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# PERFORMANCE ANALYSIS OF DECODING SCHEMES OF LDPC CODES IN 5G-NR

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***Abstract:*** In day to day life wireless communication plays a significant role .Although in wireless communication(4G LTE) fails in real time applications i.e getting high data rates and spectrum sharing.5G is introduced to improve the requirements like spectrum reliability, high data rates, higher bandwidth, high throughput, higher efficiency and that too at lower latency. Channel coding for 5G plays a crucial role for enhanced mobile broad band(eMBB) and also for Ultra Low Latency Communications. Hence efficient error Correction coding is required. Already LDPC codes are finalized for 5G by 3GPP. LDPC codes with Message passing algorithm provides more potential to error correction coding in 5G systems.

***Index Terms*** **- LDPC, eMBB, URLLC, LTE.**

## I. Introduction

### 1.1 Wireless Communication:

Communication system can be wired or wireless and the medium used for communication can be guided or unguided. In wired communication the medium is a physical path like co-axial cables. Twisted pair cable and optical fiber links etc., which guided the signal to propagate from one point to other.

Wireless communication otherwise known as over the air is the transfer of information not connected by an electrical conductor. The most common wireless technologies use radio waves. With radio waves intended distance can be short such as a few meters for Bluetooth or as far as millions of kilometers for deep space radio communication. It encompasses various types of fixed mobile and portable application including two-way radios cellular telephone personal digital assistant (PDAs), and wireless networking.

**Mobile telephone:**

One of the best-known examples of wireless technology is the mobile phone also known as a cellular phone with more than 6.6 billion mobile cellular subscription worldwide as of use radio waves from signal transmission towers to enable their users to make phone calls from many locations worldwide. They can be used within range of the mobile telephone site used house the equipment required to transmit and receive the radio signal from these instruments.

**5G technology** is the next generation of wireless communications. It is expected to provide internet connections that are least 40 times faster than 4G LTE. 5G technology may use a variety of spectrum bands, including millimeter wave radio spectrum which can carry very large amounts of data a short distance. The drawback of the higher frequencies is that they are more easily obstructed by the walls of buildings, trees and others foliage, and even inclement weather.

The forthcoming 5G technology will come from various vendors and will be compared of solutions designed to provide very fast download speed and low latency. Today-in advance of 5G's expected debut around 2020-companies such as Verizon, AT&T, Samsung, and Ericsson are testing new advances in signal processing, chips, and antenna technologies that will enable the next enable the next generation of mobile connectivity.

**Millimeter wave:** Millimeter waves are broadcast at frequencies between 30 GHz and 300 GHz, compared with the bands below 6 GHz used for 4G LTE. The new 5G networks will be able to transmit very large amounts of data-but only a few blocks at a time. Although the 5G standard will offer the greatest benefits over these higher frequencies, it will also work in low frequencies as well as unlicensed frequencies that Wi-Fi currently uses without creating conflicts with existing Wi-Fi traditional cellular towers.

**Enhanced Mobile Broadband** (eMBB) is one of three primary 5G New Radio (NR) use cases defined by the 3GPP as part of its SMARTER (Study on New Services and Markets Technology Enablers) project Enhanced Mobile Broadband (eMBB) data-driven use cases requiring high data rates across a wide coverage area.

**Ultra-reliable and low latency communication** (URLLC) is a new service category in 5G to accommodate emerging services and applications having stringent latency and reliability requirements.

**1.2 LDPC** (Low density parity check codes) were first introduced by G.Gallager at MIT in PhD thesis in 1962. The implementation complexity of LDPC codes was considered high. Therefore, these codes were not popular for a few decades. However, it gained popularity after the success of turbo codes in 1993. LDPC codes have become an active area of research for digital communication applications. It has been shown that LDPC codes when optimally designed to perform close to Shannon Limit.

This LDPC codes can be represented in two ways:

1. Tanner graph

2. Matrix form

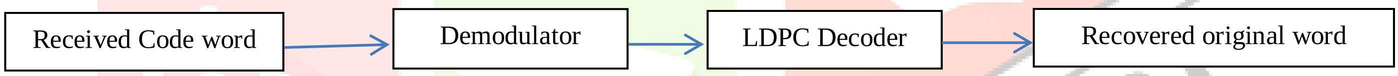
**Tanner graph**

In coding theory, a tanner graph named after Michael Tanner is a bipartite graph used to state constrains or equations which specify error correcting codes. In coding theory Tanner graph are used to construct longer codes from smaller ones both encoders and decoders employ these graphs extensively.

**Matrix form**

$$\mathbf{H}=\begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 \end{bmatrix}$$

**1.3 General Block Diagram for LDPC Decoder**




**2.Literature Review**

The problem of low complexity close to optimal channel decoding of linear codes with short to moderate block length is considered. It is shown that deep learning methods can be used to improve a standard belief propagation decoder despite the large example space. Similar improvements are obtained for the min-sum algorithm. It is also shown that tying the parameters of the decoders across iterations so as to form a recurrent neural network architecture can be implemented with comparable are required [1].

