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Efficient Decoding of Low-Density Parity Check Codes

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Abstract

Low Density Parity Check Codes (LDPC) are a type of linear-block LDPC codes which play a Prominent role in Error detection and Correction Techniques. They are Various methods for Decoding LDPC Codes. Two Prominent methods of Decoding LDPC Codes are Hard decision method and Soft Decision Method. Even though the Hard decision decoding algorithm is computationally simple, its BER performance is not appreciable. Devising soft decision decoding algorithms which are simple and good in BER performance. Quadrature Phase Shift Keying (QPSK) modulation is done and the AWGN noise is introduced to the modulated code word. This paper compares the Bit Error Rate (BER) performance of soft and hard decision decoding algorithms of LDPC codes on AWGN channel at different code rates and Modulation Order(M). The analysis is conducted in MATLAB.

***Keywords*: LDPC, SNR, BER, Hard Decision, Soft Decision, QPSK, AWGN.**

I. Introduction

Low-Density Parity Check (LDPC) Codes offer remarkable error correction performance and therefore increase the design space for communication systems. When implementation complexity and latency are not system limitations, LDPC codes can offer near-Shannon Limit performance by using large code lengths and increasing the number of iterations in the decoding process.[1][2] Furthermore, LDPC codes with smaller block sizes are also of value to the communications system designer and LDPC codes have found practical use in DVB-S2 and other standards. LDPC codes have found wide application in various fields like satellite transmission, recording in magnetic discs also in Fifth Generation (5G) shared channels due to their high throughput, low latency, low decoding complexity, and rate compatibility.[8][9] LDPC Decoding Algorithm works by exchanging messages between the check and variable nodes. LDPCs are non-systematic codes. Mainly, LDPC codes represent a class of error-correcting codes that may be employed to correct transmission errors in communication systems. An ideal transmission of data

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is said to be most accurate or idealistic if and only if the data at the transmitter end is accurately received at the receiver end without any error or delays. When the data is transmitted over a communication channel, an error can occur due to the presence of noise in the channel. The communication system's main challenge is achieving a reliable and error-free transmission of data from information source to destination.[3][7]

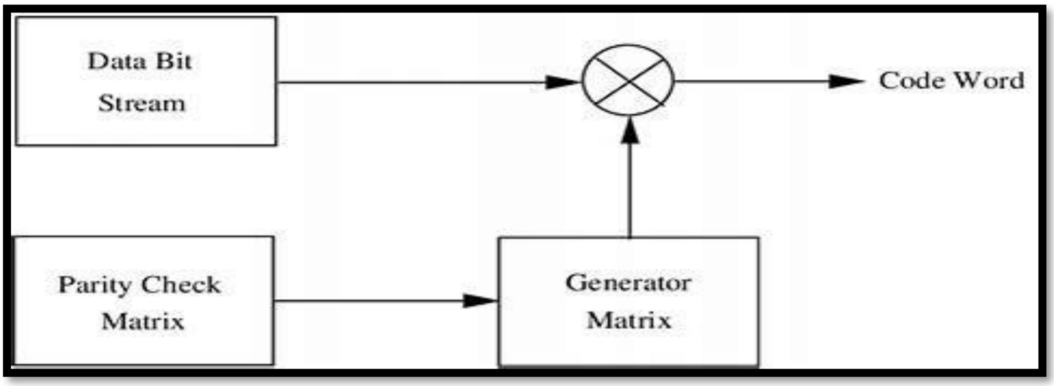

Figure 1: Generation of LDPC Code Word

II. Hard Decision Decoding Algorithm

A Hard decision refers to a decision made by a receiver based on the received signal that has been quantized to a fixed set of possible values. These decisions are typically binary decisions, where the receiver decides whether the received signal corresponds to a 0 or a 1.In other words, hard decision decoding involves the process of mapping the received signal to one of the possible transmitted symbols, based on a predetermined threshold value. This threshold value is often set to be the midpoint between the two possible symbols, but it can be adjusted based on the noise characteristics of the communication channel.

