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# EFFICIENT ENCODING OF LDPC CODES FOR eMBB IN 5G-NR

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**Abstract:-** Wireless mobile communication system become an imperative part of modern lives because the number of devices are increasing significantly and therefore the same radio spectrum is reused several times by different applications . Although 4G i.e. LTE systems are now in use worldwide but it cannot be able to meet the requirements like spectrum scarcity and energy efficiency. 5G is introduced to enhance the requirements like reliability, high data rates, higher bandwidth, high throughput, higher efficiency and that too at lower latency. 5G channel coding schemes are mainly designed for the eMBB scenario as well as for partial support of the URLLC scenario focusing on low latency. Channel coding helps to extend the reliability of wireless communication systems, already LDPC codes are finalized for data and polar codes for control information by 3GPP. As a coding scheme for data 5G LDPC codes are designed to support high throughput ,for this efficient encoding is required in this paper encoding schemes of LDPC codes are discussed and a comparison is made between them.

**Key words:** -LDPC,LTE ,NR ,eMBB , URLLC.

## 1.Introduction:

Low density parity check codes(LDPC) were first introduced by Gallager .The main advantage of LDPC cdes are implementation complexity is less. LDPC codes are a class of linear block codes that provides near-capacity performance on a huge collection of data transmission and storage channels while simultaneously admitting implementable decoders. LDPC is constructed using a sparse Tanner graph (subclass of bipartite graph). Through this LDPC codes we can transmit a message over a noisy channel. LDPC codes are having high demand in today's applications as they are used to meet the requirements like reliable and efficient information transfer over bandwidth constrained or return-channel-constrained links in the presence of disturbing noise. LDPC codes are best compared to other codes like turbo codes.

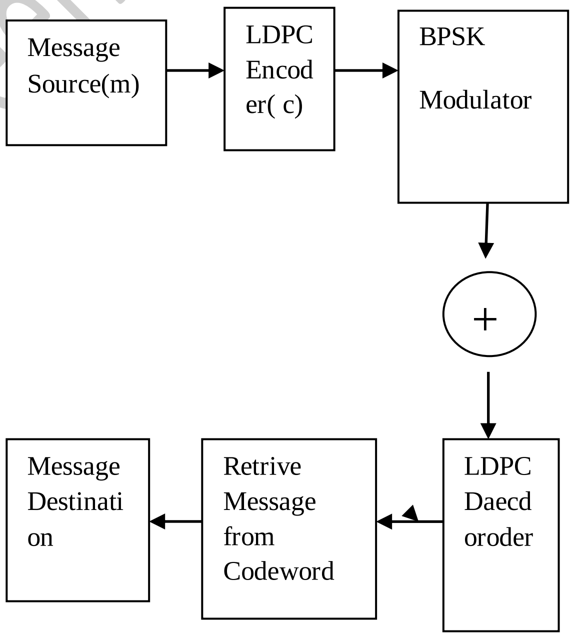


Fig: Wireless communication system with channel coding.

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**2..Error correction coding in 5G:-**

All error correction codes are based on same principal that the overabundance is append to the actual information in order to rectify any errors that could occur during transmission.

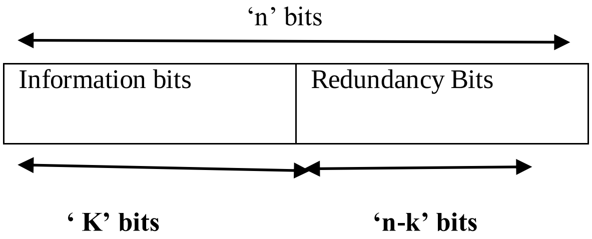


**Fig: systematic representation of block encoded data**

The error correction capability of the code depends on the rate of the code which is represented_by the ratio (k/n)

Where k is the number of information bits and n is the number of total bits including overabundance bits. The smaller the ratio, the better the error correction performance of the code. However to correct a code both the position and magnitude information is required. LDPC has been adopted as an error correcting code for 5G due to inherent parallel nature of LDPC codes , the hardware implementation of an LDPC decoder is comparatively less complex than that of turbo decoder with similar BER performance. Also the LDPC decoder does not require designing complex inter-leaver, as the interleaving is distributed in the code itself. All these codes makes LDPC codes suitable

Next generative wireless applications that require high performance encoder/decoders with low computational complexity and a low hardware resource requirement.

