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Study of Polar Code

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Abstract:- **In the technological advanced world, technology keeps on changing now and then. In mobile communication technology, everyone is familiar with 4G communication technique, the future of mobile communication and IOT technology is 5G communication. The techniques used in 4G communication is not suitable for 5G communication because, to meet two criteria speed and error free communication at higher speeds than 4G communication. This paper discusses briefly about the techniques for encoding and comparison of polar code decoders. For polar code encoding, Arikan transform is used and for decoding of polar codes, three different techniques are used, they are SC decoding technique, ASCL decoding technique, Adaptive Decoder technique.**

Keywords:- *Successive Cancellation (SC), Adaptive Successive Cancellation List (ASCL),New Radio Access Technology (NRAT), International Telecommunication Union-Radiocommunication Sector (ITU-R), Ultra-Reliable Low-Latency Communication (URLLC), massive Machine-Type Communication (mMTC), Binary Discrete Memoryless Channels (B-DMCs), Binary Phase shift Keying (BPSK), Quadrature Phase shift Keying (QPSK), Cyclic Redundancy Check (CRC), Bit Error Rate (BER).*

I. INTRODUCTION

The wireless communication system is improving rapidly nowadays. 1G or first generation was introduced in the 1980s and had a practical speed of 2.4 kbps, it provided mobile telephony services. 2G or second-generation provided digital voice and short messaging and was introduced in 1990 with a practical achieving speed up to 64 kbps. The 3G or third generation was introduced in 2003 with a practical achieving speed up to 2 Mbps and was providing services such as integrated high-quality audio, video and data. The 4G or fourth generation was introduced in 2009 with a practical achieving speed of 100 Mbps and provided dynamic information access, variable devices services. 5G or fifth generation also provided services such as dynamic data access, varied devices along with AI capabilities and was introduces in the year 2020 and can practically achieve a speed of 1 Gbps.

Up and coming fifth age (5G) of versatile correspondence is not too far off and expected to have starting commercialization by 2020. NRAT for 5G was animated by new specialized necessities and new use cases. In September 2015, ITU-R characterized three significant situations of 5G usage: improved portable broadband (eMBB); URLLC; and mMTC. Possible prerequisites for 5G channel coding are to help varying code lengths and code rates with low vitality, low dormancy, low unravelling unpredictability and high throughput. Channel coding plans for existing LTE frameworks don't bolster all the new necessities. Similarly, the closeness of Error-floor does it uncomfortable for profoundly dependable correspondence. Consequently, Turbo codes aren't suggested for 5G situations. To conquer these confinements polar codes are evolved 0 [1].

Polar codes are proven to be capacity achieving channel codes for particular channels such as binary discrete memoryless channels (B-DMCs). SC decoding algorithm [2] of polar code concept is sequential in nature, due to which the implementation of hardware is a challenging condition in real time. SC algorithm performance is not as good as maximum likelihood decoder at short and medium length code blocks, but an SC decoder provides a low complexity O (N log N) decoding. Due to this SC decoders disadvantage it is improvised to ASCL decoding algorithm [3], but ASCL decoding suffers from long delays and low throughput due to high complexity, O (L N log N) calculations as L and N increases. So, adaptive decoder [4] which is a combination of these two decoders, in order to improve the throughput of SC and decrease the delay of ASCL performance.

System consists of a source which is the information that needs to be transmitted from one place to another. The information from the source is fed to the encoder which encodes the analog or digital signals into binary bitstreams of data. This encoded stream is modulated using modulation techniques such as BPSK, QPSK or M-ary PSK which helps the data to be transmitted over long range. The modulated signal is then passed on to a AWGN or a BSC channel where the signals are mediated from transmitter to receiver. At the receiver end, the signal is demodulated using techniques which blend well in accordance with the modulation technique used. This recovered signal is then decoded using a Polar Code decoder and the message is fed to the destination.

