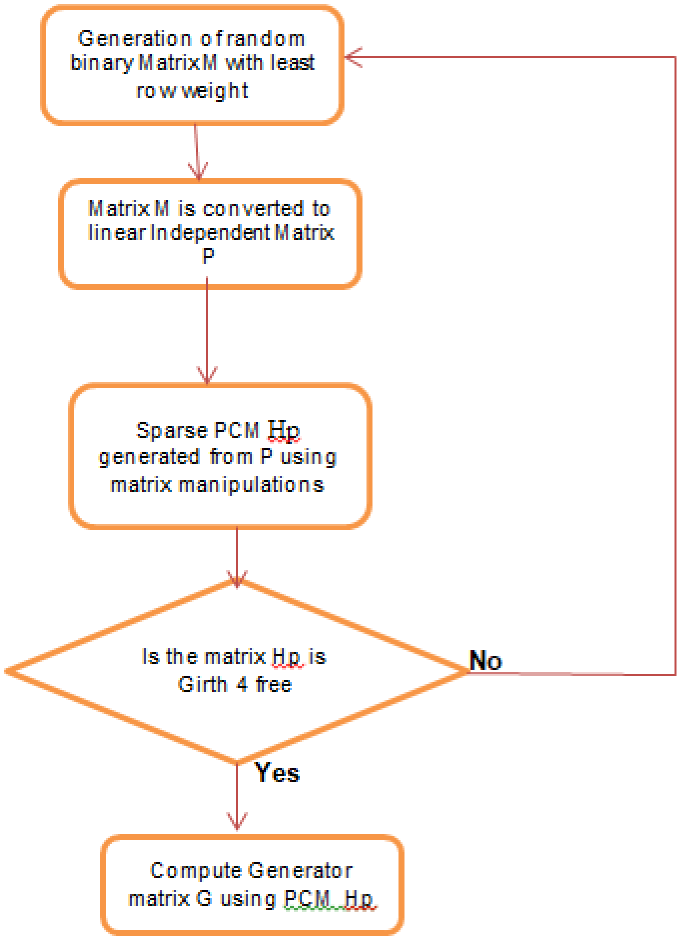

Figure 4 Flow Chart of Proposed Algorithm

The modified algorithm concentrates on increasing the sparsity of PCM to achieve girth (cycle4) free codes. The algorithm ensures the generated PCM is free of girth 4 cycles by repeating the process.

5. SYSTEM MODEL

The figure 5 shows the overall system model used for simulation of improved LDPC codes and also the model is implemented in NI labview and NI USRP 2920 Software Defined Radio.

The functions of sub blocks of the system model shown in Figure 5 are explained in the following subsections.

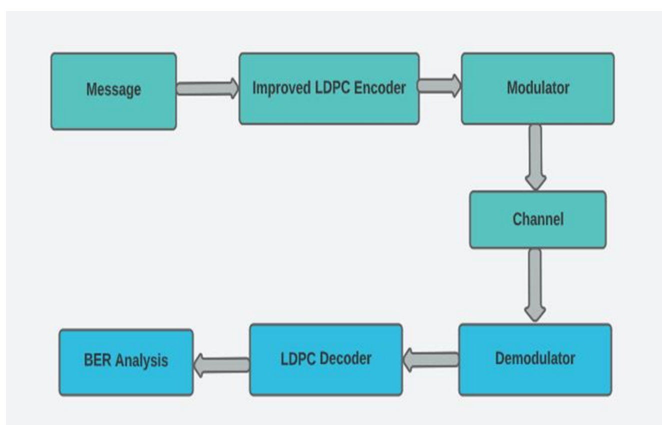

Figure 5 System model

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6. ANALYSIS OF IMPROVED LDPC CODES

This section deals with analysis of improved LDPC codes based on various parameters.

6.1. Effect of Proposed Algorithm on Short Cycles

The generated PCM is tested for girth 4 for various code rates and the results are shown in the table 1.

Table 1 Count of Girth 4

Size of PCM	Code rate	Count of girth 4	
		Conventional LDPC	Proposed LDPC
960 X 1024	0.9	138	0
580 X 950	0.6	276	0
220 X 510	0.4	193	0

The decoding procedure becomes simple if the parity check matrix doesn't have any short cycles. Since LDPC codes have loopy graphs, the technique must be iterated numerous times before it converges to a solution. It is possible to lessen the effect of girth on the performance of LDPC codes by choosing codes with longer girths [28].

