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ANALYSIS AND IMPLEMENTATION OF POLAR CODES

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***Abstract*—Error correcting codes play an important role in digital communication which makes it better than analog communication. There are many types of codes and the recently complex encoding and decoding are easily implementable thanks to the VLSI technology. Polar code is such a code that achieves maximum channel capacity. Polar codes are used in 5G communication already. In this project polar codes are studied. Various implementation methods are discussed. An encoder and decoder for polar codes in the MATLAB ® environment is developed. The bit error rate with different modulation techniques is implemented and the results are shown in graphs. The project also provides a literature survey and MATLAB ® codes for further research in this topic.**

Keywords—Error control coding, polar codes,5G, MATLAB ®

I. INTRODUCTION

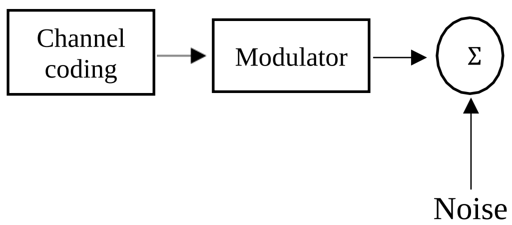
In binary digital communication, an error occurs when 1 is sent and 0 is received (Vice Versa). The error occurs due to AWGN, Channel memory, Interference, Frequency and time offset, etc. The errors have to be detected and corrected. Error Control coding is used to do this job. CRC, hamming codes, RS code, Convolution codes, etc. are some examples.

The coding introduces extra bits and reduces the channel capacity.

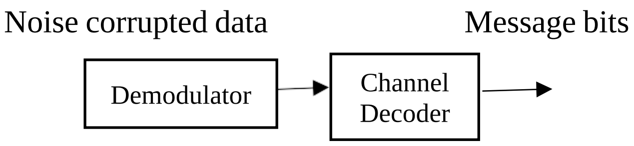
A. CHANNEL CODING

Noise present in a channel creates unwanted errors. The error probability should be very low, nearly ≤ for a Reliable communication. Shannon’ s noisy-channel coding theorem gives a result about the rate of information that can be transmitted through a communication channel with arbitrarily low error. The channel coding in a communication system introduced redundancy a control, so as to improve the reliability of the system. The source coding reduce redundancy to improve the efficiency of the system.

Input message bits



A) Transmitter



B) Receiver

II. BLOCK CODES

Unlike convolutional codes, block codes do not have memory in its encoding process. The history of block codes began when hamming developed his first algebraic approach to correct the errors by using the distance to the nearest valid codeword. In addition, hamming introduced in his remarkable work some crucial concepts associated with the channel coding such as Hamming weight and Hamming distance. The hamming weight (wt.) is defined as the number of the non-zero elements (number of ones in binary systems). With this in mind, the minimum hamming distance (MHD) denoted, is defined as the smallest Hamming distance between any pair of codewords. It was found that the maximum number of errors that the code can detect denoted by, depends on the MHD of the code].

$$e_d = d_{min}{}^{-1} \qquad (1)$$

Meanwhile, the number of the errors can be corrected by the code is denoted by t,

$$t \leq [\frac{d_{min}{}^{-1}}{2}] \qquad (2)$$

In general, the block code is decoded using either Hard decision (HD) or soft decision (SD). In the former, the performance depends mainly on the MHD whereas the SD depends on the minimum Euclidean distance. Furthermore, Read-Solomon codes are regarded as the code with the largest possible minimum hamming distance (. Owing to this merit, these codes are feasible in practice and they are used in compact disc (CD)and the deep space communications.

III.PROBLEM DEFINITION

Designing a polar code is equivalent to finding the set of good indices among the N polarized channels described. The output alphabet of the channel is {0, 1}, and consequently, the cardinality of the output alphabet of the channels after n levels of polarization grows exponentially in block-length. So, computing the extract transition probabilities of these channels seems to be intractable and hence we need some efficient methods to “appropriate” these channels to use Monte-Carlo for estimating the Bhattacharyya parameters. More precisely, given a number k, the task is to come up with efficient methods to replace channels that have more that k outputs with “close” channels that have at most k outputs. In the following, we state some comments to clarify the problem. In our problem, we define the quantization error as the difference between the true set of good indices and the approximate set of good indices. For the theoretical analysis of the problem, we consider other types of error to analyze.

$$I(\hat{W}_N^{(i)}) \leq I(W_N^{(i)}) \qquad (1)$$

Alternatively, we call Qk admission if any I and n

$$Z(\hat{W}_N^{(i)}) \leq Z(W_N^{(i)}) \qquad (2)$$

Figure 1.1 Digital Communication System with Channel Coding

Note that (1) and (2) are essentially equivalent as N grows large. Given an admissible procedure Qk and a symmetric B-DMC W, let ρ (Qk, W) be

$$\rho(q_k) = \lim_{n\to\infty} \frac{|\{i: IW_N^{(i)} > \frac{1}{2}\}|}{N} \qquad (3)$$

So, the quantization problem is that given a number κ ∈ N and a channel W, how can we find admissible procedures Qk such that ρ (Qk, W) is maximized and is close to the capacity of W. An important question which arises here is that whether we can achieve capacity of the channel ask tends to infinity.

