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VLSI Architecture of High Speed Polar Encoder and Decoder for 5th Generation Communication Application

Madhu Ojha[1], Shraddha Shrivastava[2]

M.Tech Scholar, Dept. of ECE., Lakshmi Narain College of Technology, Bhopal, India[1]

Assistant Professor, Dept. of ECE., Lakshmi Narain College of Technology, Bhopal, India[2]

ABSTRACT: Polar codes become a new channel coding, which will be common to apply for 5th generation wireless communication systems. In information theory, a polar code is a linear block error correcting code. There are many aspects that polar codes should investigate further before considering for industry applications. The original design of the polar codes achieves capacity when block sizes are asymptotically large with successive cancellation decoder. So there is a need of high speed, less area and low power encoding scheme for next generation communication. In this paper, design and performance analysis of polar encoder and decoder are presented. Experimental results show that the proposed polar code can achieve higher performance and significant area time product improvement when compared with previous designs.

KEYWORDS: Speed, Area, Power, Polar, 5G, Encoding, Decoding, Channel.

I. INTRODUCTION

There are numerous perspectives that polar codes ought to investigate further before considering for industry applications. Particularly, the original structure of the polar codes accomplishes limit when square sizes are asymptotically enormous with successive cancellation decoder. Be that as it may, in square sizes that industry applications are working, the performance of the successive cancellation is poor contrasted with the very much characterized and executed coding plans, for example, LDPC and Turbo. Polar performance can be improved with successive cancellation list decoding, be that as it may, their convenience in genuine applications still faulty because of poor execution efficiencies.

The numerical establishments of polar codes lay on the polarization impact [1] of the network G2 = [1 0]. In a (N, K) polar code of length N = 2n, the polarization impact builds up N virtual channels, and through each channel a solitary piece is transmitted. Every one of these bit-channels, or sub channels, has an alternate unwavering quality; message bits are allocated to the K most dependable channels. The polar code is henceforth characterized by the transformation lattice GN = G2⊗n, for example as the n^{th} intensity of the polarizing network, and either the solidified set F of size N − K, or its reciprocal information set I = FC of size K, where I and F are subsets of the record set 0, 1, 2n−1 . A codeword d = d0, d1, . . . , dN−1 is determined as

d = uGN (1)

where the info vector u = u0, u1, . . . , uN−1 is produced by appointing ui = 0 in the event that I , and storing information in the rest of the components. Each file I recognizes an alternate bit- channel.

A. LDPC Code

The throughput of layered BP decoder can be calculated as:

$$Throughput_{[Mbps]} = \frac{L \cdot f_{c[MHz]}}{I \cdot N_{Layer} \cdot \left(\left\lceil \frac{z}{P} \right\rceil + T_{pip} - 1 \right)}$$

where,

I denotes the number of iteration;

P denotes the parallelism level;

L denotes the length of code block without CRC;

N_{Layer} denotes the decoding layer, equals the number of rows for base matrix;

z denotes the expending factor;

T_{pip} denotes the processing clocks for CNU and VNU updating plus memory reading and writing at each decoding step;

f_c denotes the operating frequency.And, the throughput of flooding decoder with single-frame can be calculated as:

$$Throughput_{[Mbps]} = \frac{L \cdot f_{c[MHz]}}{I \cdot (N_{Layer} + T_{pip} - 1)}$$

B. Turbo Code

The throughput of turbo MAP decoder can be calculated as:

$$Throughput_{[Mbps]} = \frac{L \cdot f_{c[MHz]}}{2 \cdot I \cdot \left(\left\lceil \frac{L}{P} \right\rceil + \frac{2}{a} \cdot W \right)}$$

where,

I denotes the number of iteration;

P denotes the parallelism level;

L denotes the length of code block without CRC;

W denotes the number of extra trellis for MAP decoder;

a denotes the number of bits processed in one MAP core per clock cycle, i.e. 1 for Radix-2 and 2 for Radix-4.

f_c denotes the operating frequency.

