Performance Evaluation of Serial and Parallel Concatenated Channel Coding Scheme With Non-Orthogonal Multiple Access for 6G Networks

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ABSTRACT In recent years, with the advent of 6G and intelligent devices, sensors, and new applications such as virtual reality and autonomous driving, user data traffic has exploded, especially video traffic and small IoT packets. These bandwidth-hungry applications require an increased network capacity and user access. The 6G network may use nonorthogonal multiple access (NOMA) instead of orthogonal multiple access (OMA) to maintain higher data rates, throughput, and lower latency. On the other hand, choosing the channel coding method for future 6G mobile communication is critical for maintaining the high demand for 6G. This paper proposes two-channel coding structures to achieve higher data rates with a lower error rate floor; these structures are polar convolutional serial code (PCSC) and polar convolutional parallel code (PCPC); these structures can achieve a larger channel capacity and reduced bit error rates when used with NOMA. The obtained simulation results showed that bit error rate (BER) performance improves the overall coding gain by 1.2 dB compared to polar code in fifth-generation (5G). PCSC surpasses PCPC with a 1.5dB coding gain. This performance ranged from 4 to 6.25dB with higher system settings. The obtained throughput results showed an improvement of 56-60%, in which the enhancement percentage depended on the modulation method used in a direct proportion manner.

INDEX TERMS Concatenated coding, convolutional coding, non-orthogonal multiple access (NOMA), polar coding, terahertz (THz), 6G.

I. INTRODUCTION

The use of nonorthogonal multiple access (NOMA) radio technologies in new-generation communication 6G has recently attracted the attention of many as a replacement for orthogonal multiple access (OMA) radio technologies that have been used in previous radio communication generations, such as time division multiple access (TDMA), frequency division multiple access (FDMA), code-division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA) [1].

In the last two decades, several channel coding techniques have approached the Shannon limit exceptionally closely, providing higher throughput and lower bit error rate, such as

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turbo code, low-density parity-check (LDPC) code, and polar code (PC) have evolved. However, these codes have some weaknesses in terms of long codeword length [2].

High dependability, low latency, and increased bandwidth are all necessary for real-time, high-rate data transmission in the future 6G communication environment.

For 6G to efficiently provide higher coverage and connection, new technological requirements have emerged, including higher throughput, extremely high dependability, low power consumption, and minimal encoding/decoding lag, reaching the limit of one terabit per second with higher reliability, throughput higher than 99.99% and 1ms latency [3].

Interoperating channel coding provides overall transmission reliability allowing for a higher system throughput while reducing error rates and ensuring repressible communication of transmission faults [4]–[6].

Channel coding, also known as error correction code, can be classified into two basic categories [7].

1- Block Coding (BC)
2- Convolutional Coding (CC)

In block coding (n, k), t redundant bits added to the original data bits k transform them into n coded bits, whereas, for $n > k$, the block-code data rate is calculated using (1).

$$r = \frac{k}{n} \qquad (1)$$

Arikan [8] successfully established the perspective of a new channel code, known as the polar code (PC), which distinguishes itself from any other channel-coding technique by exceeding the Shannon channel capacity limit. The fundamental design of polar codes is proven based on channel polarisation.

Convolutional coding [9], on the other hand, uses a simple linear finite-state shift register to transform the message data to codeword as an entire sequence based on the current and previous bit state in the message data.

Forney [10] proposed concatenated code in 1966, which is a novel mathematical representation for error-correcting codes based on two error-correcting codes. The outer and inner codes are intended to improve bit error rate measurements [11], and they can be combined in either a serial or parallel approach.

Nonorthogonal multiple access has recently attracted interest as a promising radio access method for 6G networks [12]. NOMA can handle several users simultaneously with the same time or frequency band by multiplexing users in the power domain or code domain; however, this causes significant interference among users, which makes highly effective channel code a necessary need.

NOMA is classified into two types based on how resources are allocated to each user in the network: power domain NOMA (PD-NOMA) and code domain NOMA (CD-NOMA). Power-domain NOMA utilises the channel gain difference between multiplexed users by numerous superposing users in the power domain. At the same time, CD-NOMA is distinguished by its use of sparsity in spreading sequences or multi-dimensional codewords. It is worth mentioning that CD-NOMA and regular CDMA both achieve the same outcome by using different spreading codes [12]. The same principles of work are applied for both PD-NOMA and CD-NOMA; at the transmitter, many user signals are overlaid. The resulting signal is then transmitted across the same channels, the same time or frequency resources. Multiuser detection (MUD) methods, such as successive interference cancellation (SIC), are used to detect the desired signals on the receiver side.

Compared to OMA, researchers have shown that NOMA can sustain powerful connections while providing higher capacity and user fairness, resulting in lower latency, less error rate and higher throughput [13].

