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Comparison study of channel coding on non-orthogonal multiple access techniques

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ABSTRACT

Some of the benefits of fifth-generation (5G) mobile communications include low latency, fast data rates, and increased amount of perceived service quality of users and base station capacity. The purpose of this paper is to solve some of the problems in the traditional mobile system by increasing the channel capacity, non-orthogonal multiple access (NOMA), has a chance of winning the race, power-domain NOMA (PD-NOMA) is widely used in but it requires a large power imbalance between the signals allocated to various users to work. This paper also proposes an improved mobile system model and compares it with a traditional mobile system, then evaluates the effect of channel coding types on the spectrum efficiency performance. A proposed mobile system relied on increasing the number of users as well as increasing the frequency spectrum and is also proposed to improve the error rate, which is incorporated into NOMA and orthogonal frequency division multiplexing (OFDM) schemes at the same time to provide great flexibility and compatibility with other services, such as the 5G and sixth-generation (6G) systems. The mobile gully system (MGS) system is compared to a traditional system, the result is demonstrated that the proposed outperforms the orthogonal multiple access (OMA) system in terms of sum-rate capacity, and bit error rate (BER) performance.

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1. INTRODUCTION

From first-generation (1G) to fourth-generation (4G), multiple access methods are revolutionary in the evolution of mobile communications. Future communication systems (such as 5G) are expected to see a huge increase in the number of connected devices, which will make it challenging to meet the high data rate and capacity needs [1]. Mobile communication systems have traditionally relied heavily on the choice of multiple access strategies to determine the quality of service, dependability, and spectral efficiency of the system.

Due to their inability to manage a high number of connected devices, orthogonal multiple access (OMA) technologies including time-division multiple access (TDMA), frequency-division multiple access (FDMA), and code-division multiple access (CDMA) face major hurdles [2]. Because future generation communication systems employ a variety of devices, the data rate requirements may vary from device to device, which might lead to resource waste by using various access mechanisms. Opposite to the spectrally inefficient OMA systems [3]. A simple receiver allows OMA to detect quickly the user information signal sent by the device [4]. However, OMA systems struggle to fulfill the unprecedented user load needs in the newly developing massive machine-type communications. Similar to OMA, because many users may use radio resources at the same time by using power domain to multiplex the data of various devices, the non-orthogonal multiple access (NOMA) approaches may handle a large number of mobile devices and increase capacity [5], [6].

NOMA allows many users to utilize frequency and temporal resources inside the shared physical layer utilizing code or power domain multiple access [7], [8]. By utilizing superposition coding at the transmitter and successive interference cancellation at the receiver, NOMA outperforms OMA from an information-theoretical perspective [9]. Pair devices are those devices that share the same bandwidth. The optimization of these pair devices and their power distribution are important aspects to achieve a promising capacity improvement, according to the report. There is a problem with receiving data from multiple devices since they share the same bandwidth in NOMA. his gadget needs to employ successive interference cancellation (SIC) in the power domain in order to tell the distant device from the close one [10], [11].

Channel coding is an essential part of every communication system. Low-density parity-check (LDPC) code for data channel coding is part of the 5G wireless technology standard for broadband cellular networks in the fifth generation of new radio (5G-NR) [12], [13]. LDPC codes beat turbo codes despite their superior error-correction performance, because of their ability to achieve high parallelization in decoding processes, as well as their predecessors in 3G and 4G long term evolution (LTE) networks [14]. Innovative 5G applications face channel coding problems, such as multi-gigabit speed, low latency (in some situations), and substantial flexibility, while maintaining strong error-correcting performance.

All these problems are better met by LDPC codes than by turbo codes. Most significantly, there is a greater gain in coding with the LDPC codes and better error-correcting performance compared to turbo codes [15]. Afterward, some prior remarkable surveys on NOMA and LDPC are examined.

Each category of the transceiver block diagram of NOMA, including fundamental features, basic ideas, and transmission/reception algorithms, is described by Tse and Viswanath in [9]. The authors outlined the features and operating principles of several NOMA systems in [16]. Meanwhile, Wang *et al.* in [17] compared and analyzed NOMA systems. The authors concentrated on the long-term research goals, prototype development, current accomplishments, standardization, and difficulties of NOMA. Based on comparative and analytical analysis of various technologies, [18] suggests future research roadmaps for 5G waveforms and numerous access ways. Furthermore, the remarkable multiple-input-multiple-output (MIMO-outage) probability of the NOMA system is calculated using perfect user-ordering and minimal feedback [19]. As an alternative to the channel state information (CSI) at the transmitter, the method described in [20] needed more antennae at the receiver than at the transmitter.