**3.Literature Review:**

1)Michael Lentmaier[1] tells about 5G LDPC codes by introducing CRC-aided LDPC coding schemes of equal overall length and rate. A competitive performance[2] is observed if the CRC is used jointly with the 5G LDPC codes to construct candidate the list in the OSD and the performance can be achieved at manageable complexity.

2)Hai Zhu [3] presented a method for constructing QC LDPC codes[4] with girth of at least 6 from an arbitrary integers. Numerical results show that the constructed QC LDPC codes have good performance over the AWGN channel and coverage fast under iterative decoding.

3)Pen Daqinetal tells about irregular QC-LDPC code is constructed based on combinational Mathematics .This simulation results show that the constructed code wards have good error correction performance and no error leaving phenomenon when using the sum-product algorithm.

4)Hanho Lee[5] presented a novel low-complexity high-throughput encoder approach for the 5G NR standard is proposed through this encoding algorithm[6] ,five encoder architectures with different sub matrix sizes were implemented.

5) Aakanksha Devrari[7] research on Design and FPGA Implementation of LDPC Decoder Chip for Communication System using VHDL[8]. This LDPC Codes will be possible to decode by the low power microprocessor with the help of FPGA look up tables.

**4. LDPC Codes:-**

Low density parity check codes (LDPC)[10] are the block codes with parity check matrices that contain only a small number of nonzero entries. It is the sparseness of H which guarantees both a decoding complexity which increases only linearly with the code length and minimum distance which also linearly with the code length. Aside from the requirement that H be the sparse an LDPC code itself is no different to any other block code indeed existing block codes can be successfully used with the LDPC iterative decoding algorithms if they can be represented by a sparse parity –check matrix for an existing code is not practical instead LDPC codes are designed by constructing a sparse parity-check matrix first and then determined generator matrix for the code afterwards. The biggest difference between and LDPC codes and classical block codes is how they are decoded and so are usually short and designed algebraically to make

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this task less complex. LDPC codes however and decoded iteratively using a graphical representation of their parity-check matrix and so designed with the properties of H as a focus.

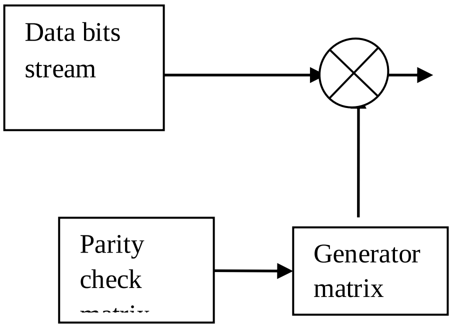



**Fig: LDPC block diagram**

eMBB:

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 low latency communications(URLLC):strict requirements on latency and reliability for mission critical communications, such as remote surgery, autonomous vehicles or the tactile internet.
- Massive machine type communication(mMTC):Massive machine type communications (mMTC) targets the cost -efficient and robust connection of billions of devices without overloading of the network.
  These applications require sub-milli second latency with error rates that are lower than 1 packet loss in 10^5 packets.

**4.1 Regular and Irregular codes:**

A parity-check matrix is said to be regular if the degree distributions of rows and columns are uniform, otherwise the matrix is said to be irregular. In regular LDPC codes, the column and row weights are constant throughout the parity-check matrix. For example, a regular (3,6) parity check matrix represents a uniform column weight represents a uniform column weight of 3 and row weight of 6. A regular parity-check matrix is preferred for hardware implementation because it leads to a constant number of edges in each of the variable and check nodes.

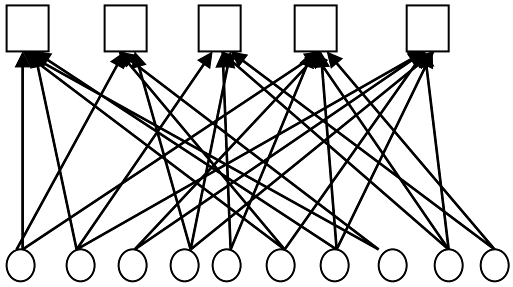
An example of parity check matrix for irregular LDPC codes is

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

**4.1.1 Representation of Parity Check Matrix Using Tanner Graphs**

The Tanner graph of the parity check matrix H is a bipartite graph. It has bit nodes or variable nodes (VN) equal to the number of columns of H, and check nodes (CNs) equal to the number of rows of H.