This paper is motivated by the ability of polar code to conduct channel capacity for Shannon limit and the relatively low

complexity of convolutional code along with 6G performance goals being compared to 5G performance limits, which are but are not limited to [14]:

- The connectivity density is ten times greater.
- The peak data rate is one terabit per second.
- The energy efficiency is 100 times better.
- The air interface latency is 0.1 milliseconds.
- The reliability is 99.99999%.

New channel codes must be thoroughly characterised and analysed to comply with 6G goals, considering the performance of channel coding with multiple access techniques.

This paper proposes and analyses the performance of a two-channel coding concatenation structure that meets 6G specifications in terms of data rate, reliability, and latency. The proposed structures, called polar convolutional serial code (PCSC), concatenate polar code as the outer code and convolutional code as the inner code for serial concatenation. For parallel concatenation, polar code is utilised as the first encoder and convolutional code as the second encoder, resulting in a polar convolutional parallel code (PCPC).

This paper is structured as follows. Section II conducts a review of pertinent recent works of literature. Section III summarises the fundamentals of channel coding and NOMA approaches. Section IV details the methodology and proposed technique. Section V examines the interaction between various structure parameters and provides numerical evaluations of the proposed system. Finally, Section VI concludes the paper.

II. RELATED WORK

With the continued deployment of cellular networks, the intrinsic limits of the network continue to be disclosed. These flaws are driving the development of the next-generation 6G network, which will allow crucial rate-hungry applications like extended reality, wireless brain-computer connections, driverless vehicles, and more to be effectively integrated. In addition, 6G will manage enormous amounts of data transfer in intelligent cities with substantially lower latency to support significant applications. This brings together several cutting-edge trends and technologies to deliver increased data speeds for ultra-reliable and low-latency communications. Recent research has focused on handling new forms of channel coding techniques regardless of the multiple access technique used, which does not provide a complete understanding of the channel coding used with actual data transmission since multiple access techniques can directly affect the information data due to possible interference. On the other hand, NOMA can cause high interference between different users if SIC is not 100% accurate, which is not considered research community.

Zhu and Wu [15] explored the encoding and decoding methods of convolutional code LDPC (CC-LDPC), block code LDPC (BC-LDPC), and polar code by comparing their error performance decoding complexity and latency. Their findings show that CC-LDPC provides significant advantages

over BC-LDPC and polar code in high dependability, low complexity, and low latency.

Agarwal and Mehta [16] combined polar coding with convolution coding using multiple-input multiple-output (MIMO) with orthogonal frequency division multiplexing (OFDM) as a multiple access technique, although their findings show better BER other than CC, reed Solomon with CC, LDPC-CC, and turbo-CC but never consider throughput and latency problems in next communication generation intention to elevate from OFDM to NOMA.

Wang *et al.* [17] Compared the concatenated polar codes with outer BCH codes, with concatenated LDPC codes and concatenated Turbo codes after applying random interleaving and blind interleaving schemes; BER performance of concatenated codes using the blind interleaving overcame the one with random interleaving while the concatenation of polar codes with BCH showed better performance.

Chen *et al.* [18] proposed hash-polar concatenated code, which performs similarly to the concatenation of cyclic redundancy check (CRC)-polar codes and outperforms parity check polar codes in terms of frame error rate; the proposed channel coding considers 5G communication and possible beyond 5G communication.

Li and He [19] Presented a new coding and decoding strategy for PC-CRC concatenated polar codes that preserve the correct paths as feasible while discarding the error paths in time, resulting in improved block error rate performance without considerably increasing complexity. Simulation findings show that the proposed system can effectively enhance block error rate performance and that it has a better effect on short and medium code length than existing schemes.

Doan *et al.* [20] suggested a CRC-polar belief propagation decoding algorithm that uses concatenated factor graphs of polar codes and CRC to transfer extrinsic information between the two-factor graphs; the proposed decoding algorithm improves error correction performance significantly when compared to a traditional belief propagation decoder. The decoding algorithm also assigns trainable weights to the edges of the CRC polar concatenated factor graph, thereby improving the error probability of the decoding algorithm.

Xu *et al.* [21] proposed interleaved concatenation scheme of the PC with the Spinal codes, a considerable BER performance improvement of PC in the finite-length domain compared to standalone PC. The concept of partial concatenation was also considered to reduce system complexity and performance losses as much as possible.

Peng *et al.* [22] propose a new method for creating parallel concatenation codes that uses PC as a basic code. In construction, these parallel concatenation codes are comparable to turbo codes. This parallel concatenation code synthesis uses the same generation matrix as Polar codes in 5G. Under the same codeword bits length and code rate, the numerical studies show that it performs similarly to the optimal Polar codes.

Chaki and Kamiya [23] proposed a concatenation structure with CRC bits appended to the end of the information bits.

The resulting vector is fed as input to the polar encoder. This approach comes with the limitation that the CRC check cannot be done until the polar decoder has decoded all the information bits. As a result, early termination of a successive cancellation decoder becomes impossible in the event of a decoding failure, resulting in latency and excessive power consumption associated with the decoding of bits that follow the first error bit.

