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Novel Hybrid Model Investing in 5G Network Optimization Under Suzuki Fading Channel

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Abstract—**Nowadays, the advancement and increased use of fifth-generation (5G) and sixth-generation (6G) systems have created a demand for more efficient and rapid transmission of information over wireless communication media. However, developing wireless communication systems that can meet these modern-day criteria for fast, reliable, and secure information exchange is a challenging task. To address this issue, this paper proposes a novel model for enhancing the 5G system. The proposed model utilizes polar code with rate matching and constitutional interleaving over the Suzuki fading channel. The combination of polar codes with rate matching and interleaving enables the communication system to achieve a lower error rate and better reliability over a Suzuki fading channel. Specifically, the polar code can correct a larger number of errors, while rate matching and interleaving can mitigate the effects of channel variations and reduce the probability of error bursts. These enhancements can lead to more robust and reliable communication in wireless networks.**

Keywords—**5G; Suzuki Fading Channel; polar code; quality-of-service (QoS); rate matching**

I. INTRODUCTION

THE third-generation (3G) mobile system integrates with all services delivered by the second-generation (2G), including voice and text, as well as mobile internet services. While fourth-generation (4G) required more development than the previous generation of services by providing high-quality multimedia for mobile nodes, However, there are still significant issues with today's 4G networks, including power consumption and spectrum scarcity [1], [2]. Nowadays, 5G aims to prop up new kinds of mobile services to optimize features, transmission quality, and resource efficiency [3]. Also, 5G technology can assist in reducing CO2 emissions and help advance modern applications that can be employed in many fields, from smart grids to precision agriculture. The main problem is providing superior quality by employing error correction codes to enhance the error performance of restoring original data on the receiving side.

For this reason, the paradigm shift in channel coding technologies is crucial for the 5G scenario [4]. Even so, the most advanced channel codes, specifically turbo and LDPC codes, which are key enablers in existing 3G and 4G mobile systems, have not been proven in many new 5G applications [5]. As such, Turbo Code wasn't chosen for the 5G because decoding it takes a long time as well as requires a lot of iterations [6]. Moreover, it is unable to satisfy the high speed and low delay needs of 5G networks.

Researchers are attempting to invent a technique for channel coding that is both robust and efficient to meet the demands of all 5G applications.

Polar codes represent a class of error correction codes that were introduced in 2009 by Erdal Arikan [7]. They are a type of channel coding scheme that is designed to improve the reliability and efficiency of data transmission in communication systems, including 5G networks [8].

In addition to high reliability and low latency, other advantages of polar codes in 5G networks include their low decoding complexity and suitability for hardware implementation, as well as their ability to support flexible code rates, which makes them adaptable to varying channel conditions [9]. However, there are also some potential drawbacks to using polar codes in 5G networks. One of the main challenges is the need for accurate channel estimation, since polar codes can be affected by changes in the channel [9].

Rate matching is a technique utilized in wireless communication systems to adapt the data rate of a transmission to match the channel capacity. It is a crucial technique for achieving reliable and efficient transmission of data in 5G networks.

In 5G networks, rate matching is often used in conjunction with forward error correction (FEC) codes such as polar codes, low-density parity-check (LDPC) and turbo codes [10]. The idea behind rate matching is to adjust the code rate of the FEC codes to match the channel capacity while ensuring that the transmitted data remains error-free.

One of the key challenges in rate matching is to balance the tradeoff between data rate and reliability. Increasing the data rate can lead to a reduction in reliability, while increasing the reliability can lead to a reduction in data rate [10]. Therefore, it is essential to find an optimal tradeoff between these factors to ensure efficient and reliable transmission of data.

Rate matching is performed through a process known as bit interleaving as well as puncturing. Bit interleaving is the process

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of changing the bits in the original data stream to make a new data stream that works better for the FEC encoding process. Puncturing is the process of taking some of the bits from the compressed data stream to make it fit the channel's capacity.

Suzuki fading channel is a type of wireless channel that is commonly used to model the propagation of radio waves in mobile communication systems. This type of channel is known for its random fluctuations in signal strength, which can be caused by factors such as multipath interference, shadowing, and scattering. One of the key advantages of the Suzuki fading channel is that it provides a realistic and accurate representation of the wireless environment, which can be valuable for evaluating the performance of communication systems in real-world scenarios [11].

