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Overview Of Channel Coding Schemes and Its Comparative Analysis For 5G Wireless Networks

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Abstract: Nowadays 5G wireless communication is a fast-growing technology. The data transmitted by the 5G wireless communication channel is exposed to error due to the unpredictable noise, interference, fading, device limitations, and other factors. Channel coding is used to fix those problems produced during data transmission and reception in 5G wireless communication networks this means channel coding is a vital unit of 5G wireless communication networks. One best solution for 5G communication is to use polar coding which achieves the capacity of binary memoryless symmetric channels with the best errorcorrecting performance. Successive cancellation (SC), successive cancellation list (SCL), and their modification are the most known polar decoding algorithms used for 5G. This article presents an overview on latest research on polar decoding algorithms and the performance comparison on appropriate polar coding techniques. The performance affecting parameters have been identified based on the analysis. The performance evaluation is done for different values of bit energy to noise spectral ratio (Eb/No), code rate, and list size to compare the performance of polar code with SC decoding, interleaving polar code with SC decoding (I-SC), cyclic redundancy check aided polar code with SCL decoding (CRC-A-SCL), interleaved cyclic redundancy check aided polar code with SCL decoding (I-CRC-A-SCL), cyclic redundancy check aided interleaved polar code with SCL decoding (CRC-A-I-SCL) and interleaved cyclic redundancy check aided interleaved polar code with SCL decoding (I-CRC-A-I-SCL) under BPSK modulation and AWGN channel model. The most performance-affecting parameters are code rate, CRC length, and list size when comparison on polar coding techniques have been done based performance measure of BER and FER. It is found based on results and analysis that the CRC-A-SCL polar coding scheme has a BER value of
0.94%, the I-CRC-A-SCL polar coding scheme has 0.45%, the CRC-A-I-SCL polar coding scheme has 0.14%, and the I-CRC-A-I-SCL polar coding scheme has 0.03% at Eb/No of 2.4dB, list size 8 and CRC length 16 over AWGN channel and BPSK modulation. The I-CRC-A-I-SCL polar coding scheme has proven to be a promising candidate for 5G wireless communication networks.

Keywords: Polar coding, Bit Error Rate,, Frame Error Rate, 5G networks

1 Introduction

Nowadays 5G wireless communication is a fast-growing technology. The data transmitted over a 5G wireless communication channel is exposed to error due to unpredictable noise, interference, fading, device limitations, and other factors. This means data on the receiving side is not the same as the data that was delivered due to channel impairments that affect the original data flow. Channel coding is used to fix those problems produced during data transmission and reception in 5G wireless communication networks (Čarapić et al., 2021). The next generation of mobile communication networks, known as 5G New Radio (NR), is anticipated to meet the growing demand for improved mobile connectivity and open the door for a wide range of new mobile services. According to its specifications, 5G NR should be able to provide data transfer with a latency of less than 1 microsecond and peak download speeds of 20 Gbps (Indoonundon & Pawan Fowdur, 2021). The selection of channel codes for 5G has been the subject of extensive research over the past ten years. LDPC for the data channel and polar codes for the control channel has already been chosen as the channel codes for eMBB (Zhu et al., 2018).

Channel coding at the transmitter side is known as the encoder and at the receiver side is known as the decoder. Shannon demonstrated in 1948 that error-free information can be transmitted over a noisy medium (channel) if the channel rate is less than or equal to the channel capacity. To develop the capacity for trustworthy codes that may be utilized in current communication technology, a significant amount of research has been done in the field of channel coding (Channels et al., 2023). The targeted characteristics of the channel coding include increased flexibility, reduced computation complexity, low latency, cheap cost, and high reliability (Čarapić et al., 2021). Polar code is one of the most powerful channel coding techniques that is chosen for 5G wireless communication networks due to its low encoding and decoding complexity, simplicity of implementation, and can extend the channel capacity (Čarapić et al., 2021). The polar coding scheme works based on the concept of channel polarization. Channel polarization divides the channel into two sets: one set, known as reliable channels, allows for the transmission of information bits; the other set, known as unreliable channels, allows for the transmission of frozen bits (Channels et al., 2023). The bit error rate, frame error rate, computational complexity, and delay at a specific signal-to-noise ratio all affect how well wireless communications work.

This work is focused on the performance evaluation of polar coding schemes for 5G wireless communication networks. The performance metric parameters such as bit error rate and frame error rate for different values of Eb/No, code rate and list size are evaluated and the comprehensive review is presented for 5G wireless communication networks. The performance evaluation of the SC polar coding scheme, Interleaved-SC polar coding scheme, CRC-A-SCL polar coding scheme, interleaved-CRC-A-SCL polar coding scheme, CRC-A-Interleaved-SCL polar coding scheme, and Interleaved-CRC-A-InterleavedSCL polar coding schemes is presented.

In this work, the challenges on channel coding for 5G and the latest coding techniques modified for 5G networks are discussed. Furthermore, the comprehensive suggestions and identifications are concluded using comparative performance analysis.

The organization of the paper is as follows: Section 2 includes an overview on state of the art 5G channel coding schemes. The related work is discussed in Section 3. In Section 4, polar coding model design with MATLAB parameters for results and analysis are presented. Finally, Section 5 gives a concluding remarks.

