Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Huffrith Algorithm with Quasi Cyclic Low Density Parity Check in NOMA Systems

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ARTICLE INFO

Article history:
Received 10 June 2023
Received in revised form 3 November 2023
Accepted 19 November 2023
Available online 24 January 2024

Keywords:
Non-Orthogonal Multiple Access (NOMA); Quasi-Cyclic Low Density Parity Check (QC-LDPC); Peak-to-Peak Average Ratio (PAPR); Huffrith Algorithm; Amplitude Phase Shift Keying (APSK)

ABSTRACT

In this paper, the high-rate Quasi-Cyclic Low-Density Parity -Check (QC-LDPC) as an error correction code is contributed for Non-orthogonal Multiple Access (NOMA) systems with high-frequency spectrum efficiency. High PAPR will affect the signal degradation and all the methods applied in the NOMA system are solving the problem of scarce time or frequency domain resources. The objectives of this paper are achieved by reducing the PAPR using Huffrith algorithms with QC-LDPC in the NOMA system. Huffrith algorithm combined with QC-LDPC to reduce the peak-to-peak average ratio in the 6G network. This method simulates using the 512 APSK modulation technique. The results were obtained by differentiating the contribution method with four types of coding techniques, which are an original data signal, Huffman, Huffrith, and Arithmetic algorithms. Besides, also differentiate three scenarios without error correction codes, LDPC codes, and QC-LDPC codes to compare which is better and more suitable using the NOMA system. Compared with different multiple access shows results that NOMA systems get highest percentage of improvement is 16.95% and 9.8 dB. Next results, seems QC-LDPC is better by getting the highest percentage of improvement is 22.31% and 9.40 dB compare with others.

1. Introduction

Nowadays in a highly centralized information age, all kinds of business are highly reliability and demanding of communication systems. This need is to be met in the context of next-generation mobile communications systems characterized by high speed, large capacity, and good quality of service (QoS) for millions of subscribers. More new mobile multimedia services become available to larger audiences, the demand for wireless communications with higher data rates and greater capacity increases. To meet these requirements, several energy and spectrum-efficient technologies have been proposed for 6G networks. Sixth generation (6G) networks require breakthroughs beyond current fifth generation (5G) networks [1]. The International Telecommunication Union (ITU)

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https://doi.org/10.37934/araset.38.1.111

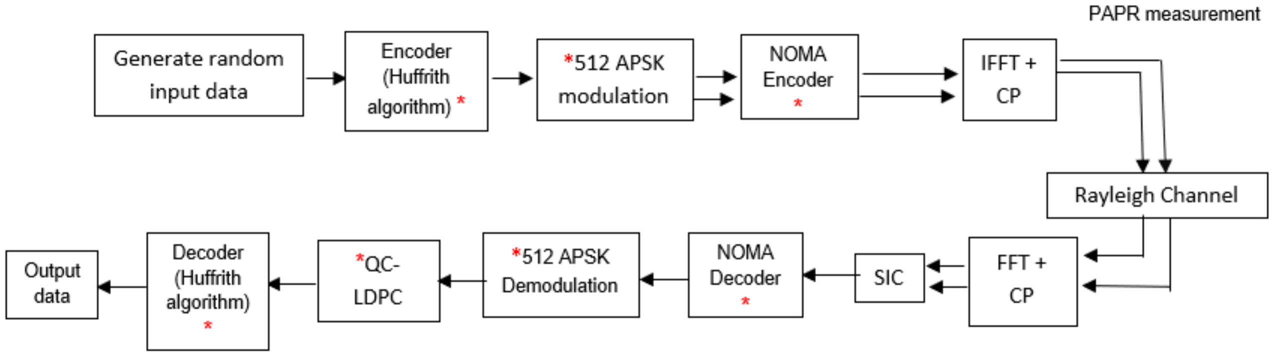
Technologies for Network 2030 was established in July 2018 to explore system technologies for 2030 and beyond. Their concepts for 6G include new holographic media, services, network architecture, and Internet Protocol (IP). Given the relatively early stage of 6G research, openness of the technology should be encouraged, like use cases, deployment scenarios, and performance requirements [2-4]. The choice of technology also reflects investments in some strategic areas of a country, which is particularly the case for 5G.