Figure 6 shows the status of Parity Check Matrix before applying algorithm.

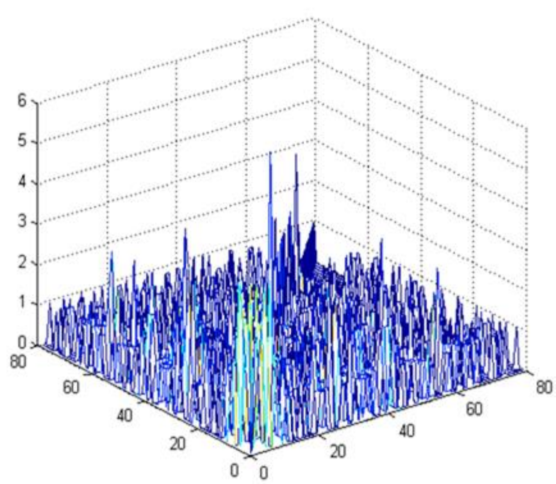

Figure 6 Mesh Diagram of Conventional PCM

It is clear from the Figure 6 that more short loops are present in the PCM. We know that short loops affect the performance of the LDPC decoder.

The Figure 7 shows the status of Parity Check Matrix after applying algorithm.

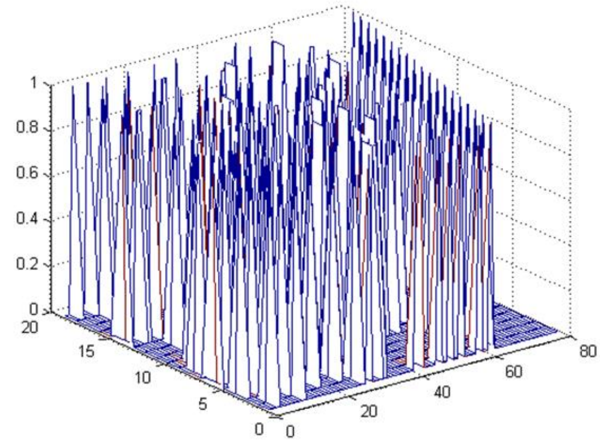

Figure 7 Mesh of Improved PCM

From the mesh graphs and table 1 it is clear that Girth 4 is removed completely after applying the algorithm. The removal of girth 4 short cycles increases the sparsity of PCM. The sparseness of the PCM leads to less iterations during decoding. The performance near to Maximum Likelihood (ML) decoding is achieved because of this.

6.2. Effect of Improved Algorithm on Encoding System Speed

The table 2 shows the effect of improved algorithm on system execution speed.

Table 2 Encoding Speed Vs Message Size

Message Size	Encoding speed of conventional LDPC encoding	Encoding speed of improved LDPC encoding
1024 bits(1KB)	12.2ms	5.5 ms
18KB	136 mS	90ms

From the table 2 it is clear that the processing time is reduced for proposed algorithm compared to conventional encoding. This experiment is done for the code rate of 0.7.

It's necessary to remember that variables other than the LDPC encoding technique itself can have an impact on the space usage. The space requirements will also be strongly affected by the overall system design, interaction with other components, and the requirements of any particular application. Therefore, in order to accurately figure out how the LDPC encoding technique affects space usage for any

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particular application, a thorough system-level investigation is required.

6.3. Analysis for Various Message and Channel Models

The Figures 8 and 9 show the analysis of Irregular LDPC codes using improved Parity Check Matrix for both fading and non-fading (AWGN) channels for smaller and larger block length.

The table 3 lists the sample values of BER Vs Eb/No for various message sizes and channel types.