A comparison of convolutional, turbo, and LDPC codes was provided in [21]. Sybis *et al.* [1] describe research on 5G channel coding options for ultra-reliable low-latency communication that takes into account block-length error rate and computing cost. On the other hand, several coding techniques for 5G brief message transmission with an emphasis on error correction are in [22].

Kim [23] presented that coding and high-order modulation methods are critical in 5G and satellite communication systems. By contrast, Yuan *et al*. [24] used LDPC code to investigate sequential interference cancellation techniques for a two-user NOMA system. The NOMA-LDPC system proposed in this paper is compared with NOMA-turbo to find the best usage performance in real-time applications, such as video and audio. The main contributions of this paper are is being as; i) it proposes a new generation mobile model for a 5G system, which supports NOMA and OFDM at the same time, ii) it supports a high number of users, iii) it improves high data rates.

According to the following structure, the rest of this article will: the NOMA and LDPC models are respectively explained in sections 2 and 3. System implementation and results are discussed in section 4. Finally, a summary finding of this paper is provided in section 5.

2. NOMA MODEL

Compared with 4G, which relies on an orthogonal method, 5G must use non-orthogonal communication for its operation. Each user in orthogonal frequency-division multiple access (OFDMA) is allocated a subset of subcarriers as information [25]. By contrast, NOMA allows all users to utilize all subcarriers concurrently.

Consequently, data throughput will improve. Figure 1 depicts the spectrum accessing strategy for a two-user cluster using NOMA and OMA [26]. Figure 2 shows that the BS may offer service to two UEs at the same time, code, and frequency as long as the power levels are different. A composite message signal will be sent to both users (UE1 and UE2) after superposition coding, with separate messages for each user as shown in Figure 3.

$$w = w_1 + w_2 \qquad (1)$$

$$w_i = \sqrt{p_i}s_i \qquad (2)$$

Where w is signal data and s is transmitted signal data, p is power for each user.

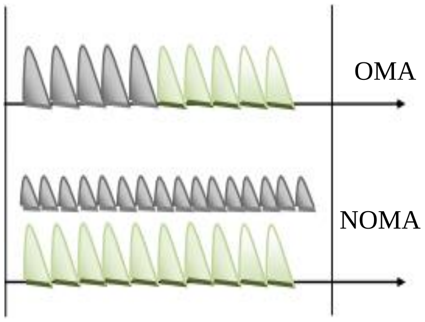

Figure 1. Sharing spectrum in NOMA

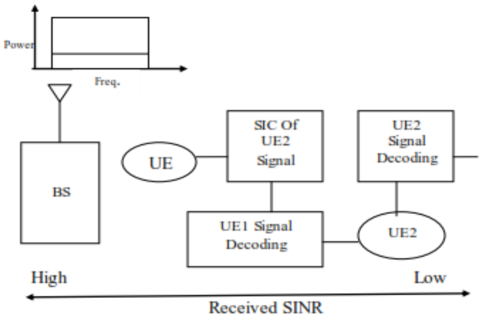

Figure 2. Block diagram of NOMA model

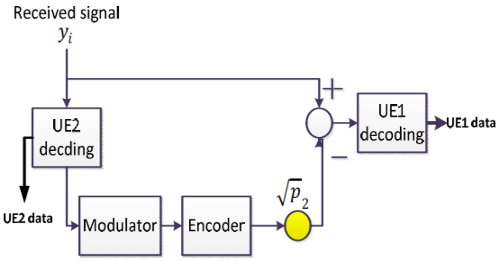

Figure 3. Block diagram of SIC in NOMA model

At the receiver, y is the received signal, n is noise and h is channel matrix [27], as shown in the following:

$$yi = h_1(w_1 + w_2) + n_1 \qquad (3)$$

3. LDPC MODEL

The technique of converting a bitstream of length k into a codeword while adhering to the rules of channel codes is known as channel coding [28], [29]. One of the most popular kinds of such codes is the code of the block. Consequently, given a(n, k) block code, the channel encoder accepts data in k-thousandths of codes. Figure 4 depicts the system block diagram, followed by LDPC coding, modulation, an S/P block, an inverse fast fourier transform (IFFT) block, and a P/S element. The cyclic prefix (CP) is then applied, and the resultant signal is sent via the channel.