Given the above examples, in this paper more focus on potential physical layer technologies for 6G, including holographic radio, terahertz communications, large smart surfaces (LIS), orbital angular momentum, advanced channel coding/modulation, visible light communications, and advanced duplex. These technologies vary in maturity, and some are still in the stage of scientific exploration [5,6]. NOMA allows controllable interference through non-orthogonal resource allocation at the cost of a tolerable increase in receiver complexity. Signals transmitted to different users are overlapped at the same time or frequency band and recovered using advanced reception algorithms. Further, the transmit and receive signals are superimposed and multiplexed into the power domain. The interference cancellation techniques such as successive interference cancellation (SIC) in downlink NOMA is performed at the high channel gain user to remove the signals from the lower channel gain users [7]. The user does not perform SIC and decodes its own signal at lowest channel gain user by considering the higher channel gain users as noise. Either each user or the overall system can obtain significant capacity by sharing the same resources. In NOMA, power allocation and user grouping scheme play an important role in significant capacity improvement, otherwise, an insufficient scheme can also lead to performance degradation [8,9].

Over recent years, researchers on LDPC have focused more on quasi-cyclic low-density parity check (QC-LDPC) codes, which is exhibit advantages over other types of LDPC codes with respect to the hardware implementations of encoding and decoding using simple shift registers and logic circuits. QC-LDPC codes as a low-complexity encoder due to the sparseness of the parity check matrix [10,11]. Low density parity check (LDPC) code structure is divided into two categories, which are random structure and structured structure [12]. The performance of random code is good, but there is no regular connection between check node and variable node. Therefore, it is necessary to store check matrix and generator matrix in storage, resulting in high complexity of coding and decoding, which is not good for hardware implementation. QC-LDPC is construct based on cyclic difference sets. The basis matrix can be represented by cyclic difference sets and unit matrixes, but this code is only suitable for high bit rates [13]. These Quasi-Cyclic (QC) codes are defined in [14] which is cyclically shifting a codeword fixed number of bits to the left or right results in another codeword. A QC code with several bits is equal to 1, obviously a cyclic code. However, another definition for QC codes is based on a sectionized cyclic structure. The QC-LDPC codes are more accurate with this research than QC with the sectionized cyclic property.

2. Methodology

The contribution method of NOMA system block diagram is illustrated in Figure 1. The input data randomly generated using the proposed method which encoder part Huffrith algorithm and 512 APSK modulation techniques. Then users signal transmits through NOMA encoder with additional combining between Fourier transform and cyclic prefix. The capability of cyclic prefix to remove Inter-Symbol Interference (ISI) from multipath channel in transmit signal. Thus, PAPR measures the performance of this part pass through Rayleigh channel and receiver part. Process reverse will be superposed through superposition coding which is SIC and Quasi Cyclic Low Density Parity Check (QC-LDPC) as error correction code. Here the performance finalizes the multiple user connection to cancel out the interference from the stronger signal. Last steps will finalize all the method contribute to this research is reduce PAPR or not with discussion all the graph results.



*Contribution of NOMA method

Fig. 1. Block diagram of NOMA system with the proposed method

The flow chart of simulation process in NOMA system is shown in Figure 2. PAPR performance is obtained in final stage after done simulate the signal. This research differentiates using error correction code to meet the objective. Quasi-Cyclic low density parity check is contributed as correction code using NOMA system. Starting by generating randomly input data signal and encoding using Huffrith algorithm and 512 APSK modulation in NOMA system. IFFT part is combining with cyclic prefix to encode the signal and analyse the PAPR results before thoroughly into Rayleigh channel. Lastly, the signals pass through into the decoder part. This part compares and evaluates the results which is achieved the objective to reduce the PAPR or not. If satisfied with the results the simulation was ended.

