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## Quasi Cyclic Low Density Parity Check Codes for Analysis

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**Abstract:** The next generation mobile communication systems i.e. fourth generation (4G) was developed to accommodate the quality of service and required data rate. This project focuses on multiple access technique proposed in 4G communication systems. It is attempted to demonstrate the IDMA (Interleave Division Multiple Access) technology. The basic principle of IDMA is that interleaver is different for each user whereas CDMA employs different signatures. IDMA inherits many advantages of CDMA such as robust against fading, easy cell planning; dynamic channel sharing and IDMA increase the spectral efficiency and reduce the receiver complexity. In this, performance of IDMA is analyzed using QC-LDPC coding scheme further it is compared with LDPC coding and at last BER is calculated and plotted in MATLAB.

**Keywords:** 4G, QC-LDPC, CDMA, IDMA

### Introduction

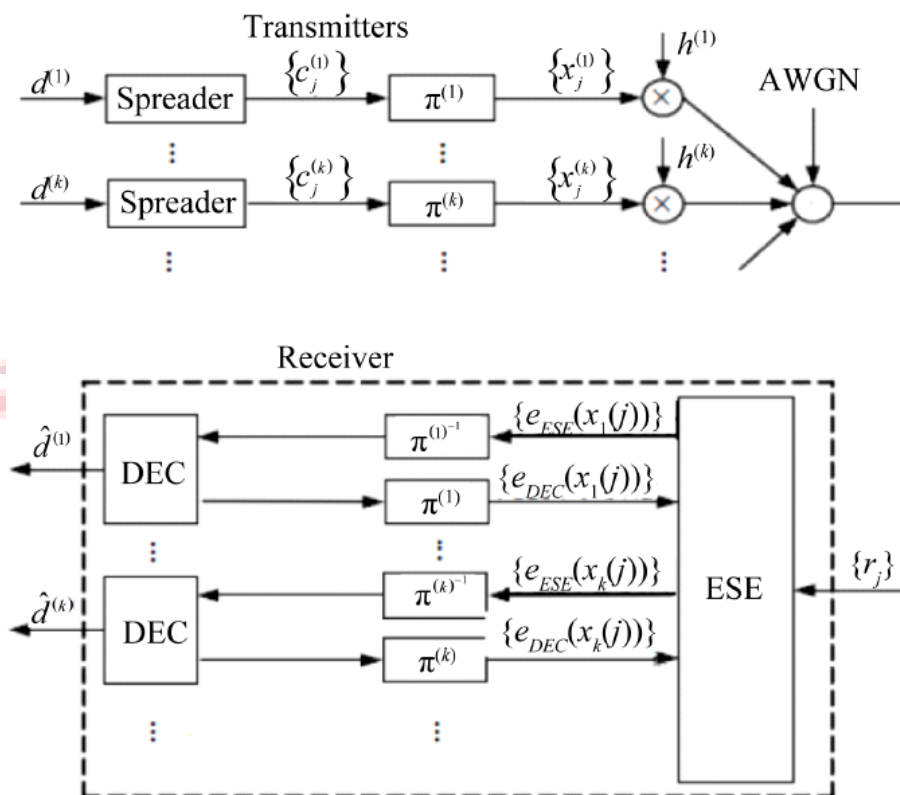
The recent successful approach for uncoordinated multiple-access is Interleave Division Multiple-Access (IDMA), IDMA is a multiple access technique that employs user specific interleavers for distinguishing the signals from different users. In communication systems, interleaving is referred as the technique commonly used to overcome correlated channel noise such as burst error or fading. IDMA is a multiple access technique that employs user specific interleavers for distinguishing the signals from different users. In communication systems, interleaving is referred as the technique commonly used to overcome correlated channel noise such as burst error or fading. In interleaving mechanism, the input data rearranges itself such that consecutive data bits are split among different blocks and is swapped in a known pattern amongst them. At the receiver end, the interleaved data is arranged back into the original sequence with the help of de-interleaver. As a result of interleaving, correlated noise introduced in the transmission channel appears to be statistically independent at the receiver and thus allows better error correction. The user-specific interleavers have an important role in the efficiency of IDMA system [1]. It not only provides de-correlation between adjacent bit sequences as provided in the case of orthodox turbo coding and decoding, but also provides a means to uncorrelate various users. The correlation between interleavers should measure how strongly signals from other users affect the decoding process of a specific user. The better the interleaver de-correlation, the lesser the iterations required for detection in IDMA multiuser detection (MUD) mechanism [1]. The de-correlation among the user specific interleavers provides a mean to reduce the multiple access interference (MAI) from the other users thus helping in the convergence of detection process.