2 Review on State of the Art Polar Coding Schemes for 5G

2.1 Polar codes

Polar code was introduced by Arikan in 2008, it is a special class of error-correcting codes that can provably achieve channel capacity (Belhadj et al., 2021). The code belongs to the first family that can work with low decoding complexity O(NlogN), where N stands for the block length, to achieve maximum channel capacity on any symmetric binary-input discrete memory-less channel (B-DMC). Recursion is the basis of Polar Codes, which divide the primary channel Wn into virtual channels W1 and W2. Arikan demonstrated that the virtual channels tend to have either high or low reliability, with sufficient division recursion the cutoff rate would be higher on the virtual channel than the original channel. This indicates that the channels are either entirely noisy or noiseless, and data transmission should take place on the noiseless channels (Rosenqvist et al., 2019).

2.2 Low-Density Parity Check (LDPC) Codes

Low-density parity check (LDPC) codes are a family of error-correcting correcting codes that were introduced by R. Gallager in 1962 (Belhadj et al., 2021). Due to its practical implementation almost achieving the Shannon channel capacity of reliable transmission, LDPC codes are particularly effective codes. According to the Shannon channel capacity rule, as block length is increased, codes with code rates

close to the capacity number result in errors going to zero when decoded using the maximum likelihood decoder. By employing random linear block codes that are represented as polynomials of time, this criterion can be satisfied. The problem of complicated calculation algorithms for encoding and decoding arises as we raise the block length for error near zero, and this ultimately forces us to compromise on performance. Hence, in this case, LDPC code successfully implements LDPC code at the Shannon limit with extended block lengths and also offers the additional benefits of simpler algorithms, faster processing, and higher accuracy (Pregara & Saigh, 2013).

2.3 Turbo Codes

A turbo code is a kind of channel coding method that was first developed by Berrou in 1993 for burst errors and is also intended for error correction. One of the greatest methods for channel coding error correction is turbo coding. This has resulted in a significant impact. Turbo codes are used to improve communication systems data transmission efficiency. Several space crafts use turbo codes, and universal mobile telecommunication systems (UMTS) and long-term evolutions (LTE) use them as well for high-speed communication. In the power-controlled system, communication channels are close to Shannon's limit, and effective communication is achievable. The purpose of channel coding is to transform data into code, allowing for the transmission of information via a communication channel. Even in the presence of noise, errors are identified and corrected (Pregara & Saigh, 2013). Turbo code is used in 3G and 4G systems. The reasons why Turbo code is not selected for 5G wireless communication networks due to more number of iterations and high decoding latency (Čarapić et al., 2021).

2.4 Interleaved CRC for polar codes

Interleaved CRC for polar code is formed by inserting interleaved between The CRC bits and the polar encoder. Interleave CRC bits before the polar encoder is used to distribute the CRC bits between the information bits and frozen bits before the encoding process happens. Distributing the CRC bits between the information and frozen bits helps CRC checks to perform earlier in the decoding process due to this the list decoding process can end when the CRC checks of all competitor paths in the list fail. These interleaved CRC bits have the ability for both early error detection and to improve the performance of error correction (Hui & Breschel, 2018).

2.5 Polar Codes with Successive Cancellation (SC) Decoding

Successive cancellation decoding is a decoding technique that works sequentially. Using soft input and soft output, SC decoding is a very effective decoding technique and it has low decoding complexity . We also ignore the soft results and choose the hard decision. The decoder typically sends out one code word after receiving the vectors (Albert Raj et al., 2021). Due to its innate serial nature, SC produces a high decoding latency (Xi et al., 2018). The decoding sequence of SC decoding is as follows. First, it sends information to the left child and receives some beliefs from the parent node; After it receives the decision from the left child, then it can send some beliefs to the right child; Once it receives the decision from the right child, it combines them and sends them to the parent node. These three distinct tasks will be carried out by these nodes.

2.6 Polar Codes with Successive Cancellation List (SCL) Decoding

The SC decoder frequently is unable to discover the ideal decoding path due to the local optimum search limit. The SCL algorithm was suggested as a solution to this issue. Finding the right decoding path is much more likely when many SC decoders are applied to the same code tree. List size L refers to the quantity of SC component decoders in this context (Yuan & Parhi, 2012). Similar to SC decoding, SCL decoding proceeds sequentially as each bits decision is dependent on that of the bits that have come before it. However, SCL maintains a list of potential bit combinations in the sequential decoding, as opposed to SC decoding, which only stores one decision per bit. The list of L candidates is updated for each new bit that is decoded (Tao et al., 2021). But as the list size increases further SCL decoding becomes more complex and it is the problem of SCL decoding.

2.7 Polar Codes with Cyclic Redundancy Check Aided Successive Cancellation List (CRC-ASCL) Polar decoding

More accuracy is achieved with bigger list sizes L, but complexity increases exponentially with L. Adding a cyclic redundancy check (CRC) to the process of choosing the final decoding option from the list of L candidates can also increase accuracy. Polar codes with CRC-A-SCL decoding can outperform SC polar decoding in error correction but it is more complex than SC decoding because of the addition of CRC (Tao et al., 2021).

2.8 Interleaving Polar Codes with SC Decoding

The polar code encoder incorporates interleaves between the intermediate stages. Interleaved polar (Ipolar) codes are those created based on this concept. All potential interleaves are taken into account when creating the ensemble of I-polar codes. One realization of the ensemble of I-polar codes is the regular polar code. I-Polar codes are also decoded using interleaved polar codes with SC decoding (Chiu, 2020).

2.9 Interleaving Polar Codes with SCL Decoding

Interleaved Polar codes intended to correct burst errors that would happen randomly. This type of polar code also uses different types of decoding algorithms to recover the original message. SCL decoding is an example of a decoding technique that is used in I-polar codes.