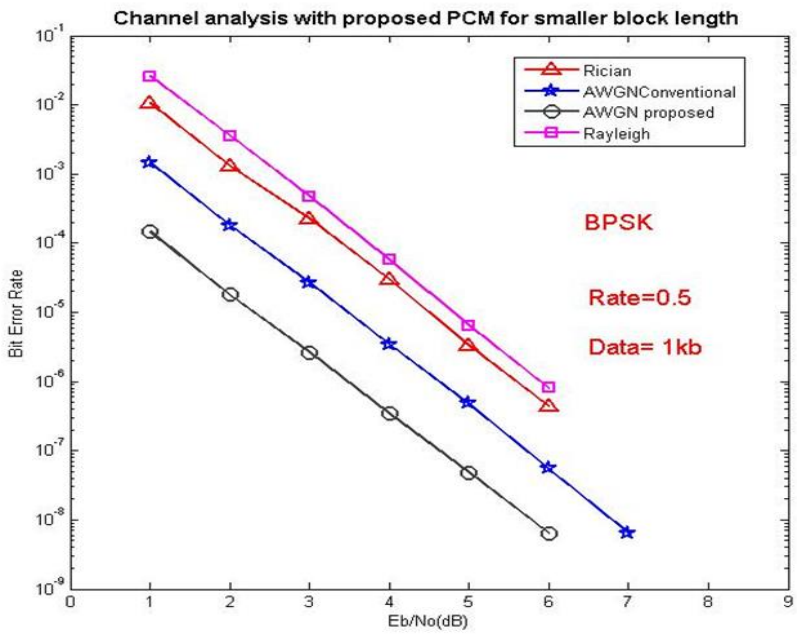

Figure 8 BER vs $\frac{E_b}{N_0}$(dB) graph –AWGN and Fading Channels for data=1k

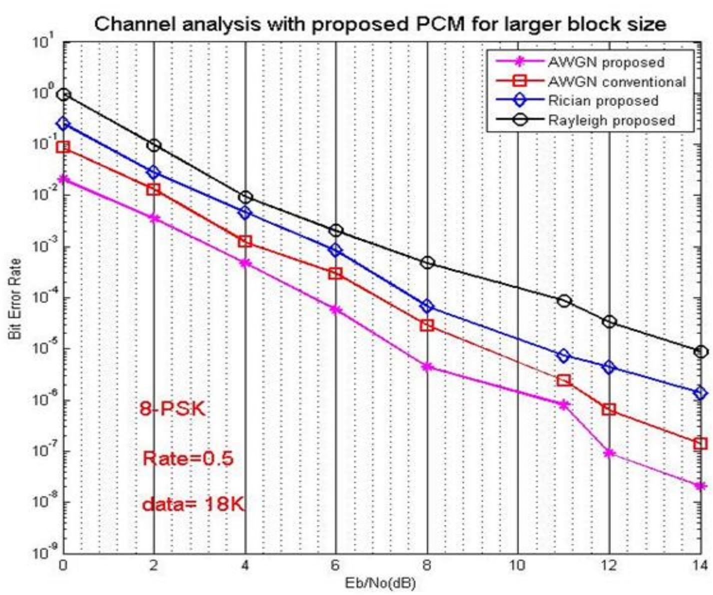

Figure 9 BER vs $\frac{E_b}{N_0}$(dB) Graph –AWGN and Fading Channels for Data=18k

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Table 3 BER for Different Channels

		Bit Error Rate			
Message	Eb/No(dB)	AWGN(improved)	AWGN (conventional)	Rayleigh (improved)	Rician (improved)
1024 bit (2-PSK)	6 dB	10^{-8}	10^{-7}	10^{-5}	10^{-6}
	2dB	10^{-5}	10^{-4}	10^{-3}	10^{-3}
18Kb (8-PSK)	8dB	10^{-5}	10^{-4}	10^{-3}	10^{-2}
	14dB	10^{-8} (approximately)	10^{-6}	10^{-5}	10^{-4}

The table 3 shows that the improved algorithm yields better BER compared to conventional LDPC. For smaller message size Rayleigh and Rician channel models perform more or less similar but while applying for large block size ie audio data of 18kb with Rayleigh performs better than other fading type. It is evident from the work that Rayleigh channel gives less BER compared to Rician [29].

6.4. Analysis for Various Modulation Techniques

The Figure 10 depicts the performance of improved LDPC for various modulation schemes with larger block size and slightly higher code rate of 0.7.

For M-PSK modulation techniques the Bit Error Rate is calculated using the formula (equation 25).

$$P_e = \frac{1}{log_2 M} \sum_{n=1}^{log_2 M} P_n \left(\frac{e}{\emptyset}\right) \quad (25)$$

Here M is the size of message and $P_n\left(\frac{e}{\emptyset}\right)$ is the probability of error of nth bit for the phase error given.

