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Implementation of Polar Codes in 5g

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Abstract*: A new proposed method for constructing codes that achieves the symmetric capacity, (the capacity of the channel with the same probabilities for the inputs), I (W) , of any Binary Discrete Memoryless Channel W (BDMC) and this is achieved by channel polarization. Channel polarization refers that out of N independent channels, a second set of N input channels $\{W\square^{i}: 1 \le i \le N\}$ such that, as N becomes large, the fraction of indices i for which $I(W\square^{i})$ is near 1 approaches I(W) and the fraction for which $I(W\square^{i})$ is near 0 approaches 1-I(W). The polarized channels $W\square^{i}$ are well-conditioned for channel coding: one need only send data at rate 1 through those with capacity near 1 and at rate 0 through the remaining. Codes constructed on the basis of this idea are called polar codes.The block length while constructing the polar codes should be $N=2^n$. Better performance is achievable by encoders and decoders with complexity O(log N) for each.

I. INTRODUCTION

After Shannon's noisy coding theorem, a new code is constructed to achieve the symmetric capacity of the channel. As traditional coding techniques like Turbo code, low-density parity-check codes(LDPC) are considered to be capacity approaching, a new method of codes construction called channel polarization was proposed by Arıkan which can achieve the symmetric capacity of any given binary-input discrete memoryless channel Polar coding is a linear block error correcting code. It utilizes channel polarisation phenomenon in which each channel approaches either a perfectly reliable or a completely noisy channel. It transforms physical channel to a virtual outer channel and is based on a multiple recursive concatenation The basic idea of polar coding is to create a coding system where one can access each channel individually and send data for which the reliability is high.First, we give some definitions and state some basic facts that are used. Consider a B-DMC with input alphabet X , output alphabet Y, and transition probabilities W(y|x),x∈X, y∈Y. The input alphabet X will always be [0,1], the output alphabet and the transition probabilities may be arbitrary .For the given BDMC channel there are two important parameters:the symmetric capacity and the Bhattacharyya parameter. The symmetric capacity I(W) is given by,

$$\sum_{y\in Y}\sum_{x\in X}\frac{1}{2}W(y|x)\log\frac{W(y|x)}{\frac{1}{2}W(y|0)+\frac{1}{2}W(y|1)}$$

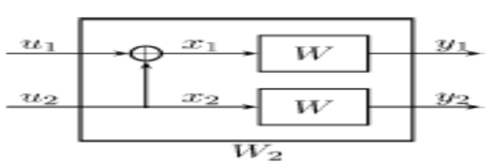
and the Bhattacharyya parameter is given by,

$$Z(W) = \sum_{y\in Y}\sqrt{W(y|0)W(y|1)}$$

I(W) is the highest rate at which reliable communication is possible with the inputs of W with equal frequency.Z(W) is an upper bound on the probability of maximum-likelihood (ML) decision error when W is used only once to transmit a 0 or 1.Z(W) AND I(W) takes values in [0,1]. The unit for code rates and channel capacities will be *bits*. One would expect that I(W)≈ 1 iff ,Z(W)≈ 0 and I(W)≈ 1 iff ,Z(W)≈ 0.

II. CHANNEL POLARIZATION

Channel polarization refers that out of N independent channels, a second set of N input channels $\{W\square^{i}: 1 \le i \le N\}$ such that, as N becomes large, the fraction of indices i for which $I(W\square^{i})$ is near 1 approaches I(W) and the fraction for which $I(W\square^{i})$ is near 0 approaches 1-I(W).



In the above figure u is a input from random source and x is the encoded output .After passing through the channel along with the

noise the output y is produced after which it has to be decoded to get the original input.
The transition probability is given by,

$$W_2(y_1, y_2|u_1, u_2) = W(y_1|u_1 \oplus u_2)W(y_2|u_2)$$

One output is obtained by EX-oring to inputs and the other output is obtained by taking the second input.

A. Channel Combining

Channel combining means combining copies of the given BDMC channel in the recursive manner.In Fig.2, two W channels are combined to form W_2 and two W_2 channels combine to form W_4 and thus this process takes place recursively.