2.10 Interleaving Polar Codes with Cyclic Redundancy Check Aided Successive Cancellation List (CRC-A-I-SCL) Polar Decoding Schemes

Interleaving is a technique intended to lessen burst errors that could happen randomly. to enhance the currently used error control codes to enable the recovery of the original message bits. Before transmission, the data bits are distributed, and if any of the information is altered while being transmitted across the channel, it can be recovered by rearrangement of the data after recovery.

2.11 Interleaved Cyclic Redundancy Check Aided Successive Cancellation List (I-CRC-A-SCL) Polar Coding Schemes

This polar decoding scheme is a type of decoding scheme that uses interleaved CRC bits instead of normal CRC bits. These interleaved CRC bits are distributed to the information block. This distribution of CRC bits along with the information block helps early error detection and correction in the list decoding process. This improves the performance of error correction and reduces the decoding latency (Hui & Breschel, 2018). This decoding type of polar code is the same as that of the CRC-A-SCL polar decoding technique but it uses Interleaved CRC (I-CRC).

2.12 Interleaved Cyclic Redundancy Check Aided Interleaved Successive Cancellation List (ICRC-A-I-SCL) Polar Coding Schemes

Interleaved CRC-aided interleaved polar decoding is a polar decoding scheme that is used to improve the performance of polar codes. Interleaved CRC-aided interleaved polar decoding involves interleaving the information bits of the polar code before encoding, and then encoding the interleaved sequence with a CRC code. The codeword is then again interleaved before transmission, and at the receiver, the interleaving is reversed and SCL decoding with CRC checking is performed. The interleaving can help to spread out errors due to noise, making the CRC code more effective in detecting and correcting errors. Additionally, the interleaving can help to mitigate any burst errors that may occur. This polar coding schemes works on both early error detection and mitigating the burst error.

3 Related Work

(Hashemi et al., 2018) examined polar codes with brief lengths and various coding rates. They demonstrate that there exists an ideal code rate at which SC and SCL decoders can achieve a fixed goal frame error rate (FER) while utilizing the least amount of power. They get the value for each code rate to begin analyzing the power efficiency of the codes in the 5G eMBB control channel. Based on the decoder used, they demonstrate that polar codes exhibit their highest level of power efficiency at a particular rate. They also examined the impact of CRC length on SCL decoding speed and error-correction performance. To increase the decoding speed and achieve the highest error correction performance, they offer a CRC selection technique. They demonstrated the usefulness of CRC for codes with longer lengths and greater rates. SCL without CRC offers adequate error-correction performance for short codes and low speeds. They also proved that CRC affects the speed of the decoders for polar codes but they only consider the simulation of FER versus Eb/No.

(Čarapić et al., 2021) Studied the benefits and drawbacks of 5G channel coding schemes, they evaluate both LDPC and Polar codes in their work. They consider several channel models (Additive White Gaussian Noise (AWGN), Rician fading + AWGN, and Rayleigh fading + AWGN). They compare the effects of different message sizes and coding rates. Also, various decoding strategies for Polar codes and various modulation schemes for LDPC codes were examined in this study. The studies have proved that Polar codes were best for short messages and LDPC codes for longer messages. This justifies the use of Polar codes for control channels and LDPC codes for data channels. They consider the performance of BER by changing the code rate and message length. In this study, they only compare depending on the BER on different channels but they cannot further compare other parameters like latency, complexity, and BLER. (Belhadj et al., 2021) studied on the selection of the best channel coding method for the 5G-mMTC scenario, this study examines the performance of various coding schemes, including tail-biting convolutional code (TBCC), low-density parity-check codes (LDPC), Turbo code, and Polar codes. For short information block lengths, the considered codes were assessed in terms of bit error rate (BER) and block error rate (BLER). Researchers also look at the complexity of their algorithms in terms of how many fundamental operations there are. The findings show that although the polar code with SC algorithms has very low computational complexity, its performance is lower compared to other coding schemes. In terms of error correction performance and computational complexity, polar code with CRC-SCL decoding algorithm performs better than TBCC, LDPC, and Turbo codes. Concerning the trade-off between computational complexity and performance in 5G mMTC, it is, therefore, reasonable to assume that polar code (CRCSCL) is more flexible than other channel coding schemes. They conclude that Polar codes with CRC-ASCL decoding appear to be the best option for 5G mMTC. Those researchers were able to go further on the performance of polar coding by considering different polar coding schemes but they don’t compare those polar codes.

(Khan & Zhang, 2020) The potential coding system for the 5g network was evaluated in this research, although their work was focused on the mMTC use case only. Information sharing across billions of intelligent devices without human intervention is a key feature of mMTC. Despite offering many benefits, mMTC also presented several difficulties. First off, as the uplink dominates the traffic coming from many mMTC devices, it is crucial to reduce uplink traffic congestion. Second, a lot of mMTC applications for emergency monitoring demanded incredibly fast response times and minimal latency. Furthermore, they must assure energy-efficient device operation because mMTC devices have limited resources, mostly due to battery limitations. Designing a suitable channel coding scheme for small packet length that satisfies the downlink and uplink-dominated traffic of mMTC applications and meets additional requirements such as low latency, low complexity, and ultra-low energy consumption is an efficient solution to tackle these difficulties. Nevertheless, due to a higher uplink-to-downlink traffic ratio than the traditional cellular system, design channel codes for mMTC applications increase implementation difficulties. The main driving force behind this effort is the need to identify the most reliable channel coding for mMTC applications. It should be noted that the scope of their work is restricted to the evaluation of dependability performance; nevertheless, to choose appropriate channel coding schemes, other factors such as computational complexity, flexibility, cost, and decoding latency must also be taken into account. By comparing those channel codes, they conclude that the best channel code for mMTC is the polar code with CRC-A-SCL. (Sinha & Bhaumik, 2021) proposed Distributed Cyclic Redundancy Check Assisted Polar (DCA-polar) coding algorithm is suggested and used in this study along with Cyclic Redundancy Check