IV.OBJECTIVES OF THE PROJECT

i. To study an advanced recent communication system in practice

ii. To construct the communication system using block diagrammatic approach

iii. To highlight the channel coding and its effect in performance of the above

constructed digital communication system.

iv. To survey the technology behind Polar codes

v. To implement polar codes

vi. To compare performance of Polar codes with existing codes

vii. To document the study and publish.

V.SOFTWARE REQUIREMENT

The project is simulated in a computer. The project can be implemented in any programming languages. MATLAB is used in the project as the language is well known by the author and has inbuilt functions which will reduce the coding techniques.

1. MATLAB with Communication tool box

2. Microsoft Word with Windows 11 OS.

VI. AWGN CHANNEL

This channel is linear and time-invariant (LTI). When a signal passes through an AWGN channel, it adds white Gaussian noise to it. The amplitude frequency response of this channel is flat, and the phase response is linear at all frequencies it allows modulated signals to pass through with no amplitude loss or phase distortion. As a result, fading does not exist in this case, and the only distortion that exists is caused by the AWGN. The received signal is simplified to where n(t) represents the noise, which has a Gaussian distribution with zero mean and variance as the noise power, and x(t) represents the transmitted signal.

VI. METHODOLOGY

Polar codes in a communication system are implemented in MATLAB.TheMATLAB implementation is straightforward and has many built in function which will help to make the programmes smaller and enable the programmer to re-use the codes. Noise-Aided Belief Propagation List Bit-Flip decoder is used. Polarization, polar coding, rate matching and re-matching are the important blocks of the process. This process can either be written or MATLAB equivalent function can be used. The decoder part is taken from [1] which is very complicated and extensive.

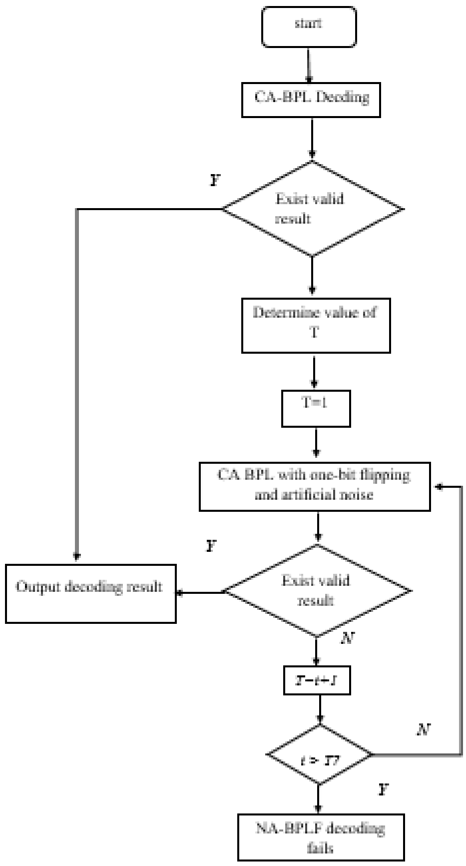


Figure:1.2 Flow Chart of NA-BPLF Decoder

VII. PUNCTURING

In this section, we give an overview on puncturing of polar codes.

Puncturing is a technique used to obtain an (Nm − p, Km) code from an (Nm, Km) mother code for any P<Nm − Km, thus increasing the code rate. As, a result, P code bits are not transmitted. The decoder handles punctured bits as erased, and applies the decoder of the mother code. In the case of polar codes, an (N, K) punctured polar code is generated by a mother polar code of length Nm = 2[log2 N]and dimension Km = K. The mother polar code is given by the transformation matrix TN and a frozen set F of size Nm − K. The information word u ∈ F2is encoded through the mother polar code into the codeword x ∈ F2Nm. However, the vector x contains > N bits, hence some of ρ the set of bits of x not to be transmitted, the encoder transmits the vector. At the decoder side, the channel LLRs for the punctured code bits are set to zero, and the decoder of the mother code is applied. Frozen and puncturing sets are deeply connected. It is worth to notice that, while the frozen set F is a subset of v, the puncturing set P is a subset of the codeword x. In fact, the absolute value of the LLR is indicating the reliability of this bit. For punctured bits, the reliability is zero, hence these bits are completely unreliable for the decoder. When the SC decoder encounters such an unreliable position, its value cannot be resolved, and a LLR of value λi = 0 is injected into the decoder. The set u(P) of the incapable bits created by the puncturing set P, depicted as incapable set, can be found by DEGA ⁄ or using the algorithm proposed. In the example, the incapable set is given by u(P) = {1, 5}. As the value of such positions cannot be resolved by SC decoding, all incapable bits must be frozen bits to avoid an error floor. As the value of such positions cannot be resolved by SC decoding, all incapable bits must be frozen bits to avoid an error floor. This gives the condition u p ⊆ F in the design of the punctured polar code. We should note that calculating the frozen set through the algorithm from the punctured set], naturally gives u p ⊆ F.

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