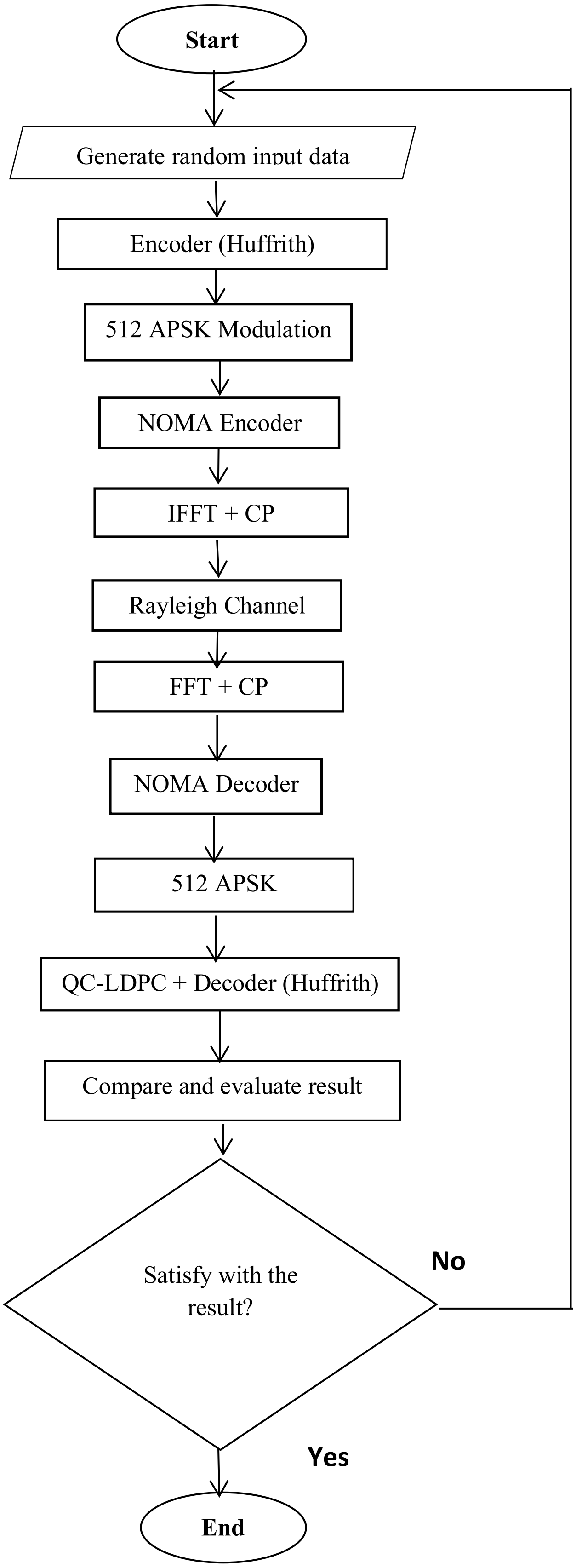


Fig. 2. The simulation process in NOMA system

3. Proposed Method

3.1 NOMA (Non-Orthogonal Multiple Access)

NOMA becoming the best candidate due to its high spectral efficiency among all the 6G candidates. Due to this benefit in NOMA, this system been considered as essential scheme to support massive connectivity such as IoT which cannot be effectively supported by OMA scheme. There are two or more users are grouped together in NOMA, and allocated different power within the same resource, which can be of the time, frequency, or spreading code [15-17]. The input signal at users is represented as [8]

$$y_i = h_i\sqrt{a_{huffrith}x_i} \tag{1}$$

where h_i is the complex channel coefficient between the users and base stations. w_i is the receiver Gaussian noise including inter-cell interference. PAPR is expressed in terms of dB, given as: [18]

$$PAPR_{dB} = 10log_{10}\frac{Maximum[|y_i(t)|^2]}{\frac{1}{T}\int_0^T[|y_i(t)|^2]dt} \tag{2}$$

where T is the period of the NOMA symbol. The complementary cumulated distribution function (CCDF) is a significant parameter which indicates the effectiveness of reduction method.