Aided Polar (CA-polar) codes to create a novel polar coding technique. This work's primary addition, in contrast to earlier works, is to provide an examination of the polar codes operation and error performance (SNR and False Alarm Rate (FAR)) for short block lengths for the NR control channel (specifically in uplink and downlink control channels). The performance of the polar codes for error detection and correction is then thoroughly evaluated for 5G NR control channels using SNR and FAR analysis. In this study, they were able to compare polar coding schemes for short information block length by changing the list size. They considered a few polar decoding algorithms only.

(Hui & Breschel, 2018) proposed a CRC code, which has a low implementation complexity and is typically primarily used for error detection, is the focus of this paper. Here, both error detection and correction are accomplished with a single CRC code. In this study, they also consider various applications of a single CRC outer code to enhance polar codes. They demonstrate how the CRC bits can be dispersed throughout the information block so that no information bit that a CRC bit depends on is behind it in the subsequent decoding order by applying an inter-leaver between a polar encoder and a CRC encoder. So, similar to Parity-Check-Concatenated (PCC) polar codes that improve the performance of combined codes concerning block errors. These CRC bits can be employed to increase the concatenated code's errorcorrection capability in addition to being used for early error detection. The average decoding delay is decreased by distributing the CRC bits more uniformly via the inter-leaver, which also enables early list decoding process termination. In their simulation result, they conclude that interleaving the CRC bits with the information bits improves early decoder termination by a small-to-moderate amount without degrading the error rate performance. But in this paper, they only consider Interleaved CRC.

(Vaz et al., 2019) considered the BER comparison and evaluation of Turbo and Polar codes by varying code rates and block lengths. In this research work the information bits are modulated using BPSK and also the channel used for data transmission or communication channel is the AWGN channel. These coding schemes are selected for 4G/5G services and satellite communication systems. As we have tried to understand from the simulation result the performance of turbo codes are decreased as the code rate increases and increases as the block length increases. In this research work, we have shown that turbo codes with greater block length and smaller code rates create a good performance.

(Tahir et al., 2017) studied the bit error rate (BER) performance for different information block lengths and code rates for convolutional, turbo, low-density parity check (LDPC), and polar codes. Further research was done on how their performance is affected by the approximation decoding algorithms, as well as on their convergence behavior concerning list size (polar) and iteration number (turbo and LDPC). The information bits are modulated by using a BPSK modulator and sent over the AWGN channel. The iterations (list size) of 32,16,8,4,1 is used in this research. Turbo codes do not give much gain if the iteration goes beyond 8. 16 number of iterations is sufficient for LDPC codes and if the iteration increases to 32 and there is very little gain. For polar codes, better performance is obtained for larger list sizes. (Cuc et al., 2023) studied the performances of turbo codes, low-density parity check (LDPC) codes, and polar codes over an additive white Gaussian noise (AWGN) channel in the presence of inter-symbol interference at a code rate of 1/3, denoting the disturbances that altered the original signal. They were used as equalizers at the level of the receiver to eliminate the negative effects of inter-symbol interference (ISI). In this research transmitted bits are modulated by using BPSK modulation. The performance of these codes becomes better as the length of the information bit becomes longer. In this research, they used five iterations for turbo codes and ten iterations for LDPC codes. In this research, they use equalization before decoding the three codes. MMSE and ZF equalizers are used in this research. At the same level of signalto-noise ratio, turbo codes offer a lower level of BER since they perform better than LDPC codes for both MMSE and ZF equalization.

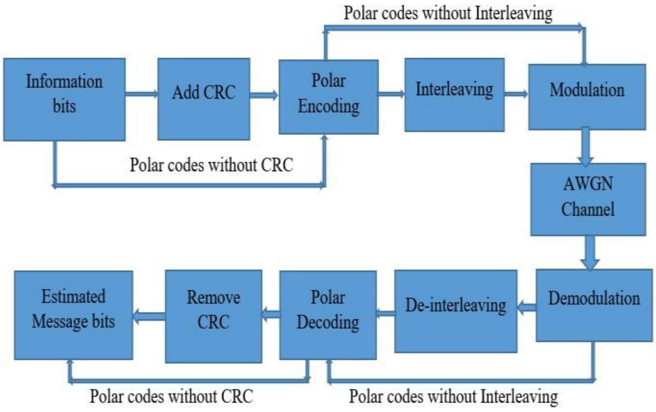
3 System Model for Polar Coding Techniques

In this section, system models are presented used for analysis.

3.1 SCL Decoding and Interleaved polar codes

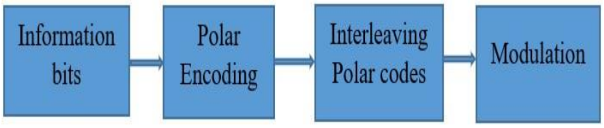
The system model in Fig. 1 is general for polar coding scheme.