The above literature review shows that many studies have shown that concatenated error correction codes can achieve channel capacity adjacent limitations. Many efforts have been made regarding bit error rate enhancement, focusing on either the decoding algorithm or different coding formations, which increased the account complexity, latency, and energy consumption. Most of the aforementioned proposals neglect the impact of interference caused by the multiple access techniques used in each communication generation. Using NOMA in 6G will complicate this problem because users use the same time and frequency resources. This paper solves that problem by proposing a new concatenation structure in a real-time transmission that considers NOMA as the proposed multiple access technique used in 6G and the shortcode limitations.

To the best of our knowledge, there are several important areas where this work makes several noteworthy original contributions. This paper contributes to the existing knowledge of channel coding with NOMA 6G multiple access optimisations by:

1) Experience the performance of two different concatenation structures, parallel and serial concatenation of polar and convolutional code, experiencing long codeword length without increasing system complexity, while the structures in the literature are serial concatenation with limited codeword length;

2) Introduce the two structures named polar convolutional serial code (PCSC) and polar convolutional parallel code (PCPC) with different modulation techniques and modulation rate binary phase-shift keying (BPSK) and quadrature amplitude modulation (QAM), while the performance in the literature is regardless of the modulation technique cannot practically implemented;

3) Provide a comparison between the proposed structures and the standalone polar code used in 5G, with and without multiple access NOMA transmission scenario, which shows the effectiveness of the proposed structures regarding possible data corruption caused by actual transmission interference.

III. PROPOSED CHANNEL CODING AND NONORTHOGONAL MULTIPLE ACCESS

For 6G mobile communications, NOMA will be the representative, multiple access techniques. NOMA's overall architecture and essential specifications must be merged with other communication system technologies to comply with the high transmission requirement for 6G [24]. NOMA provides services to many users, providing access to the same allocation

of frequencies, codes, and time with the same transmission system. At the receiving end, technologies like continuous successive interference cancellation (SIC) or multiuser detection (MUD) can increase the number of connections and reduce communication delays by removing the interference, detecting user signals, and effectively improving network capacity [25].

On the other hand, the SIC and MUD algorithms must be perfectly processed to overcome signal collisions and assure minimum error rate performance. Simultaneously channel coding is a critical component in wireless communications, which provides effective system error control. Wireless systems have always used cutting-edge channel coding technology, from 2G to 5G, such as convolutional codes for 2G, turbo codes for 3G and 4G, and polar codes, LDPC codes for 5G. Faster data speeds, improved reliability, less complexity, and lower power consumption are requirements for new channel coding schemes to outperform prior channel coding generations [26]. They must also meet a broader set of key performance measures that were not present in previous generations.

A. PROPOSED CHANNEL CODING

Two concatenated formula for channel coding is proposed and compared with real-time three user NOMA system transmission, which to the authors' knowledge, has not been investigated from the same perspective as this work.

The proposed and designed coding formulations are polar convolutional serial code (PCSC) and polar convolutional parallel code (PCPC), as depicted in Fig. (1).

Polar code parameters are defined as N, k the codeword length and the message sequence length. Based on these mathematically proven facts, and starting from the basics with $N = 2$, different values of N were investigated and compared for the proposed concatenation structure of polar and convolutional codes under NOMA and THz characteristics.

In PCSC, polar code is used as the outer encoder with the following parameters: $N = 1024$, $k = 528$, the output of the polar encoder is forwarded into a convolutional encoder as the inner code, which takes advantage of the low complexity of the shift registers defined as the memory stages for the convolutional code the coding parameters used is $N = 3$, $k = 1$, $D = 3$, the proposed concatenated code structure was tested for three users PD-NOMA where the signal was transmitted over AWGN and modulated using BPSK and QAM.

For the decoding process, the consequent codeword from the convolutional decoder is used as the input for the successive interference cancellation decoder, and the modulation affects the original transmitted information sequence after the outer encoder block.

In PCPC, polar code is used as the first encoder with the following parameters: $N = 1024$, $k = 528$. The second encoder is convolutional code with a code rate of $1/3$, in parallel concatenation formula data interleaver is used to reduce the error burst, after data interleaver the data is applied into

the convolutional encoder. The resultant two outputs are then multiplexed into one codeword.