An ultrahigh throughput low-density parity-check (LDPC) decoder with an unrolled full-parallel architecture is proposed which achieves the highest decoding throughput compared to previously reported LDPC decoder in the literature. The decoder benefits from a serial message-transfer approach between the decoding stages to alleviate the well-known routing congestion problem in parallel LDPC decoders [2].

A new multi-bit flipping decoding algorithm for low-density parity-check codes which can enhanced hard-information-based decoding performance for NAND storage system. Since the conventional enhancement techniques developed for bit-flipping decoding require soft information the long latency taken to generate the soft information makes it hard to apply them to practical NAND storage systems [3].

Irregular low-density parity-check (LDPC) codes are among the best codes currently known. Unfortunately, the performance of existing codes may deteriorate substantially with practical finite precision decoder implementations. This motivates us to extend our previous work on finite-alphabet decoder on look-up tables (LUTs) to irregular LDPC codes [4].

**2.1 LDPC Decoding**

Let us first start by describing a general class of decoding algorithms for LDPC codes. These algorithms are called message passing algorithms, and are bit flipping algorithm. The reason for their name is that at each round of the algorithm's messages are nodes to check nodes, and from check nodes back to message nodes. The message from message nodes to check nodes are computed based on the observed value of the message node and some of the message passed from the neighboring check nodes to that message node. An important aspect is that the message that is sent from a message node to a check node must not take into account the message sent in the previous round from check node to message node. The same is true for message passed from check node to message node.

Algorithms used in LDPC decoding:

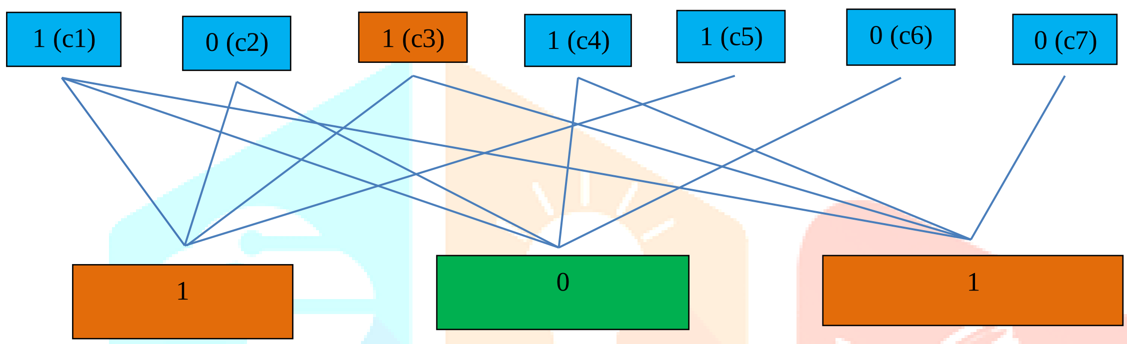
**1.** Bit flipping algorithm

**2.** Message passing algorithm

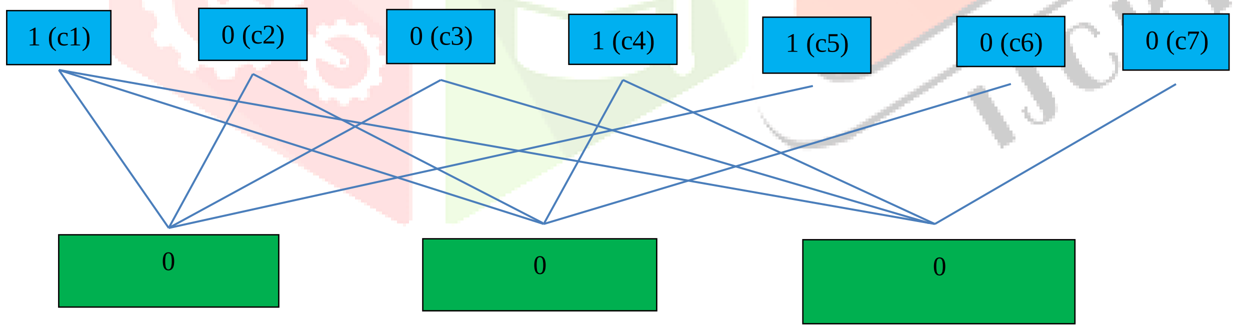
**2.1.1 Bit flipping algorithm:**

The bit-flipping algorithm is a hard-decision message passing algorithm for LDPC codes. For the bit-flipping algorithm the messages passed along the Tanner graph edges are also binary. a bit node sends a message declaring if it is a one or a zero, and each check node sends a message to each connected bit node, declaring what value the bit based on the information available to the check node. The check nodes determine that its parity –check equation is satisfied if the modulo-2 sum of the incoming bit values zero. If the majority of the messages received by a bit node are different from its received value the bit node changes its current equations are satisfied, or until some maximum number of decoder iterations has passed and the decoder gives up.