Figure 1 General Block Diagram of Polar Coding Schemes



Interleaved polar codes (I-Polar) shown in Figure 2 are a new variant of polar codes added in Figure 1.

Figure 2 Interleaved to polar codes



3.2 Successive Cancellation Decoding

Successive cancellation (SC) decoding is a polar decoding technique that decodes the received bits sequentially (Jali et al., 2022). Due to sequential cases, it has high decoding latency but low complexity. As the name suggests, the SC decoding makes decisions on the information bits in sequence. It is added after demodulation in Figure 1.

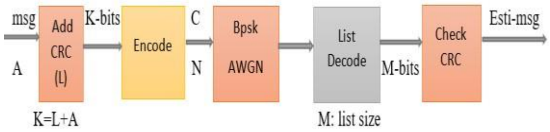
3.3 Interleaved Successive Cancellation (I-SC) Polar Coding Scheme

In an interleaved SC polar coding scheme, the input data is first divided into a series of smaller blocks, each of which is independently encoded using a polar code. The resulting codewords are then interleaved to spread out any errors that may occur during transmission. It is also added after demodulation in Figure 1.

3.3 Cyclic Redundancy Check Aided Successive Cancellation List (CRC-A-SCL) Polar Coding Schemes

The CRC code is used to detect errors in the received data before the polar code is decoded. If the CRC check fails, the decoder discards the received data and tries the next candidate codeword in the SCL list. By using the CRC code to detect errors early in the decoding process, CRC-aided SCL polar decoding can improve the error correction capability of polar codes, especially in noisy communication channels. CRC to SCL polar coding is shown in Figure 2 which can be added in Figure 1.

Figure 3 Block of CRC to the SCL polar coding



3.4 Interleaved-CRC Aided Successive Cancellation List (I-CRC-A-SCL) Polar Coding Schemes

In this polar decoding scheme, the CRC and information bits are interleaved before encoding. Idea is to inserts interleaver between the CRC encoder and polar encoder to early detect the error and mitigate burst errors.

3.2 CRC-Aided Interleaved Successive Cancellation List (CRC-A-I-SCL) Polar Coding Schemes

In CRC-aided interleaved SCL polar decoding, the transmitted data is first interleaved to spread out errors and reduce the impact of burst errors and other channel impairments. The interleaved and CRC-encoded data is then decoded using an SCL decoder. The SCL decoder used in CRC-aided interleaved SCL polar decoding is similar to the one used in CRC-aided SCL polar decoding. It considers multiple candidate codewords and keeps track of the top-ranked codewords as it proceeds through the decoding process.

3.2 Interleaved-CRC-Aided-Interleaved-Successive Cancellation List (I-CRC-A-I-SCL) Polar coding schemes

In interleaved-CRC-aided-interleaved SCL polar decoding, the interleaving is done twice: once before the CRC application and once after the CRC application. The CRC helps to early detect errors in the decoded bits and can be used to improve the decoding performance. Interleaved-CRC-aided-interleaved SCL polar decoding combines the interleaving, CRC, and SCL decoding techniques to improve the error-correction performance of polar codes.

4 Results and Discussions

In this section, the comparative performance is demonstrated using MATLAB simulations in different cases for the analysis of Bit Error Rate (BER) and Frame Error Rate (FER).

4.1 Comparison of SC and Interleaved-SC (I-SC)

The used simulation parameters is given in Table 1. As we can see from the result of our simulation from the Figure 4 at Eb/No of 3.6dB for a code rate of 1/2 1.19% of bits are in error; when we reduce the code rate to 1/4 0.93% of bits are in error in SC polar coding schemes. When we see the I-SC polar coding scheme at the same Eb/No of 3.6dB for code rate 1/2 1.19% bits are in error when we reduce the code rate to 1/4 the bit error rate is reduced to 0.7%.

Table 1 Simulation parameters of SC and I-SC

Polar size and codeword siz	(32,128), (64,128)
Code Rate (R)	1/4 and 1/2
Frames size	1000
Eb/No in dB	0.4dB - 3.6dB

Figure 4 BER versus Eb/No for SC and I-SC with Code Rate (R)

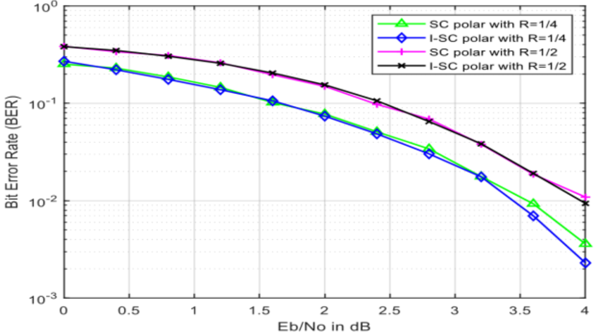
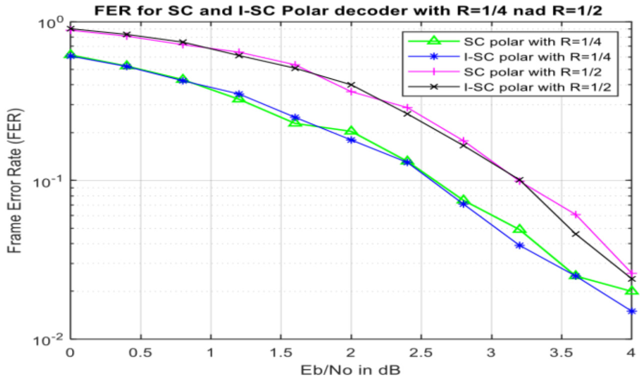