The decoding process in the parallel concatenation structure is more complicated, and the received data sequence needs to be demultiplexed first to split the codeword from the parity bits caused by the first encoder and then re-multiplexed with parity bits generated by the second encoder before the second decoder can decode the data stream.
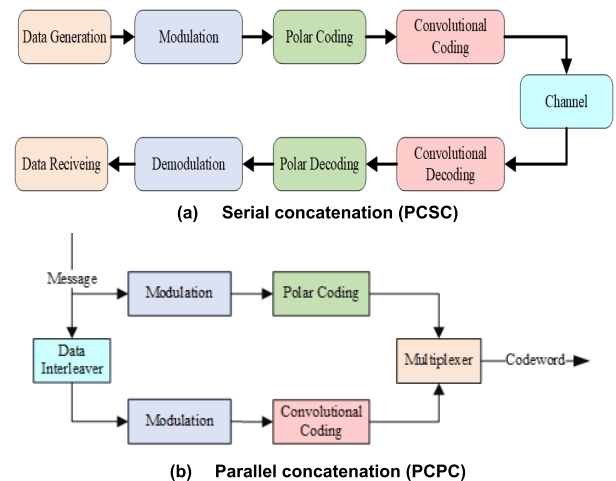

FIGURE 1. Proposed concatenated code structure (CC) block diagram.

The original data word is not yet obtained until a specific iteration limit is reached; the iteration limit is usually determined based on the applied application. The limited iteration number used in this study was 25; this number was not chosen randomly but was determined by the system based on which iteration the resultant codeword would continue to be the same without any further correction.

The initial results motivate us to proceed further with the PCSC scheme to be tested for different coding rates and modulations without adding more complexity to the system. Unlike PCPC, which adds more complexity and reasoning, more delay, resources overload, and power consumption because of the different characteristics that need to be deployed for the various codes used.

Initial results for bit error rate are shown in Fig. (5); based on that performance, further investigations of different code rates and modulations were conducted for the PCSCs. The following sections describe channel coding algorithms and NOMA system architecture implemented in this paper.

B. NONORTHOGONAL MULTIPLE ACCESS

NOMA is presented as a solution to OMA's spectral inefficiency. NOMA allows for controllable interference through nonorthogonal resource allocation at the cost of a moderate increase in receiver complexity. Signals sent to distinct users are superimposed at the same time or frequency band, and complex receiver algorithms are used to recover them. Although NOMA has been widely researched in 5G and beyond networks, past research has primarily focused on static devices and broadband users' data rates [27].

This overlooks several critical issues with next-generation multiple access, such as the impact of mobility, connectivity, reliability, and latency. Realising NOMA's full potential in real-world communication contexts is complex, and there are still many critical open issues to be resolved [28]. PD-NOMA is used in the proposed structure as a multiple access technique to comply with the 6G new communication vision.

PD-NOMA superposes multiple users in the power domain and achieves channel gain using superposition coding (SC). The transmitter side is responsible for superposing various user signals and transmitting the resulting signal over the same channel resources, as shown in Fig. (2).
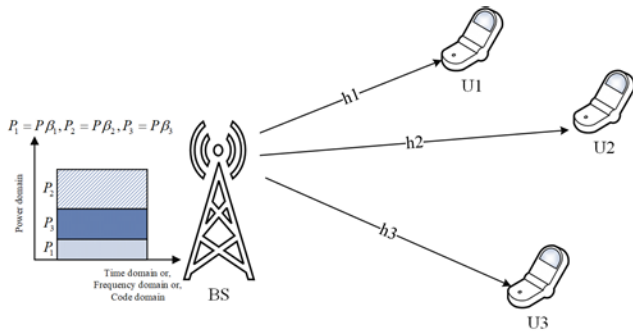
FIGURE 2. System model for PD-NOMA.

The mathematical representation for two NOMA users is presented; this can be widespread to any number of users based on the network architecture. The user signals are represented as in (2) and (3) for users 1 and 2, respectively, and the resulting superposed signal is determined using (4); which β_i represents the power factor assigned for each user from the total power P where the system is subject to the restriction $\beta_1 + \beta_2 = 1$ and S_i is the specific user signal. After transmission through the wireless channel, the received signal at each user σ^2 is expressed by (5), where w_i is the AWGN noise with zero mean and σ_n^2 variance.

$$x_1 = \sqrt{P\beta_1}S_1 \tag{2}$$
$$x_2 = \sqrt{P\beta_2}S_2 \tag{3}$$
$$X(n) = \sqrt{P\beta_1}S_1(n) + \sqrt{P\beta_2}S_2(n) \tag{4}$$
$$y_i = h_i X(n) + w_i \tag{5}$$

Suppose the transmitter performs superposition coding flawlessly and successive interference cancellation at the receiver side is performed accurately. In that case, the data rate achievable for each user i is calculated using (6), where h_i is the complex channel gain M is the maximum number of users in the NOMA system.

$$R_i = \log_2\left(1 + \frac{\beta_i P |h_i|^2}{P|h_i|^2 \sum_{k=i+1}^{M} \beta_k + \sigma_n^2}\right) \tag{6}$$

C. POLAR ENCODING
Fig.3(a) shows the encoder representation for polar code with information sequence length $N = 2$. Let us consider

the transmission of two information bits as u_1 and u_2, the resultant codeword is equal $\bar{x} = [x_1 x_2]$, where $x_1 = u_1 \oplus u_2$ and, the general mathematical representation for the relation between $\bar{x}$ and $\bar{u}$ can be stated in (7) where $\bar{u} = [u_1 u_2]$, and G is the generated matrix for $N = 2$ which is equal to:

$$G_2 = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix},$$
$$\bar{x} = \bar{u}G \tag{7}$$