Check node



Bit node

Fig 3.1(a) Tanner graph of H matrix

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

The H matrix has 10 columns and 5 rows. Hence, the associated tanner graph with 10 bit nodes and 5 CNs

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### 4.2 QC LDPC Codes

QC-LDPC stands for Quasi Cyclic –Low Density Parity check. The NR access technology marks a transition in FEC coding for the 3GPP of cellular technologies. Quasi-cyclic (QC)LDPC codes play an important role in 5G communications and have been chosen as the standard codes for 5G enhanced mobile broad band (eMBB) data channel because of deep space and high data rate applications. Since deep space applications are consider, the signals are transmitted over the Additive white Gaussian Noise(AWGN) channel, with the specific block size of 7136 bits.

### 4.3 5G-NR QC-LDPC codes:

A binary QC-LDPC code can be characterized by the null space of an array of sparse circulants of the same size [7,23,24]. Taking into account the implementation, the parity-check matrix H of a QC-LDPC code can be defined by its base graph and shift coefficients (Pi,j). Elements 1s and 0s in the base graph are replaced by a circulant permutation matrix and a zero matrix of size Z × Z, respectively. For two positive integers mb and nb , with mb ≤ nb , consider the QC-LDPC code expressed by the following mb × nb array of Z × Z circulants over GF(2):

$$\begin{bmatrix} Q(P1,1)\ Q(P1,2) \cdots & Q(P1,nb) \\ Q(P2,1)\ Q(P2,2) \cdots & Q(P2,nb) \\ Q(Pmb,1)\ Q(Pmb,2) \cdots & Q(Pmb,nb) \end{bmatrix} \quad \ldots(1)$$

The exponent matrix of H, which is E(H), has the

$$\begin{bmatrix} P1,1 & P1,2 & P1,nb \\ P2,1 & P2,2 & P2,nb\,. \\ Pmb,1 & Pmb,2 & Pmb,nb \end{bmatrix} \ldots\ldots..(2)$$

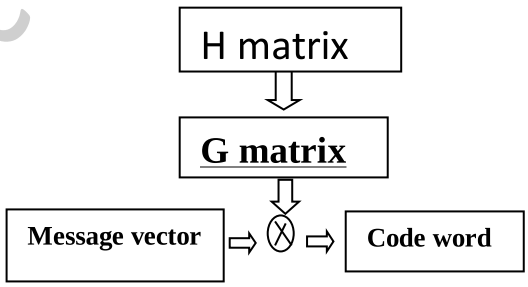
Each entry in the matrix E is referred to as a shift value. It should be noted that the parity check matrix H in Equation (1) can be constructed by following form: E(H) =

expanding the mb × nb exponent matrix E(H).

### 5. Encoding the user data using G matrix:-

**Preprocessing Method:**The conventional method of encoding of block codes involves multiplication of message bits with the generator matrix[9]. The generator matrix is derived from parity check matrix by Gaussian elimination (modulo-2). The generator matrix is not sparse and the complexity is O(n2) where n is the length of the code word. Richardson & Urbanke (2001) developed an efficient encoding algorithm exploiting the

sparseness of the parity check matrix. Optimized codes admit linear time complexity.




### 6. Efficient encoding of LDPC codes:

In pre-processing a generator matrix is derived from the parity check matrix and this generated matrix is used for encoding any arbitrary message however it has a complexity and to overcome this efficient encoding method is preferred in this no need of generating generator matrix directly with parity check matrix encoding can be efficiently done.

**Step 1:** By performing row and column permutations, the non-singular parity check matrix H is to be brought into a lower triangular form.