Figure 5 FER versus Eb/No for SC and I-SC with Code Rate (R)



As it can be seen from Figure 5 which shows the frame error rate analysis at a code rate of ¼ and ½ similar to the simulation of BER versus Eb/No (Figure 4) as the code rate increases the performance of both coding schemes reduces. When we see the FER value of both the SC polar coding scheme and I-SC polar coding scheme at a code rate of ½ and Eb/No of 2dB; 363 frames out of 1000 are in error for SC polar and 263 out of 1000 frames are in error at the same Eb/No value from this FER value of I-SC polar coding scheme is less than the FER value of SC polar coding scheme.s

4.2 Comparison of CRC-A-SCL and Interleaved (I)-CRC-A-SCL 4.2.1 Code rate ® variation Analysis

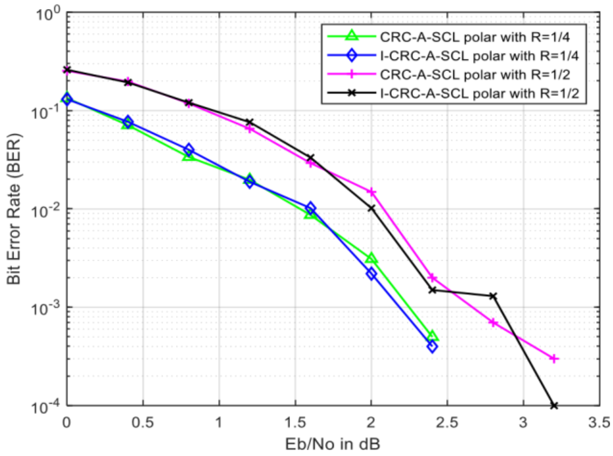
Table 2 Simulation parameters CRC-A-SCL and I-CRC-A-SCL

Polar Block size	(32,128), (64,128)

Code rate	1/4 and 1/2
No of frames	1000
CRC length	4
Eb/No	0.4dB - 3.6dB
List size	8

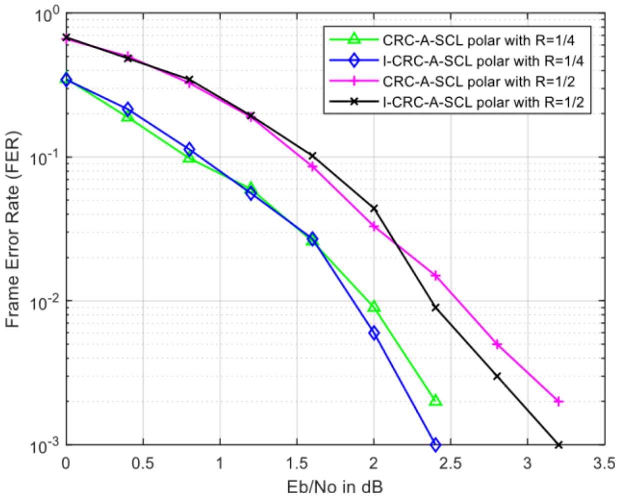
The used simulation parameters is given Table 2. As seen from Figure 6, the bit error rate of CRC-A-SCL polar coding scheme at a code rate of 1/4 is 0.0005 and the bit error rate of I-CRC-A-SCL polar coding scheme at code rate of 1/4 is also 0.0004. As a result, the performance of the I-CRC-A-SCL coding scheme seems fine with CRC-A-SCL polar coding scheme.

Figure 6 BER versus Eb/No for CRC-A-SCL and I-CRC-A-SCL with Code Rate (R)



As shown in Figure 7, for Eb/No of 2.4dB, the FER at a code rate of 1/4 is about 0.002 and 0.001 frames in error is for CRC-A-SCL and I-CRC-A-SCL polar coding schemes respectively. But increasing the code rate up-to 1/2, there is decreasing the FER at Eb/No of 2.4dB.

Figure 7 FER versus Eb/No for CRC-A-SCL and I-CRC-A-SCL with Code Rate (R)



4.2.2 List Size (L) variation Analysis

With same code rate, list size (L) is varied for both CRC-A-SCL and I-CRC-A-SCL polar coding schemes. The simulation parameters are given in Table 3.

Table 3 Simulation parameters CRC-A-SCL and I-CRC-A-SCL
Polar Block size (32,128), (64,128)

Code rate	1/2
No of frames	1000
CRC length	16
Eb/No	0.4dB - 3.6dB
List size	8, 16

As seen from Figure 8, when the list size changes from 8 to 16, BER for both coding schemes decreases. In other words, for L=8, the number of candidate solutions is less or limited but at L=16, there are more candidate solutions

Figure 8 BER versus Eb/No for CRC-A-SCL and I-CRC-A-SCL with List size (L)

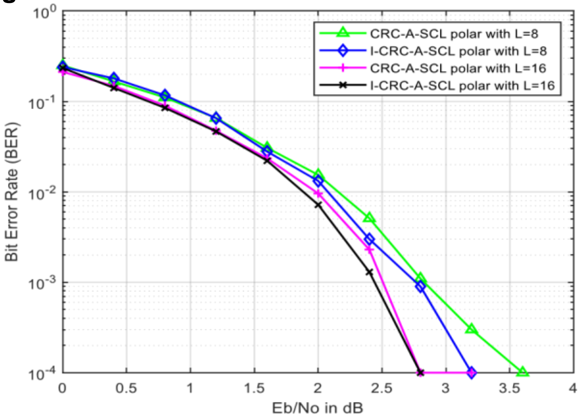


Figure 9 FER versus Eb/No for CRC-A-SCL and I-CRC-A-SCL with List size (L)