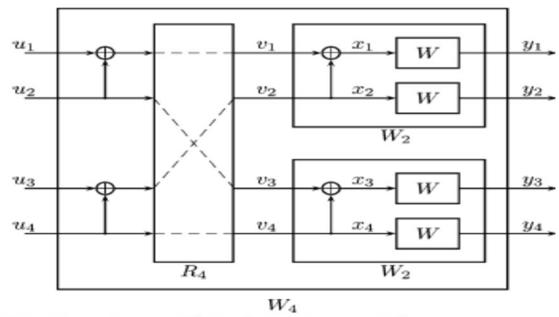
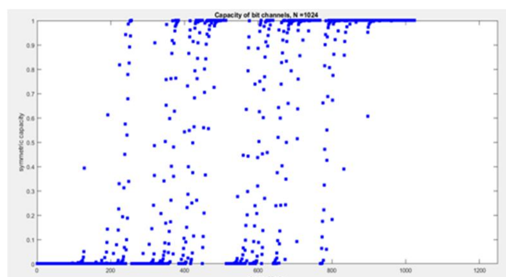


Fig. 2. The channel W_4 and its relation to W_2 and W.

B. Channel Splitting

The next step of channel polarization is to split the combined BDMC channel.



In the above figure X-axis denotes the channel index and the Y-axis denotes the symmetric capacity. And the graph is obtained for N=1024 and $\in = 0.8$.For small channel index value symmetric capacity value is near zero whereas for large channel index value symmetric capacity value value is near 1 and in the intermediate range it shows an erratic behavior.

III. ENCODING

The encoding process is done by using the following formula:

$$x_1^N = u_1^N G_N$$

where u_1^N is the random input source

G_N is the Generator matrix

The generator matrix is given by

$$G_N = B_N F^{\otimes n}$$

Here in the above equation $\otimes$ denotes the Kronecker product.

where B_N is the bit reversal operator

$$F = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$$

n=log2(N)

The bit reversal operator is given by the equation:

$$B_N = R_N(I_2 \otimes B_{N/2})$$

Rn-reverse shuffle operator .

The reverse shuffle operator seperates the given input into odd and even indices.

For binary erasure channel,

The symmetric capacity of the BDMC is I=1-p

Thus the battacharya parameter of this channel can be given by Z=1-I and the odd and even index can be seperated using the below formulas

ODD= 2*Z-Z^2 and EVEN= Z^2.

Thus the generated matrix and the randomised value are being multiplied to get 512 bit encoded input.

IV. DECODING

The decoding process we use in this paper is Successive Cancellation decoding technique. A Successive Cancellation decoder consists of three main units and they are: 1)the Processing unit 2)the Memory unit 3)the Partial Sum unit

The decoded bits are generated one after the other by the Processing unit which needs LogLikelihood ratio(LLR) that are stored in Memory unit and the partial sum that are stored in Partial Sum unit.The partial sums are the combination of previously decoded bits and it is updated whenever a bit is decoded.The LogLikelihood ratio is given by,

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

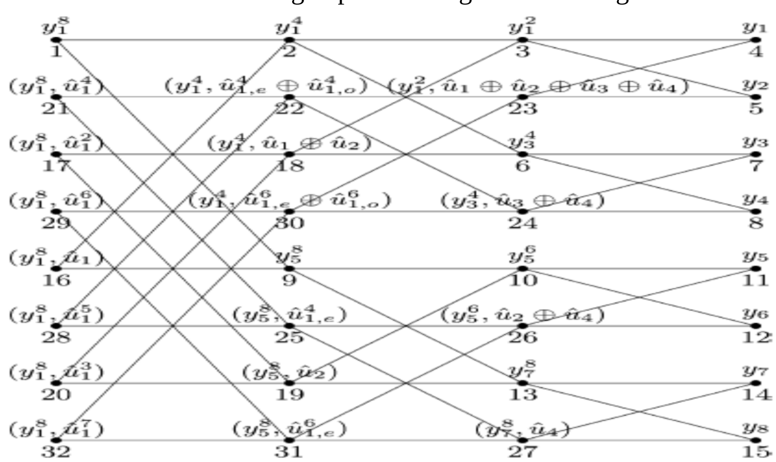
and generates its decision as

$$\boldsymbol{u_i} = \begin{cases} 0\text{, if } L_N^i(y_1^N, u_1^{i-1}) \geq 1 \\ 1\text{, otherwise} \end{cases}$$

the calculation of an LLR at length N is reduced to the calculation of two LLRs at length $N/2$. This recursion can be continued down to block length , at which point the LRs have the form $L_1^1(y_i) = W(y_i|0)\ /W(y_i|1)$ and can be computed directly.