3.2 Huffrith Algorithm

Huffrith algorithm is combination between Arithmetic and Huffman equations. This is contribution of previous research [19] where by combining both will compliment with each other. The Huffrith algorithm expressed as below.

$$a_{huffrith} = \frac{255[a-P_1(a)]}{P_2} \tag{3}$$

Assume that a is total number of bits per symbols of NOMA system and number of symbols. P_1 and P_2 is probability of codeword. Huffrith algorithm is function as a modulation technique that using to encode the string. Hence, Huffrith also as encoded the data which is the process conversion of compress data, transmit the data and data storage.

3.3 Quasi-Cyclic Low Density Parity Check (QC-LDPC)

QC-LDPC is the structured of LDPC code which is quasi-cyclic parity check matrix can be replaced by a simple linear shift Register encoding, reducing the required storage space, reducing the complexity of the hardware to achieve, has become the focus of coding research. A binary QC-LDPC code characterized by the null space of an array of sparse circulants of the same size. The parity check matrix H of a QC-LDPC are defined by the base graph and shift coefficients $(P_{i,j})$ is taking into this implementation. The elements of number bits 1s and 0s in based graph are replaced by a circulant permutation matrix and a zero matrix of size $z\ x\ z$, respectively [10,13,20]. For two positive integers m_b and n_b, with $m_b \leq n_b$, consider the QC-LDPC expressed by the form is $m_b\ x\ n_b$ array of $z\ x\ z$ circulants as shown in Eq. (4).

$$H = \begin{bmatrix} I(a_{1,1}) & I(a_{1,2}) & \cdots & I(a_{1,n_b}) \\ I(a_{2,1}) & I(a_{2,2}) & & I(a_{2,n_b}) \\ \vdots & \vdots & \ddots & \vdots \\ I(a_{m_b,1}) & I(a_{m_b,2}) & \cdots & I(a_{m_b,n_b}) \end{bmatrix} \tag{4}$$

This unit matrix that moves the corresponding place. The cyclic permutation matrix is written as a matrix $E(H)$, which is called a quasi-cyclic basis matrix [13], has shown in following form:

$$E(H) = \begin{bmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,n_b} \\ a_{2,1} & a_{2,2} & & a_{2,n_b} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m_b,1} & a_{m_b,2} & \cdots & a_{m_b,n_b} \end{bmatrix} \tag{5}$$

Each entry in the matrix E is referred to as a shift value. It should be noted that the parity check matrix H can be constructed by expanding the $m_b \; x \; n_b$ exponent matrix $E(H)$. This procedure is referred to as photograph construction [21].

4. Results

This section discusses the results obtained from the proposed method which is differentiate between NOMA (Non-Orthogonal Multiple Access) and OMA (Orthogonal Multiple Access), combine with QC-LDPC as error correction mode. Table 1 as the simulation parameters to generate random data by using the subcarrier 512 APSK coding technique.

Table 1
Simulation parameters [19]

Parameter	Specification
Subcarrier per resource block	1024
Channel	Rayleigh fading
Transmission waveform	512 APSK
Sampling factor, n	1.12
FFT size	1024
Cyclic prefix	256

Based on the observation of Figure 3, the PAPR performance graph with different type of multiple access using Huffrith Algorithm can be explicitly compared. NOMA system more reliable by applying the Huffrith Algorithm coding method.