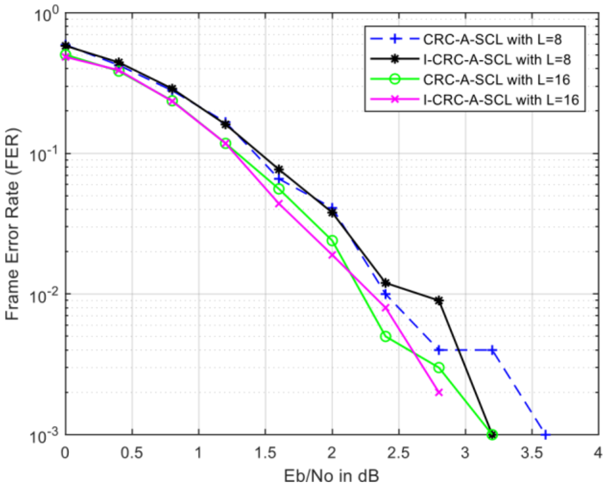


Figure 9 shows the positive effect on the performance of the CRC-A-SCL polar coding scheme and I-CRCA-SCL polar coding scheme. The I-CRC-A-SCL polar coding scheme at L=16 has better performance than I-CRC-A-SCL polar coding scheme at L=8.

4.3 Comparison of I-CRC-A-SCL and I-CRC-A-I-SCL

4.3.1 Code rate (R) variation Analysis

Results are taken by varying the code rate (i.e, change from R=1/2 to R=1/4) for both the polar schemes with the default values of the list size as 8, CRC length as 4, and the frame size as 1000 while other same parameters.

Figure 10 BER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different Code Rate (R)

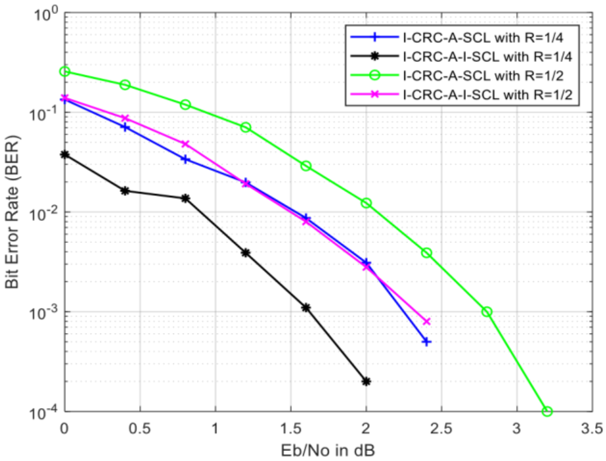
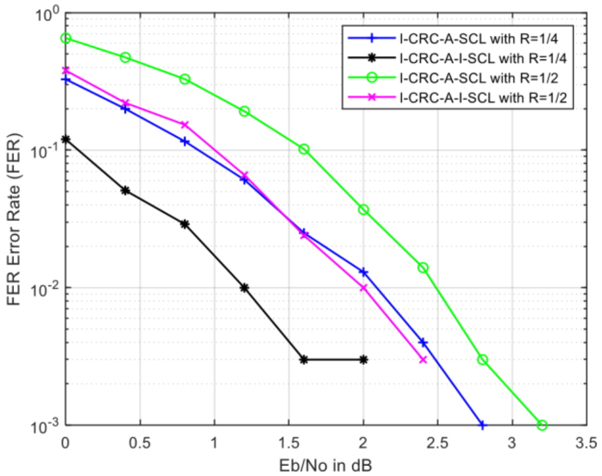


Figure 10 indicates that the performance of I-CRC-A-I-SCL at a code rate of 1/4 outperforms I-CRC-A-SCL at the same code rate. Similar behaviour is also shown in Figure 11 for FER performance. As a resultant, ICRC-A-I-SCL is promising candidate in correction of error for 5G networks.

Figure 11 FER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different Code Rate (R)



4.3.2 List Size (L) variation Analysis

Results are produced by varying the list size (i.e, change from L=8 to L=16) for both the polar schemes while considered default values as the code rate as 1/2, CRC length as 16, the frame size as 1000 and other same parameters. Figure 11 and Figure 12 show the results of BER and FER performance.

As shown in figure 11 the performance of both coding schemes increases with increasing the list size. It means the BER value decreases as the list size increases. The performance of the I-CRC-A-I-SCL polar coding scheme at list size 16 shows promising better performance relative to I-CRC-A-SCL polar coding scheme at list sizes 16, 8, and I-CRC-A-I-SCL at list size 8. Howeve, the FER value of the I-CRC-A-I-SCL polar coding scheme is lower at list size 16 as shown in Figure 12.