II. ARIKAN TRANSFORM

A. *Binary Discrete Memoryless Channel (B-DMC)*

It is a generic channel which is memoryless and as a input and output side for the channel which transmits and receives the data in the form of binary, this channel does not have the ability to store the value, because absence of the registers, hence called as Binary Discrete Memoryless Channel (BDMC) [5].

B. *Symmetric Channel*

One of the common communication channels which are used in coding techniques and information science. When a transmitter wishes to send a data, the receiver will receive a data, the data received will have a crossed over probability, and the other way it is received correctly.

C. *Log Likelihood Ratio (LLR)*

LLR test of BPSK modulation scheme denotes that the received bit(y) is directly proportional to the transmitted bit (x). Hence for decoding of polar codes LLR values are used, which is the most flexible option of detecting the codeword. This value is also known as Channel LLR, Intrinsic LLR and belief of received bit [6].

Channel LLR = $2y/\sigma$ 2
were σ is the noise power

D. *SNR v/s BER*
Signal-to-Noise Ratio of BPSK is the inverse of noise power ($1/\sigma$^2). Bit Error Rate of BPSK is related to SNR as,
BER = Q ($1/\sigma$) = Q ($\sqrt{SNR}$)
E. *EbNo v/s BER*
Bit error rate is the probability that transmitted bit u does not equal to received bit û. BER is calculated as,
BER = ne/N
where N is the number of transmitted bits
ne number of error bits
BER = Q ($\sqrt{2Eb/No}$) = 0.5erfc ($\sqrt{Eb/No}$)
F. *General Transform*

$$G_{2^n} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}^{\otimes n}$$

G is Arikan Matrix
n is total number of bits [7]

III. COMPARISON OF SC, ASCL, ADAPTIVE DECODER

A. *The comparison of different categories of SC, ASCL and Adaptive Decoder, in the below table*

SC DECODER	ASCL DECODER	ADAPTIVE DECODER
1. SC Decoder is abbreviated as Successive Cancellation Decoder	1. ASCL Decoder is abbreviated as Adaptive Successive Cancellation List Decoder	1. It is known as Adaptive Decoder itself
2. SC Decoder is the most basic decoder in polar codes	2. ASCL Decoder is the super set of SC decoder	2. Adaptive Decoder is the combinational of SC and ASCL Decoder
3. Decoding is sequential in nature	3. Decoding is sequential in nature	3. Decoding is sequential in nature
4. Does not contain Cyclic Redundancy Check (CRC) bits	4. Contain Cyclic Redundancy Check (CRC) bits	4. Contain Cyclic Redundancy Check (CRC) bits
5. Complexity is less compared to other two decoder	5. Complexity is very high	5. After obtaining both the decoders, Adaptive Decoder becomes less complex
6. Time consumed for decoding is very less compared to other two	6. Time consumed for decoding is very high compared to other two	6. Time consumed for decoding is greater than SC but lesser than ASCL
7. Efficiency is less compared to other two decoder	7. Efficiency is higher than SC but lesser than Adaptive Decoder with cost of huge amount of time	7. Efficiency is high compared to other two decoder
8. SC Decoder performance is good for shorter code length below 512 and performance decreases as the code length is increased	8. ASCL Decoder performance is good for all type of code length such as short, mid, longer	8.Adaptive Decoder performance is good for all type of code length such as short, mid, longer

Table 1:- Comparison Of Sc, Ascl, Adaptive Decoder

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B. *Comparing SC, ASCL and Adaptive decoder for 2000 iteration*

Figure 1 shows the graph of Bit Error Rate (BER) vs Eb/No (dB) for SC, ASCL and Adaptive Decoder implemented in MATLAB. In particular the graph is plotted for 1024 message bits, transmitting through 512 channel, which AWGN in its characteristics, hence the rate of transmission will be ½. This 1024 randomly generated different message bits is not sent through once, but is sent through iteratively for 2000 number of times and decoded through all the three decoders. At each iteration bit error rate is calculated and summed up at each iterative for 2000 iterative steps, then an average BER is calculated and is plotted at its respective dB value