II. PROPOSED WORK

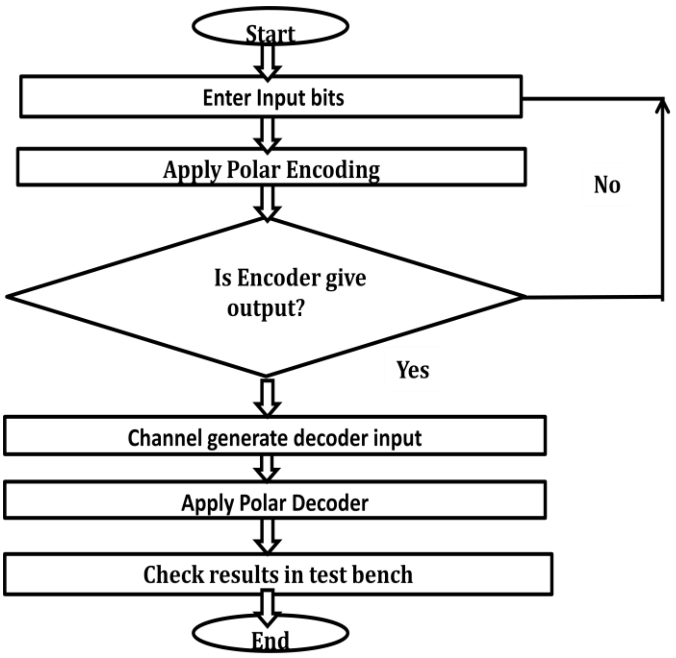

Figure 1: Flow Chart

Algorithm-

- input [15:0]enc_in;
- output [15:0]dec_out;
- wire [31:0]enc_out,channel_in;
- wire[287:0]channel_out,dec_in;
- assign channel_in = enc_out;
- assign dec_in = channel_out;
- encoder_32bit t1(enc_in,enc_out);
- channel t2(channel_in,channel_out);
- decoder_32bit t3(dec_in,dec_out);

Proposed Polar codes are a channel coding innovation and all channels coding innovation works essentially in a very comparative manner. Correspondence joins are defenseless to errors because of random commotion, impedance, gadget weaknesses, and so on that corrupt the original information stream at the less than desirable end. Channel coding essentially utilizes a lot of algorithmic procedure on the original information stream at the transmitter, and another arrangement of procedure on the got information stream at the collector to correct these errors. In channel coding wording, the totally of these activities at the transmitter and beneficiary are individually indicated as encoding and decoding tasks. Channel coding techniques extensively fall under two classes: square codes and convolutional codes. Square codes work on a square of information/bits with fixed estimate and apply the control to this square at the transmitter and collector. Reed-Solomon codes, ordinarily utilized on the hard circles of PCs, are one case of this kind of code. Convolutional codes, then again, work on floods of information with more discretionary quantities of information/bits. These codes apply a sliding window strategy that gives a significant decoding advantage. Basic Viterbi codes are a case of this kind of code.
As you would speculate, significant beneficial exploration has been done throughout the years into the connection of square and convolutional codes to consolidate the advantages of both. For instance, the RSV code, which was the best performing code until turbo codes, was a half and half of the Reed-Solomon code, which is a square code, with a Viterbi convolutional code.
Polar codes encoding ready to encode the polar codes with the assistance of a straightforward organizing strategy. The space unpredictability of the encoder is equivalent to O(N) and the time multifaceted nature is O(Nlog(N)). The generator network G can be characterized by GN = BNF ⊗n where n = log(N), BN is known as the bit-inversion framework and F⊗n is the Kronecker item where F = [1 0 1] as it is referenced already. Beforehand structure a 8-piece polar encoding. On the off chance that we have polar code with blocklength N, it comprises of an information vector u1 N for example u1 8 = [0 0 1 0 1 0 1] and the vector at the yield is x1 N for example x1 8 = [1 1 0 1 1]. Moving between the information vector and the yield vector u1 N → x1 N is straight over Galois Field (GF(2)).
Polar codes break the wheel to some degree in the field of channel coding with an unorthodox methodology that looks like a portion of the tasks more ordinarily found in the standard correspondence chains between the baseband and radio front finishes.
Perhaps the greatest shock in 5G standardization so far has been the acknowledgment of polar codes as an official channel coding innovation. Such choices are obviously mind boggling ones that are frequently as much about political influence as innovation goodness. In any case, the reality accomplished by this generally early innovation is astounding. It was just a short time back that the prevalent view was that turbo codes could never be obscured.
Polar codes break the wheel to some degree in the field of channel coding. Polar codes work on squares of images/bits and are therefore actually individuals from the square code family. The development of these codes follow an unorthodox methodology contrasted with more customary methodologies like turbo codes. From multiple points of view, the strategies take after a portion of the activities that are generally utilized in standard correspondence chains between the baseband and radio finishes, basically the group of Fast Fourier Transform (FFT) like methods that anyone with an interchanges or sign handling foundation will be much acquainted.