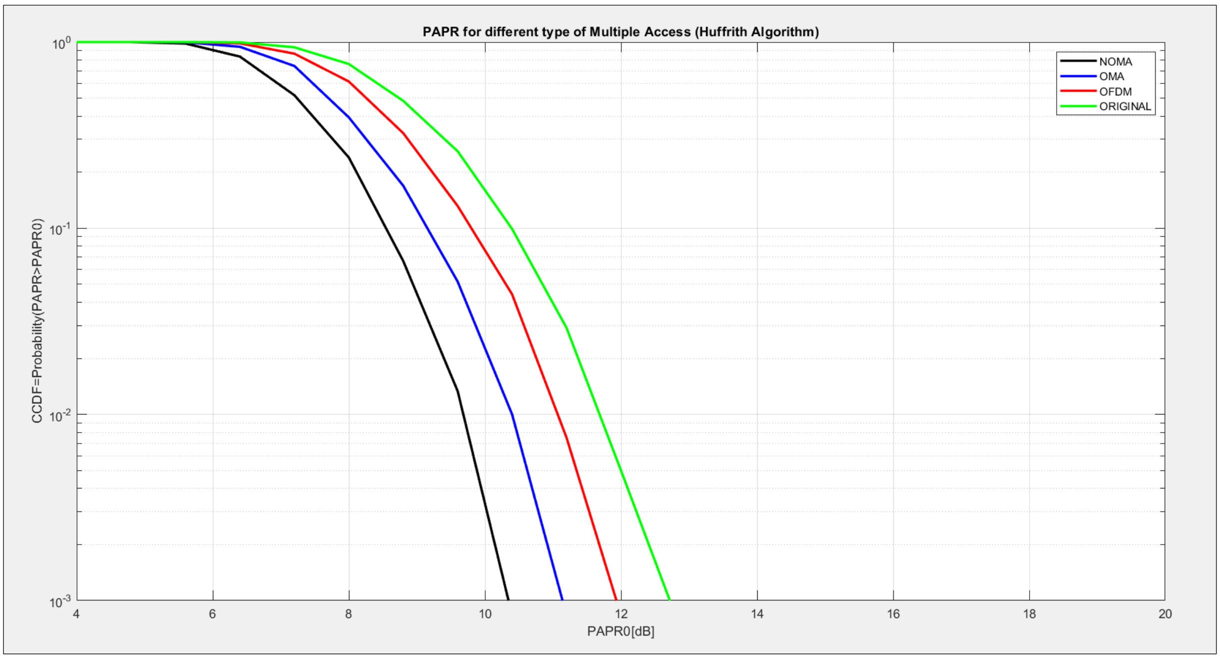


Fig. 3. PAPR performance graph for different type of Multiple Access (Huffrith Algorithm)

Meanwhile, Table 2 summarize the PAPR value for different four type of multiple access by using Huffrith algorithm. Results shows that NOMA more reduce the PAPR against others system. In fact, NOMA has been considered as essential scheme to support massive connectivity which cannot be effectively supported by other system. The percentage for NOMA is 16.95% with 9.8 dB, following by OMA is 13.56% with 10.2 dB and OFDM value is the lowest 5.08% with 11.2 dB. It is huge gap between the NOMA and without using any system seems it compatible method are used to reduce the PAPR.

Table 2
Summary of PAPR value between different Multiple Access (Huffrith Algorithm)

Multiple access	PAPR value at 10^{-2}dB	Percentage of improvement (%)
Non-orthogonal Multiple access (NOMA)	9.8	16.95
Orthogonal Multiple access (OMA)	10.2	13.56
Orthogonal Frequency-Division Multiplexing (OFDM)	11.2	5.08
Without Multiple Access (Original)	11.8	-

There are three additional methods had compared towards NOMA system which one is the best in reducing PAPR either without error correction code or low-density parity check (LDPC) or quasi-cyclic low density parity check (QC-LDPC). In Figure 4, PAPR performance graph without correction code indicates that the proposed code Huffrith algorithms is better than the comparable code. Huffrith shown PAPR reduction with 9.55 dB, following by Arithmetic and Huffman same value is 9.65 dB and original data is 11.5 dB at 10^{-2} dB, respectively. Therefore, it concluded that the Huffrith algorithm outperform in reducing PAPR for NOMA system and data signal compression randomly. Based on 10^{-1}, the graph Huffrith, Huffman and Arithmetic seems not much different value regarding no error correction code is applying in decoder part.