AWGN channel at a code rate of 0.7 error of 10^{-6}can be attained at the $\frac{E_b}{N_0}$ of 3.5 dB with proposed PCM where as in conventional method error of 10^{-5} can be achieved at the same signal strength.. Similarly in the case of higher order modulation 8-PSK a bit error rate of 10^{-6}can be obtained at the $\frac{E_b}{N_0}$ of 7 dB with proposed PCM and same BER occurred at $\frac{E_b}{N_0}$ of 8 dB.

As the code rate increases error rate becomes less with lower values of Eb/N0 for higher order modulation schemes.

6.5. Implementation of Improved LDPC in NI USRP 2920

The system model in the Figure 5 is implemented in Software Defined Radio NI USRP 2920 to validate the improved algorithm**.** The laboratory set up is shown in Figure 11. NI USRP 2920 acts as transceiver. The performance of Irregular LDPC codes with improved PCM for larger block length in NI USRP 2920 for various code rates is shown in figure 12.

A bit error rate around 10^{-8} can be achieved at $\frac{E_b}{N_0}$ of 4 dBand 6 dB for the code rates of 0.9 and 0.7 respectively. But maximum BER of $10^{-7}$is obtained at $\frac{E_b}{N_0}$ of 5dB .The modulation technique used here is BPSK. The analysis shows that higher code rate provides reduced error rate at low $\frac{E_b}{N_0}$

Figure 13 compares the performances of irregular LDPC codes with improved PCM and conventional PCM with larger data sizes (18 kb) in NI USRP 2920 for a code rate of 0.7 and using 8PSK modulation scheme. With improved PCM a maximum bit error rate of 10^{-9} can be achieved at $\frac{E_b}{N_0}$ of 15dB. On the other side with conventional PCM a maximum bit error rate of 10^{-7} can be achieved at $\frac{E_b}{N_0}$ of 14dB. The result shows that the improved PCM works well with larger data, higher modulation scheme and a slightly higher code rate.

6.6. Limitation of Proposed Algorithm

The algorithm eliminates Girth 4 short cycles are removed completely. However higher order girths are still present. This can be considered in future. The algorithm can be improved further to remove Girth 6 in future.

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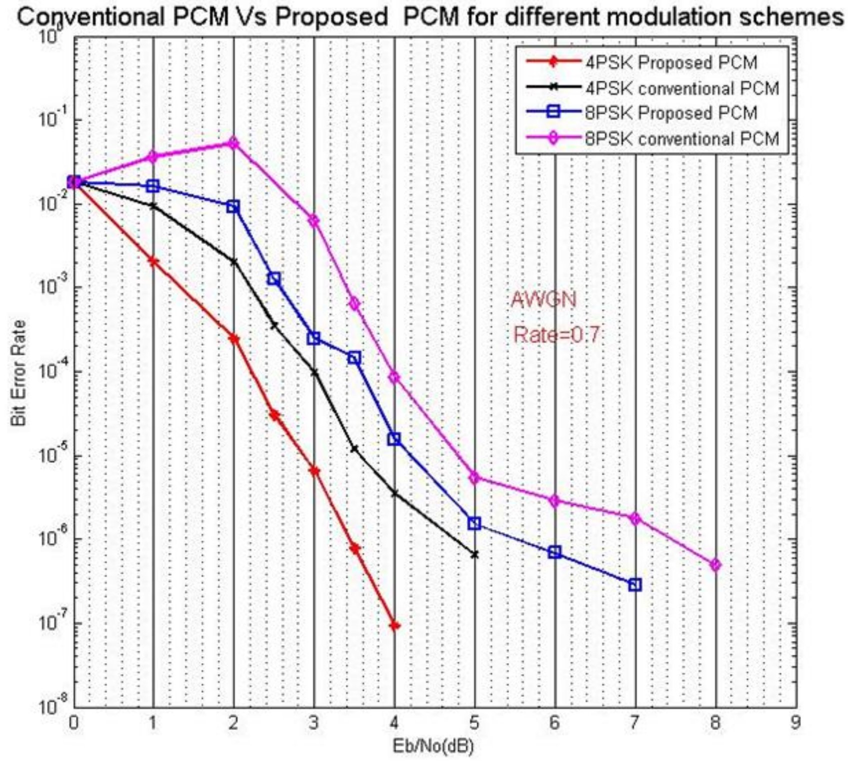

