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SOFT DECODE COMPRESS AND FORWARD RELAYING SCHEME USING POLAR CODES

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Abstract

From the basis of information theory concept, channel coding techniques must achieve the Shannon's channel capacity. Polar codes are the recent concept of channel polarization phenomenon to achieve better channel codes capacity. It has recursive encoding and decoding structures. The Genetic algorithm based optimization technique is integrated from evolution and natural selection. The relay with MIMO is chosen to achieve high capacity coverage, diversity gain and high-speed transmission. In this paper, Genetic decoding is done to analyze the spectral efficiency and select the optimized path. This work proposed is chosen to improve capacity of cellular system, reduce latency through decode-compress and forward scheme and optimize the decoding method using Genetic algorithm. The validity and performance of the described method done by calculating SNR vs. BER values for relay channel and Cost vs. Iteration of Genetic algorithm and finally the SNR vs. Capacity of the proposed system model.

Keywords:

CRC Encoding, Decoding, Relay, Genetic Algorithm, Selection, Crossover, Mutation

1. INTRODUCTION

Cellular network is the technology used in mobile phones, personal communication systems, wireless networking, etc. The standards like 2G, 3G, 4G/LTE were introduced in the cellular communication. Now upcoming 5G succeeds the other standards. Some of them predict that 5G is the next evolution in the cellular communication as this target a higher bandwidth and data rates with a significantly lesser transmission delay. Information theory plays an important role in improving channel capacity and it has given the theoretical limit of the coding problem in communication systems by using the mathematical theory of communication.

The channel coding techniques must be able to achieve Shannon's channel capacity. The polar code is considered to be a channel code for 5G and these codes approach Shannon's capacity in both stationary memoryless sources and binary input memoryless channels with a low computational and also a low space complexity. Within the ongoing 5^{th} generation wireless systems (5G) standardization process of the 3^{rd} generation partnership project, the polar codes are usually being used as a channel coding technique for both uplink and downlink control information for the enhanced mobile broadband [1]- [3].

The construction of polar codes consists of the identification of the channel reliabilities associated to each one of the bits to be encoded. Polar codes always operate on the blocks of symbols/bits. This is based on the Fast Fourier Transform that fix some bits to 0 and the decoding algorithm which computes the probability that the input bits are equal to 0 given the previous input bits and the probabilities of the output bits. It takes advantage of the polarization effect to construct the codes that achieve the symmetric channel capacity $I(W)$. The basic idea of polar coding is to create a coding system where one can access each coordinate channel $W(\mathrm{I})N$ individually and send data only through those for which $Z(\mathrm{W(I)N})$ is nearly zero.

The encoding operation is done by using the expression [3] [4]

$$G_N = R_N(I_2 \otimes B_N/2) \tag{1}$$

where G_N is the generator matrix and B_N is a permutation matrix, because it is the product of two permutation matrices, R_N and $I_2 \otimes B_N/2$.Generally, the decoding algorithm is done by successive cancellation decoding method. Other decoding methods are simplified successive cancellation, fast simplified successive cancellation, list based and stack-based algorithms.

CRC codes are used to detect errors in a digital telecommunication system. These codes are based on the binary division process and are referred to as polynomial code checksum. In CRC, check bits with a fixed number, called a checksum. The check bits are appended to the message that needs to be transmitted. Then, the received data at the reception side will be inspected by the receiver to validate the errors in a system. This can be done with the help of polynomial division of the transmitted data. A negative acknowledgement will be sent to the transmitter once the system generates an error. In this situation, the data has to be retransmitted again [3] [4].

The design of CRC polynomial depends on block length protection, error protection features, CRC implementation resource, and performance. These checks are relatively easy to implement in hardware and analyzed analytically. It is one of the superior methods in detecting common errors of transmission [12]-[20].

In this work, the Cyclic redundancy check (CRC) aided polar codes is considered and the decoding is carried out using likelihood ratio. In this paper, in polar codes the decoding method has been done using the Genetic algorithm concept to achieve optimization

Section 2 discusses the existing system model using polar codes and section 3 describes the proposed work of this paper. Section 4 demonstrates the simulation results and section 5 is the conclusion followed by the references.

2. EXISTING METHODOLOGY

Polar Codes, proposed by Arikan, achieve the symmetric capacity of memoryless channels as the code length (N) approaches infinity using low-complexity successive-cancellation (SC) decoding algorithm. Their error-correction performance, however, is mediocre for codes of short and moderate lengths (a few thousand bits) and is worse than that of other moderate codes, such as low-density parity-check (LDPC) codes. To improve their performance, polar codes can be concatenated with cyclic redundancy check (CRC) as an outer code and then decoded using list decoding algorithms (list-CRC). The one among the existing work is the BER estimation using CRC aided polar codes [3] and also the performance comparison of polar, turbo and LDPC codes [4]. The detailed system model of the existing work is shown in Fig.1 as follows [4] [15].