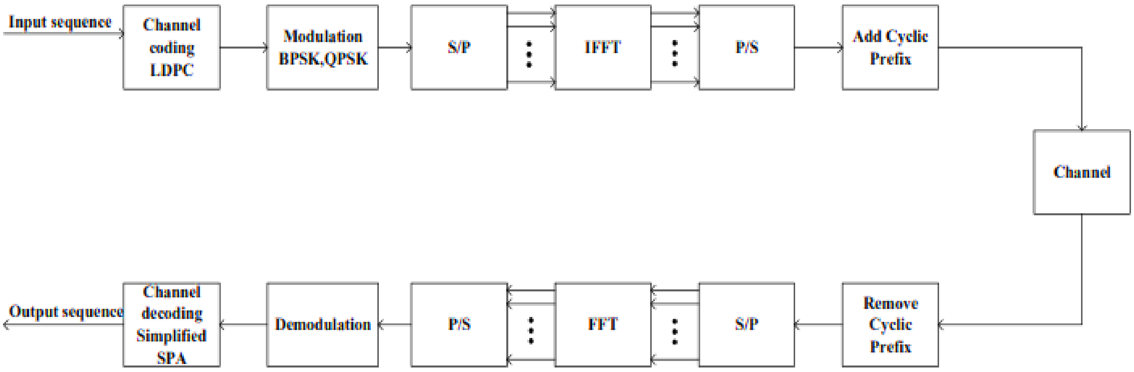

Figure 4. Block diagram of LDPC model

The CP is removed in the receiver. As a result of the S/P block, the data are converted from series to parallel, and then transferred to an FFT block, and finally converted back to series by decoding the LDPC is done using sum-product. After receiving information in k-byte blocks, the encoder inserts (n-k) superfluous symbols algebraically linked to the k-byte messages and generates an encoded element of n codes known as the codeword to create (n, k) code. Block codes must be linear with a systematic structure to simplify the encoding process. If this requirement is met, a message component of k information symbols, as well as a redundant checking portion of parity-check symbols, must not be altered.

$$\mathrm{c} = \mathrm{m.G} \tag{4}$$

where c is the codeword of a linear combination, m is the message vector, and g is the channel matrix.

$$G = \begin{pmatrix} g_0 \\ g_1 \\ \cdots \\ g_{k-1} \end{pmatrix} \tag{5}$$

G is also defined is being as:

$$\mathrm{G} = [\mathrm{I_K}|\mathrm{P}] \tag{6}$$

where I is the identity matrix, and P is the matrix of dimension (kx(n – k))

$$\mathrm{m} = [\mathrm{m_0}, \mathrm{m_1}, \ldots.\mathrm{m_{k-1}}] \tag{7}$$

The following is the codeword for a systematic linear block code:

$$c = [m|b] \tag{8}$$

Where b is the parity check.

4. THE PROPOSED SYSTEM MODEL

Some of the 5G system's components are included in the planned mobile generation system (MGS). Data generation, improved channel coding, advanced modulation type, NOMA waveform, an open and closed loop of transmission mode, massive MIMO up to 32 antennas, mapping, and precoding are all included in the proposed system shown in Figure 5. The addition of the blue blocks will improve system performance. Instead of turbo coding, the next generation of mobile devices will employ LDPC Improved.

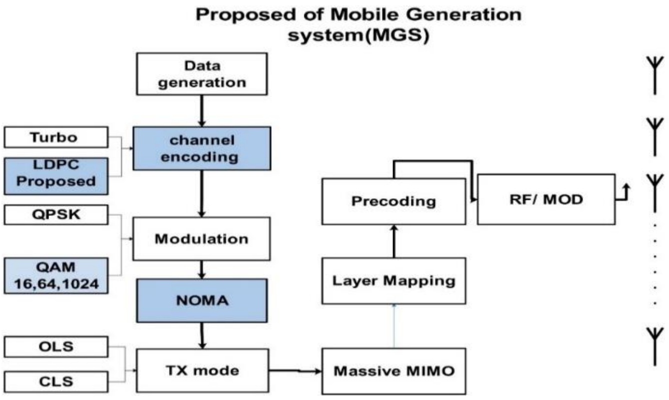

Figure 5. Components of the proposed mobile generation system model

5. RESULTS AND DISCUSSION

In this section, the suggested model system's performance is evaluated. To improve the level of confidence in the results, extensive simulations were run in MATLAB using the Monte Carlo approach. The simulation architecture includes two base stations and a variable number of UE, the system model simulation is outlined in Figure 6. Table 1 displays the parameters of the simulation. There are 72 subcarriers in each

BS. The first BS only allows two users, thus each one receives 36 subcarriers, The second cell supports NOMA operation and therefore may handle two groups of two overlaid devices (by using the power-domain technique). One of the overlaid devices in each group had much more path loss than the other.