Hard decision decoding is used in a variety of communication systems, including digital communication systems that use binary modulation schemes like amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK). The process of making hard decisions introduces errors in the received signal, as the quantization process may cause the received signal to be misinterpreted. The magnitude of these errors depends on the quality of the received signal and the threshold used for quantization. The Prominent Hard decision decoding algorithms are Bit Flipping Algorithm , Weighted Bit Flipping Algorithm, Modified WBF Algorithm, Improved MWBF Algorithm Multi-Bit Flipping Algorithm

II.a Bit Flipping Algorithm

The Bit Flipping Algorithm is a simple heuristic algorithm used for decoding low-density parity-check (LDPC) codes. It is often used as a suboptimal decoding algorithm, particularly when the optimal decoding algorithm, such as the belief propagation algorithm, is computationally expensive. The Bit Flipping Algorithm operates on the hard-decision version of the received signal, where the received signal is quantized to either 0 or 1. The algorithm flips the bits of the received signal that violate the parity constraints until either all the constraints are satisfied or a predetermined maximum number of iterations is reached.[5][10]

The Bit Flipping Algorithm is simple to implement and has low computational complexity, making it a popular choice for decoding LDPC codes in practical applications. However, the algorithm can suffer from high error rates for high noise levels and high code rates, and it may not converge to the correct codeword in all cases.

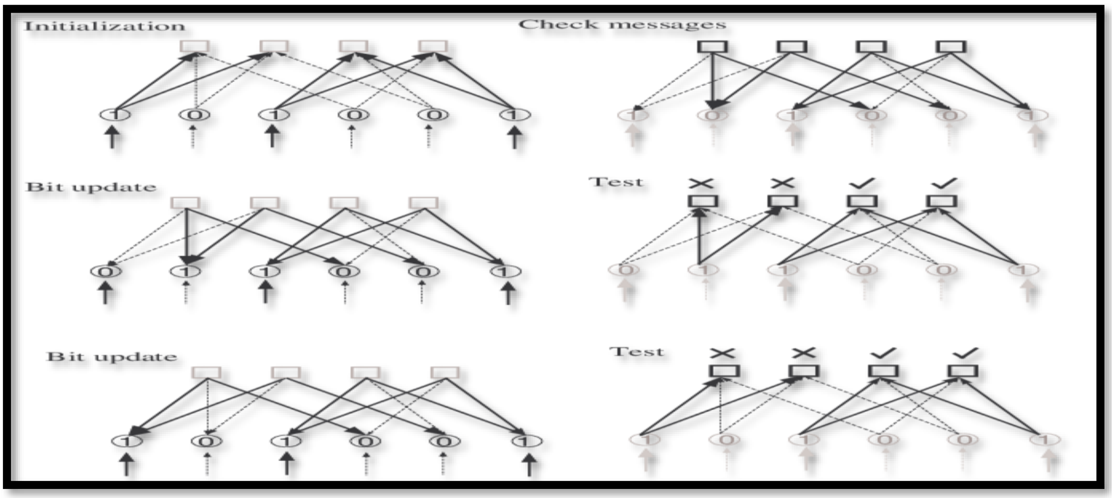

Figure 2: Bit Flipping Technique

III. Soft Decision Decoding Algorithm

Soft decision decoding is a technique used in communication systems to decode digital signals that have been affected by noise or interference during transmission. The soft decision is a method used in communication systems to measure the likelihood that a received signal corresponds to each possible transmitted signal, rather than making a binary decision based on a predetermined threshold. In contrast, soft decision decoding considers the probability that each received symbol belongs to each possible transmitted symbol, rather than simply making a binary decision. This probability is calculated based on the likelihood of the received symbol given each possible transmitted symbol and the noise and interference present in the channel.