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III. SIMULATION RESULTS

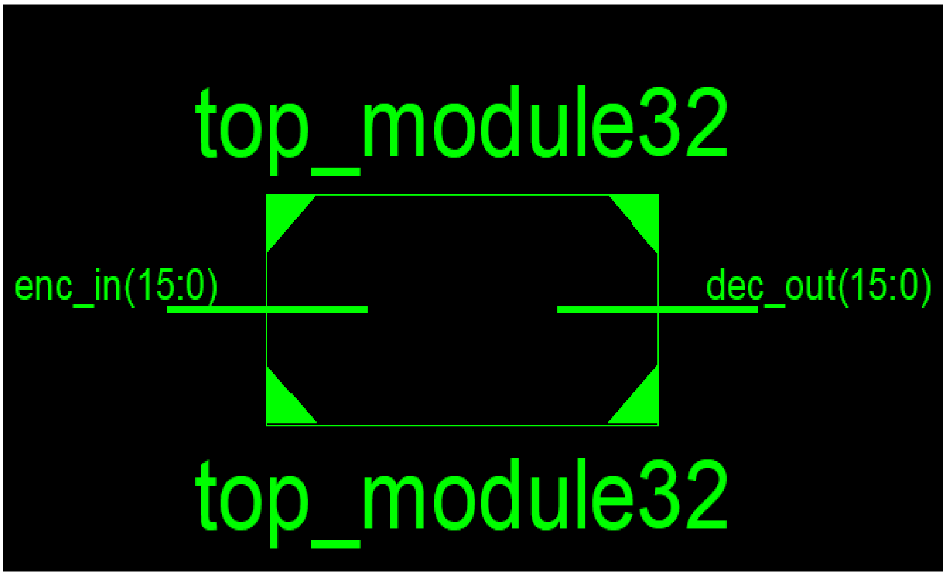

Figure 2: Top view of proposed model

In figure 2, showing top level of proposed polar code model. Here apply 16 bit input and after complete process it gives 16 bit output.