The generator matrix for any even number value of N is obtained using (8), which $N = 2^n$, $F = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$, B_N is calculated using (9): The initials for, i.e., B_2 and, are denoted by the $N \times N$ reverse-shuffle permutation matrix. Different polar encoder N values are obtained in the proposed structure.

$$G_N = B_N F^{\otimes n} \tag{8}$$
$$B_N = R_N\left(I_2 \otimes B_{\frac{N}{2}}\right) \tag{9}$$

Polar codes parameters are defined as N, k, in which N is the codeword length and k is the information sequence length.
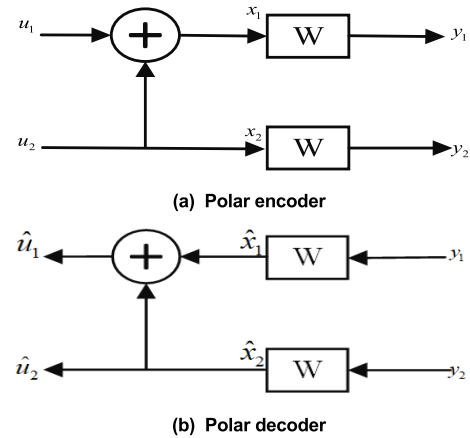

FIGURE 3. Polar encoder and decoder for N = 2.

D. POLAR DECODING
Decoding for polar codes interpolates a recursive manner called successive cancellation decoding (SCD) [29]. SCD is a sequential bit-by-bit decoding algorithm in which the decoding of the current bit depends on the previously decoded bits, as shown in Fig.3(b). The successive cancellation decoding algorithm used for the serial concatenation structure depends on the butterfly diagram likelihood ratios (LR_S), where the likelihood ratio is calculated using (10), and decoded data bits $\hat{u}_i$ follow the condition stated in (11).

$$L_N^{(i)}\left(y_1^N, u_1^{i-1}\right) = \frac{W_N^{(i)}\left(y_1^N, u_1^{i-1} | u_i = 0\right)}{W_N^{(i)}\left(y_1^N, u_1^{i-1} | u_i = 1\right)} \tag{10}$$

$$\hat{u}_i = \begin{cases} 0, & \text{if } L_N^{(i)}\left(y_1^N, u_1^{i-1}\right) \geq, 1 \\ 1, & \text{otherwise} \end{cases} \tag{11}$$

On the other hand, for parallel concatenation structure to be correctly decoded more powerful decoding algorithm is suggested, based on the soft input soft output (SISO) segment principle. The decoding is being processed serially, as described in Algorithm 1. The first decoder depends on the belief propagation (BP) algorithm [30], based on the factor graph representation of polar codes. Each node of the factor graph has two probabilities and receives computational results from the left-and right-side nodes to detect their node values, namely, left-to-right probability $P_{l \to r}$ and right-to-left probability $P_{r \to l}$.

According to this illustration, the log-likelihood ratio is calculated using (12), and the output decision is determined using (13).

$$LL_N^{(i)}(u) = \ln \left(\frac{P_{l \to r}^u(1)}{P_{l \to r}^u(0)} \right) + \ln \left(\frac{P_{r \to l}^u(1)}{P_{r \to l}^u(0)} \right) \quad (12)$$

$$\hat{u}_i = \begin{cases} 1, & \text{if } LL_N^{(i)}(u_i) > 0 \\ 0, & \text{otherwise} \end{cases} \quad (13)$$

E. CONVOLUTIONAL ENCODING

Three parameters are used to define convolutional codes $N, k, and D$ the number of memory stages which is also known as the constraint length. The codeword is obtained by applying the information sequence of length k $u_k = u_0 u_1 \ldots u_{k-1}$ into several finite shift registers equals D. The codeword vector for each shift register is calculated using (14), (15), and (16), and the final codeword vector is obtained using (17).

$$v^{(1)} = v_0^{(1)} v_1^{(1)} \ldots v_{k-1}^{(1)} \quad (14)$$

$$v^{(3)} = v_0^{(3)} v_1^{(3)} \ldots v_{k-1}^{(3)} \quad (15)$$

$$v^{(4)} = v_0^{(4)} v_1^{(4)} \ldots v_{k-1}^{(4)} \quad (16)$$

$$v = v_0^{(1)} v_0^{(3)} v_0^{(4)} v_1^{(1)} v_1^{(3)} v_1^{(4)} \ldots v_{k-1}^{(1)} v_{k-1}^{(3)} v_{k-1}^{(4)} \quad (17)$$

F. CONVOLUTIONAL DECODING

The decoding of the convolutional code depends on the maximum likelihood decoding algorithm known as Viterbi, which uses a trellis diagram to determine the shortest path and retrieve the original information. An empirically higher rate of convolutional code will consume more time for decoding and path metric calculations which means an expected higher latency compared to the most challenging aspect of the newly developed 6G technology.