Figure 11 BER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different list Size (L)

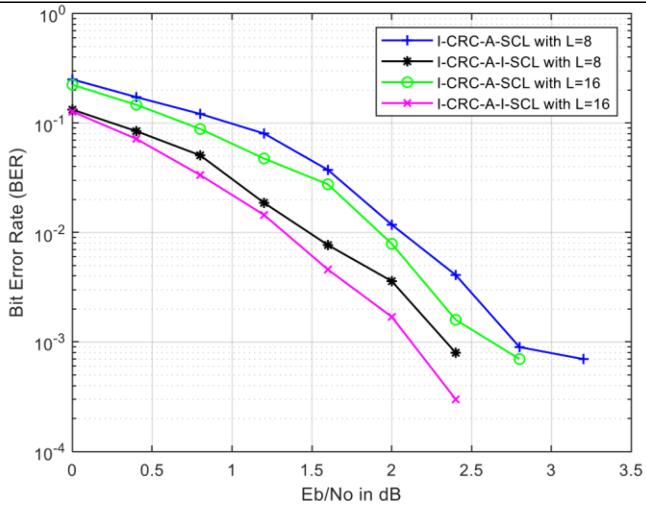
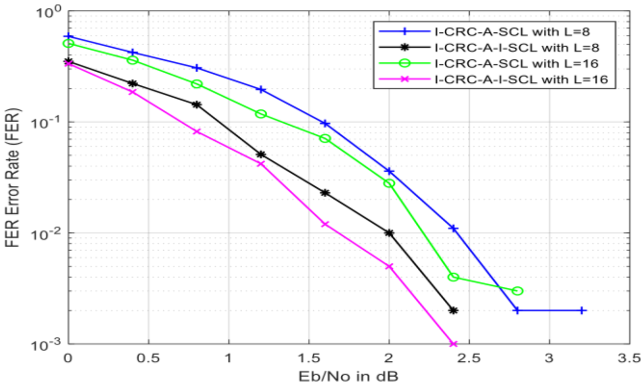


Figure 12 FER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different list Size (L)



4.3.3 CRC Length variation Analysis

In this subsection, Results are produced by varying the CRC-length (i.e, change from CRC=8 to CRC=16) for both the polar schemes while considered default values as the code rate as 1/2, the list size as 16, the frame size as 1000 and other same parameters. Figure 13 and Figure 14 show the results of BER and FER performance.

It has been seen from the Figure 13, that the performance of the I-CRC-A-I-SCL at CRC = 16 is remarkable than the I-CRC-A-I-SCL at CRC = 8 and I-CRC-A-SCL at CRC length = 8, 16. Using Figure 13 and Figure 14, as compared with I-CRC-A-SCL at CRC = 8, 16, the performance of the I-CRC-A-SCL at list size 16 is remarkable than that of I-CRC-A-SCL at L=8.

Figure 13 BER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different CRC length

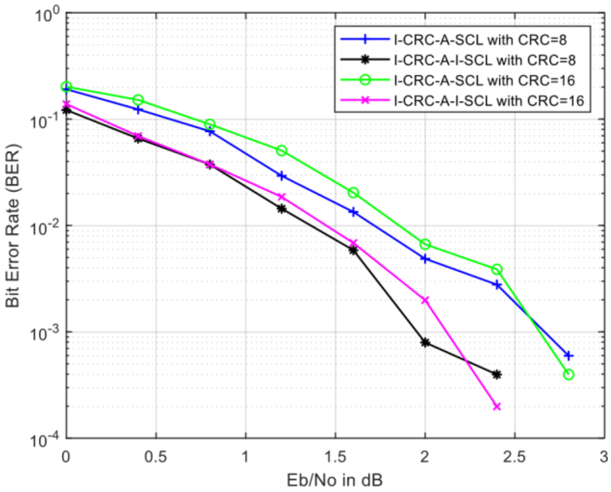
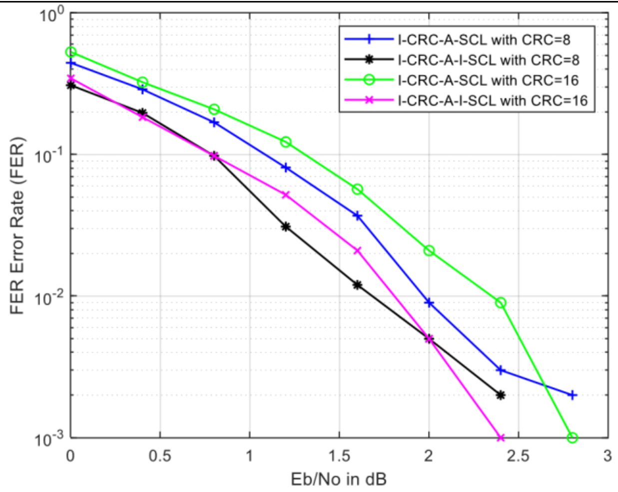


Figure 14 FER versus Eb/No for I-CRC-A-SCL and I-CRC-A-I-SCL with different CRC length



5 Conclusions

5G wireless networks is expected to most demanding technology in the era of Internet of Things. 5G services and applications are vast due to adoption of many sectors. Polar coding schemes for 5G wireless communications are most promising techniques for high throughput with high SNR levels. In this paper, most recent polar techniques are reviewed, analyzed. Based on simulation analysis, best candidate is identified. Specifically, the performance of bit error rate and frame error rate are evaluated for polar coding schemes such as SC polar, I-SC polar, CRC-A-SCL polar, I-CRC-A-SCL polar, CRC-A-I-SCL polar, and ICRC-A-I-SCL with different values of bit energy to noise spectral ratio, CRC length, code rate, and list size. Finally, it is concluded that the polar coding schemes with lower code rate outperforms than that of polar codes with higher code rate. The I-CRC-A-I-SCL polar coding scheme is proven to be promising candidate for 5G wireless communication networks due to its high error correction rate.

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