### 1. Typical Structure Of IDMA System

The Fig.1 shows the transmitter structure of the multiple access schemes under consideration with  $K$  simultaneous users. The input data sequence  $d_k$  of user- $k$  is encoded based on a low-rate code  $C$ , generating a coded sequence  $c^k \equiv [c^{k(1)}, \dots, c^{k(j)}, \dots, c^{k(J)}]^T$ , where  $J$  is the frame length. The elements in  $c^k$  are referred to as coded bits. Then  $c^k$  is permuted by an interleaver  $\pi^k$ , producing  $x^k \equiv [x^{k(1)} \dots x^{k(j)} \dots x^{k(J)}]^T$ . Following the CDMA convention, we call the elements in  $x^k$  "chips". Users are solely distinguished by their interleavers and hence the name interleave-division multiple-access (IDMA). The key principle of IDMA is that the interleavers  $\{\pi^k\}$  should be different for different users. We assume that the interleavers are generated independently and randomly. These interleavers disperse the coded sequences so that the adjacent chips are approximately uncorrelated which facilitates the simple chip-by-chip detection scheme discussed below [1, 2]. We adopt an iterative sub-optimal receiver structure, as illustrated in Fig.1, which consists of an elementary signal estimator (ESE) and  $K$  single-user a posteriori probability (APP) decoders

(DECs) [1]. The multiple access and coding constraints are considered separately in the ESE and DEC. The outputs of the ESE and DEC are extrinsic log-likelihood ratios (LLRs) about  $\{x^{(j)}\}$  is given as

$$e(x_k(j)) = \log \left( \frac{p(y / x_k(j) = +1)}{p(y / x_k(j) = -1)} \right) \quad \forall k, j \quad \text{-----} \quad 1$$



**Fig. 1 IDMA Chip-By-Chip Multiuser Detection**

The Chip-By-Chip decoding methodology for IDMA is explained by Li Ping in his paper [1] where he introduced IDMA technique.

## 2. Quasi-Cyclic Low Density Parity Check Codes

Low Density Parity Check codes are the channel codes that come under the category of linear block codes [3]. QC-LDPC codes are special subclass of LDPC codes that have cyclic property [3]. That means a cyclic shift of  $p$  generates a new code. An  $(n, k)$  linear block code of dimensions  $n = m \cdot n_0$  and  $k = m \cdot k_0$ , is known as Quasi-Cyclic if every cyclic shift of a codeword by  $p$  positions is another codeword. Therefore, a cyclic code is a QC code with  $p = 1$ . The length of block  $n$  of a Quasi-Cyclic code is a multiple of  $p$ , or  $n = m \times p$ . Quasi cyclic (QC) codes have been a challenging and ongoing research subject in algebraic coding theory since their introduction in late 1960's [4]. These codes asymptotically achieve the Varshamov-Gilbert bound [3]. Recent research of these codes has been focused on a subclass of these codes, known as QC low-density parity-check (LDPC) codes. LDPC codes were first

discovered by Gallager in 1962 [3, 4] and then rediscovered in late 1990's [3]. They achieve the Shannon capacities for a wide range of channels with iterative decoding based on belief propagation.

Their main advantage against randomly constructed codes is that they involve easier implementation in terms of the encoding procedure. Due to their advantageous structure they require less memory as compared with the conventional LDPC codes

The QC-LDPC code parity-check matrices are specified as an array of sparse circulant of the same size. A square matrix consists of each row in the cyclic shift of the row above is a circulant, and the first row is normally the cyclic shift of the last row. It's all columns is the downward cyclic shift of the column on the left and first column is the cyclic shift of last column [5]. The weight  $w$  of the row and column of a circulant are equal. If the weight  $w$  of circulant is equal to 1, then the circulant is called circulant permutation matrix. The generator of the circulant is characterized by the first row or the first column of the same circulant.  $H_x$  is a parity check matrix which is represented as shown in equation. [6]

$$H_x = \begin{bmatrix} Q_{1,1} & Q_{1,2} & \dots & Q_{1,t} \\ Q_{2,1} & Q_{2,2} & \dots & Q_{2,t} \\ \vdots & \vdots & \ddots & \vdots \\ Q_{c,1} & Q_{c,2} & \dots & Q_{c,t} \end{bmatrix} \quad \text{-----} \quad 2$$