Viterbi algorithm is summarised as follows; the decoding starts by finding the largest path metric along with the trellis representation as in Fig. (4) by comparing all paths branch metrics at each node in the trellis; the search procedure is done level by level. The path metric at every level is calculated and compared with other trellis path metrics; the decoder remembers the path with the least metrics value and eliminates all other paths. The remembered paths are called the

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Algorithm 1 Decoding for Parallel Concatenation

rd → received data, dp1→ data1+parity1, dp2 → parity2
L=length(received data bits)
for i=1:L
dp$_i$ = received data bits$_i$: received data bits$_{i+1}$
dp2$_i$ =received data bits$_{i+2}$: received data bits$_{i+3}$
end
for k=1:k_max
%apply BP algorithm %
for i=1:max-iteration
initialize variable_nodes and factor_nodes messages
for j = 1:length(dp1)
compute outgoing message $m_j(x_j)$from the incoming message
compute a belief $b_j(x_j) = \sum m_j(x_j)$
check the stop conditions: beliefs unchanged their lowest value and max iteration reached
if $b_{j+1}(x_{j+1}) = b_j(x_j)$ or i=max_iteration
$m_j(x_j) = b_j(x_j)$
$databits(n) = m(n)$
else return to step 4
end
%interleaver%
function inter(databits)
arrange the data into the M*N matrix in row-by-row order
read the output data column-by-column
end
%multiplexer%
db → databits
function multiplexer (db, dp2)
Combine the two streams as one following the multiplexing order (one bit from each input data) and return one variable
end
%Viterbi decoding%
function viterbi(db,length(db))
set two variables for path detection length of correct path (L) and (c$_m$) starting state of the algorithm (0 as initialization)
for each state in the trellis diagram find L(c$_{m+1}$) =min L(c$_m$, c$_{m+1}$)
save L(c$_{m+1}$) as P(c$_{m+1}$), where p indicates the survivor path
repeat until k=length(db)
%deinterleaver%
function deinter(db)
arrange the data as into M*N matrix as column-by-column order
read the output data as row-by-row
end
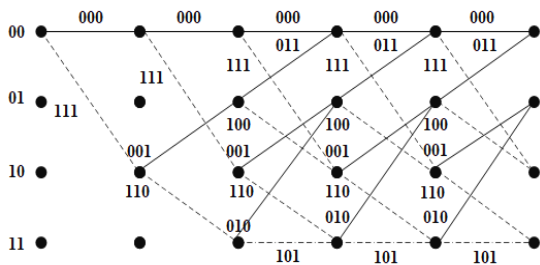If k=k_max
decoded stream= db
end % if
end %for (k)

FIGURE 4. Trellis diagram representation of convolutional decoder.

TABLE 1. Performance evaluation of the different coding schemes.

CODE SNR	PCSC (BPSK)	PCPC	PC (BPSK)	PCSC (QAM)	PC (QAM)	Un-coded NOMA
0	0.052	0.536	0.780	0.136	1.398	0.1449
0.5	0.007	0.292	0.569	0.092	1.176	0.131
1	0.00057	0.156	0.286	0.056	1.028	0.11
1.5	1.4e-05	0.010	0.029	0.030	0.980	0.09
2	2.6e-07	0.00089	0.00089	0.014	0.769	0.0722

survivor paths, whereas reaching the end of the transmission sequence, there is only one survivor path which represents the maximum likelihood path for the codeword.

IV. PERFORMANCE EVALUATION RESULTS

The deployed NOMA architecture without any channel coding is examined first to compare the effectiveness of the proposed concatenated structure within real-time 6G data rate transmission. On the other hand, performance evaluation for the same NOMA architecture is compared with PC as the channel coding technique used in 5G with the highest channel capacity-achieving code. As a known fact in any communication system, channel coding is a crucial part of real-time transmission without increasing system complexity or transmission delay.

The above-observed system performance is compared with the proposed concatenation structures PCSC and PCPC in Fig. (5). Results of parallel concatenation structure PCPC compared with the standalone polar code under BPSK modulation delivers a slightly better performance until 10^{-3} BER, where their performance match; Then, this performance starts to resemble that of polar code, and with more transmissions, polar code outperforms PCPC by approximately 1dB.

The performance of PCSC is also compared against PC and PCPC, which shows noticeable achievement where PCSC can reach 10^{-3} data rate within 0.75 dB compared to polar code reaching this limit at 2dB with 1.25 coding gain.

Table 1 compare the achieved system results with and without NOMA for the proposed concatenated structures along with polar code for BPSK.

The performance of PCSC code outer performs other codes as noticed from the above comparison; this achievement puts the PCSC under focus for more system analysis; PCSC shows more favourable performance, a coding gain of 1.5dB is achieved in comparison with PC.