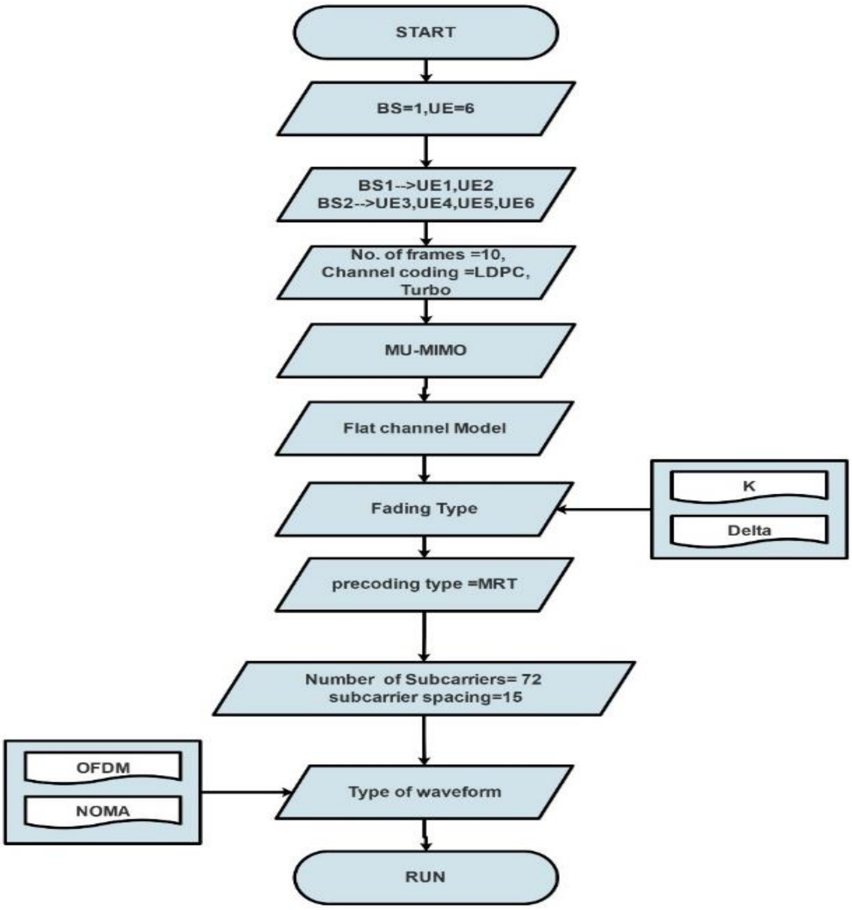

Figure 6. Simulation steps of the proposed system model

Table 1. Parameters of simulation

Parameters	Values
User velocity (m/s)	30
Structure of frame	FDD
Number of frames	10
Center frequency (GHz)	2.5
Subcarrier spacing (kHz)	15
No. of subcarriers	72
Channel modulation	QPSK, QAM
Number of antennae	0 to 42
Channel coding	LDPC, Turbo
LDPC decoding	Min-Sum
Turbo decoding	Linear-Log-MAP
Decoding Iterations	16

Figure 7 shows a comparison of the sum of throughput outcomes for two BSs (NOMA and OMA) with two-channel coding types, namely LDPC, and turbo coding. The proposed model (NOMA-LDPC) surpasses the NOMA-turbo across the SNR range of 0–40 dB. The model also provides the highest throughput when the SNR is 20 dB. Figure 8 shows a comparison of bit error rate (BER) results for two UEs in OMA with two-channel coding types, namely LDPC and turbo coding. UE1 with OMA-LDPC outperforms the UE1 with OMA-turbo across the SNR range of 0–40 dB, while UE2 with OMA-LDPC provides the lowest BER performance with SNR ranges of 5–40 dB due to the high interference of another UE. Figure 9 shows a comparison of the sum of throughput outcomes for four UEs in NOMA with two-channel coding types, namely LDPC and turbo coding. The proposed model (NOMA-LDPC) at each UE surpasses the NOMA-turbo across the SNR range of 0–40 dB. The proposed model provides the highest throughput when the SNR is 10 dB in UE4.

Figure 10 shows a comparison of BER results for four UEs in NOMA with two-channel coding types, namely LDPC and turbo coding. UEs with NOMA-LDPC outperform those with OMA-turbo across the SNR range of 0–40 dB. Meanwhile, UE4 with NOMA-LDPC provides the lowest BER performance at the SNR range of 25–45 dB due to the interference effect of UE6. Figure 11 illustrates a comparison of maximum throughput results concerning the NOMA and OMA over different channel coding. The proposed system (NOMA-LDPC) provides a higher throughput (approximately 10.13 Mbps) than the traditional system (OMA-turbo, 9.74 Mbps).