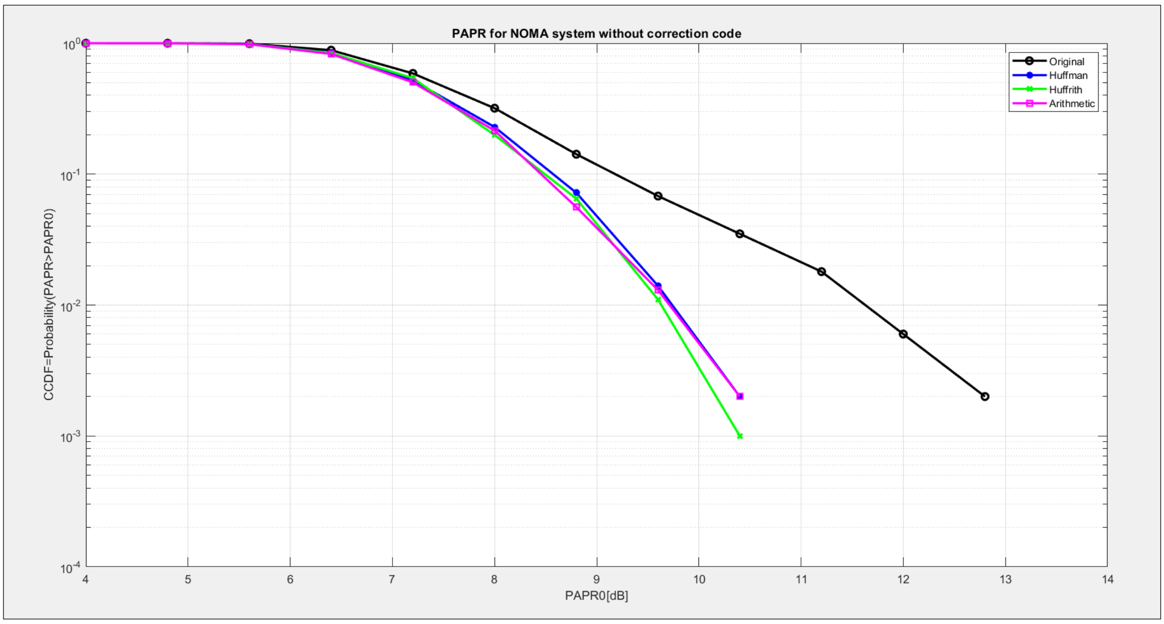


Fig. 4. PAPR performance graph for NOMA system without correction code

Figure 5 shows the PAPR performance of four different type of block coding technique using 512 APSK modulations with low density parity check (LDPC) codes. LDPC decoder functional as easy to integrate and high data rate power line communication where all wireless and wireline hardware designers an off-the shelf. Referring to 10^{-2} dB, Huffrith algorithm led better performance is 9.5 dB. Following by Huffman and Arithmetic algorithms get same value is 9.6 dB, and original signal data is 11.6 dB. Applying the modulation scheme like Huffrith will gets smooth performance graph and more improvement of percentage error. Huffrith algorithm also shows good results while applying LDPC code.