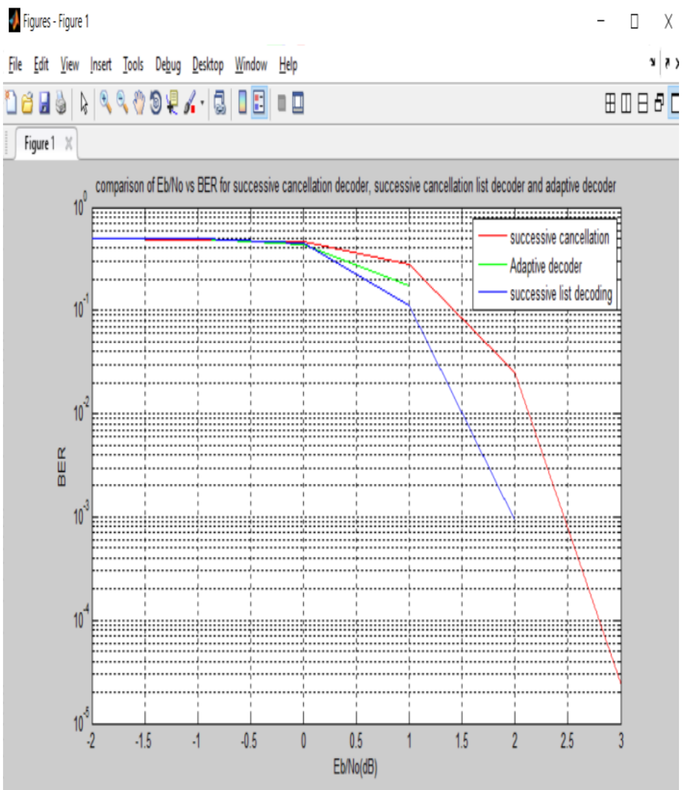

Fig. 1 Comparison of SC, ASCL, Adaptive Decoder

IV. CONCLUSION

In today's world is advancing in technology towards 5G communication, polar codes encoder and decoders acts as capacity achieving codes, at higher speeds and correctness. A brief explanation of polar encoder and comparison polar code decoder such as SC, ASCL and Adaptive decoder is given in this paper. For better understanding purpose the comparison graph of Bit Error Rate (BER) vs Eb/No (dB) for SC, ASCL and Adaptive Decoder is executed in MATLAB. By comparison the performance efficiency of Adaptive Decoder is found to be much higher than the SC and ASCL decoders. The decoders are operated for 1024 code length going through 512 AWGN channel at rate ½ for 2000 iterations.

REFERENCES

[1]. Marwan DHUHEIR, Sıtkı ÖZTÜRK, "Polar Codes Analysis of 5G Systems", 2018 6th International Conference on Control Engineering & Information Technology (CEIT), 25-27 October 2018, Istanbul, Turkey

[2]. K. M. Prakash, G. S. Sunitha, "Efficient High-Performance Successive Cancelation Decoder for Polar Code", 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT)

[3]. Wenqing Song, Chuan Zhang, Shunqing Zhang, and Xiaohu You, "Efficient Adaptive Successive Cancellation List Decoders for Polar Codes", 2016 IEEE

[4]. Altu˘gS¨ural, "An FPGA Implementation of Successive Cancellation List Decoding For Polar Codes".

[5]. Dazu Huang, JianquanXie, Ying Guo, "Fast polarization construction on binary discrete memoryless channels", 2010 IEEE International Conference on Progress in Informatics and Computing"

[6]. Alaa A. Hasan, Ian D. Marsland, "Channel optimization and LLR approximation-based SC of polar codes", 2017 8th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)

[7]. Jie Cheng, Hui Li*,Ming Ye, Lijie Wang, Chi Zhang, "Systematic Polar Codes Based on 3x3 Kernel Matrix", 2019 International Conference on Communications, Information System and Computer Engineering (CISCE)