Bit flipping algorithm is only used for, if one or two bits of data is missed from the input data this algorithm is used. If block or more data is missed then we use message passing algorithm.




Tanner graph with the impact of a single bit error

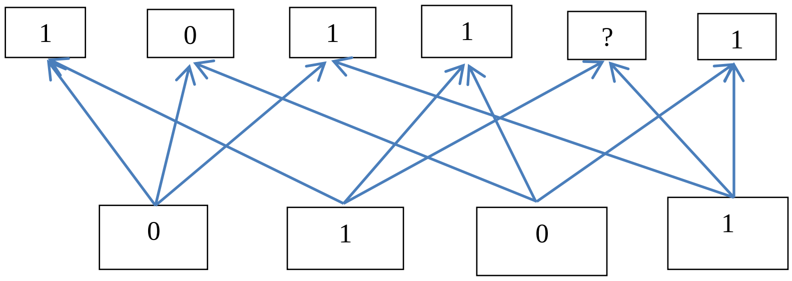



Tanner graph after correction of bits

**2.1.2 Message passing algorithm:**

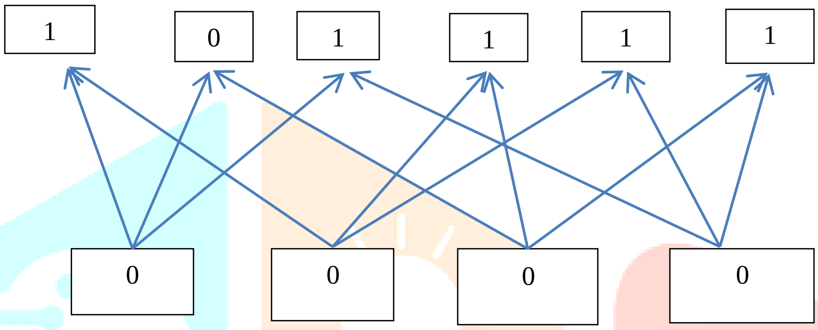
Linear block and LDPC codes can be decoded on the factor graph by message passing algorithm. Which are represented by the connection between variable and check nodes. These nodes perform local decoding operation and exchange the message along the edges of the factor graph. So, in the first iteration, the incoming message received from the channel at the variable nodes are directly passed along the edges to the neighboring check nodes because there are no incoming messages from the check nodes in the iteration. After every one complete iteration, it will be checked whether codeword is found or not.

**First iteration**

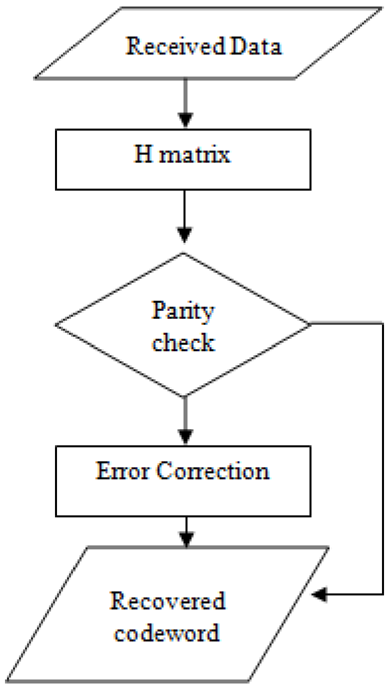



Check nodes two and four are connected as they have one incoming erased by parity check condition the bit is recovered

**Second iteration**




**Flow chart of decoding process of LDPC codes with message passing algorithm**



**COMPARISON OF BIT FLIPPI NG AND MESSAGE PASSING ALGORITHM**

| Bit flipping Algorithm | Message passing Algorithm |
|---|---|
| Number of message bits can be corrected is only one. | Number of message bits can be corrected is maximum three. |
| Code word= [1 0 1 0 1 1] | Code word= [1 0 1 0 1 1] |
| Received Data= [0 0 1 1 0 1] | Received Data= [1 0 e e e l 1] |
| To recover the original message, 3 iterations are required. | To recover the original message, 4 iterations are required. |
| If more than one bit is mistake in the received data, we cannot get the original data even after completing the maximum number of iterations. | In this method iterations are depending on erased bits. |

**Conclusion:** In communication Error correction plays a major role. So, Efficient Decoder must be built in these systems. In this paper we have discussed about Message passing Algorithm and Bit flipping Algorithm. Simulation results shows that Message passing algorithm is best when compared to bit flipping because when more than one bit is erased then bit flipping algorithm will fail and we cannot recover the original data. So, from these outcomes we can say that Message passing algorithm scheme have improved performance when compared to bit flipping algorithm.

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