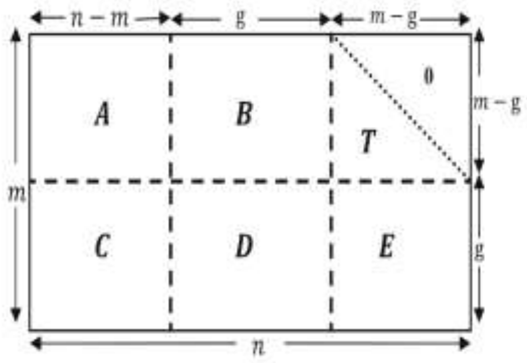



**Fig: The parity check matrix in approximate lower triangular form**

More precisely, the H matrix is brought into the for

$$H_t = \begin{bmatrix} A & B & T \\ C & D & E \end{bmatrix}$$

**Step 2:** Premultiply $H_t$ by

$$\begin{bmatrix} I_{m-g} & 0 \\ -ET^{1} & I_g \end{bmatrix}$$

**Step 3:** Obtain $p_1$ using the following

$$P_1^T = -\emptyset^{-1}(ET^{-1}A + C)s^T$$

**Step 4**: Obtain $p_2$ using the following:

$$P_2^T = -T^{-1}(As^T + Bp_1^T)$$

**Step 5:** Form the code vector c as

C=[s p1 p2]

Finally efficient encoding is the best solution for 5G-NR eMBB(enhanced mobile broad band)

compared to pre-processing method for low-density parity-check(LDPC) codes can be considered serious competitors to turbo codes in terms of performance and complexity and they are based on a similar philosophy.

We consider the encoding problem for codes specified by sparse parity-check matrices. We show how to exploit the sparseness of the parity-check matrix to obtain efficient encoders. for regular LDPC code, for example, the complexity of encoding is essentially quadratic in the block length. However, we show that the associated coefficient can be made quite small, so that encoding codes even of length n~100000 is still quite practical. more importantly, we will show that "optimized" codes actually admit linear time encoding. It was suggested to use cascaded rather than bipartite graphs. By choosing the number of stages and the relative size of each stage carefully one can construct codes which are encodable and decodable in linear time.one drawback of this approach lies in the fact that each stage (which acts like subcode) has a length which is, in general, considerably smaller than the length of the overall code. This results, in general, in a performance loss compared to a standard LDPC code with the same overall length.

It was have lower triangular shape. This restriction guarantees a linear time encoding complexity but, in suggested to force the parity-check matrix we have(almost) lower triangular form, i.e., the ensemble of codes is restricted not only by the degree constraints but also constraint that the parity-check matrix general, it also results in some loss of performance.

**7. Simulation parameters:-**

*Modulation* :The modulation scheme used by the transmitter, for example, BPSK, QPSK.

*Signal to Noise Ratio*:The ratio of energy per bit ($E_b$) to the noise energy ($N_o$). This ratio is generally represented in terms of decibels, $E_b/N_o$(db).

*Additive White Gaussian Noise*:Commonly used to simulated background noise in a wireless communication channel.

**8. Bit error rate versus SNR by using LDPC codes :-**Bit error rate(BER) expressions of generalized selections combining with low-denisty parity-check (LDPC) codes, using binary phase shift keying signal.

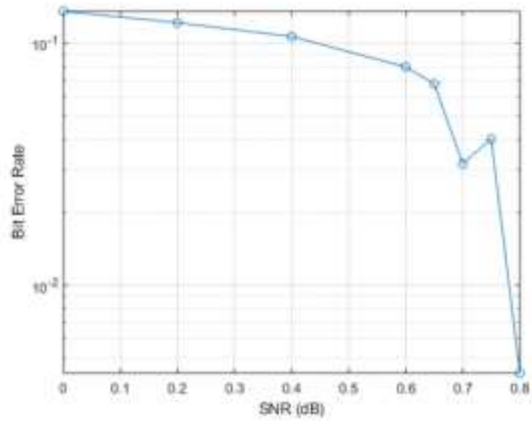



Fig: **Bit error rate Vs SNR(dB)**

**9.Conclusion:**

In this paper we discuss LDPC codes and its encoding techniques. Generally, for coding purposes, we derive a generator matrix G from the parity check matrix H for LDPC codes by means of Gaussian elimination in modulo-2 arithmetic. Since the matrix G is generated once for a parity check matrix, it is usable in all encoding of messages. As such this method can be viewed as the pre-processing method. However, it has a complexity and hence LDPC code can be encoded using efficient encoding method simulation results shows that with less number of iterations the code word can be generated by using efficient encoding method.

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