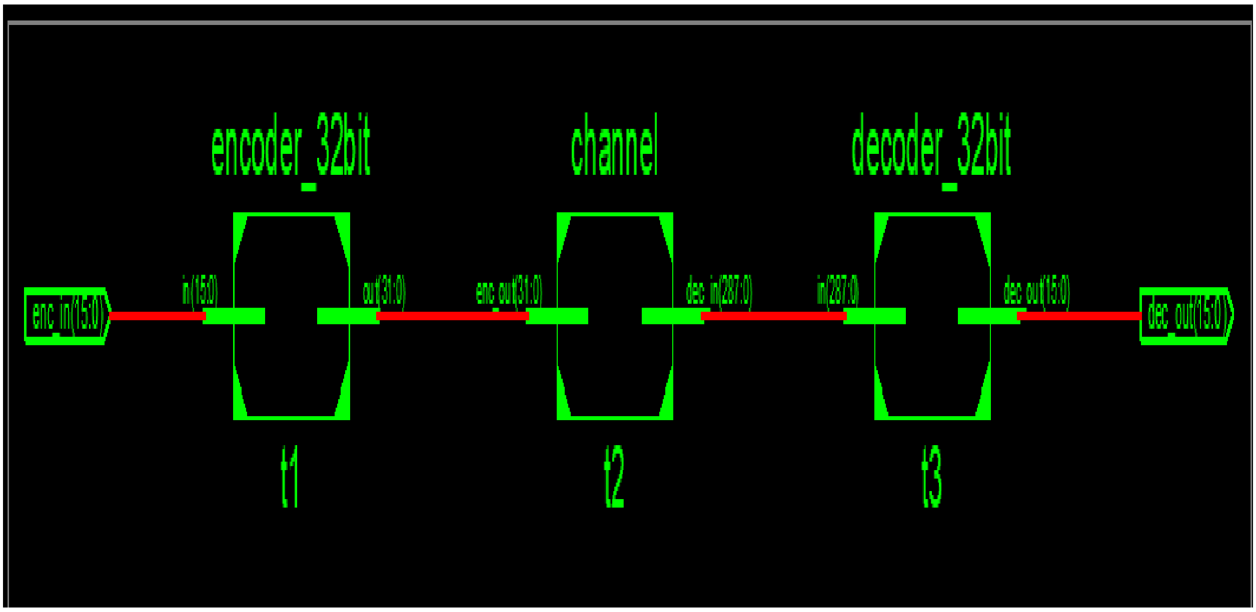

Figure 3: Complete process of proposed model

Figure 3 presenting complete process block diagram in form of RTL view. Here it is clear that all process divide in three steps. The details of all process is explain step via step in below diagrams.

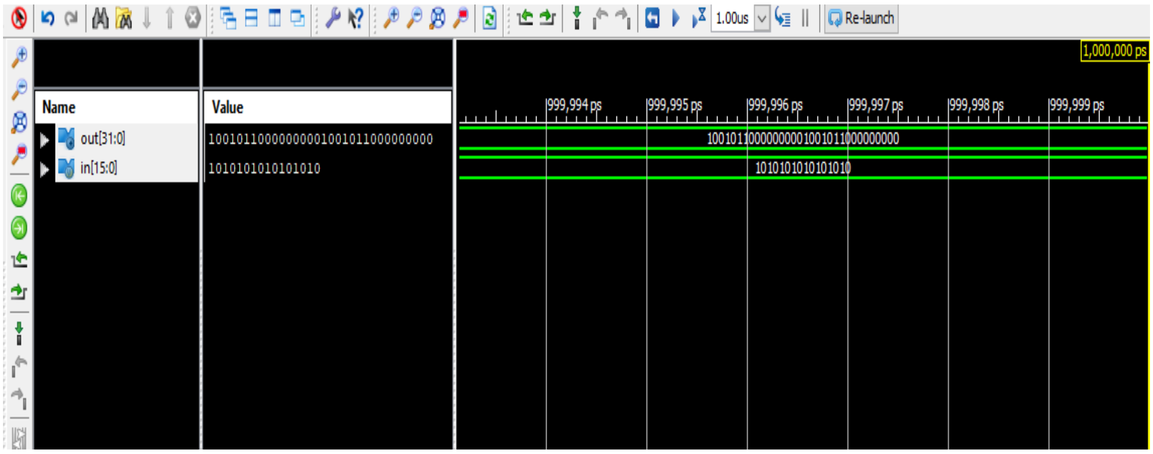

Figure 4: Test bench result at encoder

Figure 4 showing result in test bench, here apply 16 bit input that is 1010101010101010. After encoding it generate 10010110000000000100101100000000.