Utilization of Suzuki fading channels in 5G wireless channel modeling is important because it provides a realistic simulation of the wireless channels that 5G systems operate [11]. Suzuki fading channels are able to represent a wide range of wireless environments, such as urban, suburban, and rural areas, and can simulate various types of fading, such as Rayleigh, Rician, and Nakagami-m fading. This is important for evaluating the performance of 5G wireless systems in different environments and conditions, as well as optimizing the system for the best possible performance [12].

In addition to evaluating the performance of 5G wireless systems, Suzuki fading channels can also be used to test new technologies, such as beam forming and mm wave, which are important components of 5G wireless systems. By using Suzuki fading channels to test these technologies, researchers and engineers can better understand their performance and optimize them for use in 5G wireless systems [13].

The main goal of using quadrature amplitude modulation (QAM) in 5G wireless communication is to achieve high data rates over limited bandwidths. By modulating both the amplitude and phase of a carrier wave, QAM allows a greater number of bits to be sent per symbol, which increases the amount of data that can be transmitted in a given amount of time. This makes QAM a very efficient modulation scheme for high-speed data transmission [14].

The remainder of the research paper will be presented as follows: The second part covers the literature survey. The contribution of this work is demonstrated in Part III. Additionally, Part IV reveals the proposed model. In Part V, the outcomes of the simulation are presented. In Part VI, explain the conclusions and future work.

II. LITERATURE SURVEY

The current progress of 5G technology is prospering, and its global deployment is increasing. Therefore, there is still a need for 5G research to enhance service and performance. Included in the research studies are quality-of-service (QoS), energy efficiency, huge connectivity, dependable communications, and security. This section offers a brief overview of several significant literary works.

In 2018, F. Hamidi-Sepehr et al. [15] evaluated the performance of LDPC code with rate matching algorithms employed for 5G and also debated the structure of LDPC code and its essential features. According to the research findings suggest that the NR LDPC design is both flexible and dependable.

In 2019, Wen Jun Lim et al. [16] proposed study aims to advance the Analogue Fountain code (AFC) as a smooth rate adaptation mechanism, primarily intended for extended block lengths. Additionally, the research will explore the AFC's potential as a design solution for short packet communications, a communication scenario prevalent in 5G ultra-reliable and low-latency communications.

In 2020, Benson Mansingh et al. [17] proposed a new system to improve the BER for the 5G network depending on utilizing LDPC code and convolutional code. The outcomes showed that the system utilizing LDPC codes enhanced BER performance over the existing convolutional codes by about 10^{-6} as well as that LDPC complexity has been decreased by minimizing the number of iterations when compared to conventional turbo codes.

In 2021, Priyanka Pateriya et al. [18] introduced a study that analyzed 5G networks based on LDC code and Non-Orthogonal Multiple Access technology. The findings indicate that the LDC performs better than the standard STBC and that the optimum coefficient LDC may boost bit error rate performance at a higher signal-to-noise ratio when paired with many-order PSK modulation techniques in wireless communication systems.

In 2022, A. Devi Dharmavarem et al. [20] introduced new methodology to design and analyze employing hamming error-detecting and correcting encoder and decoder for 5G communications.

III. CONTRIBUTION OF THIS WORK

The main contribution of the paper "A Novel Hybrid Model Investing in 5G Network Optimization Under Suzuki Fading Channel" is to propose a hybrid model for optimizing 5G network performance under Suzuki fading channel conditions. The model combines polar codes, rate matching, and 32 QAM modulation to achieve efficient and reliable transmission of data in 5G networks. The paper also discusses the advantages and challenges of using polar codes and rate matching in 5G networks, as well as the importance of Suzuki fading channels for evaluating the performance of 5G wireless systems. The proposed hybrid model is evaluated through simulations, and the results demonstrate its effectiveness in improving the error performance and the spectral efficiency of 5G networks under Suzuki fading channel conditions.

IV. THE PROPOSED MODEL

This section clarifies the suggested model seen in Figure 1.