The  $(j, k)$  QC LDPC codes are defined in terms of circulant permutation matrices  $Q$ . This class of QC LDPC codes is characterized by a parity check matrix  $H$ , which consists of square blocks, as already mentioned [5,6]. The square blocks could either be the zero matrix or circulant permutation matrices. Equation illustrates a permutation matrix  $Q$  of size  $l \times l$ .

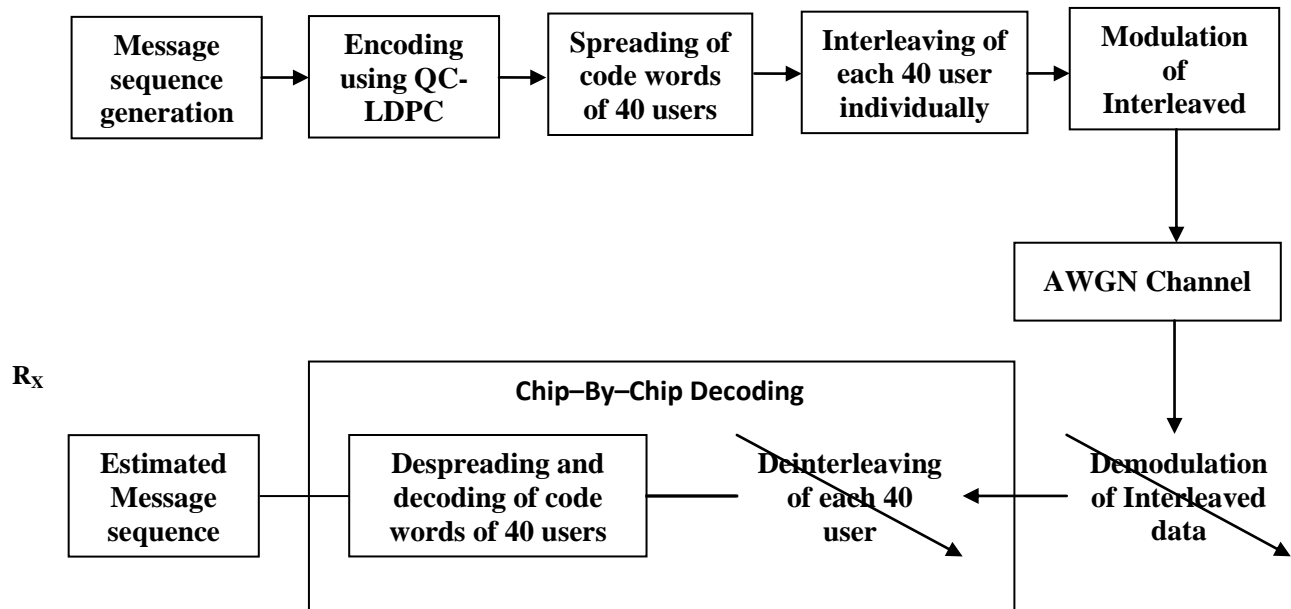
$$Q_i = \begin{bmatrix} 0 & 0 & 0 & \dots & 0 \\ 1 & 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ 0 & 1 & 0 & \dots & 0 \end{bmatrix} \quad \text{-----} \quad 3$$

$Q_i$  is a matrix stands for the circulant permutation matrix, which is derived from the identity matrix  $I$  after the later one is shifted to the right by  $i$  times ( $0 \leq i \leq q$ ) and the resulting parity check matrix is  $H$  in equation.[6]. The encoding and decoding process is same as traditional LDPC codes [6 ].

### 3. Research Methodology And Simulation Results

IDMA using LDPC has been implemented by Ajit Singh and Rajan Mishra [7] and BER is plotted. In this research approach the QC-LDPC is implemented in IDMA system. (Interleave Division Multiple Access) IDMA refer to Fig 1, which gives general description of IDMA system implementation with QC LDPC code and performance is analyzed. Further comparison of QC –LDPC. LDPC and QC-LDPC codes are compared by plotting BER plot for both.