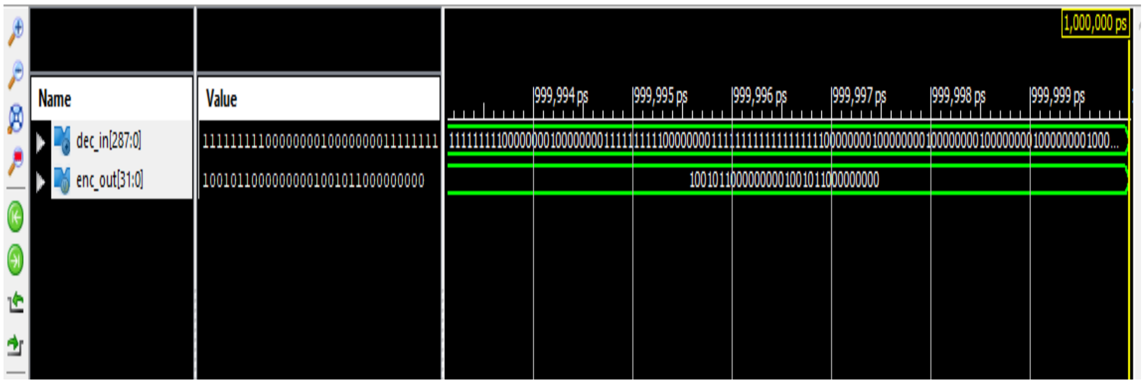

Figure 5: Result at channel

Figure 5 showing channel result in test bench, here apply 32 bit encoder output that is 10010110000000000100101100000000. It generates 288 decoder input bit that is hff80403ff00ffffe0100804020100804020 1ff80403ff00ffffe01008040201008040201 in hexadecimal.

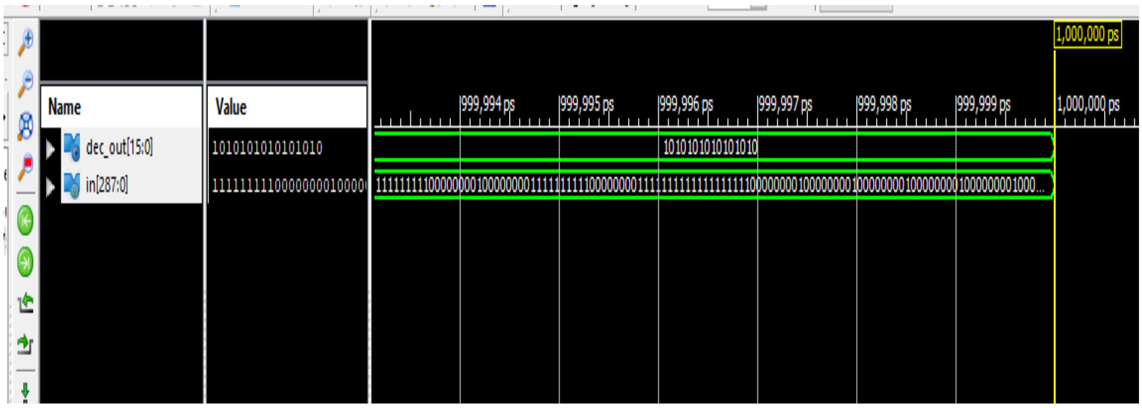

Figure 6: Result at decoder

Figure 6 showing decoder stage of proposed model in test bench, here apply 288 decoder input bit that is hff80403ff00ffffe01008040201008040201ff80403ff00ffffe01008040201008040201 and it generate 16 bit output 1010101010101010.On the other hand, we recover original data.

Table 1: Simulation Parameter and Comparison with previous work

Sr No.	Parameter	Previous Work	Proposed Work
1	Method	Polar decoder	Polar encoder and polar decoder
2	Area	5.35 mm^2	2.33 mm^2
3	Delay	1534ns	139.612ns
4	Power	1072.9 mW	43mW
5	Time	NA	30.48 secs
6	PDP	164153	6003

Table 1 showing comparison of proposed work with previous work, so it can be seen that proposed work gives better result than existing work.

IV. CONCLUSION

In this work audited the best in class in polar code in encoding and decoding form. It was indicated that the many decoding algorithms were created and executed to address different application necessities. Additionally contrast polar code and CRC code. Numerous specialists suggest that polar code can be utilized ahead of time remote correspondence for people to come.

In this work, we have point by point the polar code encoding process inside the fifth era remote frameworks standard, giving the better results and an easy to use depiction to understand, actualize and mimic 5G-consistent polar code encoding. This encoding chain exhibits the effective efforts of the 3GPP standardization body to meet the different necessities on the code for the eMBB control channel: low depiction intricacy and low encoding multifaceted nature, while covering a wide scope of code lengths and code rates.

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