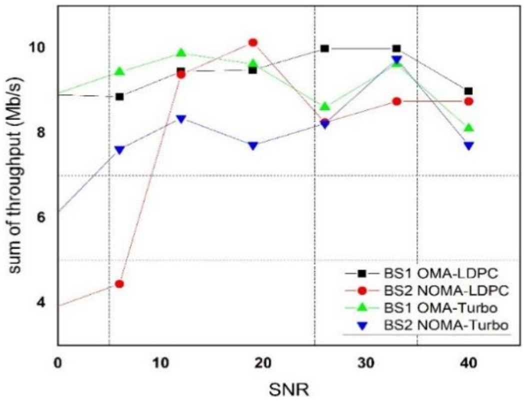

Figure 7. Sum of the throughput in OMA and NOMA system models

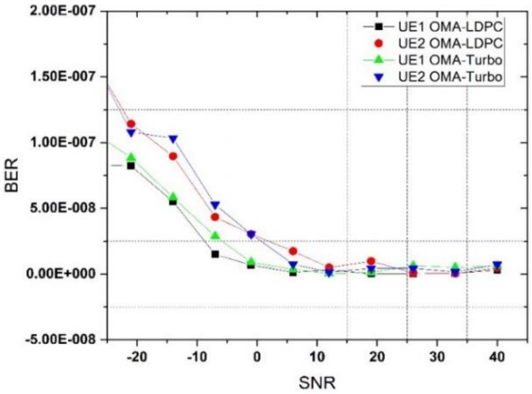

Figure 8. Sum of BER in OMA system model with LDPC and turbo coding

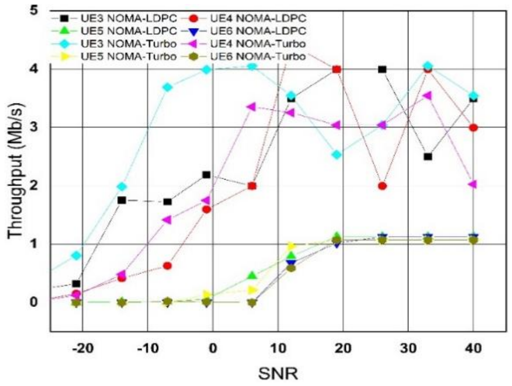

Figure 9. Throughput results in NOMA system model with LDPC and turbo coding

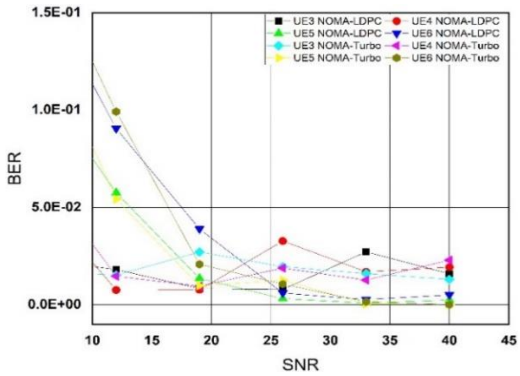

Figure 10. BER result in NOMA system model with LDPC and turbo coding

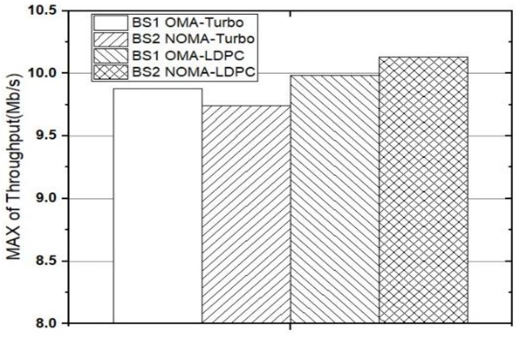

Figure 11. Summary of maximum throughput results with multiple access of frequency spectrum

6. CONCLUSION

In this work, some of the traditional mobile system-based problems have been addressed by proposing a new mobile system. It designs and investigates a new MGS with multiple access of frequency spectrum: OMA and NOMA. NOMA is one of the possible contenders for attaining the aforementioned goal. Then, MGS has been compared with traditional mobile systems, such as 5G. This scheme has emerged as a potential strategy for next-generation mobile networks. Two model systems in channel coding, namely LDPC and turbo, the effect of the channel coding types on the performance of the mobile system were studied. Finally, each type of multiple access model is incorporated with each channel coding model type. The simulation result revealed that MGS supported with four UEs outperforms 5G with only two UEs. In addition, it could provide a better throughput performance with approximately the same BER. Overall, the proposed model provides the highest number of users by approximately 20–50% more than the traditional system.

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