Soft decision decoding could accurately decode digital signals in noisy environments, as it takes into account the uncertainty introduced by the noise and interference. However, it requires more complex processing and computational resources compared to hard decision decoding. Soft decision decoding is commonly used in modern communication systems, such as digital mobile communication and satellite communication. Soft decision decoding is used in situations where the received signal is affected by noise or interference, as it provides a more accurate estimation of the transmitted signal compared to hard decision decoding. The higher the probability of error, the less complex the algorithm needs to be, and vice versa. The Prominent Soft decision decoding algorithms are Belief Propagation Algorithm , Sum-Product Algorithm, Improved Belief Propagation Algorithm

III.a Belief Propagation Algorithm

The belief propagation (BP) algorithm is a widely used soft-decision decoding algorithm for error-correcting codes. It is an iterative algorithm that can be used to decode both convolutional codes and block codes. BP algorithm is also known as the sum-product, message-passing, or belief network propagation algorithm. The BP algorithm operates on a factor graph representing the code's structure. The factor graph consists of variable nodes and factor nodes. The variable nodes represent the unknown symbols, and the factor nodes represent the constraints imposed by the code. The BP algorithm computes the likelihood of each possible transmitted symbol given the received signal and the noise and interference present in the channel. It provides a soft output, which is a probability distribution over the possible transmitted symbols, rather than a hard output that selects a single transmitted symbol.[4][6]

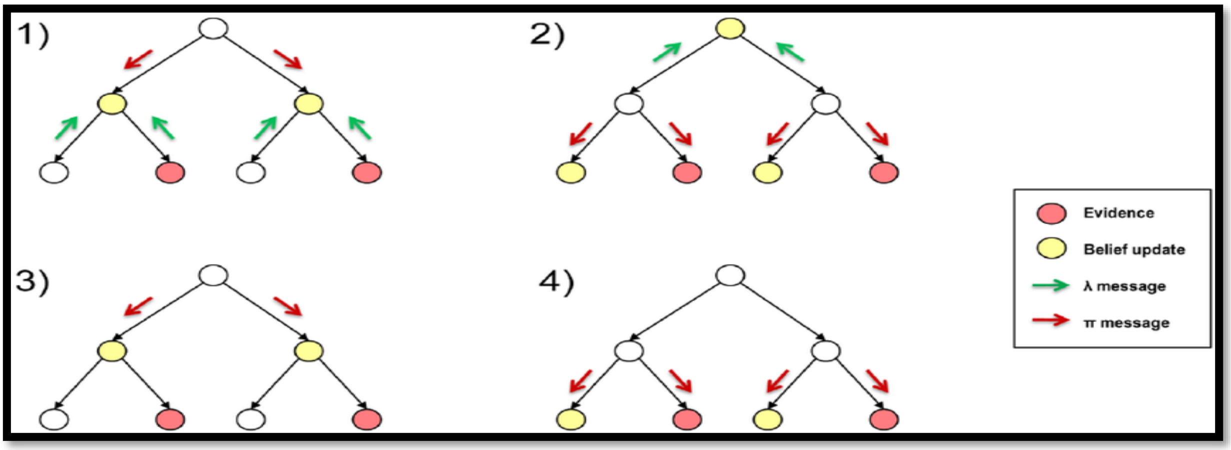

Figure 3: Belief Propagation Technique

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IV. Results

In this section, the modulation order, different code rates are the parameters used for the analysis of LDPC codes.