These initial results were obtained with the following parameters for polar code $N = 1024$, $k = 528$ and $N = 3$, $k = 1$, $D = 3$ for convolutional code with three users PD-NOMA along with un-coded BPSK and QAM modulation transmission.

To fully understand the performance of PCSC throughput data transmission is shown in Fig. (6). The PCSC achieved THz data throughput starting from 2dB.
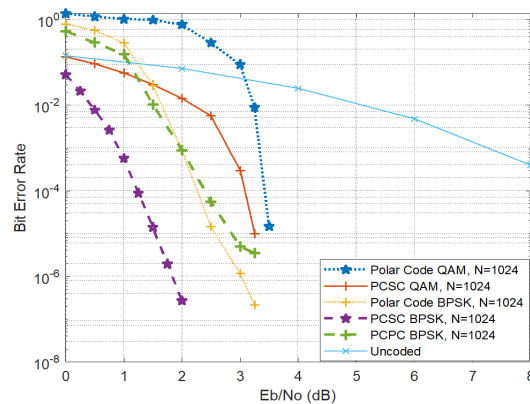

FIGURE 5. Comparison of PCSC, PCPC, and polar code in terms of BER performance for three users PD-NOMA, N = 1024.
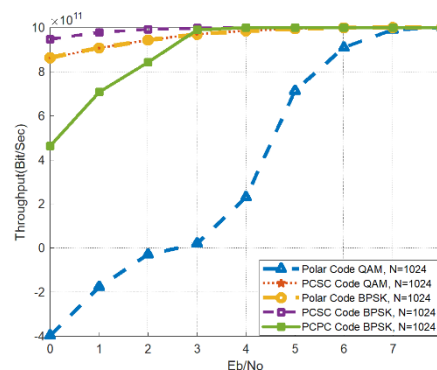

FIGURE 6. Comparison of PCSC, PCPC, and polar code in terms of throughput performance for three users PD-NOMA, N = 1024.

Because the essential contribution in this paper is to increase the NOMA performance in connection with the new technological revolution in 6G, it is critical to test further the serial proposed scheme, which may operate directly with different outer encoder rates. On the one hand, different outer encoder rates must be used in the parallel concatenation scheme to achieve accurate multiplexing, which will add more complexity to the system.

PCSC was applied within the NOMA system for 16 QAMs; the performance of PCSC is illustrated in Fig. (7) for three different codeword lengths. PCSC show better performance even when we apply a longer codeword length as for N = 8192, which will overcome the problem of limited codeword length for PC in 5G. This performance
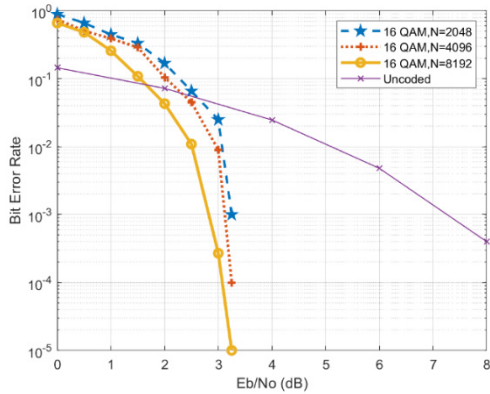
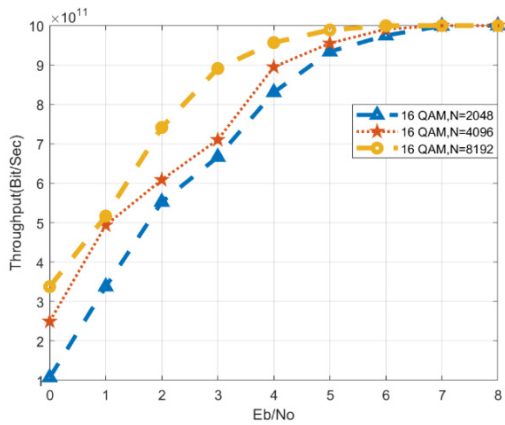**FIGURE 7.** Comparison of PCSC for three users PD-NOMA with 16 QAM for different codeword length.