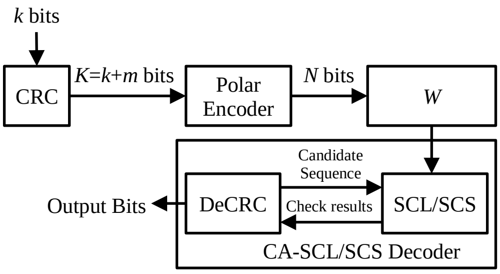

Fig.1. Existing Model [4]

It was recognized that certain decoding steps in SC decoding were redundant for certain group of bits. Hence, by breaking the serial constraint imposed by SC decoding the speed of SC decoders can be improved. In that approach, called simplified successive cancellation (SSC), group of frozen bits (viewed as Rate-0 code in tree structure) values are already known (usually known) and group of information bits (as Rate-1 code) are estimated by threshold, instead of serial SC. Furthermore, the speed of SC is increased by parallel decoding of some other Rate-R codes in the tree. The Fast-SSC algorithm which is used in the context of list decoding, considers a variety of constituent codes such ah single-parity-check (SPC) and repetition codes [5]. The improvements in performance is achieved in this paper by,

- The algorithm has been reformulated in terms of log-likelihood ratios (LLRs)
- Developing the Fast-SSC algorithm for list decoding (list-fast-SSC) and implement it
- A general path metric (or reliability metrics) is derived from codeword likelihoods, which is then used as the basis for calculating all specialized decoder output metrics.

Similarly, the other already existing works concentrate on the concept of less time complexity by using relaxed polar codes [6]. With the use of relay in transmission the minimization of BER is done through DCF relaying protocol [7] and simplified successive cancellation list decoding [8] of polar codes. The reduction in BLER using Soft Decode-Compress-Forward with selective cooperation of relays [9] and the existing work has been extended to MIMO scenario with multiple relays [10]. The Genetic algorithm (GA) based approach is integrated with CRC-aided successive cancellation decoding for the estimation of bit error [11]. The proposed work deals with cooperative relays with polar codes.

3. PROPOSED METHODOLOGY

3.1 RELAY WITH MIMO

Communication systems using relays offer significant gains in spectral efficiency and increase the link reliability between the source and the destination. Multiple Input and Multiple Output (MIMO) relay networks of Amplify and Forward (AF) protocol provide low processing complexity. MIMO relays can provide better coverage for high data rate services.

In MIMO channel, the source messages are transmitted directly from the source to the relay and to the destination, source messages have to travel through various channels, which are combined both in parallel and in serial. MIMO relays can be used in distributed antenna systems and femtocells for a heterogeneous network.

Compared to the single-antenna relay channel, the MIMO relay channel introduces additional degrees of freedom that make it possible to perform more sophisticated encoding and decoding techniques thus can improve system performance. Here 2×2 MIMO system is used. The combination of these two techniques has the advantages of high transmission rate, reduce propagation delay, wide coverage and efficiency and can provide significant gain performance when used with the traditional transmission method.

3.2 GENETIC ALGORITHM

The decoding method here is with search path optimization using Genetic approach. The system model of the proposed methodology is shown in Fig.2. The Genetic algorithm is the search procedure that uses a random choice and selects the optimized solution. The principle and procedure of Genetic algorithm can be summarized as; the algorithm starts by creating a random initial population. If it is not suitable it creates a new generation or population from the current population by performing crossover and mutation and then replaces them with the current on the basis of their best fitness value.

Finally, the algorithm stops when the stopping criteria are met. Generally, the stopping criteria for the algorithm is one of the following,

- Maximum Number of Generation
- Maximum Time Limit
- Maximum Fitness limit
- Stall Generations
- Stall Time Limit

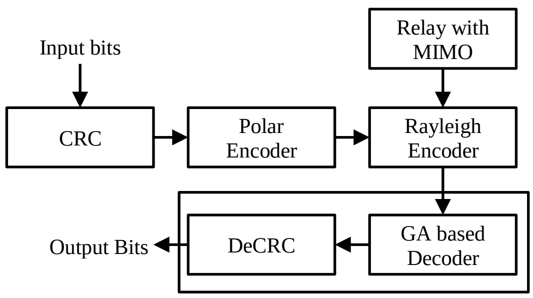

Fig.2. Proposed Model

The detailed system model is discussed in the following, the input bits are initially encoded by CRC technique followed by polar codes. The transmission is done through the Rayleigh channel with the help of relay with MIMO. At the other end, the decoding process is carried out by the Genetic algorithm procedure followed by CRC decoding operation.