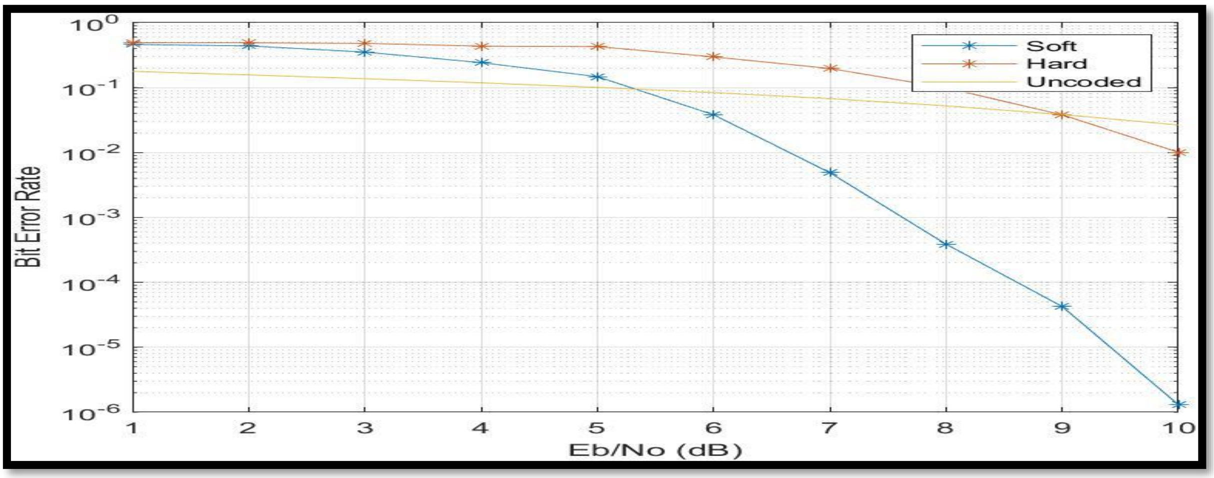

Figure 4 : BER VS E_b/ N_O for Modulation Order : 64 Code Rate : ½

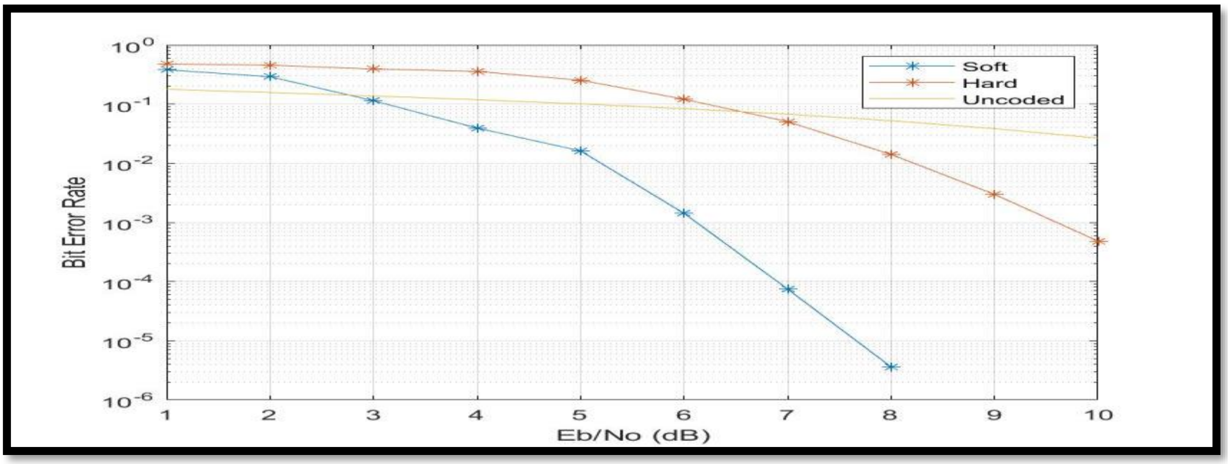

Figure 5 : BER VS E_b/ N_O for Modulation Order :64 ; Code Rate : ¾

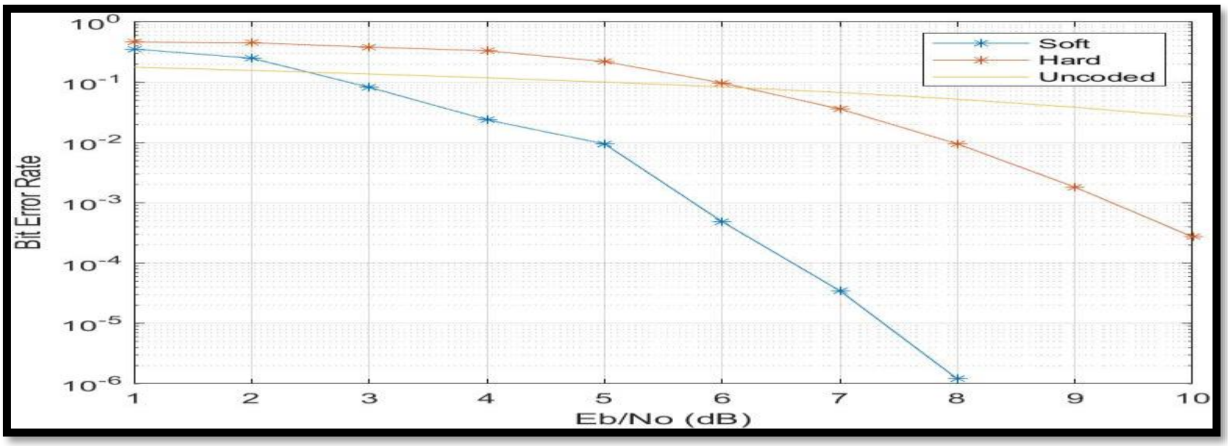

Figure 6 : BER VS E_b/ N_O for Modulation Order :64 ; Code Rate :4/5

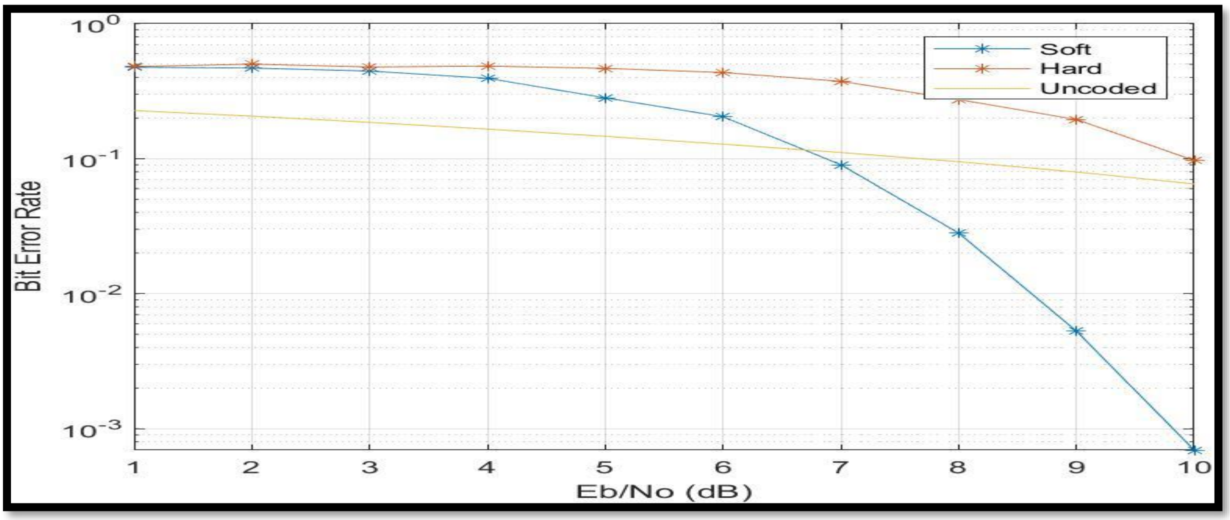

Figure 7 : BER VS Eb/ No for Modulation Order : 128 Code Rate : ½