The proposed model starts by generating a random bit sequence, and a cyclic redundancy check (CRC) is added to the bit sequence. The bit sequence is then encoded using a polar encoder, interleaved, and rate-matched based on the number of information bits and the number of encoded bits. The rate-matched bits are modulated using Quadrature Amplitude Modulation (QAM). A Suzuki fading channel is generated, and the simulation loops through different SNR values for a fixed number of iterations. For each SNR value, Gaussian noise is added to the modulated symbols based on the noise variance.

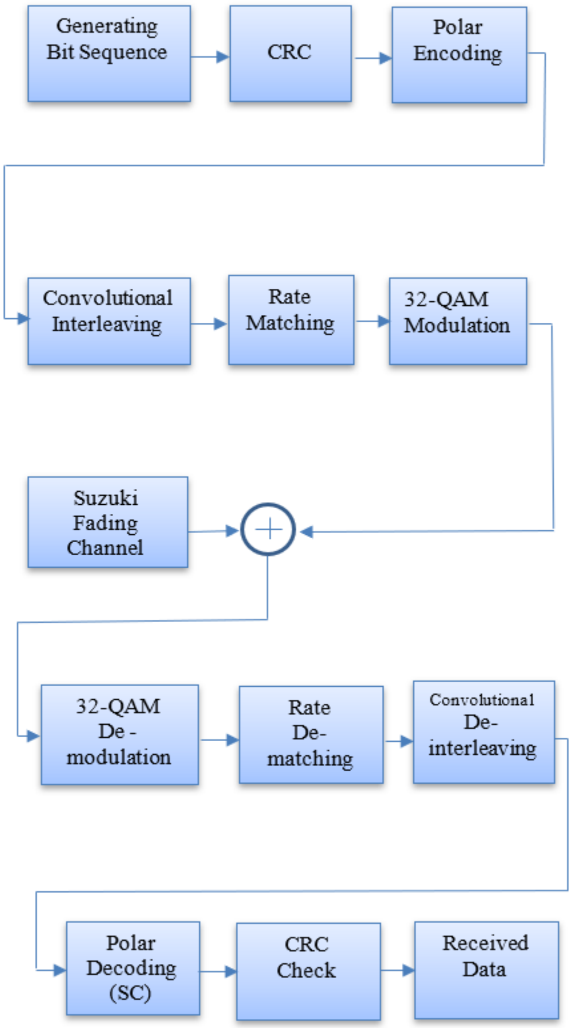

Fig. 1. The proposed model

The signal is transmitted over the Suzuki fading channel and decoded using Successive Cancellation (SC) decoding. The Block Error Rate (BLER) is then calculated by comparing the decoded bits with the interleaved bits. The BER is averaged over all iterations for each SNR value, and the BER vs SNR curve is plotted using a semi logarithmic scale. The resulting plot gives an idea of the system's performance under different SNR values. The main simulation program is clarified in Appendix 1.

V. SIMULATION RESULTS

This section focuses on evaluating the Block Error Rate (BLER) performance of a proposed system model, specifically exploring the use of combining polar codes with rate matching over a Suzuki fading channel in 5G systems. This combination can provide high reliability, low latency, and flexibility to satisfy the demanding requirements of 5G applications. Furthermore, optimizing the system parameters such as code rate and block length based on the test results can help achieve the best possible performance under real-world conditions, which ultimately improves the overall reliability and performance of 5G communication systems. Table I provides a summary of the simulation parameters used for this work.

TABLE I
THE SIMULATION PARAMETERS EMPLOYED IN THIS STUDY

No	Parameters	Details
1	Polar code (N,K)	(256,128), (512,256),(1024,512),(2048,1024)
2	Channel	Suzuki fading channel
3	Modulation	32-QAM
4	Decoding algorithm	Successive Cancellation
5	CRC	CRC24
6	Interleaves Type	Convolutional interleaves
7	subcarrier	10^4
8	SNR range	[-2:-0.5:2]

The simulation findings, as depicted in Figure 1, illustrate that the efficiency of polar codes with the SC decoding algorithm is contingent on the block size. The outcome indicates that the simulation, where the block size (1024, 512) was employed, outperforms the Polar Codes with smaller block sizes. The simulation results indicate that, for a 1e-5 BLER, the use of a block size of (2048,1024) with Polar Codes provides a coding gain of approximately 0.4505 dB compared to the use of a block size of (1024,512). In other words, the (2048,1024) block size can achieve the same decoding performance as the (1024,512) block size with a signal strength that is 0.4505 dB lower. Moreover, when compared to smaller block sizes such as (512,256) and (256,128), the gain in coding performance is greater than 0.4505 dB.