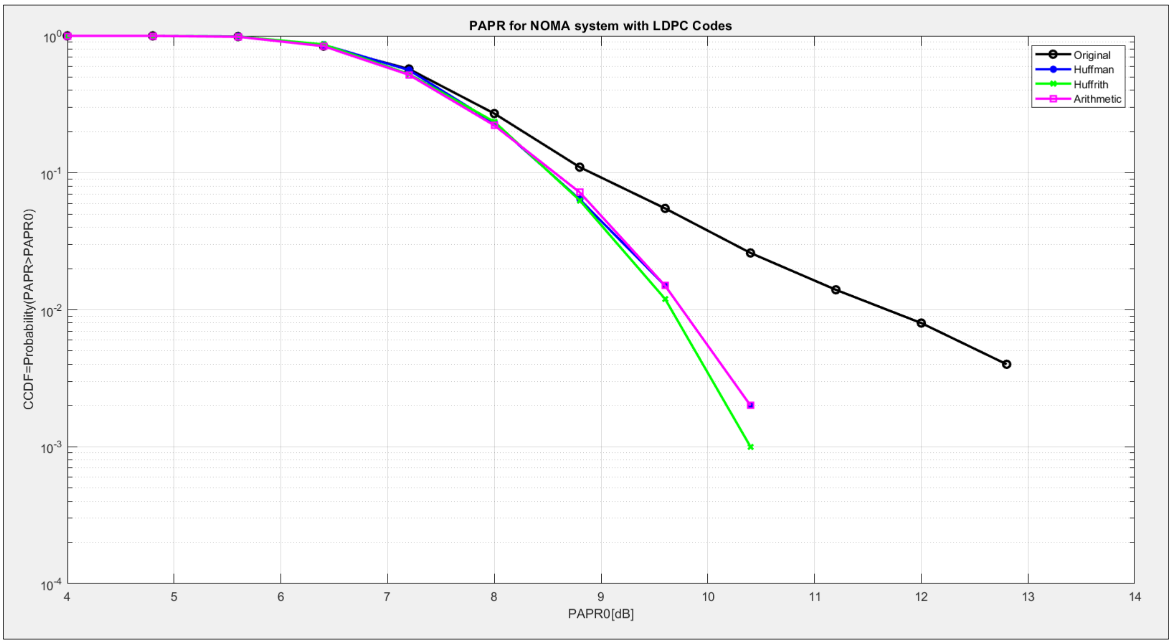


Fig. 5. PAPR performance graph for NOMA system with LDPC Codes

Figure 6 portrays the PAPR graph using different types of modulation scheme combining with quasi-cyclic low density parity check (QC-LDPC) codes. QC-LDPC is advance coding technique that applied in this research. At 10^{-2}, Huffrith shows better results than the others modulation scheme which is 9.4 dB. Following by Huffman is 9.55 dB, Arithmetic is 9.6 dB and original data is 12.1 dB. Therefore, the proposed algorithm combining with QC-LDPC codes is quite useful in the design of NOMA system. QC-LDPC is so far the strongest available and will become more and more a mandatory decoders solution. The proposed coding technique is reducing more high data rate than the comparable coding technique.