FIGURE 8. Comparison of PCSC code in terms of throughput performance for three users PD-NOMA with different N values with 16 QAM.
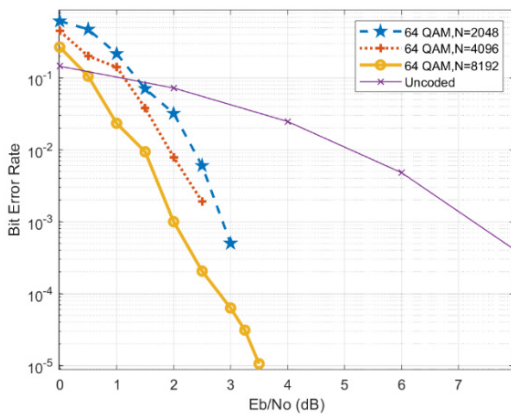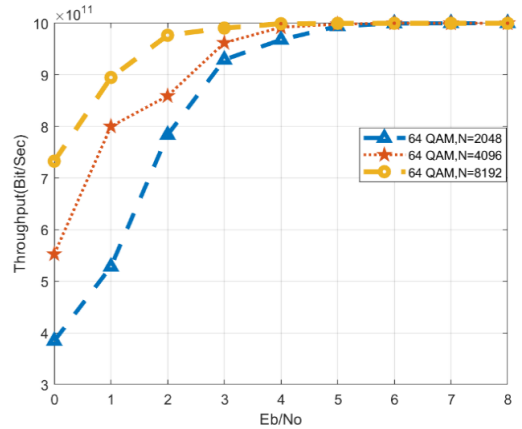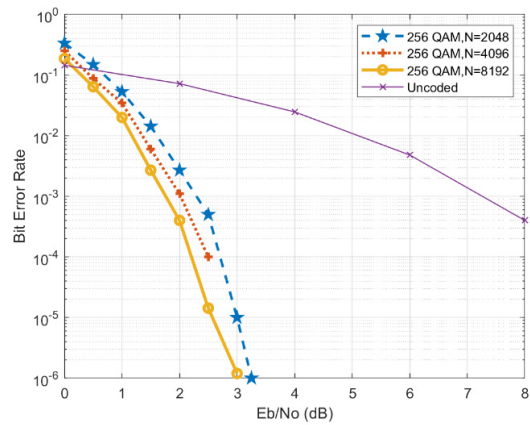

FIGURE 9. Comparison of PCSC for three users PD-NOMA with 64 QAM for different codeword length.

FIGURE 10. Comparison of PCSC code in terms of throughput performance for three users PD-NOMA with different N values with 64 QAM.

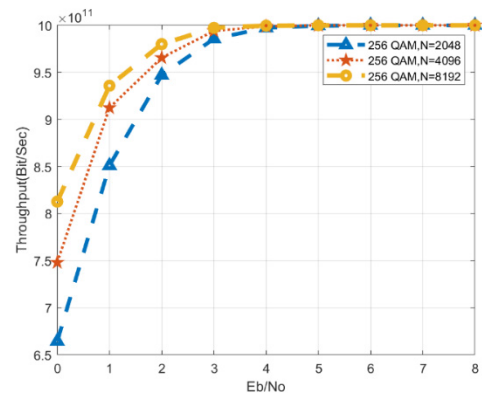**FIGURE 11.** Comparison of PCSC for three users PD-NOMA with 256 QAM for different codeword length.

FIGURE 12. Comparison of PCSC code in terms of throughput performance for three users PD-NOMA with different N values with 256 QAM.

is reflected in system throughput as in Fig. (8), where the improvement reaches up to 70% when the codeword length increases from 1024 to 8192. New-generation technology 6G will provide massive connection and artificial intelligence applications with possible deep learning solutions, which can be practically deployed with higher modulation rates.

According to these future technological aspects, the PCSC scheme is investigated under higher modulation rates with 64 QAM and 256 QAM for different codeword lengths, as shown in Fig. (9), Fig. (10), Fig. (11) and Fig. (12), respectively.

TABLE 2. Performance evaluation of PCSC with different codeword length.

PCSC (Codeword length)	Throughput (%)	Coding gain (dB)
2048	83.85	4.5
4096	66.65	5.75
8192	58.45	6.25

Table 2 illustrate the achieved coding gain and throughput percentage improvement regarding these modulation orders with three different codeword lengths. The comparison is presented against data transmission through the NOMA system with PC, which is the channel coding approach with the most channel capacity achievement.

V. CONCLUSION

The emerging field of wireless communication is rapidly increasing, which requires an unlimited data transmission rate to reach the terahertz limits. Also, ensuring the correct receipt of transmitted data must be considered. 6G network performance must be achieved without increasing the system complexity; these considerations present new challenges for new research areas, such as investigating applicable channel coding schemes for adopting the 6G perspective.

This paper proposed and compared the performances of different channel coding structures that are proven, based on their performance, to be engaged as the channel coding method used in 6G communication and achieve the terahertz transmission limit.

In this paper, serial and parallel concatenated channel coding structures demonstrate their ability to provide higher coding gain without increasing NOMA system complexity. The obtained results show that the serially concatenated code PCSC surpasses that of the parallel concatenated scheme PCPC with approximately 1.5dB of coding gain. At the same time, this achievement behaves in a directly proportional manner against codeword length, with a coding gain of up to 6.25dB.

The overall performance indicates that the proposed PCSC structure can achieve higher throughput when the number of encoding parameters is increased while maintaining the same system complexity. However, PCPC requires further investigation and development to overcome possible complexity, considering the potential use of deep learning solutions to simplify the decoding process.

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