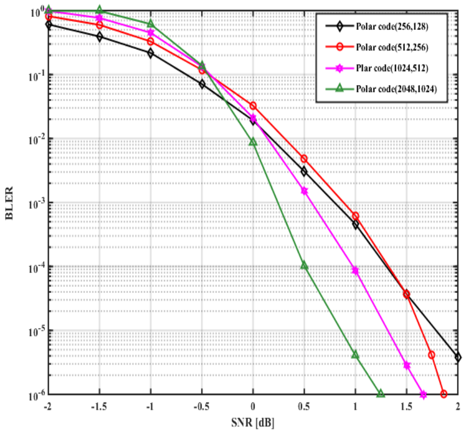

Fig. 2. The BLER vs SNR of the Proposed model without the effect of rate-matching

Figure 3 depicts a simulation in which the transmission employs rate matching with repetition. Redundant bits are generated during rate matching to simulate repetition. Each encoded bit is duplicated twice after rate matching, and the resulting bits are sent over the channel. It is evident from the results that the larger block size of (2048,1024) achieved superior performance compared to smaller block sizes, with a coding gain around 0.4884 dB at BLER 10^{-4}.

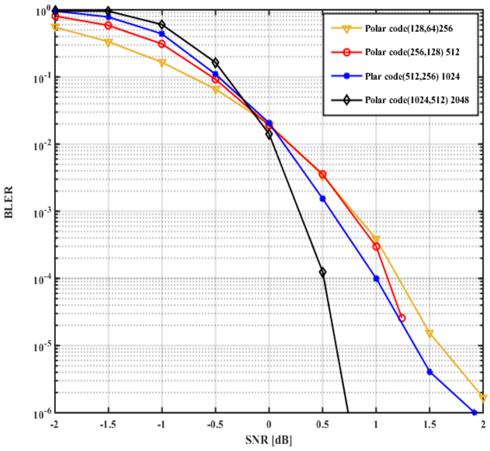

Fig. 3. The BLER vs SNR of the Proposed model with the effect of rate-matching

Next, when utilizing rate matching with puncturing, the block sizes transmitted over a channel can be reduced. For the purpose of assessing the performance of Polar Code with this technique, simulations were conducted where 25% of the bits were punctured prior to transmission. Figure 3 displays the results of these simulations, which employed the use of puncturing. Moreover, It is worth mentioning that utilizing puncturing does not result in a significant decrease in performance. Moreover, if a more robust signal is accessible, implementing this method can lead to enhancements in performance.

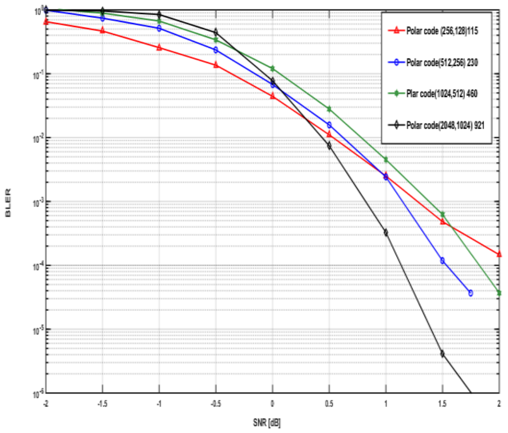

Fig. 4. The BLER vs SNR of the Proposed model from the effect of rate-matching with puncturing