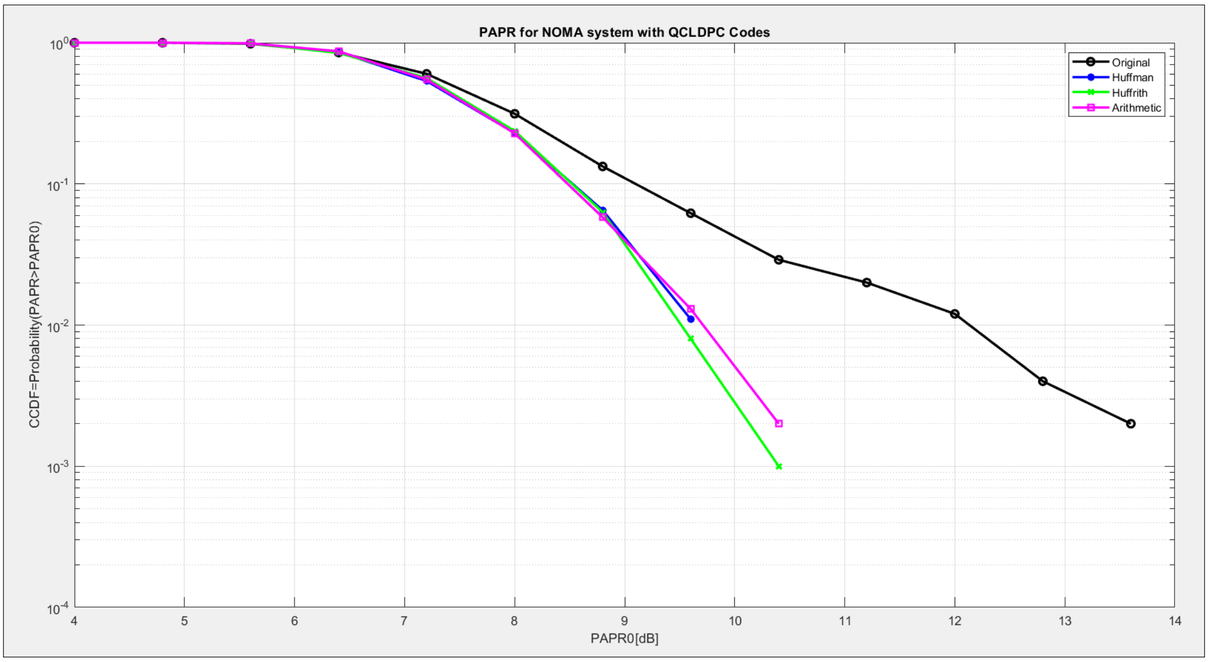


Fig. 6. PAPR performance graph for NOMA system with QC-LDPC Codes

In Table 3, three different scenarios which is without correction code, LDPC codes and QC-LDPC codes simulate with different types of block coding technique. Also applying 512 APSK modulation. These scenarios shows that Huffrith algorithms was led better PAPR performance and get higher percentage of improvement. Without correction code, Huffrith highest percentage with 16.96%. Then by using LDPC codes also Huffrith is the highest percentage of improvement with 18.10%. Apply QC-LDPC codes by upgrading the method is really have improvement with percentage error 22.31%. It seems QC-LDPC combine with Huffrith algorithms in NOMA system more reliable and suitable.

Table 3
Summary of PAPR value between different scenarios

Scenario	Block coding scheme	PAPR value at 10^{-2}dB	Percentage of improvement (%)
Without correction code	Original	11.50	-
	Huffman	9.65	16.09
	Huffrith	9.55	16.96
	Arithmetic	9.65	16.09
LDPC codes	Original	11.60	-
	Huffman	9.60	17.24
	Huffrith	9.50	18.10
	Arithmetic	9.60	17.24
QC-LDPC codes	Original	12.10	-
	Huffman	9.55	21.07
	Huffrith	9.40	22.31
	Arithmetic	9.60	20.66

4. Conclusions

This paper gives better interpretation and new contribution method in NOMA system terms of the concept and performance results. High PAPR will affect the signal degradation and all the methods applying in NOMA system is solving problem about scarce time or frequency domain resources. PAPR performance evaluates with new contributors Huffrith algorithm combining method QC-LDPC codes. Both methods more reliable and achieved the objectives of this paper to reduce the PAPR using Huffrith algorithms with QC-LDPC in NOMA system. First results shows that NOMA systems get highest percentage of improvement is 16.95% and 9.8 dB. The second results obtained QC-LDPC better by getting highest percentage of improvement is 22.31% and 9.40 dB. So, all the new method and contribution is suitable for NOMA system in getting PAPR reduction.

Acknowledgement

The authors would convey their profound appreciation and gratitude to the College of Engineering, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia for permitting us to perform this study. Special thanks to those who contributed to this project directly and indirectly.

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