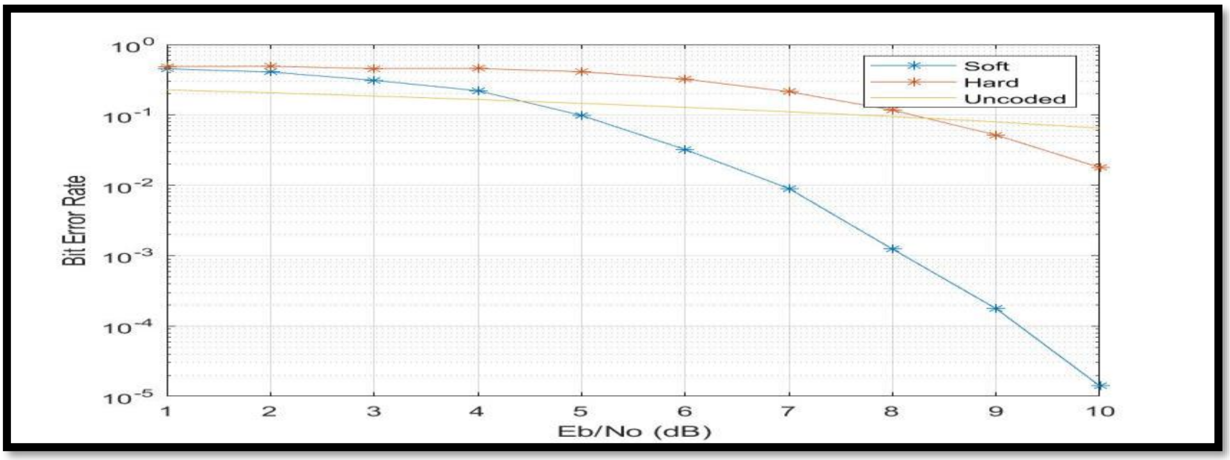

Figure 8 : BER VS Eb/ No for Modulation Order :128 ; Code Rate : ¾

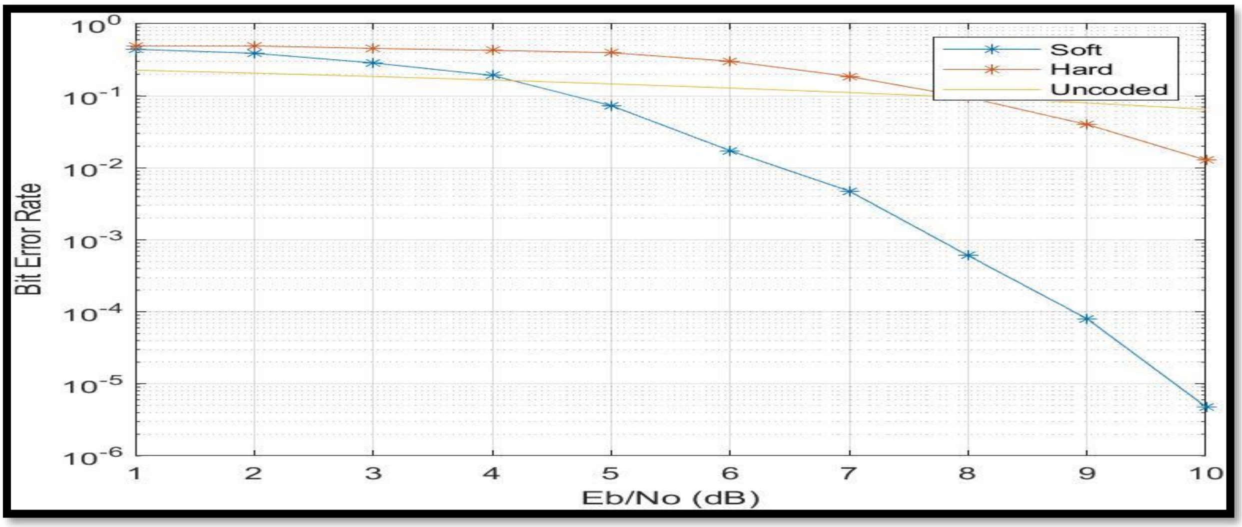

Figure 9 : BER VS Eb/ No for Modulation Order :128 ; Code Rate :4/5

V. Conclusion & Future Scope

LDPC codes were successfully decoded using both Hard decision and Soft Decision Algorithms. For Hard Decision Bit Flipping Algorithm is used and for Soft Decision Belief Propagation Algorithm is used. The analysis is carried out in Matlab for different Modulation order and different code Rates. It has been observed that the BER vs E_b/N_O values were effective when they are Properly coded and decoded using Soft Decision Algorithms. The effectiveness of the LDPC Codes can be improved if different Bit Flipping and Sum Product Algorithms are used. It can also be achieved by varying the Parameters like Modulation order

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