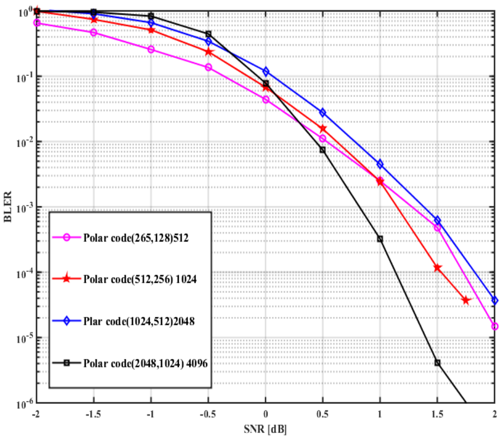

Fig. 5. The BLER vs SNR of the Proposed model from the effect of rate-matching with shorting

In this study, a 25% shortening rate is used to see how shortening affects how well BLER works. Particularly, this means that rate matching eliminates 25% of the bits during transmission.

VI. CONCLUSIONS AND FUTURE WORK

This paper presents a new model to optimize the 5G system. Polar codes were invested with the Successive Cancellation algorithm, and its performance was measured within a simulation environment. The results from the simulation show that when the proposed model depends on polar codes with larger block sizes, the performance is better compared with smaller block sizes. Also, the suggested model was assessed for various rate matching approaches, repetition, puncturing, and shortening. Future work of this paper the proposed model focuses on enhancing the reliability of communication in wireless networks, but it is also essential to ensure the security of these networks. One possible future work is to analyze the security of the proposed model and identify potential vulnerabilities and countermeasures.

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APPENDIX

```
% Initialization
clear all;
clc;
% Parameters
SNR_dB = [-2 -1.5 -0.5 -1 0 0.5 1 1.5 2]; % Signal to noise ratio values in dB
SNR = 10.^(SNR_dB/10);
num_bit = 1024; % number of bits
M = 32; % 32-QAM modulation order
N = 512; % number of subcarriers as Example
K = 256; % number of data subcarriers as Example
R = K/N; % code rate
crc_poly = [1 0 1 1]; % CRC generator polynomial
crc_len = length(crc_poly) - 1; % length of CRC
n = log2(N); % number of bits per subcarrier
k = log2(K); % number of bits per data subcarrier
Eb_N0 = SNR*log2(M)*R; % Eb/N0 values

% Generating bit sequences
data = randi([0 1], 1, num_bit);

% CRC encoding
crc_data = crc_generator(data, crc_poly);
crc_len = length(crc_poly)-1;
crc_encoded_data = [crc_data zeros(1, crc_len)];

% Polar encoding
polar_encoded_data = polar_encoder(crc_encoded_data, N, K);
% Interleaving
interleaved_data = reshape(polar_encoded_data, [], n).';
const_int_data = interleaver(interleaved_data, 'constellation');

% Rate matching
[rm_data, E] = rate_matching(const_int_data, K, N);

% Modulation
modulated_data = qammod(rm_data, M);

% Channel
for i = 1:length(SNR)
    ch_coeff = sqrt(1/2)*(randn(1,N) + 1i*randn(1,N)); % channel coefficients
    faded_data = modulated_data.*ch_coeff; % fading
    noise = sqrt(1/(2*Eb_N0(i)))*(randn(1,N) + 1i*randn(1,N)); % AWGN noise
    received_data = faded_data + noise; % received data
    equalized_data = received_data./ch_coeff; % equalization
    sc_decoded_data = sc_decoder(equalized_data, E, N, K); % SC decoding
    demodulated_data = qamdemod(sc_decoded_data, M); % demodulation
    demodulated_data = reshape(demodulated_data.', [], 1); % convert to column vector
    derm_rm_data = rate_dematching(demodulated_data, K, N); % rate dematching
    deinterleaved_data = interleaver(derm_rm_data, 'constellation', N, K); % deinterleaving
    polar_decoded_data = polar_decoder(deinterleaved_data, N, K, crc_poly); % polar decoding
    crc_check = crc_detector(polar_decoded_data, crc_poly); % CRC check
    if crc_check == 1 % if no errors in data
        err_count(i) = 0;
    else % if errors in data
        err_count(i) = 1;
    end
end
```

```
% Bit error rate calculation
BLER = err_count/num_bit;

% Plotting BLER vs SNR
figure;
semilogy(SNR_dB,BLER,'-*');
xlabel('SNR (dB)');
ylabel('BLER');
title('BLER vs SNR');
grid
```