Generally, the genetic algorithm performs faster at an initial stage when population diversity is wide spread but gradually slow down at the later stage when the population is nearly homogeneous individuals. These could increase the crossover and mutation rates when there is no significant improvement in the fitness value. The procedure repeats for much iterations until the stopping criteria is reached.

4. RESULT AND DISCUSSION

Generally, the relay networks play a vital role in improving the capacity and coverage of cellular networks. The relay forwards the received signal to the destination when the threshold level is met by the system. The signal-to-noise (SNR) ratio helps to analyze the maximum rate at which the information can be transmitted without any errors. Generally, signal-to-noise ratio is a function of signal quality, signal power and channel characteristics.

The amplify and forward relay is the protocol normally used for cooperative relays. Here in Fig.3 the graph is plotted between signal-to-noise ratio and bit error ratio (BER). We can see that the bit error ratio keeps on decreasing as the signal-to-noise ratio increases gradually.

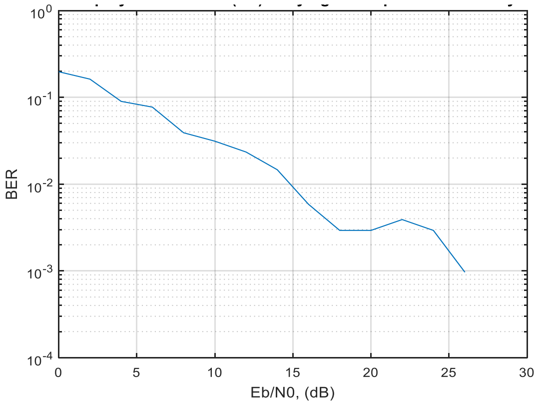

Fig.3 SNR vs. BER for relay channel

The Fig.4 shows plots of convergence of cost function vs. iterations done by the genetic algorithm. After few iterations we can see that the cost function has become constant. The cost function represents the relationship between different parameters which is to be optimized. The computational cost is to reduce the population after the first process of iteration.

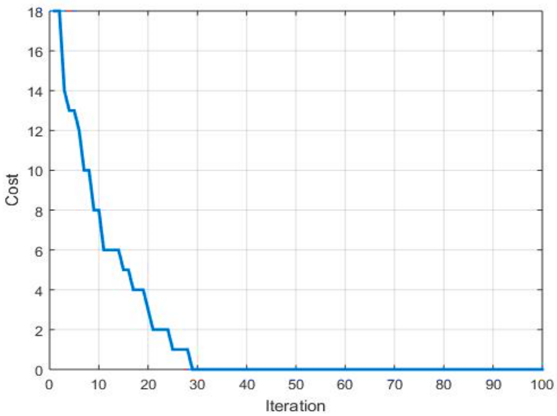

Fig.4. Cost vs. Iteration for Genetic algorithm

The channel capacity is defined as the maximum amount of signal that can be transmitted over the channel. The information capacity depends on both the Signal to noise ratio and the bandwidth. The output graph obtained is the plot of SNR vs. capacity. As the algorithm goes on, the graphical plot of each successive generation keeps on increasing the closeness of outcome to the optimum point.

From the Fig.5, we can see that as the signal to noise ratio increases there is also increase in the capacity value. Thus, we achieve better capacity performance and the efficiency by the combination of the techniques, the cyclic redundancy checks aided polar encoding followed by decoding process using the Genetic algorithm.

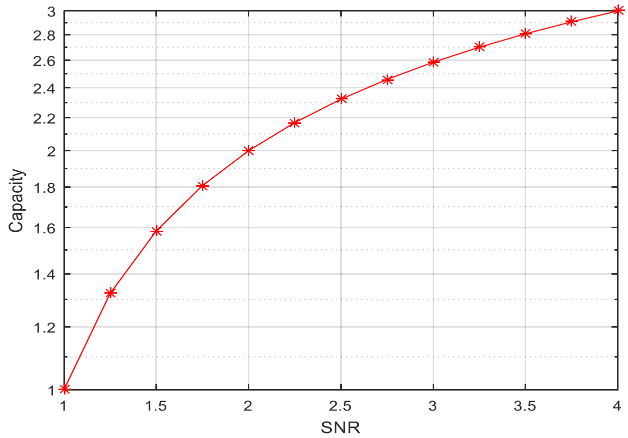

Fig.5. SNR vs. Capacity

5. CONCLUSION

In this paper, the capacity of the proposed scheme over Rayleigh channel has been investigated. The simulation results show that the proposed scheme provides capacity increase as the SNR also increases. From the results we can state that the polar code is considered to be a simplest and most efficient solution. It is apparent from the simulation results that the polar code with Genetic algorithm decoder outperforms other type of codes for almost all controlled block length and code rates. It has excellent error correcting performance with no error floor observation. The future work may be incorporated for large MIMO systems in achieving efficient coverage and capacity.

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