$T_x$



**Fig. 2 Block Diagram of IDMA implementation using QC-LDPC**

The H-matrix for QC-LDPC used is given in equation [4]

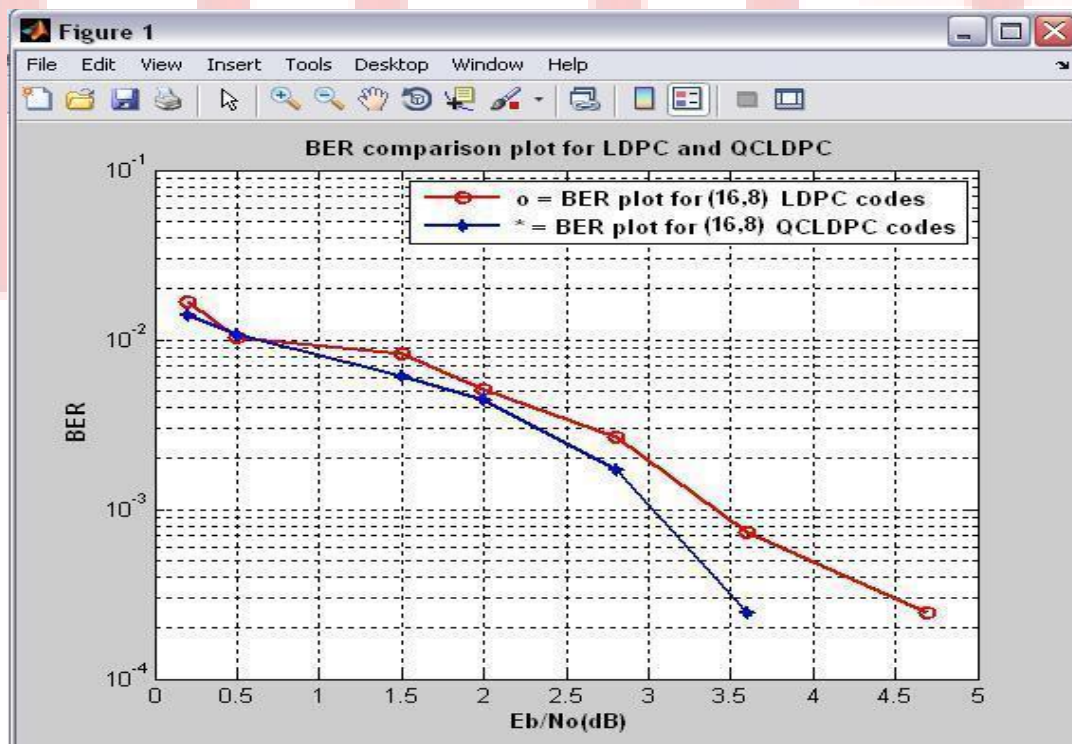
$$H = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 &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

4

The H-matrix for LDPC used is given in equation [5]

$$H = \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \quad \text{-----} \quad 5$$

The BER is calculated for both (16, 8) QC-LDPC and (16, 8) LDPC codes. Since the code word matrix size is [256 X 16], total no. of bits is  $256 \times 16 = 4096$ . The BER plot in Fig. 3 shows the comparison between these two types of codes. The BER performance is subjected to the H matrix. The Red plot indicates the BER of LDPC codes, where as blue plot indicates BER of QC –LDPC codes. As from BER plot Fig.3 it is clearly shown that the performance of QC-LDPC is better than LDPC codes. The plot of QC-LDPC is steeper and more close to Shannon limit as compared to LDPC code. The min value of BER for (16, 8) QC-LDPC codes is  $2.4414e-04$ .



**Fig. 3 BER plot for LDPC and QC-LDPC performance analysis**

#### 4. Conclusion

The algorithm used for encoding based on circulant matrices and implemented on MATLAB for simulation results. Decoding technique was achieved with sum product and bit flipping algorithms. Low Bit Error Rate (BER) was noticed as shown in result of BER. There are some drawbacks as far as IDMA is concerned that, though the calculations in IDMA of decoding is much simpler at receiver side but the calculations are bit lengthy. Further the performance of IDMA can be made better by including better performing interleaver that has very less correlation.'

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