The process takes place by separating odd and even indices separately. One of the outputs is obtained by adding odd and even indices and the other output is obtained by taking the even indices directly.

The below diagram is the implementation of SC decoding in polar coding for block length N=8.



V. CONCLUSION

In this paper,we have implemented the encoding and decoding process for the 512 bit input that is generated by the random input source. However, there are lots of open problems that can be done in future to improve the performance of these codes to assess the potential of polar coding for practical applications.

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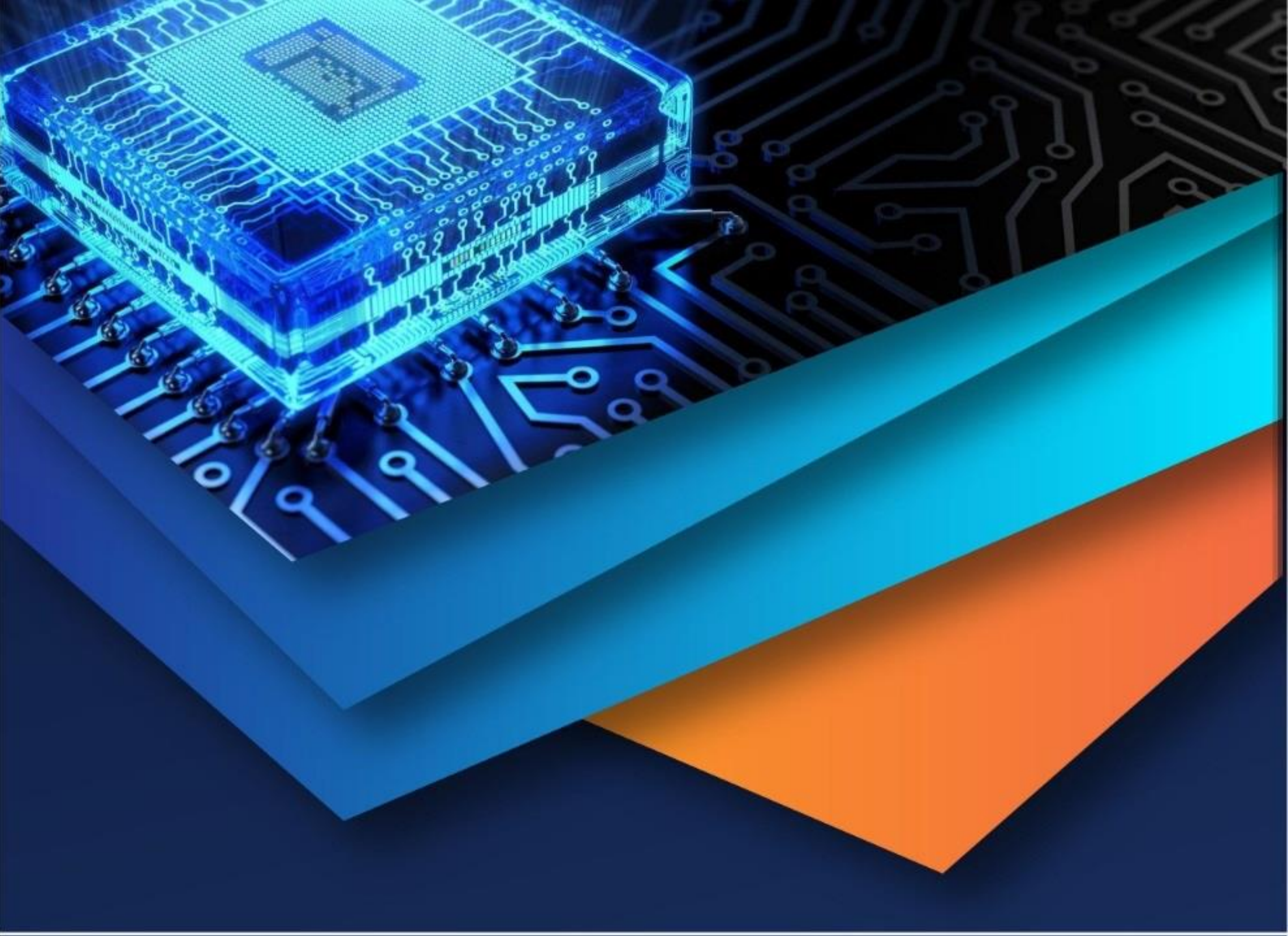

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