Figure10 BER Vs $\frac{E_b}{N_0}$ (dB) for Different Modulation Schemes

Figure 11 Laboratory Setup

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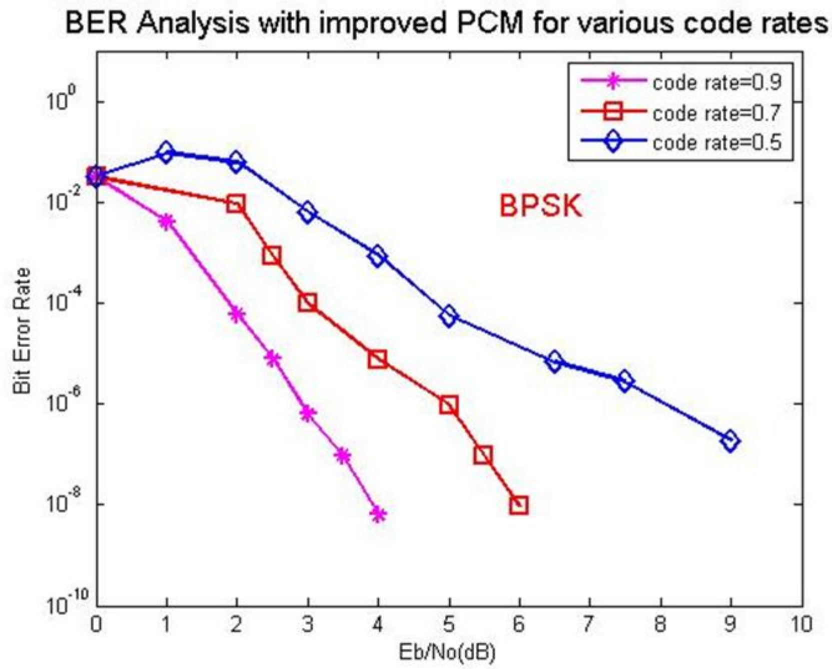

Figure 12 BER Vs $\frac{E_b}{N_0}$ (dB) in USRP 2920

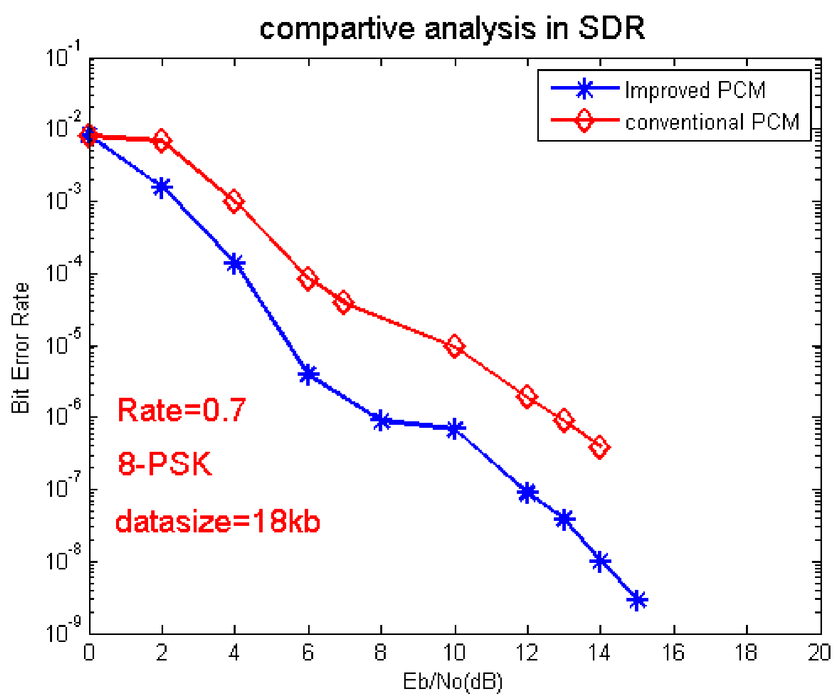

Figure 13 BER Vs $\frac{\mathrm{E_b}}{\mathrm{N_0}}$ (dB) in USRP 2920 for High Code Rate

7. CONCLUSION

5G communication is meant to attain very high data rate with minimal Error. Multiple evaluations and comparisons with traditional algorithms show that the suggested technique performs better with respect to the BER. Furthermore, the algorithm's efficacy has been validated through real-time

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implementation using Software Defined Radio (SDR) across multiple data rates. The experimental outcomes exhibit promising results, affirming the feasibility of practicing the proposed algorithm into both storage systems and wireless communication system.

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